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SAFETY EVALUATION OF DISTRESS FLARES AND SMOKES.(U)

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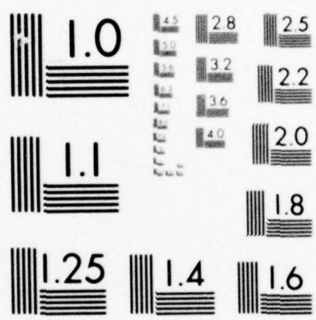

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Report No. CG-D-89-77

SAFETY EVALUATION OF DISTRESS FLARES AND SMOKES

EDWARD T. McHALE

NOVEMBER 1977
FINAL REPORT

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16. Abstract

An evaluation program was conducted for the purpose of uncovering any safety hazards that might be associated with the use of distress flares and smokes, particularly those hazards that would pertain to the use of the devices by the public on recreational boats. Devices tested included hand-held flares and smokes, self-contained and pistol-launched meteors and parachute flares, and floating smokes. Testing was performed to assess hazards of: spattering and slag dripping on personnel, on materials, and on ignition of exposed liquid fuel; toxicity of smoke or other combustion products; heatup of casing or hardware parts; recoil from self-contained or pistol-fired flares. Additionally, several performance criteria were analyzed: burn time, intensity, effect of aging, failure rate, ease of use, and altitude attained by launched flares. The principal safety problems that were exposed involved: 1) the tendency of slag to drip from hand-held flares and to ignite many types of materials that it falls onto; 2) possible toxicity of products of orange smokes; 3) excessive failure and significant recoil of certain pistol-fired parachute flares. The overall failure rate of all units tested in the course of the project was six percent (not counting pistol-fired parachute flares).

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METRIC CONVERSION FACTORS

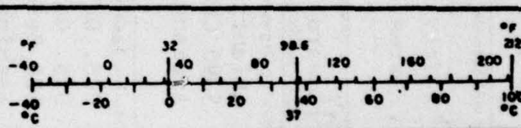
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The present program was conducted for the purpose of uncovering any safety hazards that might be associated with the use of distress flares and smokes. Devices tested included hand-held flares and smokes, self-contained and pistol-launched meteors and parachute flares, and floating smokes. In the course of the program, many performance characteristics of the distress signals were also measured, although emphasis was placed on hazards, particularly those that would pertain to the use of the devices by the public on recreational boats.

The evaluation study was to be in large part directed to qualitative effects, observations and impressions during the testing. Quantitative technical data were also required in some cases. Motion pictures and still photographs were taken of many tests. The testing that was performed to assess hazards of hand-held and aerial devices included: spattering and slag dripping on personnel, on materials such as clothing, surface finishes, plastics, etc., and on ignition of exposed liquid fuel; toxicity of smoke or other combustion products; singe or burn of operator due to heatup of casing or hardware parts; recoil from self-contained or pistol-fired flares. Additionally, the types of performance criteria that were analyzed in the course of the study included: burn time, intensity, effect of aging, failure rate, ease of use, and altitude attained by launched flares.

The principal safety problems that were exposed in the present study involved: 1) the tendency of slag to drip from hand-held flares and to ignite many types of materials that it falls onto; 2) possible toxicity of products of orange smokes; 3) excessive failure and significant recoil of certain pistol-fired parachute flares. The overall failure rate of all units tested in the course of the project was six percent (not counting pistol-fired parachute flares).

The results are presented in two ways in the following sections of the report. An overall summary is given in the next section, followed by a detailed description of tests and results in Section 3.0.

2.0 GENERAL DESCRIPTION OF FINDINGS

A descriptive summary of the project results, omitting detailed data, is presented in this section. For reference purposes, a listing of the types of devices and tests that were to be performed is presented in Table I of the appendix. Also, a tabulation of the types and quantities of the signal devices received from the Coast Guard is given in Table II. A number of motion pictures (and still photos) were taken in the course of the testing, and those that turned out satisfactorily are logged in Table III.

All devices tested appeared to be satisfactory as far as serving the purpose of providing a recognizable signal that would attract attention. However, this is based on observations made at close range (50-100 yards); no observations were made at far distances (e.g., one mile or more). The smokes could only be used in daytime; the brighter aerial flares (20,000 and 100,000 candlepower) could be used in daylight or at night; the 500 candlepower flares would be satisfactory at night but might not be very conspicuous during the day. Some are better than others in performance, there were some safety problems uncovered, and of course the devices have to ignite in order to provide a signal. Overall, for over 100 units tested the failure rate was approximately six percent (not counting one type of parachute flare which had an extremely high failure rate). The following main safety items are summarized:

I. Hand-held Flares and Smokes

In general, the smokes produced no safety hazard. The devices will not cause fires or ignite materials or liquid fuels even on direct contact. There might be a cosmetic problem (staining) if the smoke wafted onto certain finished material on a boat. Wind shift can cause the smoke to reverse direction, which sometimes can be annoying to the operator. The active agents in the smoke formulation (p-nitroaniline and orange oil 7078V) have significant toxicological ratings, but this is not a major problem for the expected exposure scenario (single exposure for short time).

There is a serious problem associated with the hand-held flares in that slag (sometimes copious amounts) continuously is ejected or drips out of the casing. This hot slag has been shown to be able to ignite almost all of the test materials: floor covering, paper, cloth, wood, fuel, etc. There is no direct hazard to personnel if they avoid the slag, although some spattering of fine particles can cause stinging of the skin or mar clothing. The Smith and Wesson flares produced less slag than the other brands tested. The combustion products of the red flares do not represent a toxicity hazard in the intended application.

It is noted that with both the flares and the smokes, the printing on the labels could be easier to read, and also the plastic bag in which they are enclosed could be easier to open (exception is the Smith and Wesson devices, with which there were no problems). The Smith and Wesson bag had a V-shaped notch at one end which did not interfere with the sealing but allowed the operator to easily rip open the plastic. Printing was not obscured by paraffin or sealing tape on the labels.

II. <u>Self-Contained Meteors and Parachute Flares</u>

The meteors were rated for nominal 200 feet altitude - one type exceeded this rating and the other type averaged 83% of it. The parachute devices were rated for 1200 feet altitude and all tested units exceeded the specification. The only safety item of significance was an incident with one (of 12) of the high altitude devices in which the unit failed to travel vertically after launch and instead flew horizontally for about 100 feet and then impacted on the ground.

III. <u>Pistol-Fired Meteors and Parachute Flares</u>

Three types were tested: 25mm Meteor; 25mm Parachute; and 12 gauge Meteor. All were rated for 200 feet altitude and actual measured altitudes varied widely as given in the following sections of this report. The following problems were found. Recoil was significant: The meteor flares produced a moderate jolt when held with one hand by a strong adult. The parachute flares produced substantially more recoil and definitely should be held firmly with both hands. The failure rate for the parachute flares was excessively high. Of 12 units tested, all ejected from the gun, however, the flare did not ignite in one case, and in 8 others the parachutes did not open. Three of 12 performed satisfactorily.

IV. Floating Smoke

Essentially the same remarks apply as made above for the hand-held smokes. In general, the smokes produced no safety hazard. The devices will not cause fires or ignite materials or liquid fuels even on direct contact. There might be a cosmetic problem (staining) if the smoke wafted onto certain finished material on a boat. Wind shift can cause the smoke to reverse direction, which sometimes can be annoying to the operator. The active agents in the smoke formulation (p-nitroaniline and orange oil 7078V) have significant toxicological ratings, but this is not a major problem for the expected exposure scenario (single exposure for short time).

V. Aged Pyrotechnics

Several 3 to 4 year-old hand-held red flares were tested to evaluate their performance and safety after aging. The visible light emission was found to be reduced as compared to new units, but still within the 500 candlepower rating. It appeared that slightly more slag was produced with the older flares, although this was not measured quantitatively. No other differences between new and aged devices was found.

3.0 EXPERIMENTAL TESTS AND RESULTS

In this section, details of the testing and the results are presented for all devices tested. The categories previously used, numbered I through V, will be continued.

I. Hand-held Red Flares and Orange Smokes

1. FLARES: Manufacturers tested: Smith and Wesson
Kilgore
Bristol (some)

A. Heat at Handle. These devices have wooden handles which do not get at all warm during the entire burning of a flare.

B. Heat at Head and Along Casing. As the pyrotechnic composition burns inside the casing, the casing itself burns away. In order to measure the temperature along the casing, fine Chromel-Alumel thermocouples were taped near the center on the outside and the temperature rise recorded as the burning surface approached the couple. The best way to present the data is to list the temperature values that were measured one inch and two inches below the burning surface, and also the final readings before the thermocouple melted or broke as the surface reached it.

	Smith and Wesson	Kilgore
Temperature on casing two inches from burning surface	105°F	100°F
One inch from surface	250°F	335°F
Final temperature recorded as thermocouple failed	1250°F	1375°F

So long as an operator does not put his hand to within about an inch of the burning surface (which a person would not tend to do), there is no hazard from the heat of the casing.

C. Effect of Slag Dripping on Liquid Fuels. The flare devices produce large amounts of slag. The slag is discharged from the device in two forms: 1) small incandescent particles are ejected as the flare burns; and 2) large globules of residue tend to accumulate inside the casing and periodically fall out in the form of hot molten mass. The globules of slag are the more hazardous and were found to be able to ignite fuel and other materials (see below). The small ejected particles never ignited fuel and only caused small char spots on materials.

The fuel ignition tests were performed using both heptane and diesel fuel. A square trough, 3' x 3' x 9" deep, was filled with liquid fuel to a depth of approximately one-quarter inch. Hand-held flares were held (remotely) horizontally at 3' and 6' heights above the level of the fuel, and the slag or particles allowed to drop into the liquid.

Results: Neither the Smith and Wesson nor the Kilgore flares ignited deisel fuel at either height. Kilgore flares ignited heptane at both 3' and 6' heights. Smith and Wesson flares did not ignite heptane in any tests at either height. It was observed that fuel ignition occurred when large globules of slag dropped into the liquid, rather than when small particles fell into it. Smith and Wesson flares produce some but much less slag than the Kilgore (or Bristol, see V below) flares. However, even though the Smith and Wesson flares failed to ignite heptane in these tests, it would not be a safe assumption that ignition could never occur.

D. Effect of Slag Dripping on Materials. Flares were held in a horizontal position, three feet above samples of various materials, so that slag would fall onto the surface of the samples. The following results were obtained:

Material	Smith and Wesson	Kilgore
Cardboard	Ignition	Quickly Ignited
Newspaper	Ignition	Ignition
Carpeting (Indoor/Outdoor)	Ignition	Quickly Ignited
Clothing (Polyester-Cotton Blend)	Charring but No Ignition	Ignition
Canvas	Charred and Smoldered	Ignition
Vinyl Sheeting	Charred Only	Charred Only
Fiberglass Reinforced Polyester	Slight Charring	Charred
Unfinished Wood	Charred	Charred Badly
Varnished Wood	Charred	Charred
Painted Wood	Charred	Charred

By ignition it is meant that the slag initiated burning of the material, which then continued to propagate as a fire.

It is apparent that slag from the hand-held flares can ignite a variety of materials upon contact. Photographs illustrating the results of some of these tests are presented in Figures 1 - 3 of the appendix.

E. Temperature of Slag after Dropping. It is not possible to specify a value for the temperature of slag or its cooling rate after a vertical drop. The temperature of slag as it discharges from the flare casing varies greatly, often times smaller pieces being incandescent. The cooling rates would span a large range depending on the initial temperature and size of the slag droplet and on the height over which it fell. It is possible, however, to estimate a range of temperatures for slag and an upper value that it must have at least attained in several tests. This is based on the ignition temperatures for some of the materials and fuels that were ignited by the slag. The data to make this estimate are mainly derived from the source: "Fire and Explosion Manual for Aircraft Accident Investigators," by Joseph M.Kuchta of the U. S. Bureau of Mines, Pittsburgh Mining and Safety Research Center, Pittsburgh, Pennsylvania, Report No. 4193, August 1973.

Ignition temperatures depend on the size and shape of the material being ignited, and the size, shape and material of the ignition source. However, ignition temperatures for materials such as newspaper and cotton cloth (canvas) are generally in the range of 900°F, so this level of temperature must have been common for hot slag particles since these types of samples readily charred and ignited.

Higher temperatures than this were definitely realized by slag in some tests because the ignition temperature of heptane is higher than that of cotton or paper. Again the exact value depends on the size and shape of the ignition source (rods, wires, hot surfaces) but for sources with dimensions in approximately the 1/2-inch range (estimated size of slag globules that caused ignition) the ignition temperature for heptane is about 1300 ± 100°F. Hence, this temperature level must have been achieved with some slag particles even after a six-foot drop. Not very many slag particles were this hot, however, because only an occasional one would ignite heptane. This temperature then may be a practical upper limit value. The reason that diesel fuel did not ignite is because its flash point, estimated to be approximately 150°F, is above ambient temperature. The flashpoint does not mean that material cannot be ignited at lower temperature, but for a case of hot slag falling into diesel fuel and immediately being quenched, there will be no problem with ignition.

F. Spattering Effects. The hand-held flares when held horizontally spew slag particles outward and sometimes sideways for a distance of 2-3 feet. The large masses of slag tend to fall straight down from the casing. The small particles occasionally manage to eject backwards causing small char spots on shoes and clothing (but never showing signs of igniting clothing) and stinging the arm of the operator.

G. Burn Time. All of the hand-held red flares that were tested, including the old and new Bristol flares (see Section V), burned for between two and two-and-one-half minutes per the specification for this type flare. Burn times were measured using a stop watch.

H. Toxicity Level of Combustion Products. Thermochemical equilibrium calculations were performed for the 500 candlepower hand-held red flares using the Atlantic Research computer code to determine the theoretical combustion product composition. The flare formulation was taken to be:

Strontium Nitrate	70.0% by weight
Sulfur	15.0% by weight
Potassium Perchlorate	10.0% by weight
Polyethylene Powder	4.5% by weight
Kerosine	0.5% by weight

The theoretical burning temperature is 2523°K. The main product species in the cooled exhaust smoke are computed to be:

CO	2% by weight
CO_2	12% by weight
H_2O	7% by weight
N_2	9% by weight
SO_2	30% by weight
SrO (solid)	34% by weight
KCl (solid)	6% by weight

These products will of course immediately mix with ambient air and become very diluted. This fact, plus the unique exposure scenario associated with the use of flare or smoke devices (i.e., probably a single exposure for a short time), makes it very difficult to assign a toxicity hazard to the products of combustion. In any case, the solid products, SrO and KCl, are not toxic substances. Sulfur dioxide is generally regarded as a toxic gas (the OSHA listed TWA exposure limit is 5 ppm, although this value is not at all applicable to the present situation). For use as distress signals on recreational boats, hand-held red flares should be regarded as not posing a significant toxicity hazard.

I. Failure Rate. The following failures occurred during testing of hand-held red flares:

Smith and Wesson	0/14
Kilgore	2/18
Bristol	0/10

The two failures with the Kilgore flares were a result of the primer material that is attached to the head of the flare falling off when it was scratched with the striker bonnet.

2. SMOKES: Manufacturers tested: Smith and Wesson
Olin

A. Heat at Handle. The wooden handles do not get at all warm during firings.

B. Heat at Head and Along Casing. The hand-held smoke devices operate similarly to the flares. Using fine Chromel-Alumel thermocouples taped to the outside of the casing, temperature-time-burning rate data were obtained, from which the following results are presented:

	Smith and Wesson	Olin
Temperature on casing two inches from burning surface	165°F	230°F
One inch from surface	295°F	430°F
Final temperature recorded as surface reached thermocouple	490°F	550°F

It is noted that even though the final temperatures recorded for the smoke devices is much lower than that realized with flares, the casing exterior is hotter. This is because the pyrotechnic mixture of smokes tends to burn down inside the casing at greater depth than that of flares before the casing itself burns. In spite of the smoke casing being somewhat hot, there does not appear to be much hazard to an operator since he would not tend to grasp the casing itself.

C. Effect of Combustion Products Impinging on Fuels and Materials. The smoke devices do not produce slag as do flares. Accordingly, the hazards associated with flare slag (items I.c, d, e, f above) are essentially absent with smoke. However, there is a question of whether smoke exhaust could ignite material if it impinged directly on it, and also what undesirable cosmetic effects might be produced. While cosmetic effects are not an essential part of a safety study, it is worth noting that the orange smokes do stain material, and the operator does not have complete control over the direction in which smoke drifts because of shift in wind.

Tests were performed with both Olin and Smith and Wesson smoke devices to attempt to ignite material and fuel. Results were negative in all cases. Smoke exhaust, directly from the casing, was allowed to impinge onto heptane fuel at all distances down to about one inch. No ignition could be obtained. Similarly, exhaust impinged directly onto newspaper and cotton cloth and no ignition occurred, although the exhaust was hot enough to char the material.

There are no spattering problems with smoke devices, although a shift in wind direction can cause the smoke cloud to engulf the operator if he is limited in his area of maneuverability.

D. Burn Time. The smoke devices were rated for 50 seconds burn time. All devices tested exceeded this specification and burned between 70 and 75 seconds.

E. Toxicity Level of Combustion Products. Thermochemical equilibrium calculations were performed using the Atlantic Research computer code to predict the final combustion conditions. The following smoke propellant formation was used:

Potassium Chlorate	13% by weight
Lactose	17.4% by weight
Orange Oil 7078V	34.8% by weight
p-Nitroaniline	34.8% by weight

The computations were made assuming that the orange oil and the p-nitroaniline remain chemically unchanged during the burning of the formulation and act only as diluents which vaporize. The lactose and $KClO_3$ react as fuel and oxidizer. The final computed combustion temperature is 671°K. The main products produced in the smoke will be:

CO_2	12% by weight
H_2O	6% by weight
Carbon	3% by weight
CH_4	1% by weight
KCl (solid)	8% by weight
Orange Oil	35% by weight
p-Nitroaniline	35% by weight

Only the orange oil and p-nitroaniline are of interest among these products. Sax's handbook[(1)] classifies p-nitroaniline in its Toxic Hazard Rating Code 3 - "High: May cause death or permanent injury after very short exposure to small quantities." It lists the TLV value as 1 ppm; OSHA gives the TWA value as 1 ppm also. While the seriousness of this rating should be recognized, it is however noted that it can be misleading and that many other common chemicals (e.g., carbon tetrachloride) are similarly classified.

(1) N. Irving Sax, "Dangerous Properties of Industrial Materials," 4th Edition, Van Nostrand Reinhold Co., New York, 1975.

The specific question to be considered concerns the acute toxicity of p-nitroaniline in an exposure situation that an operator would encounter while using orange smoke as a distress signal in a boating incident. Such a typical exposure regimen can be estimated as follows. A hand-held orange smoke device contains of the order of 40-50 grams (~0.1 lb) of p-nitroaniline. When all of this material is dispersed, the orange smoke cloud might have estimated dimensions of 6' in diameter by 30' in length or roughly 850 cu ft. Taking the cloud density as equal to that of air (0.075 lb/cu ft), the concentration of p-nitroaniline in the cloud would be roughly 1500 ppm by weight (or 2000 mg/m^3). Burn times for the devices are of the order of one minute. If exposure of an operator occurred, it would be due to wind shift, which would have the effect of diluting the cloud concentration, possibly by a considerable amount. Hence, an exposure scenario of approximately 1000 ppm for some fraction of a minute would be conservatively realistic. Skin and inhalation routes should both be considered.

The toxicity of p-nitroaniline has not been investigated under such an exposure regimen. There are a number of reports[(1)] related to poisoning, biological activity, toxic action, etc., of aniline and its derivatives, including the para-nitro compound. However, these deal with exposure to high concentration for relatively long periods and are not very relevant to the present case. There is no doubt that p-nitroaniline exhibits toxic action, however, LD_{50} values (see reference 1a) indicate that it is in the same class as similar aromatics such as henzene, toluene, aniline, and their derivatives. Similarly, TLV or TWA values are only applicable to very long term exposure. In the absence of specific data at dosages of about 1000 ppm for one minute or less, the best that one can conclude is that p-nitroaniline would behave similarly to compounds such as carbon tetrachloride or benzene, which based on common experience would not be considered very toxic for a single exposure.

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(1)

a) Freed, V. H. and Hague, R., Environmental Health Perspectives 13, 23 (1976).
b) A. Anderson, British Journal of Industrial Medicine, p. 243 (1947).
c) Grozgins, P. H., Aniline and Its Derivatives, D. von Nostrand Co., New York, (1921).
d) Handbook of Toxicology, NAS and NRC, Saunders, Philadelphia.

The Orange Oil 7078V goes by the name of Solvent Yellow 14 and has a Colour Index(1) number of 12055. It is a monoazo dye with many uses; chemically it is known as 1-phenylazo-2-naphthol. It is a suspected carcinogen(2), as are innumerable organic dyes and related compounds. Whereas any toxic problem with p-nitroaniline would be acute, with orange oil it would tend to be chronic in the sense that frequent exposure over a long period would be required to produce carcinogenic effects. No toxicity hazard would exist in a scenario involving a single exposure for a short period.

F. Failure Rate. No failures occurred during testing of eight Smith and Wesson and eight Olin hand-held orange smoke devices.

II. Self-Contained Meteors and Parachute Flares

Manufacturers tested: Kilgore - Red Meteor Signal
Survival Systems - Red Aerial Signal
Smith and Wesson (Icarus) -
Rocket Propelled Parachute Red Flare and Rocket Propelled Parachute Illuminating Flare

A. Burn Time.

Kilgore Red Meteor	7, 5.5, 7 seconds (all flares were still burning on impact)
Survival Systems Red Aerial	7, 7.5, 8 seconds
Smith and Wesson Red Flare	38, 41 seconds
Smith and Wesson Illuminating	32, 35 seconds

B. Altitude Attained and Failure Rate. These measurements were made using ballistic theodolites with firings conducted in large open fields. The reduced data are presented in the following table.

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(1) Colour Index, 2nd Edition, The American Association of Textile Chemists and Colorists, Lowell Technological Institute, Lowell, Massachusetts, 1956.

(2) David B. Clayson, "Chemical Carcinogenesis," Little Brown, Boston, Mass., 1962.

ALTITUDE ATTAINED BY SELF-CONTAINED AERIAL FLARES

Type	Measured Altitude (Feet)			Failure Rate
Kilgore Unistar Red Meteor Signal	180	154	165	0/3
SSI Skyblazer Red Aerial Meteor	205	259	196	0/3
Smith and Wesson Rocket Propelled Parachute Illuminating Flare		1400	1500	0/4
Smith and Wesson Rocket Propelled Parachute Red Distress Flare		1500	1500	1/8

The Kilgore and SSI Meteors were rated for 200 feet and the Smith and Wesson parachute flares for 1200 feet by the manufacturers. The average altitude (166 ft) of the Kilgore Meteor represents 83% of the rated altitude. The accuracy of the high altitude (1500 ft) measurements is approximately ±100 ft; that of the low altitude approximately ±15 ft. The failure that occurred with the Smith and Wesson Red Parachute Flare was a result of the unit turning into a horizontal flight path, sideways from the operator, rather than vertical upon being ejected from the casing. The unit flew for approximately 100 ft before hitting the ground. This type of failure is potentially hazardous since the unit can apparently take any erratic flight path during such an event. The parachute failed to eject from its casing during this failure.

C. Miscellaneous Observations. The low altitude devices are small units and produce slight but not significant recoil. The Smith and Wesson high altitude devices are relatively large and produce moderate recoil which was not judged to present a major problem to an operator. There was slight but not significant heat developed at the casings of the devices. All units ejected a small amount of material, mostly smoke, from the exit end of the launch tube. No hazard was apparent. The Smith and Wesson units do spatter a slight amount of black particles back onto the operator, but this did not constitute any hazard. There is significant noise produced when the

Smith and Wesson units are launched which can be a little startling but not hazardous. All parachutes (made of cloth) opened satisfactorily on the Smith and Wesson devices.

III. Pistol-Fired Meteors and Parachute Flares

Manufacturers tested: Olin - 25 mm Red Meteor Flare
W.W. - 12 gauge Red Meteor Flare
Olin - 25 mm Red Parachute Flare

These units were all fired with an Olin-Winchester 25 mm Signal Flare Launcher which had an insert adapter to accomodate 12 gauge flares. This was a simple device to operate, although there were two misfires (firing pin failed to ignite primer), and one case of a spent casing jamming in the pistol. There was no apparent hazard associated with these instances.

A. Burn Time.

25 mm Meteor: All devices (12) burned for between 5.4 and 6.5 seconds, except one which burned for 10 seconds.

12 ga. Meteor: All devices (12) burned for between 4.0 and 4.5 seconds, except one which burned 5.0 seconds and one which burned 3.7 seconds.

25 mm Parachute: Six devices which were timed burned between 20 and 25 seconds. As noted below, in eight of 12 firings, the parachute did not open, which resulted in the flares continuing to burn after they impacted on the ground.

B. Altitude Attained and Failure Rate.

As described above, these measurements were made using a ballistic theodolite.

	Measured Altitude (Feet)				Failure Rate
Olin 25 mm Meteor Flare Signal	172	191	230	178	2/12
12 ga. Red Meteor	188	180	154		0/12
Olin 25 mm Parachute Flare	235 172	172 162	169 165	240	9/12

These devices were rated by the manufacturers for 200 feet altitude. Actual measured altitudes varied widely. The two failures with the 25 mm Meteor Flares were due to the flares failing to ignite, although they all launched satisfactorily. The Olin 25 mm Parachute Flares only produced three successful firings out of 12 attempts. Eight of the nine failures occurred because the parachutes (made of paper) did not open (although the flares burned); one other device failed to launch.

C. Recoil. The 12 gauge meteor flares produced very slight recoil; the 25 mm Meteors produced slight recoil. Neither type was a problem. However, the 25 mm Parachute Flares produced strong recoil, requiring an adult operator to hold the pistol with both hands. This strong recoil was judged to be very undesirable.

D. Post-Firing Temperatures and Spillover. Neither the 25 mm meteor nor the 12 gauge meteor produced any significant temperature increases on the pistol barrel or flare casing after firing. There was no significant debris ejected during launch with these or the 25 mm parachute flare. The parachute flare produced slight warming of the pistol barrel, and the casing became very warm, although this did not constitute a hazard.

IV. Floating Smokes

Manufacturer tested: Survival Systems, Inc.

These devices are similar to the hand-held orange smokes except that, following ignition, the entire unit is to be thrown into the water where it burns as it floats. The remarks concerning toxicity that were made about the hand-held smokes also would apply to the floating smokes.

A. Failure Rate and Burn Time. There was one partial failure in six tested units. The failure occurred after 30 seconds of normal burning; a small cap blew out of the casing into the air and the device burst into flame. The burn times of the other units ranged from about 60 to 65 seconds. One device was ignited and allowed to burn in a moderate rain and performed satisfactorily.

B. Heat of Container. The exterior of the container does not heat during the short time it takes to initiate burning and to throw the device into water. However, it does get hot as it burns and after a short time becomes too hot to hold. A case temperature of 560°F was measured by taping a thermocouple to the exterior of the casing in a test in which the unit was placed on the ground and not in water.

C. Spattering Effects. Spattering is not a consideration during burning because the device is floating on water. However, during ignition one unit spattered hot particles onto the hand of the operator causing minor annoyance.

D. Ignition of Fuel on Water. A 3' x 3' pan was filled to a depth of eight inches with water and an approximately 1/4" layer of heptane placed on top of the water. In two separate tests floating smoke devices were thrown into the pan and allowed to completely burn. No ignition of the fuel occurred in either test.

V. Evaluation of Aged Pyrotechnics

Manufacturers tested: Kilgore
Bristol
Smith and Wesson (new)

The objective of these tests was to determine whether there was any change in the performance of hand-held red flares that were several years old compared with relatively new flares. The observations to be made were: Intensity; heat at head and handle; spattering; and failure rate. The flares tested were:

Kilgore -	February 1973	3
	September 1973	3
Bristol -	January 1973	3
	July 1973	3
	June 1976	4

There were no failures in any units and there was no detectable difference in heat or spattering between new and aged devices. However, it appeared to the operator that there was somewhat more slag with aged units, although no quantitative measurement of this was made. Visual observation by the operator during the tests could detect no difference in light intensity between new and old units at short range. However, this is not an accurate way to assess intensity because the flares are all very bright at close distance. The Bristol flares (new 1976 and aged 1973) were subjected to light emission tests and the results are given below, together with a measurement on one new Smith and Wesson flare.

Visible Light Intensity. These measurements were made in a manner similar to that described in CFR 160.021-4. The flares were mounted in a horizontal position with a radiant flux meter and a thermoelectric-type sensor located a known distance away from the flares. The output of the meter was continuously monitored on a recorder chart. Preliminary tests showed that enormous light emission is measured from the flares if light filters are not used because the burning and incandescent exhaust emits heavily in the infrared as well as the visible region of the spectrum. Accordingly, filters were used with the following characteristics: 1) A filter which passed only visible light (4000 to 7700 Angstroms) and suppressed all infrared and ultraviolet light. 2) A filter which passed only 6500 ± 50 Angstrom light (approximately the center of the visible red region). The results below are corrected for filter transmission and represent total spherical emission over 4π steradians.

Results of Light Intensity Measurements on Hand-Held Red Flares

	Full Visible Emission (Candlepower)	Red Emission (Candlepower)
Bristol		
June 1976	1117, 1509	206, 192
January 1973	876	154
July 1973	970	220
Smith and Wesson		
July 1977	745	160

The flares all exceeded the 500 candlepower rating that was listed on the labels. However, there are a few points to note about the above data. There is a very wide fluctuation in light output, both between different units of the same manufacturer, and also as a function of time during the testing of any single unit. The values tabulated above represent measurements at one position of the light detector relative to the flare. If it were possible to average measurements over all spherical positions around the flare as it was burning, the spherical average candlepower would be lower. Hence, the candlepower measurements listed in the table are not true absolute values. However, it still appears that the intensity of aged Bristol flares (four years old) exceeds the 500 cp specification.

APPENDIX

Tables and Figures which are separate from the main body of the report.

TABLE I. SUMMARY OF DEVICES AND TEST MEASUREMENTS TO BE MADE

I. Hand-held Flares and Smoke

- a. Heat at head
- b. Heat at handle
- c. Effect of slag dripping on liquid and vaporized fuel
- d. Effect of slag dripping on construction materials
  - 1. Indoor/Outdoor carpeting
  - 2. Plastics
  - 3. Wood
  - 4. Fiberglass
  - 5. Surface coverings
    - a. Paints and varnishes
    - b. Vinyl
    - c. Canvas
  - 6. Clothing materials
  - 7. Newsprint (Papers)
- e. Temperature of slag after 3' and 6' drop, and cooling rate
- f. Spattering effects on Operator (amount generated) area affected
- g. Burn time
  - 1. Flare
  - 2. Smoke
- h. Toxicity level of smoke generated
- i. Failure rate

II. Self-Contained Meteors and Parachute Flares

- a. Burn time
- b. Altitude attained
- c. Recoil
- d. Heat at exhaust point
- e. Heat of casing after launch
- f. Spillover or splash at exit end of tube
- g. Failure rate

III. Pistol Fired Meteors and Parachute Flares

- a. Burn time
- b. Altitude attained
- c. Recoil
- d. Barrel temperature
- e. Temperature of spent casing at ejection
- f. Spillover or splash at muzzle
- g. Operability, ease of use
- h. Failure rate

IV. Floating Smokes

- a. Failure rate
- b. Heat of container
- c. Spattering effects
- d. Ignition of fuel on water

V. Evaluation of Aged Pyrotechnics

- a. Intensity
- b. Heat at head
- c. Heat at handle
- d. Spattering effect
- e. Failure rate

TABLE II. DEVICES RECEIVED FOR TESTING

	Item	Quantity
I (1)	Hand-held Red Flare Distress Signal Smith & Wesson June 1977 Lot No. 26	18
I (1)	Hand-held Red Flare Distress Signal Kilgore Corporation July 1977 Lot No. 268	12
I (2)	Hand-held Orange Smoke Distress Signal Smith & Wesson 1977 Lot No. 12	12
I (2)	Hand-held Orange Smoke Distress Signal Olin Corporation July 1976 Lot No. 81	12
I (2) (extras)	Hand-held Orange Smoke Distress Signal Olin Corporation September 1976 Lot No. 88	4
II(1)	("Self-Contained Meteor") Red Aerial Meteor Distress Signal Flare Survival Systems, Inc. "Skyblazer" Model 20R Use before January 1980 (200 ft altitude)	15
II(1)	Self-Contained Red Meteor Signal Kilgore Corporation Unistar (200 ft) Lot. No. 10, 11 (200 ft altitude)	12 - Lot 11 6 - Lot 10
II(2)	Hand-held Rocket Propellant Parachute Red Flare Distress Signal Smith & Wesson April 1977 Lot No. 58 (1200 ft altitude)	12

(TABLE II - CONTINUED)

	Item	Quantity
II(2)	Hand-held Rocket Propelled Parachute Illuminating Flare Smith & Wesson July 1973 Lot No. 1 (1200 ft altitude)	15
III(1)	(25) Red 25 mm Meteor Flare Signal Olin (200 ft altitude)	12
III(1) (extra)	12 GA. Red Meteor for Flare Guns Only W.W. (200 ft altitude)	12
III(2)	107 Red 25 mm Parachute Flare Signal Olin (200 ft altitude)	12
IV(1)	("Floating Smoke") Survival Systems, Inc. Skymark 60 Use before January 1980	15
V	Hand-held Red Flare Distress Signal Bristol Flare Corporation	
	July 1973 Lot No. 83	3
	January 1973 Lot No. 80	3
	June 1976 Lot No. 101	4
V	Hand-held Red Flare Distress Signal Kilgore Corporation	
	September 1973 Lot No. 217	3
	February 1973 Lot No. 209	3

TABLE III. LIST OF MOTION PICTURES TAKEN IN THE COURSE OF THE STUDY

Reel	Date	Test
1	7/21/77	1 - Smith and Wesson Orange Smoke
		2 - Olin Orange Smoke
2	7/21/77	3 - Smith and Wesson Red Flare
		4 - Kilgore Red Flare
3	7/22/77	5 - Smith and Wesson Red Flare over Heptane
4	7/22/77	6 - Survival Systems Floating Smoke over Heptane.
5	7/25/77	7 - Kilgore Red Flare over Heptane
6	7/28/77	8 - Kilgore Red Flare over Heptane
7	8/19/77	9 - Olin 25 mm Parachute (5-6 tests, Only 1 or 2 opened)
8	8/19/77	10 - Olin 25 mm Parachute (3 tests, None opened)

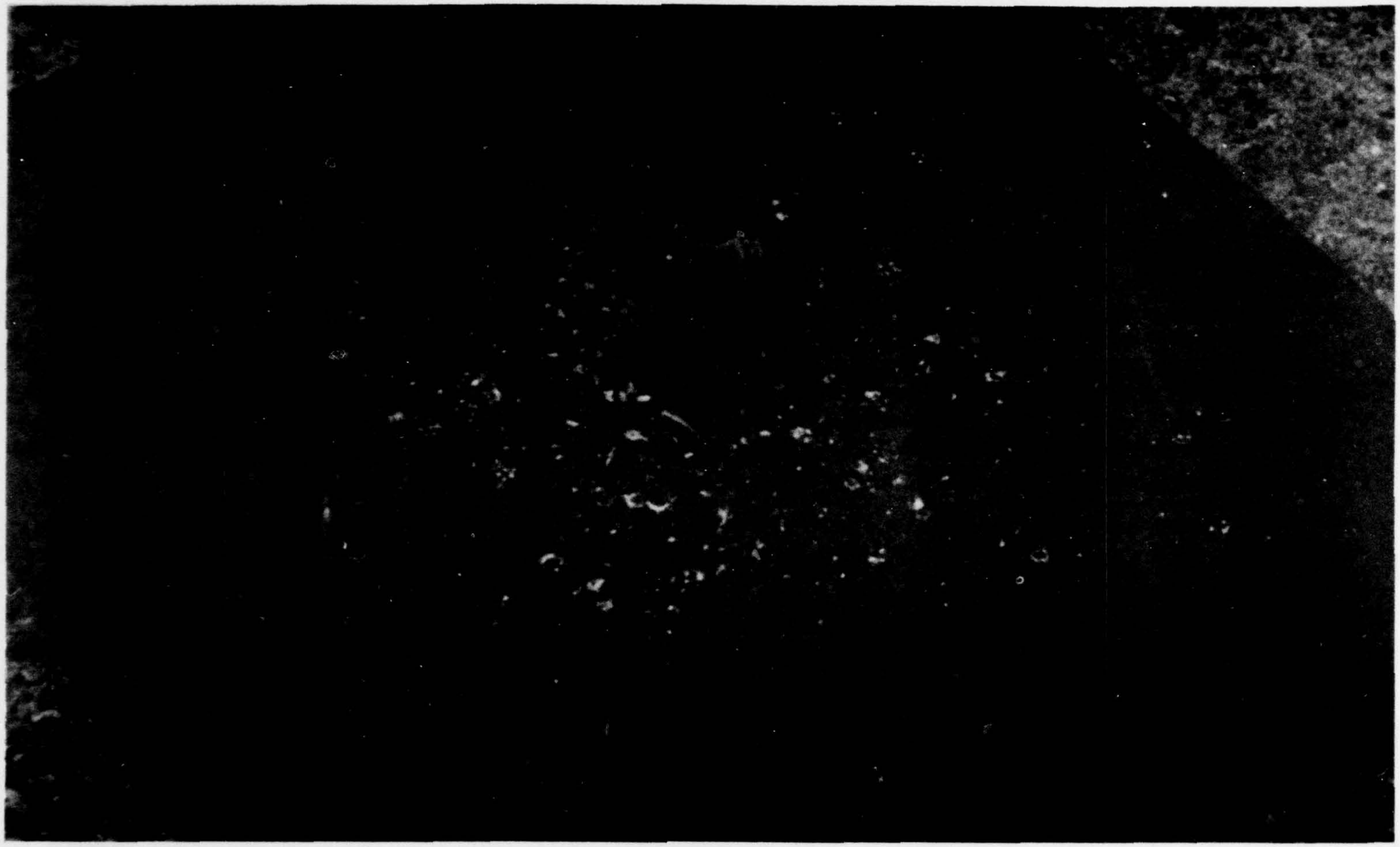


FIGURE 1. Photograph illustrating the ignition and burning of indoor-outdoor carpeting tiles caused by dripping slag from a hand-held red flare.

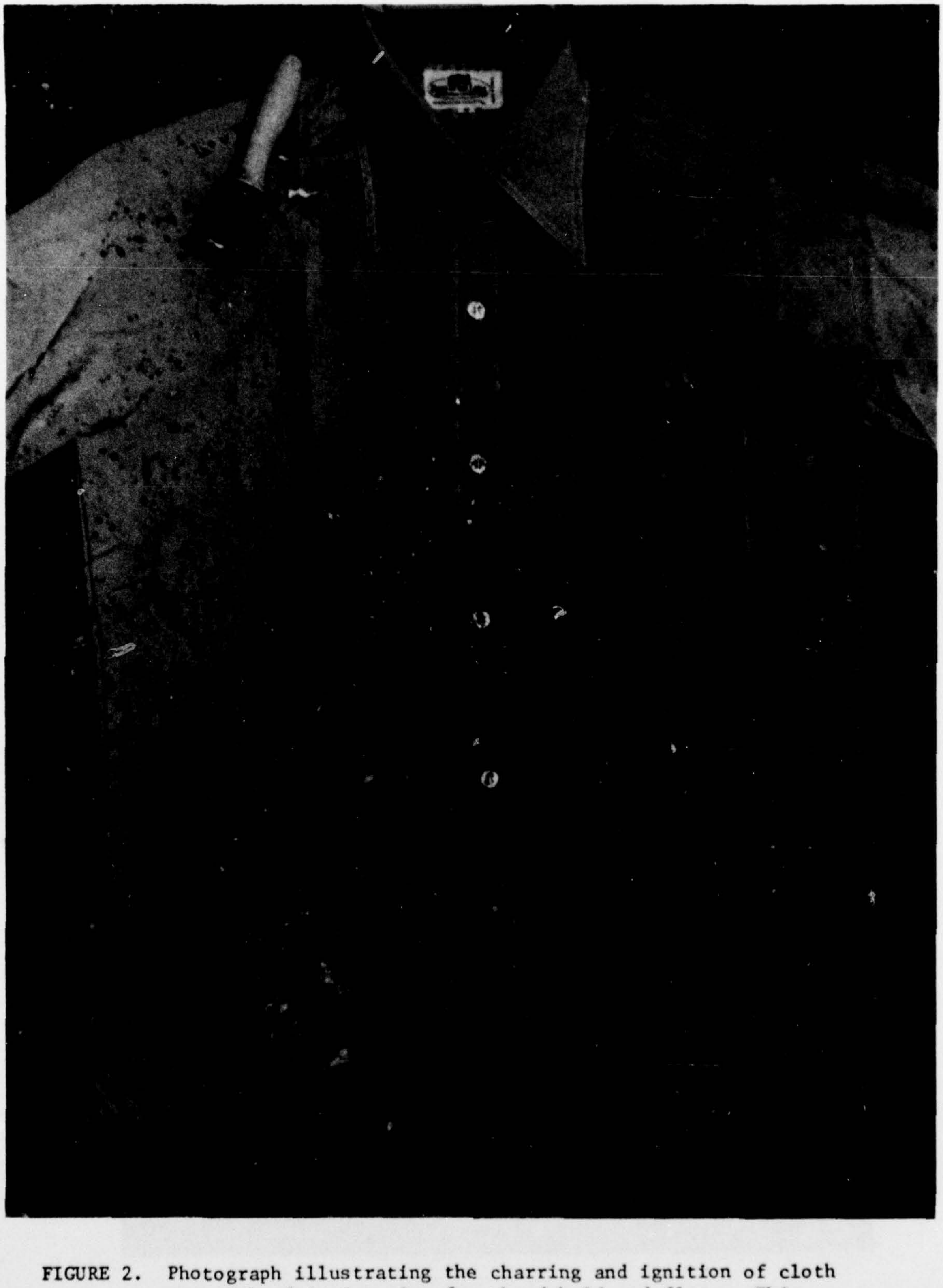
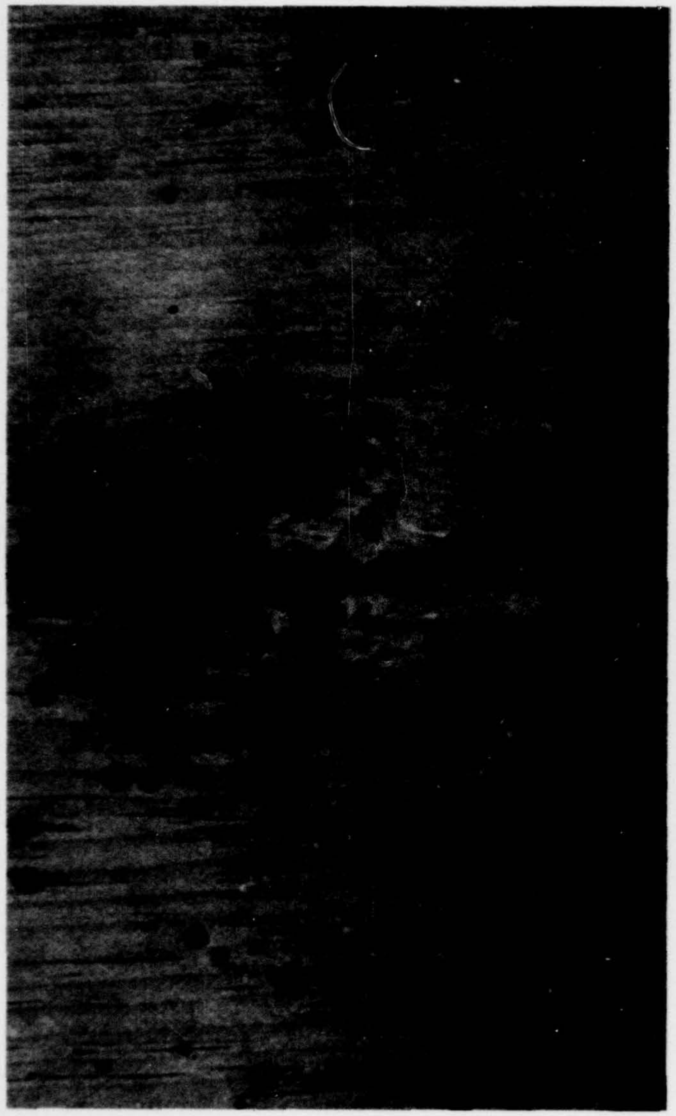
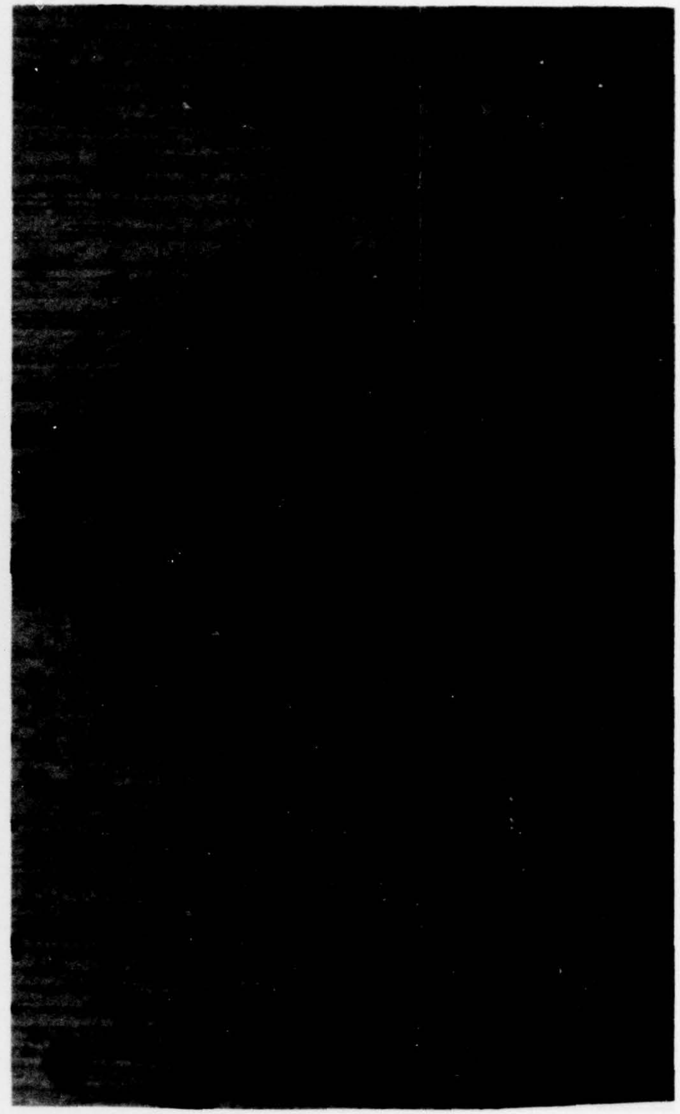


FIGURE 2. Photograph illustrating the charring and ignition of cloth caused by dripping slag from hand-held red flare. This and other tests shown in these photos were performed by laying the test materials flat on the ground.



A



B

FIGURE 3-A, B. Photographs illustrating the charring of wood caused by dripping slag from hand-held red flares. Photos A and B represent flares from two different manufacturers.