U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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Crane, Indiana 47522

RDTR No. 126
1 March 1968

STUDY OF SPECTRA OF METAL-OXIDANT COMBINATIONS

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The report was reviewed for adequacy and technical accuracy by B. E. Douda.

Released

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Research and Development Department

UNCLASSIFIED

Final Report 3976-6803-F

STUDY OF SPECTRA OF METAL-OXIDANT COMBINATIONS

Final Report
1 March 1967 - 1 March 1968

by
R. M. Blunt

Prepared under Contract N00164-67-C-0320 for the Research and Development Department, U.S. Naval Ammunition Depot, Crane, Indiana, 47522 by the Mechanics Division, Denver Research Institute, University of Denver, Denver, Colorado, 80210.

UNCLASSIFIED

FOREWARD

This report summarizes and describes the work accomplished on Contract N00164-67-C-0320 during the period from February, 1967 through February, 1968.

It is a pleasure to acknowledge the work of Denver Research Institute personnel who have contributed to the material contained in this report; they are Mr. Ralph Williams, Mr. James Brewer, Mr. Robert Marchese and Mr. Vincent Miller. The author also has been aided by discussions of flare problems with Mr. William Cronk, Capt. Gene Holder and Mr. Lyle Gorzkiewicz of Eglin Air Force Base, Target and Missiles Division, Dr. Robert Evans of Atlantic Research Corp., Dr. Hal Waite of Ordnance Research Inc. and Mr. B. E. Douda, Mr. James Swinson ad Mr. Duane Johnson of the U. S. Naval Ammunition Depot, Crane, Indiana, Research and Development Department.

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I. ABSTRACT

The time-integrated grating spectra obtained at a dispersion of 14.8 Å/mm from flames produced by Mg-$Ba(NO_3)_2$, Mg-$NaNO_3$, Mg-$Ba(NO_3)_2$ - $Sr(NO_3)_2$-TFE, Al-$NaClO_4$-PVC, Al-$KClO_4$-PVC, Al-$Sr(ClO_4)_2$-PVC, B-$Ba(ClO_4)_2$-PVC, B-$KClO_4$-PVC, Mg-$LiClO_4$-PVC, Mg-$NaClO_4$, at different weight percentages are photographically reproduced.

These spectra have been obtained from flames burning in ambient air ranging in pressure from 630 torr to 70 torr.

Time-resolved spectra have been obtained from these same compositions, burning at the same ambient pressures, with a Perkin Elmer Model 108 Scanning Spectrometer at a rate of 3 per second. Photographic enlargements of typical spectra as photographed on the CRO are shown.

The colorimetric purity, dominant wavelength, intensity and integrated light output from the same mixtures burning under the same conditions are tabulated and also plotted on C.I.E. chromaticity charts.

The absorption of the light resulting from its passage through the smoke evolved during combustion has been determined and absorption coefficients tabulated for the smoke from several different compositions and ambient pressures.

Suggestions have been made for further studies of combustion problems.

II Introduction

The data presented in this report were collected to determine the intensity and spectral distribution of the visible radiation produced by the alkali and alkaline earth perchlorates when burned with magnesium, aluminum and boron. This report makes available for reference spectral data on the materials commonly employed as fuels and oxidants in solid flare compositions, when added to the data presented in earlier studies.

Because the work to be done under this contract was in several respects an extension of the work done under Contracts N00164-10520 and N164-11171 and reported in RDTR35 and RDTR91, U.S. Naval Ammunition Depot, Crane, Indiana some of the problems which were noted during those studies have been re-examined. As a result, it was hoped that more information could be obtained from the spectra with a moderate increase in effort. The discussion presented later will explain in detail the manner in which it was hoped to obtain this additional information.

The supply of materials that had been used in the previous tasks had been depleted. Some forty suppliers of chemicals were contacted to determine the best source - in some cases the only source - from which to obtain the alkali and alkaline earth nitrates and perchlorates and magnesium, aluminum and boron needed in this study. Anhydrous, - 320 mesh materials were preferred, but proved difficult to come by. Material which was supplied by the U. S. Naval Ammunition Depot, Crane, Indiana consisted of perchlorates of barium and strontium and a quantity of amorphous boron. Supplies of powdered aluminum were donated by Reynolds Metals as samples and powdered anhydrous perchlorates of lithium, sodium, potassium and barium were finally obtained from the Geo. Smith Co.* It was necessary to regrind most of these commercial materials to the desired size.

Because of the "chimney effect" which occurs when flares are burned in red fiber or other flame-resistant cases, which has some influence on the color, spectra and temperatures of the flame, it was hoped that it would be possible to eliminate the casing. Thin-walled epoxy tubing, epoxy and polyurethane coating materials were investigated.

Data was acquired from the combustion of a number of pyrotechnic compositions containing Mg, Al or B as the fuel and Na, K, Ba or Sr perchlorates as the oxidants. Mixtures containing magnesium and Na, Ba or Sr nitrate were also tested, primarily to provide a direct experimental link with the earlier work and also as a convenience to the reader by providing examples of the spectra from Mg-$NaNO_3$. It is thus less necessary to refer to reports RDTR 91 and RDTR 35. The earlier work on the Mg-$Ba(NO_3)_2$/$Sr(NO_3)$ mix, (F-16), had not been completed in time to appear in RDTR 91 and was therefore included.

* G. Frederick Smith Chemical Co., Columbus, Ohio

Smoke produced during combustion tends to interfere with measurements of the intensity and color of the flare rather early in a burn. A procedure was adopted which aided the estimation of the magnitude of the smoke obscuration, which is described in detail in Section III.

It is assumed that readers of this report are, generally, familiar with the history and state of the art in pyrotechnics. However, those who are new to this field may find it convenient to browse through some background material. As an aid to this process, a few references to the literature are included in the bibliography. Unfortunately, a great deal of interesting material is not readily available but must be unearthed from the DDC files; this task must here be left to the individual. (15-24)

III Experimental Work

Most of the equipment used in this work had been acquired, and described, in the course of preceding work in this area. Therefore, it will not be discussed in detail in this report.* However, some changes have been made to improve the extent or accuracy of the data produced by the various units.

A new photomultiplier was purchased for use with the Perkin-Elmer 108 Spectrometer. This is a Type 6217, 10-stage tube with S-10 response (Ag-Bi-O-Cs) which exhibits a current gain of 2.5×10^6. The 10 percent response points fall at 3200 $\pm$ 150 angstroms and 6950 $\pm$ 350 angstroms, thus providing output over about the same wavelength region as the Linagraph Shellburst film sensitivity covers. Peak response is at 4500 $\pm$ 300 angstroms. This tube has been mounted on a plate which fits the kinematic locating V-s of the I.R. detector-ellipsoidal mirror mount and is interchangeable with it.

The electronic colorimeter head which was built two years ago has twice been recalibrated. A plot of the results obtained is shown in Figure 1. Wratten gelatin filters 65 and 22, and a narrow band-pass interference filter with peak transmission at 0.557 micron were used to color the light from a 35 mm slide projector, thus providing a source of illumination of approximately known dominant wavelength and purity. Care being exercised to obtain even illumination across the four cells of the colorimeter, it was found that the results from the Wratten filters were in good agreement with the dominant wavelength and purity values given in "Kodak Wratten Filters for Scientific and Technical Use". See also Plate No. 63.

The measured values were 0.501 micron, 65 percent purity and 0.595 micron, 100 percent purity for the 65 and 22 filters, respectively. The published values were given for Illuminant A as 0.501 micron, 74 percent purity and 0.599 micron, 100 percent purity. The same tests were repeated with a piece of glass inserted in the light path. This glass is used to cover the porthole on the High Altitude Chamber through which the measurements will be made. A shift was found to occur toward the green; values with this glass in place are 0.506 micron, 65 percent; 0.589 micron, 93 percent. Although the color change represented by the difference between measured and published values is almost negligible without the porthole glass in the path, the change caused by the glass is (0.005, 0.010 micron) which is from 5 to 10 times the minimum noticeable amount. (See 10.) The response of the y-cell to intensity was also checked and found to be within 10 percent of the value found previously.

The compositions of the mixes that have been made for the present study are shown in Table 1. Prints of typical spectra recorded on the B & L 1.5 m. grating, from a point in the flames 1/2 - 3/4" above the flare casing, are shown in Plates 1 -11. Spectra were obtained simultaneously with the Perkin-Elmer Model 108 and the B & J grating spectrograph. Some of the typical spectral records from the P-E 108 spectrometer are reproduced in Plate Nos. 13-54. In addition to these records, the data obtained simultaneously from the colorimeter are presented in Table 2.

*See Bibliography 12, 13, 14.

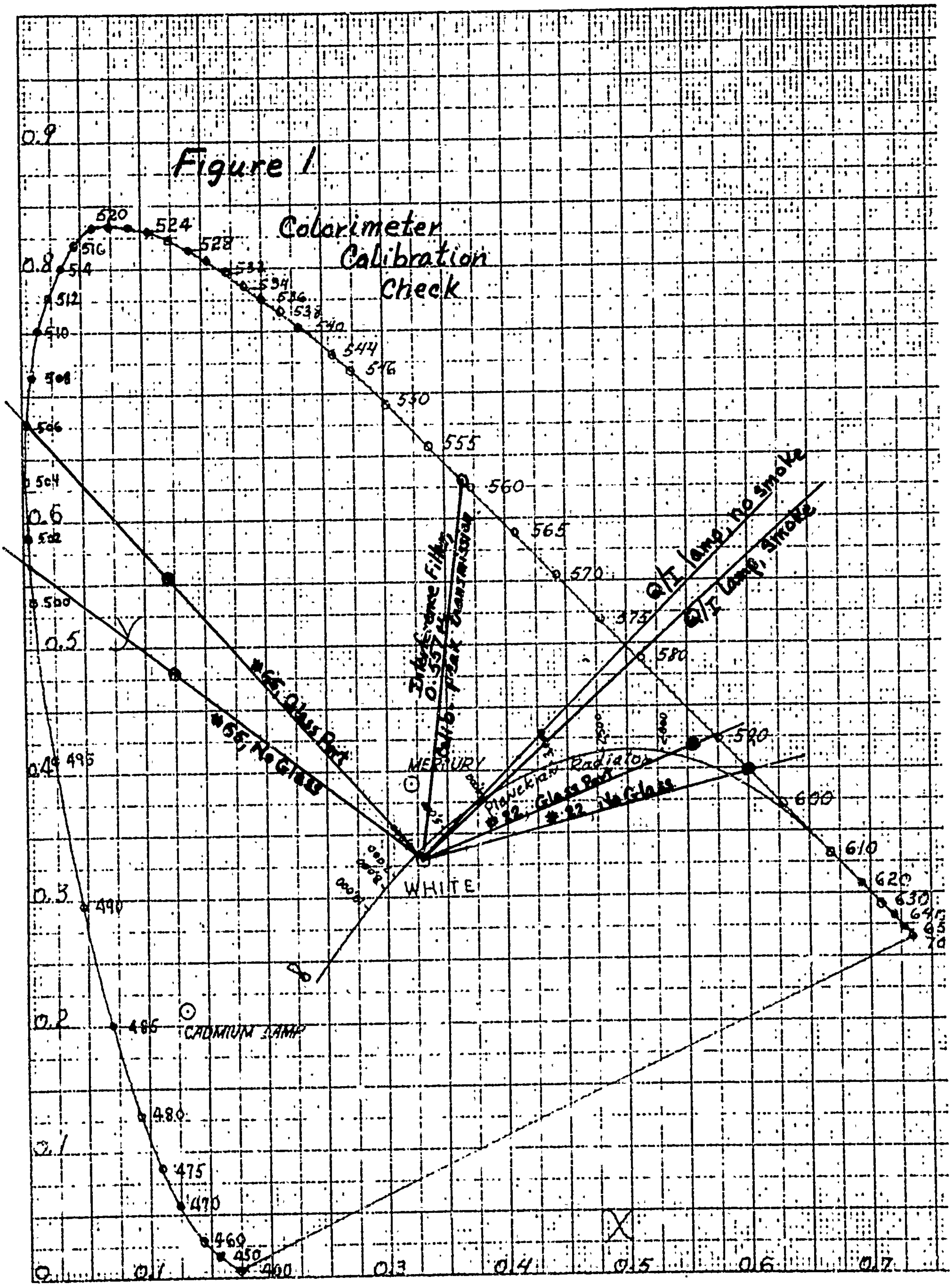
Figure 1
Colorimeter
Calibration
Check
0.9
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0.3
0.4
0.5
0.6
0.7
Y
X
520
524
528
555
560
565
570
575
580
590
600
610
620
630
WHITE
MERCURY
CADMIUM LAMP
Planckian Radiator
#66, Glass Port
#66, No Glass
#22, Glass Port
#22, No Glass
Q/I lamp, no smoke
Q/I lamp, smoke
490
486
480
475
470
460
450
400

TABLE 1

Composition Code, Weight Percent

Mix No.F-	Al	B	Mg	Li ClO_4	Na ClO_4	K ClO_4	Ba $(ClO_4)_2$	Sr $(ClO_4)_2$	Na NO_3	Ba $(NO_3)_2$	Sr $(NO_3)_2$	TFE	PVC
Mix 3			25							65			10
1			35						65				
3			40						60				
4			40							30		30	
7			25							65		10	
8			60						40				
14			26				74						
15			30				60					10	
16			51							37	7	5	
30	35				60								5
31	32					63							5
32	35						60						5
33	37							58					5
34		37					58						5
35		27				68							5
36			37			58							5
37	37			58									5
38			37	58									5
39			37		58								5
40			37				58						5
41			37					58					5
42		37			58								5
43		37						58					5
44		37		58									5
45	58				37								5
46	68					27							5
47	58						37						5
48	58							37					5
49	58			37									5
50		58					37						5
51		68				27							5
52		58			37								5
53		58						37					5
54		58		37									5
55			58			37							5
56			58	37									5
57			58		37								5
58			58				37						5
59			58					37					5

TABLE 2

Flare Color, Intensity and Related Data

Run No.	Mix No.	Pressure torr	Burn Time secs	Candela Seconds Total	Candela Average	Dominant Wavelength Av. mμ	Purity
1	F-1	630	5.5	26536	4300	608	0.748
2	F-1	630	9.0	37468	4027	607	0.818
3	F-1	630	No color data;		Visually yellow-white, bright		
4	F-1	630	No color data;		Visually yellow-white, bright		
5	F-3	630	9.2	31004	3445	603	0.822
6	F-3	630	7.3	22073	2945	597	0.813
7	F-4	630	24.5	hand calc.	4070	600	0.940
8	F-4	630	20.0	(Approx).	3764	593	0.910
9	F-4	630	29.0	120005	4181	609	0.904
10	F-3	630	Runs 10 - 13 inclusive were made to determine the best control settings for the P-E Model 108 scanning spectrometer.				
11	F-3	630					
12	F-4	630					
13	F-4	630					
14	F-31	630	77	No colorimeter data. Visually, blue-white flame noted on all Runs 14-21. Data is lacking because the flame is of low intensity and is often forked or skewed from its expected location. Thus, radiation is not focussed on the spectrometer/spectrograph slits.			
15	F-31	630	90				
16	F-31	630	68				
17	F-31	630	75				
18	F-31	630	73				
19	F-31	630	73				
20	F-31	630	75				
21	F-31	630	75				
22	F-8	630		Burned less than 3 secs; no data			
23	F-4	630	4	Colorimeter records off-scale at 20:1 attenuation.			
24	F-14	630		None of these attempts to burn F-14 or F-15 mixes were successful. The flares refused to ignite by any of the usual techniques.			
25	F-14	630					
26	F-14	630					
27	F-14	630					
28	F-15	630					
29	F-15	630					
30	F-15	630					
31	F-16	630	5				
32	F-16	630	5.5	94352	17155	595	0.628
33	F-16	630	5	94352	17186	587	0.629
34	F-14	630	Would not burn				
35	F-16	300	7	109396	15622	577	0.72
36	F-16	300	7.6	112336	14978	580	0.729
37	F-16	630	5	112038	20394	577	0.662
38	F-16	150	11	112038	10181	580	0.799

TABLE 2 (Continued)

Flare Color, Intensity and Related Data

Run No.	Mix No.	Pressure Torr	Burn Time secs	Candela Seconds Total	Candela Average	Dominant Wavelength Av. mμ	Purity
39	F-16	75		85417	4383	577	0.831
40	F-16	50	8.3	Partial burn, colorimeter record n.g.			
41/ 41A	F-16	50		No burn obtained from 2 attempts.			
42	F-16	630	4.8	75260	15052	594	0.625
43A	F-16	70	20	59260	2964	591	0.824
44	F-30	630	48	24318	700	594	0.879
45	F-30	630	50	21347	428	593	0.847
46	F-31	630	71	No data taken; burned to try He-Ne laser			
47	F-8	630		attenuation by flame.			
48	Mix 3	630	12	Color data not usable; eval. of laser.			
49	F-16	630	5	Color data not usable; eval. of laser.			
50	Mix 3	630	12	60210	5178	562	0.606
51	Mix 7	630		No color head data taken; side burned.			
52	Mix 3	630		No color head data taken; side burned.			
53	Mix 3	630		No color head data taken; side burned.			
54	Mix 3	630		No color head data taken; side burned.			
55	Mix 3	630		No color head data taken; plume wobbled.			
56	Mix 3	630		No color head data taken; poor burn, split.			
57	Mix 7	630		No color head data taken; poor burn.			
58	Mix 3	630	12.5	24670	1899	507	0.562
59	F-36	630	17.5	21990	1224	562	0.204
60	F-36	630	19	23336	1246	564	0.259
61	F-36	630	19	34529	1918	570	0.171
62	F-36	300	24	No color data; visually blue-white, bright.			
63	F-36	300	33	No color data; visually white.			
64	F-36	300	39	12775	336	581	0.275
65	F-36	150	48	3193	250	567	0.339
66	F-36	150	9	Partial Burn; no Color data; visual white; dim.			
67	F-36	150	49	3599	353	563	0.341
68	F-36	70	68	1132	320	560	0.52
69	F-36	70	31.5	Partial Burn; very poor burn, very erratic. No data obtained. White, bright.			
70	F-35	630	5	35782	7157	558	0.464
71	F-35	630	4	No colorimeter record - no spectral data.			
72	F-35	630	4.5	28732	6394	564	0.485
73	F-35	630	4.5	30351	6747	566	0.436
74	F-35	300	6	24321	4055	565	0.541

TABLE 2 (Continued)

Flare Color, Intensity and Related Data

Run No.	Mix No.	Pressure torr	Burn Time secs	Candela Seconds Total	Candela Average	Dominant Wavelength Av. mμ	Purity
75	F-35	150	8	3321	416	569	0.613
76	F-35	150	7.5	3668	489	576	0.657
77	F-35	70	9.5	295	42	595	0.552
78	F-35	70	10	164	18	586	0.588
79	F-35	150	7	3829	547	574	0.62
80	F-35	630	4.5	33360	7417	576	0.561
81	F-34	630	6	32968	5495	568	0.594
82	F-34	630	6	29160	4860	569	0.58
83	F-34	300	8	21196	2649	570	0.606
84	F-34	300	8	22723	2840	571	0.614
85	F-34	150	11.5	16082	1398	567	0.634
86	F-34	70	20.5	12050	588	588	0.743
87	F-34	70	20	12203	610	586	0.718
88	F-34	70	No useful data; Instrument difficulties.				
89			Not a flare burn, but calibration check of P-E 108.				
						max. min.	
90	F-39	630	19	81414	4523	595 586 575	0.793
91	F-39	630	20	66040	3669	598 593 591	0.80
92	F-39	630	19	101297	5333	597 593 587	0.839
93	F-39	300	30	92243	3181	604 591 582	0.889
94	F-39	300	27	93185	3584	612 594 582	0.879
95	F-39	150	31	22685	756	626 597 587	0.846
96	F-39	150	40	40073	1028	602 595 591	0.928
97	F-39	70	42	10242	282	619 595 588	0.918
98	F-39	70	46	7274	232	545	0.785
99	F-39	300	29	59137	2262	581 590 599	0.907
100	F-38	630	45	5779	263	599	0.339
101	F-34	630	9	40814	5102	540 567 575	0.586
102	F-34	630	8	32469	5396	571 569 567	0.597
103	F-34	300	9	36023	5130	571 572 574	0.592
104	F-34	300	11	30036	3334	581 571 567	0.63
105	F-34	300	12	27448	2495	597 573 561	0.642
106	F-34	630	8	37964	5423	584 571 570	0.619
107	F-38	630	50	No data; visually pink, dim.			
108	F-38	630	53	20467	418	668 599 555	0.536
109	F-38	300	72	2758	42	644 596 580	0.586
110	F-38	300	70	3481	51	609 591 548	0.578
111	F-38	150	64	1895	33	603 583 563	0.604
112	F-38	150		Uneven, split flame poor burn. Visually pink, dim.			

TABLE 2 (Continued)

Flare Color, Intensity and Related Data

Run No.	Mix No.	Pressure torr	Burn Time secs	Candela Seconds Total	Candela Average	Dominant Wavelength Max Av Min mμ	Purity
113	F-38	150	65	3552	56	601 587 568	0.609
114	F-38	630	51	5603	135	596	0.55
115	F-38	70	Wouldn't burn in 3 attempts.				
116	F-33	630	Very irregular burn - not reduced; visually red, dim.				
117	F-33	630	45	3611	84	631 585 501	0.691
118	F-33	630	50	3680	75	627 594 499	0.82
119	F-33	300	55	1395	26	607 593 554	0.743
120	F-33	300	Record unusable; visually red, dim. Flame split.				
122	F-33	300	Only very small part of flare burned - not useful.				
123	F-56	630.	34	Record went off-scale; visually pink.			
124	F-56	630	29	14636	585	627 595 576	0.503
125	F-56	630	31	5421	243	661 602 519	0.511
126	F-56	300	38	7594	238	642 591 557	0.501
127	F-56	300	42	6029	159	635 600 574	0.546
128	F-56	150	72	3670	52	637 588 567	0.546
129	F-56	150	73	3936	58	609 585 572	0.645
130	F-56	70	71	1297	19	595 557 530	0.555
131	F-56	70	77	1850	25	626 582 527	0.596
132	F-57	630	14	60562	6726	595 593 590	0.83
133	F-57	630	12	92528	8412	606 597 594	0.83
134	F-57	150	25	37618	1728	596 590 580	0.908
135	F-33	630	53	Flare burned mouth down; deposit build-up same as mouth-up burn.			
136	F-57	300	17	89790	5612	603 593 586	0.832
137	F-57	300	20	102892	5716	606 600 594	0.879
138	F-57	150	26	23921	1139	659 596 500	0.852
139	F-57	150	29	83175	2971	598 593 581	0.893
140	F-57	70	40	7125	193	603 586 559	0.657
141	F-57	70	39	8400	221	624 610 592	0.83

The effects of the smoke produced during combustion on the radiation reaching the colorimeter have been documented by simple measurements. A G.E. Co. Type DXW, 1000 watt, quartz lamp mounted in the altitude chamber was lit before the burn and the red, blue and green response from the colorimeter recorded. After the burn, the lamp was again lit and the same set of responses recorded. A small circulating fan was then turned on to stir and homogenize the smoky atmosphere and a third set of readings taken. The ratio of the second or third readings to the first set provides a measure of the change in transmission due to smoke and of the shift in color, if any, due to absorption and scattering by the smoke. It seems that the ratio obtained from the stirred condition is most useful as an average measure of smoke effects, because it eliminates wild variations caused by uneven distribution of the smoke in the chamber. Data on smoke transmission were not taken until the first fifty or so burns of the current study had been made. The idea was conceived at that time and the data were obtained on all of the subsequent runs, when possible. It is believed that it may be the only data readily available on the effects of smoke on the output from small laboratory tests of pyrotechnic illuminants and signals. It is artificial in that the field conditions under which pyro is used and the laboratory conditions are not very comparable. However, many tests have been made in the laboratories of those studying pyrotechnics under conditions somewhat similar to these. The effects of smoke are very noticeable when these materials burn in confinement; the data reported here, it is hoped, may be useful in correcting for these confined conditions of burn. A better extrapolation of small-scale laboratory tests to full-sized flares for field use may thus be possible.

Table 3 contains the data obtained from the colorimeter readings of the 1000 watt lamp prior to burning a flare. A plot of the candela, dominant wavelength and purity of the lamp alone is presented in Figure 2 to permit a rapid assessment of the range of values. Within any one group of tests during a period of one or two days the variation tends to be less than the overall variation. Since the purpose of the readings is to obtain relative values of intensity and dominant wavelength; i.e., without and with smoke in the radiation path, the long-time changes are not especially significant. They are of interest insofar as they may be considered to represent the stability of the entire lamp-plus-colorimeter system. The shift of about $\pm$ 10% in lamp intensity, $\pm$ 1/2% in dominant wavelength is considered acceptable. The shift is due both to the variations in line voltage applied to the lamp, which would be affected by about $\pm$ 15% in luminance by a $\pm$ 5% change in voltage, and to lamp aging. If the worst variations are dropped out the luminance change is of the order of 5%. The values of dominant wavelength and purity shown in Table 4 are unaffected by small changes in filament temperature, to the accuracy to which this work is done. The values in Table 5 were computed from the initial and final values of luminance obtained when the run was made, and only short-term fluctuations of line voltage would be effective in altering them. While these fluctuations can occur, the usual experience has been that the line voltage will remain steady over the period required for one of these determinations. The variations shown in Figure 2 occurred over a period of weeks and probably give a pessimistic picture of the accuracy

TABLE 3

Reference Lamp Stability

Run No.	Candela	Dominant Wavelength	Purity	Run No.	Candela	Dominant Wavelength	Purity
42	2056	477	0.382	100	2239	577	0.472
43A	2075	579	0.462	101	2328	576	0.479
44	2153	578	0.467	102		No Data	
45	2084	577	0.463	103		No Data	
48	2194	578	0.479	104	2328	576	0.479
49	2122	579	0.479	105	2286	576	0.468
50	2081	579	0.472	106	2286	576	0.471
61	2395	578	0.465	107	2275	575	0.47
63	2241	579	0.475	108	2223	575	0.463
64	2297	578	0.465	109	2270	575	0.469
65	2329	578	0.476	110	2330	575	0.473
67	2517	578	0.468	111	2303	576	0.474
68	2542	593	0.509	112		No Data	
72	2373	578	0.47	113	2352	576	0.477
73	2401	579	0.47	114	2270	575	0.476
74	2398	579	0.47	115		No Data	
75	2407	579	0.475	116	2264	576	0.489
76	2451	579	0.474	117	2328	577	0.495
77	2451	579	0.474	118	2327	577	0.48
78	2257	580	0.487	119	2281	576	0.471
79	2272	580	0.475	120	2277	576	0.472
80	2435	580	0.486	121	2460	575	0.593
81	2351	583	0.456	122		No Data	
82	2586	578	0.484	123	2416	576	0.478
83	2269	579	0.474	124	2396	576	0.474
84	2357	578	0.48	125	2217	576	0.471
85	2376	578	0.483	126	2273	576	0.471
86	2382	579	0.484	127	2325	576	0.492
87	2398	579	0.482	128	2303	576	0.486
90	2259	575	0.462	129	2231	575	0.49
91	2328	577	0.47	130	2237	575	0.48
92	2341	577	0.47	131	2314	576	0.48
93	2355	576	0.482	132	2295	576	0.464
94	2314	577	0.475	133	2334	576	0.472
95	2273	577	0.471	134	2413	576	0.472
96	2273	576	0.475	135	2402	576	0.478
97	2286	577	0.483	136	2363	575	0.471
98	2314	577	0.48	137	2368	577	0.489
99	2322	577	0.48	138	2275	576	0.478

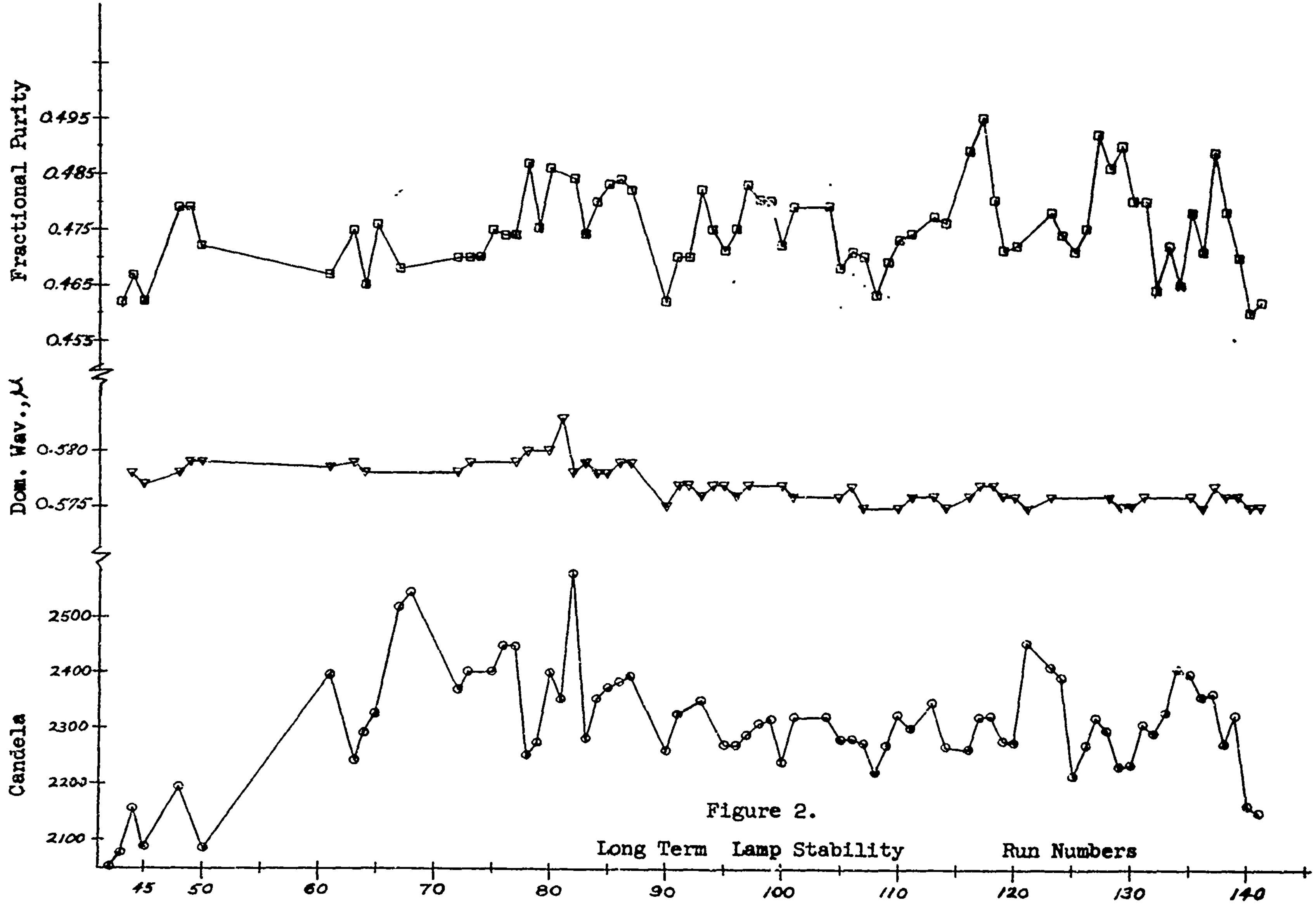

Figure 2.

Long Term Lamp Stability

TABLE 4

Observed Effects of Smoke on Dominant Wavelength

Run No.	Mix No.	Candela		Dominant Wavelength		Purity	
		Clear	Smoke	Clear	Smoke	Clear	Smoke
61	F-36	2394	790	578	577	0.47	0.49
63	F-36	2241	802	579	579	0.47	0.5
64	F-36	2297	800	578	578	0.46	0.56
65	F-36	2340	1310	577	580	0.48	0.63
67	F-36	2516	1314	578	577	0.47	0.56
68	F-36	2560	1570	577	579	0.48	0.53
72	F-35	2372	626	578	578	0.47	0.54
73	F-35	2401	659	579	578	0.47	0.53
74	F-35	2398	671	579	580	0.47	0.57
75	F-35	2407	1276	579	576	0.47	0.58
76	F-35	2451	256	579	578	0.47	0.57
77	F-35	2451	1667	579	579	0.47	0.53
78	F-35	2256	1661	580	579	0.49	0.53
79	F-35	2272	1122	580	579	0.48	0.57
80	F-35	2435	535	580	579	0.49	0.56
81	F-34	2517	608	578	580	0.46	0.56
82	F-34	2586	598	578	580	0.48	0.55
83	F-34	2269	585	579	580	0.47	0.58
84	F-34	2357	634	578	578	0.48	0.58
85	F-34	2376	1059	578	578	0.48	0.56
86	F-34	2382	1210	579	578	0.48	0.56
87	F-34	2398	1260	579	578	0.48	0.55
90	F-39	2215	589	576	573	0.48	0.51
91	F-39	2328	578	577	574	0.47	0.51
92	F-39	2341	606	577	574	0.47	0.52
93	F-39	2355	743	576	575	0.48	0.58
94	F-39	2314	645	577	575	0.48	0.51
95	F-39	2273	490	577	576	0.47	0.57
96	F-39	2273	457	577	577	0.47	0.58
97	F-39	2286	1375	578	575	0.48	0.56
99	F-39	2322	901	577	576	0.48	0.58
100	F-38	2239	408	577	576	0.47	0.49
104	F-34	2328	545	576	577	0.48	0.60
105	F-34	2286	581	576	576	0.47	0.60
106	F-34	2286	448	577	579	0.47	0.58
107	F-38	2275	291	575	576	0.47	0.49
108	F-38	2223	311	575	578	0.46	0.47
109	F-38	2270	328	575	575	0.47	0.48
110	F-38	2330	345	575	576	0.47	0.49

TABLE 4 (Continued)

Observed Effects of Smoke on Dominant Wavelength

Run No.	Mix No.	Candela		Dominant Wavelength		Purity	
		Clear	Smoke	Clear	Smoke	Clear	Smoke
111	F-38	2303	419	576	575	0.47	0.48
113	F-38	2352	420	576	575	0.48	0.48
114	F-38	2270	504	575	574	0.48	0.46
116	F-33	2264	1505	576	577	0.49	0.57
117	F-33	2328	1080	577	575	0.495	0.58
118	F-33	2328	1450	577	578	0.48	0.56
119	F-33	2281	1575	576	576	0.47	0.56
120	F-33	2377	1496	576	576	0.47	0.56
123	F-56	2316	340	576	575	0.48	0.48
124	F-56	2396	369	576	576	0.47	0.49
125	F-56	2217	261	576	577	0.47	0.47
126	F-56	2273	295	576	577	0.48	0.47
127	F-56	2325	295	576	577	0.49	0.49
128	F-56	2303	362	576	577	0.49	0.49
129	F-56	2231	372	575	577	0.49	0.5
130	F-56	2237	437	575	575	0.48	0.47
131	F-56	2314	421	576	576	0.48	0.46
132	F-57	2295	523	576	574	0.46	0.53
133	F-57	2336	604	576	576	0.47	0.55
134	F-57	2413	1118	576	575	0.46	0.58
135	F-33	2402	1603	576	576	0.48	0.54
136	F-57	2363	903	575	577	0.47	0.6
137	F-57	2360	923	577	577	0.49	0.59
138	F-57	2275	1352	576	577	0.48	0.55
139	F-57	2330	1297	576	578	0.47	0.58
140	F-57	2162	1420	575	575	0.46	0.55
141	F-57	2149	1460	575	576	0.46	0.54

of this set of measurements.

Computations were made using Lambert's Law with the initial lamp candela as I_0 and the final candela reading, I, obtained when the smoke had been homogenized by stirring.

$$I = I_0 e^{-ad}$$

The value of (a) is in units of cm^{-1} and is listed in Table 5.

The last column in Table 5 gives the path length over which a reduction to $1/e^{th}$ of the initial intensity would occur. This may be more easily visualized in terms of physical effect than the value of (a) is. Because the data were readily available as a result of the above recordings, it seemed useful to look for evidence of a shift in the dominant wavelength of the source as seen thru the smoke. The data in Table 4 illustrate the changes that may be expected. No change in color due to passage of the radiation through the smoke cloud was measured. Either the effect is too small to measure for these smokes, with this apparatus, or a much longer path is required. Purity is higher through the smoke, by 10% - 20%; the reason is not apparent at this time.

The following outline discussion summarizes the investigation which was made in an effort to secure more information from the spectrum photographs than had been possible to date, relative to intensity and temperature.

In order to establish working curves by which the source intensity can be evaluated in terms of the photographic density that the source produces, the following detailed steps were followed:

1. Three temperatures, say 2200°K, 2400°K and 3000°K were chosen as operating temperatures for a tungsten strip lamp. A fourth value, say 2600°K, was chosen to provide a check on the results of the following procedure to determine flare temperatures.

2. A computer run was made to obtain values of W_λ at 0.010 micron intervals for these four temperatures, normalized at 0.6150 micron (an arbitrary choice), from 0.35 to 0.75 micron. It is instructive to plot these values of W_λ and $W_\lambda/W_{.615}$ as in Figure 3. W_λ is the power radiated per $cm^{-2}\mu^{-1}$ in 2π steradians in watts, as it is tabulated in RDTR No. 90.

3. Films were exposed in the B & L 1.5 meter grating spectrograph through a step-wedge over the slit. The wedge had been calibrated on the Jarrell-Ash microdensitometer and found to have the following characteristics:

TABLE 5

Smoke Attenuation Coefficients

Mix	Fuel	Pressure, torr	a(x 10^3) cm^{-1}	Path length for $I/I_o = e^{-1}$
F-16	Mg	630	4.9	202
F-16	Mg	70	1.8	556
F-30	Al	630	4.9	197
F-33	Al	630	3.2	333
F-34	B	630	6.6	154
F-34	B	70	3.0	331
F-35	B	630	6.5	154
F-35	B	70	1.8	573
F-36	Mg	630	5.6	180
F-36	Mg	70	2.2	447
F-38	Mg	630	7.9	127
F-38	Mg	150	9.0	111
F-39	Mg	630	7.0	142
F-39	Mg	70	2.7	370
F-56	Mg	630	10.4	96
F-56	Mg	70	8.7	114
F-57	Mg	630	7.4	136
F-57	Mg	70	2.1	475

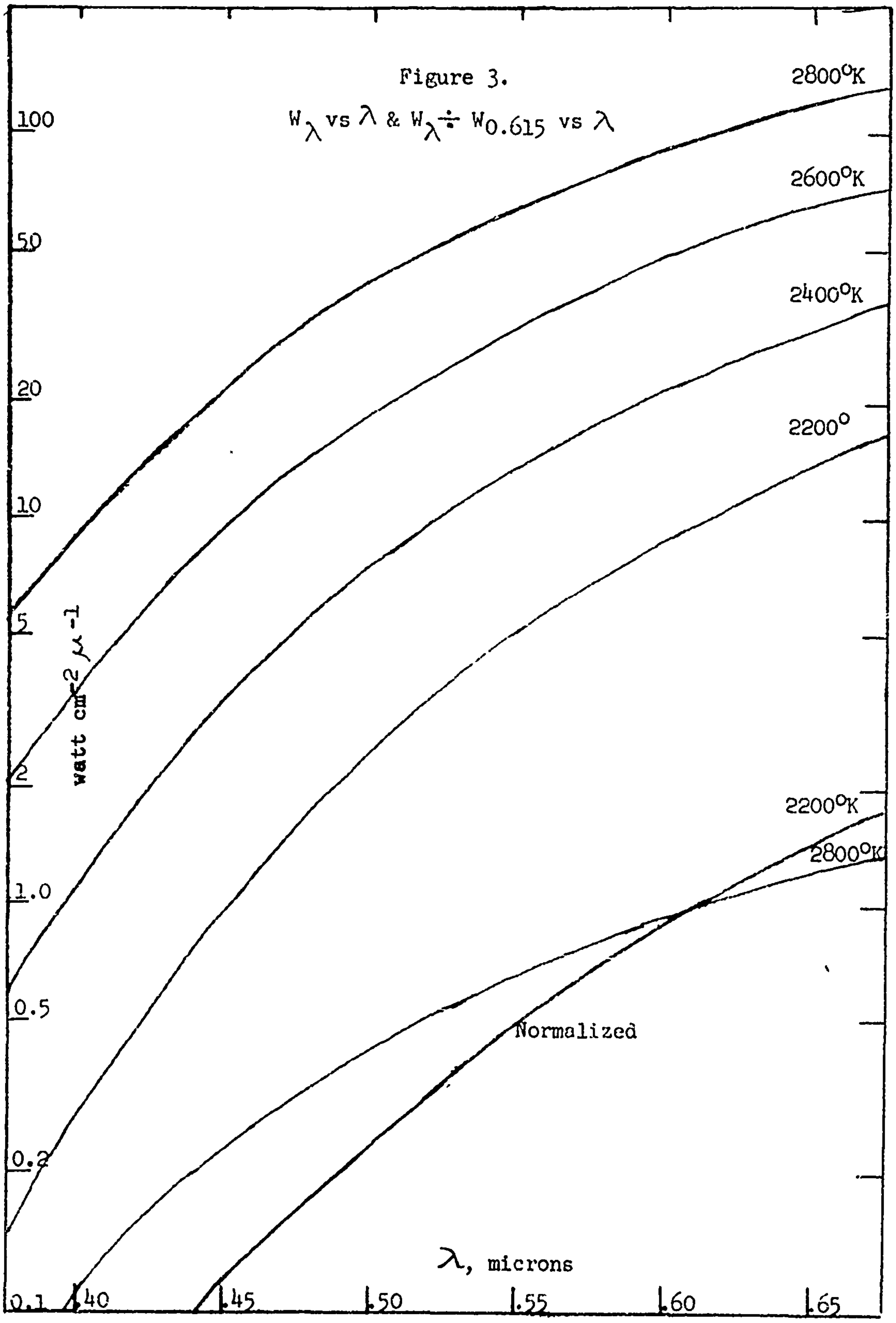
Figure 3.
W_λ vs λ & $W_\lambda \div W_{0.615}$ vs λ
2800°K
2600°K
2400°K
2200°
2200°K
2800°K
Normalized
watt $cm^{-2}\ \mu^{-1}$
100
50
20
10
5
2
1.0
0.5
0.2
0.1
.40
.45
.50
.55
.60
.65
λ, microns

Step Wedge Transmission and Density Values

Step No.	Fractional Transmission, T	Density	Seidel Δ
0	1.000	0.000	-2.00
1	.334	0.476	0.2997
2	.147	0.833	0.764
3	.067	1.174	1.144
4	.029	1.538	1.525
5	.012	1.921	1.916
6	.004	2.398	--
7	.002	2.699	--
8	--	--	--

4. The physical setup of apparatus was held constant while several exposures were made with the lamp at each of the four chosen temperatures. One exposure was made at five seconds, one at thirty seconds and one to produce a density of 0.6 on the fifth wedge step at a wavelength of the order of 0.5 micron. Five seconds was chosen because that duration occurred in many tests; thirty seconds was used for some tests because of the increased burning time experienced at pressures of the order of 40 torr. Reciprocity failure can be partially compensated by using data from the film strip which most nearly matches the exposure duration of the burn. See Plate 55.

5. These films were measured to obtain the transmission of each step, from 0.35 micron to 0.75 micron, at 0.010 micron intervals.

6. When the transmission is less than 0.10, accuracy becomes poor. In such case, the Jarrell-Ash densitometer can be readjusted to show T = 1.00 when a Wratten 96 filter of effective D = 1.00 is in the beam. This filter is then removed and readings made of those film areas for which $T \leq 0.1$. These readings must then be divided by F to obtain the true value of T. F will be a number close to 10, determined from an actual calibration of the Wratten 96 filter transmission, which is nominally 10 percent. Generally, readings of $T \leq 0.1$ were not used except to extend the range of data as a check on the results.

7. A table of values was constructed which contained the wavelengths and transmissions just obtained. Each value was then converted to the Seidel Δ-function (11). This function is usually found to produce a linear portion in the plot of Δ against log E which extends over a wider range of values of T, roughly from $0.03 \leq T \leq .97$, than does the linear portion of the customary D-log E curve. E, of course, is defined as the exposure and when I is intensity in appropriate units, perhaps erg/cm^2, and t is time in seconds, E = It.

8. The values of Δ were normalized to the value obtained at $\lambda = 0.500\mu$, resulting in Δ_n. A plot was made of the values obtained from the computer run of $W_\lambda/W_{.500}$ vs. λ, a separate plot for each temperature, Θ, being convenient. The values of Δ_n which cover the greatest range of λ were

plotted on the same graph with $W_\lambda/W_{.500}$. At each λ, the ratio F, of Δ_n to $W_\lambda/W_{.500}$ is the correction factor needed to account for the deviation from linearity with respect to wavelength which all film exhibits in its sensitivity. A plot of this ratio vs. λ was made. It should be the same for each temperature, i.e., the points from each of the three calibration temperatures should fall on this plot, unless values of Δ are involved which fall outside the linear range of this function.

9. Another set of plots could now be constructed in which the abscissal values are log (W_λ) for Θ = 2800°K and the ordinates are Δ_λ. The values of W_λ would have to be divided by the appropriate step-wedge transmission, T, when plotting these curves. This would normalize every step to the direct exposure value of the zero step.

10. The values of Δ_λ from the other temperatures, suitably corrected for the step wedge T and with values of W_λ appropriate to the respective temperatures may be plotted as in 9. Again, unless the linear range of the Δ-function is exceeded, these points should "fit". It is now possible to relate the transmission of the film at any wavelength to the relative exposure which caused the film density, and thence to the relative intensity of the source. From these values, a value for the source temperature may be obtained by various methods. If it is assumed that the source is a grey-body, the ratio of the "intensities" at two wavelengths can be used to define a temperature. If atomic line radiation which is not affected too greatly by absorption in the flame can be found in the spectrum, an excitation temperature can be defined by well-known relationships when transition probabilities and statistical weights are known for these lines. If several lines are available, an atomic Boltzmann plot can be used, the slope defining the temperature.

Some of the points in the preceding comments are emphasized for greater clarity in the following paragraphs.

11. A great deal of work has been done on the radiant emittance of the strip filament lamps mentioned above in 1. (1-5) A General Electric SR8 filament, 18A/T10/1 lamp is used; the temperature of the filament is determined with a Leeds and Northrop Optical Pyrometer, operating at an effective wavelength of 0.655 micron (6). For this wavelength, the emissivity of tungsten is given by DeVos as 0.43 in the temperature range of interest; i.e., 2200° - 2800°K. The variation with temperature is from 0.438 to 0.426, which is within the limits established by other experimental errors. A further correction is made to account, somewhat empirically, for the reflection losses due to passage of the radiation through the glass lamp bulb. A loss of eight percent is assumed, and the effective emissivity is thus taken as 0.40.

12. Operating temperatures for the strip lamp are chosen to give four convenient points for calibration and check. Correction of the desired to the observed temperature is made with the aid of tables (7). For true temperatures of 3000°K, 2400°K and 2200°K the temperatures observed with the optical pyrometer are 2402°C, 1912°C, and 1742°C. An error of the order

of $\pm$ 5°C is expected in setting these desired temperatures.

13. Because it was known that the flare compositions to be studied might burn for times so short as to make exposures longer than five seconds difficult to achieve, this exposure duration was used as a basis. Changes were made when required to produce useful records from low-intensity sources; e.g. flares burning at low pressures.

14. Film is subject to reciprocity effects which must be considered when calibration exposures differ from test exposures. The film chosen for this work is Eastman Kodak Linagraph Shellburst, clear backing. Data from (8) was replotted to obtain a curve of the exposure required to produce a density of 0.3 above fog for development in D-19. This curve, for times from 0.1 to 100 seconds, is almost linear and is of the form

$$\log It = 0.303 \log t - 2.06$$

when I is in meter-candle seconds and t is in seconds. A change from $t = 1$ sec to $t = 10$ sec is seen to require a corresponding change in exposure of approximately 2X, for the same density to be obtained from a source one-tenth as intense.

15. It is customary to plot the film response in terms of (density) versus (log exposure). The result is an S-shaped curve from which values near low or high densities cannot be easily and accurately related to the exposure. In order to improve the reading of values of exposure from low and high density regions of the calibration curve, the Seidel function has been used (9). This function replaces density, D, with $\log (\frac{1}{T} - 1)$ where T is the transmission or transparency. T is the result of the usual microphotometer reading, which usually must be converted to density by the relations $D = \log O = \log \frac{1}{T} = -\log T = -\log \frac{I}{I_o}$. I is the transmitted, I_o the incident intensity of radiation in the microphotometer. D-log E curves are usually approximately linear from $D = 0.4$ to $D = 1.8$, whereas the Seidel plot is linear from about $D = 0.1$ to $D = 2.1$.

16. Response of the film is required at each wavelength of interest because of the variation of its characteristics with wavelength. Both sensitivity and gamma vary with wavelength of the exposing radiation. The required data are obtained by the combination of step wedge transmission factors and the known spectral distribution of the strip lamp at various temperatures, which determine the exposure, and the readings of density from the microphotometer.

17. It should be noted that the original choice of a normalizing wavelength at 0.615 micron was poor because few readings could be obtained from the film at this point. It was therefore necessary to change the normalizing wavelength to 0.500 micron. See paragraph 2, and Figure 3.

The material that has evolved in the process of applying the approach to temperature measurement just described above is illustrated and amplified in Plates 56-62. It was found to be almost a necessity to develop the conversion chart in Plate 56 to expedite the measurement of the negatives. A change of the switch position which controls the sensitivity of the Jarrell-Ash Densitometer was found to be a more rapid and a reproducible means of reading high density portions of a negative, replacing the method initially used and described in paragraph number 6. With the switch positioned at 8, a reading of 15 obtained with a switch setting of 7 becomes a reading of 37.5, etc. The emissivity of tungsten as determined by DeVos has been used in these calculations. His summary plot of emissivity vs. temperature is therefore given in Plate 57. The computer program which was developed to calculate the various energy and delta values is shown in Plate 58. The output from this program for data obtained from a negative exposed to a strip lamp is shown in Plates 59-61. The lamp temperature was determined to be 2400°C, or 2673°K apparent. Correction for emissivity and losses in the lamp envelope produces a true temperature of 3000°K. Similarly, the lower temperature was measured as 2077°C and corrected to 2603°K, true. Plates 59 and 61 contain the entire results of the computation program in Plate 58; Plate 60 shows the summary only of the data needed to plot the film response vs. exposure. A plot of this data from the 3008°K source negative is presented in Plate 62 It is easy to verify by plotting points from the 2603°K data that further work is needed to find the source of the discrepancy in the results. Although the points from either temperature source should, for a given wavelength, fall on the same line, they do not. The error probably lies in the energy values used to calculate (log intensity) as determined from the source temperature and step wedge transmission. It appears from the linearity of the plotted data that the method should be usable if this problem can be overcome.

The variation seen in the slope of the Seidel vs. log intensity lines, with wavelength, is not unexpected. A variation in film gamma with wavelength, which this represents, has long been known.

Recordings of the spectral distribution of the radiation as seen through the fore-optics of Plate 65 by the scanning monochromator are reproduced in Plates 12-54. So far as possible, these plates have been chosen to match the spectra in Plates 1-11; however, when experimental difficulties produced good data from only one instrument during a test, the data from two different burns have been used in the plates. The records have not been corrected for the system response; a correction curve is given in Plate 68 that was derived from the records shown in Plates 66 and 67. The relation between the abscissal location on the record and the wavelength of the radiation is shown in Plate 64.

Results of the data on dominant wavelength and purity that were obtained with the colorimeter have been plotted on C.I.E. chromaticity diagrams in Plates 70 - 81. Correction of the tabulated values which were plotted in these plates may be desirable in the extreme red and blue regions; it was felt that for most purposes the data were acceptable as they are. Corrections can be obtained from Plate 69.

The presence of a non-consumable case results in the creation of a motor effect during the later stages of combustion and is believed to produce some changes in the character of the visible (as well as the concealed portion) flame. These changes have not been studied but an effort has been made in the current study to minimize their effects. This has been attempted by endeavoring to obtain the time-resolved data during the early part of the burn, but after it is well established. This is not possible in many cases.

IV. DISCUSSION AND CONCLUSIONS

A considerably larger than normal amount of raw data has been included in this report. This has been done in order to make the results of this study available to interested persons as rapidly as possible. It also serves to preserve the material until such time as it becomes possible to analyze its content to a greater extent than has proved possible at this time.

It is believed that an extension of the spectral data, to include those compositions which were listed in the F-forty group and a few others, should be made. With this exception, it appears that spectral data from the flames of small flares have been obtained for representative mixtures of those materials which are of general interest. However, this represents, essentially, a survey of the field rather than an exhaustive study of it. In particular, the changes in the species that are in these flames which must occur with changes in the distance from the burning surface have not been investigated.

The same comment also applies to the changes in color, luminosity and temperature. Furthermore, results which have been obtained to date apply to quite small flares; e.g., 1/2" diameter, and to flares burning in cases which have a strong chimney or motor-action influence on the combustion process. Differences of significance may be expected in the parameters mentioned when they are measured on large flares, or on flares which consume the covering as they burn. Some further study should be made (with this same set of apparatus, to eliminate as many unwanted sources of difference as possible) of selected compositions to establish the magnitude of such differences.

Efforts are finally being made to reconcile the results produced by thermochemical, computer calculations of the kind long-used in the rocket motor developments with the performance of flare compositions.(25) Determinations of the optical density and absorption characteristics of flare flames will be needed to back up these calculations. The role played by metallic fuels should be more fully investigated, particularly with regard to their influence on the reaction rate and the amount and source of continuum radiation. That is, the role of MgO or MgOH in Mg-fueled flares is of interest. By comparing the spectral distributions produced by, say, Mg-$NaClO_4$ and CH_3OH-$NaClO_4$, some data bearing on the relative importance and amount of radiation from MgO can be obtained.

The measurement of temperature by the method of spectral intensity ratios, etc. has been disappointingly difficult to implement. A stronger effort was made to accomplish this task in this study than had been made previously and it is believed that the expenditure of a reasonable additional effort - two man months - should bring it to a successful conclusion. This would provide a valuable tool in future studies of the temperature distribution in "dirty" or opaque flames. It can be used also in studies designed to provide the high temperature thermochemical data which is needed in the computer calculations of flame temperature and reaction product concentrations.

Because the radiation from the flare may contain not only the line and band radiation of atomic and molecular species, but also the radiation of particles of, say, MgO, some thought should be given to the manner in which this latter radiation occurs. The radiation from massive pieces of hot MgO - say, below 2800°K to 3000°K - should lie mainly in the long-wave spectrum beyond 7 microns, since it is transparent in the region from 0.3 micron to 7.0 micron or more, and consequently would not be expected to act as a good radiator. However, the combustion of magnesium with oxygen produces an intense light with an excess of short-wave (blue) radiation. In this example it appears probable that the major radiating species is MgO, although possibly a nitride or hydroxide could be formed. If MgO is indeed the major species and responsible for the majority of visible radiation from the combustion of magnesium in air, an apparent anomaly exists which should be investigated. The fact that magnesium is the fuel used in most illuminating flare compositions makes this question interesting, because of its application to the description of the radiative processes which occur in these flames. Eventually the information would be useful in the creation of a theoretical, computational model of flare performance.

The color and purity of the light produced by the B-$Ba(ClO_4)_2$ was neither as green nor as pure as had been hoped for. None of the compositions burned produced radiation of particularly high color purity or intensity. The most nearly colorless, in the sense that low purity of color indicates a high percentage of "white", was F-36. This mix contains Mg-$KClO_4$ and is quite low in its candela rating; it would not appear to be especially useful, even though essentially colorless. Caution must be used to avoid confusing Mix 3 with F-3. F-3 is a 40/60 Mg-$NaNO_3$ composition, whereas Mix 3 is 25/65/10 Mg-$Ba(NO_3)_2$ -PVC and is carried over from earlier work.

The effects of smoke produced by the combustion of these mixes on the color and purity of the light seem to indicate that smoke has not seriously affected these measurements. Earlier work was done in a much smaller chamber; the smoke concentration would be higher, and greater effects might have been produced under those conditions. It is interesting to note the apparent increase in purity that is recorded in Table 4, amounting to about 20 percent. Whether this represents a sort of Christiansen filter effect, or perhaps a scattering of some blue out of the measured radiation, is a matter for speculation.

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25. Hamrick, Jos. T., et al., "Exploratory Development of Illuminating Flares," Aerospace Research Corp., 5454 Jae Valley Rd., Roanoke, Va. 24014, on Contract No. F08635-67-C-0161, Illumination Branch, Targets & Missiles Division, Eglin Air Force Base, Fla. August 1967 - April 1968.

The following list of wavelengths identifies the materials of Plate 1 through Plate 11.

LIST OF TYPICAL SPECIES VS. WAVELENGTH*

Species		Approximate Wavelengths, Lines & Band Edges, Relative Intensities and Direction Band Degrades, Violet and Red; Angstroms
Elemental	Molecular	
Mg		5184/500, 5173/200 5167/100, 3838/300, 3832/250 3829/100
Sr		7070/1000 6893/100, 6878/500, 6791/200 6644/100, 6617/150, 6550/100 5481/100, 4876/200, 4607/1000
Ba		7060/2000, 4554/1000 3501/1000
Li		6708/3000,4603/800, 4273/200 4132/400, 3986/100
Na		6161/6154//500, 5896/5000 5890/9000, 5688/300, 5676/150 5670/100, 5154/600, 5149/400, 4983/200/4669/200
K		6939/500, 6911/300, 4047/400 4044/800, 3448/100, 3447/150
	MgF	3685 V
	MgCl	3775 V
	MgO	3816-9-R; 4974-7-V; 4986-8-V; 4997-9-V; 5007-10-V; 5286-3-V; 5519-4-V; 5776-5-V
	BaCl	5066-1-V; 5136-10-R; 5139-10-V; 5167-2-R; 5213-1-V; 5241-10-R; 5371-3-V
	BaO	4851-6-R; 4965-3-R; 5087-6-R; 5215-7-R; 5350-8-R; 5493-10-R; 5644-9-R; 5701-8-R; 5805-6-R; 5865-10-R; 6040-9-R; 6165-6-R; 6291-8-R
	SrCl	6756-3-V; 6745-5-V; 6620-5-V; 6614-10-V; 6483-4-V; 6362-5-V; 6359-10-V; 6239-2-V;
	SrOH	6110-1-V; 6101-3-V; 6096-4-V; 6090-6-V; 6085-10-V; 6077-8- V

*An index bar appears at the top or right end of each spectrum, which is at approximately 3400 A°.

PLATE 1

Data Zone	Run	Mix	Metal %	Oxidant %	Binder PVC %	Pressure Torr	Exposed Secs
1"	4	1	Mg 35	$NaNO_3$ 65	0	630	8.7
1"	6	3	Mg 40	$NaNO_3$ 60	0	630	7.3
1"	8	4	Mg 40	$NaNO_3$ 30	30(TFE)	630	20.0
1"	22	8	Mg 60	$NaNO_3$ 40	0	630	less than 3

Plate 1.

PLATE 2

Date Zone	Run	Mix	Metal %	Oxidant %	Binder PVC %	Pressure Torr	Exposed Secs
1"	33	16	Mg 51	$Ba(NO_3)_2$ 37 & $Sr(NO_3)_2$ 7	5(TFE)	630	5
1"	35	16				300	5
1"	38	16				150	11
1"	39	16				70	21

See P'ates 19 and 20

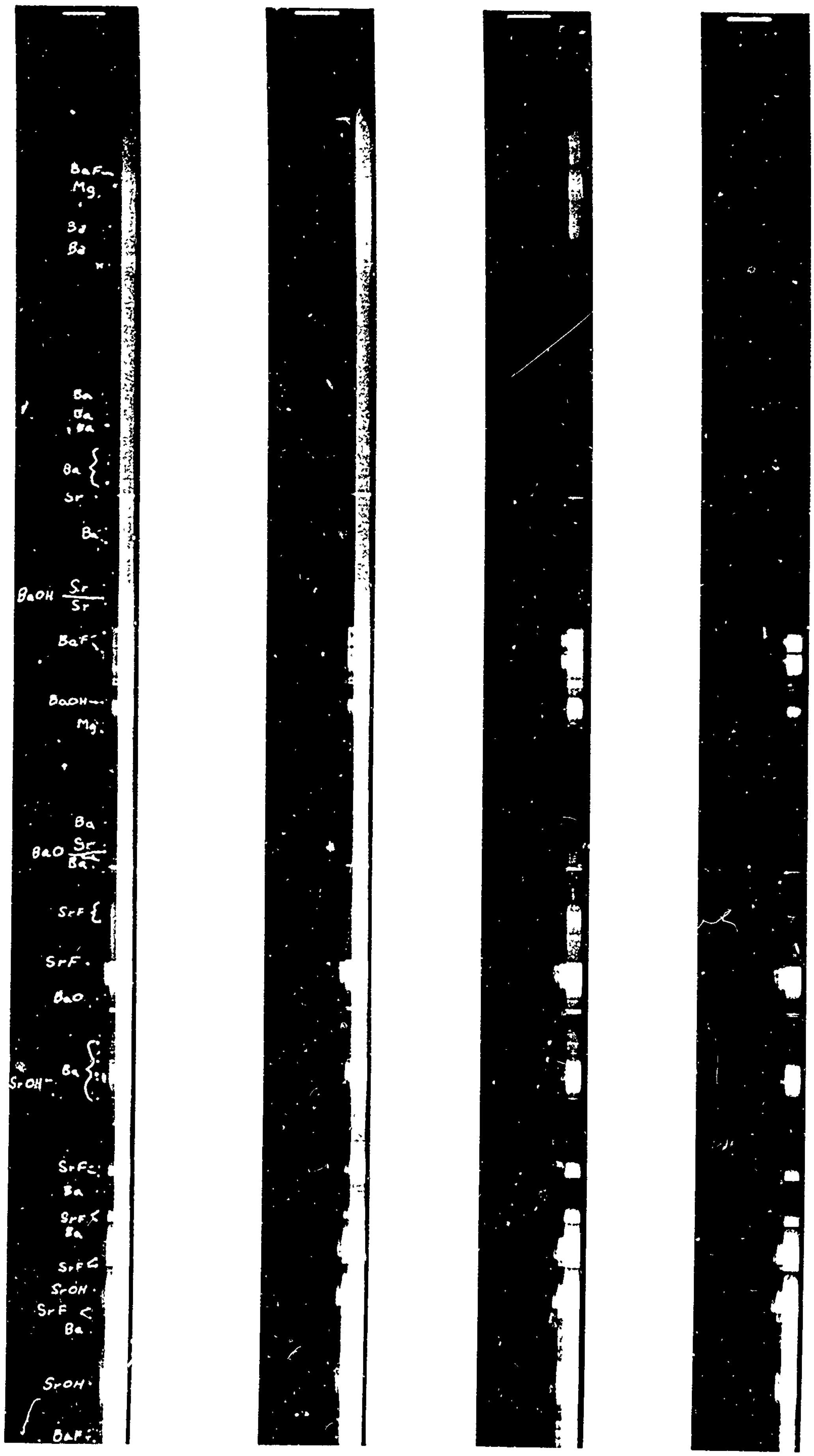

BaF
Mg
Ba
Ba
Ba
Ba
Ba
Ba
Sr
Ba
BaOH Sr
Sr
BaF
BaOH
Mg
Ba
BaO Sr
Ba
SrF
SrF
BaO
SrOH
Ba
SrF
Ba
SrF
Ba
SrF
SrOH
SrF
Ba
SrOH
BaF

Plate 2.

PLATE 3a

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1"	44	F-30	Al	35	$NaClO_4$	60	5	630	50
1"	20	F-31	Al	32	$KClO_4$	63	5	630	78

PLATE 3b

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1"	117	F-33	Al	37	$Sr(ClO_4)_2$	58	5	630	42
1"	120	F-33	Al	37	$Sr(ClO_4)_2$	58	5	300	62

See Plates 24 and 25

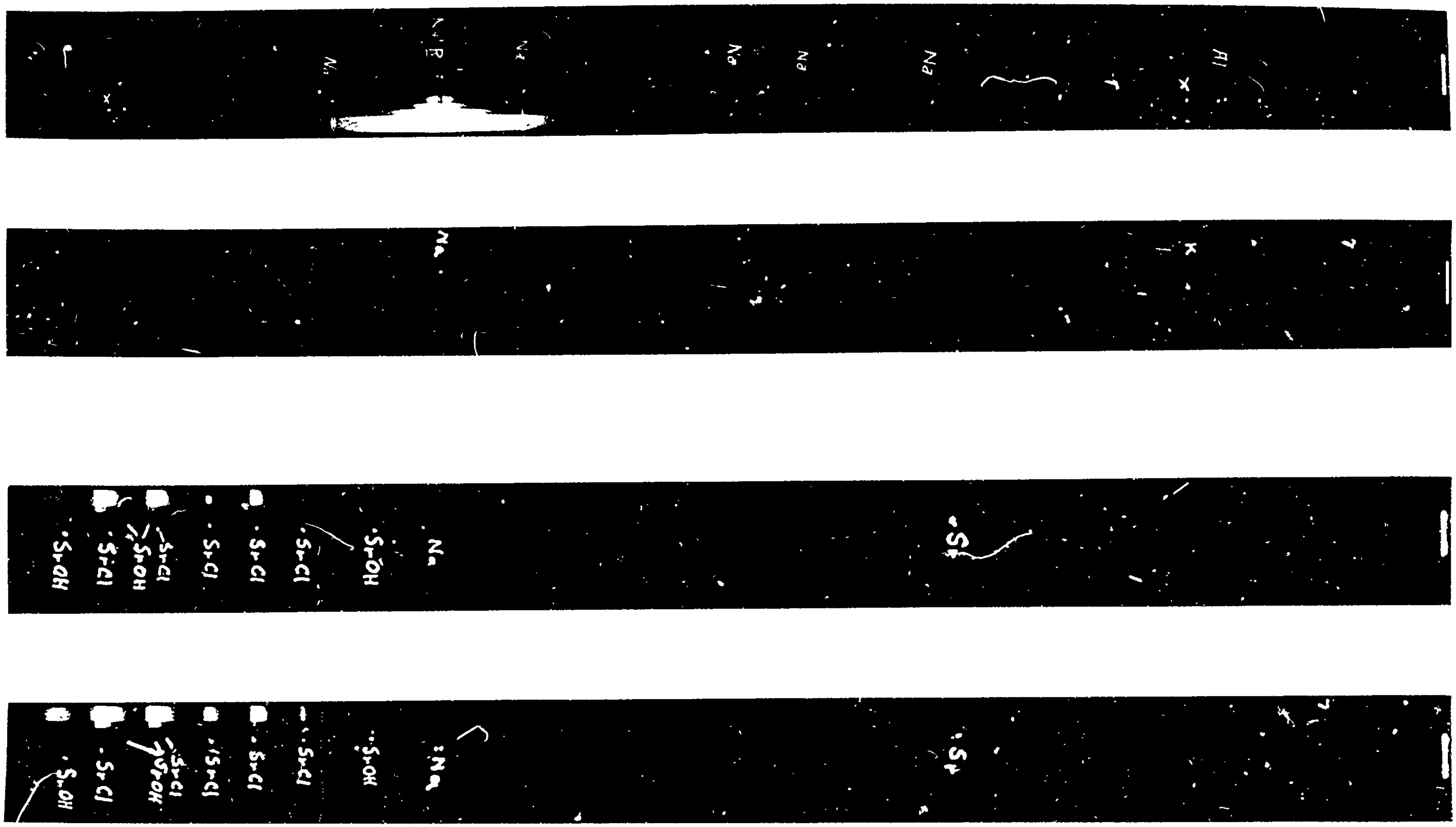


Plate 3a (top). 3b (bottom).

PLATE 4

Data Zone	Run	Mix	Metal %		Oxidant	%	Binder PVC %	Pressure Torr	Exposed Secs
7"	106	F-34	Boron	37	$Ba(ClO_4)_2$	58	5	630	7.2
1"	82	F-34	Boron	37	$Ba(ClO_4)_2$	58	5	630	5.7
1"	84	F-34	Boron	37	$Ba(ClO_4)_2$	58	5	300	8.1
1"	85	F-34	Boron	37	$Ba(ClO_4)_2$	58	5	150	11.2

See Plates 28, 29, and 30

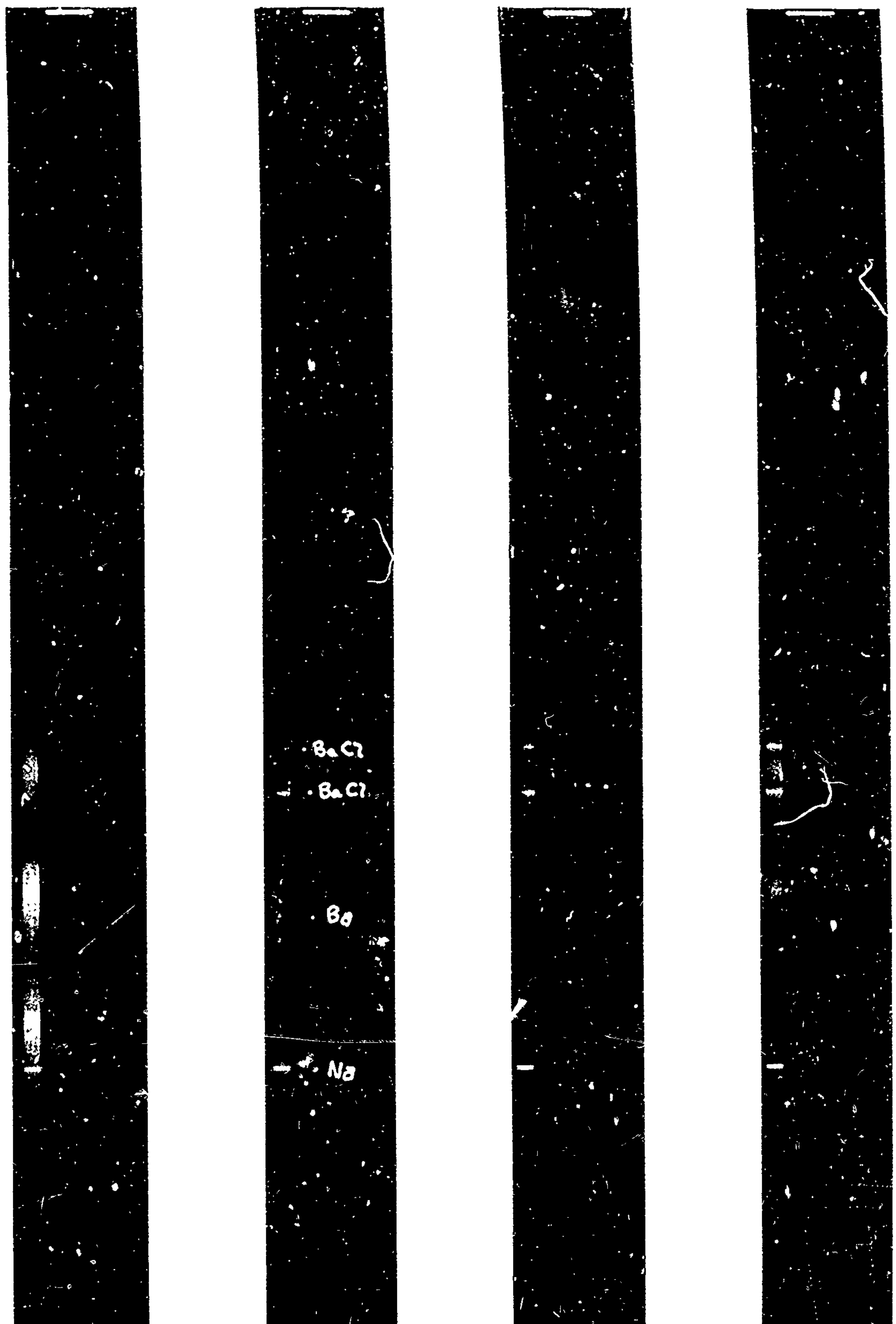

BaCl
BaCl
Ba
Na

PLATE 5

Data Zone	Run	Mix	Metal %	Oxidant %	Binder PVC %	Pressure Torr	Exposed Secs
1"	80	F-35	Boron 27	$KClO_4$ 68	5	630	4.3
1"	74	F-35	Boron 27	$KClO_4$ 68	5	300	5.5
1"	79	F-35	Boron 27	$KClO_4$ 68	5	150	7.4

See Plates 32, 33, and 34

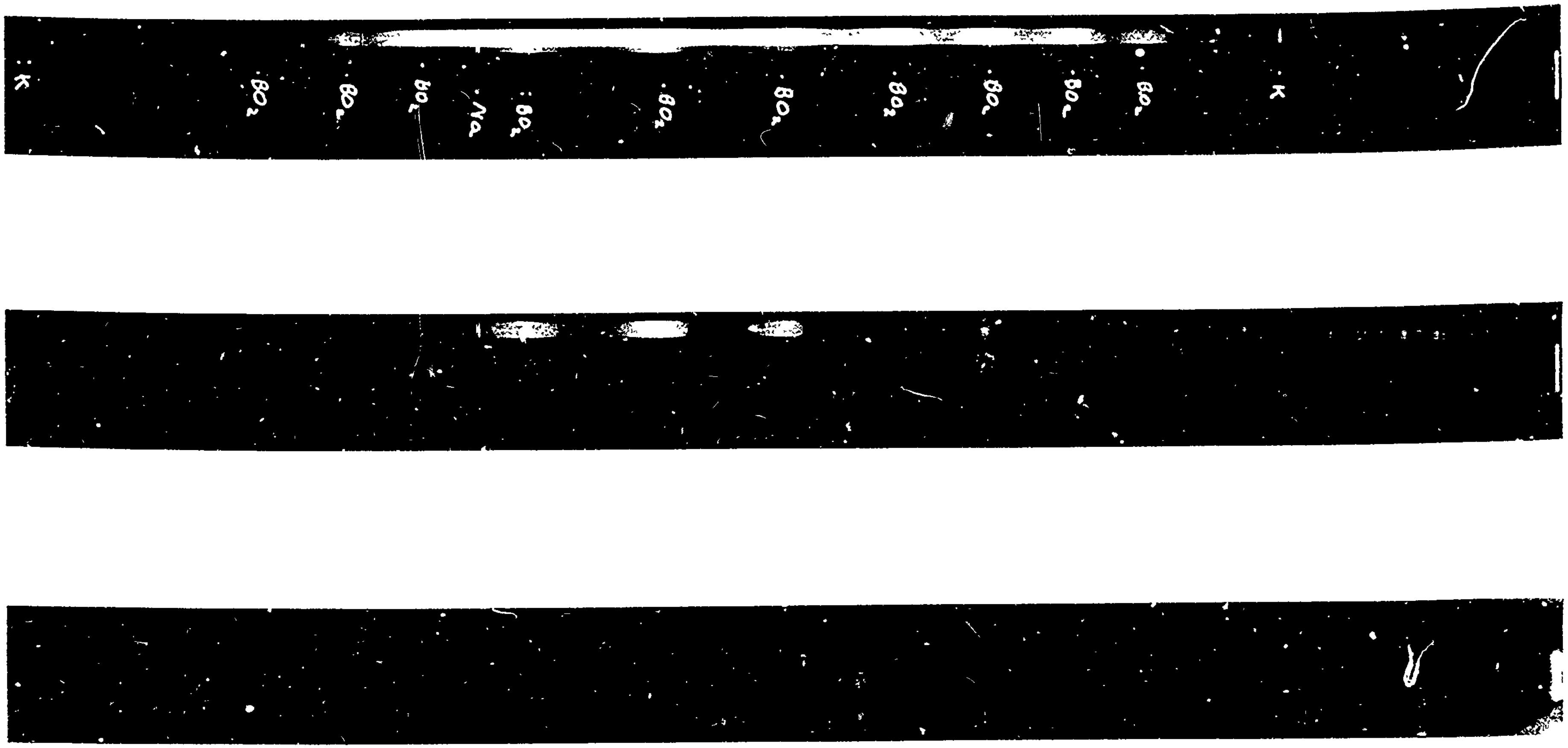


Plate 5.

PLATE 6

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1"	60	F-36	Mg	37	$KClO_4$	58	5	630	19
1"	62	F-36	Mg	37	$KClO_4$	58	5	300	24
1"	65	F-36	Mg	37	$KClO_4$	58	5	150	50
1"	68	F-36	Mg	37	$KClO_4$	58	5	70	68

See Plates 38 and 39

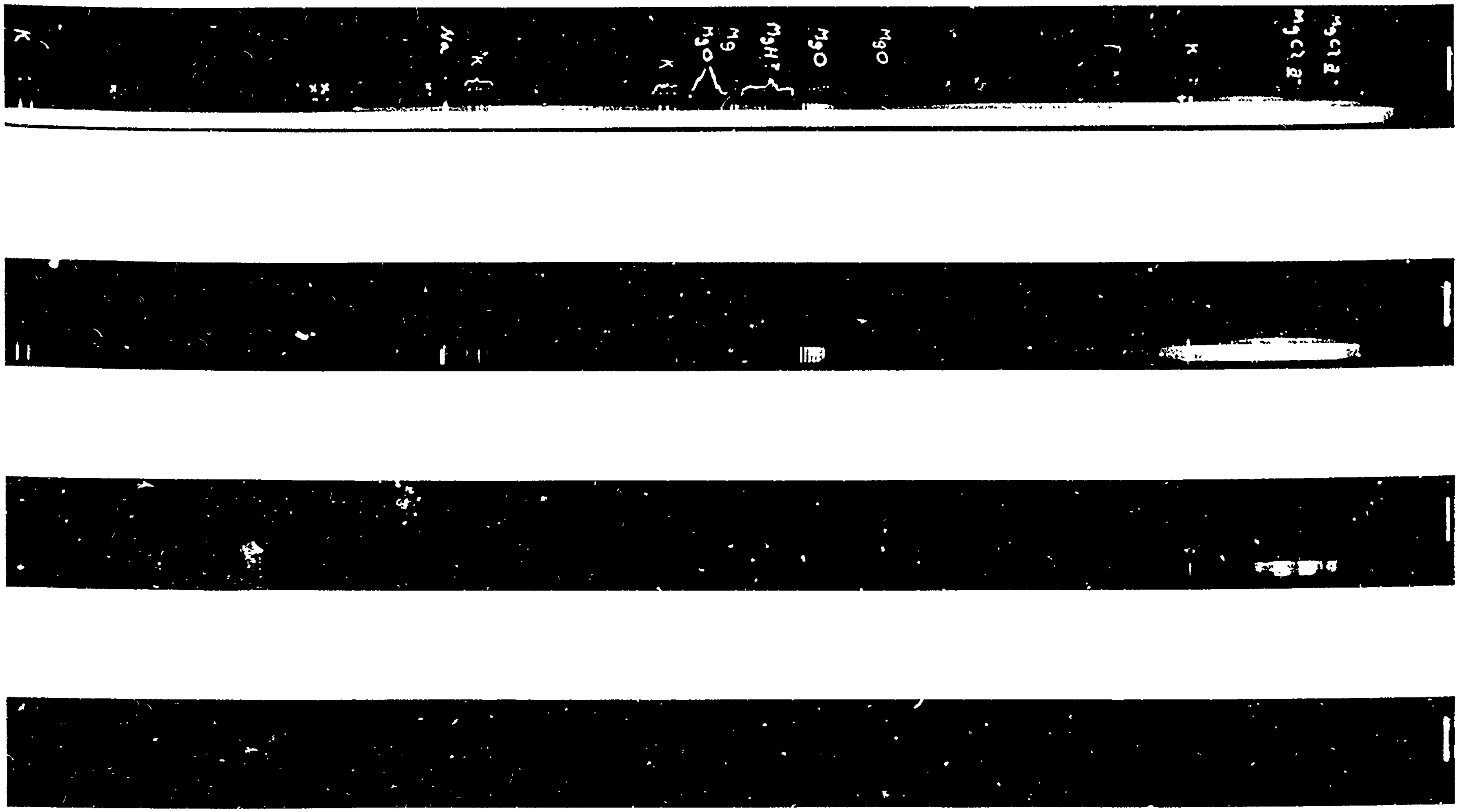


Plate 6.

PLATE 7

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1"	100	F-38	Mg	37	$LiClO_4$	58	5	630	49
1.5"	114	F-38	Mg	37	$LiClO_4$	58	5	630	50
2"	108	F-38	Mg	37	$LiClO_4$	58	5	630	51

See Plate 40

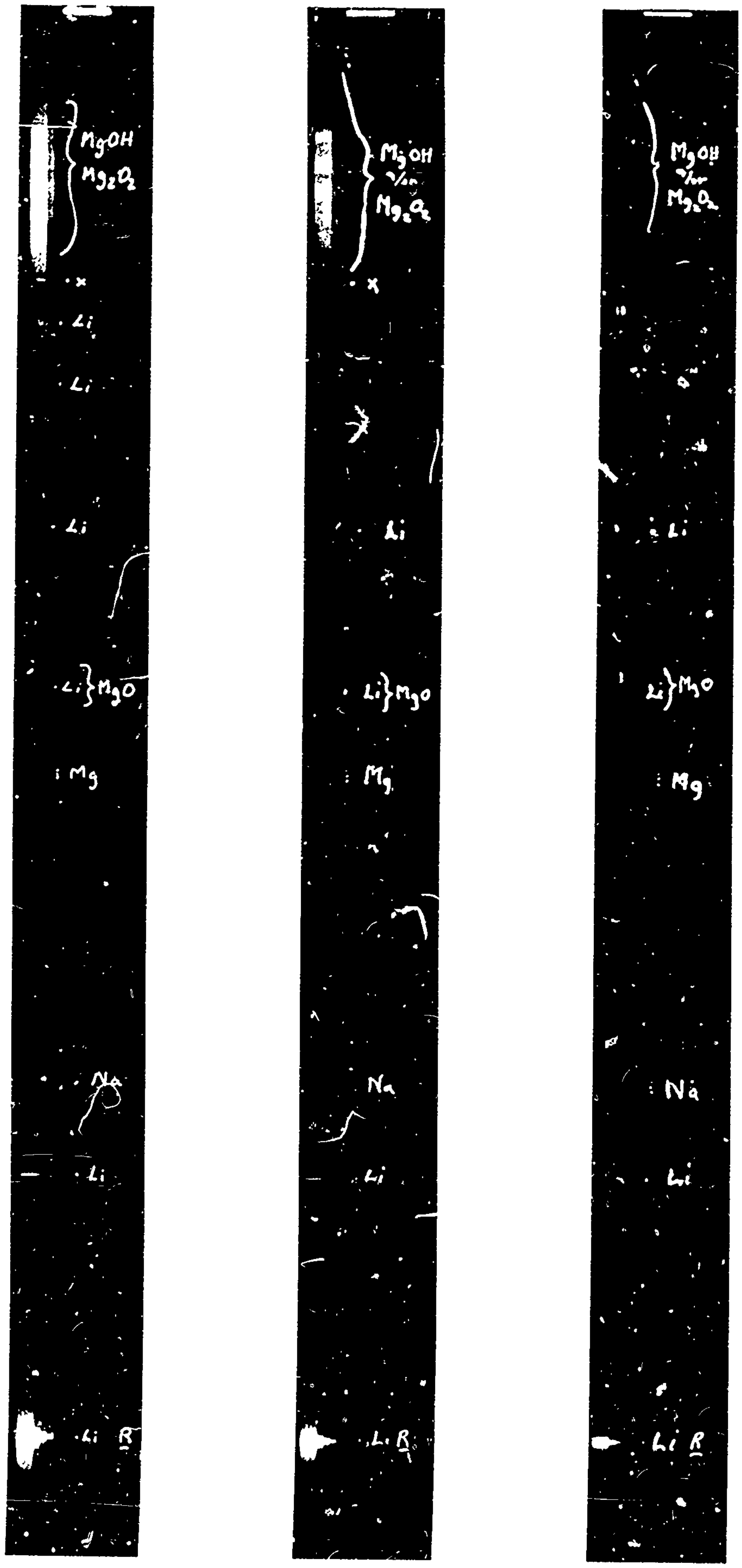

MgOH
Mg2O2
Li
Li
Li
Li}MgO
Mg
Na
Li
Li R
MgOH
Mg2O2
Li
Li}MgO
Mg
Na
Li
Li R
MgOH
Mg2O2
Li
Li}MgO
Mg
Na
Li
Li R

Plate 7.

PLATE 8

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
2"	107	F-38	Mg	37	$LiClO_4$	58	5	630	48
1.5"	110	F-38	Mg	37	$LiClO_4$	58	5	300	70
1.5"	112	F-38	Mg	37	$LiClO_4$	58	5	150	66

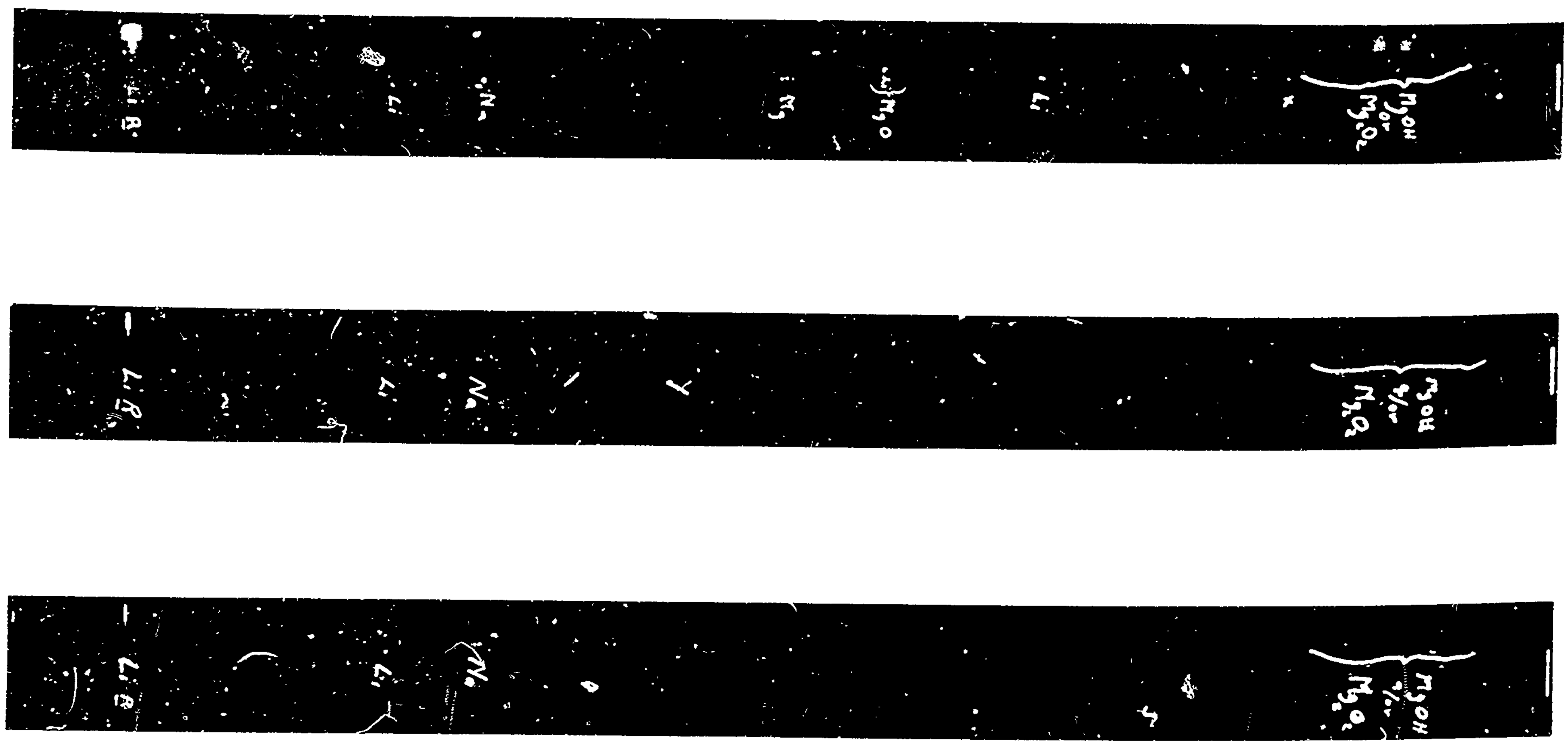


Plate 8.

PLATE 9

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1"	92	F-39	Mg	37	$NaClO_4$	58	5	630	18
1"	93	F-39	Mg	37	$NaClO_4$	58	5	300	29
1"	95	F-39	Mg	37	$NaClO_4$	58	5	150	32
1"	97	F-39	Mg	37	$NaClO_4$	58	5	70	42

See Plates 43 thru 46

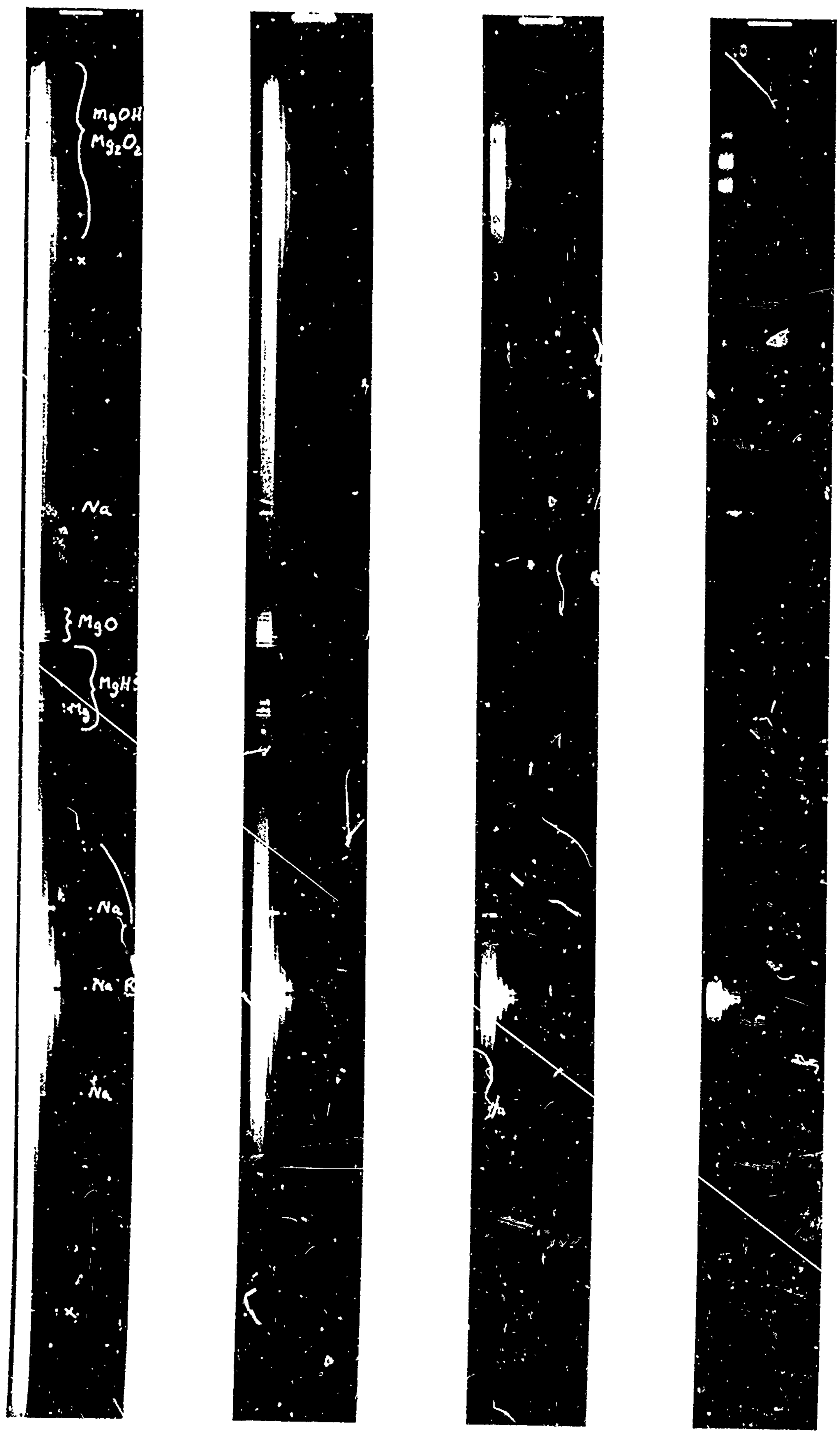


Plate 9.

PLATE 10

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1.5"	124	F-56	Mg	58	$LiClO_4$	37	5	630	27
1.5"	126	F-56	Mg	58	$LiClO_4$	37	5	300	36
1.5"	129	F-56	Mg	58	$LiClO_4$	37	5	150	74
1.5"	131	F-56	Mg	58	$LiClO_4$	37	5	70	76

See Plates 48 and 50

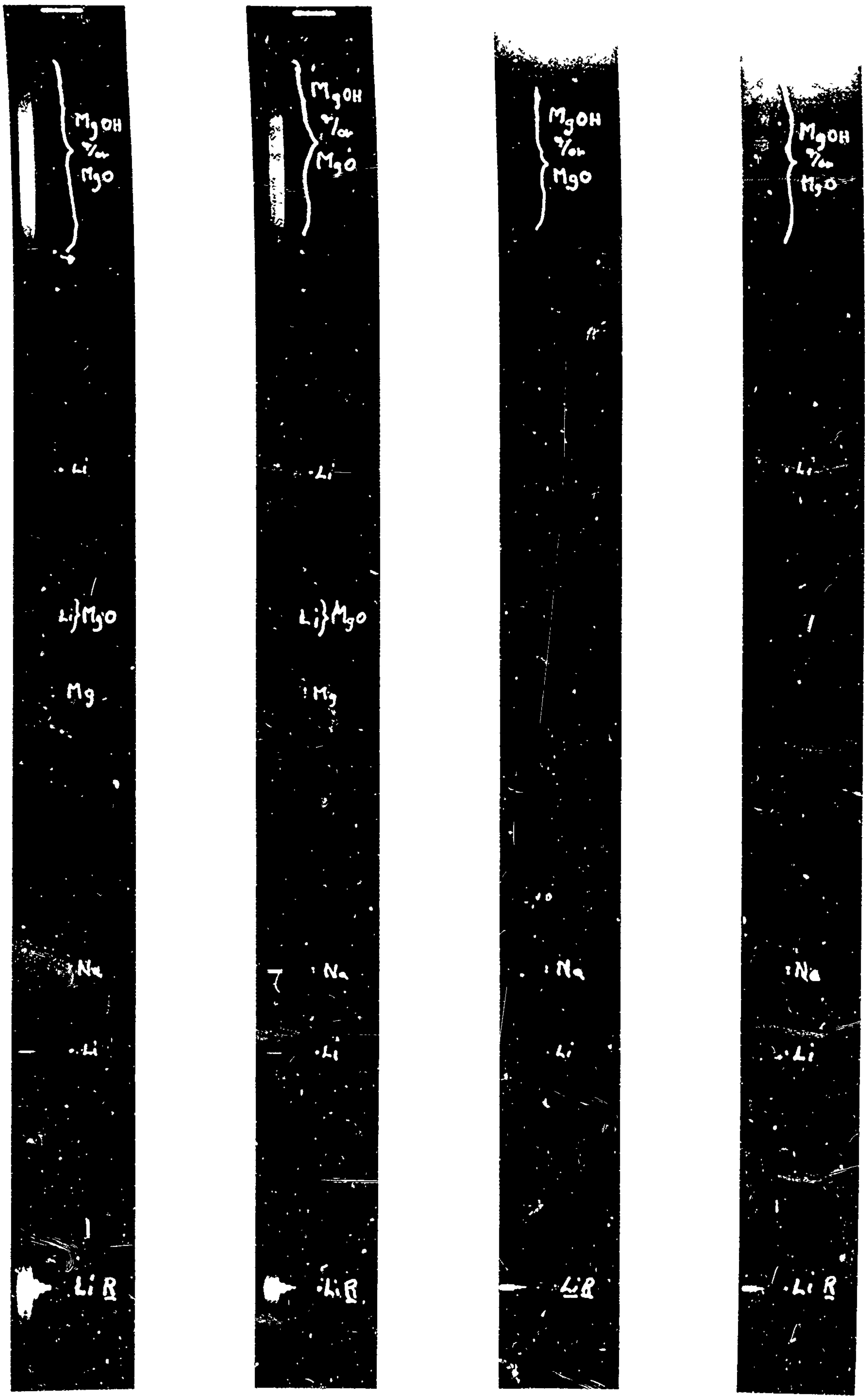

MgOH or MgO
Li
Li}MgO
Mg
Na
Li
Li R
MgOH or MgO
Li
Li}MgO
Mg
Na
Li
Li R
MgOH or MgO
Na
Li
Li R
MgOH or MgO
Li
Na
Li
Li R

PLATE 11

Data Zone	Run	Mix	Metal %		Oxidant %		Binder PVC %	Pressure Torr	Exposed Secs
1.5"	132	F-57	Mg	58	$NaClO_4$	37	5	630	12
1.5"	136	F-57	Mg	58	$NaClO_4$	37	5	300	16
1.5"	139	F-57	Mg	58	$NaClO_4$	37	5	150	29
1.5"	141	F-57	Mg	58	$NaClO_4$	37	5	70	39

See Plates 52 and 54

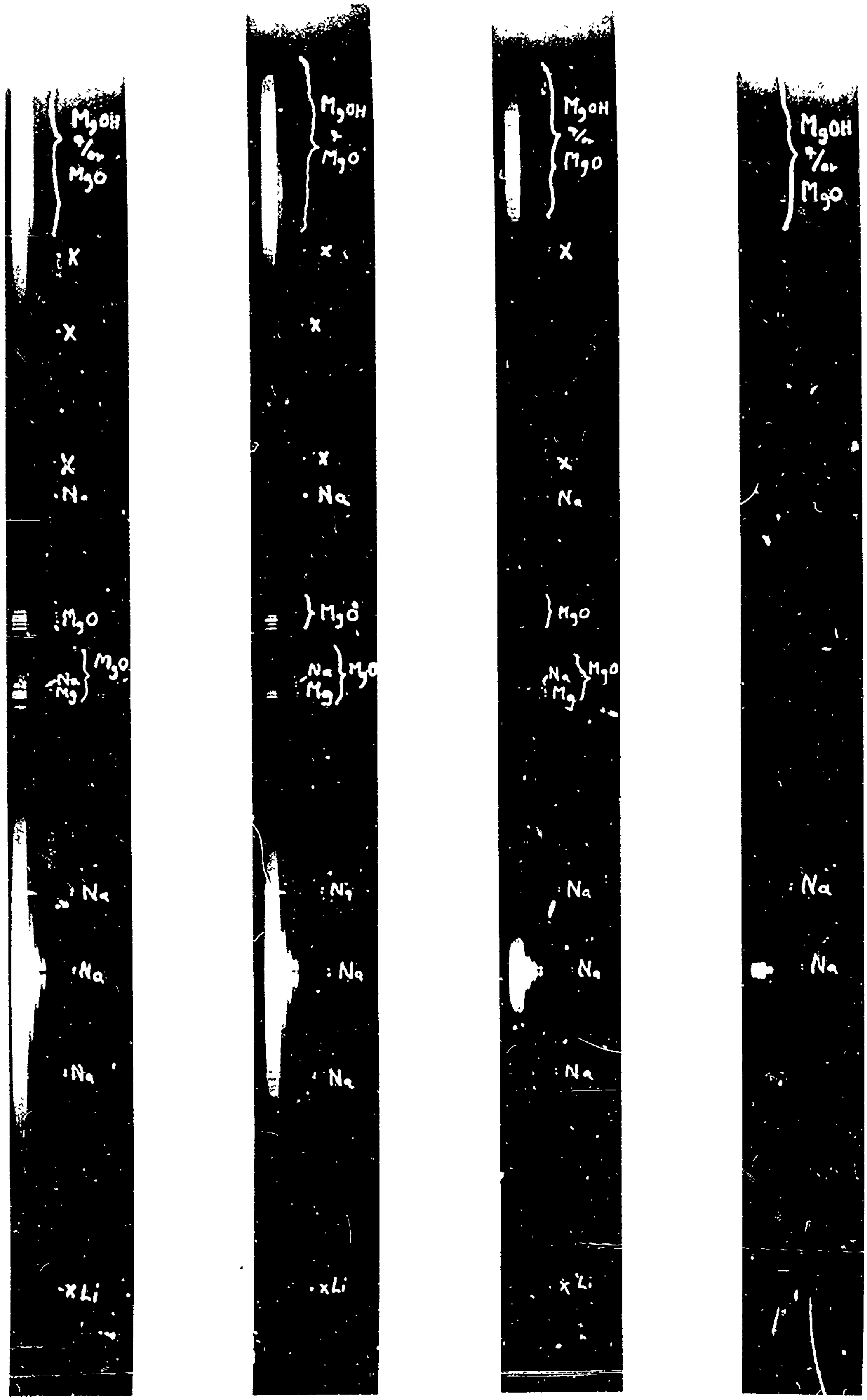

MgOH +/or MgO
X
X
X
Na
MgO
Na Mg
MgO
Na
Na
Na
x Li
MgOH + MgO
x
x
x
Na
MgO
Na Mg
MgO
Na
Na
x Li
MgOH +/or MgO
X
x
Na
MgO
Na Mg
MgO
Na
Na
Na
x Li
MgOH +/or MgO
Na
Na

Plate 11.

PLATE NOS. 12-54

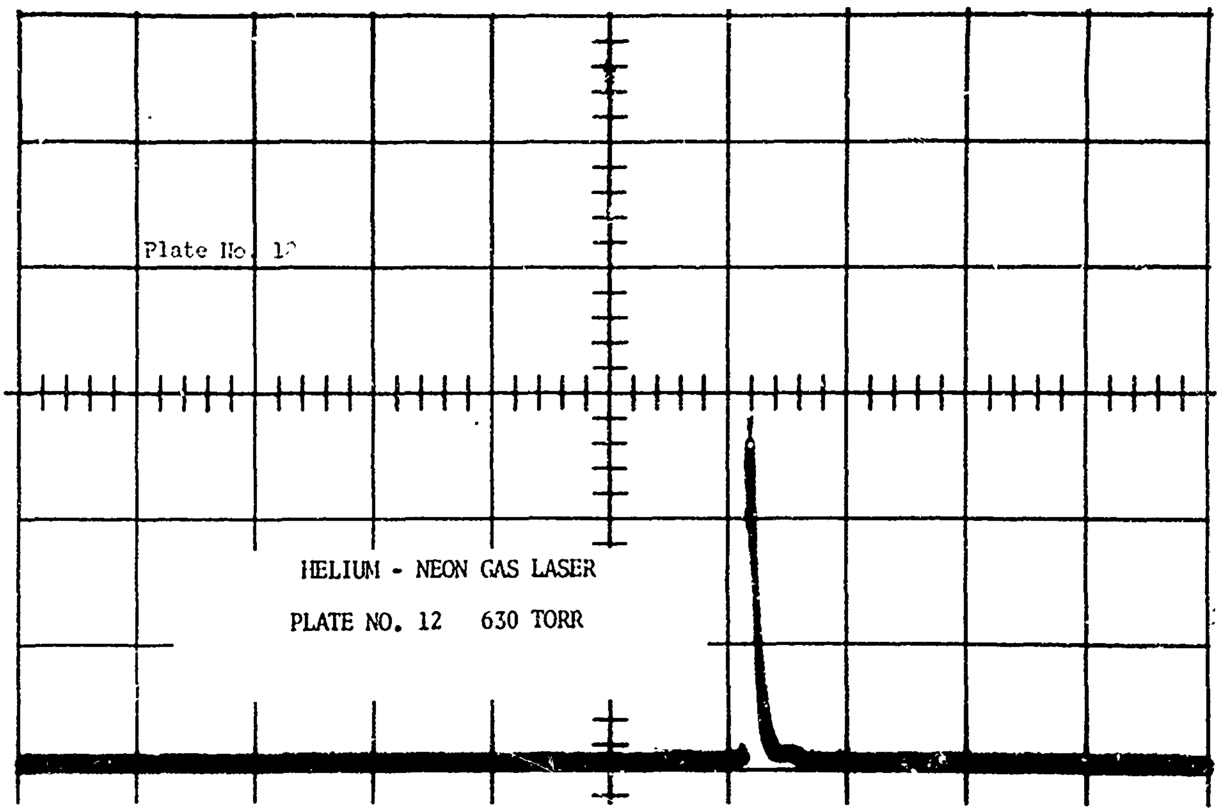
Flame Spectra from the Scanning Spectrometer*

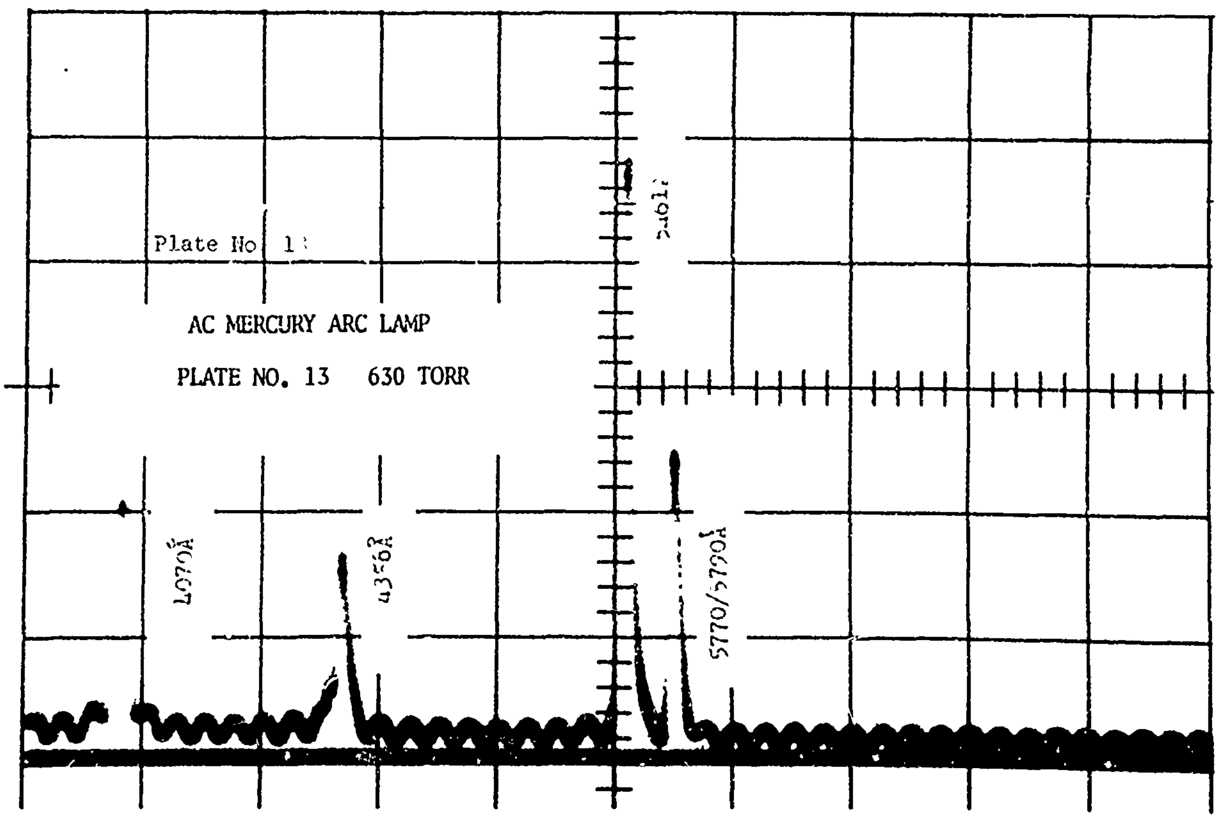
Plate No.	Run No.	Mix No.	Pressure, torr	Slit, mm	PAR atten.	Zone, inches
12	48a	---	630	0.04	0.001	-
13	57w	---	630	0.30	0.002	-
14	56	3	630	0.05	0.001	1
15	13b	4	630	0.05	0.001	1
16	57	7	630	0.05	0.001	1
17	32	16	630	0.05	0.001	1
18	36	16	300	0.05	0.001	1
19	38	16	150	0.05	0.001	1
20	39	16	75	0.06	0.001	1
21	45a	30	630	0.10	0.001	1
22	45b	30	630	0.06	0.001	1
23	16	31	630	0.50	0.001	1
24	117a	33	630	0.40	0.001	1
25	117b	33	630	0.40	0.001	1
26	119a	33	300	0.20	0.001	1
27	101	34	630	0.10	0.002	1
28	106	34	630	0.15	0.001	7
29	84	34	300	0.18	0.001	1
30	85	34	150	0.20	0.001	1
31	87	34	70	0.25	0.001	1
32	80	35	630	0.045	0.001	1
33	74	35	300	0.05	0.001	1
34	79	35	150	0.15	0.010	1
35	77	35	70	0.15	0.05	1
36	61	36	630	0.03	0.001	1
37	64	36	300	0.06	0.002	1
38	65	36	150	0.07	0.05	1
39	68	36	70	0.085	0.01	1
40	114a	38	630	0.075	0.001	1
41	109b	38	300	0.075	0.001	1
42	113b	38	150	0.125	0.01	1.5
43	92a	39	630	0.035	0.001	1
44	93a	39	300	0.04	0.001	1
45	95a	39	150	0.045	0.001	1

*Flint Glass Prism, Settings C.F. 19, N.M. 1.5.
Type 6217 Photomultiplier Detector
C.R.O. Tektronix Type 536/H Preamp Gain, lv/div.
Sweep Rate at 3 scans/second.

PLATE NOS. 12-54 (Cont'd)

Plate No.	Run No.	Mix No.	Pressure, torr	Slit, mm	PAR atten.	Zone, inches
46	97a	39	70	0.05	0.001	1
47	123a	56	630	0.07	0.001	1.5
48	126a	56	300	0.075	0.001	1.5
49	128b	56	150	0.08	0.02	1.5
50	131b	56	70	0.125	0.05	1.5
51	133b	57	630	0.05	0.001	1.5
52	136a	57	300	0.045	0.001	1.5
53	134	57	150	0.02	0.001	1.5
54	141b	57	70	0.07	0.02	1.5


HELIUM - NEON GAS LASER
PLATE NO. 12 630 TORR


AC MERCURY ARC LAMP
PLATE NO. 13 630 TORR
5770/5790Å

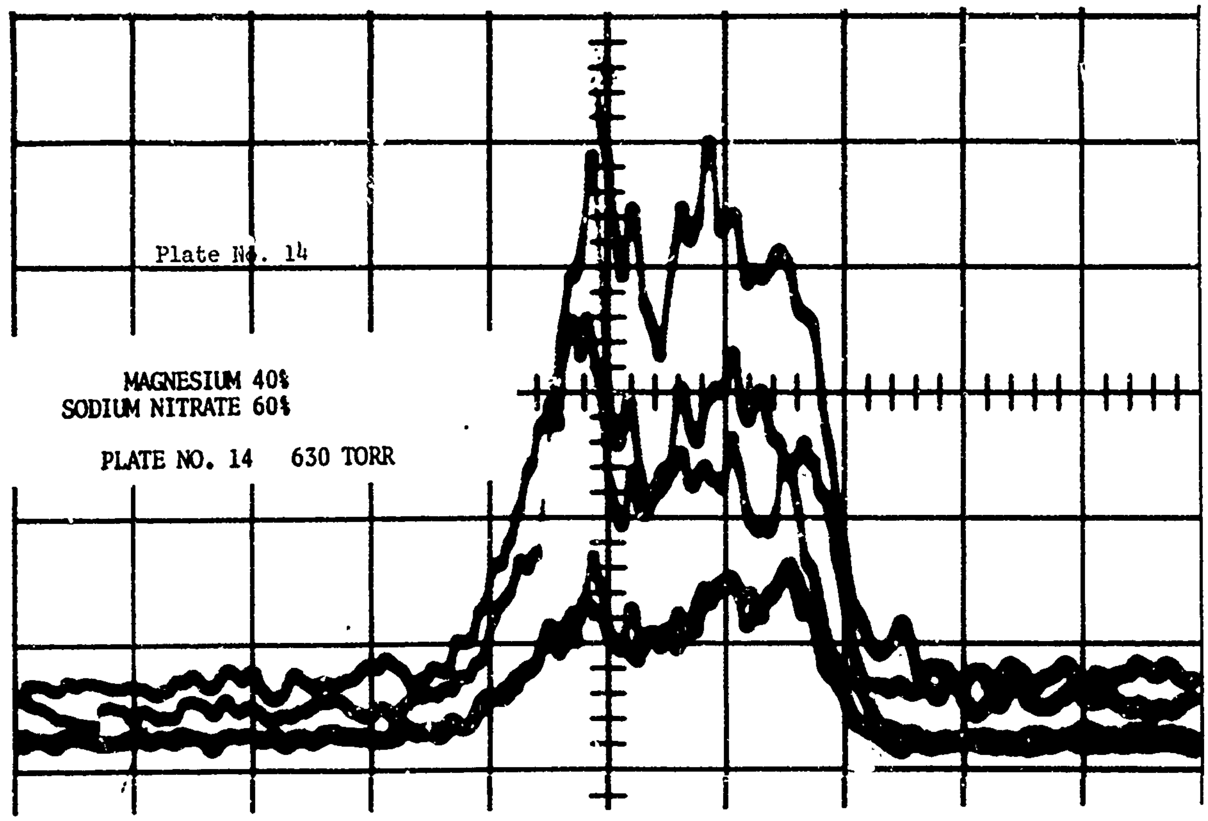


Plate No. 14
MAGNESIUM 40%
SODIUM NITRATE 60%
PLATE NO. 14 630 TORR

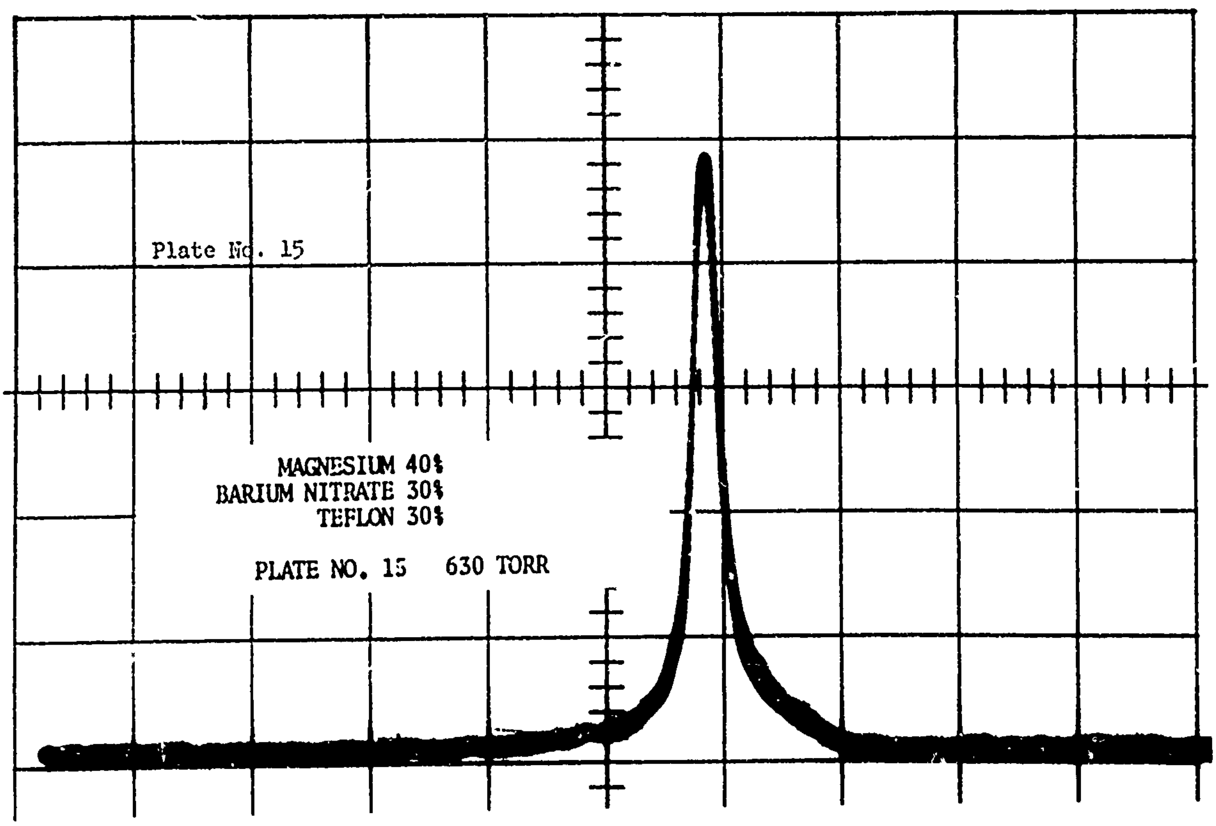


Plate No. 15
MAGNESIUM 40%
BARIUM NITRATE 30%
TEFLON 30%
PLATE NO. 15 630 TORR

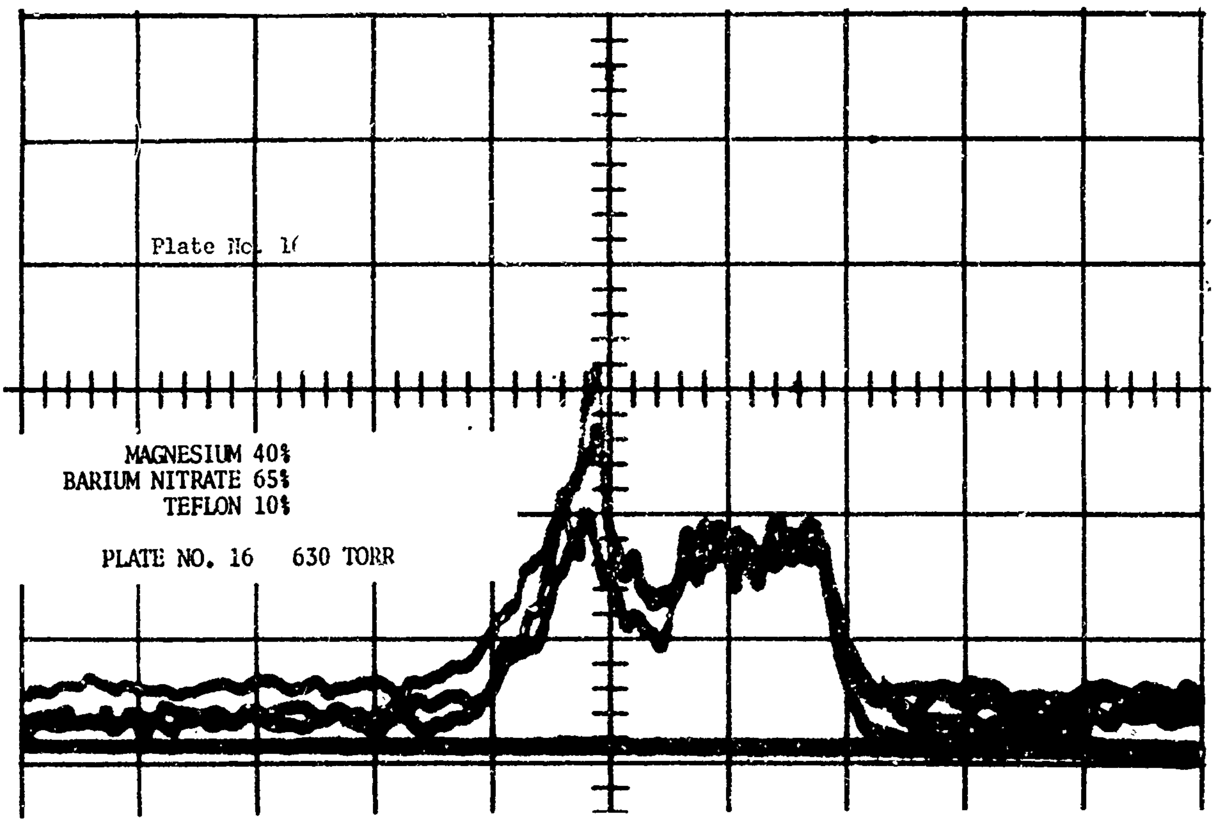


Plate No. 16
MAGNESIUM 40%
BARIUM NITRATE 65%
TEFLON 10%
PLATE NO. 16 630 TORR

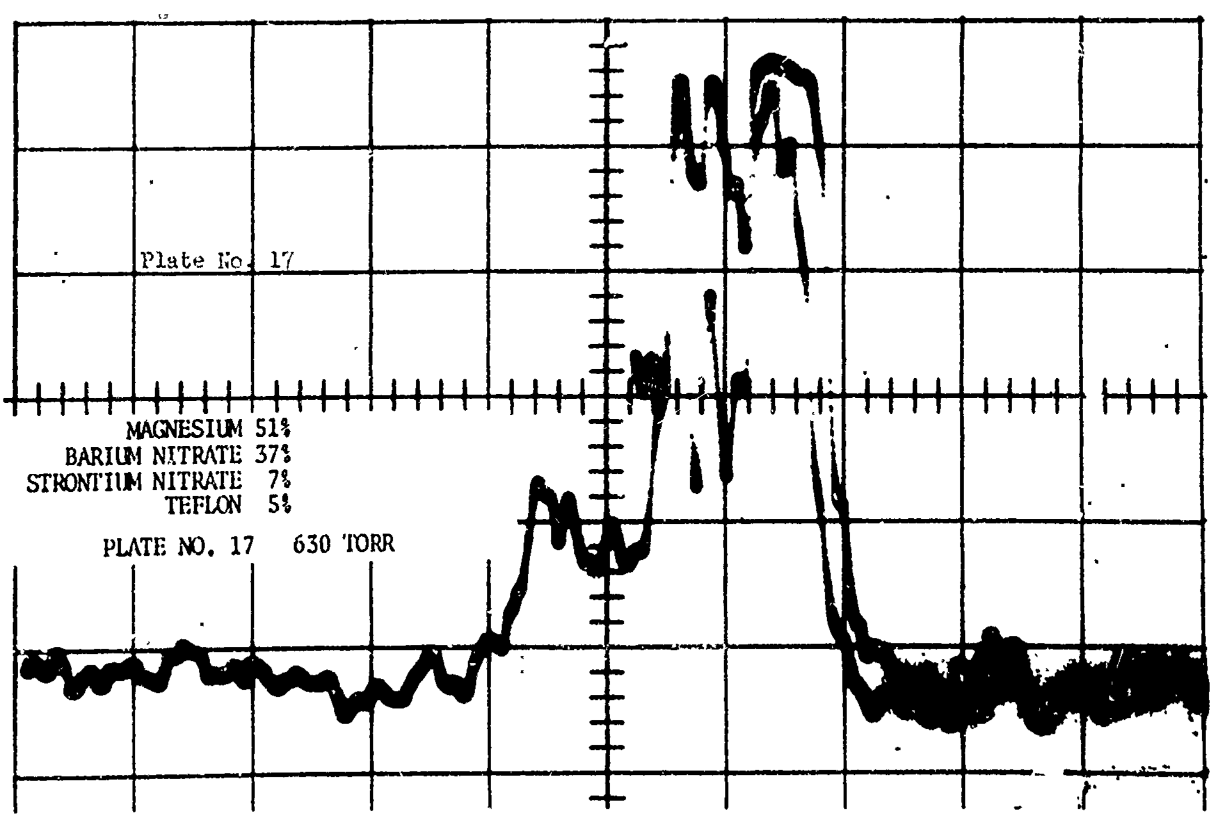


Plate No. 17
MAGNESIUM 51%
BARIUM NITRATE 37%
STRONTIUM NITRATE 7%
TEFLON 5%
PLATE NO. 17 630 TORR

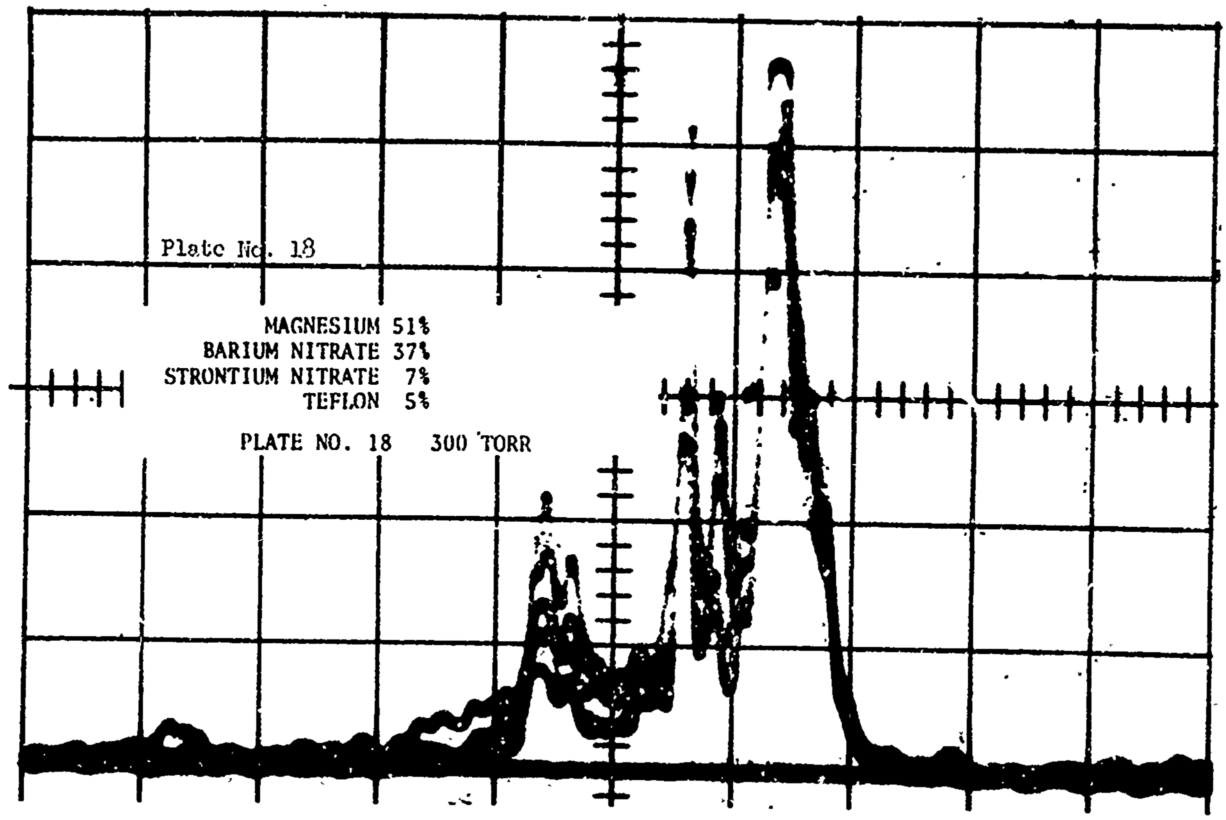


Plate No. 18
MAGNESIUM 51%
BARIUM NITRATE 37%
STRONTIUM NITRATE 7%
TEFLON 5%
PLATE NO. 18 300 TORR

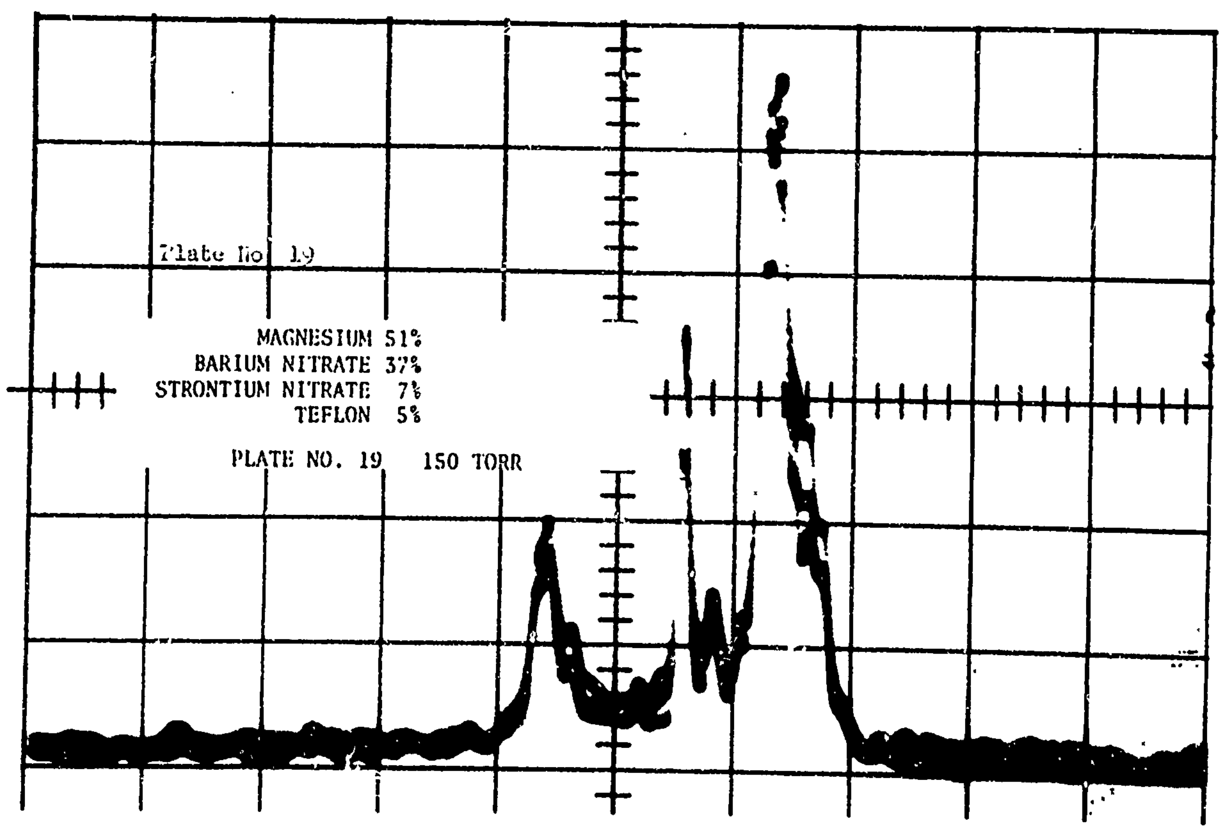


Plate No. 19
MAGNESIUM 51%
BARIUM NITRATE 37%
STRONTIUM NITRATE 7%
TEFLON 5%
PLATE NO. 19 150 TORR

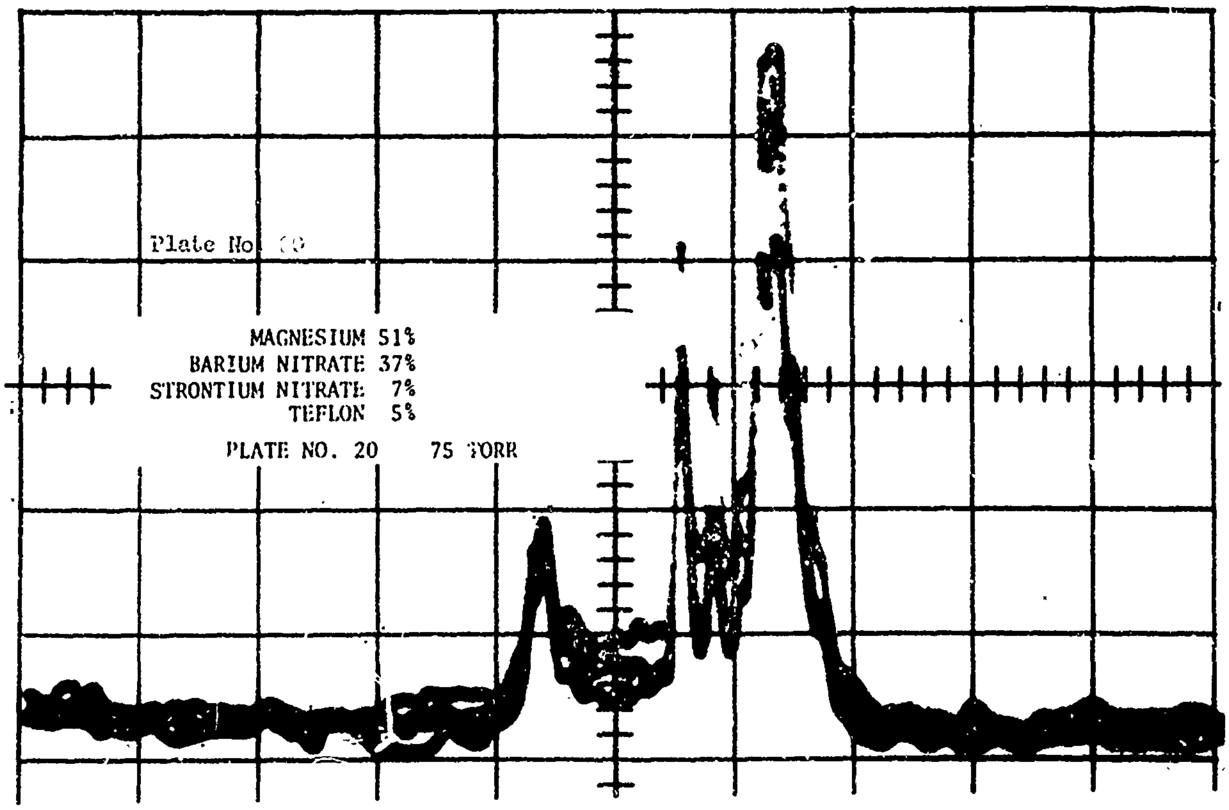


Plate No. 20
MAGNESIUM 51%
BARIUM NITRATE 37%
STRONTIUM NITRATE 7%
TEFLON 5%
PLATE NO. 20 75 TORR

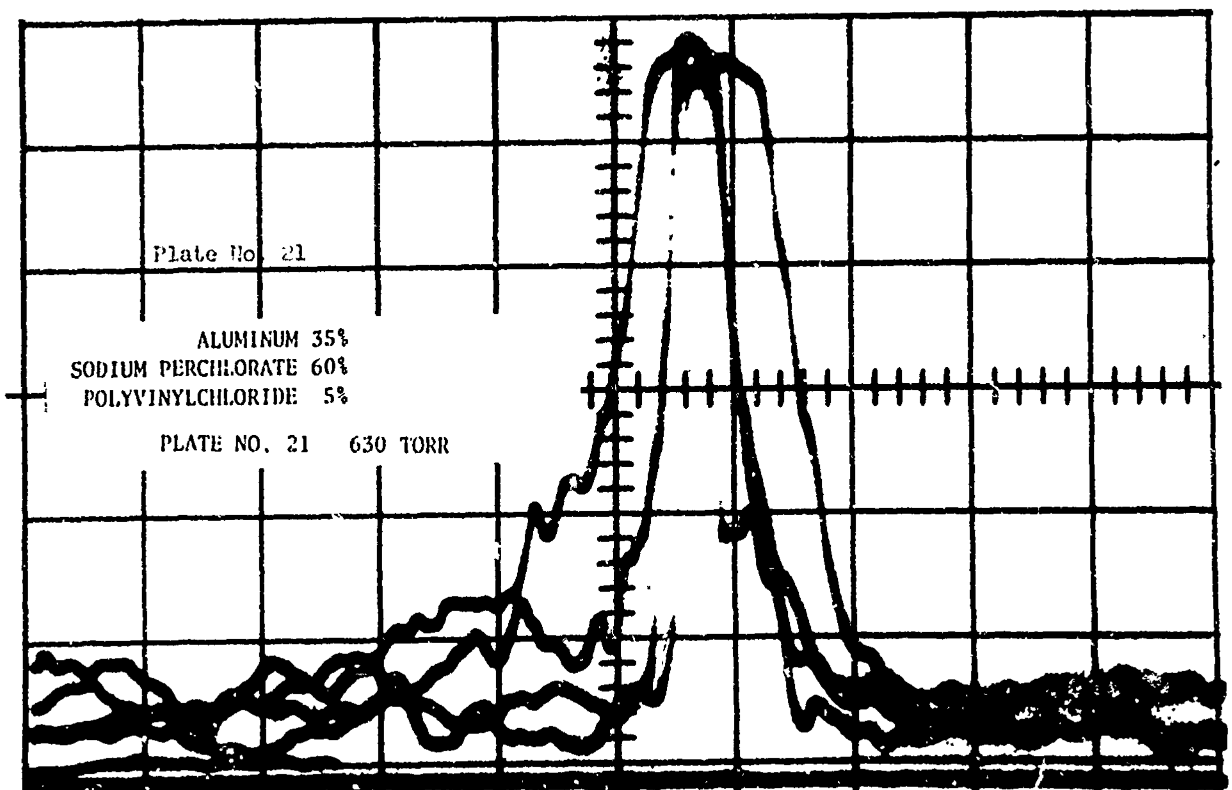


Plate No. 21
ALUMINUM 35%
SODIUM PERCHLORATE 60%
POLYVINYLCHLORIDE 5%
PLATE NO. 21 630 TORR

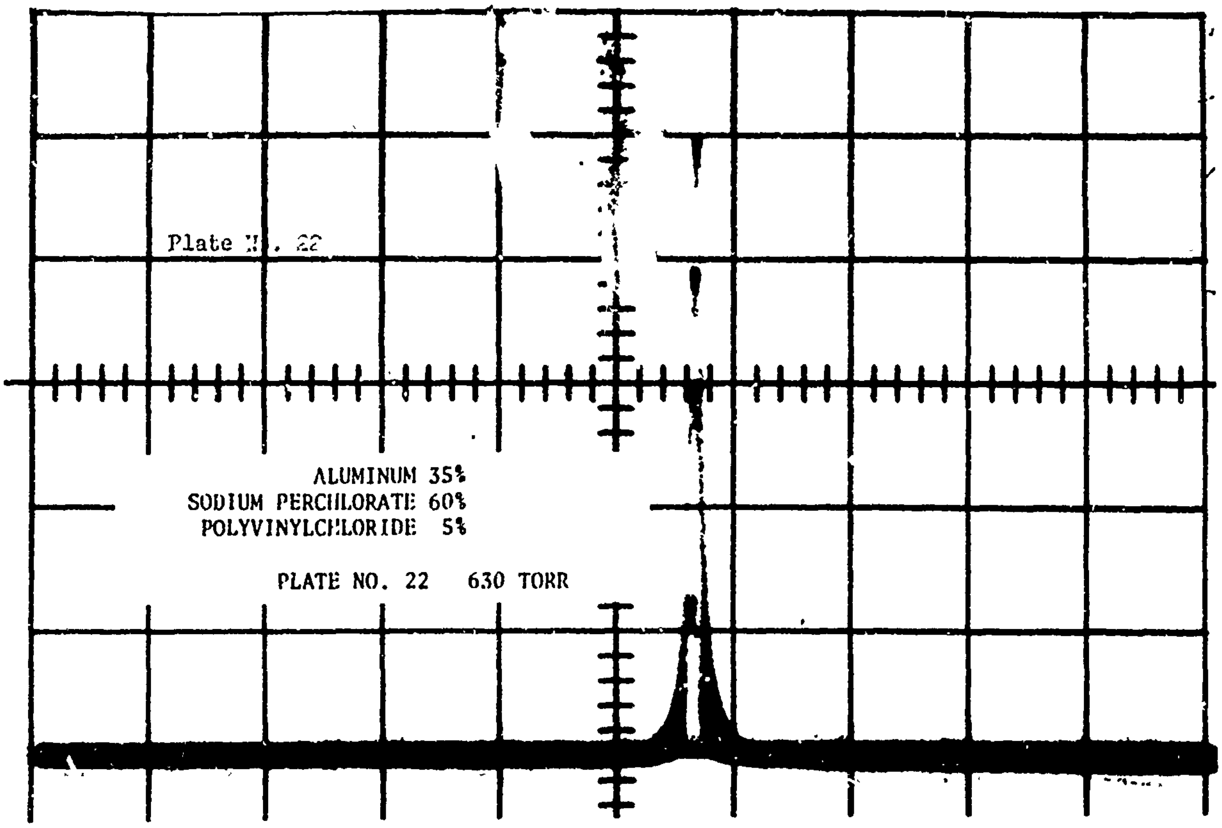


Plate No. 22
ALUMINUM 35%
SODIUM PERCHLORATE 60%
POLYVINYLCHLORIDE 5%
PLATE NO. 22 630 TORR

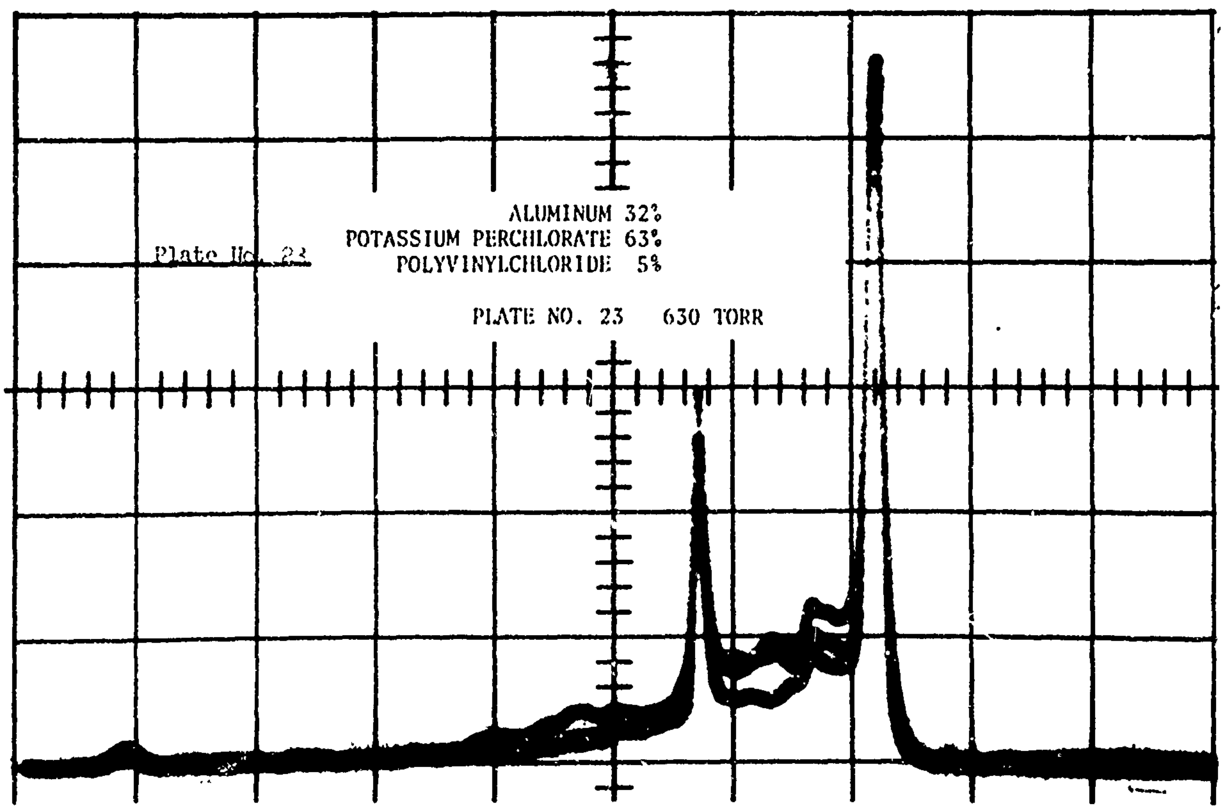


Plate No. 23
ALUMINUM 32%
POTASSIUM PERCHLORATE 63%
POLYVINYLCHLORIDE 5%
PLATE NO. 23 630 TORR

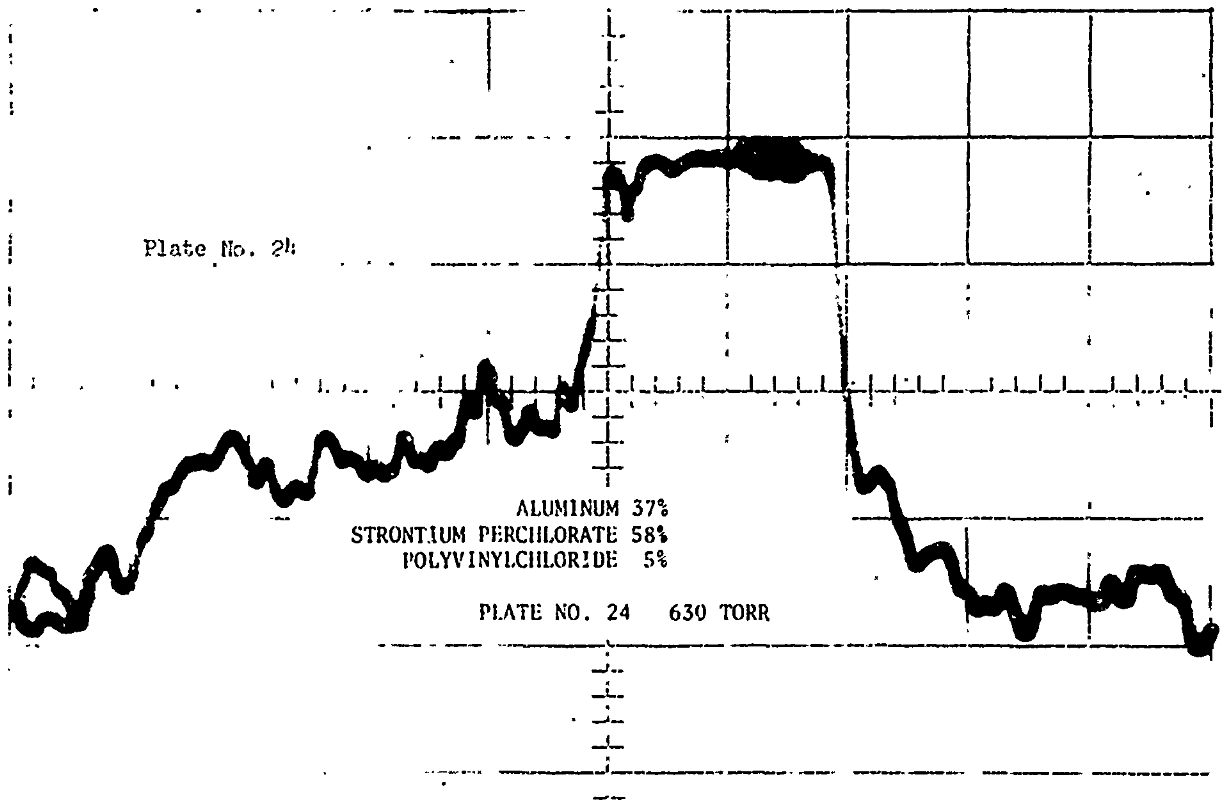
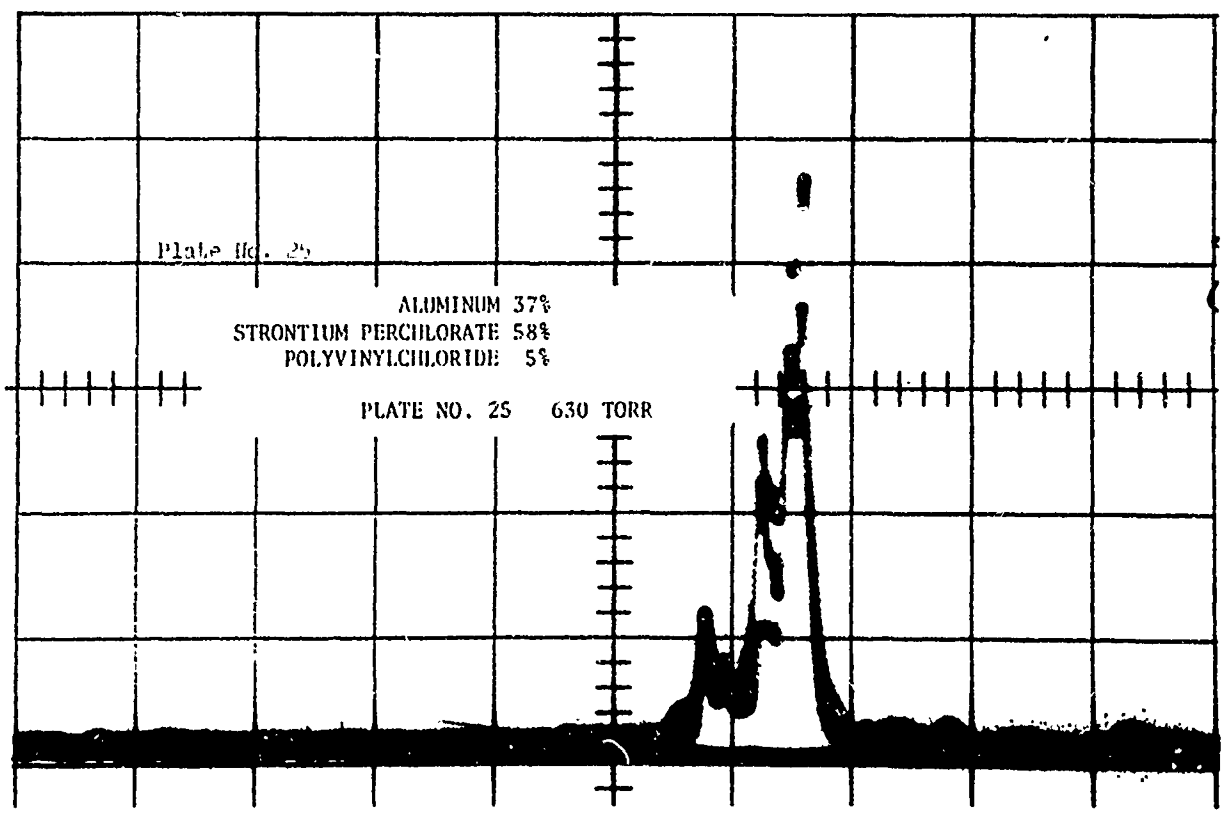


Plate No. 24
ALUMINUM 37%
STRONTIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 24 630 TORR


ALUMINUM 37%
STRONTIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 25 630 TORR

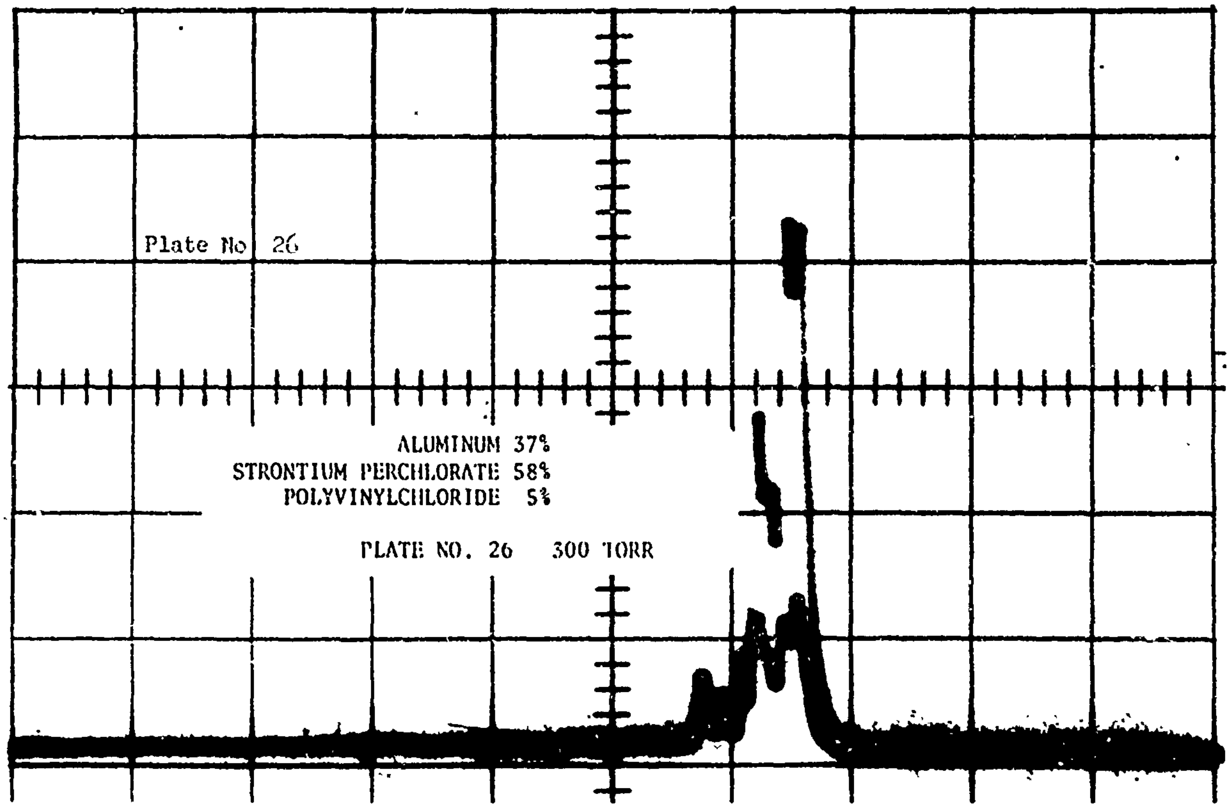


Plate No 26
ALUMINUM 37%
STRONTIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 26 300 TORR

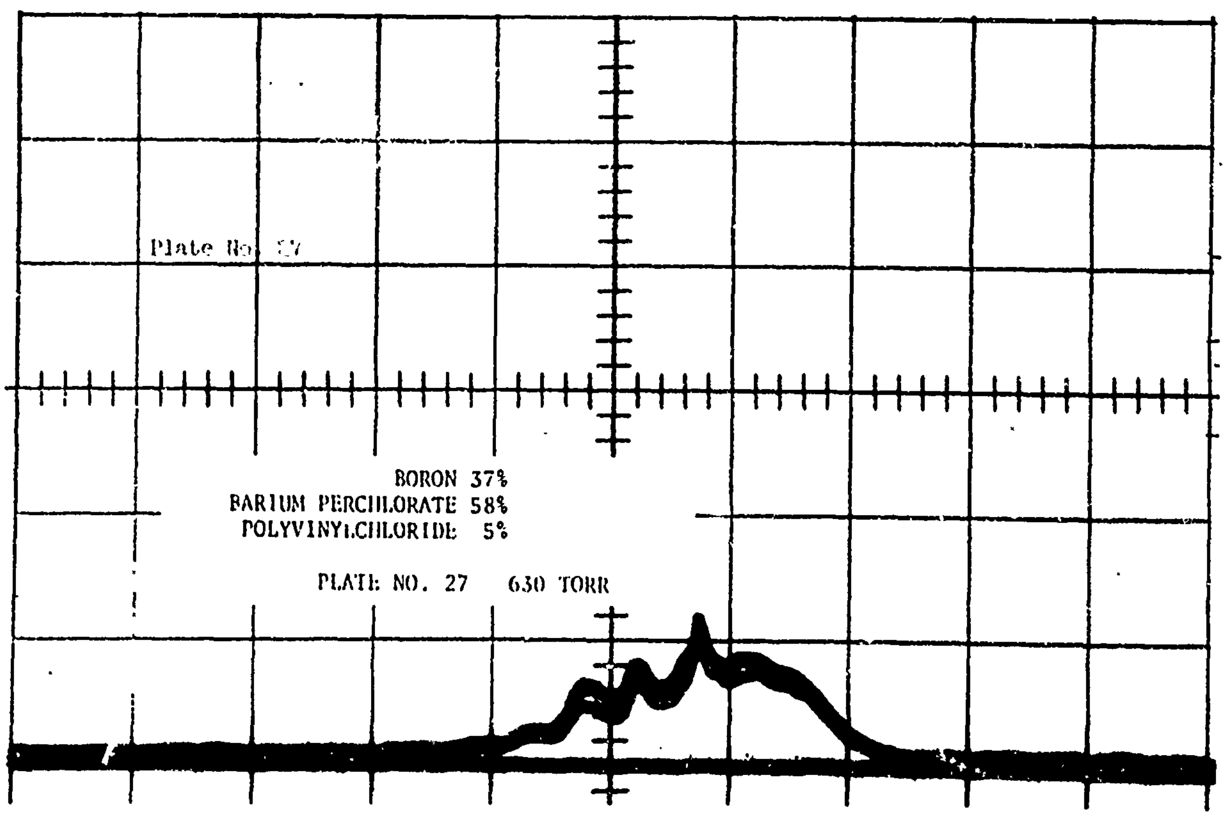
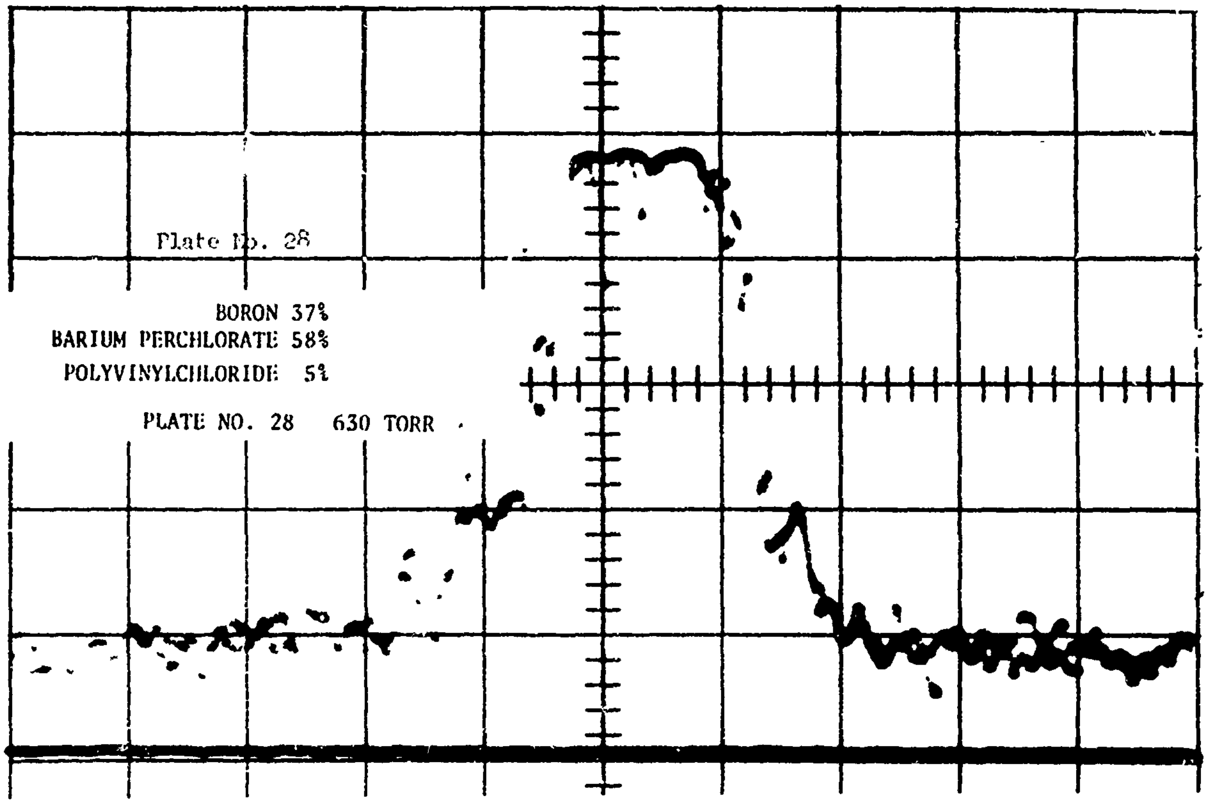
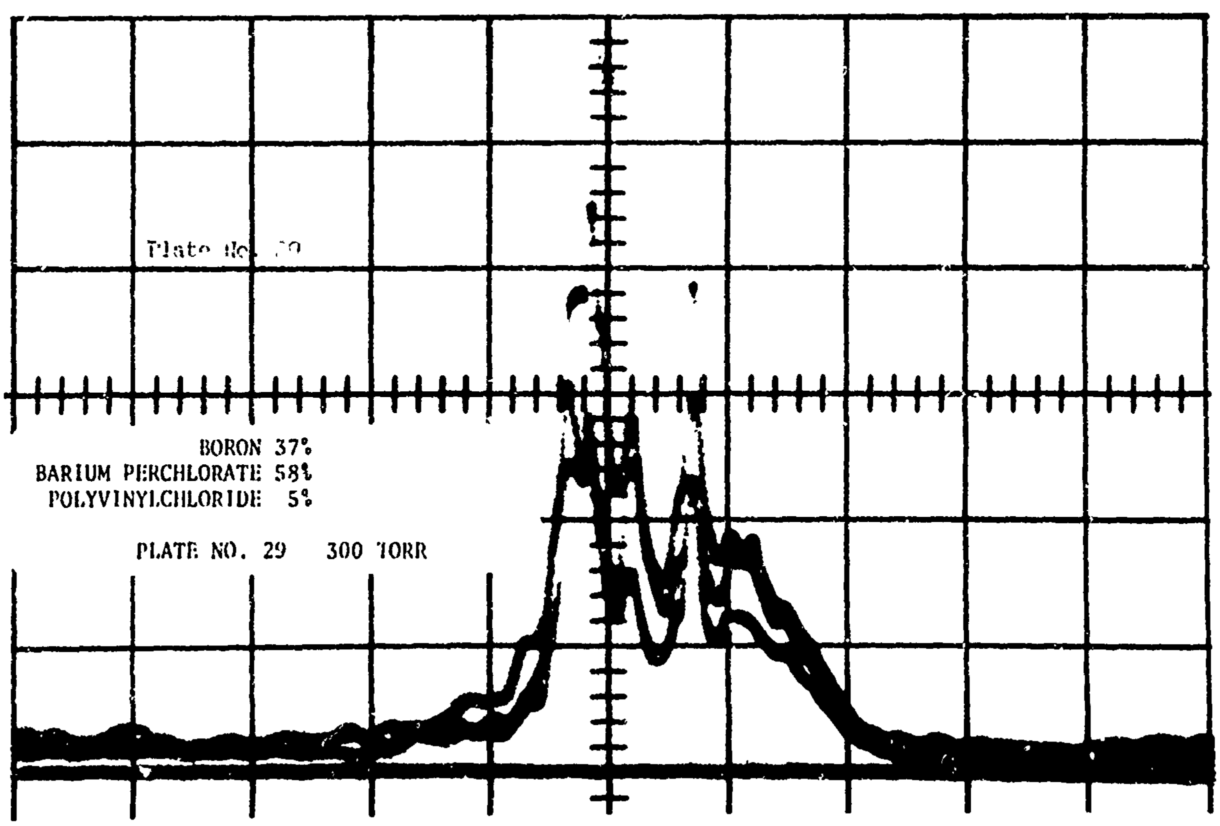
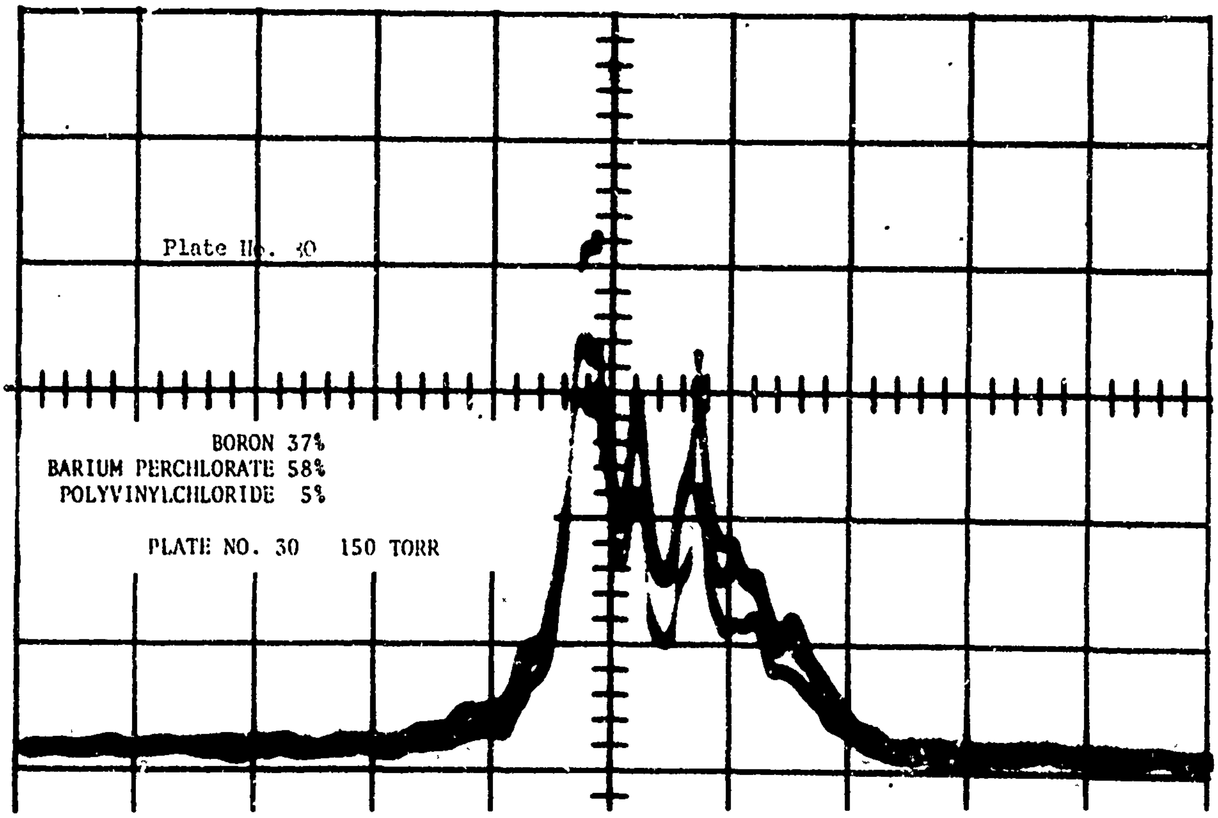
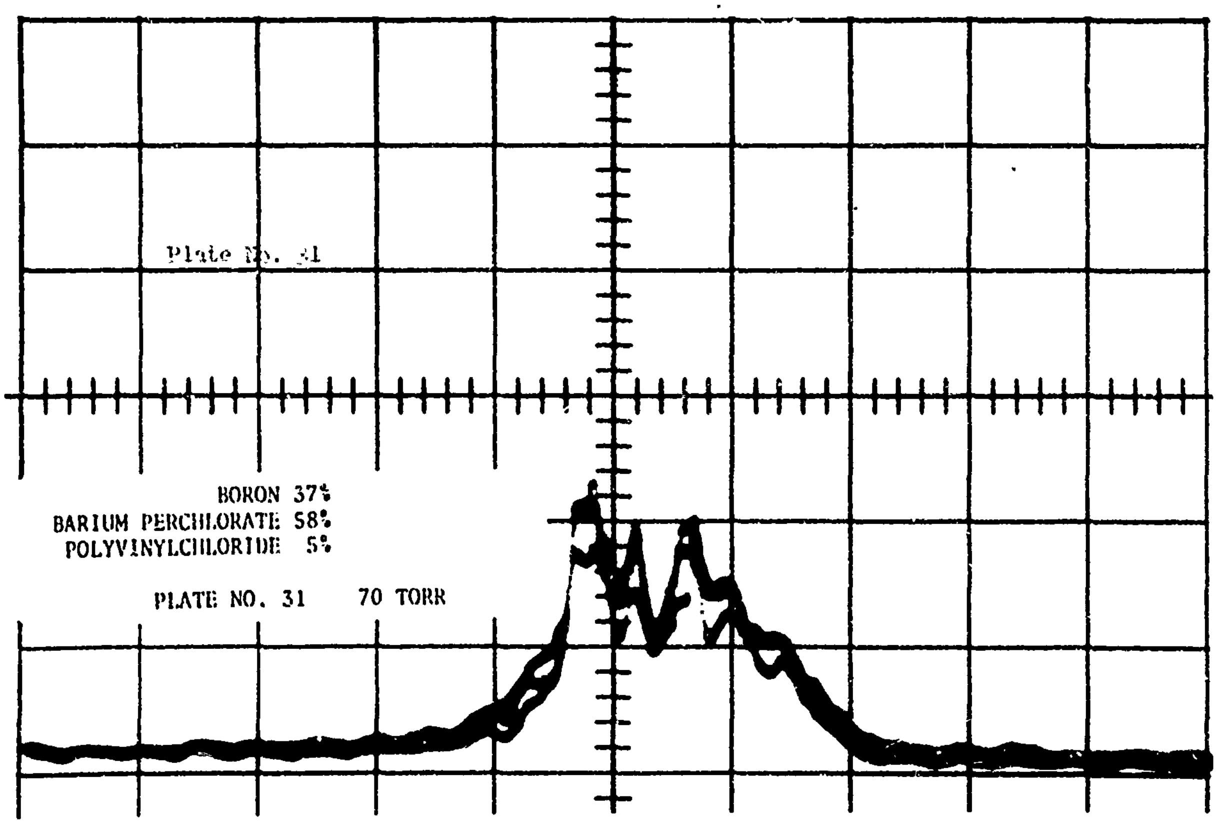


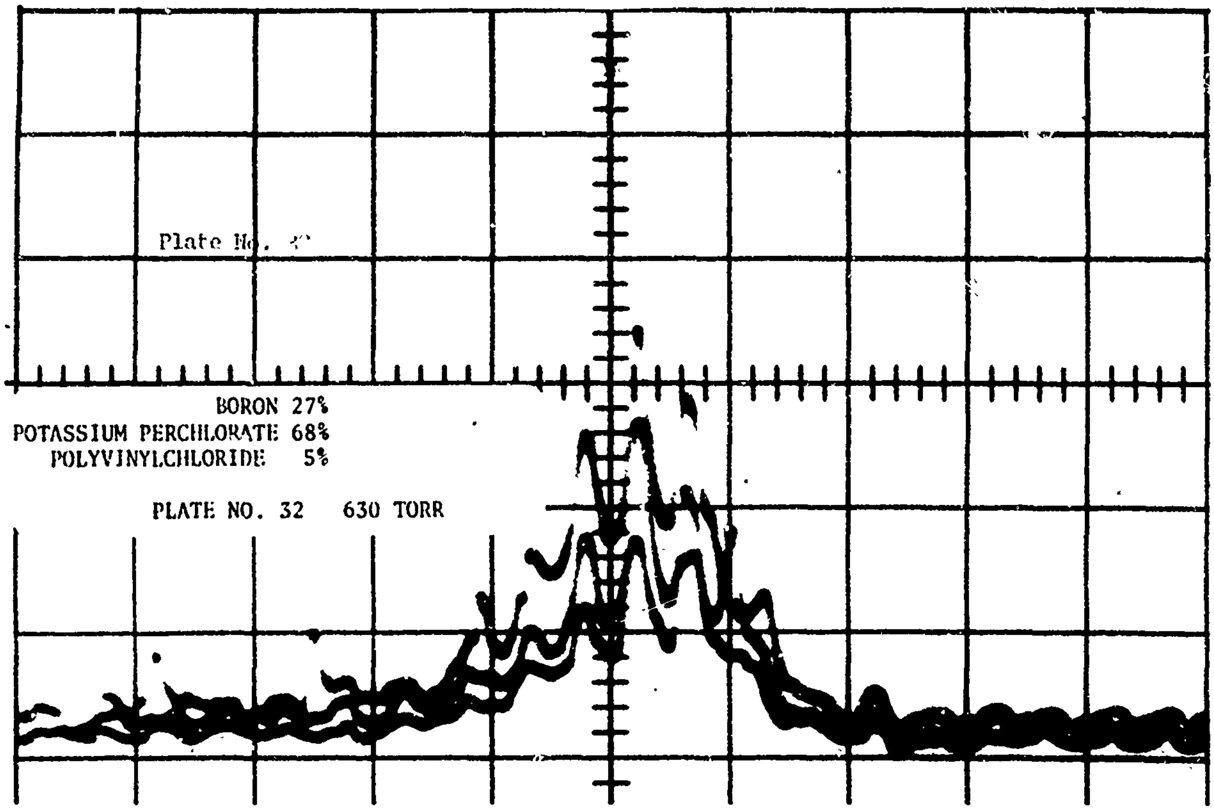
Plate No
BORON 37%
BARIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 27 630 TORR

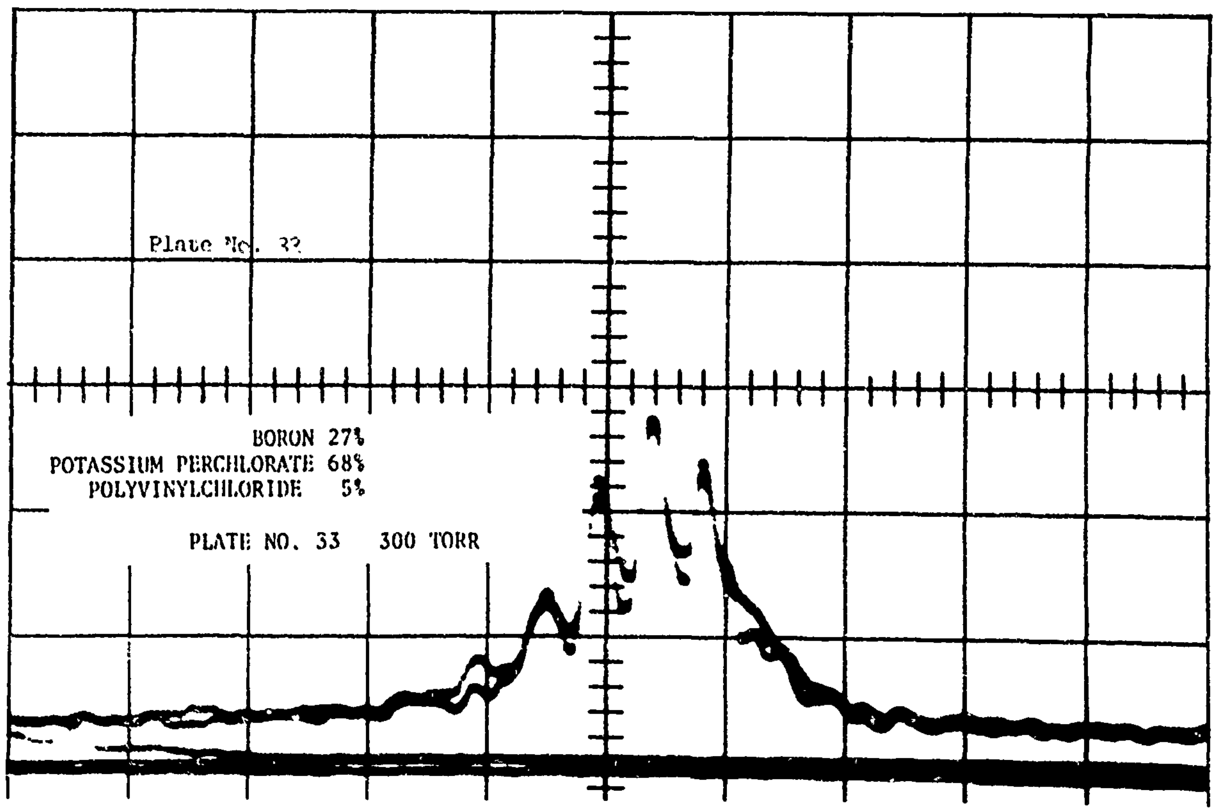

BORON 37%
BARIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 28 630 TORR


BORON 37%
BARIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 29 300 TORR


BORON 37%
BARIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 30 150 TORR


BORON 37%
BARIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 31 70 TORR


BORON 27%
POTASSIUM PERCHLORATE 68%
POLYVINYLCHLORIDE 5%
PLATE NO. 32 630 TORR


BORON 27%
POTASSIUM PERCHLORATE 68%
POLYVINYLCHLORIDE 5%
PLATE NO. 33 300 TORR

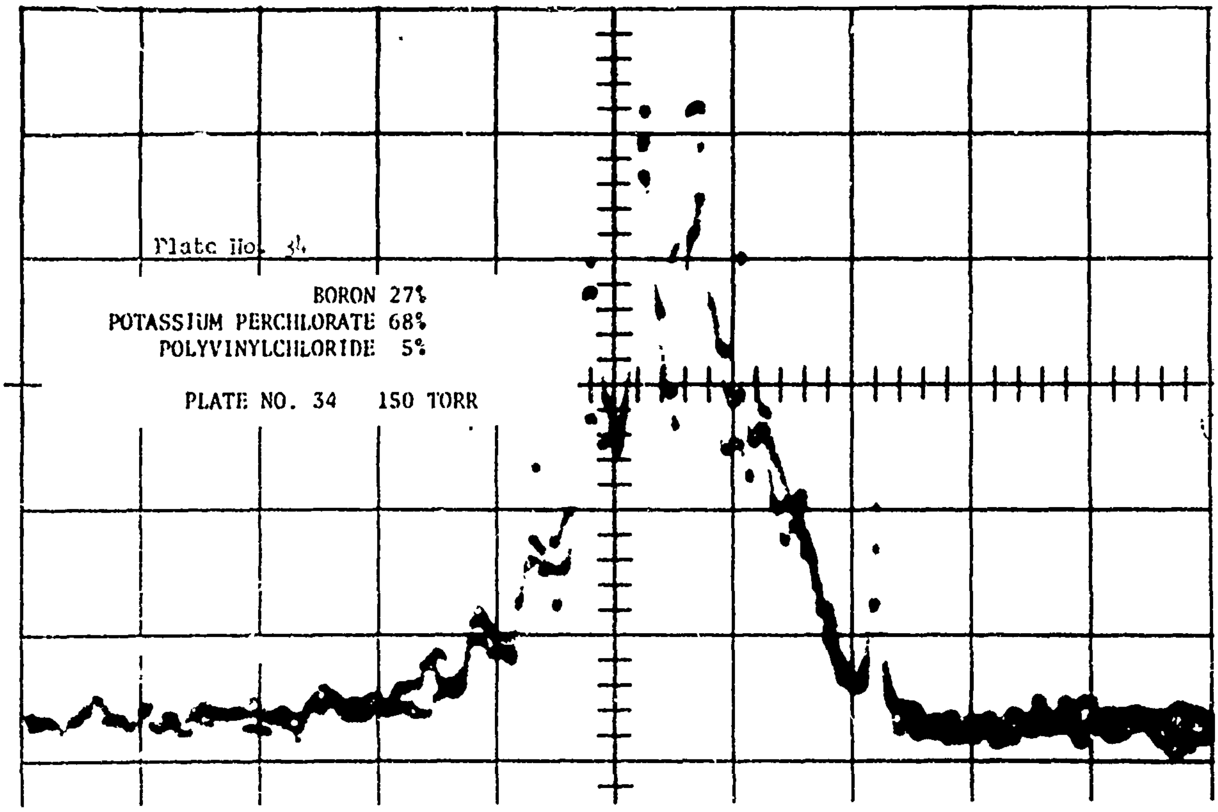
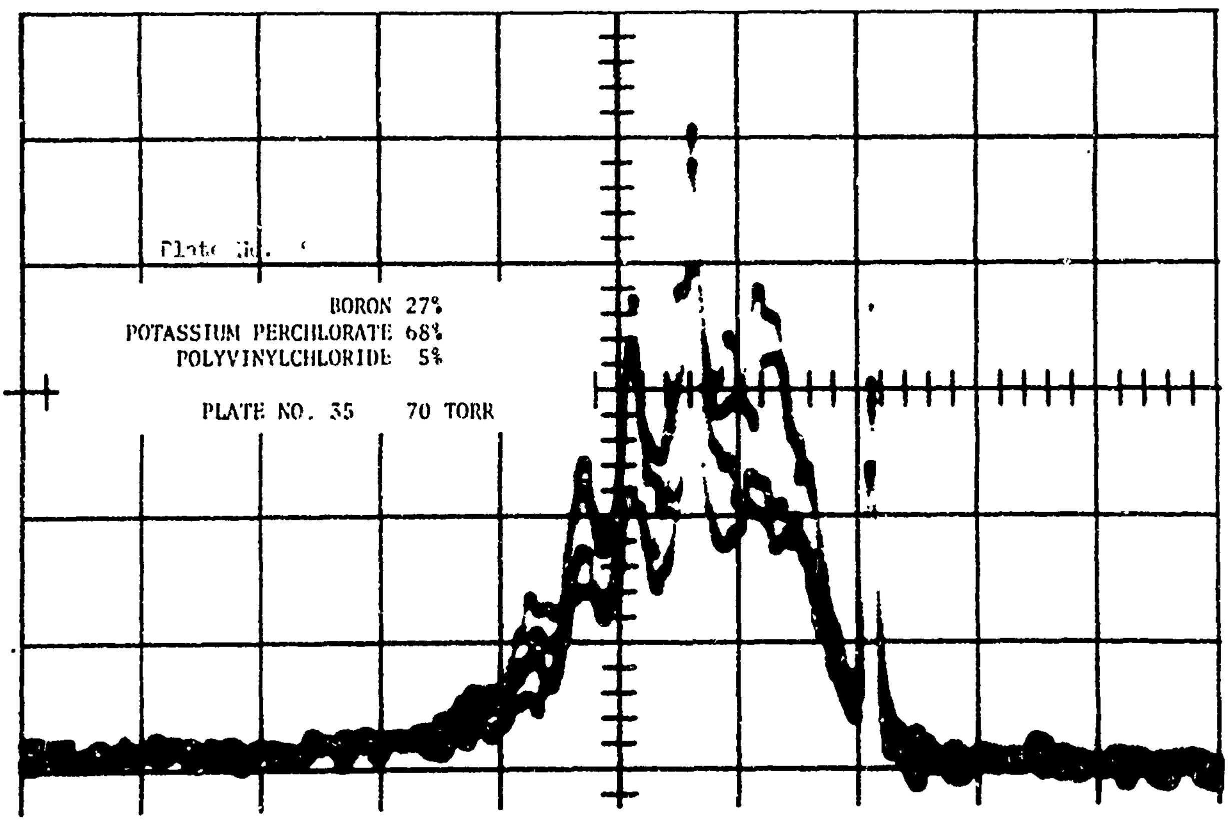
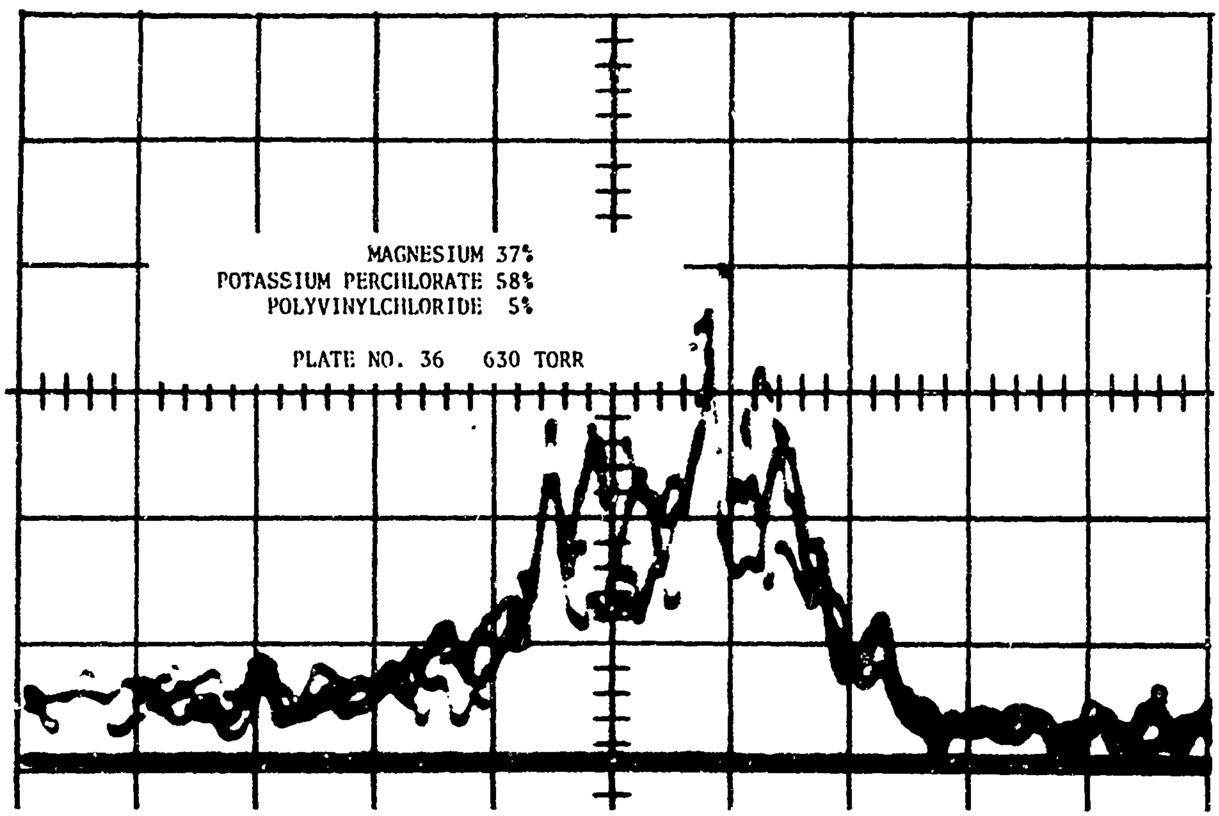


Plate No. 34
BORON 27%
POTASSIUM PERCHLORATE 68%
POLYVINYLCHLORIDE 5%
PLATE NO. 34 150 TORR


BORON 27%
POTASSIUM PERCHLORATE 68%
POLYVINYLCHLORIDE 5%
PLATE NO. 35 70 TORR


MAGNESIUM 37%
POTASSIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 36 630 TORR

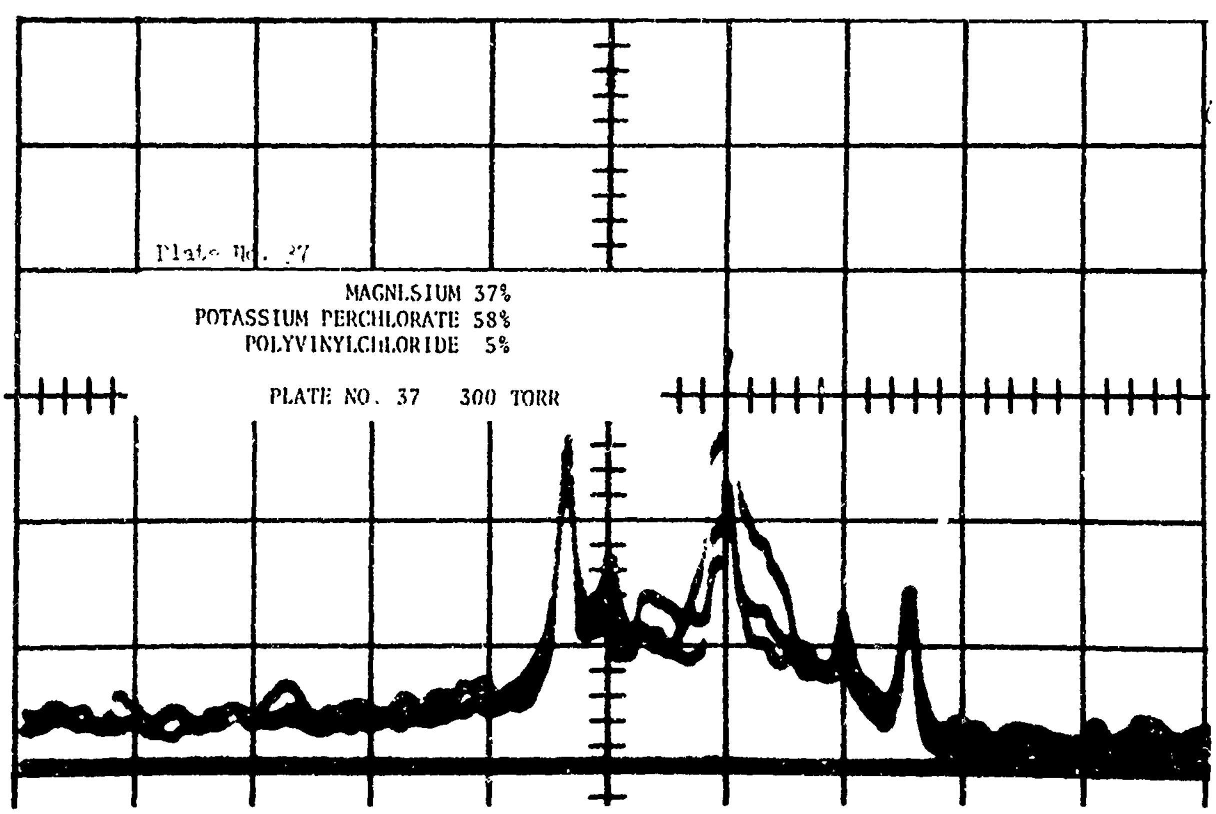


Plate No. 37
MAGNESIUM 37%
POTASSIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 37 300 TORR

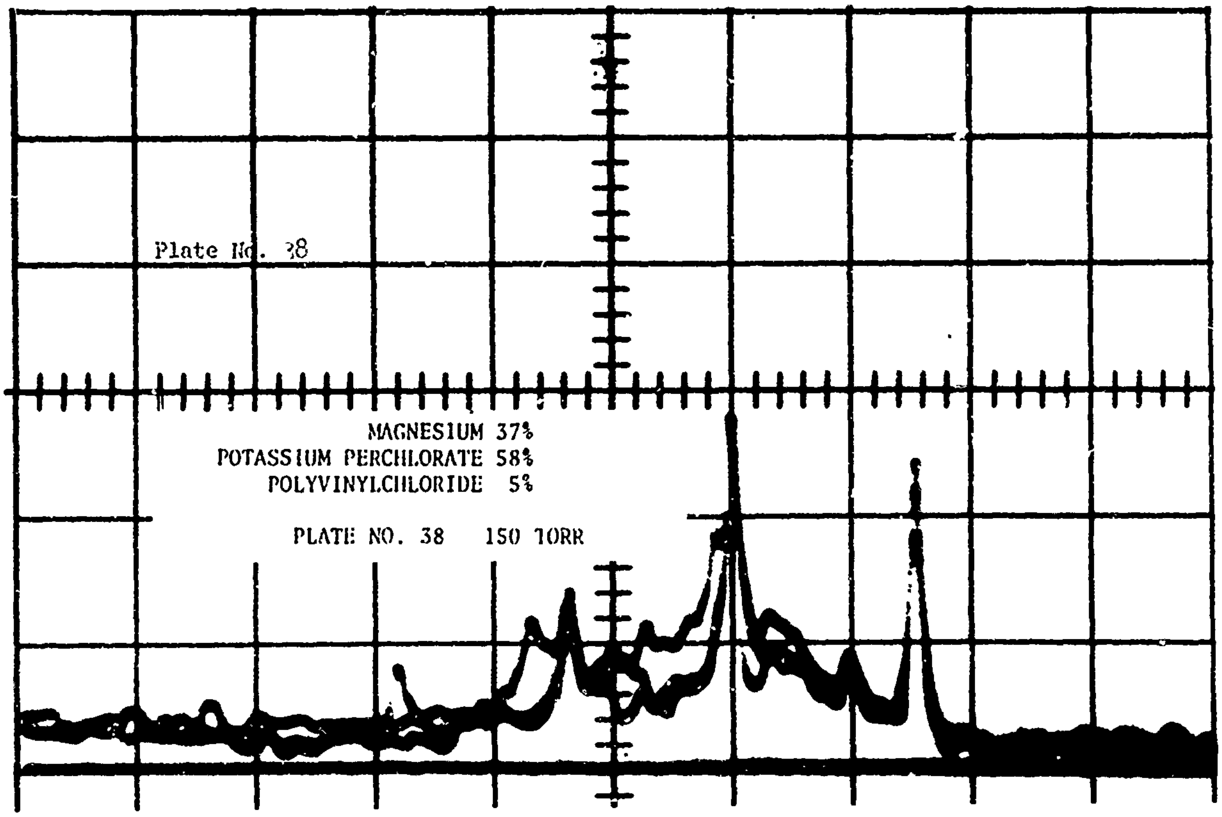
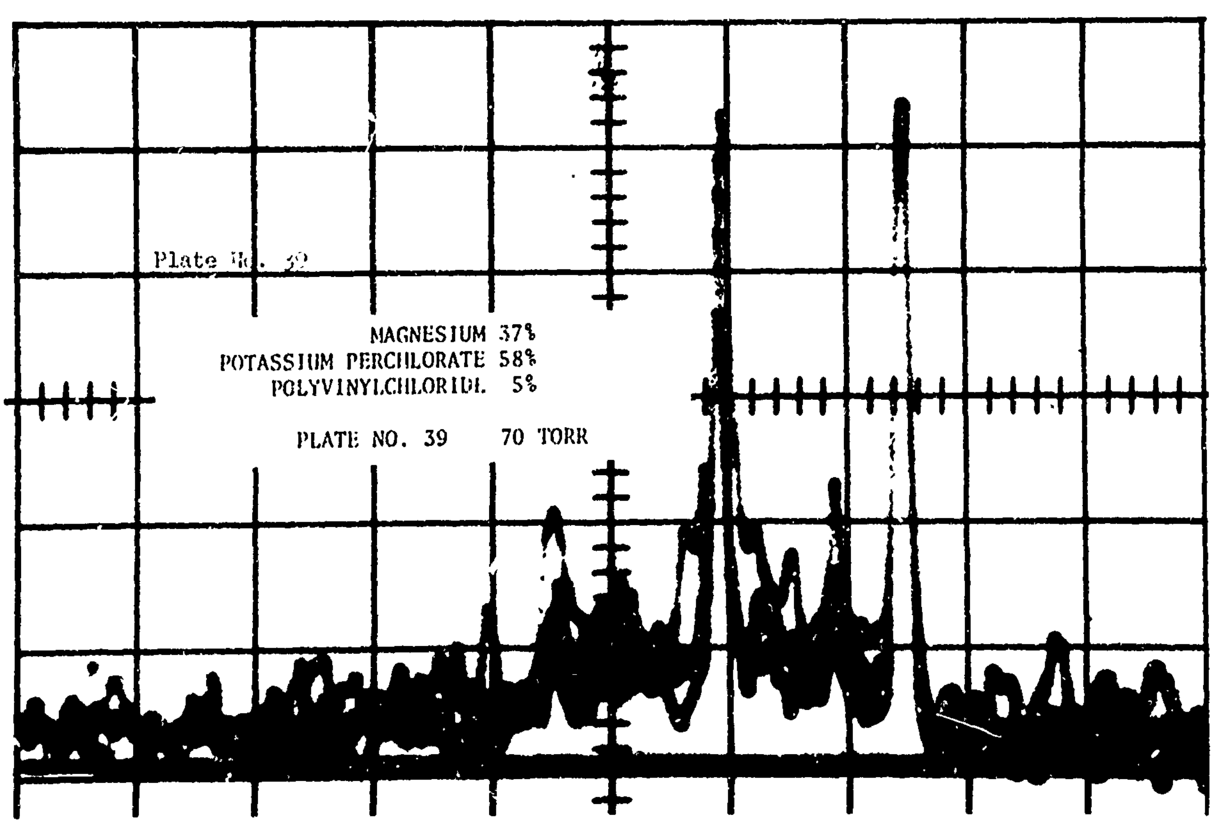


Plate No. 38
MAGNESIUM 37%
POTASSIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 38 150 TORR


MAGNESIUM 37%
POTASSIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 39 70 TORR

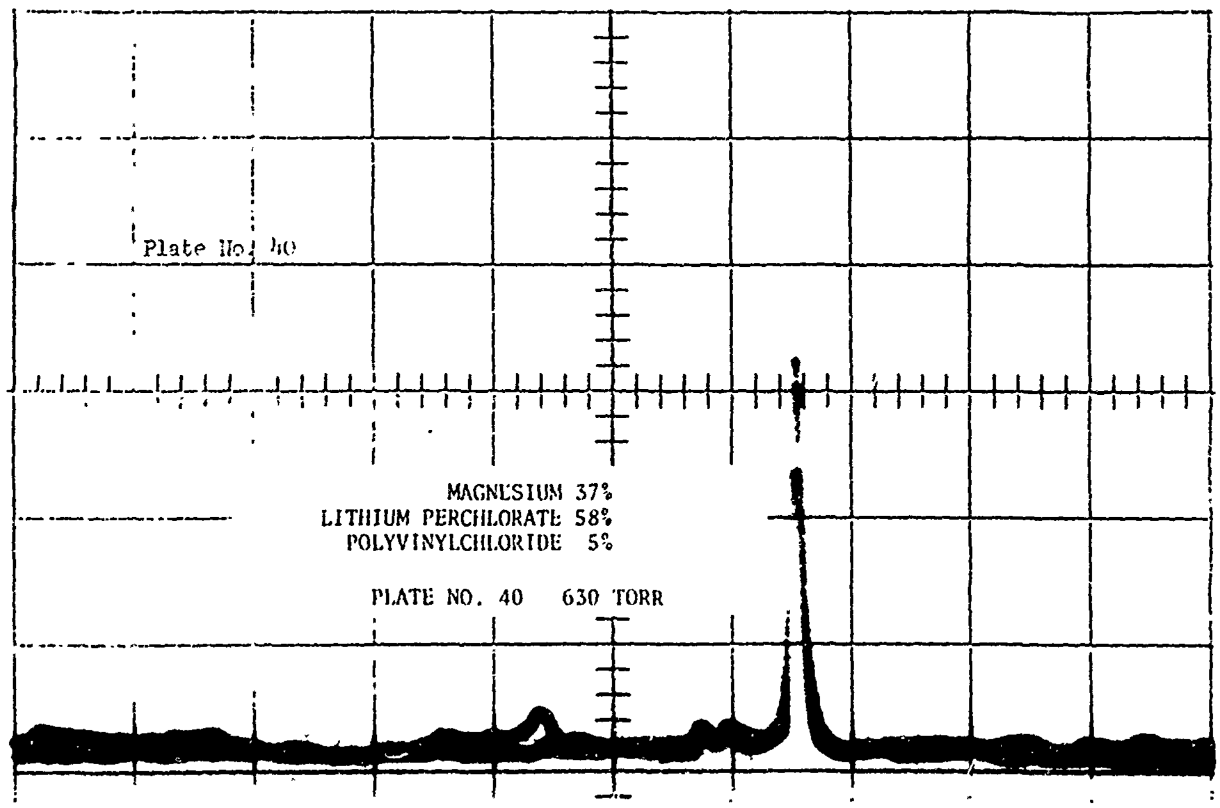


Plate No. 40
MAGNESIUM 37%
LITHIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 40 630 TORR

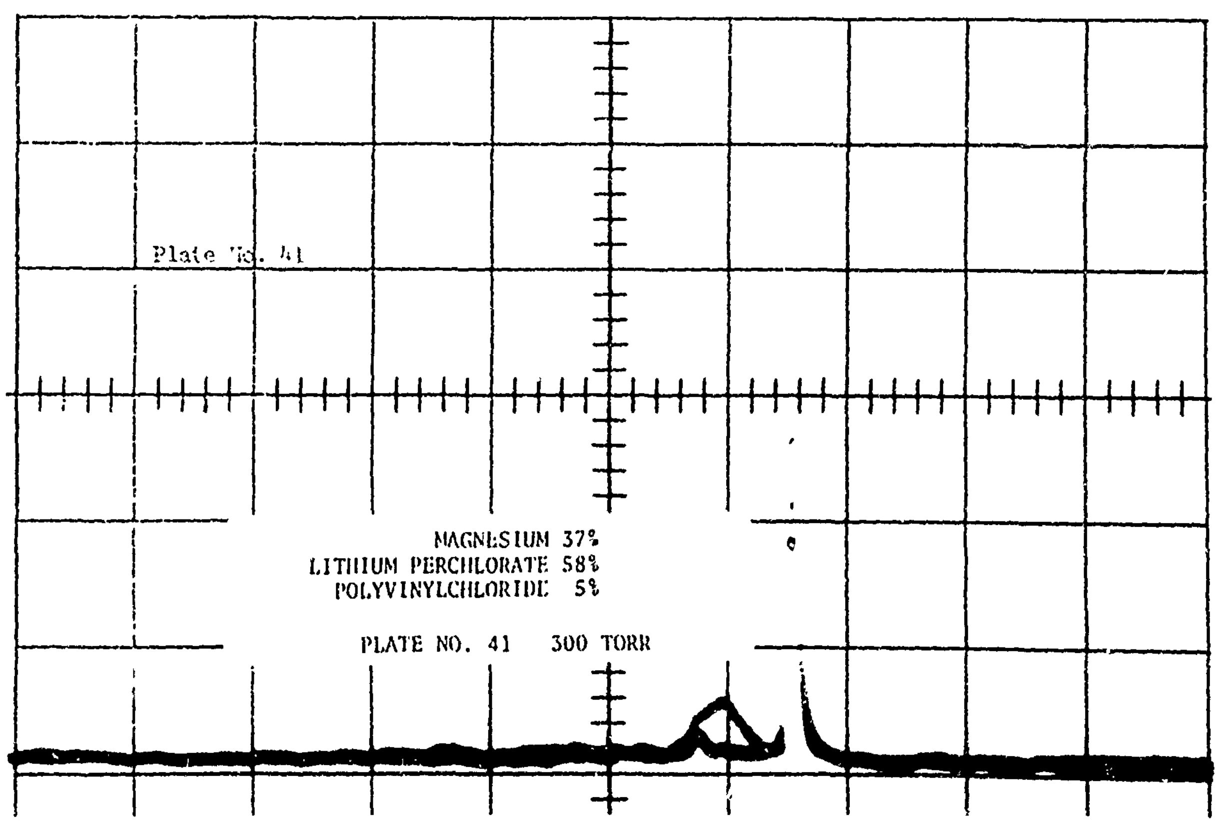


Plate No. 41
MAGNESIUM 37%
LITHIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 41 300 TORR

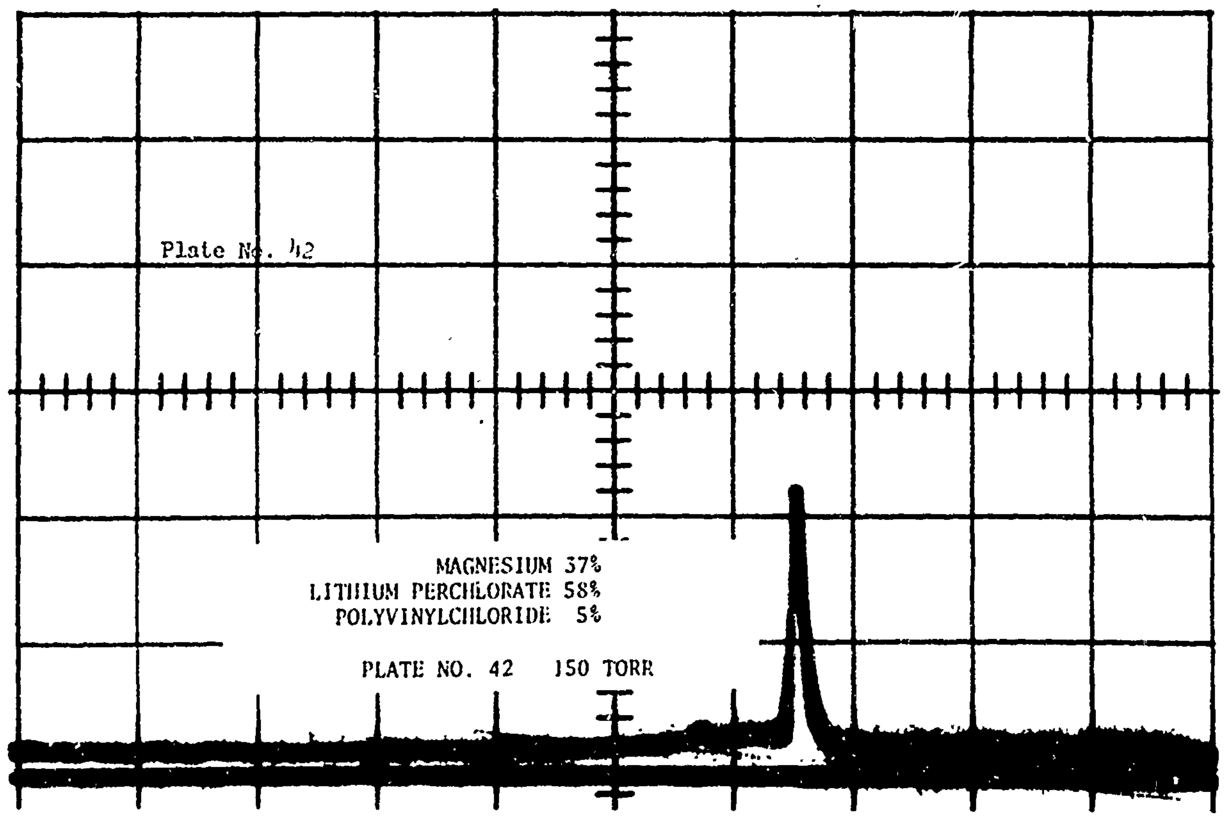
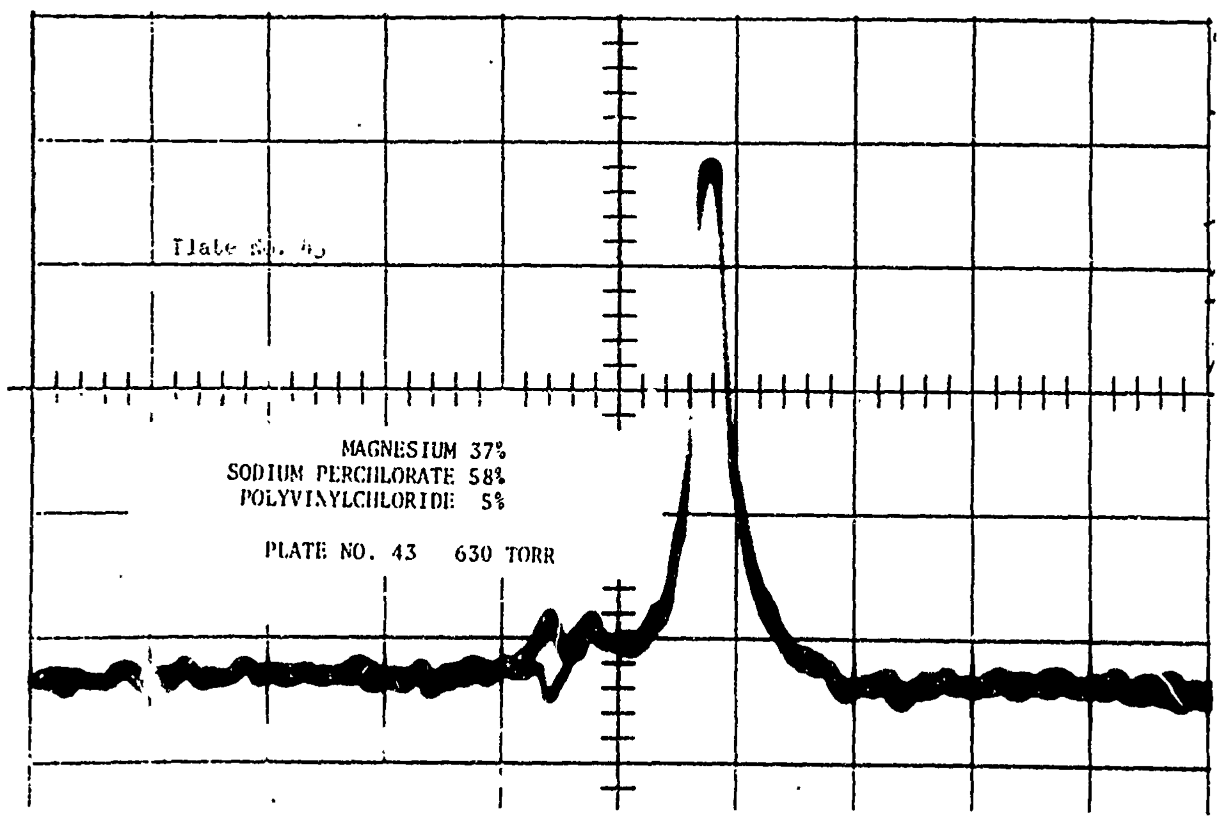


Plate No. 42
MAGNESIUM 37%
LITHIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 42 150 TORR


MAGNESIUM 37%
SODIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 43 630 TORR

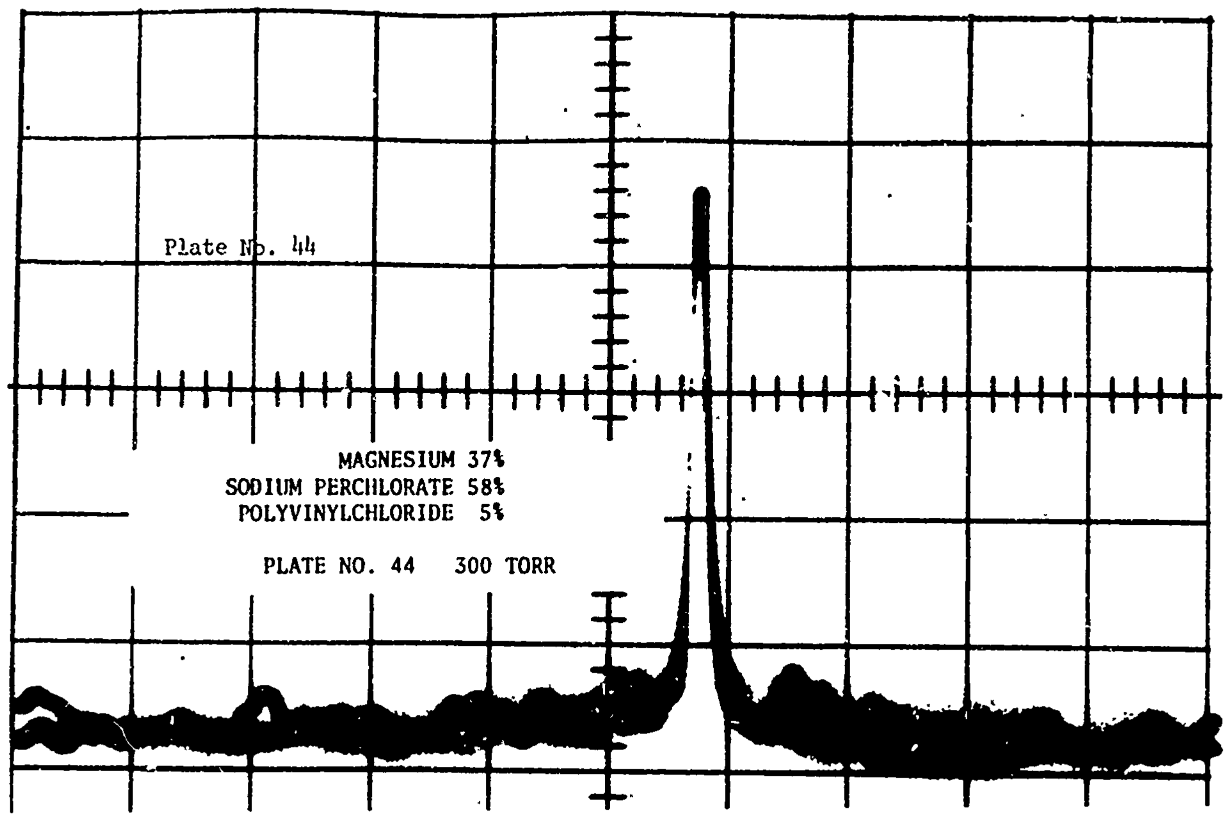


Plate No. 44
MAGNESIUM 37%
SODIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 44 300 TORR

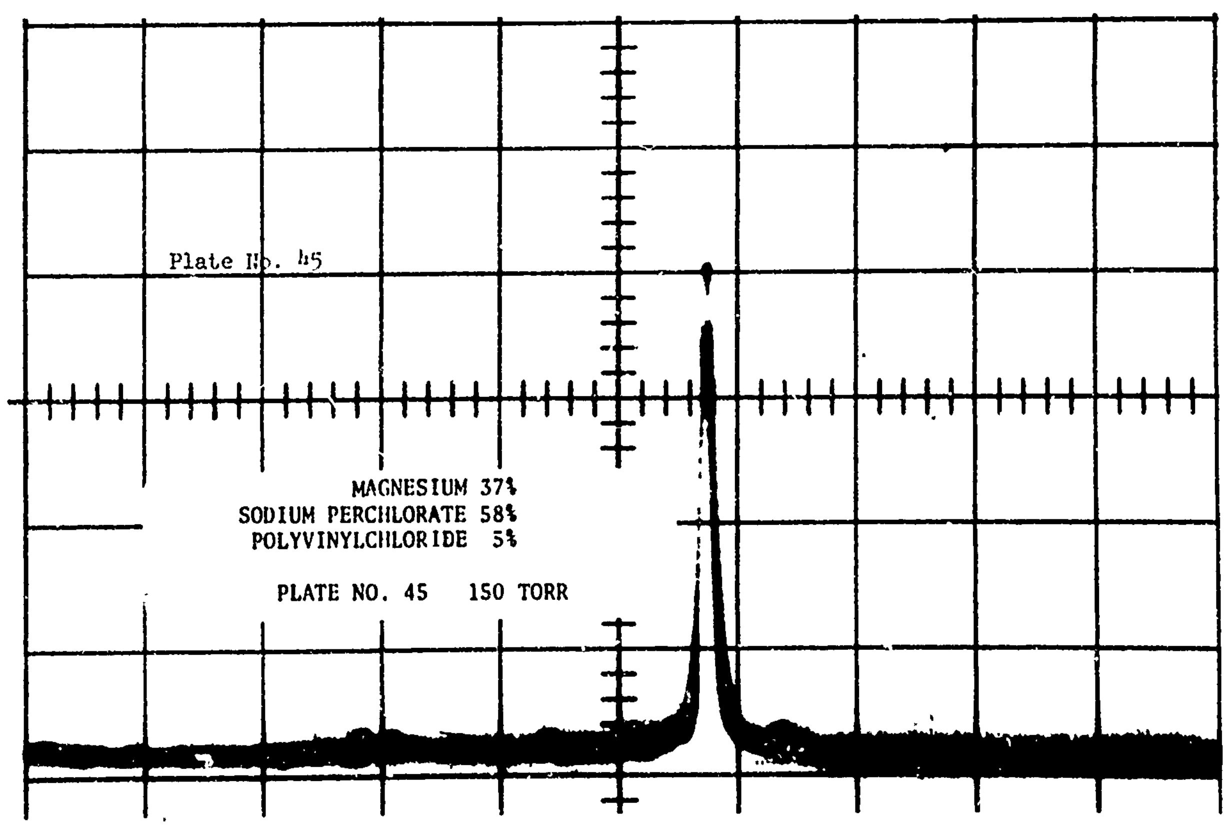


Plate No. 45
MAGNESIUM 37%
SODIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 45 150 TORR

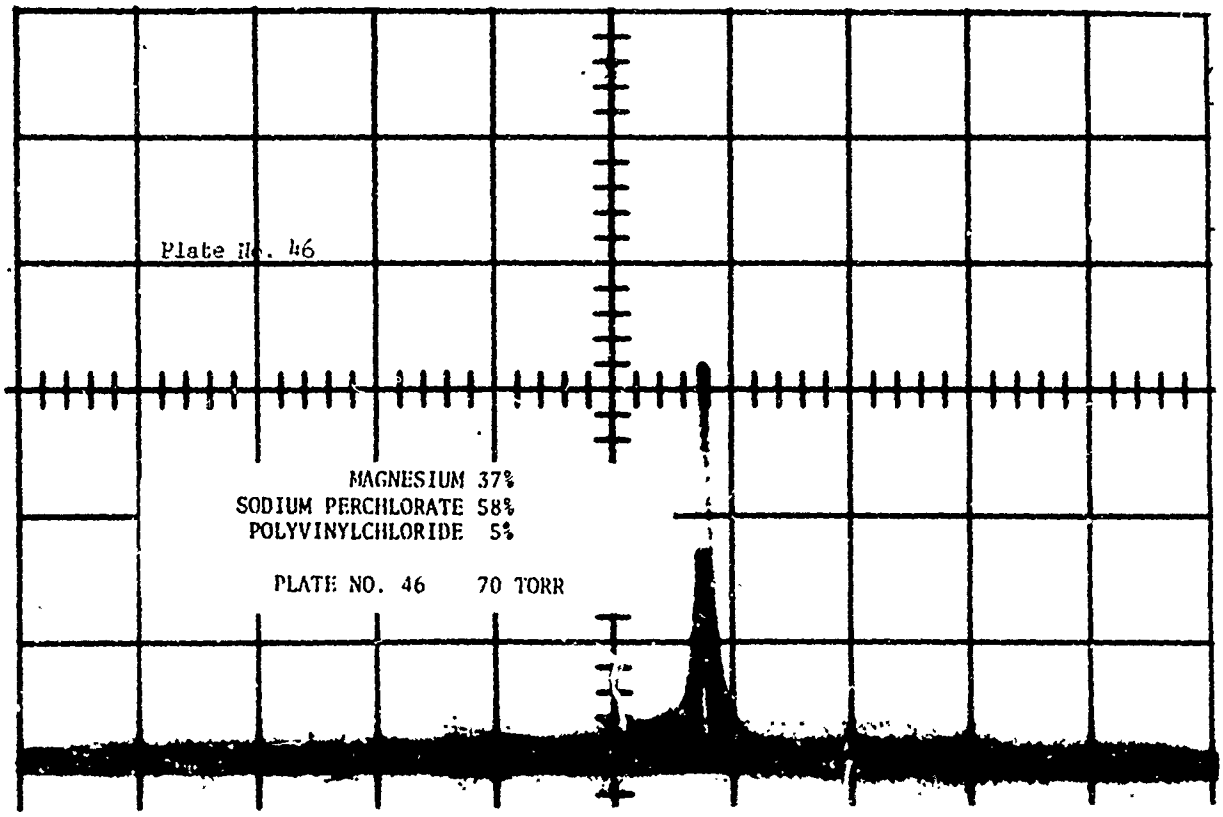
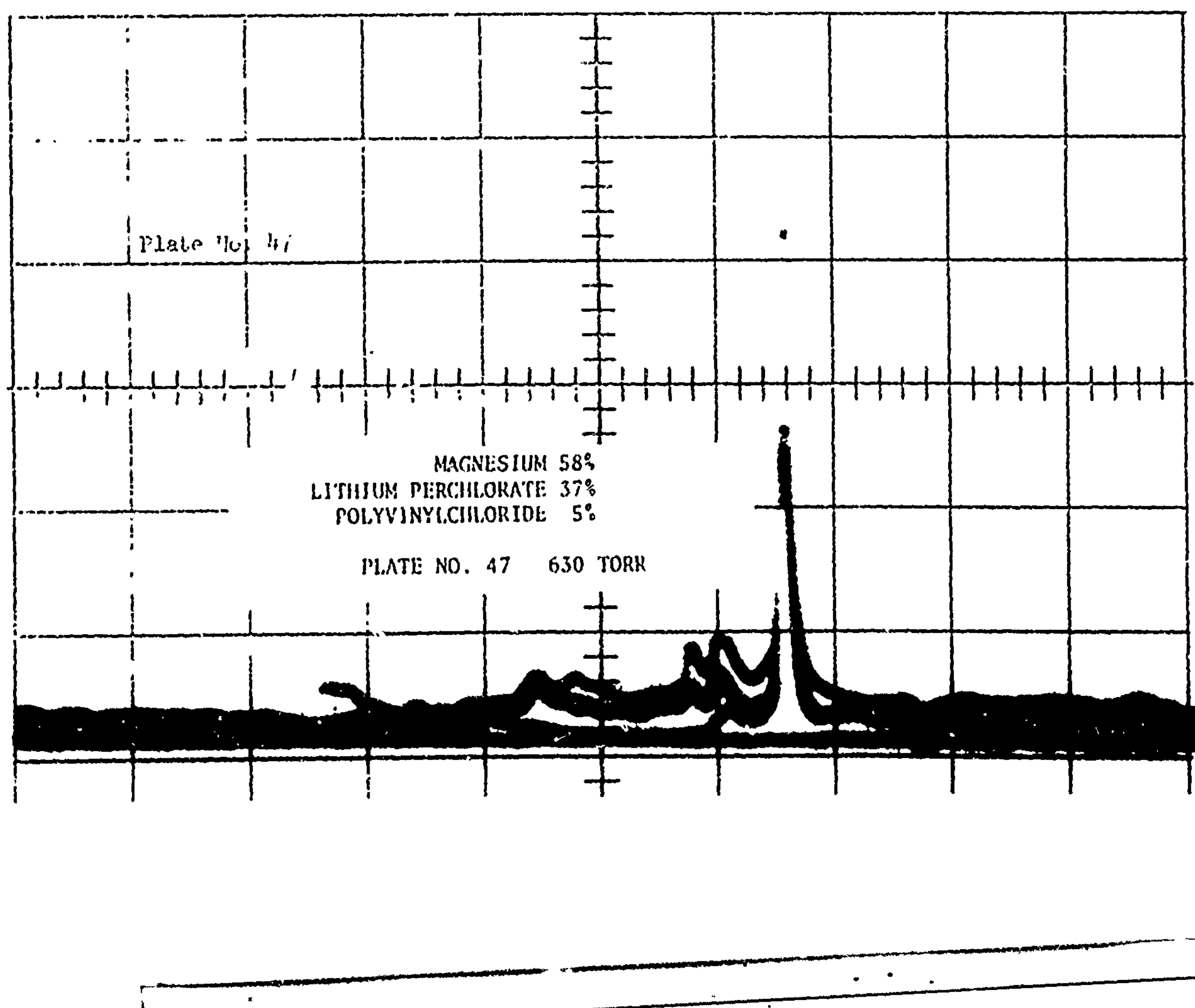


Plate No. 46
MAGNESIUM 37%
SODIUM PERCHLORATE 58%
POLYVINYLCHLORIDE 5%
PLATE NO. 46 70 TORR


MAGNESIUM 58%
LITHIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 47 630 TORR

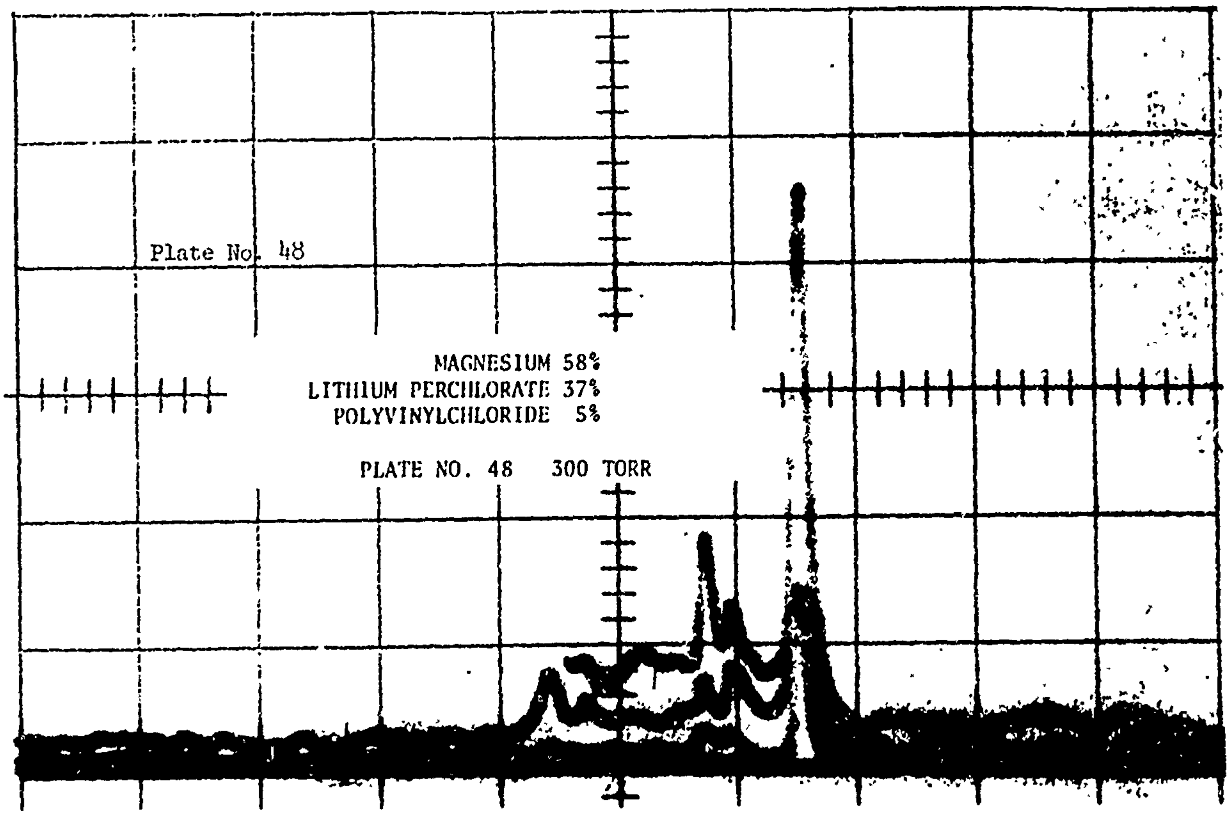
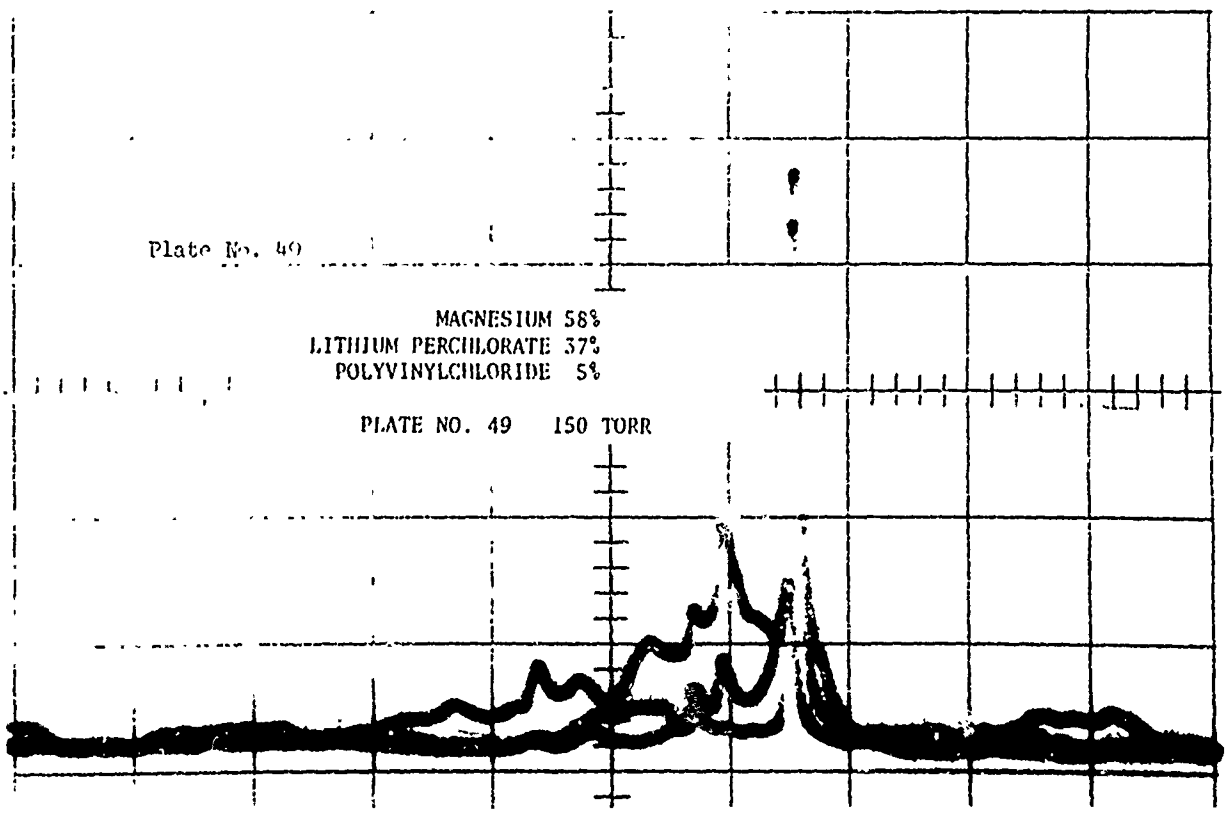


Plate No. 48
MAGNESIUM 58%
LITHIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 48 300 TORR



MAGNESIUM 58%
LITHIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 49 150 TORR

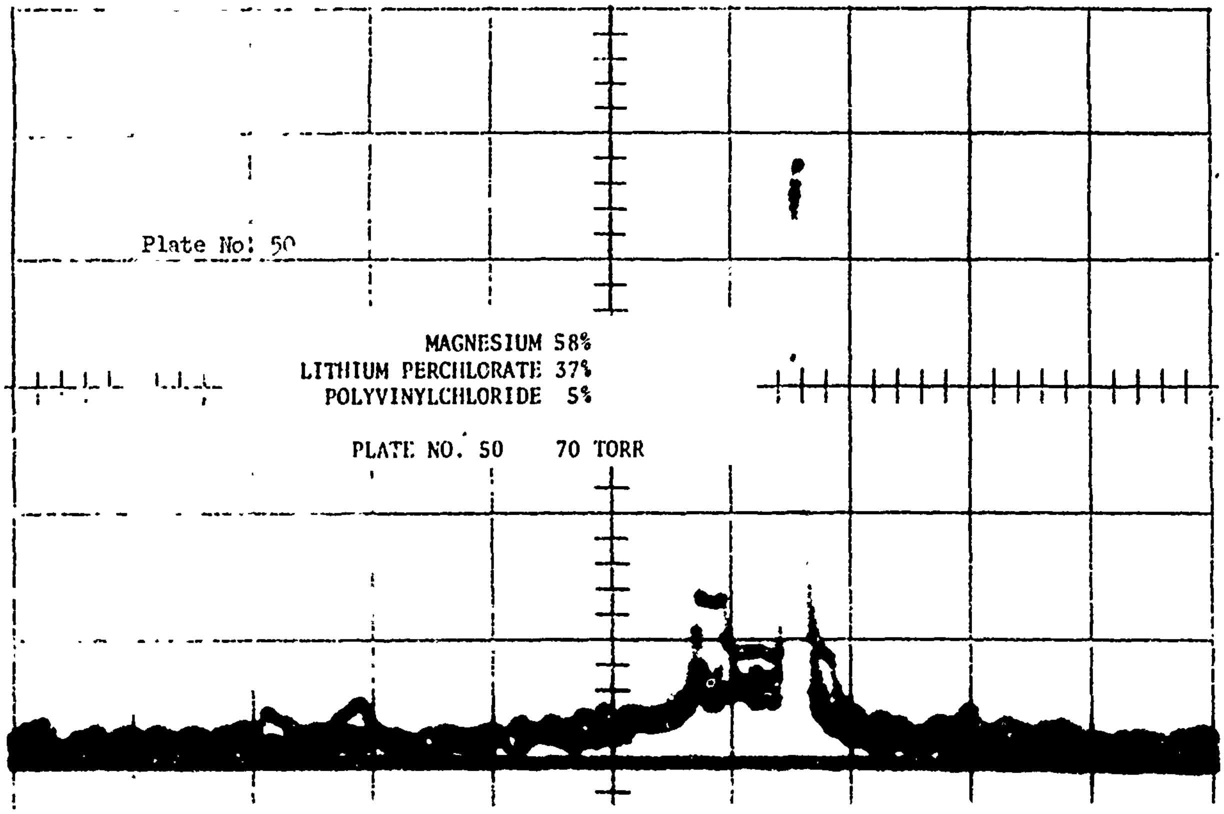
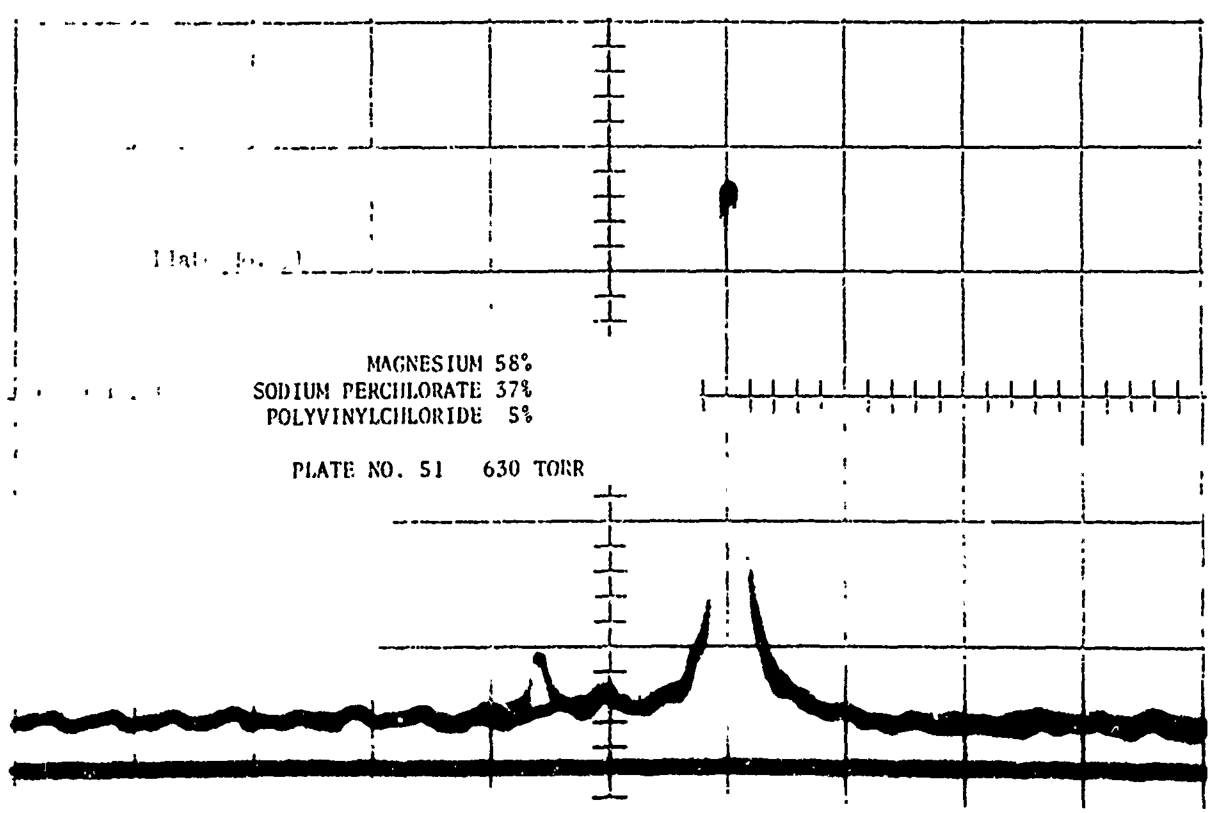
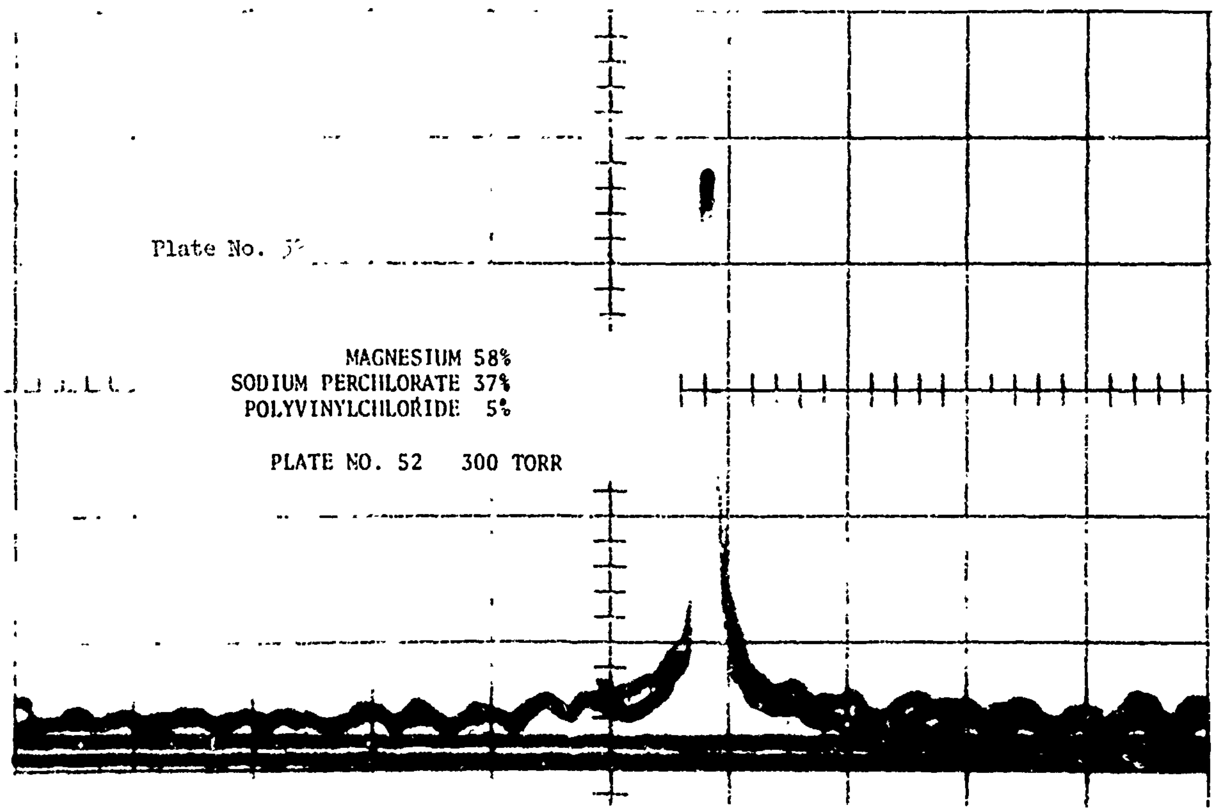
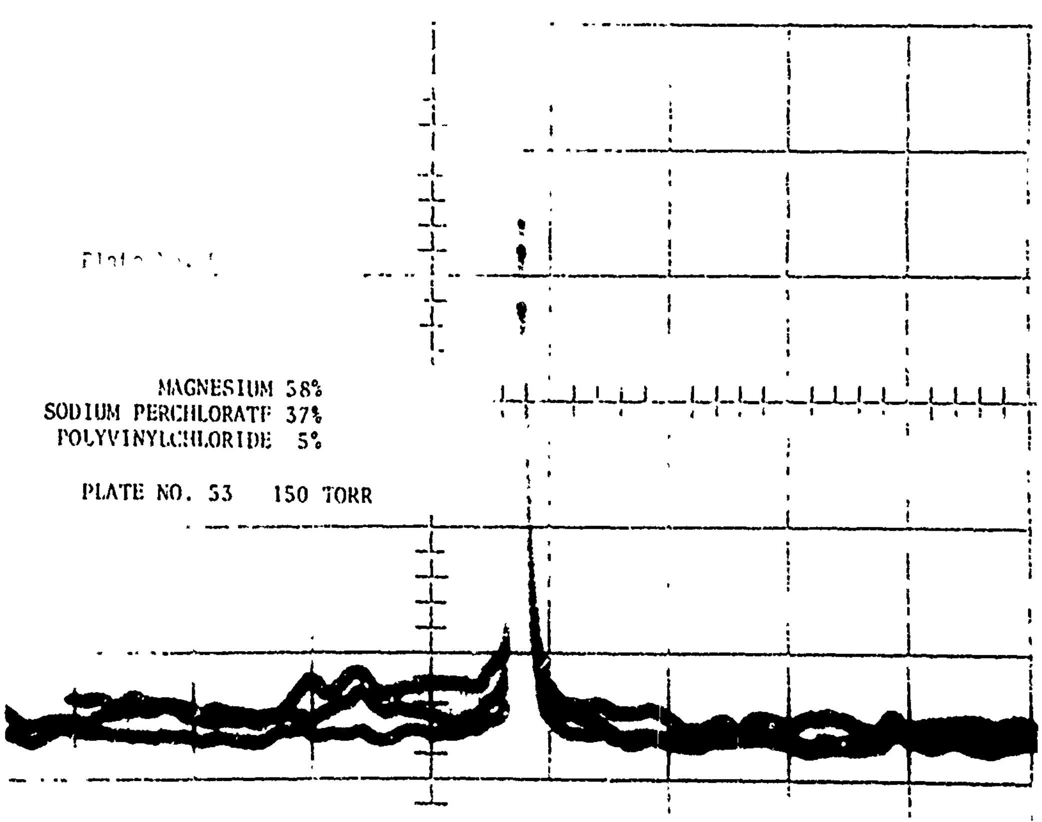


Plate No: 50
MAGNESIUM 58%
LITHIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 50 70 TORR


MAGNESIUM 58%
SODIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 51 630 TORR


MAGNESIUM 58%
SODIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 52 300 TORR


MAGNESIUM 58%
SODIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 53 150 TORR

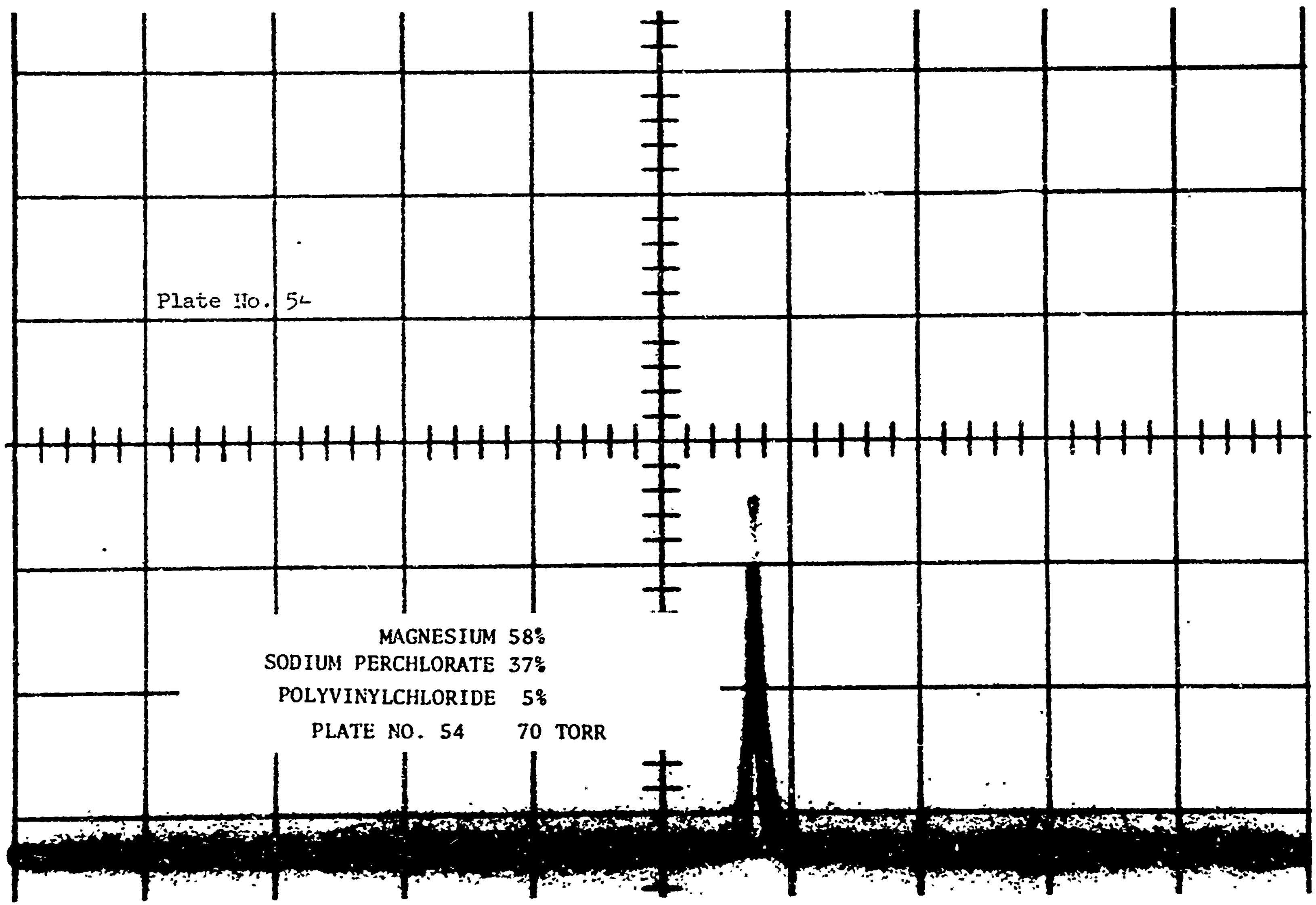
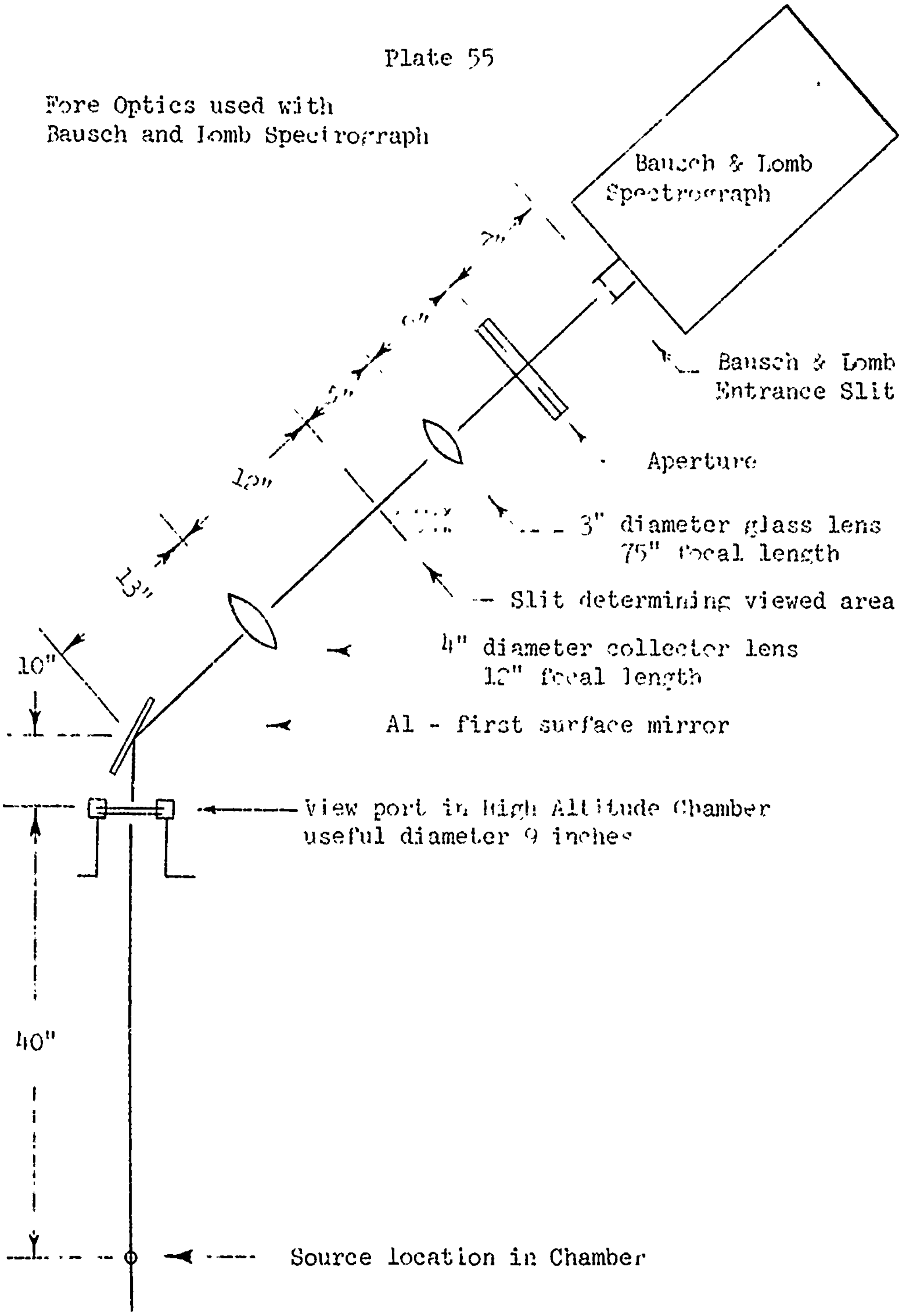


Plate No. 54
MAGNESIUM 58%
SODIUM PERCHLORATE 37%
POLYVINYLCHLORIDE 5%
PLATE NO. 54 70 TORR

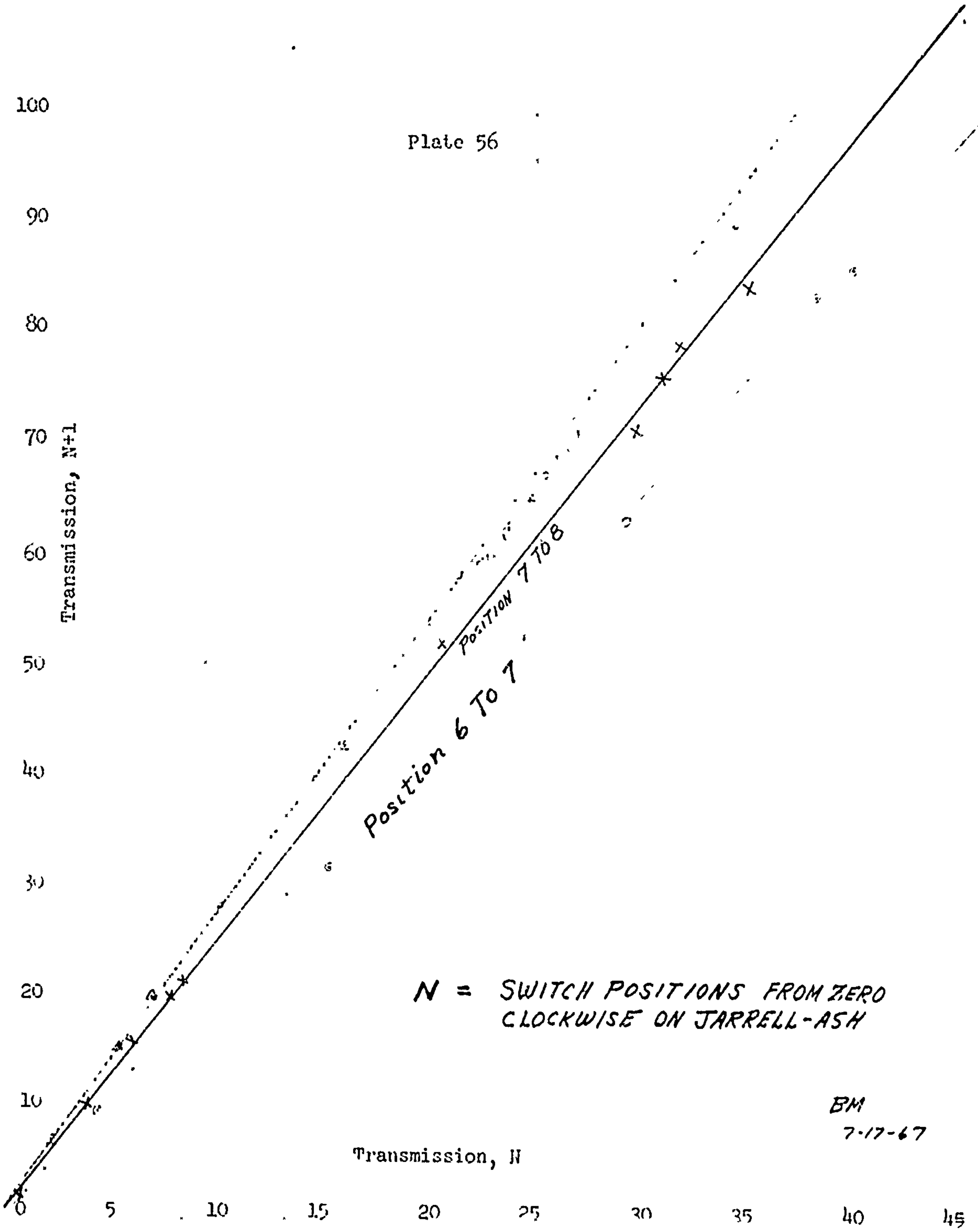
Plate 55

Fore Optics used with
Bausch and Lomb Spectrograph



Plan View

Plate 56



Transmission, N+1
100
90
80
70
60
50
40
30
20
10
Transmission, N
0
5
10
15
20
25
30
35
40
45
Position 6 To 7
Position 7 To 8
N = SWITCH POSITIONS FROM ZERO CLOCKWISE ON JARRELL-ASH
BM
7-17-67

DeVos, J. C., "A New Determination of the Emissivity of Tungsten Ribbon", Physica, Vol. XX, 690-714, 1954.

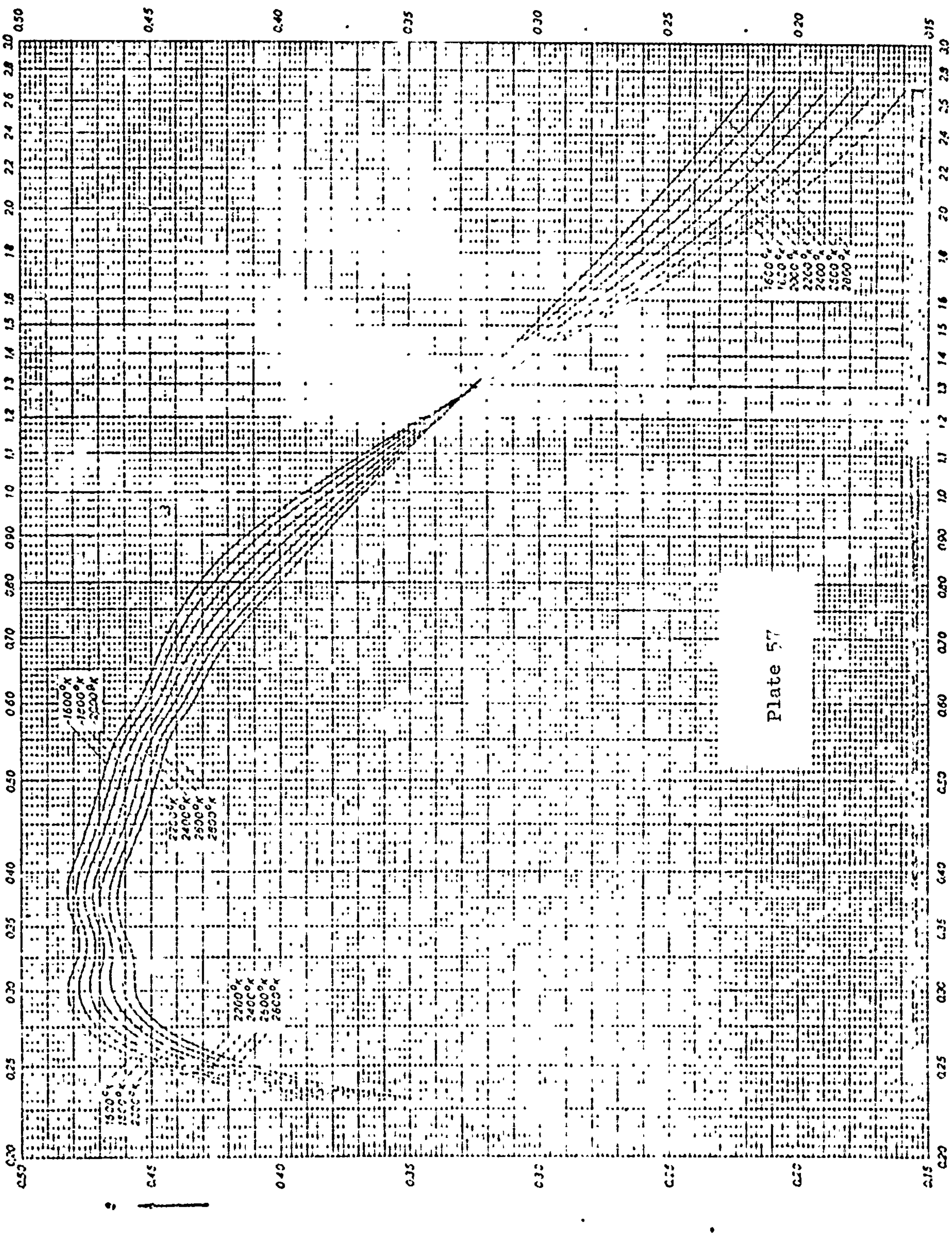


Fig. 6. The emissivity of well-defined tungsten ribbon as a function of wavelength at temperatures between 1600°K and 2800°K. The dotted parts of the curves are obtained by extrapolation. The accuracy at ... and in the measurements is indicated by the line at the bottom of the figure. The width of this line is equal to the mean square error of the average of a set measurements.

Plate 58

```
          BEGIN
COMMENT          PROGRAM TO CALCULATE NET INTENSITIES FOR VARIOUS
                 WAVELENGTHS, EMISSIVITY AND TEMPERATURE AND TO PLOT
                 VS SEIDEL DELTA FUNCTION, A.S.WEST;
FILE IN          CARD (2,10);
FILE OUT         LINE 4(2,15);
PROCEDURE DATELINE(PROGRAM);VALUE PROGRAM;ALPHA PROGRAM;BEGIN OWN BOOLEA*
N USED;FORMAT HD(,,I2,", ",A4,X2,"TIME:",I5,X10,"OUTPUT FROM PROGRAM ",*
A6,X10,"UNIVERSITY OF DENVER COMPUTING CENTER"///),LAYT(//"EXECUTION TIM*
E =",I5,X3,"I/O TIME =",I5," SECONDS  ",A4,I3,", ",A4,X03,"TIME:",I7///*
);LABEL GOTIT;ALPHA MO,MINS,FEB,HRS,YR,DAY;USED←USED AND PROGRAM.[18:6]=*

0;DAY←TIME(0);YR←DAY.[18:12]+"1900";DAY←DAY.[42:6]+10×DAY.[36:6]+100×DAY*
.[30:6];FEB←IF YR.[42:6] MOD 4=0 THEN"(FEB."ELSE"<FEB.";FOR MO←"←JAN.",FE*
B,"<MAR.","<APR.","← MAY","<JUNE","←JULY","←AUG.","<SEPT","←OCT.","<NOV.*
","←DEC."DO BEGIN IF DAY≤MO.[18:06]THEN GO TO GOTIT;DAY←DAY-MO.[18:6];EN*
D;GOTIT:MINS←TIME(1)/3600;HRS←100×(MINS DIV 60)+MINS MOD 60;IF USED THEN*
 WRITE(LINE,LAYT,TIME(2)/60,TIME(3)/60,MO,DAY,YR,HRS)ELSE WRITE(LINE,HD,*
MO,DAY,YR,HRS,PROGRAM);USED←TRUE;END OF DATELINE;                       *

FORMAT F10(///"WAVELENGTH = ",F5.3,X11,"STEP NO." ,X7,"DELTA FUNCTION", *
X7,"LOG NET INTENSITY");

FORMAT F11(X31,I3,X13,F7.4,X16,F7.4);                                   *

LABEL L25;                                                              *
INTEGER I1,IJ,IK;                                                       *
INTEGER          I,J,K,N1,N2,N3,N4,Q,STEPE;                             *
INTEGER QQ;                                                             *
INTEGER  N5,N6;                                                         *
REAL N10;  LABEL L20;                                                   *
FORMAT           HD1(X40,"SEIDEL DELTA FUNCTION VS NET INTENSITY"///);  *

FORMAT          HD2(//,X1,"TEMPERATURE = ",I4," DEGREES KELVIN");       *

FORMAT          HD3(X1,"EMISSIVITY  = ",F4.2//);                        *

FORMAT          HD4(X1,"STEP NUMBER = ",I4//);                          *

FORMAT HD5("WAVELENGTH",X3,"TRANSMISSION",X3,"DENSITY",X4,"DELTA",X4,   *
   "LOG NET INTENSITY",X3,"Y1=INTENSITY NORM",X3,"Y2= DELTA NORM",      *
   X5, "R = Y1/Y2");                                                    *

FORMAT          HD6("  MICRONS"),                                       *

FORMAT          FER(//,"TRANSMISSION DATA VALUE EQUAL TO OR GREATER",   *
                     " THAN ONE PROGRAM STOPS"//);                      *

FORMAT          FER2(//,"NET INTENSITY LESS THAN ZERO PROGRAM STOPS"//);*
FORMAT  F1(6(F6.1,F6.4));                                               *
```

```
EMIT[I];                                                                     *
                    EKEL[STEPE,K] ← EMIT[I]×IF[K]×SWT[STEPE]×NLAM[STEPE,K];  *
EKNL[STEPE,K] ← LI(EKEL[STEPE,K]) × 0.43425;                                 *
DPTS ← LI(TRAN[K])×0.43425;                                                  *
NA←((C3×LAM*(-5)×(1.0/(EXP((2/(LAM×TEMP[I]))-1.0))×EMIT[I]);                 *
IF(ABS(Z2)<0.0001 THEN GO TO L20;                                            *
                    Y2[STEPE,K] ← DEL[STEPE,K]/DK;                           *
IF(ABS(Z2) < 0.0001) THEN GO TO L20;                                         *
                    Y1[STEPE,K] ←NLAM[STEPE,K]/NK;                           *
IF(ABS(Y2[STEPE,K]) < 0.0001) THEN GO TO L20;                                *
                    R[STEPE,K]  ←  Y1[STEPE,K]/Y2[STEPE,K];                  *
WRITE(LINE,F4,LAM[K],TRAN[K],DPTS,DEL[STEPE,K],EKNL[STEPE,K],Y1[STEPE,K]*
    ,Y2[STEPE,K],R[STEPE,K]);                                                *
L20:                                                                         *
END;                                                                         *

            END;                                                             *
WRITE (LINE [PAGE ]);                                                        *
WRITE(LINE,HD2,TEMP[I]);                                                     *
WRITE(LINE,HD3,EMIT[I]);                                                     *
FOR K ← 1 STEP 1 UNTIL NA DO                                                 *
BEGIN                                                                        *
LABEL L28;                                                                   *
IF(LAM[K]=0.0) THEN GO L28;                                                  *
WRITE(LINE,F10,LAM[K]);                                                      *
FOR STEPE ← 0 STEP 1 UNTIL N3 DO                                             *
BEGIN                                                                        *
LABEL L25;                                                                   *
IF(EKNL[STEPE,K]=0.0)THEN GO TO L25;                                         *
WRITE(LINE,F11,STEPE,DEL[STEPE,K],EKNL[STEPE,K]);                            *
L25:                                                                         *
END  ;                                                                       *

L28:                                                                         *
END;                                                                         *

WRITE (LINE [PAGE]);                                                         *
END                                                                          *
           END;                                                              *

DATELINE(0);                                                                 *
END.                                                                         *

 IS SEGMENT NUMBER 0026,PRT ADDRESS IS 0141
 IS SEGMENT NUMBER 0027,PRT ADDRESS IS 0140
PUT(W) IS SEGMENT NUMBER 0028,PRT ADDRESS IS 0034
ACK CONTROL IS SEGMENT NUMBER 0029,PRT ADDRESS IS 0005
UT(W) IS SEGMENT NUMBER 0030,PRT ADDRESS IS 0122
OL WRITE   IS SEGMENT NUMBER 0031,PRT ADDRESS IS 0014
OL READ    IS SEGMENT NUMBER 0032,PRT ADDRESS IS 0015
OL SELECT  IS SEGMENT NUMBER 0033,PRT ADDRESS IS 0016

 ERRORS DETECTED =    0.  COMPILATION TIME =    12 SECONDS.
```

```
FORMAT         F2 (3F5.3);                                                    *

FORMAT         F3 5I5);                                                       *

FORMAT  F5(5(F5.3 I5.1));                                                     *

FORMAT F4(E9.2,X7,F6.3,X6,F6.3,X5,F6.3,X7,E12.5,X6,E12.5,X7,E12.5,X6,         *
  E12.5);                                                                     *

FORMAT  F7(2F5.3);                                                            *

REAL  LAMB,                                                                   *
REAL  DEGS;                                                                   *
REAL ARRAY TEMP[0:10],EMIT[0:10],LAM,TF,TRAN[0:100],SWT[0:20],                *
     DEL,NL,EKNL,Y1,Y2,R[0:20,0:100] ;                                        *
REAL ARRAY       NLAM[0:20,0:100];                                            *
REAL             C1,C2,NG,DK;                                                 *
DATELINE("DELTR ");                                                           *
                 WRITE(LINE,HD1);                                             *
                 READ(CARD,F3,N1,    N3,N4);                                  *
READ(CARD,F3,N10),                                                            *
            BEGIN                                                             *
LABEL L20:                                                                    *
LIST   L3(FOR Q ← 0 STEP 1 UNTIL N3 DO SWT[Q]);                               *
LIST   L4(FOR G ← 1 STEP 1 UNTIL N4 DO TF[Q]);                                *
                 READ(CARD,F2,L3),                                            *
                 READ(CARD,F2,L4),                                            *
FOR I ← 1 STEP 1 UNTIL N1 DO                                                  *
BEGIN                                                                         *
LABEL L20;                                                                    *
FOR Q ← 0 STEP 1 UNTIL N3 DO                                                  *
FOR QQ ← 0 STEP 1 UNTIL N4 DO                                                 *
DEL[Q,QQ]←EKNL[Q,QQ]←0.0;                                                     *
READ(CARD,F1,TEMP[I],EMIT[I]);                                                *
READ(CARD,F3,N2);                                                             *
FOR II ← 1 STEP 1 UNTIL N2 DO BEGIN                                           *
READ(CARD,F3,STEPE,N5,N6),                                                    *
READ(CARD,F7,FOR K ← N5 STEP 1 UNTIL N6 DO[LAM[K],TRAN[K]]);                  *
                 WRITE(LINE,HD2,TEMP[I]),                                     *
                 WRITE(LINE,HD3,EMIT[I]);                                     *
                 WRITE(LINE,HD4,STEPE);                                       *
                 WRITE(LINE,HD5);                                             *
                 WRITE(LINE,HD6);                                             *
FOR K ← N5 STEP 1 UNTIL N6 DO                                                 *
BEGIN                                                                         *
LABEL L20;                                                                    *
IF TRAN[K] = 0.0 THEN GO TO L20,                                              *
DEL[STEPE,K] ← LN((1.0/TRAN[K])-1.0)×0.43425;                                 *
LAMB ← 0.5;                                                                   *
                 C1 ← 37405.0,                                                *
                 C2 ← 14305.0,                                                *
DK← LN(1.0/TRAN[N'0]-1.0)×0.43425;                                            *
NLAM[STEPE,K]←(C1)×LAM[K]*(-5)×(1.0/(EXP(C2/(LAM[K]×TEMP[I]))-1.0))×          *
```

WAVELENGTH MICRONS	TRANSMISSION	DENSITY	DELTA	LOG NET INTENSITY	Y1=INTENSITY NORM	Y2= DELTA NORM	R = Y1/Y2
0.37	0.960	0.016	-1.380	1.51942E-01	1.56447E-01	-6.91615E-01	-2.26205E-01
0.38	0.570	0.244	-0.122	2.62597E-01	1.92386E-01	-6.13371E-02	-3.13654E+00
0.39	0.220	0.658	0.550	3.63299E-01	2.33298E-01	2.75437E-01	8.47012E-01
0.40	0.090	1.046	1.005	4.53996E-01	2.79300E-01	5.03498E-01	5.54718E-01
0.41	0.040	1.398	1.380	5.35488E-01	3.30440E-01	6.91615E-01	4.77780E-01
0.42	0.020	1.699	1.690	6.10706E-01	3.86702E-01	8.46946E-01	4.56584E-01
0.43	0.010	2.000	1.995	6.79626E-01	4.48005E-01	1.00000E+00	4.48005E-01
0.44	0.010	2.000	1.995	7.44436E-01	5.14205E-01	1.00000E+00	5.14205E-01
0.45	0.010	2.000	1.995	8.03657E-01	5.85104E-01	1.00000E+00	5.85104E-01
0.46	0.010	2.000	1.995	8.58925E-01	6.60455E-01	1.00000E+00	6.60455E-01
0.47	0.010	2.000	1.995	9.10495E-01	7.39963E-01	1.00000E+00	7.39963E-01
0.48	0.010	2.000	1.995	9.59473E-01	8.23301E-01	1.00000E+00	8.23301E-01
0.49	0.010	2.000	1.995	1.00475E+00	9.10107E-01	1.00000E+00	9.10107E-01
0.50	0.010	2.000	1.995	1.04739E+00	1.00000E+00	1.00000E+00	1.00000E+00

TEMPERATURE = 3008 DEGREES KELVIN
EMISSIVITY = 0.40

Plate 59

STEP NUMBER = 1

WAVELENGTH MICRONS	TRANSMISSION	DENSITY	DELTA	LOG NET INTENSITY	Y1=INTENSITY NORM	Y2= DELTA NORM	R = Y1/Y2
0.36	0.999	0.000	-2.999	-4.43860E-01	1.25296E-01	-2.51015E+00	-4.99160E-02
0.37	0.980	0.009	-1.690	-3.15302E-01	1.56447E-01	-1.41442E+00	-1.10608E-01
0.38	0.820	0.086	-0.658	-2.04646E-01	1.92386E-01	-5.51091E-01	-3.49101E-01
0.39	0.560	0.252	-0.105	-1.03945E-01	2.33298E-01	-8.76464E-02	-2.66182E+00
0.40	0.370	0.432	0.231	-1.32480E-02	2.79300E-01	1.93425E-01	1.44397E+00
0.41	0.230	0.638	0.525	6.02446E-02	3.30440E-01	4.39141E-01	7.52470E-01
0.42	0.160	0.796	0.720	1.43462E-01	3.86702E-01	6.02656E-01	6.41664E-01
0.43	0.120	0.921	0.865	2.12382E-01	4.48005E-01	7.24116E-01	6.18692E-01
0.44	0.040	1.398	1.380	2.77192E-01	5.14205E-01	1.15501E+00	4.45195E-01
0.45	0.080	1.097	1.061	3.36413E-01	5.85104E-01	8.87631E-01	6.59176E-01
0.46	0.070	1.155	1.123	3.91681E-01	6.60455E-01	9.40089E-01	7.02544E-01
0.47	0.070	1.155	1.123	4.43251E-01	7.39963E-01	9.40089E-01	7.87120E-01
0.48	0.080	1.097	1.061	4.92229E-01	8.23301E-01	8.87631E-01	9.27526E-01
0.49	0.080	1.097	1.061	5.37506E-01	9.10107E-01	8.87631E-01	1.02532E+00
0.50	0.060	1.222	1.195	5.80150E-01	1.00000E+00	1.00000E+00	1.00000E+00
0.51	0.040	1.398	1.380	6.20332E-01	1.09258E+00	1.15501E+00	9.45946E-01
0.52	0.020	1.699	1.690	6.57349E-01	1.18743E+00	1.41442E+00	8.39520E-01
0.53	0.020	1.699	1.690	6.93073E-01	1.28414E+00	1.41442E+00	9.07896E-01
0.54	0.010	2.000	1.995	7.26346E-01	1.38230E+00	1.67002E+00	8.27714E-01

TEMPERATURE = 3008 DEGREES KELVIN
EMISSIVITY = 0.40

STEP NUMBER = 2

WAVELENGTH MICRONS	TRANSMISSION	DENSITY	DELTA	LOG NET INTENSITY	Y1=INTENSITY NORM	Y2= DELTA NORM	R = Y1/Y2
0.36	0.999	0.000	-2.999	-8.12823E-01	1.25296E-01	-9.16293E+00	-1.36743E-02
0.37	0.980	0.009	-1.690	-6.64263E-01	1.56447E-01	-5.16313E+00	-3.03007E-02
0.38	0.940	0.027	-1.195	-5.73610E-01	1.92386E-01	-3.65036E+00	-5.27035E-02
0.39	0.830	0.081	-0.689	-4.72908E-01	2.33298E-01	-2.10359E+00	-1.10905E-01
0.40	0.690	0.161	-0.347	-3.82211E-01	2.79300E-01	-1.06149E+00	-2.63121E-01
0.41	0.550	0.260	-0.087	-3.00719E-01	3.30440E-01	-2.66222E-01	-1.24122E+00
0.42	0.450	0.347	0.087	-2.25501E-01	3.86702E-01	2.66222E-01	1.45255E+00
0.43	0.370	0.432	0.231	-1.56581E-01	4.48005E-01	7.06072E-01	6.34503E-01
0.44	.340	0.468	0.288	-9.17709E-02	5.14205E-01	8.79967E-01	5.84346E-01
0.45	0.300	0.523	0.368	-3.25505E-02	5.85104E-01	1.12408E+00	5.20520E-01
0.46	0.280	0.553	0.410	2.27179E-02	6.60455E-01	1.25298E+00	5.27107E-01
0.47	0.300	0.523	0.368	7.42877E-02	7.39963E-01	1.12408E+00	6.58285E-01
0.48	0.320	0.495	0.327	1.23266E-01	8.23301E-01	1.00000E+00	8.23301E-01
0.49	0.350	0.456	0.269	1.68543E-01	9.10107E-01	8.21255E-01	1.10819E+00
0.50	0.320	0.495	0.327	2.11187E-01	1.00000E+00	1.00000E+00	1.00000E+00
0.51	0.230	0.638	0.525	2.51369E-01	1.09258E+00	1.60302E+00	6.81575E-01
0.52	0.180	0.745	0.658	2.88385E-01	1.18743E+00	2.01168E+00	5.90269E-01
0.53	150	0.824	0.753	3.24110E-01	1.28414E+00	2.30123E+00	5.58025E-01
0.54	00	1.000	0.954	3.57383E-01	1.38230E+00	2.91497E+00	4.74207E-01
0.56	0.070	1.155	1.123	3.88332E-01	1.48149E+00	3.43166E+00	4.31711E-01
0.56	0.040	1.393	1.380	4.17928E-01	1.58130E+00	4.21620E+00	3.75054E-01
0.57	0.030	1.523	1.509	4.45423E-01	1.68136E+00	4.61161E+00	3.64593E-01
0.58	0.040	1.398	1.380	4.70918E-01	1.78128E+00	4.21620E+00	4.22485E-01
0.59	0.040	1.398	1.380	4.95355E-01	1.88071E+00	4.21620E+00	4.46068E-01
0.60	0.040	1.398	1.380	5.17970E-01	1.97931E+00	4.21620E+00	4.69454E-01
0.61	0.050	1.301	1.279	5.39265E-01	2.07677E+00	3.90627E+00	5.31650E-01
0.62	0.070	1.155	1.123	5.59316E-01	2.17279E+00	3.43166E+00	6.33160E-01
0.63	0.090	1.046	1.005	5.78190E-01	2.26710E+00	3.06941E+00	7.38612E-01
0.64	0.110	0.959	0.908	5.95952E-01	2.35946E+00	2.77371E+00	8.50651E-01
0.65	0.090	1.046	1.005	6.12662E-01	2.44963E+00	3.06941E+00	7.98079E-01
0.66	0.070	1.155	1.123	6.28374E-01	2.53743E+00	3.43166E+00	7.39416E-01
0.67	0.040	1.398	1.380	6.43143E-01	2.62266E+00	4.21620E+00	6.22043E-01
0.68	0.030	1.523	1.509	6.57016E-01	2.70518E+00	4.61161E+00	5.86602E-01
0.69	0.030	1.523	1.509	6.70041E-01	2.78484E+00	4.61161E+00	6.03877E-01

TEMPERATURE = 3008 DEGREES KELVIN
EMISSIVITY = 0.40

STEP NUMBER = 3

WAVELENGTH MICRONS	TRANSMISSION	DENSITY	DELTA	LOG NET INTENSITY	Y1=INTENSITY NORM	Y2= DELTA NORM	R = Y1/Y2
0.40	0.890	0.051	-0.908	-7.32567E-01	2.79300E-01	2.77371E+00	1.00696E-01
0.41	0.820	0.086	-0.658	-6.51074E-01	3.30440E-01	2.01168E+00	1.64261E-01
0.42	0.760	0.119	-0.501	-5.75857E-01	3.86702E-01	1.52922E+00	2.52876E-01
0.43	0.710	0.149	-0.389	-5.06937E-01	4.48005E-01	1.18787E+00	3.77149E-01
0.44	0.670	0.174	-0.308	-4.42127E-01	5.14205E-01	9.39522E-01	5.47305E-01
0.45	0.620	0.208	-0.213	-3.82906E-01	5.85104E-01	6.49465E-01	9.00902E-01
0.46	0.590	0.229	-0.158	-3.27638E-01	6.60455E-01	4.82859E-01	1.36780E+00
0.47	0.620	0.208	-0.213	-2.76068E-01	7.39963E-01	6.49465E-01	1.13934E+00
0.48	0.660	0.180	-0.288	-2.27090E-01	8.23301E-01	8.79967E-01	9.35604E-01
0.49	0.690	0.161	-0.347	-1.81813E-01	9.10107E-01	1.06149E+00	8.57389E-01
0.50	0.680	0.167	-0.327	-1.39169E-01	1.00000E+00	1.00000E+00	1.00000E+00
0.51	0.590	0.229	-0.158	-9.89869E-02	1.09258E+00	4.82859E-01	2.26273E+00
0.52	0.510	0.292	-0.017	-6.19704E-02	1.18743E+00	5.30735E-02	2.23733E+01
0.53	0.450	0.347	0.087	-2.62456E-02	1.28414E+00	-2.66222E-01	-4.82358E+00
0.54	0.320	0.495	0.327	7.02739E-03	1.38230E+00	-1.00000E+00	-1.38230E+00
0.55	0.270	0.569	0.432	3.79764E-02	1.48149E+00	-1.31953E+00	-1.12274E+00
0.56	0.200	0.699	0.602	6.75726E-02	1.58130E+00	-1.83914E+00	-8.59804E-01
0.57	0.150	0.824	0.753	9.50676E-02	1.68136E+00	-2.30123E+00	-7.30636E-01
0.58	0.200	0.699	0.602	1.20553E-01	1.78128E+00	-1.83914E+00	-9.68539E-01
0.59	0.220	0.658	0.550	1.45000E-01	1.88071E+00	-1.67911E+00	-1.12006E+00
0.60	0.200	0.699	0.602	1.67614E-01	1.97931E+00	-1.83914E+00	-1.07621E+00
0.61	0.240	0.620	0.501	1.88910E-01	2.07677E+00	-1.52922E+00	-1.35806E+00
0.62	0.330	0.481	0.308	2.08960E-01	2.17279E+00	-9.39522E-01	-2.31266E+00
0.63	0.390	0.409	0.194	2.27835E-01	2.26710E+00	-5.93432E-01	-3.82032E+00
0.64	0.400	0.398	0.176	2.45597E-01	2.35946E+00	-5.37915E-01	-4.38630E+00
0.65	0.390	0.409	0.194	2.62306E-01	2.44963E+00	-5.93432E-01	-4.12791E+00
0.66	0.330	0.481	0.308	2.78019E-01	2.53743E+00	-9.39522E-01	-2.70076E+00
0.67	0.240	0.620	0.501	2.92787E-01	2.62266E+00	-1.52922E+00	-1.71504E+00
0.68	0.180	0.745	0.658	3.06661E-01	2.70518E+00	-2.01168E+00	-1.34474E+00
0.69	0.210	0.678	0.575	3.19685E-01	2.78484E+00	-1.75773E+00	-1.58434E+00
0.70	0.660	0.180	-0.288	3.31903E-01	2.86154E+00	8.79967E-01	3.25188E+00

TEMPERATURE = 3008 DEGREES KELVIN
EMISSIVITY = 0.40

STEP NUMBER = 4

WAVELENGTH MICRONS	TRANSMISSION	DENSITY	DELTA	LOG NET INTENSITY	Y1=INTENSITY NORM	Y2= DELTA NORM	R = Y1/Y2
0.39	0.999	0.000	-2.999	-1.15768E+00	2.33298E-01	2.82792E+00	8.24983E-02
0.40	0.980	0.009	-1.690	-1.06699E+00	2.79300E-01	1.59348E+00	1.75277E-01
0.41	0.970	0.013	-1.509	-9.85494E-01	3.30440E-01	1.42326E+00	2.32171E-01
0.42	0.940	0.027	-1.195	-9.10276E-01	3.86702E-01	1.12659E+00	3.43249E-01
0.43	0.920	0.036	-1.061	-8.41357E-01	4.48005E-01	1.00000E+00	4.48005E-01
0.44	0.900	0.045	-0.954	-7.76546E-01	5.14205E-01	8.99637E-01	5.71570E-01
0.45	0.870	0.060	-0.825	-7.17326E-01	5.85104E-01	7.78333E-01	7.51741E-01
0.46	0.850	0.071	-0.753	-6.62057E-01	6.60455E-01	7.10219E-01	9.29931E-01
0.47	0.870	0.060	-0.825	-6.10488E-01	7.39963E-01	7.78333E-01	9.50703E-01
0.48	0.900	0.046	-0.954	-5.61509E-01	8.23301E-01	8.99637E-01	9.15148E-01
0.49	0.920	0.036	-1.061	-5.16232E-01	9.10107E-01	1.00000E+00	9.10107E-01
0.50	0.920	0.036	-1.061	-4.73589E-01	1.00000E+00	1.00000E+00	1.00000E+00
0.51	0.890	0.051	-0.908	-4.33406E-01	1.09258E+00	8.56038E-01	1.27632E+00
0.52	0.860	0.065	-0.788	-3.96390E-01	1.18743E+00	7.43256E-01	1.59761E+00
0.53	0.820	0.086	-0.658	-3.60665E-01	1.28414E+00	6.20857E-01	2.06834E+00
0.54	0.760	0.119	-0.501	-3.27392E-01	1.38230E+00	4.71956E-01	2.92888E+00
0.55	0.650	0.187	-0.269	-2.96443E-01	1.48149E+00	2.53461E-01	5.84503E+00
0.56	0.540	0.268	-0.070	-2.66847E-01	1.58130E+00	6.56511E-02	2.40865E+01
0.57	0.440	0.357	0.105	-2.39352E-01	1.68136E+00	-9.87419E-02	-1.70278E+01
0.58	0.540	0.268	-0.070	-2.13357E-01	1.78128E+00	6.56511E-02	2.71326E+01
0.59	0.590	0.229	-0.158	-1.89420E-01	1.88071E+00	1.49023E-01	1.26203E+01
0.60	0.580	0.237	-0.140	-1.66806E-01	1.97931E+00	1.32157E-01	1.49770E+01
0.61	0.620	0.208	-0.213	-1.45510E-01	2.07677E+00	2.00442E-01	1.03610E+01
0.62	0.740	0.131	-0.454	-1.25459E-01	2.17279E+00	4.28264E-01	5.07349E+00
0.63	0.810	0.092	-0.630	-1.06585E-01	2.26710E+00	5.93695E-01	3.81863E+00
0.64	0.830	0.081	-0.689	-8.88229E-02	2.35946E+00	6.49223E-01	3.63428E+00
0.65	0.830	0.081	-0.689	-7.21136E-02	2.44963E+00	6.49223E-01	3.77318E+00
0.66	0.770	0.113	-0.525	-5.64009E-02	2.53743E+00	4.94734E-01	5.12887E+00
0.67	0.700	0.155	-0.368	-4.16324E-02	2.62266E+00	3.46920E-01	7.55985E+00
0.68	0.620	0.208	-0.213	-2.77590E-02	2.70518E+00	2.00442E-01	1.34961E+01
0.69	0.680	0.167	-0.327	-1.47346E-02	2.78484E+00	3.08626E-01	9.02336E+00
0.70	0.990	0.009	-1.690	-2.51611E-03	2.86154E+00	1.59348E+00	1.79579E+00

TEMPERATURE = 2603 DEGREES KELVIN
EMISSIVITY = 0.40

Plate 60

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
WAVELENGTH = 0.360			
WAVELENGTH = 0.370			
WAVELENGTH = 0.380	0	-1.9954	-0.5877
WAVELENGTH = 0.390	0	-1.2786	-0.4652
WAVELENGTH = 0.400	0	-0.9541	-0.3538
	1	-1.9954	-0.8210
WAVELENGTH = 0.410	0	-0.4319	-0.2526
	1	-1.2786	-0.7198
WAVELENGTH = 0.420	0	-0.1224	-0.1586
	1	-1.0047	-0.6259
WAVELENGTH = 0.430	0	0.0871	-0.0718
	1	-0.7883	-0.5390
	2	-1.9954	-0.9080
WAVELENGTH = 0.440	0	0.2499	0.0101
	1	-0.6585	-0.4572

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	-1.9954	-0.8261
WAVELENGTH = 0.450	0	0.3888	0.0856
	1	-0.5006	-0.3616
	2	-1.3801	-0.7506
WAVELENGTH = 0.460	0	0.4542	0.1565
	1	-0.4542	-0.3107
	2	-1.2786	-0.6797
WAVELENGTH = 0.470	0	0.5247	0.2230
	1	-0.4542	-0.2442
	2	-1.1233	-0.6132
WAVELENGTH = 0.480	0	0.5006	0.2863
	1	-0.5006	-0.1809
	2	-1.1949	-0.5499
WAVELENGTH = 0.490	0	0.5006	0.3453
	1	-0.5006	-0.1219
	2	-1.1949	-0.4909
WAVELENGTH = 0.500	0	0.6297	0.4011
	1	-0.4319	-0.0661
	2	-1.0606	-0.4351
WAVELENGTH = 0.510	0	0.8652	0.4540
	1	-0.2880	-0.0132
	2	-1.1233	-0.3822
WAVELENGTH = 0.520	0	1.0606	0.5032

	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	-0.0696	0.0359
	2	-0.9541	-0.3330

WAVELENGTH = 0.530	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.1949	0.5506
	1	0.0522	0.0834
	2	-0.7883	-0.2856

WAVELENGTH = 0.540	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.3801	0.5952
	1	0.2311	0.1279
	2	-0.6020	-0.2410

WAVELENGTH = 0.550	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.6900	0.6370
	1	0.4542	0.1698
	2	-0.3679	-0.1992

WAVELENGTH = 0.560	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.9954	0.6771
	1	0.6585	0.2098
	2	-0.1224	-0.1591

WAVELENGTH = 0.570	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	0.8255	0.2475
	2	0.0871	-0.1215

WAVELENGTH = 0.580	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	0.7201	0.2827
	2	-0.0871	-0.0863

WAVELENGTH = 0.590	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	0.6885	0.3166
	2	-0.1402	-0.0524

WAVELENGTH = 0.600	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	0.7883	0.3483
	2	-0.0348	-0.0207

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.610	1	0.7201	0.3784
	2	-0.1402	0.0095

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.620	1	0.5247	0.4070
	2	-0.3475	0.0380

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.630	1	0.4319	0.4341
	2	-0.4542	0.0652

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.640	1	0.4319	0.4599
	2	-0.4542	0.0909

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.650	1	0.4542	0.4843
	2	-0.4542	0.1154

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.660	1	0.6297	0.5076
	2	-0.3273	0.1386

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.670	1	0.8255	0.5296
	2	-0.1581	0.1607

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.680	1	1.0606	0.5506
	2	0.0522	0.1816

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.690	1	1.0047	0.5704
	2	-0.0174	0.2015

TEMPERATURE = 3008 DEGREES KELVIN Plate [illegible]
EMISSIVITY = 0.40

WAVELENGTH = 0.360	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	-2.9993	-0.4439
	2	-2.9993	-0.8128

WAVELENGTH = 0.370	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	-1.3801	0.1519
	1	-1.6900	-0.3153
	2	-1.6900	-0.6843

WAVELENGTH = 0.380	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	-0.1224	0.2626
	1	-0.6585	-0.2046
	2	-1.1949	-0.5736

WAVELENGTH = 0.390	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	0.5496	0.3633
	1	-0.1047	-0.1039
	2	-0.6886	-0.4729
	3	-2.9993	-1.1577

WAVELENGTH = 0.400	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.0047	0.4540
	1	0.2311	-0.0132
	2	-0.3475	-0.3822
	3	-0.9079	-0.7326
	4	-1.6900	-1.0670

WAVELENGTH = 0.410	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	0	1.3801	0.5355
	1	0.5247	0.0682
	2	-0.0871	-0.3007
	3	-0.6585	-0.6511
	4	-1.5095	-0.9855

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0	1.9954	[illegible]
1	1.0606	0.4522
2	0.3273	[illegible]
3	-0.2880	-0.2271
4	-0.9541	-0.5015

WAVELENGTH = 0.490

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0	1.9954	1.0047
1	1.0606	0.5375
2	0.2688	0.1685
3	-0.3475	-0.1818
4	-1.0606	-0.5162

WAVELENGTH = 0.500

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0	1.9954	1.0474
1	1.1949	0.5801
2	0.3273	0.2112
3	-0.3273	-0.1392
4	-1.0606	-0.4736

WAVELENGTH = 0.510

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
1	1.3801	0.6203
2	0.5247	0.2514
3	-0.1581	-0.0990
4	-0.9079	-0.4334

WAVELENGTH = 0.520

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
1	1.6900	0.6573
2	0.6585	0.2884
3	-0.0174	-0.0620
4	-0.7883	-0.3964

WAVELENGTH = 0.530

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
1	1.6900	0.6931
2	0.7533	0.3241
3	0.0871	-0.0262
4	-0.6585	-0.3607

WAVELENGTH = 0.540

STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
1	1.9954	0.7263
2	0.9541	0.3574
3	0.3273	0.0070
4	-0.5006	-0.3274

WAVELENGTH	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
0.550	2	1.1253	0.3883
	3	0.4319	0.0380
	4	-0.2688	-0.2984
0.560	2	1.3801	0.4179
	3	0.6020	0.0676
	4	-0.0696	-0.2868
0.570	2	1.5095	0.4454
	3	0.7533	0.0951
	4	0.1047	-0.2394
0.580	2	1.3801	0.4709
	3	0.6020	0.1206
	4	-0.0696	-0.2139
0.590	2	1.3801	0.4954
	3	0.5496	0.1450
	4	-0.1581	-0.1894
0.600	2	1.3801	0.5180
	3	0.6020	0.1676
	4	-0.1402	-0.1668
0.610	2	1.2785	0.5393
	3	0.5006	0.1889
	4	-0.2126	-0.1455
0.620	2	1.1231	0.5593
	3	0.3075	0.2090

	[illegible]	-0.[illegible]	-0.[illegible]

WAVELENGTH = 0.[illegible]0	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.004[illegible]	0.[illegible]
	3	0.[illegible]	0.[illegible]
	4	-0.[illegible]	-0.[illegible]

WAVELENGTH = 0.640	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	0.9079	0.5960
	3	0.1761	0.2450
	4	-0.6466	-0.0868

WAVELENGTH = 0.650	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.0047	0.4187
	3	0.1992	0.2823
	4	-0.6084	-0.0721

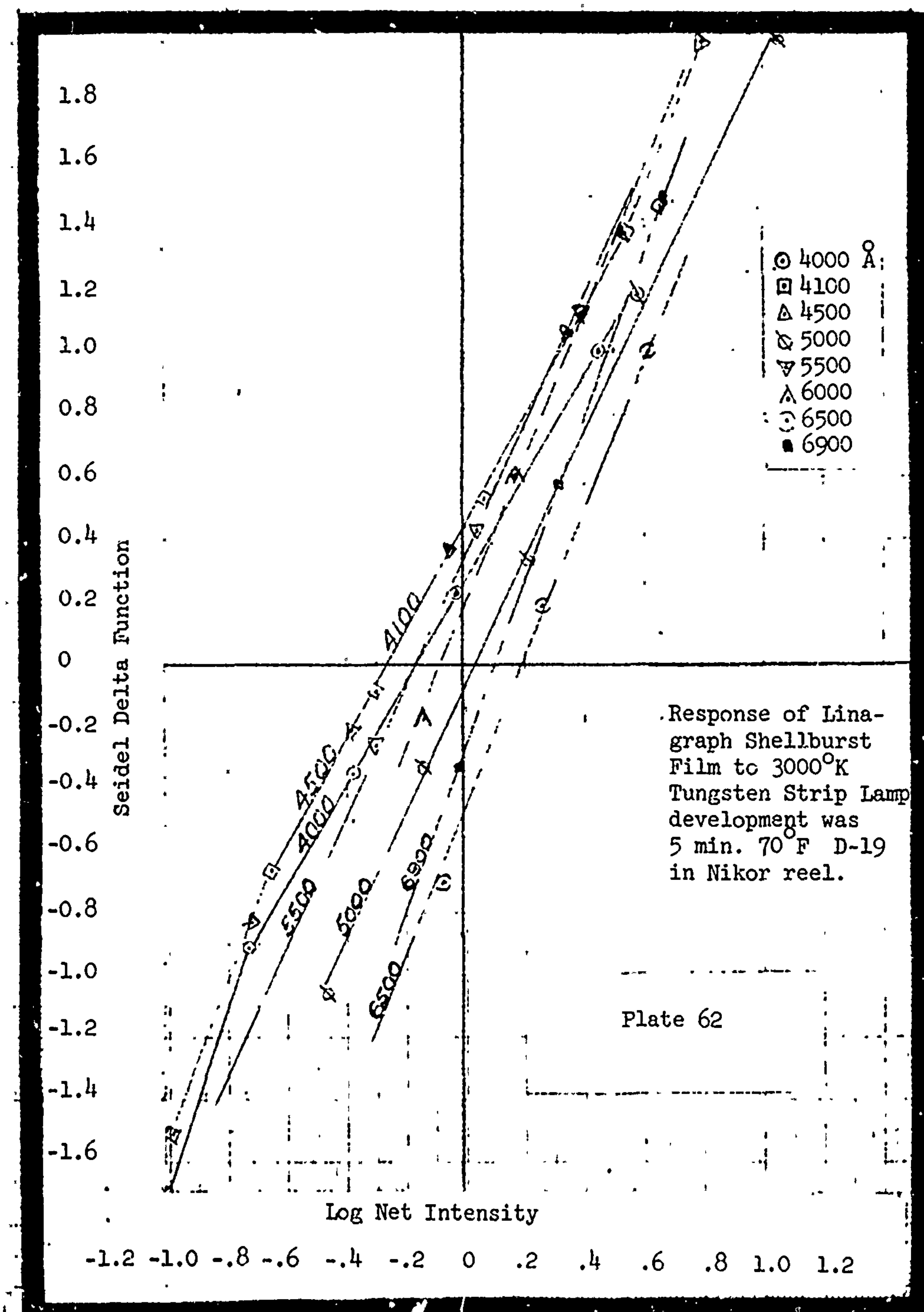
WAVELENGTH = 0.660	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.1231	0.[illegible]234
	3	0.3075	0.2780
	4	-0.5247	-0.0564

WAVELENGTH = 0.670	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.3891	0.6831
	3	0.5006	0.2928
	4	-0.3679	-0.0818

WAVELENGTH = 0.680	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.5095	0.6570
	3	0.6585	0.3067
	4	-0.2126	-0.0278

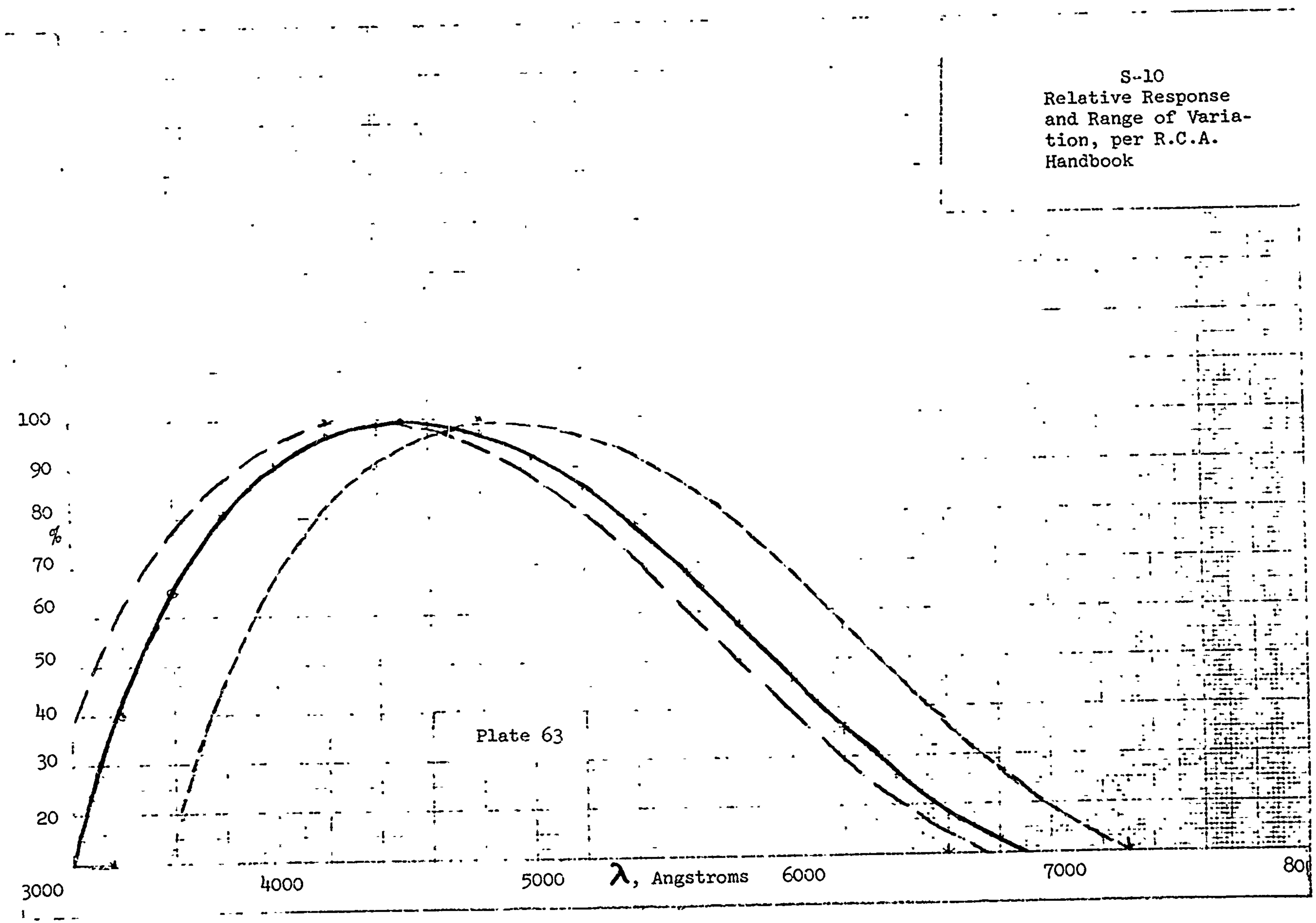
WAVELENGTH = 0.690	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	2	1.5095	0.6700
	3	0.5753	0.3197
	4	-0.3273	-0.0187

WAVELENGTH = 0.700	STEP NO.	DELTA FUNCTION	LOG NET INTENSITY
	1	-0.2880	0.1319



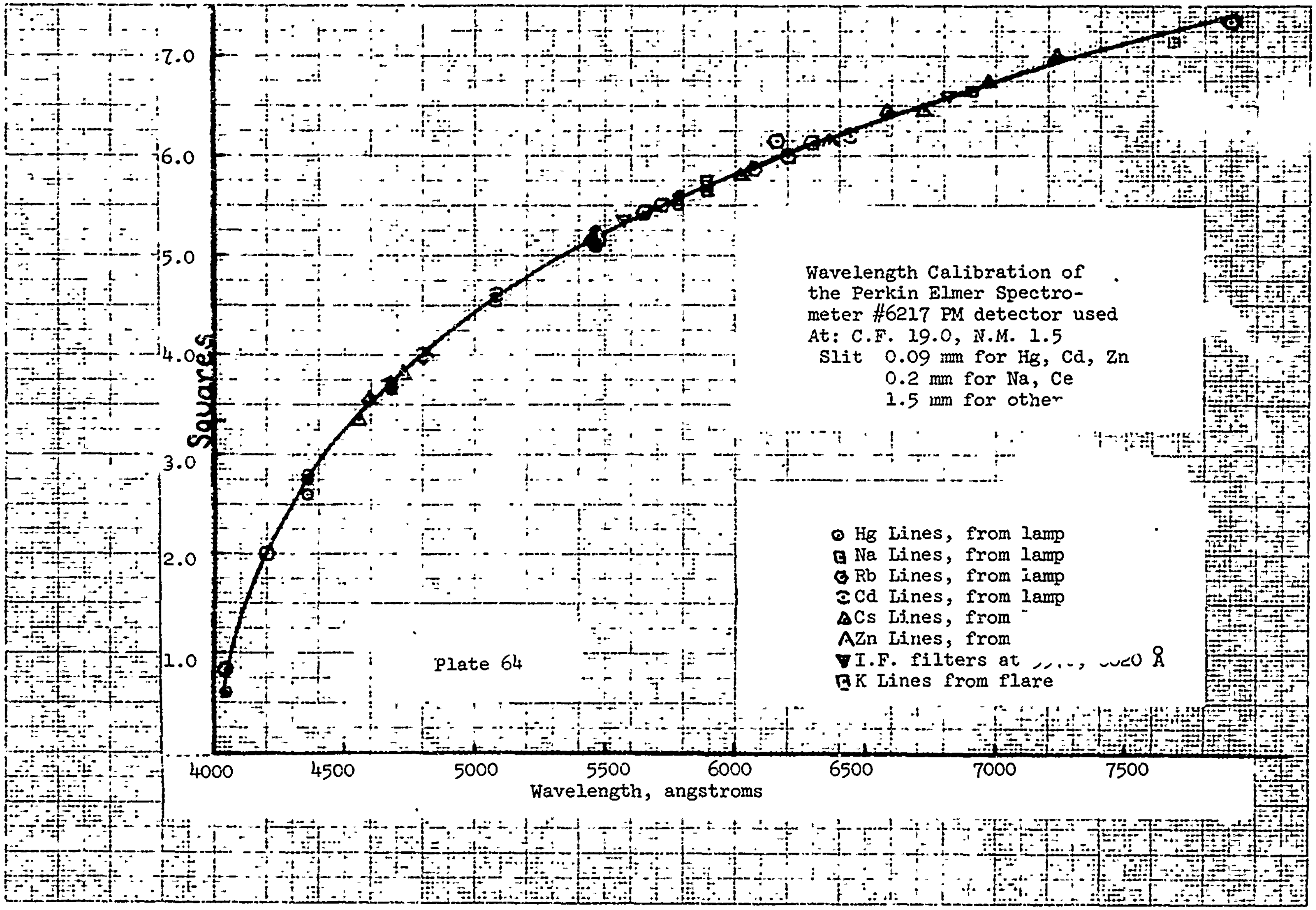
Response of Linagraph Shellburst Film to 3000°K Tungsten Strip Lamp development was 5 min. 70°F D-19 in Nikor reel.

Plate 62



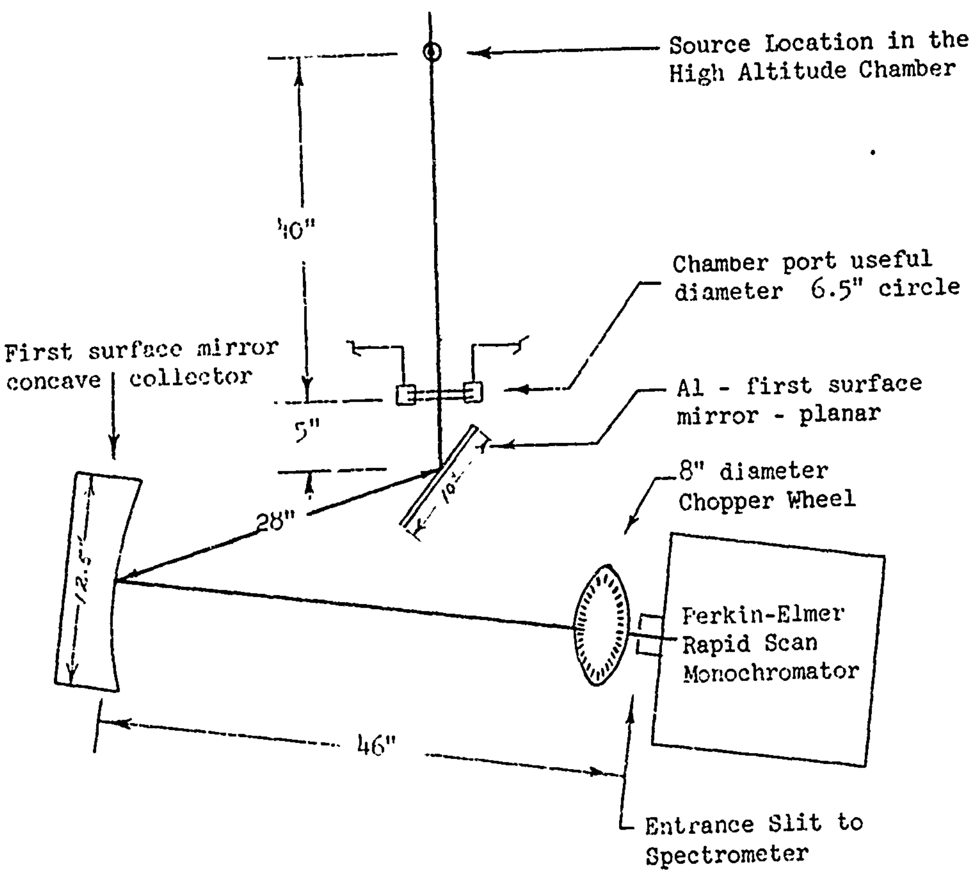
S-10
Relative Response and Range of Variation, per R.C.A. Handbook
100
90
80
%
70
60
50
40
30
20
3000
4000
5000
λ, Angstroms
6000
7000
80

Plate 63



Wavelength Calibration of the Perkin Elmer Spectrometer #6217 PM detector used
At: C.F. 19.0, N.M. 1.5
Slit 0.09 mm for Hg, Cd, Zn
0.2 mm for Na, Ce
1.5 mm for other
Hg Lines, from lamp
Na Lines, from lamp
Rb Lines, from lamp
Cd Lines, from lamp
Cs Lines, from
Zn Lines, from
I.F. filters at
K Lines from flare
Plate 64
Squares
7.0
6.0
5.0
4.0
3.0
2.0
1.0
4000
4500
5000
5500
6000
6500
7000
7500
Wavelength, angstroms

Fore Optics used with Perkin Elmer 108 Spectrometer



Plan View

Plate 65

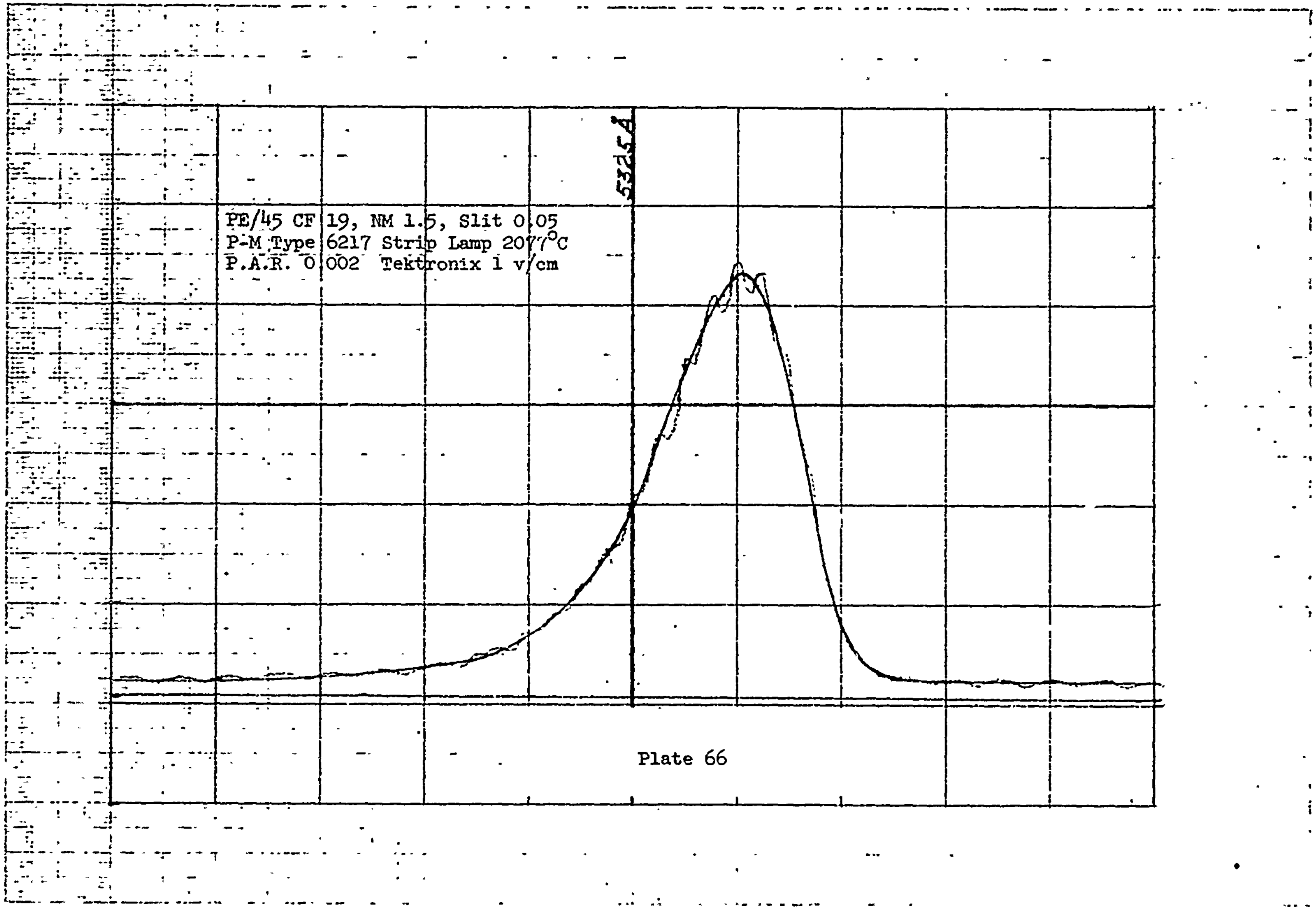

5325 Å
PE/45 CF 19, NM 1.5, Slit 0.05
P-M Type 6217 Strip Lamp 2077°C
P.A.R. 0.002 Tektronix 1 v/cm

Plate 66

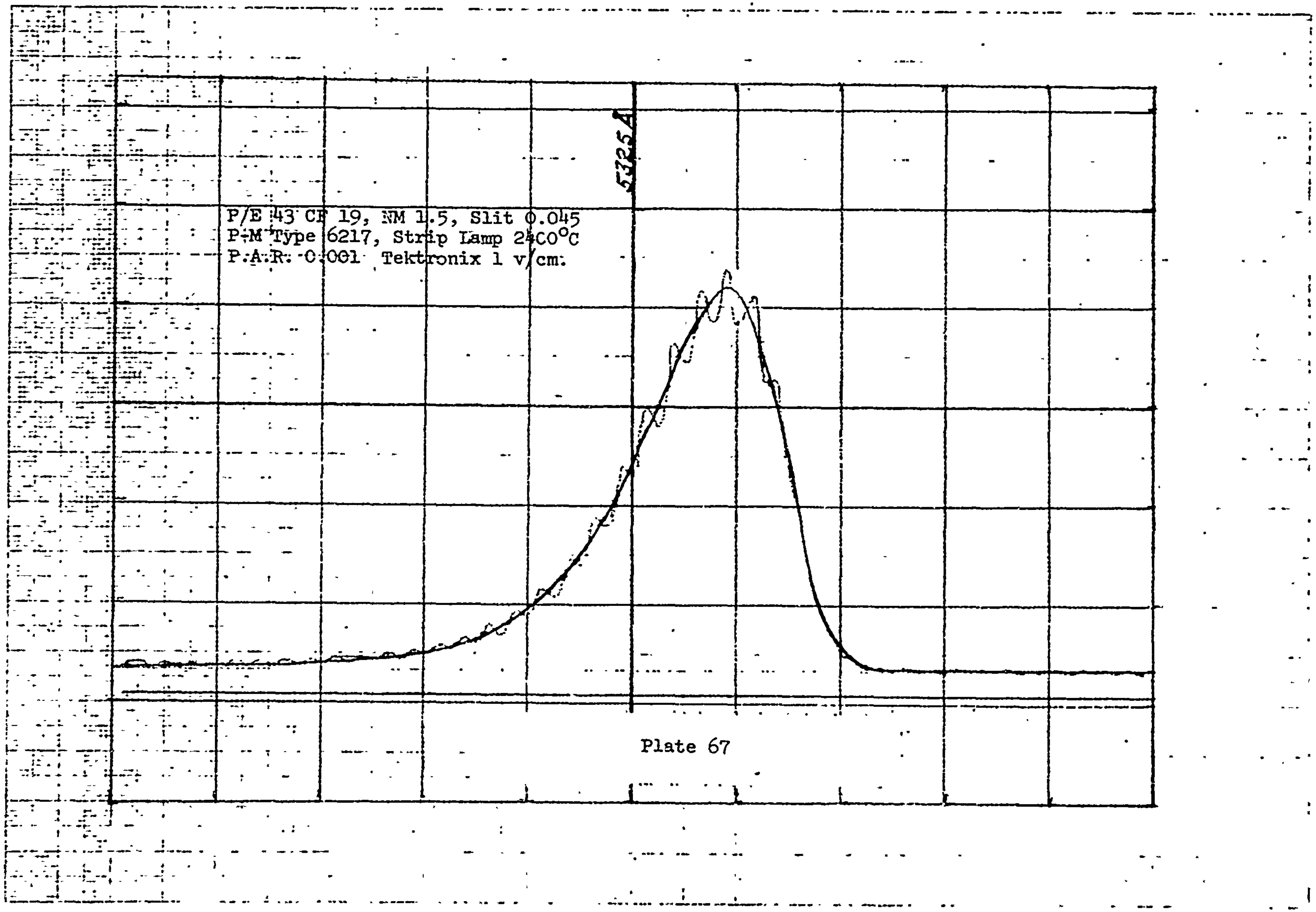
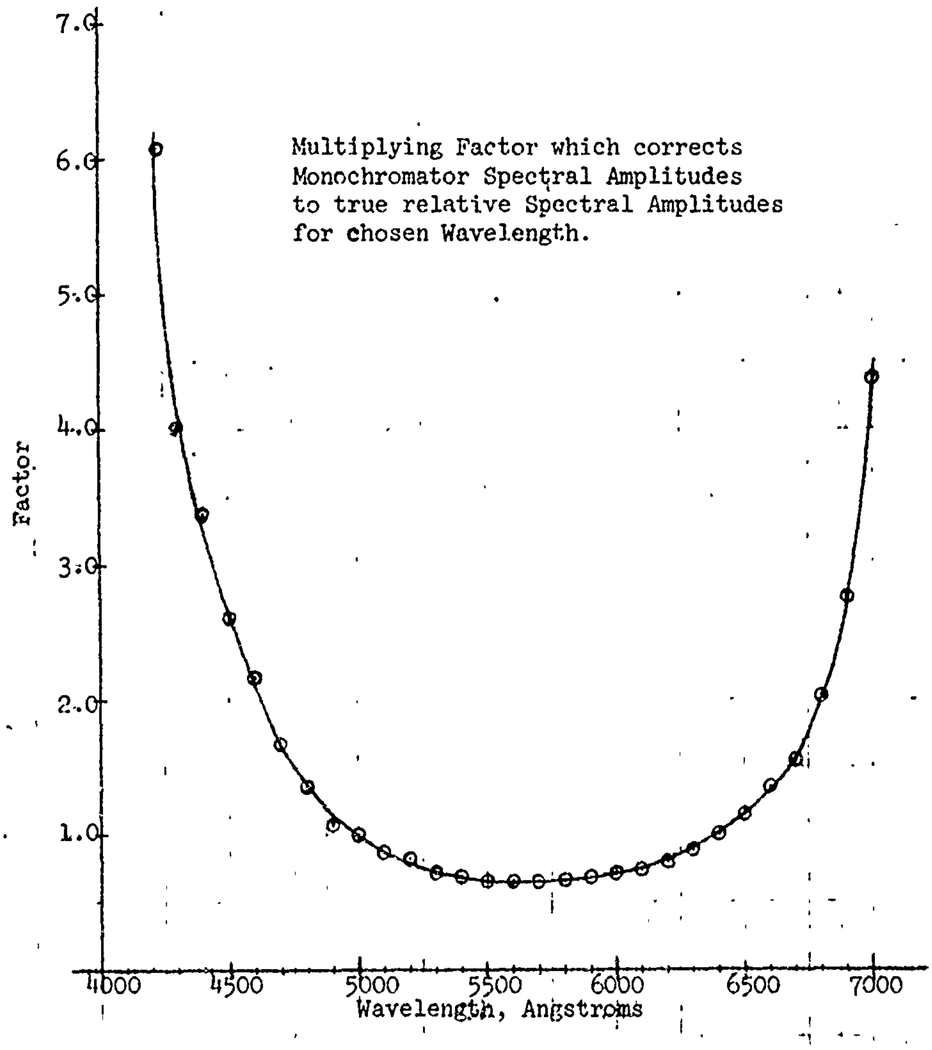

5325 A
P/E 43 CF 19, NM 1.5, Slit 0.045
P-M Type 6217, Strip Lamp 2400°C
P.A.R. 0.001 Tektronix 1 v/cm.

Plate 67



Multiplying Factor which corrects
Monochromator Spectral Amplitudes
to true relative Spectral Amplitudes
for chosen Wavelength.
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Factor
4000
4500
5000
5500
6000
6500
7000
Wavelength, Angstroms

Plate 68

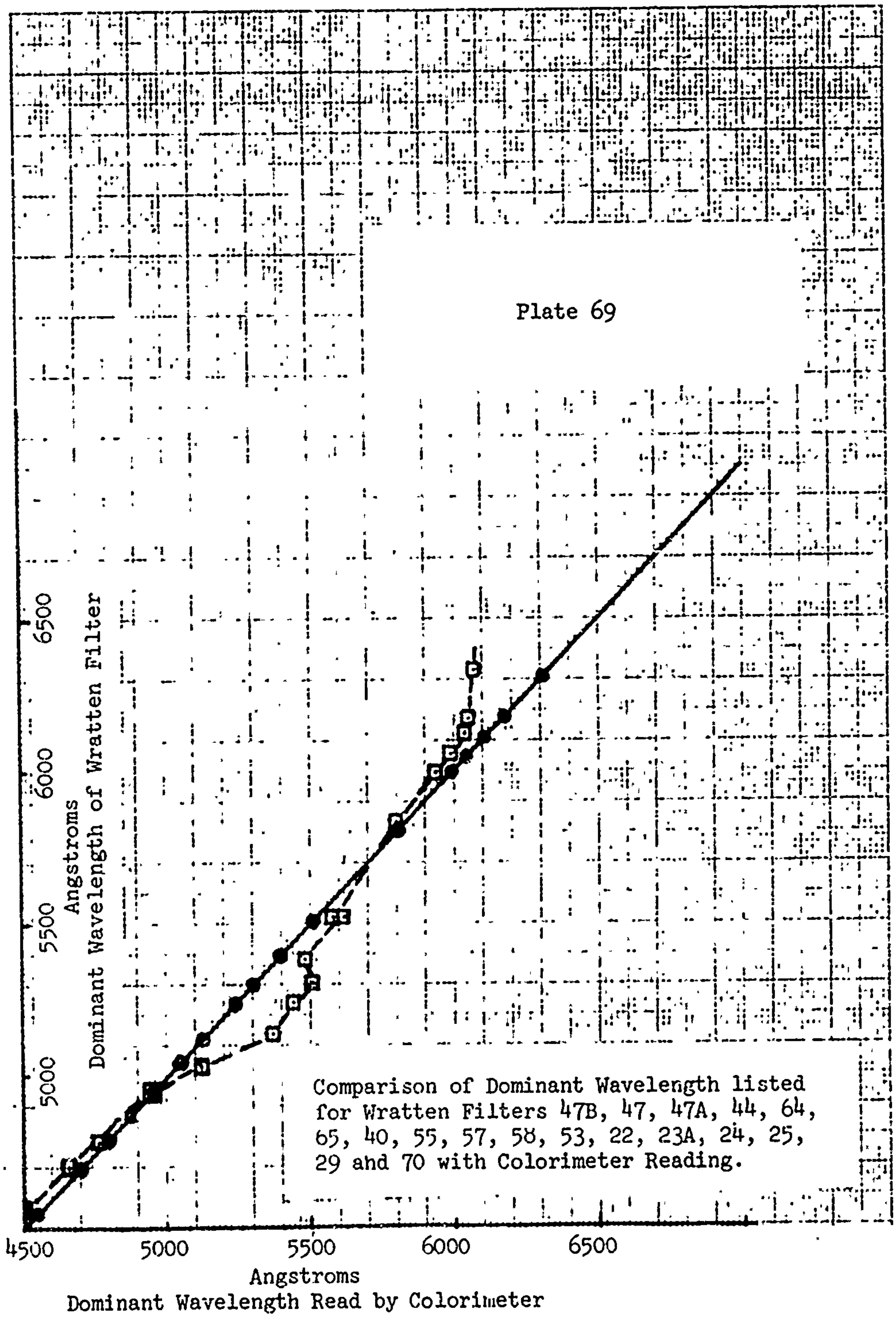
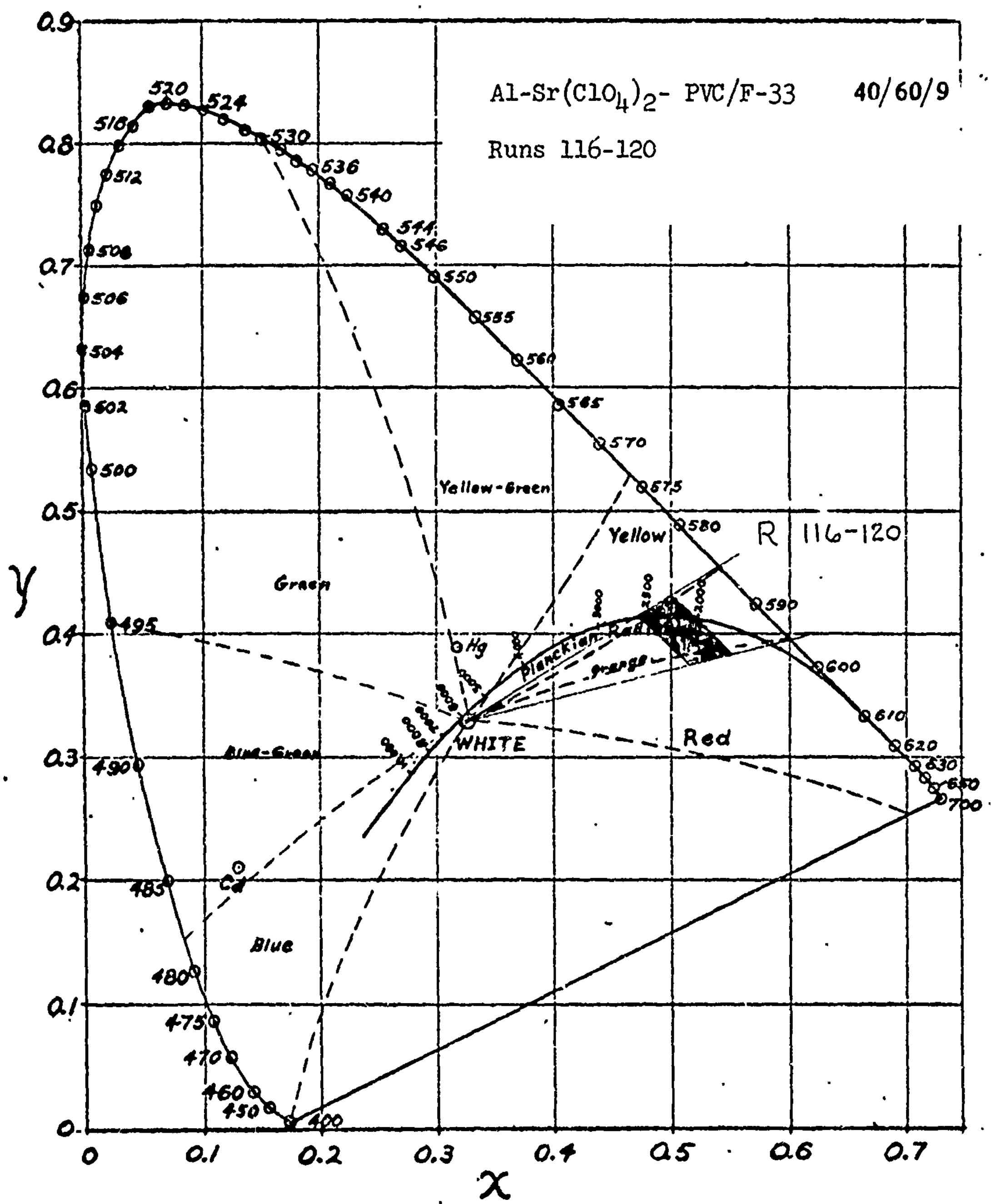


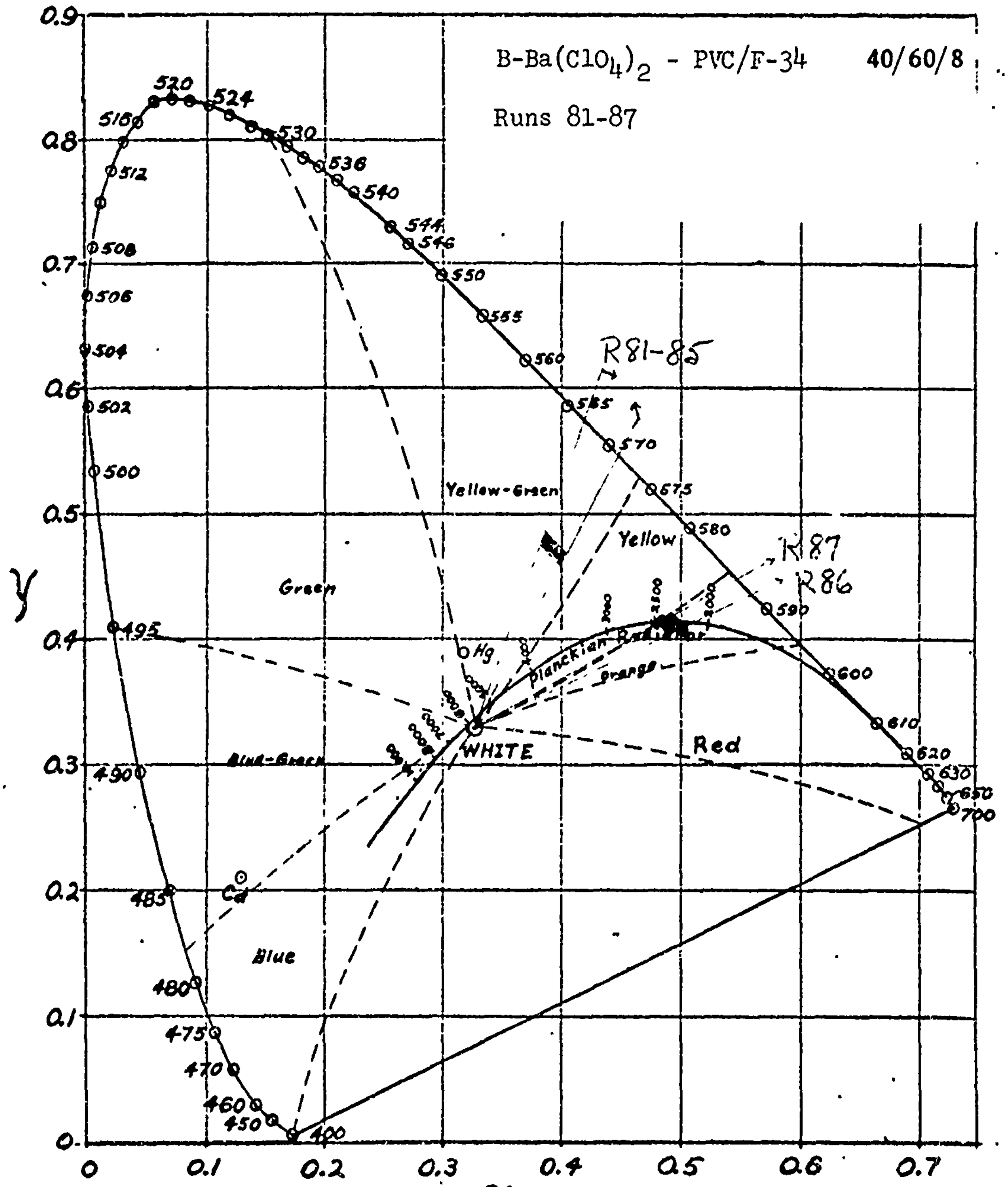
Plate 69
Comparison of Dominant Wavelength listed for Wratten Filters 47B, 47, 47A, 44, 64, 65, 40, 55, 57, 58, 53, 22, 23A, 24, 25, 29 and 70 with Colorimeter Reading.
5000
5500
6000
6500
Angstroms
Dominant Wavelength of Wratten Filter
4500
5000
5500
6000
6500
Angstroms
Dominant Wavelength Read by Colorimeter

Plate 70



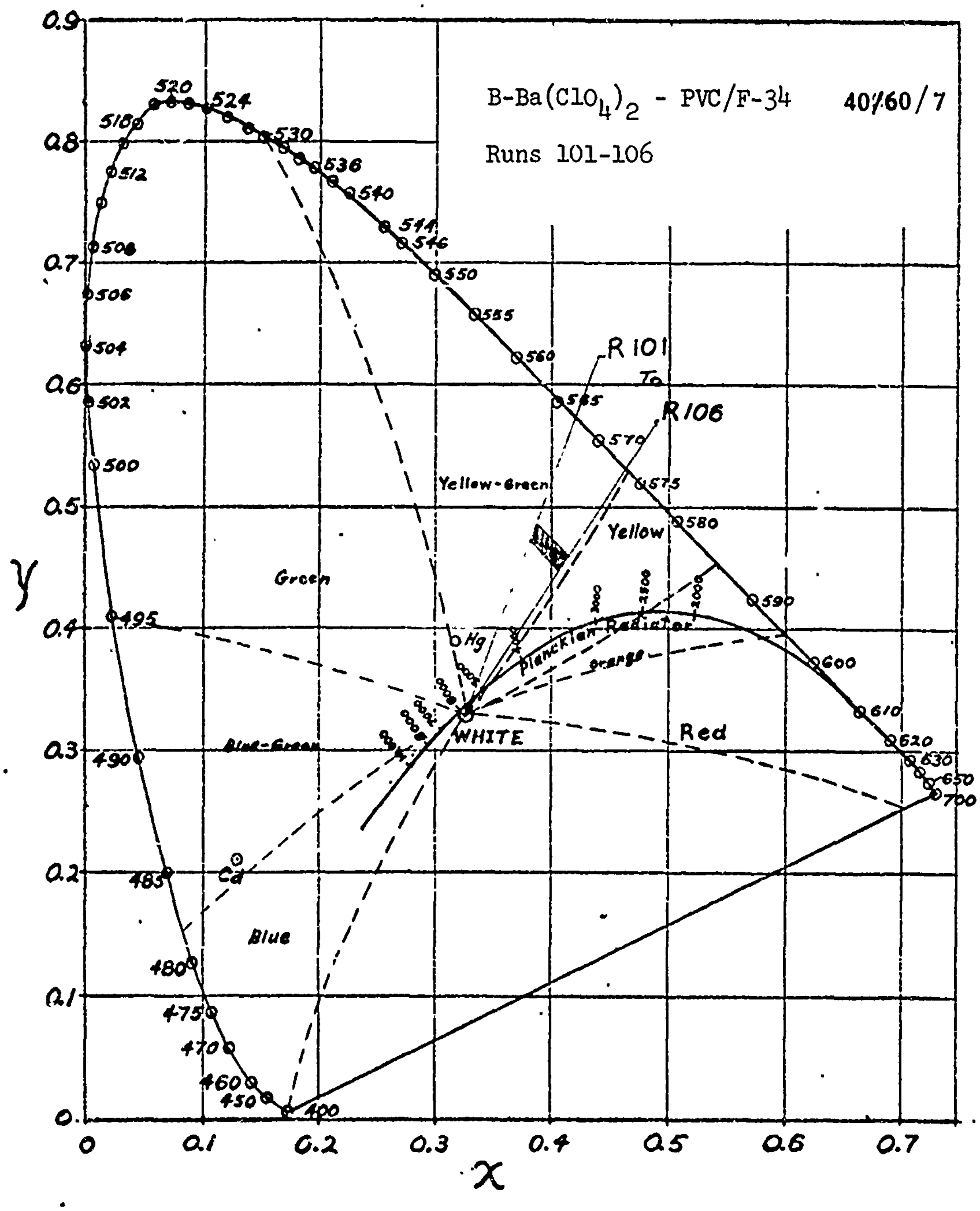
Al-Sr(ClO4)2- PVC/F-33 40/60/9
Runs 116-120
R 116-120
Yellow-Green
Yellow
Green
Blue-Green
Blue
WHITE
Red
Hg
Cd
y
x
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
520
524
530
536
540
544
546
550
555
560
565
570
575
580
590
600
610
620
630
650
700
518
512
508
506
504
502
500
495
490
485
480
475
470
460
450
400

Plate 71



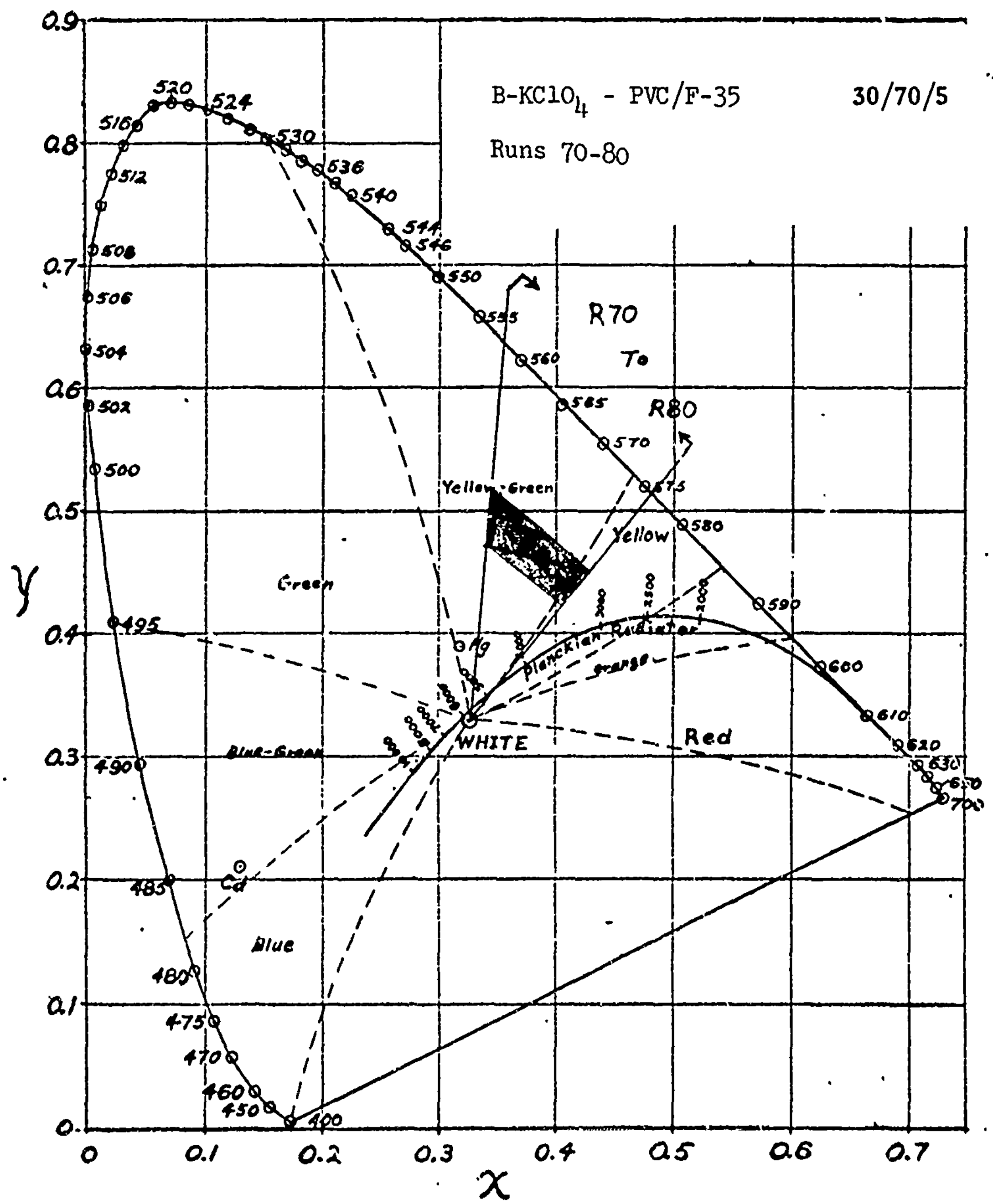
B-Ba(ClO4)2 - PVC/F-34 40/60/8
Runs 81-87
R81-85
R87
R86
Yellow-Green
Yellow
Green
Blue-Green
Blue
Red
Orange
WHITE
Planckian Radiator
Hg
Cd
y
x

Plate 72



B-Ba(ClO4)2 - PVC/F-34
40/60/7
Runs 101-106
R 101
To
R 106
Yellow-Green
Yellow
Green
Blue-Green
Blue
Red
WHITE
Hg
Cd
Planckian Radiator
Orange
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
y
x
520
524
530
536
540
544
546
550
555
560
565
570
575
580
590
600
610
620
630
650
700
518
512
508
506
504
502
500
495
490
485
480
475
470
460
450
400

Plate 73



B-KClO$_4$ - PVC/F-35
30/70/5
Runs 70-80
R70
To
R80
Yellow-Green
Yellow
Green
Blue-Green
Blue
WHITE
Red
Planckian Radiator
Orange
Cd
Hg
y
x

Plate 74

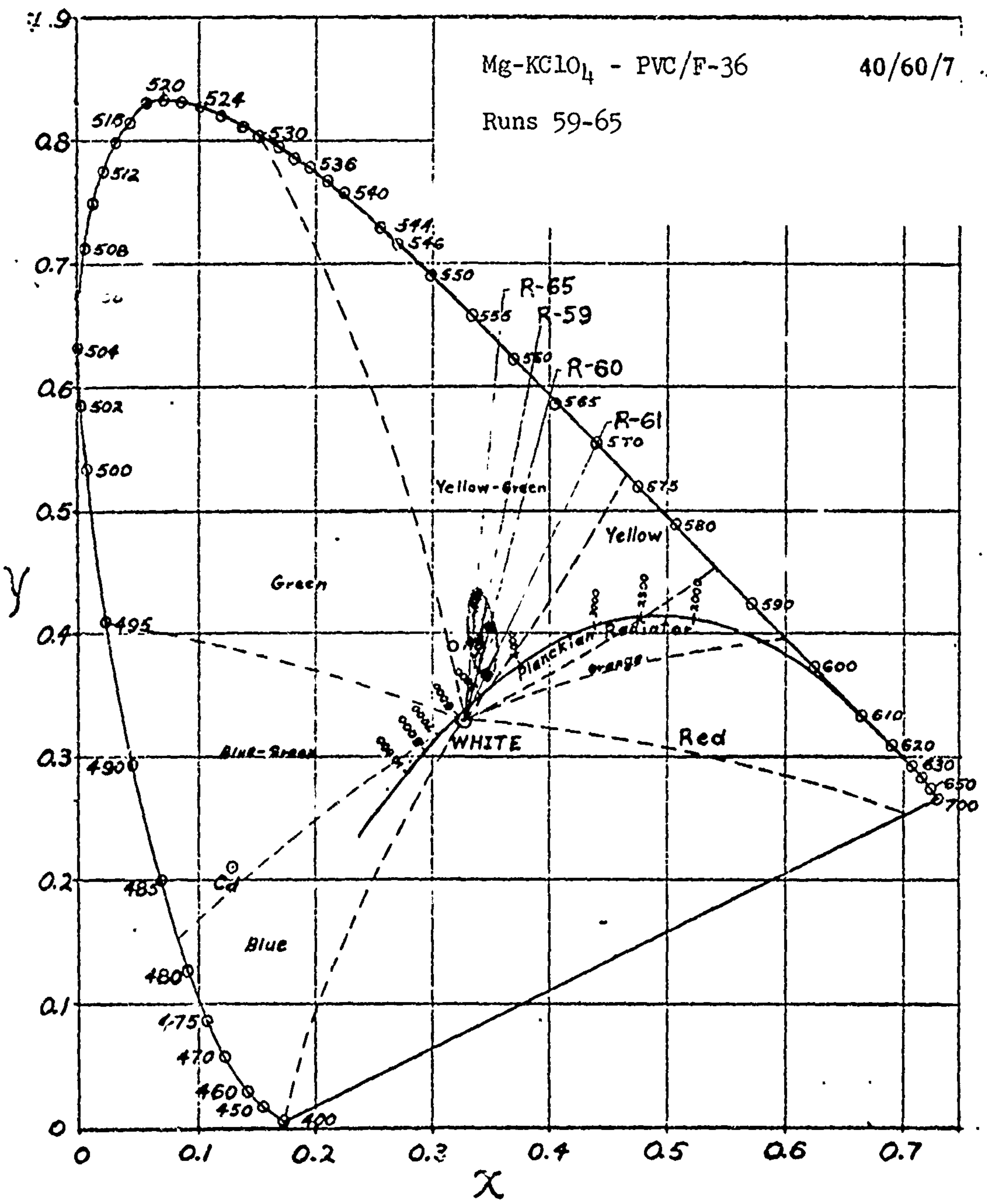
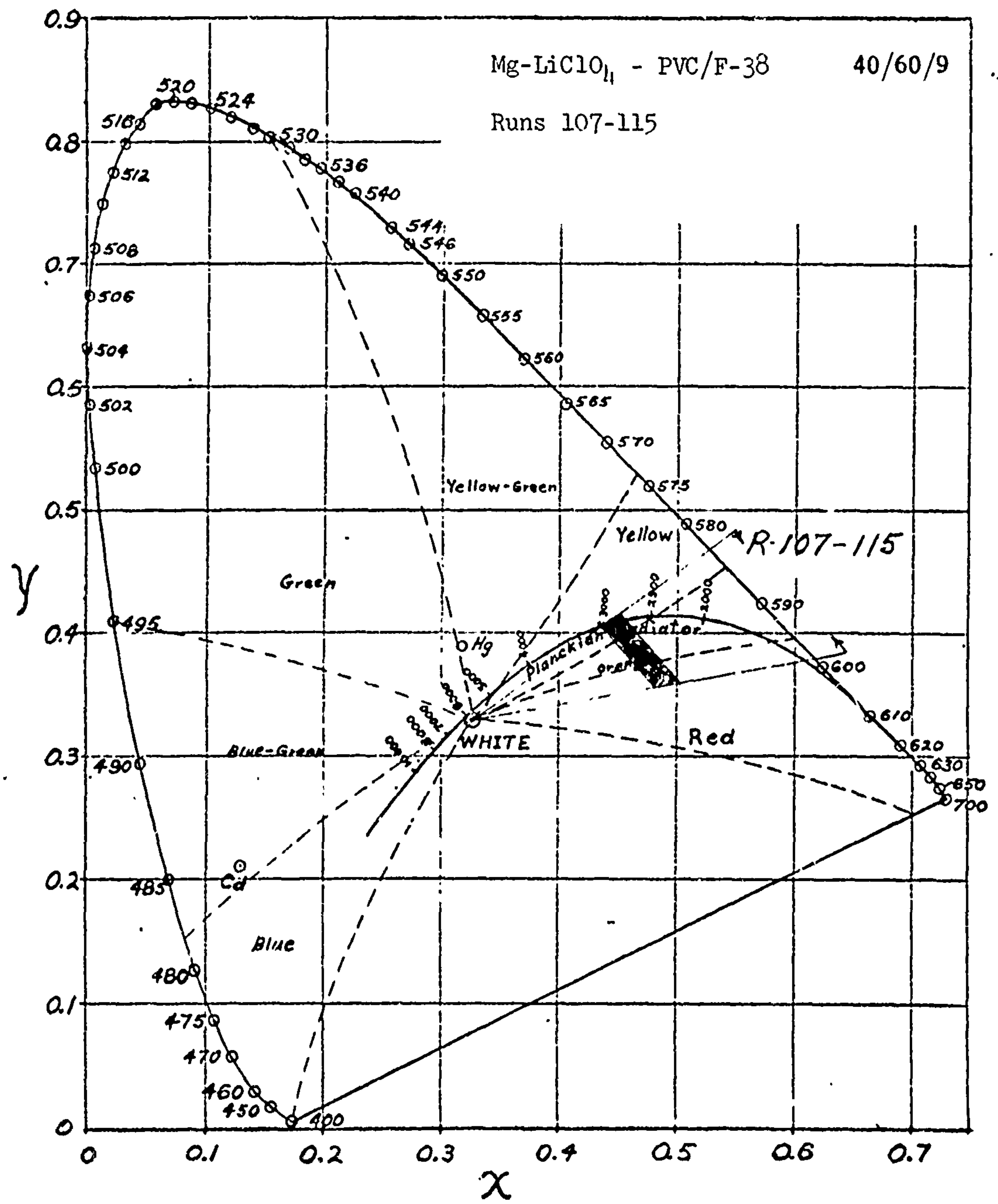
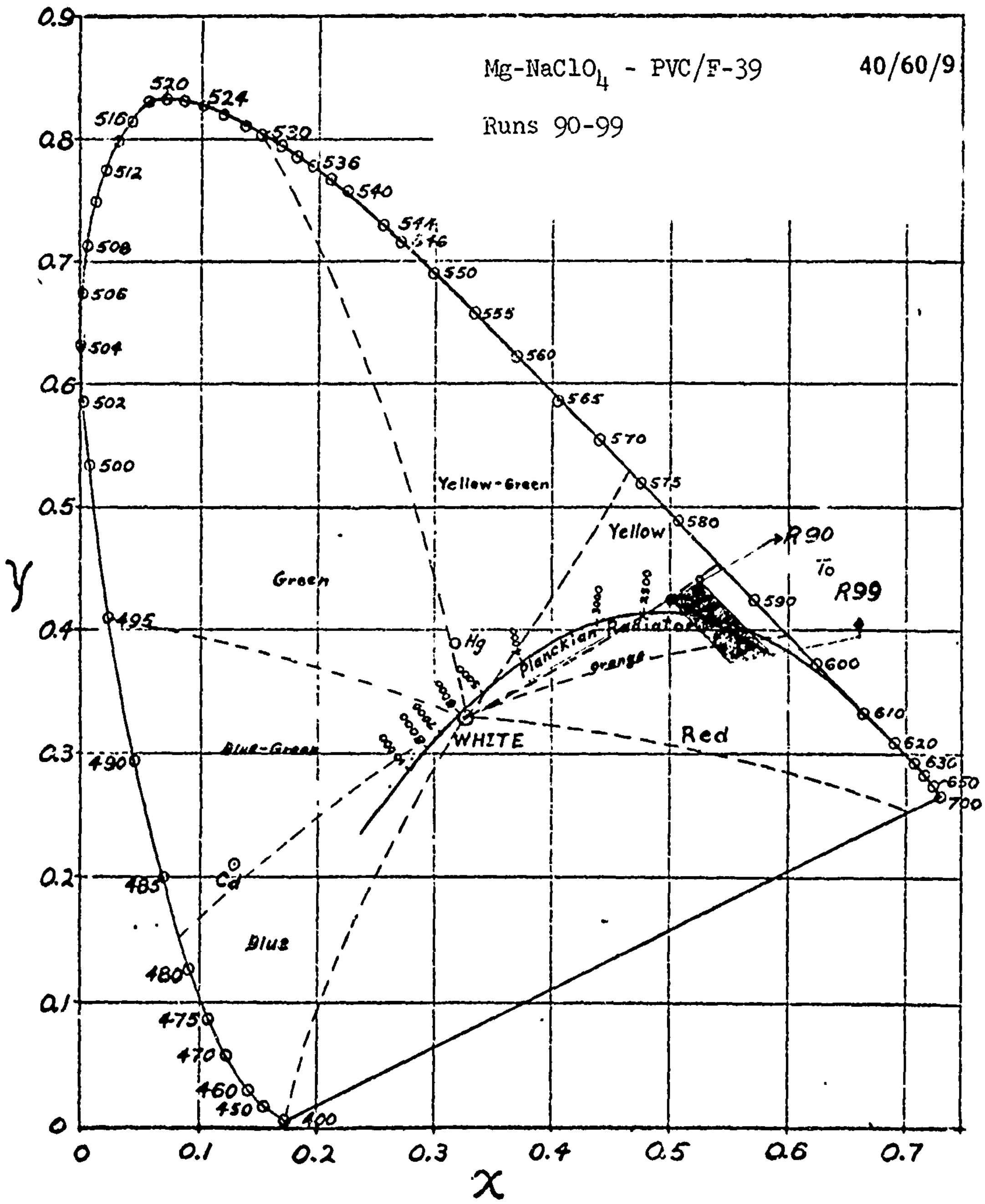

Mg-KClO4 - PVC/F-36
40/60/7
Runs 59-65
R-65
R-59
R-60
R-61
Yellow-Green
Yellow
Green
Planckian Radiator
orange
WHITE
Red
Blue-Green
Cd
Blue
y
x

Plate 75



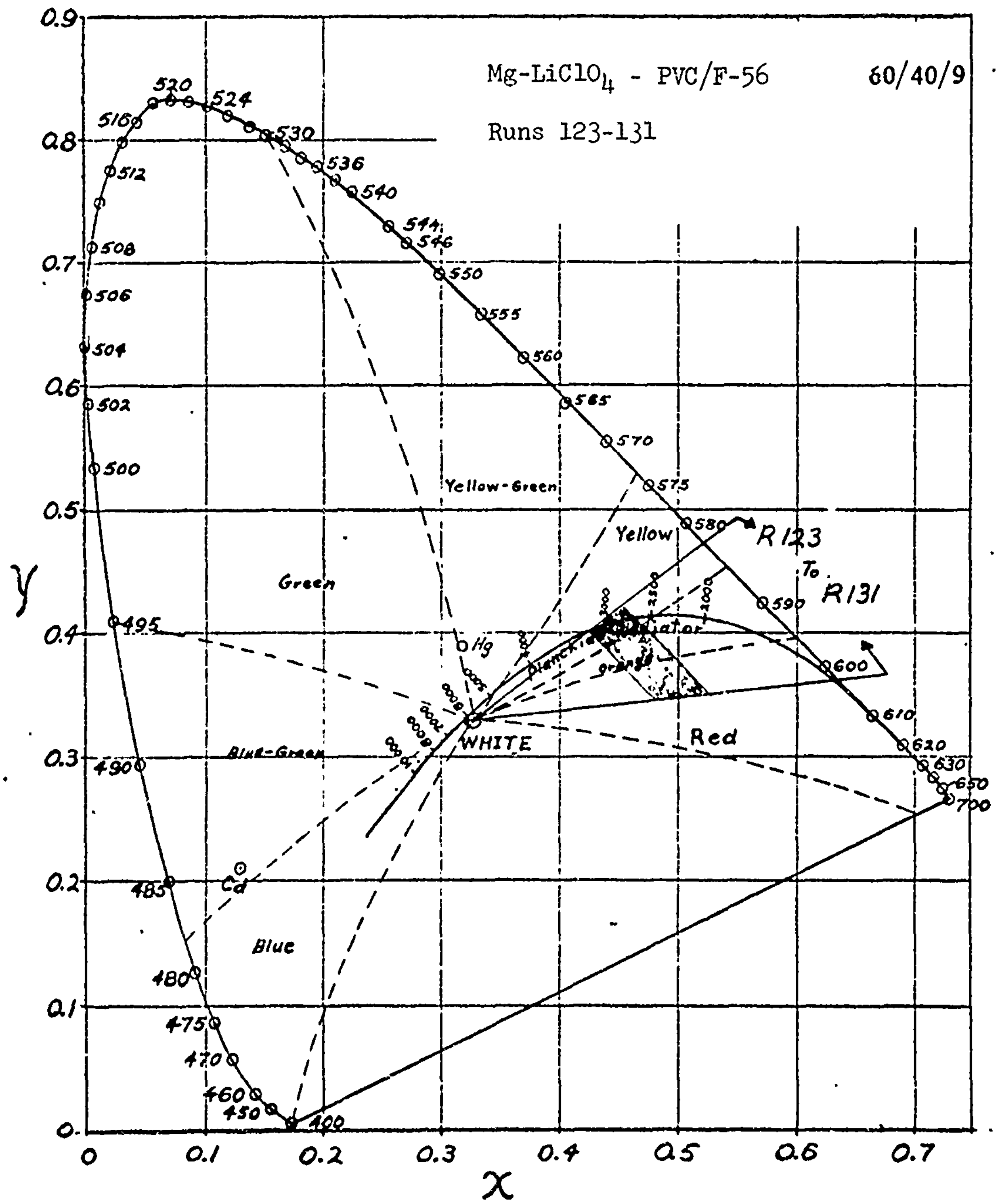
Mg-LiClO$_4$ - PVC/F-38 40/60/9
Runs 107-115
R-107-115
Yellow-Green
Yellow
Green
Blue-Green
Blue
Red
WHITE
Hg
Cd
Planckian Radiator
y
x
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Plate 76



Mg-NaClO4 - PVC/F-39
40/60/9
Runs 90-99
R90
To
R99
Yellow-Green
Yellow
Green
Blue-Green
WHITE
Red
Blue
Planckian Radiator
orange
Hg
Cd
y
x

Plate 77



Mg-LiClO4 - PVC/F-56
60/40/9
Runs 123-131
R 123
To
R 131
Yellow-Green
Yellow
Green
Blue-Green
Blue
Red
WHITE
Hg
Cd
y
x

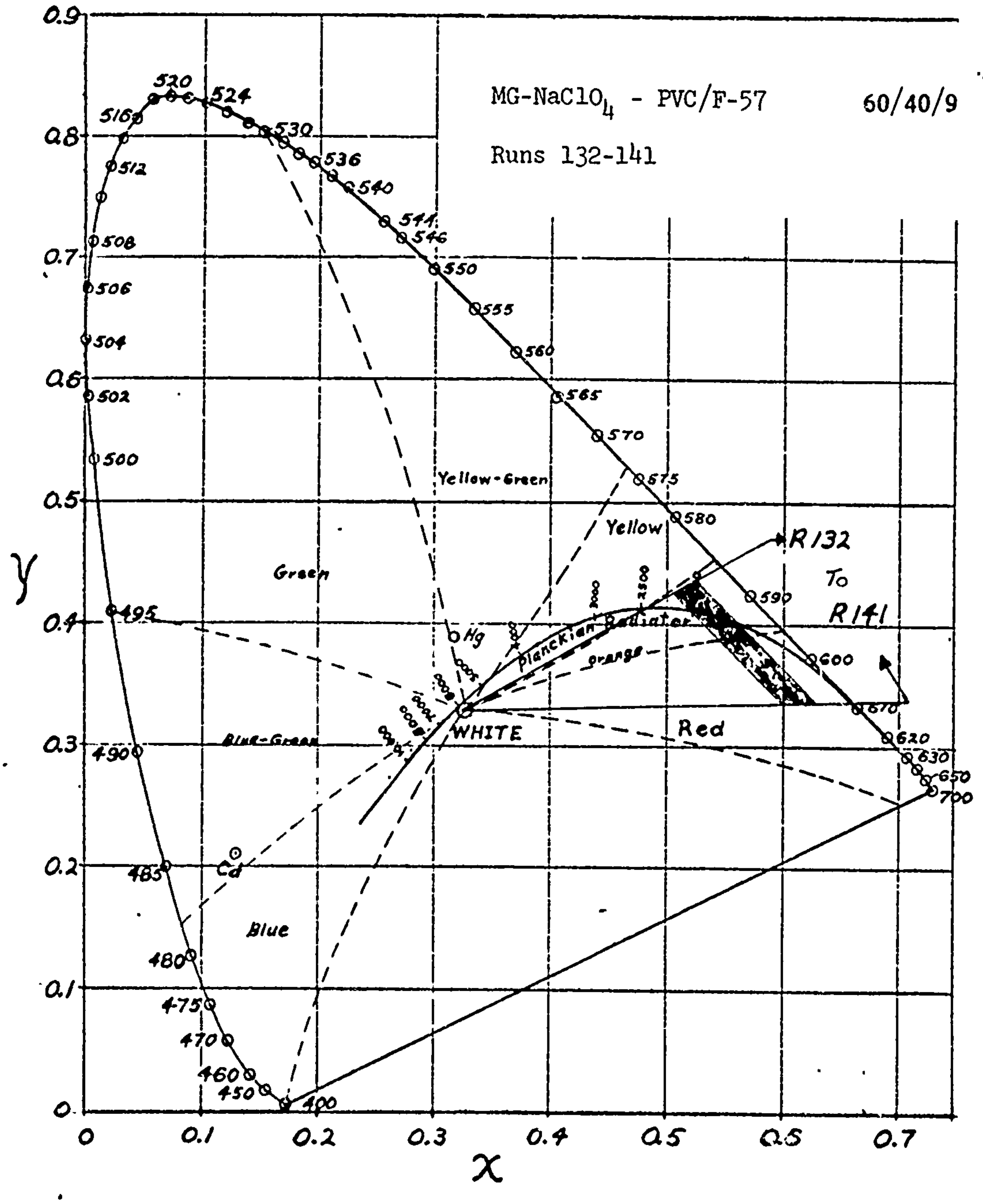
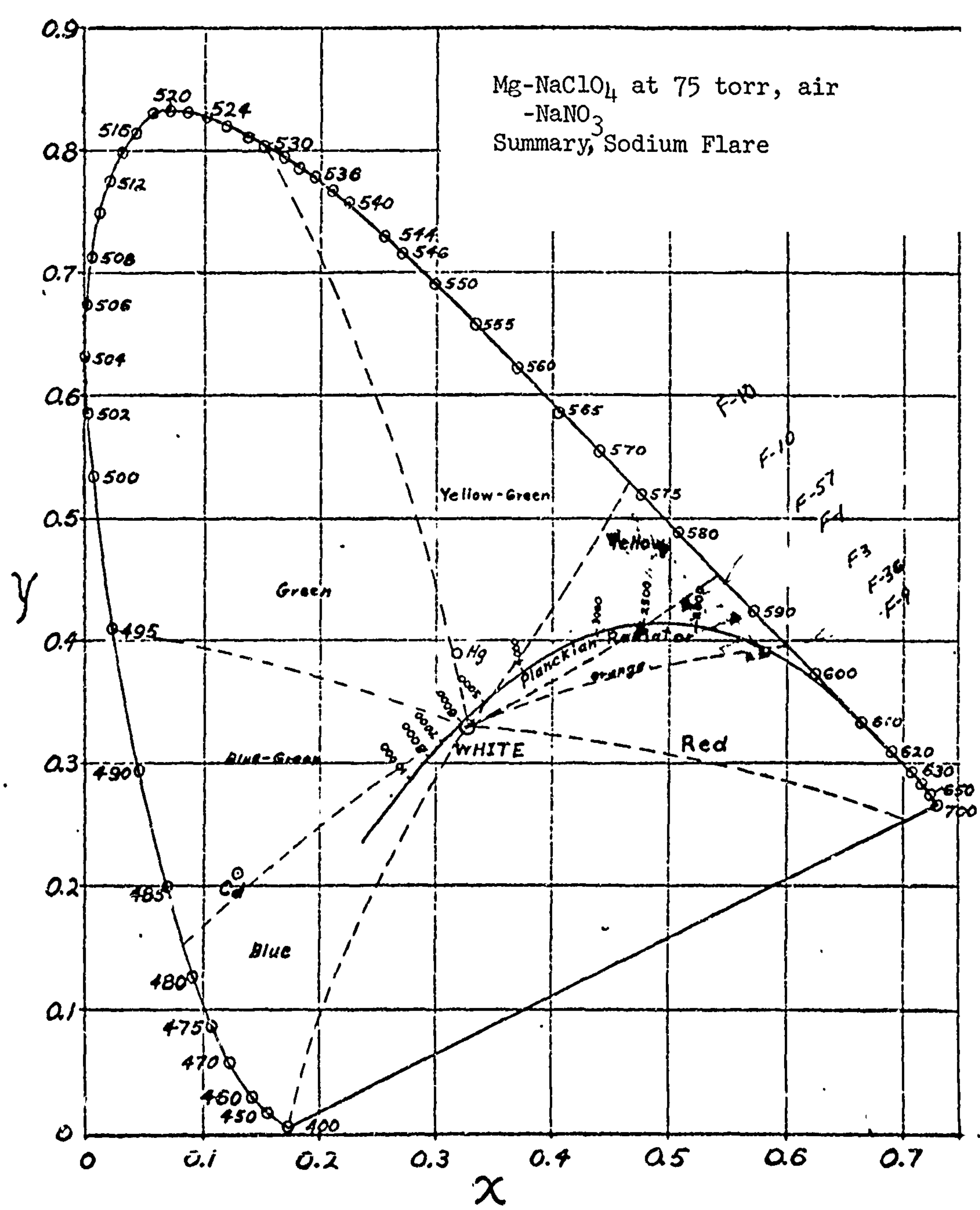
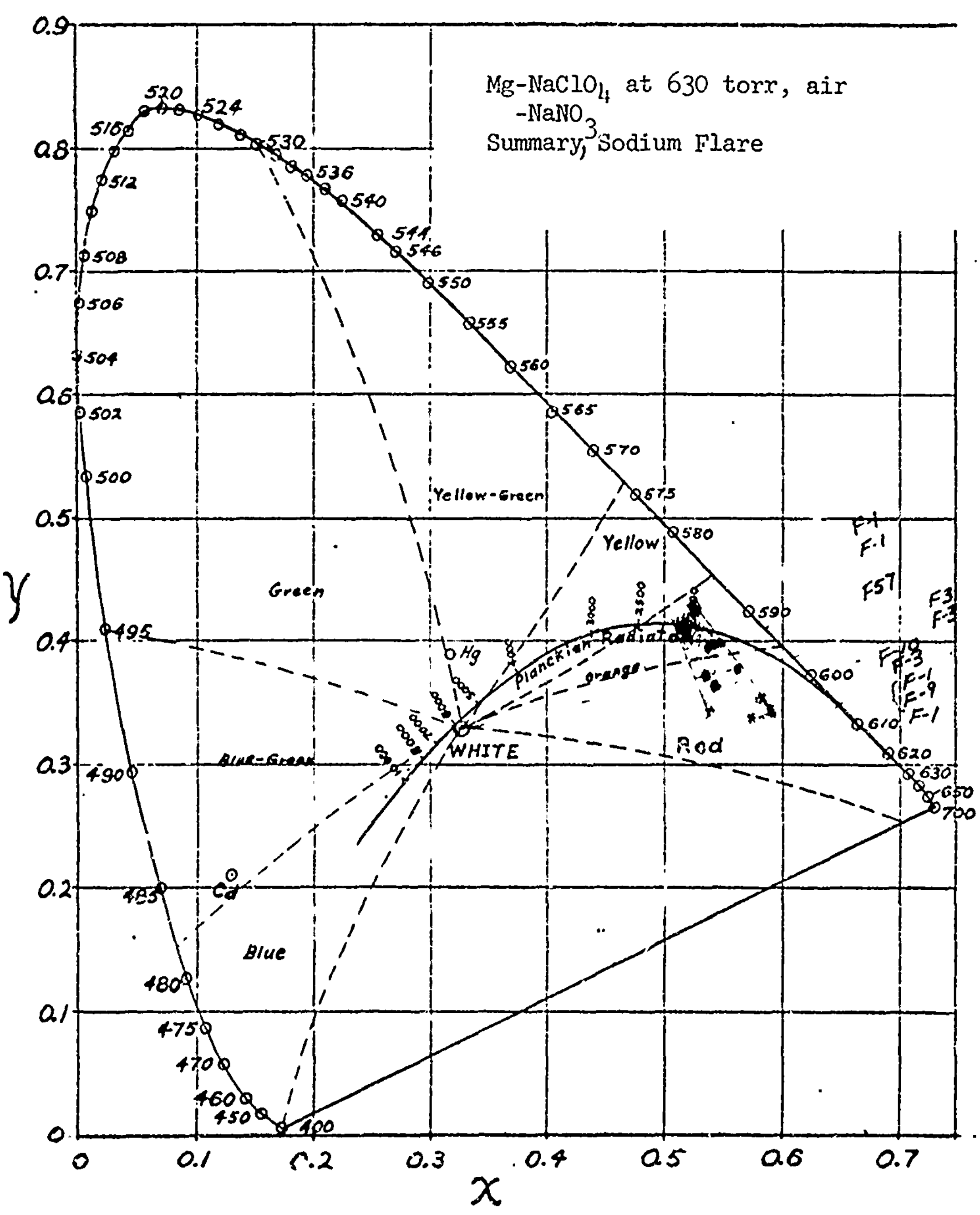

MG-NaClO4 - PVC/F-57
60/40/9
Runs 132-141
R132
To
R141
y
x
Yellow-Green
Yellow
Green
Blue-Green
Blue
WHITE
Red
Orange
Planckian Radiator
Hg
Cd
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
520
524
516
530
512
536
540
508
544
546
506
550
555
504
560
502
565
570
500
575
580
590
495
600
610
620
490
630
650
700
485
480
475
470
460
450
400

Plate 79



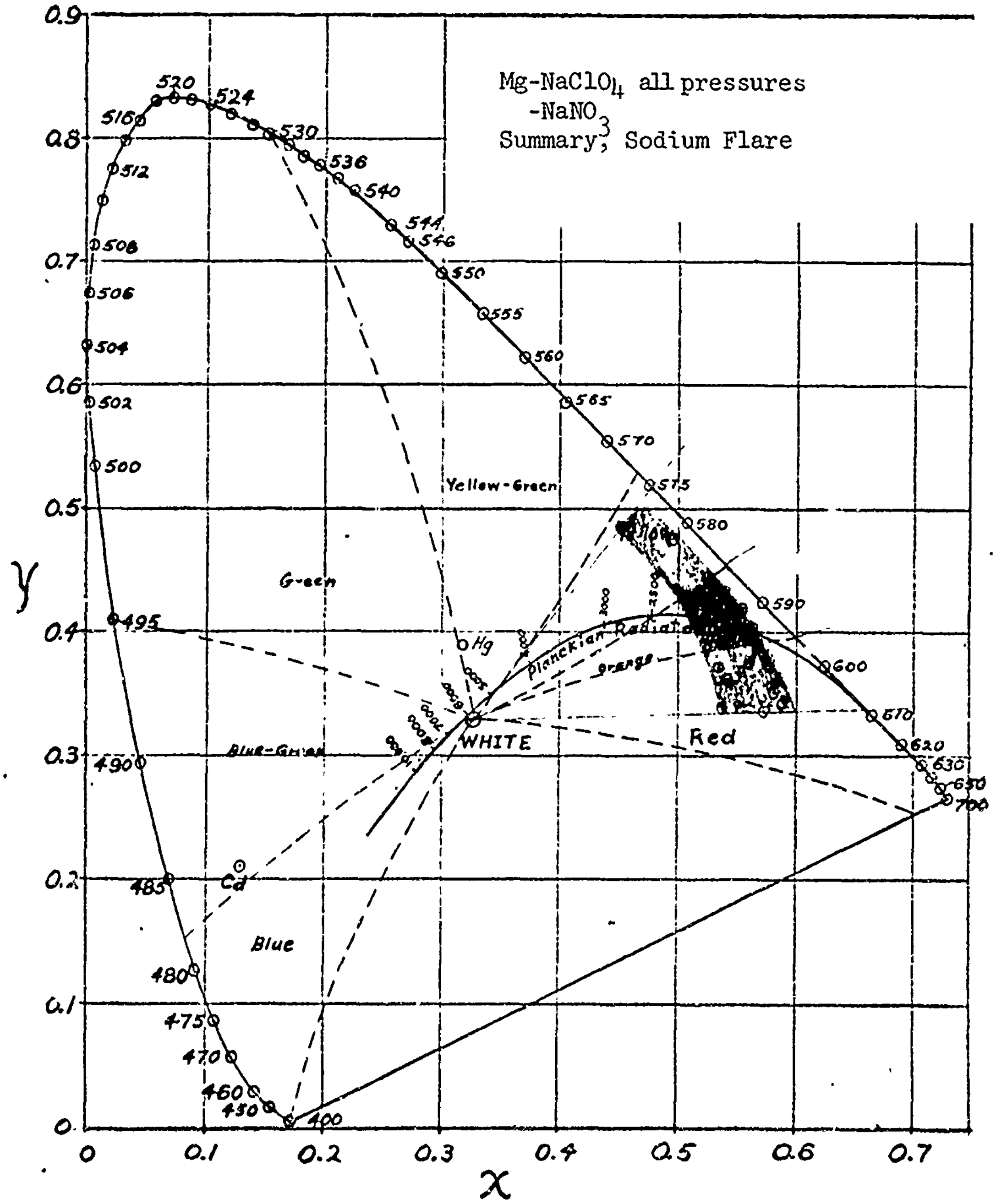
Mg-NaClO4 at 75 torr, air -NaNO3
Summary, Sodium Flare
Yellow-Green
Green
Yellow
Planckian Radiator
Orange
Blue-Green
WHITE
Red
Blue
Hg
Cd
F-10
F-1
F-57
F4
F3
F-36
F-9
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
x
y
520
524
516
530
536
540
544
546
550
555
560
565
570
575
580
590
600
610
620
630
650
700
512
508
506
504
502
500
495
490
485
480
475
470
460
450
400

Plate 80



Mg-NaClO$_4$ at 630 torr, air
-NaNO$_3$
Summary, Sodium Flare
Yellow-Green
Yellow
Green
Hg
Planckian Radiator
Orange
WHITE
Red
Blue-Green
Cd
Blue
x
y

Plate 81


Mg-NaClO4 all pressures
-NaNO3
Summary; Sodium Flare
Yellow-Green
Green
Blue-Green
Blue
WHITE
Red
Orange
Planckian Radiator
Hg
Cd
x
y

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Mechanics Division Denver Research Institute University of Denver Denver, Colorado 80210	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP -------

3. REPORT TITLE

STUDY OF SPECTRA OF METAL-OXIDANT COMBINATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report March 1967 - March 1968

5. AUTHOR(S) (Last name, first name, initial)

Blunt, Robert M.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1 March 1968	-----	

8a. CONTRACT OR GRANT NO. AIRTASK NO. A35-532-022/323-1/F008-17-02	9a. ORIGINATOR'S REPORT NUMBER(S) Final Report 3976-6803-F
b. PROJECT NO. Work Unit #4	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RDTR No. 126
d. N00164-67-C-0323	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
----------------	U.S. Naval Ammunition Depot Crane, Indiana 47522

13. ABSTRACT

The time-integrated grating spectra obtained at a dispersion of 14.8Å/mm from flames produced by Mg-$Ba(NO_3)_2$, Mg-$NaNO_3$, Mg-$Ba(NO_3)_2$ - $Sr(NO_3)_2$-TFE, Al-$NaClO_4$-PVC, Al-$NaClO_4$-PVC, Al-$KClO_4$-PVC, Al-$Sr(ClO_4)_2$-PVC, B-$Ba(ClO_4)_2$-PVC, B-$KClO_4$-PVC, Mg-$LiClO_4$-PVC, Mg-$NaClO_4$, at different weight percentages are photographically reproduced.

These spectra have been obtained from flames burning in ambient air ranging in pressure from 630 torr to 70 torr.

Time-resolved spectra have been obtained from these same compositions, burning at the same ambient pressures, with a Perkin Elmer Model 108 Scanning Spectrometer at a rate of 3 per second. Photographic enlargements of typical spectra as photographed on the CRO are shown.

The colorimetric purity, dominant wavelength, intensity and integrated light output from the same mixtures burning under the same conditions are tabulated and also plotted on C.I.E. chromaticity charts.

The absorption of the light resulting from its passage through the smoke evolved during combustion has been determined and absorption coefficients tabulated for the smoke from several different compositions and ambient pressures.

Suggestions have been made for further studies of combustion problems.

DD FORM 1 JAN 64 1473

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Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Flares						
Illuminating Flares						
Signalling Flares						
Colored Flares						
Color Purity						
Dominant Wavelength						
Flames						
Emitters						
Spectra						
Luminous Intensity						

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