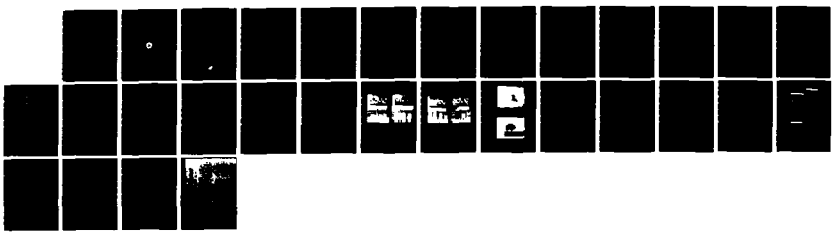
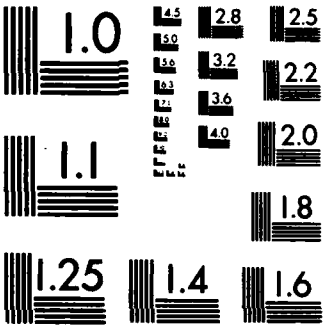
AD-A133 066 RELIABILITY OF PORTABLE DRY CHEMICAL FIRE EXTINGUISHERS 1/1
IN USE ON MOTORBOATS(U) COAST GUARD RESEARCH AND
DEVELOPMENT CENTER GROTON CT W C HELGSSON JUN 83
UNCLASSIFIED CGR/DC-2/83 USCG-D-24-83 F/G 13/12 NL





REPORT NO: CG-D-24-83

(12)

RELIABILITY OF PORTABLE DRY CHEMICAL FIRE EXTINGUISHERS IN USE ON MOTORBOATS

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Avery Point Groton, Connecticut 06340

FINAL REPORT

JUNE 1983

PREPARED FOR
U. S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON D.C. 20593

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-24-83	AD-A133066	

4. Title and Subtitle	5. Report Date
Reliability of Portable Dry Chemical Fire Extinguishers In Use On Motorboats	June 1983
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
W.C. Helgeson	CGR&DC-2/83
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
United States Coast Guard Research and Development Center Groton, CT 06340	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final Report
Department of Transportation U.S. Coast Guard Office of Research and Development Washington, D.C. 20593	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The reliability of fire extinguishers on motor boats was investigated by exchanging new extinguishers for ones in use on boats in southeastern Connecticut. Each extinguisher was continuously discharged. The percentage by weight discharged, the discharge distance, and the duration of discharge were compared to the performance test minimums in Underwriters' Laboratories, Inc. "Standard for Safety" (UL 299). Of the one hundred and thirty (130) extinguishers tested, seventeen (17) failed to meet one or more of these tests.

Thirty-three of the extinguishers were manufactured in 1970 or earlier. None of these had been recharged or inspected by a professional fire equipment company. Eleven of these (or 33%) failed at least one performance test.

The remaining ninety-seven extinguishers were manufactured in 1971 or later. Six of these (or 6%) failed at least one test. This is a large enough sample to predict with 95% confidence that the true failure rate of extinguishers made in 1971 or later is between 1.2% and 11.2%.

17. Key Words	18. Distribution Statement
Fire extinguishers, small craft, dry chemical extinguishing agents	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

METRIC CONVERSION FACTORS

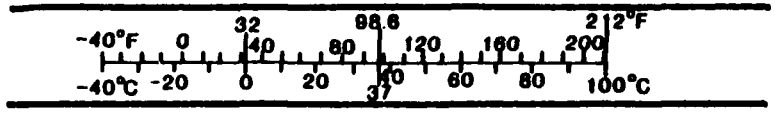
Approximate Conversions to Metric Measures

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	0.125	cups	c
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

1.1 Background

By law the Coast Guard is tasked with setting requirements for "marine type" portable fire extinguishers and establishing procedure to approve such extinguishers when they meet the requirements. (Title 46 Part 162.028 CFR). As a part of this, the Coast Guard may conduct "Follow-up check tests, examinations and inspections of products listed and labeled as a "marine-type" portable fire extinguisher acceptable to the Commandant (of the Coast Guard) as approved for use on merchant vessels and motorboats." (Title 46 Part 162.018-6 CF6). A preliminary survey on small (Class I) dry chemical extinguishers was conducted during October 1982 to substantiate reports of failures. Eleven of the fifty-seven extinguishers failed the UL 299 operational test requiring 80% (by weight) of the rated capacity of dry chemical be discharged when operated. Most of the failures were due to packing and caking.

This is a follow-up survey designed to see if the failure rate of extinguishers is statistically significant and to examine the causes for failure. For this survey one hundred and thirty new extinguishers were exchanged for ones in use on boats in southeastern Connecticut.

1.2 Objectives

The objectives of this survey were to determine if the probability of failure for a large population of apparently good extinguishers is statistically significant, and to investigate the degree of packing and caking in the failed extinguishers.

1.3 Coast Guard Requirements

The Commandant of the Coast Guard approves four different agents for use in portable fire extinguishers carried on motorboats. They are carbon dioxide, dry chemical, foam, and Halon. Each extinguisher is classified by a letter and a number (Roman numeral). The letter designates the class of fire the extinguisher will extinguish. The basic classes of fires are A, B, C and D. Class A fires are fueled by ordinary combustible materials such as wood, cloth, paper, rubber and many plastics. Class B fires are fueled by flammable liquids, oils, greases, lacquers and flammable gases. Class C fires involve energized electrical equipment where the electrical nonconductivity of the extinguishing agent is important. Class D fires are fueled by combustible metals such as magnesium, titanium, lithium, potassium and zirconium. The number represents the size of fire the extinguisher could extinguish. It also indicates the minimum amount of extinguishing agent a fire extinguisher must contain. Extinguishers approved for motorboats are hand-portable of either B-I or B-II classification. They are suitable for extinguishing fires involving flammable liquids and greases. Their sizes are shown in table 1.

Formerly, all hand-portable fire extinguishers as well as semi-portable and fixed fire extinguishing systems were required to be of a type found on the Coast Guard approval lists. Currently, portable extinguishers may be identified as approved by one of three methods.

If manufactured prior to 1 January 1962, acceptability will be determined by comparing manufacturer's name and model with CG-190 "Equipment Lists." Some of these extinguishers do contain a Coast Guard approval number. Extinguishers manufactured between 1 January 1962 and 1 January 1965 will be labeled: "MARINE TYPE USCG TYPE _____ SIZE _____." Those manufactured after 1 January 1965 will be labeled: "MARINE TYPE USCG TYPE_____ SIZE_____APPROVAL NUMBER 162.028/EX."

Fire extinguishers must meet two conditions before they are acceptable to boarding officers conducting a boating safety inspection. The two requirements are that they be (1) Coast Guard approved, and (2) in good and serviceable condition.

1.4 Dry Chemical Extinguishers

Dry chemical portable extinguishers are activated by two different means: stored-pressure and cartridge activated. The stored-pressure type is the most widely used and is best suited where infrequent use is anticipated and where skilled personnel with professional recharge equipment are available. The cartridge-operated type can be quickly refilled in remote locations without the need for special equipment. To obtain one hundred thirty (130) extinguishers approximately one hundred twenty-five (125) boaters were contacted. All used the stored-pressure type of extinguisher.

Inspection, maintenance and recharging are factors of prime importance in ensuring operation at the time of the fire. Inspection is a "quick check" that an extinguisher is available and will operate. It is intended to give reasonable assurance that the extinguisher is fully charged and operable. This is done by seeing that it is in its designated place, that it has not been actuated or tampered with and there is no obvious physical damage or condition to prevent operation.

Maintenance is a "thorough check" of the extinguisher. It is intended to give maximum assurance that an extinguisher will operate safely and effectively. For a stored pressure dry chemical extinguisher a thorough examination of the gauge reading, nozzle, bottle condition, and age should indicate any necessary repair or replacement. It will normally reveal if there is a need for hydrostatic testing. A professional service company can also test the actual pressure in the bottle to verify the gauge reading.

Recharging is the replacement of the extinguishing agent and the expellant. The extinguishers should be recharged after use or as indicated by an inspection. When recharging, the recommendations of the manufacturer should be followed, the proper agent should be used, and the introduction of moisture should be minimized. Most boaters regularly checked the gauges and kept the extinguishers readily accessible. A few did not and had extinguishers with low pressure readings. The intent of this survey was to examine extinguishers which appeared to be in good and seviceable condition. For this reason, extinguishers with low pressure readings were not accepted into the survey.

1.5 Dry Chemical Caking and Packing

One set of problems which is difficult to detect during inspection or maintenance involves the phenomena of caking and packing. These two phenomena result from completely different interactions of the dry chemical with its particular environment. Caking is caused by a chemical reaction between moisture and the dry chemical, which results in the formation of agglomerates or aggregates. These consist of smaller particles of the dry chemical which react with the moisture and stick together, building up a large number of particles of dry chemical into a lump. Provided the extinguisher has not been partially discharged, moisture can only be introduced in the chemical or in the propellant. The propellant is either air or nitrogen which should have the moisture removed.

Packing is caused by the interaction between particles of the dry chemical when subjected to a vibrational spectrum, usually created by mechanical motion in a vertical plane. Packing is dependent on particle size distribution, not the presence or absence of moisture or elevated temperatures. It may also be dependent upon the relative geometry of the extinguisher shell. Segregation of particles usually occurs during packing. The degree of segregation depends upon the differences in particle sizes that are present in the chemical. A large difference in particle size will result in more severe packing. Packing has been observed when dry chemical is stored in a vertical or upright cylindrical container, as is common for portable extinguishers. Underwriter's Laboratory (UL) does test extinguishers for packing problems.

According to the "Technical Bulletin Number 45" of the Ausul Company, Marinette, Wisconsin, packing is presumed to occur whenever an extinguisher is subjected to vertical motion. The gas distribution and the amount of gas is designed to overcome any packing provided the dry chemical is not contaminated with moisture. In other words a properly designed extinguisher should not fail due to packing alone.

1.6 Extinguisher Failure History

The Office of Merchant Marine Safety has reason to suspect that a number of motorboat fires in which severe property loss resulted might otherwise have been reduced or prevented had the dry chemical extinguisher carried aboard these motorboats expelled their contents. To our knowledge, there has been no attempt to recover these extinguishers or any laboratory investigation to seek the reason for failure.

The American Trucking Association has had some reports that drivers were experiencing problems with dry chemical extinguishers carried on tractor trailers. This association keeps various statistics on the trucking industry but does not do extensive research on hardware used by the industry. Among the statistics which it keeps is the number of truck fires and the number of extinguishers used to combat these fires. The association has never taken a random sample of extinguishers used by truckers in order to estimate their reliability.

The Naval Research Laboratory has completed extensive work in the area of extinguisher reliability. Their work focused on very large dry chemical extinguishing systems. It was discovered that the failure of such systems is often caused by the packing and caking of dry chemicals.

Another association, the National Association of Fire Equipment Distributors, was contacted. This Association recognizes that packing and caking can be a potential problem in dry chemical extinguishers, but have not performed any research into the two phenomena . They did forward a copy of a study entitled "A Computerized Study on Fire Extinguisher Effectiveness" completed in 1976 for the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). This study included information on the use of liquid, foam, CO_2, dry chemical, and Halon extinguishers in actual fires compiled from member reports. The overall rate of failure to extinguish the fire was 6% on 5,400 fires. Half of these failures were attributed to the size of the fire leaving 3% of the failures due to previous use, wrong type, malfunction or operator inexperience.

The Federal Highway Administration (FHWA) was contacted. They require extinguishers on motor carriers. No study or data has been taken on the use or reliability of these extinguishers. Likewise, the Federal Railroad Administration (FRA) requires extinguishers on locomotives but no study or data on the use or reliability has been done. The Federal Aviation Administration (FAA) has done extensive testing of commercial aircraft fire extinguishing systems but has not studied the reliability of hand-held extinguishers. They contracted a study of hand-held extinguisher use in Civil Aviation. The report titled, "Study of Hand-Held Fire Extinguishers Aboard Civil Aviation Aircraft," did not address the reliability of the extinguishers.

The U.S. Department of the Interior, Bureau of Mines, contracted a study titled "Reliability of Hand Portable Fire Extinguishers in the Minerals Industry". The study by Allen Corporation of America, dated 10 April 1981, had results of the inspection and firing of six hundred (600) hand-portable extinguishers. One hundred and eighty (180) of these were the stored pressure type. The probability of failure with 90% confidence was 5.3% $\pm$ 1.5%. The study also tried to correlate inspection characteristics which would predict failure of the extinguishers. The factors examined included date of manufacture, date of the last recharge, temperature, humidity, vibration, shock, paint, dents, corrosion, nameplate, nozzle, location, tamper indicator, weight, connections, threads, agent, gage, and gage reading. The study found only three factors were correlated with failure of stored pressure extinguishers. Those were the weight of the extinguisher, the gage reading, and broken tamper indicators. Only 3.5% of the extinguishers in the study were over ten years and only 3.5% of the total number of extinguishers had recharge dates over one year old.

2.0 TEST PROCEDURES

2.1 Test Requirements

For a portable fire extinguisher to be Coast Guard approved and labeled, it must meet special standards as evidenced with tests by a recognized laboratory. At this time the only recognized laboratory (46 CFR 126.028-5) is Underwriter's Laboratories, Inc. (UL), Northbrook, Illinois. UL's Standard for Safety for Dry-chemical Fire Extinguishers is UL 299. To determine whether the fire extinguisher functioned satisfactorily, three of the performance tests listed in UL 299 were used. To pass, all three of the following requirements must be met. The extinguisher must discharge not less than 80 percent (by weight) of the rated capacity of dry chemical when operated at an angle of 45 degrees in any direction from the normal operating position, but not more than 45 degrees from the vertical position. The extinguisher must discharge the chemical so that it falls at a distance of not less than ten (10) feet from the nozzle initially and practically all of the chemical must fall beyond five feet from the nozzle. The duration of effective discharge must be greater than eight seconds. No fire testing of the extinguishers was conducted.

2.2 Survey Method

During June 1982 new extinguishers were exchanged for those in use on boats in the southeastern Connecticut region. Extinguishers were exchanged only if their pressure gages indicated that the extinguisher was properly pressurized. When possible the extinguishers were operated at the boat location. When not possible the extinguishers were transported by a light truck less than ten miles where they were tested. Each extinguisher was weighed before and after operation on a scale graduated in one-half ounces. Each was held upright and continuously discharged holding the bottle still. If the discharge stream did not initially travel ten (10) feet or if the stream fell off to less than five feet, a notation was made. The discharge time was measured between the first appearance of chemical until the stream became clear or the pressure was exhausted. It should be noted that of the eighteen failures only one failed to discharge any chemical. Although the remaining seventeen failures would have provided a limited amount of fire fighting capacity, most boaters had only one or two extinguishers on board. Hence, a failure to meet these tests could represent serious consequences for a motor boat operator.

2.3 Extinguishers Sampled

One hundred thirty (130) extinguishers were collected. They ranged in age from one to twenty-two years. They were made by seventeen different companies, but one hundred and ten (110) of the extinguishers were made by five companies.

3.0 TEST RESULTS AND DISCUSSION

3.1 Description of Failures

The amount of powder expelled compared to the rated capacity is shown in Figure 1 for all the extinguishers. Over half of the extinguishers discharged 90% or more of their rated capacity. Seventeen (17) of the one hundred thirty (130) extinguishers failed one or more of the tests. Appendix A describes each failed extinguisher. Tables 1 through 5 categorize the extinguishers by manufacturer and dates. Figure 2 shows pictures of the cut-open, failed extinguishers.

Only two different chemical agents were in the sample of extinguishers. One hundred and sixteen (116) of the extinguishers had sodium bicarbonate as the agent. All of the failures were from this group. Fourteen (14) of the extinguishers had potassium bicarbonate as the agent. This number is not large enough to make any comparisons of failure rates based on agent type.

Only six extinguishers had been recharged. These all worked properly. All had been recharged within the previous four years. Again this number is so small that no comparisons of the failure between original and recharged extinguishers can be made.

All of the extinguishers that failed were cut open and examined. All had powder that was packed to some degree. They were laid gently on their sides. If the powder fell loose, then the agent was judged satisfactory. If the powder fell when gently tapped, the agent was judged to be packed. If there were lumps or agent would not fall loose, the agent was judged to be caked. All siphon tubes and valves were examined for evidence of packing or caking. A breakdown in the types of failures is given in Table 6. Five of the failures had powder which looked identical to that found in extinguishers which had operated properly. The failure was attributed to insufficient pressure. None of the gauges on the extinguishers failed to move or read recharge after firing of the extinguisher. Two of the extremely old extinguishers had too little agent in them. There was no evidence to indicate whether these had been partially operated or recharged improperly.

There was no correlation between size and failure rate. Nor was there any correlation to indicate vertical mounting or horizontal mounting increased or decreased the failure rate. Corrosion on the bottles will be discussed later, but there was no relation between how an extinguisher looked and whether it failed. There was no significant difference in the failure rate among the different manufacturers. There was a correlation between the age of the extinguisher and the failure rate. The true proportion of failures in extinguishers made in 1970 or earlier is higher than the true proportion of failures in newer extinguishers.

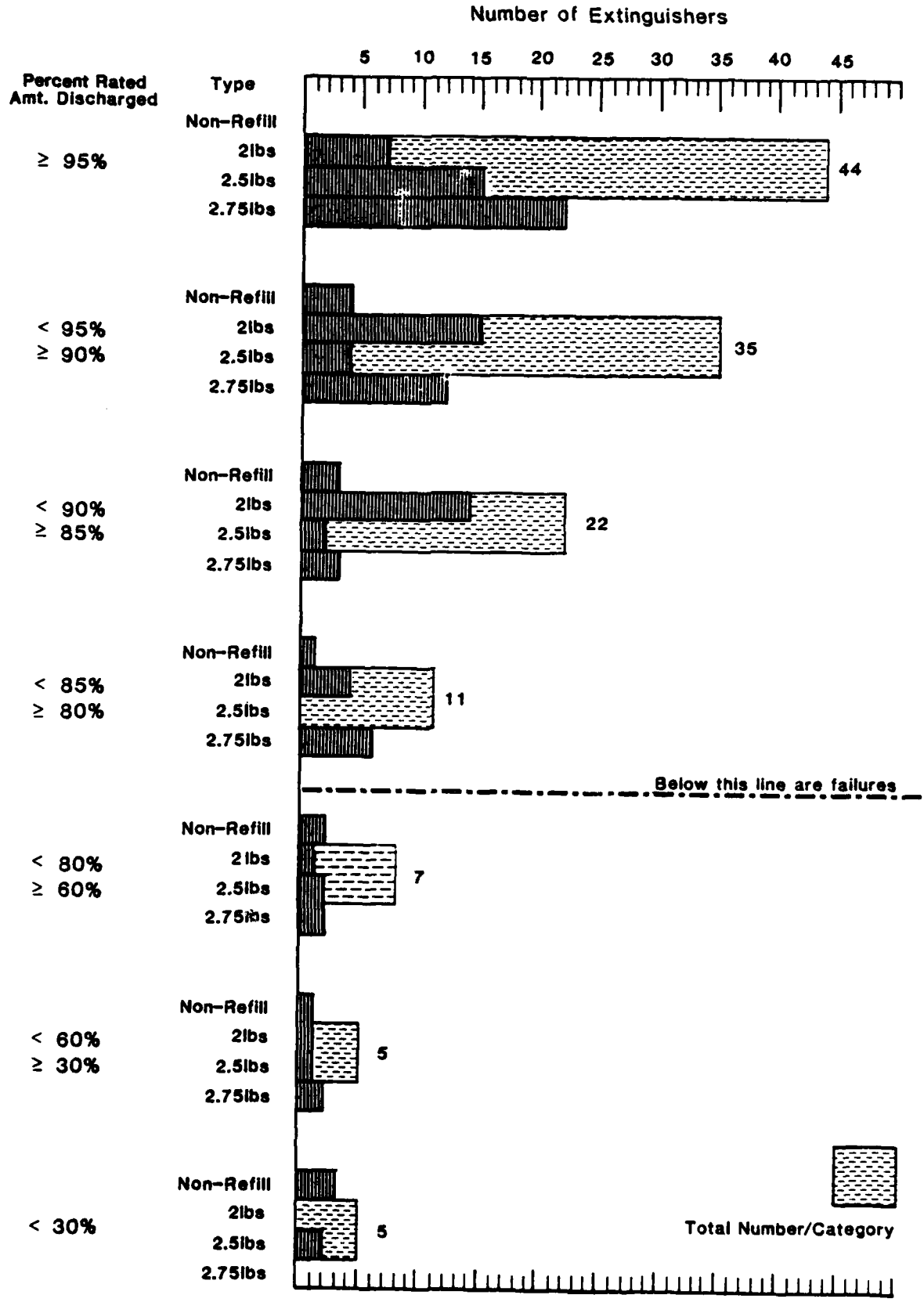


FIGURE 1

COMPARISON OF DISCHARGE AMOUNTS

TABLE 1

SUMMARY OF EXTINGUISHER FAILURES BY DATE MANUFACTURED

Number Failed/Total Number of Specific Type

Date Manufactured	Non-refill	2 lb.	2 1/2 lb.*	2 3/4 lb.	Total	Cum.
1960	-	-	5/6	0/1	5/7	5/7
1962	0/1	-	0/2	-	0/3	5/10
1964	0/4	-	-	0/2	0/6	5/16
1965	-	-	-	0/1	0/1	5/17
1966	1/1	-	-	0/2	1/3	6/20
1967	-	-	-	2/2	2/2	8/22
1968	-	-	-	0/1	0/1	8/23
1969	3/4	-	-	-	3/4	11/27
1970	-	0/1	0/1	0/4	0/6	11/33
1971	-	0/1	-	0/5	0/6	11/39
1972	0/2	-	0/1*	0/3	0/6	11/45
1973	-	1/5	0/3	0/6	1/14	12/59
1974	-	0/3	0/1*	1/2	1/6	13/65
1975	-	0/2	-	0/4	0/6	13/71
1976	-	1/3	0/1*	0/4	1/8	14/79
1977	-	0/7	0/3*	0/1	0/11	15/90
1978 (2 were re-filled)	2/3	0/7	0/2	0/2	2/14	16/104
1979	0/1	0/12	-	1/4	1/17	17/121
1980 (4 were re-filled)	-	0/1	0/5	0/1	0/7	17/128
1981	-	-	-	0/2	0/2	17/130
TOTALS	6/16	2/42	5/25	4/47	17/130	17/130

* Two 2 lb. 5 oz. and three 2 5/8 lb. extinguishers are included in this category

TABLE 2

SUMMARY OF EXTINGUISHER FAILURES BY MANUFACTURERS

Number Failed/Total Number of Specific Type

Manufacturer	Non-refill	2 lb.	2 1/2 lb.*	2 3/4 lb.	Total
AMEREX	-	-	0/5	-	0/5
AMERICAN LaFRANCE	-	0/12	-	1/24	1/36
ANSUL	-	-	-	0/1	0/1
ASCOA	-	-	-	0/2	0/2
BALKAMP	-	-	0/1	-	0/1
BADGER	-	-	-	0/3	0/3
BERNZOMATIC	-	0/1	-	-	0/1
CASCO	-	-	-	1/2	1/2
FYR-FYTER	-	-	0/1	1/1	1/2
GENERAL Fire Ext. Corp.	-	-	5/7	0/3	5/10
WALTER KIDDE Co.	2/7	-	0/4*	0/4	2/15
NORRIS Industries	-	-	0/1	-	0/1
PERFECTION	-	-	-	0/1	0/1
R.C. Industries	4/9	2/29	0/2	1/4	7/44
ROTUNDA	-	-	-	0/1	0/1
SEARS	-	-	0/3*	0/1	0/4
STOP-FIRE	-	-	0/1	-	0/1
TOTAL No. FAILURES	6/16	2/42	5/25	4/47	17/130

* Two 2 lb. 5 oz. and three 2 5/8 lb. extinguishers are included in this category

TABLE 3

FAILURE OF EXTINGUISHERS MANUFACTURED BY
GENERAL FIRE EXTINGUISHER CORP.

Number of Failures/Total Number of Specific Type

Date Manufactured	Type 2 1/2 lb.	2 3/4 lb.	Total for Each Year
No label, but is identical to General models 1960-62 age	1/1 Insufficient Agent	0/1	1/2
No date marked, identical to models 1960-62 age	1/1 Insufficient Agent	-	1/1
1960	3/4 Caked Agent	-	3/4
1962	0/1	-	0/1
1971	-	0/1	0/1
1973	-	0/1	0/1
TOTALS	5/7	0/3	5/10

TABLE 4

FAILURE OF EXTINGUISHERS MANUFACTURED BY
R.C. INDUSTRIES

Number of Failures/Total Number of Specific Type

Date Manufactured	Type 2 lb. Non-refill	2 lb.	2 1/2 lb.	2 3/4 lb.	Total for Each Year
1969	2/3 Packed agent	-	-	-	2/3
1970	-	0/1	-	-	0/1
1971	-	0/1	-	-	0/1
1972	0/2	-	-	-	0/2
1973	-	1/5 Caked agent (1)	-	-	1/5
1974	-	0/3	-	-	0/3
1975	-	0/2	-	-	0/2
1976	-	1/3 Packed agent	-	0/1	1/4
1977	-	0/4	-	0/1	0/5
1978	2/3 Packed agent	0/7	-	-	2/10
1979	0/1	0/3	-	1/2 Packed agent	1/6
1980	-	-	0/2 both recharged	-	0/2
Totals	4/9	2/29	0/2	1/4	7/44

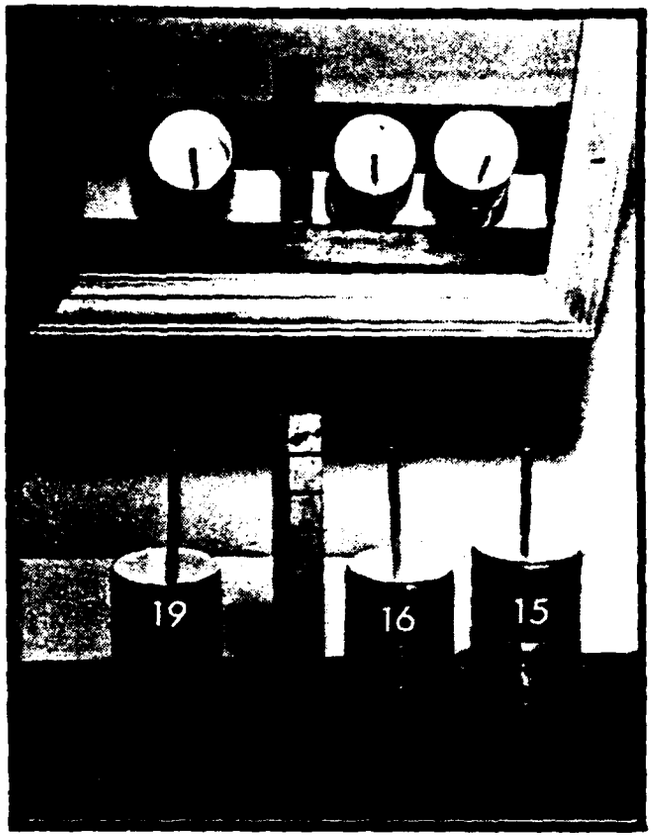
TABLE 5

FAILURE OF EXTINGUISHERS MANUFACTURED BY AMERICAN LAFRANCE

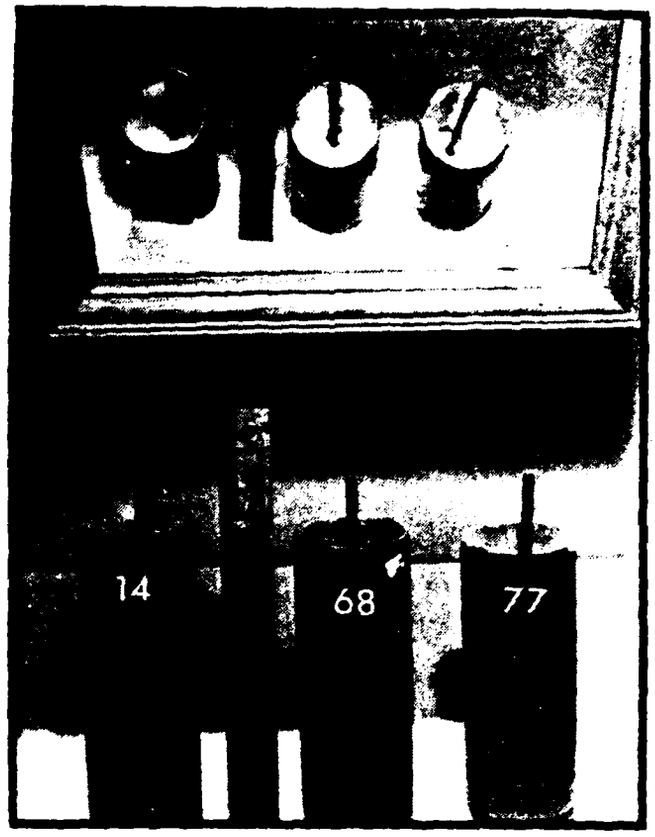
Number of Failures/Total Number of Specific Type

Date Manufactured	Type		Total for Each Year
	2 lb.	2 3/4 lb.	
1965	-	0/1	0/1
1966	-	0/1	0/1
1968	-	0/1	0/1
1970	-	0/4	0/4
1971	-	0/2	0/2
1972	-	0/2	0/2
1973	-	0/5	0/5
1974	-	1/1 Caked agent	1/1
1975	-	0/2	0/2
1976	-	0/3	0/3
1977	0/2	-	0/2
1978	-	0/2	0/2
1979	0/9	-	0/9
1980	0/1 recharged	-	0/1
TOTALS	0/12	1/24	1/36

The following pictures show examples of some of the failed extinguishers. Each marking stake is 10 inches long and the level of agent remaining is marked by a line on the exterior of the bottle.



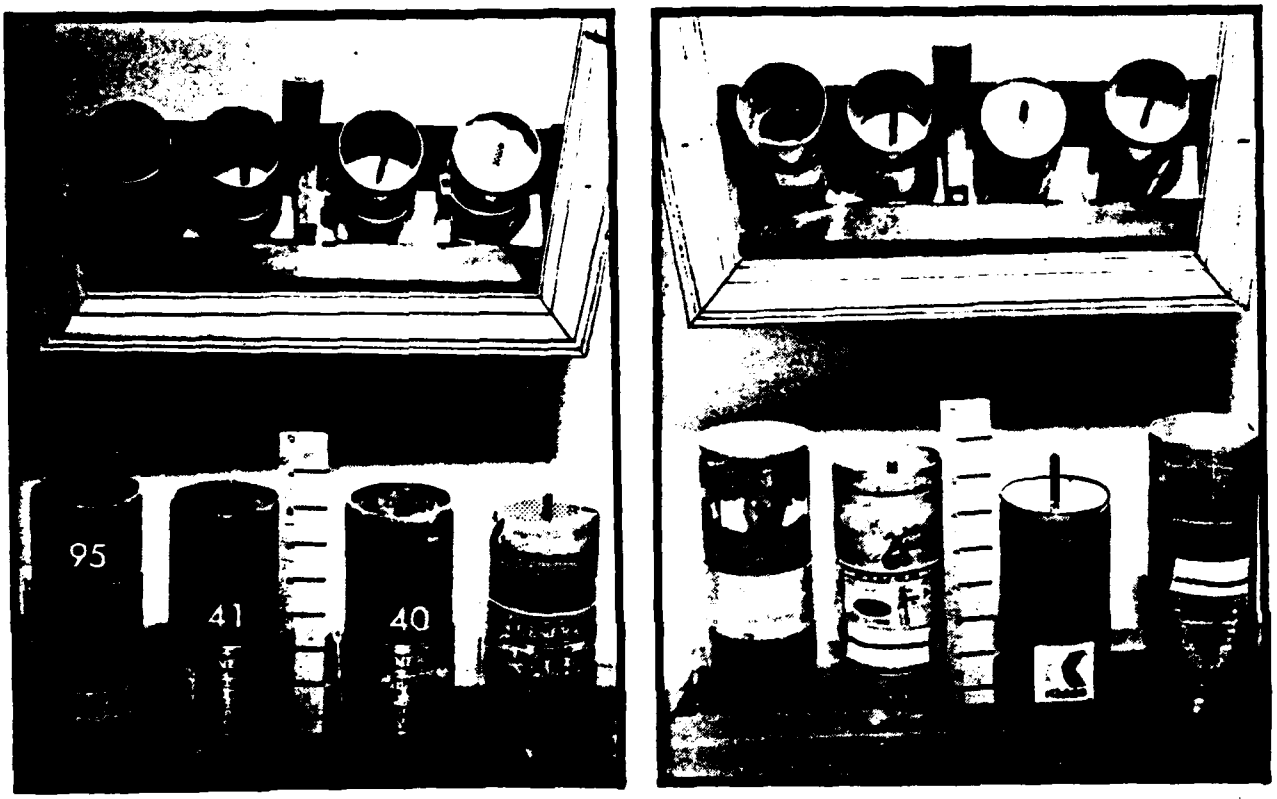
(a) This shows how much agent remained in three of R.C. Industries' non-refillable bottles



(b) This shows packed agent in R.C. Industries' refillable bottles
Note that the powder did not flow in around the marking stake.

FIGURE 2

PICTURES OF FAILED EXTINGUISHERS ((a) through (f))

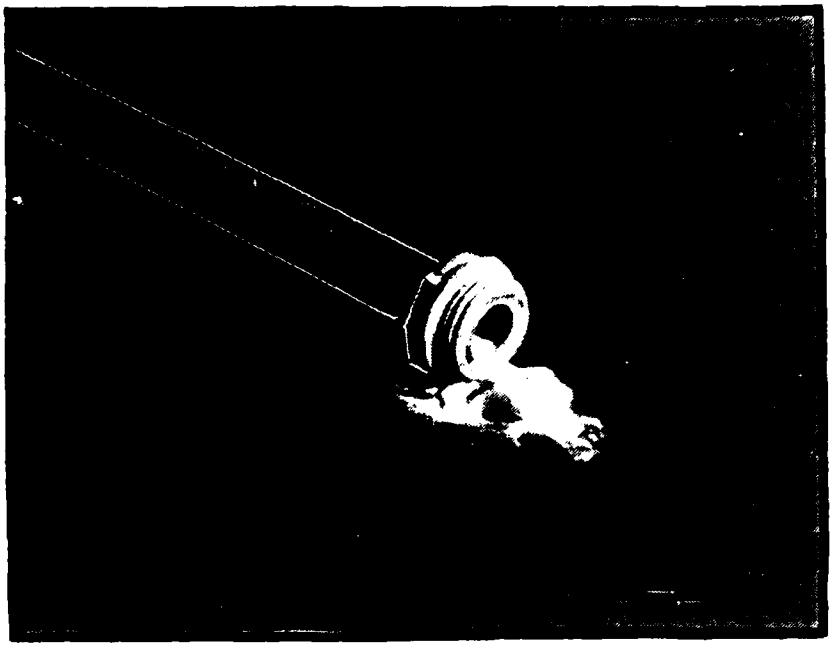


(c) This shows the oldest extinguishers. Note the caking in all three of 41, 40 and 97. A picture of the caked powder from 97 is on the next page.

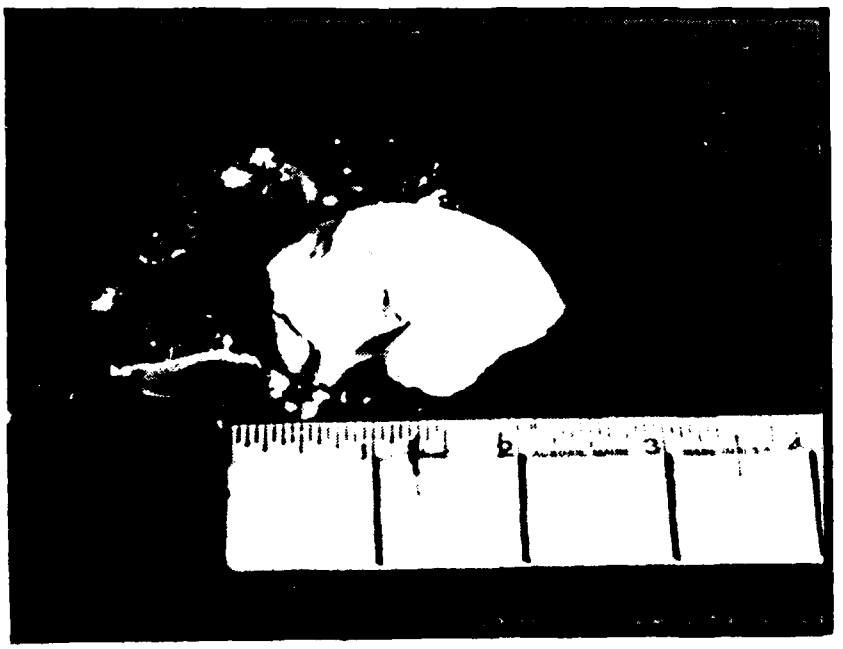
(d) This is a picture of older bottles Note lumps in 76, corrosion on 65 and 127. 127 was a non-refillable that failed completely. 69 was clogged at the valve end of the siphon tube.

FIGURE 2 (Continued)

PICTURES OF FAILED EXTINGUISHERS



(e) This shows the caked plug from "Fyr-Fyter" survey number 69.



(f) This shows a caked lump of agent from "General" survey number 97.

FIGURE 2 (Continued)

PICTURES OF FAILED EXTINGUISHERS

TABLE 6

SUMMARY OF EXTINGUISHER FAILURES BY CAUSES

Date Manufactured	Insufficient Pressure	Agent Packed or Siphon Tube Packed	Caked Powder	Insufficient Powder
1960	0	0	3	2
1966	1	0	0	0
1967	1	0	1	0
1969	1	2	0	0
1973	0	0	1	0
1974	0	0	1	0
1976	0	0	1	0
1978	1	1	0	0
1979	0	1	0	0
TOTALS	4	4	7	2

3.2 Corrosion of Extinguishers

All of the bottles were examined for corrosion. Generally, the aluminum bottles with plastic valves showed the least amount regardless of age. More of the older steel bottles had surface rust than the newer ones. Most of the steel bottles over two years old developed rust at the seams. The steel bottles kept on commercial fishing boats had the most severe rust regardless of age. However, none of the extinguishers or gauges failed due to corrosion. There was no correlation between how much corrosion a bottle had and its performance.

3.3 Statistical Analysis

The survey found a higher number of failures in older extinguishers compared to newer ones and a slightly higher number of failures in one brand compared to other brands. To statistically evaluate whether these actual failure rates predict a difference in reliability, the data was examined by the techniques given in Probability and Statistics for Engineers and Scientists by R.E. Walpole and R.H. Raymond. The technique is applied below.

To compare older to newer extinguishers, the survey was split into two groups. Group one contains those made in 1970 or earlier, and group two contains those made in 1971 and later.

Data: $n_1 = 33$ Number of extinguishers in group one.
$n_2 = 97$ Number of extinguishers in group two.

$x_1 = 11$ Failures in group one.
$x_2 = 6$ Failures in group two.

$p_1 = 11/33$ Proportion of failures in group one.
$p_2 = 6/97$ Proportion of failures in group two.

Assumption: These extinguishers are random samples from two binomial populations.

The difference between the estimated proportion of failures $(\hat{p}_1 - \hat{p}_2)$ has an approximately normal distribution. If both samples are large, then the test statistic (Z) is a random variable which has an approximately normal distribution. A sample is accepted as large if it numbers 30 or more. The test statistic for comparison is calculated by

$$Z = \frac{p_1 - p_2}{\sqrt{pq\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where p is the true population proportion of failures and q is defined as 1-p. To estimate p and q, $\hat{p}$ and $\hat{q}$ are used.

$$\hat{p} = \frac{x_1 + x_2}{n_1 + n_2} \quad \text{and} \quad \hat{q} = 1-\hat{p}$$

The test statistic becomes

$$Z = \frac{p_1 - p_2}{\sqrt{\hat{p}\hat{q}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

The null hypothesis (H_0) is tested. H_0: $p_1 = p_2 = p$ with the alternate hypothesis (H_1) $p_1 > p_2$. The level of significance chosen is $\alpha = 0.01$. The critical region is $z > z_\alpha = 2.33$. The calculation follows:

$$\hat{p} = \frac{11+6}{33+97} = \frac{17}{130} \text{ and } \hat{q} = \frac{113}{130}$$

$$Z = \frac{{}^{11}/_{33} - {}^{6}/_{97}}{\sqrt{{}^{17}/_{130}\left({}^{113}/_{130}\right)\left(\frac{1}{33} + \frac{1}{97}\right)}} = 4.00$$

Since $4.00 > 2.33$, H_0 is rejected, thus with 99% confidence the true proportion of failure is higher for older extinguishers.

Within the limitations of using samples which contain at least 30 extinguishers, the actual failure rates of the different brands of extinguishers were similarly examined. The true proportion of failures is not statistically different for any brand in this survey.

4.0 CONCLUSIONS

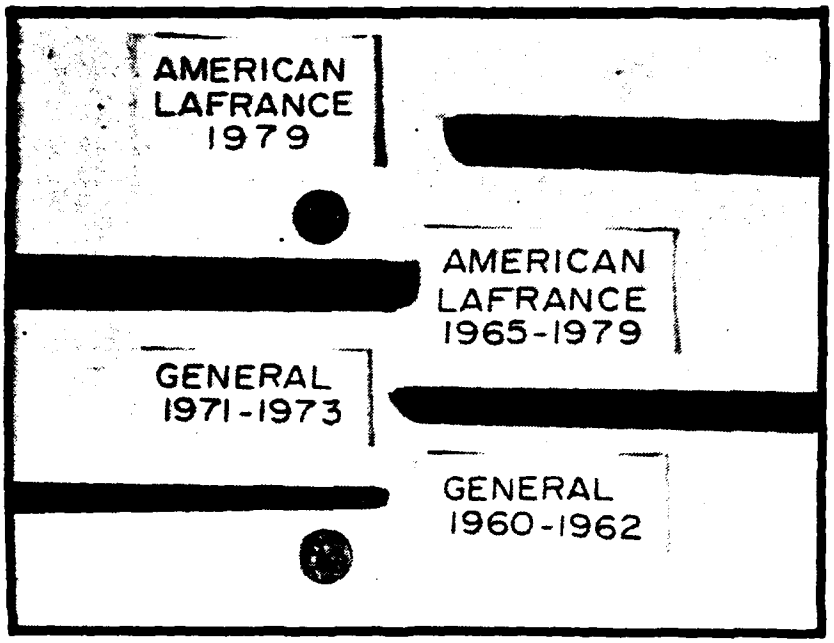
The true failure rate of extinguishers manufactured in 1970 and earlier is higher than the true failure rate for those manufactured in 1971 and later. The sample size of the 1971 and later group is large enough to state with 95% confidence that the true failure rate of extinguishers is 6.2 $\pm$ 5% or between 1.2 and 11.2%.

Although there was some packing and caking of the chemical agent, these conditions did not occur enough times to merit another survey or corrective measures. There also has been a design change which should lessen the effects of any packing. The siphon tube size has been increased from 5-7mm on 1960-1969 models to 8-14mm on the 1970-1982 models. Since 1975 some of the tubes have circular cut-outs or are cut at an angle to increase the surface area of the end of the tube. Figure 3 shows the different tubes photographed next to a dime to indicate the size.

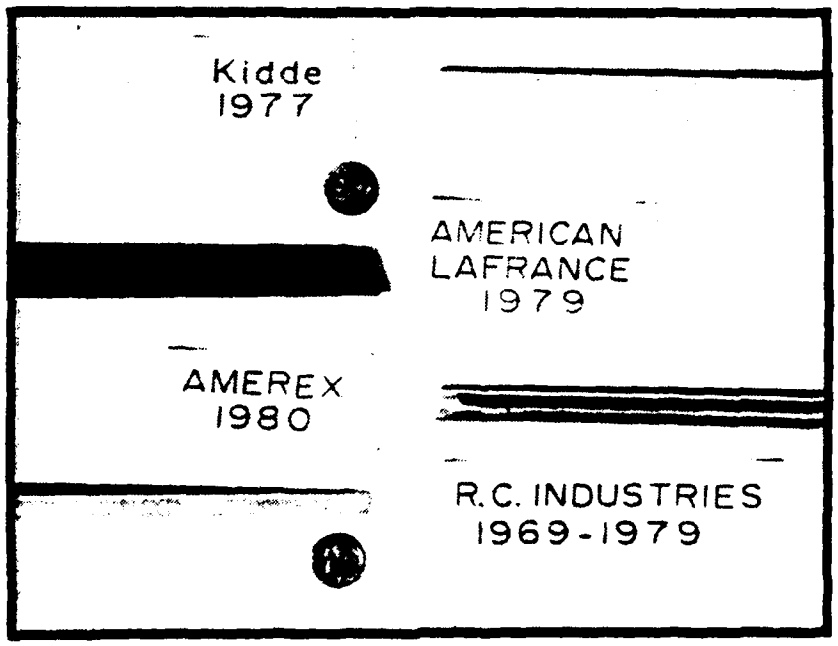
5.0 RECOMMENDATIONS

It is recommended that the Coast Guard change the wording of the requirements for extinguishers on motorboats to highlight the need for maintenance on extinguishers in accordance with ANSI/NFAA 10. This could help eliminate the older, less reliable extinguishers present on motorboats. Most boaters asked how often they should replace their extinguishers. They were not aware of any need to have them checked every six years.

This survey contained samples only from the southeastern Connecticut coastal region. This was done to complete the survey quickly. The climate, sea state, and boating season (May-October) are unique to Long Island Sound. Therefore, the reliability of extinguishers located elsewhere in the United States could be different. In order to tell if the reliability of all extinguishers in use were similar, sampling would have to be conducted nation-wide using at least six sites. If 6% is a reasonable estimate of the failure rate, then at least 90 samples would have to be taken at each location. This would cost approximately $20K.



Comparison of typical 1960's small siphon tube to the newer, larger tubes. The small tube is copper. The rest are rigid plastic.



Comparison of 1970's siphon tubes. Kidde and American LaFrance have rigid plastic tubes. Amerex has an aluminum tube. R.C. Industries has a semi-flexible, plastic tube.

FIGURE 3

PICTURE COMPARISON OF SIPHON TUBES

APPENDIX A

FAILED EXTINGUISHER INFORMATION

No.	Type	Date Mfd.	Manufacturer	Serial No.	Percent Rated Amount Discharge %	Duration of Discharge Seconds
1. (95)	2 1/2 lb	Appears to be 1960	General Fire Ext. Corp.	C-416314	12.5	13.7

There was insufficient agent in the bottle. The charged weight was supposed to be 4 3/4 lb. This one was 2 3/4 lb.

2. (102)	2 1/2 lb	Appears to be 1960	Identical to General models	No label	73.86	7.0

The extinguisher apparently had been refilled. The contents were purple in color rather than light blue like the other General extinguishers. Only two ounces of powder remained. There was insufficient agent.

3. (40)	2 1/2 lb.	1960	General Fire Ext. Corp.	D 92270	39.06	6.2

The agent inside was light blue in color, and caked.

4. (97)	2 1/2 lb.	1960	General Fire Ext. Corp.	C-580838	15.56	3.2

The siphon tube was packed and caked at the tip. Severe tapping only loosened some of the agent. Contents caked.

5. (41)	2 1/2 lb.	1960	General Fire Ext. Corp.	D 101829	63.44	8.5

The agent was well packed and caked. The color was light blue.

6 (86)	2 3/4 lb. Non-refillable	1966	Walter Kidde Company, Inc.	P 452253	95.45	44.0

When fired the powder spilled out only about 1 1/2 - 2 feet. Powder also sprayed out a hole at the neck of the valve. The powder that remained appeared fine.

7. (65)	2 3/4 lb.	1967	CASCO Products Corp.	T 611768	47.44	6.4

The stream fell short between 4 and 5 seconds. The siphon tube was slightly packed at the end. The rest of the powder appeared fine. There must have been insufficient pressure.

FAILED EXTINGUISHER INFORMATION (continued)

No.	Type	Date Mfd.	Manufacturer	Serial No.	Percent Rated Amount Discharge %	Duration of Discharge Seconds
8. (69)	2 3/4 lb.	1967	FYR-FYTER	N-660086	79.83	9.2
	The siphon tube was packed and the agent was caked. There was a caked plug at the valve end of the tube.					
9. (15)	2 lb. Non-refillable	1969	R.C. Industries	Z 181039	25.00	4.9
	The agent was well packed.					
10. (16)	2 lb. Non-refillable	1969	R.C. Industries	Z 187747	26.69	5.0
	The agent was well packed.					
11. (127)	2 3/4 lb. Non-refillable	1969	Walter Kidde Company, Inc.	T 429485		
	Nothing was discharged when the extinguisher was fired.					
	The pressure gauge indicated that the pressure was between discharged and full. There was no pressure nor was there any indication of powder around the nozzle indicating the extinguisher had been fired before.					
12. (68)	2 lb.	1973	R.C. Industries	852	71.09	9.0
	The agent was packed and caked. The powder had small lumps.					
13. (76)	2 3/4 lb.	1974	American LaFrance	AJ 261472	36.65	6.4
	The agent was well packed and slightly caked.					

FAILED EXTINGUISHER INFORMATION (Continued)

No.	Type	Date Mfd.	Manufacturer	Serial No.	Percent Rated Amount Discharge %	Duration of Discharge Seconds
14. (77)	2 lb.	1976	R.C. Industries	CB-731666	75.00	8.5
	The tip of the siphon tube was packed. The agent was well packed and slightly caked.					
15. (19)	2 lb. Non-refillable	1978	R.C. Industries	CV 369217	31.25	6.4
	Both the siphon tube and the neck of the nozzle were packed with powder.					
16. (58)	2 lb. Non-refillable	1978	Fire Control	CS 613061	85.55	8.4
	The stream shot out barely 5 feet initially and dropped off to less than that quickly. There was insufficient pressure to propel the powder. The agent was only slightly packed.					
17. (14)	2 3/4 lb.	1979	R.C. Industries	DE 904610	66.19	8.2
	The bottom six inches of the siphon tube was plugged with packed powder. The tube had to be vigorously tapped to empty the tube. The agent was slightly packed. When tipped on the side the agent fell loose.					

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