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EDGEWOOD ARSENAL ABERDEEN PROVING GROUND MD
THE USE OF DYE 2-ANISOLE-AZO-BETA-NAPHTHOL, IN COLORED SMOKE GR--ETC(U)
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EA-TCIR-357

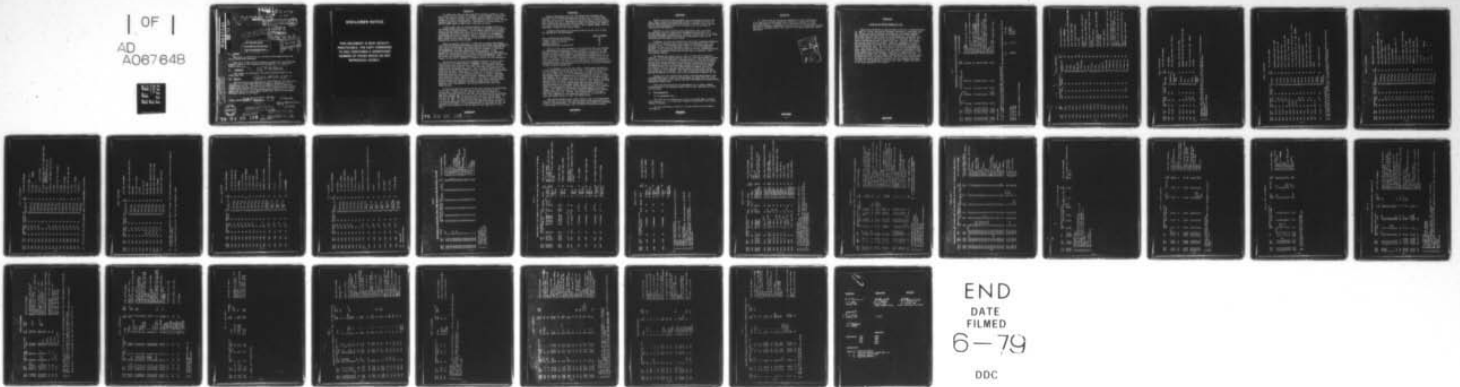
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T.C.I.R. No. 357
Project No: A13
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6 The Use of Dye
2-anisole-azo-beta-naphthol,
in colored smoke grenades

I. Object:

The object of project A13 is to develop colored smoke mixtures for use in colored smoke munitions.

The object of this work is to develop a formula for a red smoke hand grenade in which the dye 2-anisole-azo-beta-naphthol, or a similar dye could be used.

II. Authority:

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This project is authorized by the project specifications for the fiscal year 1945.

III. Results:

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The dye 2-anisole-azo-beta-naphthol, Colour Index No. 113, was one of the first to be tested where work was initiated on modification of the colored Smoke Pot, M3. The results were promising enough to warrant an extensive and protected study of this dye, but it never produced a colored smoke cloud as good as that from 1-methylamine anthraquinone, the red dye adapted for use in the colored Smoke Grenade, M16, and all colored smoke munitions subsequently developed.

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In common with other azo dyes this dye is thermally unstable. When mixed with a fuel and burned in a grenade, it has a tendency to burst into flames, and produce a mixture of colorless, gaseous products and carbon, instead of a cloud of colored smoke. Even when this does not occur, the dye undergoes appreciable decomposition in the process of volatilization, so that the smoke varies in color from a light red, to white.

It was thought that the decolorization of the dye might be due to the passage of dye vapors over the hot carbonaceous residue that is always found in colored smoke munitions. It was further thought that the gases formed from the burning fuel, which act as a "carrier" for the dye vapors in expelling them from the grenade, might in themselves be inflammable. Their combustion with the oxygen of the air on emission from the grenade might ignite the dye vapors intermixed with them and cause the excessive flaming often observed with azo dyes.

Recent experiments, the object of which was to prevent from flaming a fast-burning colored smoke mixture containing beta-naphthol-azo-dimethylaniline, led to the discovery that certain ammonium salts also prevented the decolorization of azo dyes. Most ammonium salts decompose at relatively low temperatures, and their products are wholly gaseous. It was thought that the gaseous products formed on decomposition of these salts might expel the dye vapors from the grenade before decomposition could occur and dilute the effluent gases sufficiently to prevent ignition. Such, indeed, was the result, regardless of whether this be the true explanation.

The addition of ammonium sulfate markedly improved the color, while the addition of ammonium sulfamate, $\text{NH}_4\text{SO}_3\text{NH}_2$, produced a smoke whose color equalled and, under available conditions, even surpassed that from 1-methyl amino anthraquinone. The color, which was excellent initially faded some as the burning progressed. This was largely eliminated by the addition of an inert diluent such as kaolin, floated silica, or precipitated tricalcium phosphate. The addition of a very bulky substance such as kieselguhr, asbestos shorts, magnesium carbonate, or sodium or ammonium lignin sulfonate, had the opposite effect. Ammonium sulfate, when mixed with potassium chlorate, was too unstable to be used in a colored smoke munition without deterioration in storage. Other salts, ammonium oxalate, ammonium thiosulfate, ammonium chloride, ammonium sulfate, ammonium phosphate, urea, diphenylamine, and aniline hydrochloride were found unsatisfactory.

It was found that the intensity of the color produced was proportional to the rate of burning, and that the best color was produced with a burning time of less than sixty seconds. This dye would seem to be especially suitable for use in such fast burning munitions as the streaming type rifle grenade, M23, (T.D.M.R. No. 806), the 60 mm. mortar shell, T10, (T.D.M.R. No. 357), and the colored smoke trail bombs, M37 and E13R2, (T.D.M.R. No. 861). It has also been found very satisfactory in the 4.2" C.M. colored smoke shell, E72, in which the explosive filling consists of a mixture of EC powder, U.S. Army Specification No. 50-13-8B, and dye, and when the time of exposure of the dye vapor to high temperature is very short.

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Earlier experiments with other dyes showed that decreasing the particle size of the $KClO_3$ decreased the burning time of colored smoke munitions. It was found that with this dye decreasing the particle size also improved the color. Experiments in which the effect of fine particle size in decreasing the burning time was offset by decreasing the quantity of chlorate by the addition of a "cooler", such as $NaHCO_3$, $KHCO_3$, Urea, or Epsom Salt, resulted in an inferior smoke.

A smoke mixture having the following composition was found to give the best smoke in the M18 grenade:

	<u>Parts by weight:</u>
Dye, 2-anisole-azo-beta-naphthol	40
Potassium Chlorate, Micropulverized	20
Sucrose, Micro, pulverized	20
Ammonium Sulfamate	10
Tricalcium phosphate, precipitated	10

The hue of the smoke produced by this dye differs from that produced by 1-methylamino anthraquinone, being a yellowish red, or scarlet, (8R, see Note on Munsell Color System at end of Report), instead of red (3R). Attempts to make the hue redder by the addition of another dye to the mixture met with little success, resulting either in deterioration of the color, or flaming. A more satisfactory method of changing the hue is to alter the composition of the dye, by the addition of other substituents in the aromatic rings. The dyes, 2,5-dimethoxy benzene-azo-beta-naphthol and 5-methyl-2-anisole-azo-beta-naphthol, have been found to produce red smokes of hues 3R and 5R, respectively.

It is customary to oil the dyes used in colored smoke munitions to decrease dustiness during mixing and filling. The addition of Petroleum Oil, C.W.S. Spec. No. 196-131-168, Kerosene, or Halowax oil #1000, a chlorinated hydrocarbon, to the colored smoke mixtures containing this dye produced smoke of inferior color and increased the tendency to flame. This tendency can be largely eliminated by insulating the smoke filling from the ends of the grenade body with washers of fibre board or asbestos. Leaving a small air space, one-fourth to one-half inch, between the smoke filling and the top of the grenade body, was also found beneficial. Promising results in eliminating flaming were obtained by adding to the smoke mix a cold-setting plastic such as Resinous Products Co.'s Uformite, (urea, - formaldehyde) or Pittsburgh Plate Glass Company's Selectron (alkyd-type). The semi-fluid mix thus formed is poured into the grenade body and allowed to set. However, acidic constituents of the resin react with components of this smoke mix resulting in the evolution of gases and causing the mix to swell and become porous.

The tables appended to this report contain a list of the experiments involving the use of this dye in burning type colored smoke munition performed by the undersigned. For each experiment the notebook and experiment or page number of the original entry is listed for reference purposes.

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Tables I and 2 list the experiments in which ammonium sulfate was used. Table 3 summarizes experiments in which other dyes were added to colored smoke mixtures containing this dye in an attempt to alter the hue. Table 4 lists experiments with other azo dyes similar in structure to 2-anisole-azo-beta-naphthol.

Tables 5, 6, and 7 summarize early experiments with a potassium chlorate-sugar fuel, and those with a potassium chlorate-sulfur fuel. A colored smoke mixture containing dye, potassium chlorate, sulfur, and sodium bicarbonate produces excellent clouds with anthraquinone dyes, but is unsatisfactory with dyes of other types.

EC Powder, U.S. Army Specification No. 50-13-8B, consisting essentially of a mixture of nitrocellulose, barium nitrate and potassium nitrate, was tried as a fuel. It gave satisfactory results in the Aerial Smoke Puff (T.D.M.R. No. 679) and 4.2" C.M. Shell, E72, but not in a burning-type munition. Other fuels-lead dioxide and sulfur or lactose, potassium chlorate and charcoal, potassium nitrate with sulfur, sugar, or charcoal - were tried without success.

The Germans and Italians use azo dyes, and this dye in particular (CMTR 40), in colored smoke munitions, but only in the form of small pellets, which burn in 10 to 12 seconds, or extruded granules. When the filling is in this form, the dye vapors are in contact a very short time with the hot carbonaceous residue which may catalyze thermal decomposition of the dye. Colored smoke mixtures containing dye, chlorate and lactose were pressed to a depth of only one inch into grenades having diameters of 3-1/4 to 5-1/2 inches, to give a greater burning surface and more rapid burning. The results were not promising. This type of construction has apparently, enabled the British to use this dye in the colored smoke Generator, No. 26.

Samples have been received from several different manufacturers under different trade names. Most of the experiments were made with lots of dye from Calco Designated as Oil Scarlet OBN, and from Federal Color Laboratories, designated as Signal Red.

Since the characteristics and performances of the various samples differed slightly, the particular sample used in each experiment is stated in the tables.

IV. Recommendations:

It is recommended that:

(1) This dye be considered for use in the Grenade, Smoke, Colored (Fast Burning) EB, in the event that a grenade burning faster than the M18 grenade is desired.

(2) The performance of this dye in other burning-type munitions be investigated.

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3. That because of the special composition in which this dye is to be used, and the extra precautions necessary in mixing and filling, it be considered not to replace, or as a substitute for the two dyes specified at present, 1-methylamino anthraquinone and 9-dithylamino rosindone, but only to supplement them in the event of a shortage of these two latter-named dyes.

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A Note on the Munsell System of Color

Color can be described in terms of three attributes, or characteristics: (1) Hue; (2) Value, also called lightness, intensity, or brilliance; and (3) Chroma, also called strength or saturation. The Munsell System of Color represents these attributes as the dimensions of a color sphere. The central vertical axis of the color solid represents the neutral value scale with black at the bottom and increasing in brightness through ten readily distinguished steps to white at the top. Colors in this central axis possess neither Hue nor Chroma. Chroma is represented by a radial distance away from the neutral axis, while hue corresponds to angular distance around the axis. The hue circle is divided into five principal hues - red, yellow, green, blue, and purple - and five intermediate hues evenly spaced between each two of these - yellow-red, green-yellow, blue-green, purple-blue, and red-purple. To facilitate identification of hues intermediate between these ten major hues, each is divided into ten numerical divisions, with the number 5 falling directly on the hue itself. In describing a color by Munsell notation, the hue is given first and is followed by a symbol written in fraction form, the numerator indicating the value and the denominator indicating the chroma. Examples are given on the tables appended to this report.

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TABLE I

Compositions for M18 Grenade containing Ammonium Sulfamate

Note-book	Expt. No.	Composition Dye	KClO ₃	(Parts by wt.) Sucrose NH ₄ SO ₃ NH ₂ etc.	BT* sec.	Color and Performance
2016	6/12-11	35 (1)	25 (2)	20	54	bad flaming
2016	6/12-12	35	25 (3)	20	32	bad flaming from one end of grenade
1782	5/25-5	35	30	25	23	7R5/8 (4)
1782	5/29-1	40	20	20	45	flaming from one end, color uniform, no fading slightly dull
1782	5/29-3	40	20	20	45	flaming from one end after 12 sec.
1782	5/27-1	45	20	15	-	7R6/12, slightly pale and variable
1782	5/29-5	45	20	15	45	flaming from one end, somewhat pale and dull
1782	5/26-12	50	20	10	45	7R6/14, fading last few sec., excellent volume
1782	5/27-3	50	20	10	45	some fading at last
1782	5/29-11	50	20	10	43	color generally good, fading at last
2016	5/3-3	50	20	10	45	bad flaming, hand pressed, filled solid
1782	5/27-5	45	20	25	32	color slightly variable, fading at last, good volume
1782	5/26-2	40	25	10	27	7R5.5/12
2016	6/9-4	40	25 (3)	10	27	pale, no fading.
2016	6/9-12	40	25 (2)	10	30	color very good, fading last 10 sec.

*Burning Time

1. Dye - Signal Red A or 0.1 Scarlet ONN in all experiments
 2 & 3. Samples of KClO₃ having particle size different from that specified in CWS Specification No. 196-111-92

	(2)	(3)	CWS Spec.
Held on 60 Mesh	0	0	2 (Max.)
Held on 100 Mesh	32	0	15 (Max.)
Held on 200 Mesh	47	28	30-60
Held on 200 Mesh	19	69	40-70

4. Notation used in Munsell Color System.

TABLE 1 (continued)

Note book	Expt. No.	Composition (parts by wt.) Dye KClO ₃	Sucrose	NH ₄ SO ₃ NH ₂ etc.	BT sec.	Color and Performance
1782	6/1-5	35	20	10 KHCO ₃	29	color pale, variable
1782	6/2-2	40	20	10 KHCO ₃	47	color generally good, finally fading badly
1782	6/1-2	35	20	10 KHCO ₃	41	color uniform, rather pale
1782	6/1-3	35	20	15 NH ₄ Cl	45	color bright but variable
1782	6/1-4	35	20	15 (NH ₄) ₂ SO ₄	135	color pale
2016	6/12-5	35	25	15 (NH ₄) ₂ C ₂ O ₄	25	flaming after 15 sec., color good at first
2016	6/13-5	40	20	5 Urea	27	color good, very little fading
1782	5/27-7	40	20	5 Urea	38	color variable, rather pale, bad fading at last
1782	5/27-8	40	20	10 Ca(OH) ₂	59	last 10 sec. fading
1782	5/27-10	35	20	10 CaSO ₄	38	color slightly pale, dull, and variable finally fading
1782	5/27-9	40	20	10 CaSO ₄	38	slight fading
1782	6/1-8	35	20	10 Soap (5)	35	color pale, fading
1782	6/2-3	38	20	10 Kieselguhr	38	color generally good, last 5 sec. fading
1782	6/2-5	40	20	5 Kieselguhr	50	color initially excellent, then turning paler, duller, finally fading
1782	6/1-6	40	20	5 Kieselguhr	60	color bright, uniform, except last 5 sec. fading
1782	6/2-1	40	20	10 Kieselguhr	60	disc at top (6), bad fading last 15 - 20 sec.
2016	6/15-9	40	20	10 Kieselguhr	49	good, slightly pale and variable, some fading
2016	1067	40	10(7)	10 Kieselguhr	38	somewhat pale, good volume

Table I (continued)

Note- book	Expt. No.	Composition (parts by wt.)		BT sec.	Color and Performance
		Dye KClO ₃	Sucrose NH ₄ SO ₃ NH ₂		
1782	6/2-10	40	20	40	bad flaming
				10 Kieselguhr	
1782	6/2-4	35	20	45	generally good, last 5 sec. fading
				10 Kieselguhr	
				5 KHCO ₃	
1782	6/1-7	40	20	50	bright, uniform, slight fading
				10 SiO ₂ (8)	
1782	6/2-9	40	20	35	flaming from one end, pale smoke from other
				10 SiO ₂	
2016	1188	40	18 (7)	37	735/14
				10 SiO ₂	
2016	1187	40	18 (7)	75	initially good color, then fading
				5 KHCO ₃	
2016	1289	40	13 (7)	36	735+/12+
				10 Fullers Earth	

5. Detergent, Sand, Federal Specification No. P-D-221, containing 60 - 76% siliceous material
6. Smoke charge insulated from ends of grenade body with asbestos discs
7. Micropulverized
8. Precipitated, or Floated

Table I (continued)

Note- book	Expt. No.	Composition Dye	Composition KClO ₃	Sucrose	(parts by wt.) NH ₄ SCNH ₂	BF sec.	Color and Performance
2016	6/13-8	40	20	20	10 10 Kaolin	35	excellent except fading at last
2016	6/15-6	40	20 (2)	20	10 10 Kaolin	57	7R6/14, slight fading at last
2016	6/16-1	40	20 (2)	20	10 10 Kaolin	49	6R6/14, fading last 5 sec.
2016	1028	40	20 (7)	20	10 10 Kaolin	29	1M, (9) slightly pale, fading at last
2016	6/16-7	40 (10)	20 (2)	20	10 10 Kaolin	35	7R6/11, last 10 - 15 sec. fading
2016	6/16-3	40 (11)	20	20	10 10 Kaolin	63	color good, volume fair, fading last 10 - 15 sec.
2016	1017	38 (11)	22	20	10 10 Kaolin	60	7R6/12, fading after 40 sec., 3 sec. flaming
2016	1039	40	18 (7)	20	10 10 Kaolin	40	M6, slightly pale, fading at last
2016	1066	40	13 (7)	20	10 10 Kaolin	48	color good, slightly pale
2016	6/16-9	40	18	22	10 10 Kaolin	63	slightly dull, fading last 10 - 15 sec.
2016	1021	40	17 (7)	20	10 10 Kaolin	56	slightly pale, some fading from one end
2016	6/15-2	36.7	20	20	10 10 Kaolin	42	GR6/12
2016	6/16-6	40	20 (2)	20	10 10 Kaolin 3.3 NaHCO ₃	65	6R6/12, fading at last
					10 4 Dextrine		

9. no hole in bottom of grenade body

10. Dye blended with 4% by wt. Halowax Oil # 1000, a chlorinated hydrocarbon containing 23% chlorine

11. Dye blended with 4% by wt. Petroleum Oil, CW8 Specification No. 196-131-168

TABLE I (continued)

Note-book	Expt. No.	Dye	Composition KClO ₃	Sucrose	(parts by wt.) NH ₄ SO ₄ , NH ₂ etc. sec.	BT	Color and Performance
2016	1003	40	20	20	10	42	very good except some fading at last
2016	1022	40	20	20	5 Ca ₃ (PO ₄) ₂	53	good, slight fading at last
2016	1027	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	30	very good, no fading
2149	1507	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	54	5R 6/10, pale, Flaming
2149	1507	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	75	6R 5 +/12 Flaming
2149	1510	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	71	6R 5.5/10, Flaming. Discs (6)
2149	1510	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	58	6R 5.5/12 "
2149	1726	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	36	8R 5.5/12, discs, very little fading
2149	1791	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	33	7R 5.5/12, Flaming, discs
2149	1791	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂		7R 5.5/12, Discs, no flaming
2149	1801	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	60	6R 5/10 +, discs, flaming
2149	1801	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	65	7R 5.5/12, discs, some fading
2149	1801	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	70	7R 5 +/12, " "
2149	1802	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	47	8R 6/10 " flaming
2149	1802	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	47	7R 6/12 " "
2149	1802	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂	52	7R 5.5/12 " "
2149	1802	40	20 (7)	20	10 Ca ₃ (PO ₄) ₂		

TABLE I (continued)

Note-book	Expt. No.	Composition Dye	Composition (parts by wt.) Sucrose	NH ₄ SCN ₂ etc. sec.	BT	Color and Performance
2149	1802	40	20	20	57	8R 5.5/12 discs ----
2149	1810	40	20	20	66	7R 5.5/12 " flaming
2149	1810	40	20	20	--	7R 5.5/14 "
2149	1810	40	20	20	46	7R 5/12 " slight fading
2149	1769	40	20	20	61	8R 5 +/13 slight fading, 5000 lb. dead load filling pressure (12)
2149	1769	40	20	20	64	8R 5/14 some fading, 5000 lb. d.l.
2149	1784	40	20	20	41	7R 5.5/12 +, some fading, 5000 lb. d.l.
2149	1784	40	20	20	35	7R 5 +/13
2149	1790	40	20	20	--	8R 5.5/12 + 5000 lb. dead load
2149	1790	40	20	20	32	7R 5.5/12 "
2149	1792	40	20	20	59	7R 5.5/10 + fading
2149	1790	40	20	20	--	7R 5.5/12 + 5000 lb. dead load
2149	1790	40	20	20	32	7R 5.5/12
2149	1792	40	20	20	59	7R 5.5/10 + fading
2149	1792	40	20	20	37	7R 5.5/10 +

12. 2000 lb. dead load filling pressure used in other experiments in this table.

TABLE I (continued)

Note-book	Expt. No.	Composition Dye	KClO ₃	(parts by wt.) Sucrose	NH ₄ SCN ₂ etc.	BT sec.	Color and Performance
2016	1064	40	20	20	10	62	good, fading from one end after 35 sec.
2016	1038	40	18 (7)	20	10 Ca ₃ (PO ₄) ₂	40	excellent
2016	1065	40	18 (7)	20	10 Ca ₃ (PO ₄) ₂	57	very good, no fading
2016	1077	40	18 (7)	20	10 Ca ₃ (PO ₄) ₂	43	7.5R6/14
2016	1078	40	18 (7)	20	10 Ca ₃ (PO ₄) ₂	34	6R, no void (13)
2016	1068	40 (14)	18 (7)	20	10 Ca ₃ (PO ₄) ₂	46	slightly pale
2016	1069	40 (14)	18 (7)	20	10 Ca ₃ (PO ₄) ₂	52	slightly pale, fading at very last
2016	1070	40 (10)	18 (7)	20	10 Ca ₃ (PO ₄) ₂	52	slightly pale, fading at very last
2016	1071	40 (10)	18 (7)	20	10 Ca ₃ (PO ₄) ₂	40	7.5R6/12, flaming!
2016	1043	40	16 (7)	20	10 Ca ₃ (PO ₄) ₂	50	slightly pale, some fading

13. grenade body filled completely instead of leaving $\frac{1}{4}$ inch space between top of filling and top of body, as in other experiments

14. Dye blended with 4% by wt. No. 2 fuel oil, from Huntsville Arsenal

TABLE I (continued)

Note-book	Expt. No.	Composition Dye	Composition $KClO_3$	(parts by wt.) Sucrose	NH_4SO_4 , NH_2 etc. sec.	BT	Color and Performance
2149	1474	40	18 (7)	20	10	60	4R 5/12-14, volume good
2149	1474	40	18 (7)	20	10 $Ca_3(PO_4)_2$	46	4R 5/12-14, volume poor
2016	1206	40	22 (7)	20	10 $Ca_3(PO_4)_2$	46	bad flaming
2149	1753	40	22 (7)	20	10 $Ca_3(PO_4)_2$	40	7R 5.5/10 † fading
2149	1753	40	22 (7)	20	10 $Ca_3(PO_4)_2$	31	7R 5.5/10. discs flaming.
2149	1754	40	24 (7)	20	10 $Ca_3(PO_4)_2$	35	7R 5.5/12, fading
2149	1754	40	24 (7)	20	10 $Ca_3(PO_4)_2$	47	7R 5.5/12 fading
2149	1788	60	20	20	10 $Ca_3(PO_4)_2$	91	7R 6/10 †, turning paler
2149	1789	50	20	20	10 $Ca_3(PO_4)_2$	62	7R 6/10 †
2016	1049	40	20 (7)	20	10 $Ca_3(PO_4)_2$	52	Slightly pale, no fading
2016	1058	40	20 (7)	20	10 $Ca_3(PO_4)_2$ 3 Na_2CO_3	56	Excellent color at first, bad fading last 15 sec.
2016	1185	40	18 (7)	20	10 $Ca_3(PO_4)_2$ 5 K_2CO_3	60	7R 5/14
2016	1201	40	18 (7)	20	10 $Ca_3(PO_4)_2$ 3 Urea	64	7R 5/12-14, no fading
2016	1205	40	20 (7)	20	10 $Ca_3(PO_4)_2$ 5 Urea	55	bad flaming

TABLE I (cont'd)

Note-book	Expt. No.	Composition Dye KClO ₃	(parts by wt.) Sucrose NH ₄ SO ₄ NH ₃ etc. sec.	BT	Color and Performance
2016	1206	40 22 (7)	20 10 10 Ca ₃ (PO ₄) ₂	46	bad flaming
2149	1753	40 22 (7)	20 10 10 Ca ₃ (PO ₄) ₂	40	7R 5.5/10 † fading
2149	1753	40 22 (7)	20 10 10 Ca ₃ (PO ₄) ₂	31	7R 5.5/10. discs flaming
2149	1754	40 24 (7)	20 10 10 Ca ₃ (PO ₄) ₂	35	7R 5.5/12, fading
2149	1754	40 24 (7)	20 10 10 Ca ₃ (PO ₄) ₂	47	7R 5.5/12 fading
2149	1788	60 20	20 10 10 Ca ₃ (PO ₄) ₂	91	7R 6/10 †. turning paler
2149	1789	50 20 (7)	20 10 10 Ca ₃ (PO ₄) ₂	62	7R 6/10 †
2016	1049	40 20 (7)	20 10 10 Ca ₃ (PO ₄) ₂	52	Slightly pale, no fading
2016	1053	40 20 (7)	20 10 3 Na ₂ CO ₃	56	Excellent color at first, bad fading last 15 sec.
2016	1185	40 18 (7)	20 10 5 KHCO ₃	60	7R 5/14
2016	1201	40 18 (7)	20 10 3 Urea 10 Ca ₃ (PO ₄) ₂	64	7R 5/12-14, no fading
2016	1205	40 20 (7)	20 10 5 Urea 10 Ca ₃ (PO ₄) ₂	55	bad flaming
2149	1475	40 18 (7)	20 10 5 Urea 10 Ca ₃ (PO ₄) ₂	88	4.5 R 5/12 †
2149	1688	40 20 (7)	20 10 3 MgSO ₄ (15) 10 Ca ₃ (PO ₄) ₂	55	7R 5/14, fading

15. Epsom Salt

16. Guanidine Nitrate

TABLE 2

Experiments in Which Other Samples Than Signal Red and Oil Scarlet Were Used

Note-book	Expt. No.	Source	Dye	KClO ₃	Composition (1) (parts by wt)	Sucrose	NH ₄ SO ₃ NH ₂	Cs ₃ (PO ₄) ₂	BT sec.	Color and Performance
2149	1495	R (2)	40	18	20	20	10	10	60	7R 5/12 †, slight fading
2149	1495	R	40	18	20	20	10	10	68	6R 5/12 †
2149	1512	R	40	20	20	20	10	10	58	6R 6/10 †
2149	1512	R (3)	40	20	20	20	10	10	120	7R 5/10 †
2149	1518	X	40	20	20	20	10	10	137	7R 6/10 †
2149	1520	X (4)	40	20	20	20	10	10	132	7R 5.5/10 † flaming
2149	1533	G	40	20	20	20	10	10	60	7R 5/14, good volume
2149	1533	G	40	20	20	20	10	10	34	7R 5/14, slight flaming
2149	1601	G	40	20	20	20	10	10	69	6R 5.5/10 † discs (5) flaming
2149	1601	G	40	20	20	20	10	10	71	pale color "
2149	1660	G	40	20	20	20	10	10	58	7R 5/14 fading discs
2149	1660	G	40	20	20	20	10	10	66	7R 5/12 † " " Volume good
2149	1660	G	40	20	20	20	10	10	22	7R 5/14 --- "
2149	1691	G	40	20	20	20	10	10	37	7R 5.5/12 †
2199	1691	G	40	20	20	20	10	10	59	7R 5/14 fading
2149	1692	G	40	20	20	20	10	10	38	7R 5.5/12 flaming
2149	1692	G	40	20	20	20	10	10	94	----- flaming

1. Micropulverized
2. Reichold Chemicals
3. H. Kohnstamm and Co.
4. General Dyestuff Corp.
5. See Table 1, Note 6

TABLE 3

Compositions for M18 Grenade in which other dyes were added to alter the hue of the smoke

Note-book	Expt. No.	Composition (parts by wt.) CH 113 (1) / Other Dye	XClO ₃	Sucrose	Cooler	BT sec.	Color and Performance
1185	3/20-1	20 Red AlOO	(2) 29.5	11.5 S(3)	19 NaHCO ₃	-	M16 (4), poor color
1083	P. 19	25 Red AlOO	21.6	8.4 S	20 NaHCO ₃	197	M16, flamed 30 sec., good red color
1185	3/22-2	30 Red AlOO	20	20 L (5)	--	165	M16, burning OK
2016	1014	4 Red AlOO	20	20	10 NH ₄ SO ₃	58	6R 5/12 (6), good color except slight fading at last
					NH ₂		
					10 Kaolin		
1782	4/29-11	27 Rosindone	(7) 23	23	--	57	color pale, fading
2016	6/16-5	10 Rosindone	20(8)	20	10 NH ₄ SO ₃		
					NH ₂	51	flaming, color pale, fading
					10 Kaolin		
1782	5/1-1	25 O11 Red	(9) 25	25	--	60	flaming after 20 sec., color pale, bad decolorisation
2016	1004	6.7 Oranger	(10) 20	20	10 NH ₄ SO ₃	66	7.5R5/12, Color slightly pale, dull, fading at last
					NH ₂		
					10 Kaolin		
2016	1044	8 Rhodamine	18(11)	20	10 NH ₄ SO ₃	30	3 - 4R, flaming
					NH ₂		
					10 Ca ₃ (PO ₄) ₂		
2016	1062	8 Rhodamine	20(11)	20	10 NH ₄ SO ₃	39	flaming, color rather pale
					NH ₂		
					10 Ca ₃ (PO ₄) ₂		
					3 Urea		
2016	1063	7 Rhodamine	20(11)	20	20 (NH ₄) ₂ SO ₃	50	good volume, Color rather pale, fading
					10 Ca ₃ (PO ₄) ₂		
2149	1476	8 Rhodamine	18	20	10NH ₄ SO ₃	58	5R5 t/12 +, fading
					10 Ca ₃ (PO ₄) ₂		

TABLE 3 (CONT'D)

Note-book	Expt. No.	Composition (parts by wt.) CI 113 Other Dye	KClO ₃	Sucrose	Cooler	BT sec.	Color and Performance
2149	1476	32 8 Rhodamine	18	20	10 NH ₄ SO ₃ NH ₂ 10 Ca ₃ (PO ₄) ₂	59	5R 5 +/12, †, fading
2149	1477	32 8 Rhodamine	18	20	10 NH ₄ SO ₃ NH ₂ 10 Ca ₃ (PO ₄) ₂ 3 Epsom Salt	67	5R 5.5/10 †, fading
2149	1477	32 8 Rhodamine	18	20	10 NH ₄ SO ₃ NH ₂ 10 Ca ₃ (PO ₄) ₂ 3 Epsom Salt	68	5R 5 +/12, fading

1. 2-anisole-azo-beta-naphthol
2. 1-methyl amino anthraquinone, CWS Specification No. 196-111-78
3. Sulfur
4. Grenade, Sacks, Colored, M16
5. Lactose
6. Munsell Color Notation
7. 9-diethyl amino rosindone, CWS Specification No. 196-111-100
8. See Note 2, Table 1
9. o-toluene-azo-o-toluene-azo-beta-naphthol
10. alpha-amino anthraquinone, CWS Specification No. 196-111-97
11. Micropulverized

TABLE 3 (CONT'D)

Note-book	Expt. No.	CI 113	Composition (parts by wt.) Other Dye	K ₂ O ₃	Sucrose	Cooler	RT sec.	Color and Performance
1185	6/4-6	21	21 Indigo	21.6	8.4 (3)	28 KHCO ₃	165	ML6(4), no flaming, color thin, poor, pink
2016	6/14-10	33.3	15.7 Indigo	25 (8)	20	25 (NH ₄) ₂ SO ₃	45	4R6/11 (6)
2016	6/14-11	32	3 Indigo	25 (8)	20	25 (NH ₄) ₂ SO ₃	46	5R6/10, color pale, no fading
2016	6/15-8	36.7	3.3 Indigo	20	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	71	color dull, pale, variable
2016	1023	32	8 Blue 2B (12)	20	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	53	color dull, slightly pale and variable
2016	6/15-7	33.3	1.7 Blue B (13)	20 (8)	20	25 (NH ₄) ₂ SO ₃	81	6R6/11, color good
2016	6/16-2	36.7	3.3 Blue B	20	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	37	6R5/11, duller without Blue B
2016	6/16-10	33.3	6.7 Blue B	20 (8)	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	55	4.5R4/6, dull reddish-brown, fading at last
2016	6/16-11	33.3	6.7 Blue MA (14)	20 (8)	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	57	dull, reddish-brown, pale, fading
2016	6/16-3	36.7	3.3 Green B (15)	20	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	39	6R6/9, pale fading
2016	6/16-4	36.7	3.3 Leuco-Violet (16)	20	20	10 NH ₄ SO ₃ NH ₂ 10 Kaolin	41	5.5R6/10, pale
2016	1040	32	8 Violet 2 (17)	20 (11)	20	10 NH ₄ SO ₃ NH ₂ 10 Ca ₃ (PO ₄) ₂	28	8R5/10, no fading
2016	1224	40	5 Mon. Blue (18)	18	20	10 NH ₄ SO ₃ NH ₂ 10 Ca ₃ (PO ₄) ₂	81	color pale, flaming

12. 5,7,5', 7'-tetrabrom indigo
13. 1,4-dimethylamino anthraquinone, CWS Specification No. 196-111-101
14. 1,4-di-n-amyldimino anthraquinone
15. 1,4-di-p-toluidino anthraquinone, CWS Specification No. 196-111-80
16. 1,4-diamino-2,3-dihydro anthraquinone, CWS Specification No. 196-111-81
17. p chlorbenzene-azo-alpha-naphthylamine + 3% Indigo
18. Monastral Fast Blue, a phthalocyanine

TABLE 4 Part I

Compositions for M16 Grenade containing dyes similar in structure to 2-anisole-azo-beta-naphthol

Note- beck	Expt. No.	Dye	Composition (parts by wt.) Dye KClO ₃ Saltp. NaHCO ₃ etc.	ET sec.	Color and Performance
1083	p. 14	777 (1)	41 19.5 14.5 26	--	very light pink color, poor burning, very slow
1083	p. 14	777	38 17.9 14.1 30	--	light pink color, poor burning, very slow
1083	p. 7	760 (2)	42 21.6 8.4 28	180	color light red, variable, burning even
1083	p. 8	760	45 19.4 9.6 28	217	flaming, poor volume, color light, variable, burning uneven
988	p. 71	719 (3)	60 21.6 8.4 10 NH ₄ Cl	180	bluer than 1-methyl amino anthraquinone, evolution of smoke good, flamed
988	p. 71	719	70 16.2 6.3 7.5 NH ₄ Cl	--	good color, slightly blue, flamed after 20 sec.
988	p. 73	719	65 16.2 6.3 12.5 NH ₄ Cl	--	color pink to red
988	p. 73	719	60 21.6 8.4 10 NH ₄ Cl	180	color almost as good as 1-methyl amino anthraquinone, flaming after 30 sec.
988	p. 95	719	42 21.6 8.4 28	--	fairly good evolution of bluish-red smoke
988	p. 95	719	42 21.6 8.4 28	175	good color, very good evolution of blue-red smoke
988	p. 95	719	40 25.2 9.8 25	150	very good volume, good color, slight flaming
988	p. 96	719	35 25.2 9.8 30	145	good evolution of blue-red smoke, no flaming, some decomposition, not as good as 1-methyl amino anthraquinone or Rhodamine
1083	p. 10	787 (4)	55 21.6 8.4 15	--	color pink to red, slightly blue, good volume
1083	p. 10	788 (5)	55 21.6 8.4 15	--	flamed, poor color
1083	p. 10	789 (6)	55 21.6 8.4 28	--	flamed, color poor
988	p. 116	773 (7)	42 21.6 8.4 28	--	color blue-red, considerable decomposition
988	p. 115	762 (8)	42 21.6 8.4 28	--	poor, dirty orange color, volume good
988	p. 115	771 (9)	42 21.6 8.4 28	--	good evolution of blue-red smoke
988	p. 116	771	31.8 21.6 8.4 28 4.2 Aursamine	--	fairly good red color
1085	p. 19	771	50 19.6 15.4 15	195	good volume, flamed after 15 sec.

1. 4-anisole-azo-beta-naphthol
2. 4-chlor-2-anisole-azo-beta-naphthol
3. 2,5-dimethoxybenzene-azo-beta-naphthol
4. 719 containing ammonium sulfamate
5. 719 containing 50% camphor
6. 719 containing 20% camphor
7. 4-chlor-2,5-dimethoxybenzene-azo-beta-naphthol
8. 2,5-dimethoxybenzene-azo-beta-naphthylamine
9. 2,5-dimethoxybenzene-azo-beta-naphthol

TABLE 4 Part 2

Compositions for M18 Grenade Containing Dyes Similar in Structure to 2-anisole-azo-beta-naphthol

Note-book	Expt. No.	Dye	Composition (Parts by wt.)			BT sec.	Color and Performance
			Dye	KClO ₃	Sucrose NH ₄ SC ₃ NH ₂ Ca ₃ (PO ₄) ₂		
2149	1515	719	40	20	20	10	3R5.5/10 † fading flaming
2149	1522	719	40	20	20	5	2.5R5.5/10 † discs (11) no flaming
1782	4/25-12	61101 (12)	50	25	25	---	2-3 R. initially good, then fades
2016	1141	61101	40	20	20	10	6R5/14 †
2016	1251	61101	40	20	20	10	5R 5/14 Flaming
2016	1259	61101	40	20	20	10	6R5/14
2016	1266	61101	40 (13)	20	20	10	5R5/14, slight fading
2016	1266	61101	40 (13)	20	20	10	5R5/14, slightly pale
2016	1275	61101	40 (13)	20	20	10	6R5.5/12
2016	1275	61101	40 (13)	20	20	10	5R5.5/10 †
2016	1270	61101	40 (14)	21.5	20	10	5R6/10 † flaming
2016	1270	61101	40 (14)	21.5	20	10	5R5/12-14
2016	1274	61101	40 (14)	18	20	10	5R5.5/12
2016	1274	61101	40 (14)	18	20	10	5R5.5/12
2016	1277	61101	40	17	20	10	5R5/14, slight fading
2016	1277 (15)	61101	40	17	20	10	5R5 †/12, slight fading
2016	1281	61101	40	17	20	10	5R5/12, flaming
2016	1281	61101	40	17	20	10	5R5/10 † flaming
2016	1281	61101	40	17	20	10	bad flaming
2016	1281	61101	40	17	20	10	6R5†/13, fading
2016	1281	61101	40	17	20	10	6R5†/12 "
2016	1281	61101	40	17	20	10	6R5.5/12, flaming
2016	1290	61101	40	17	20	10	5R5/14, some fading
2016	1267	61101	40 (13)	20	20	10	5R5/14, some fading
2016	1271	61101	40 (13)	20	20	10	5R5/12 †
2016	1260	61101	40	20	20	10	6R5/14, slight fading
2016	1285	61101	40	17	20	10	5R5/14
2016	1301	61101	40	17	20	10	5R5/14

TABLE 4 Part 2 (cont'd)

Note-book	Expt. No.	Dye	Composition (parts by wt.)			BT sec.	Color and Performance	
			Dye	KClO ₃	Sucrose			MF ₄ SO ₃ NH ₂ Ca ₃ (PO ₄) ₂
2016	1302	61101	40	14	20	10(19)	37	5R5/12. volume fair, persistency poor 6R5 +/12 + 5R5 +/10 +
2016	1304	61101	50	17	20	10(19)	35	
2016	1283	61101	40	17	20	10	49	

10. Micropulverized

11. See Note 6, Table I

12. 5-methyl -2-anisole-azo-beta-naphthol

13. dye blended with 4% by weight Halomax Oil # 1000

14. dye blended with 4% by weight kerosene

15. tested after 1 and 3 months storage at 65°C.

16. Fullers Earth

17. Kaolin

18. Ammonium Oxalate

19. Ammonium Thiosulfate

TABLE 4 Part 2 (cont'd)

Note-book	Expt. No.	Dye	Composition (parts by wt). Dye KClO ₃ C ₁₂ H ₂₂ O ₁₁	NH ₄ SO ₃ NH ₂	Ca ₃ (PO ₄) ₂	BT sec.	Color and Performance
2016	1347	61102(20)	20	---	---	43	376/10, fading
2016	1323	61102	17	10	10	35	525/13, persistency good
2016	1341	61102	17	10	10	53	525/12 + " "
2016	1367	61102	17	10	10	57	Volume fair 525/12 some fading one burst of flame, 5000 lb. filling pressure. (21)
2016	1379	61102	17	10	10	64	525 4/12, flaming 5000 lb. press.
2016	1386	61102	19	10	10	---	flaming, 5000 lb. pressure.
2016	1386	61102	19	10	10	48	626/10 +, fading, 5000 lb. pressure
2016	1391	61102	17	10	10	60	525.5/12, volume fairly good
2016	1342	61102	15	10	10	80	525/12, pale, volume fair
2016	1348	61102	16	10	10	64	525/14 volume fair
2016	1356	61102	17	10/3 (22)	10	---	flaming
2016	1357	61102	17	10/3 (18)	10	120	flaming
2016	1361	61102	17	10/3 (23)	10	66	525/10 + pale

20. 5-Ethyl-2-Anisole-Azo-Beta-Naphthol

21. 2000# Dead lead filling pressure used in other experiments in this table

22. Ammonium formate

23. NaHCO₃

TABLE 4 Part 2 (continued)

Note-book	Expt. No.	Dye	Composition (parts by wt.) Dye KClO ₃ (10) sucrose	NH ₄ SO ₃ NH ₂	Ca ₃ (PO ₄) ₂	BT sec.	Color and Performance
2016	1345	69007 (24)	60	20	20	56	TR6/10, fading, flaming
2016	1287	69007	60 (13)	20	20	48	TR6 +/12, flaming
2016	1266-A	69007	40 (13)	10	10	52	TR5 +/14
2016	1266-A	69007	40 (13)	10	10	67	TR6/14, slight fading
2016	1312	69007	40 (25)	10	10	43	TR5.5/12
2016	1322	69007	40	10	10 (17)	30	1.5 TR5.5/12
2016	1219	69007	40	10	10 (17)	21	TR4.5/12
2016	1231	69007	40	10	10 (17)	70	TR5/14, some fading, good volume
2016	1267-A	69007	40	10 (19)	10 (17)	56	TR6/12, flaming
2016	1299	69007	60	10	----	36	TR5 +/12 +

24. 4-chlor-2-anisole-azo-beta-naphthol
 25. dye blended with 10% by weight soda ash

TABLE 5

Compositions containing potassium chlorate - sugar as fuel

Note-book	Expt. No.	Dye	Composition (parts by wt.) KClO ₃ Sugar	BT sec.	Munition	Color and Performance
1083	p.75	60 (1)	20 20L (2)	210	M16	flamed, fair red color, some decomposition
1083	p.75	60	20L	200		color good, too much flaming
1083	p.78	60	20L	210		flamed, poor volume, color white to red
"	p.78	60	20L	250		volume small, color good, persistency poor
"	p.85	60	20 (4)	250		hand pressed, good smoke, negligible flaming
"	p.85	60	20 (4)	210		1300 lb. dead load (5)
"	p.85	60	20L	175		1100 lb. dead load, mix micropulverized
"	p.104	60	20L (4)	190	M18	good smoke, mix micropulverized
1185	4/7-3	60	20	97		no flaming, best yet, not comparable with
1185	4/8-5	60	20L (4)	65	M18	1-methyl amino anthraquinone
NR 1232	1/13-38	60	20 (6)	70	105 (7)	flamed a short time, good red cloud, some white in it.
1232	1/13-42	60	20S	75	105	excellent bright cloud
1232	1/13-42	60	20S	295	105	bad flaming last 40 sec.
1232	1/21-55	60	20D (8)	115		filled solid, flamed first 55 sec. then good, slightly pink cloud
1232	1/27-68	60	20D (9)	290		bad flaming
1232	1/27-68A	60	20D (10)	95		20 sec. flaming, color good
1232	1/27-68E	60	20D	90		insufficient mixing, color pale, intermittent flaming
						good mixing, color pale, uneven, intermittent flaming

1. Dye - Signal Red
2. L- Lactose, Technical Milk Sugar
3. M16 unless otherwise indicated
4. Micropulverized
5. total filling pressure, see Par. E-4a, GWS specification No. 196-111-92C
6. S - Sucrose, micropulverized with 3/4 Cornstarch
7. Canister, Smoke, Colored, M2 (for 105 M1. Base Ejection Chemical Shell, M84), GWS Specification 196-131-162A
8. D - Dextrose
9. Sugar damp
10. Sugar anhydrous

TABLE 5 (continued)

Note-book	Expt. No.	Composition Dye	Composition KClO ₃	(parts by wt.) Sugar	BT sec.	Mani-tion	Color and Performance
1232	1/27-68G	60	20	20D	112		
1232	1/27-68D	60	20	20D	118		mix micropulverized, color very bad
1232	1/4-19	66	20	14S	85	75 (11)	dye not micropulverized, also bad
1083	P. 75	60	22	18L	150		slow starting, good cloud
							volume good, color good at first, flamed after 100 sec.
1083	P. 99	56	22	22D	175		surging. color variable, fair to good
1232	1/22-57	55 (12)	22.5	22.5	240	105 (7)	filled solid, bad flaming
1582	11/10-10	46 (12)	24	30L (10)	50	M18	discs (13), color variable, no flaming
1232	2/1-82	62	19	19L (10)	185		color good, but variable
1083	P. 104	60	19	19L	210		mix micropulverized, good smoke, smooth burning
				2 Sulfur			
1083	P. 105	69	19.8	6.6L	120		mix micropulverized, good color, flamed 60 sec.
				4.4 Sulfur			after first 30 sec.
1083	P. 105	70.6	20.3	6.7L	140		mix micropulverized, flamed 60 sec.
				2.4 Sulfur			color good when not flaming
1782	4/7-4	55 (12)	20	10S			color pale, bad after 25 sec.
				15 Tall Oil (14)			color pale, bad after 25 sec.

11. Canister, Smoke, Colored, M2 (for 75 mm. Base Ejection Chemical Shell, T19), CWS Specification No. 196-111-223

12. Dye - Oil Scarlet OEH

13. smoke filling insulated from ends of grenade body by asbestos discs

14. Tall Oil, a by-product of the sulfite pulp industry, has the following approximate composition:

Resin Acids 47 - 50%, Fatty Acids 43 - 47%, Unsataponifiable Material 5 - 8%

TABLE 5 (continued)

Note-book	Expt. No.	Composition Dye	Composition KClO ₃	Sugar	Cooler	BT sec.	Munition	Color and Performance
1083	P. 75	50	24	16L	10NaHCO ₃	200		caught fire after 80 sec.
1232	1/25-61	60	18	18S	4 "	110	105(7)	color pale
1582	11/10-11	46	(12)	25L	9 "	74	M18	surging, no flaming, much white smoke
					6.7 Shorts (15)			
1782	4/27-6	35	(12)	25S	15 KHC0 ₃	52	M18	color fair to poor
1782	4/10-2	45	(12)	25S	5 "	42	M18	no flaming, bad decolorisation
1185	5/12-5	50	(12)	20L	10 MgCO ₃	90		flamed badly, much white smoke
1185	5/12-4	50	(12)	20L	10 CaSO ₄	55		no flaming, but fading
1185	5/12-3	50	(12)	20L	10 CaSO ₄ ·2H ₂ O	660		slight flaming, excellent red cloud
1185	5/14-3	50	(12)	20L	10 CaSO ₄ ·2H ₂ O	60		large volume of red smoke, too much white in it
1185	6/11-1	50	(12)	20L	10 "	120		flamed badly
1185	5/15-2	50	(12)	15L	10 "	50		bad flaming, mostly white smoke
1185	5/15-3	45	(12)	20L	10 "	50		much white smoke
1185	5/5-1	47	20	15L	18 GK(16)	-		flamed badly
1185	5/6-1	54	18	18L	10 Sil-o-Cel	-		bad flaming, practically no red smoke
1782	4/10-1	45	(12)	25S	5 Bicelite(17)	55	M18	flaming first 20 sec., bad decolorization
1232	1/27-67	45	15	15L	25 Iron filings	360		fair cloud, color slightly pale
2016	6/12-6	40	25	25S	10 C ₂ Cl ₆	35		color pale, fading
1185	4/23-1	40	20	20L	13 Dextrine	175	M18	bad flaming
					7 (NH ₄) ₂ SO ₄			
1185	3/27-1	36	20	20L	9.6 Dextrine	300		flamed badly, poor volume
					10.2 (NH ₄) ₂ SO ₄			
					4.2 B-Naphthol			
1185	4/28-2a	33.6	20	20L	13.2 Dextrine	210		slight flaming, color good
					7.2 (NH ₄) ₂ SO ₄			
					6.0 B-Naphthol			
1185	4/28-2b	33.6	20	20L	13.2 Dextrine	210		bad flaming
					7.2 (NH ₄) ₂ SO ₄			
					6.0 B-Naphthol			
					2.0 Shorts (15)			

15. Johns Manville Asbestos Shorts #352

16. Guanidine Nitrate

17. a kind of siliceous earth

TABLE 5 (continued)

Note-book	Expt. No.	Composition (parts by wt.)		Cooler	BT sec.	Munition	Color and Performance
		Dye	KClO ₃ Sugar				
1231	1/13 p.25	58	20	20S	--	GS(18)	bad flaming for 20 sec., good smoke when not flaming
1231	1/19 p.27	58	20	20S	42	GS	good color
1185	11/29-11	45	23	23L	180		good vol of red smoke slightly tinged with white
2016	6/9-5	35	25	20S	105	M18	color pale, slight fading
2016	6/9-10	40	25	25S	96	M18	color, dull, pale, fading

16. Signal, Ground, Parachute, M17

TABLE 6

Compositions containing a mixture of 72% $KClO_3$ - 28% Sulfur as fuel

Note-book	Expt. No.	Compositions (parts by wt.) Dye $KClO_3$ S	Cooler	BT (1) sec.	Muni- (2) tion	Color and Performance
1083	P. 77	(3) 60	--	--	M16	vigorous flaming
1083	P. 77	(3) 55	--	--	"	"
1083	P. 77	(3) 60	--	--	"	flamed extensively
1083	P. 77	(3) 70	--	10 min.	M18 (5)	slight flaming at last
1185	6/2-7	(4) 42	28 $NaHCO_3$	220	"	good color, flamed at start
1185	6/2-9	42	28 "	310	"	color pink, transparent,
1185	6/2-6	42	28 "	240	"	burning sporadic
TDMR 497		45	28 "	--	"	pinkish color, good volume, flamed
988	P. 109	(6) 40	30	--	"	pink color, some decomposition
1083	P. 11	(6) 42	28 "	185	"	good cloud, pink color, burning
1185	5/31-3	42	28 "	240	"	slightly uneven, slight sparking
1185	6/2-10	(3) 42	28 "	270	"	color fair, too white, no flaming
1185	6/3-1	42	28 "	270	"	color pinkish, no flaming
1185	6/3-5	42	28 "	210	"	color pinkish, too white, no flaming
1185	6/2-8	42	28 "	92	M18	color too pinkish, slight flaming at last
1185	6/3-2	42	28 "	92	M18	color pinkish, no flaming
1782	4/7-6	40	28 "	55	M18	no flaming, bad fading, 2.36/6(7)
1083	P. 21	(6) 34	33	90	"	good color at first, later turning white grenade $\frac{1}{2}$ full
1083	P. 75	(3) 38	28	215	"	color good in spots, extensive decomposition
1083	P. 75	(3) 40	20	145	"	good only in parts, appreciable decomposition
1185	6/2-5	42	18 "	170	"	some decolorization, slight flaming
1232	7/21-3	42	20 $NaHCO_3$ 3 $MgCO_3$	95	"	flamed some, color pink

TABLE 6 (continued)

Note-book	Expt. No.	Dye	Composition (parts by wt.) KClO ₃ S	Cooler	BT(1) sec.	Munition (2)	Color and Performance
1232	7/21-8	42	21.6 8.4	20 NaHCO ₃ 2 MgO	120		flamed, partially decolorized
1185	5/3-4	42	21.6 8.4	28 NaHCO ₃ 2 Lactose	170		no flaming, color pink

1. Burning Time
2. Grenade, Smoke, Colored, M16, CWS Specification No. 196-111-61, unless otherwise indicated
3. Dye - Signal Red B
4. Dye - Oil Scarlet OBN, unless otherwise indicated
5. Grenade, Smoke, Colored, M18, CWS Specification No. 196-111-92
6. Dye - AD 779
7. Munsell Coordinates

TABLE 6 (continued)

Test No.	Expt. No.	Dye	Composition (parts by wt.) KClO ₃	8	Cooler	HT sec.	Munition	Color and Performance
1083	P. 78	50 (3)	18	7	25 NHCO ₃	240		poor volume, flamed, intermixture of pink and white smoke
1083	P. 78	50 (8)	18	7	25 "	260		small volume, color white and red
1185	6/5-6	42	19.4	7.6	31 "	137		no flaming, good smoke
1083	P. 78	47 (3)	20.2	7.8	25 "	180		caught fire
1185	6/3-3	42	21.6	8.4	28 "	190		color better than with NaHCO ₃ , slight flaming
1185	6/3-7	42	21.6	8.4	28 "	120		no flaming or fading, orange-red color, best yet
1232	6/7-3	42	21.6	8.4	28 " (9)	135		good red cloud, no flaming
1582	9/11-2	42	21.6	8.4	28 "	45		good orange-red cloud, hand pressed
1582	9/10-4	42 (10)	21.6	8.4	28 "	45		color fair, hand pressed
1582	9/10-1	42	21.6	8.4	28 "	100		bad flaming, color bad, hand pressed
1582	9/10-2	42	21.6	8.4	28 "	58		4000 lb. Dead Load (11), no good
1582	9/8-5	42	21.6	8.4	28 "	37	M18	slight flaming, pretty good color, but variable
1582	11/4-2	42	21.6	8.4	28 "	660	M18	color good but variable, no flaming
1232	6/14-3	42	21.6	8.4	28 "	125	T8 (12)	poor color
1582	9/8-5	42	21.6	8.4	28 "	21	75 mm (13)	no flaming, color variable, considerable white smoke
1185	6/5-1	50	21.6	8.4	20 "	127		slight flaming, good red smoke
1083	P. 77	50	21.6	8.4	20 "	--		good color and volume, flamed discs (14), slight flaming
1582	11/11-1	50	21.6	8.4	20 "	72	M18	too much white smoke

8. Dye - Signal Red A

9. Micropulverized

10. containing 4% by weight Oil, Petroleum, CWS Specification, No. 196-131-168

11. total filling pressure, see Par. E-4a, CWS Specification No. 196-111-920

12. 60 mm. Mortar Shell, T8, Ord. Drawing No. GA 2204

13. Canister, Smoke, Colored, M2 (for 75 mm. Base Ejection Chemical Shell, T19), CWS Specification No. 196-111-223

14. Smoke filling insulated from ends of grenade body with asbestos discs

TABLE 6 (continued)

Note-book	Expt. No.	Dye	Composition (parts by wt.) KClO ₃ S	Cooler	BT sec.	Munition	Color and Performance
1782	4/8-1	40	23 9	20 KHCO ₃	85	M18	no flaming, complete decolorization
1782	4/27-4	40	23 9	20 "	128		no flaming, color fair red to white
1983	9. 77	45 (3)	25.2 9.8	20 "	85		some flaming, good evolution of red smoke
1185	6/4-5	50	25.2 9.8	15 "	101		some flaming, color pale, good volume
1185	6/4-4	42	20.8 11.2	18 "	90		color not good, no flaming
1232	6/16-1	42	21.6 8.4	30 Na ₂ CO ₃ 10 "	210		slight flaming and decolorization
1232	6/18-2	42	21.6 8.4	18 "	195		good color, considerable flaming
1185	6/3-5	40	21.6 8.4	10 LiCO ₃ 25 KHCO ₃ 5 Lactose	120		no flaming, good volume, good orange-red color, no white smoke, burning even
1582	11/11-6	42	20.1 4.0	30 KHCO ₃ 3.9 Lactose	73	M18	no flaming, too much white smoke
1232	6/18-1	42	21.6 8.4	28 LiCO ₃	175		flamed
1232	6/17-5	42	21.6 8.4	28 Na ₂ CO ₃	110		flaming and decolorization
1232	7/7-7	42	21.6 8.4	28 Urea	13 min.		good color, slight flaming
1782	5/6-7	36.7 (8)	30 11.7	Crystals 22 Armon.	43	M18	3R6/10, 3 sec. flaming, volume fair
2016	6/9-6	36.7 (8)	30 11.7	Sulfite 21.7 Armon. Sulfanate	-	M18	bad flaming, very pale

TABLE 7

Compositions containing a fuel mixture consisting of $KClO_3$ and excess sulfur

Note-book	Expt. No.	Dye	Composition ($KClO_3$ S)	Parts by wt.	Cooler	BT sec.	Munition	Color and Performance
1083	p. 11	42 (1)	17.3	12.7	28 $NaHCO_3$	240	M16	good pinkish-red color, slight decomposition
"	p. 11	50	23	17	10 "	77		Good red color but flamed badly
"	p. 12	50	19.6	15.4	15 "	135		Good red color, good evolution of smoke, flaming after 14 sec.
"	p. 13	55	19.6	15.4	10 "	147		flaming
"	p. 16	48	19.6	15.4	17 "	175		flamed
"	p. 13	45	18.5	14.5	22 "	200		Good smoke, irregular evolution, flaming at beginning
"	p. 13	47	17.4	13.6	22 "	215		good smoke, flaming after 130 sec.
"	p. 15	40	17.9	14.1	28 "	9 1/2 min.		light pink color
"	p. 15	38	17.9	14.1	30 "	335		color fair at times, light pink
"	p. 17	30	19	15	30 "	255		mostly white smoke
"	p. 17	32	21.3	16.7	30 "	385		mostly white smoke
"	p. 16	51.2	20.5	16.1	6.1 $NaHCO_3$ 6.1 Arnon.	-		flamed
"	p. 15	38	20.5	11.5	Sulfamate	195		light pink color, fair at times
"	p. 16	34	21.8	12.2	30 $NaHCO_3$	220		--
"	p. 17	35	22.4	12.6	32 "	180		Little red, the lots of white smoke
"	p. 17	32	21.3	13.7	30 "	195		all white smoke after 60 sec.

- Dye - AD 779 (duPont) Grenade
- Assumed to be M16 unless otherwise indicated

Submitted:

W P Munro

W. P. MUNRO
Captain, CWS

Supervised:

J. C. Driskell

J. C. DRISKELL
Captain, CWS
Chief, Smokes Branch

Approved:

C. B. Drennon, Jr.

C. B. DRENNON, JR.
Lt. Colonel, CWS
Chief, Pyrotechnics Division

J. H. Guion

T. H. GUION *
Captain, CWS

* Author

S. J. Magram
S. J. MAGRAM

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Notesbook No.	988	1232
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	1185	1782
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