

Fire Tests of Bulb-Type Carbon-Tetrachloride Fire Extinguishers

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Preface

The National Bureau of Standards has received numerous inquiries relative to the effectiveness of small bulb-type carbon-tetrachloride fire extinguishers, not only when used as hand extinguishers for first-aid fire protection but also when employed for the automatic protection of enclosed spaces.

This paper gives the results of some fire tests that the Bureau's Fire Protection Section has made of devices of this sort. The information is intended to assist in the evaluation of fire extinguishing equipment of small capacity.

E. U. CONDON, *Director.*

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Fire Tests of Bulb-Type Carbon-Tetrachloride Fire Extinguishers

O. J. Hodge

Results are given of fire tests on samples of seven different bulb-type carbon-tetrachloride fire extinguishers ranging in capacity from 0.44 to 1.75 quarts. Six of the extinguishers were tested both for manual and automatic operation. The seventh device was tested for automatic operation only, since it was not designed for manual use.

The tests of the devices as automatic extinguishers were conducted in a room with ventilation just sufficient to permit the test fires to burn freely until the fuel was consumed, with no extinguishers present.

The test results showed that the bulb-type carbon-tetrachloride fire extinguishers, as represented by the samples tried, when operated by hand were distinctly less effective than the ordinary one-quart carbon-tetrachloride pump-gun extinguisher, and when employed as automatic devices were not effective for the protection of the enclosed space. The seven devices were tested in the number recommended by the manufacturer and six of them were also tried in double that number.

I. Introduction

The National Bureau of Standards has conducted several series of tests to determine the effectiveness of bulb-type fire extinguishers using carbon tetrachloride as the extinguishing agent. The devices investigated included seven different models, of which six were designed both for hand and automatic operation. The seventh extinguisher was designed for automatic operation only. The capacities of the extinguishers ranged from 0.44 qt (14 fl oz) to 1.75 qt (56 fl oz):

II. Description of Devices Tested

The six extinguishers designed for both hand and automatic operation consisted essentially of a glass flask or bottle containing from 0.44 to 1.00 qt of extinguishing liquid. The extinguishers were mounted in a bracket intended to be hung on the wall or, in some cases, from the ceiling. The general character of the extinguishers is shown in figure 1. The sketches are diagrammatic to illustrate two styles of the devices tested, but do not represent them exactly.

For hand operation, the bottle was intended to be removed from its bracket and the contents applied either by throwing the extinguisher into the fire forcibly enough to break the bottle or by sprinkling the liquid from the bottle on the fire.

For automatic operation, each of the six extinguishers was equipped with a thermostatic device intended to release the liquid when the temperature at the extinguisher reached a predetermined value. The thermostatic device was attached to the bracket or to the extinguisher itself. Two methods of release were included. One permitted the bottle to fall to the floor and break, thus discharging the liquid; the other permitted the liquid to sprinkle from the bottle while still held in the bracket.

The extinguisher intended for automatic operation

only was mounted in a bracket to be hung from the ceiling and was especially designed to discharge 1.75 qt of extinguishing liquid in the form of a spray when the temperature of the air surrounding the device rose above a predetermined value.

The extinguishers included in the tests are designated by A to G, as listed in table 1.

In all the tests of the devices designated as automatic extinguishers, the units were installed in accordance with the manufacturer's instructions.

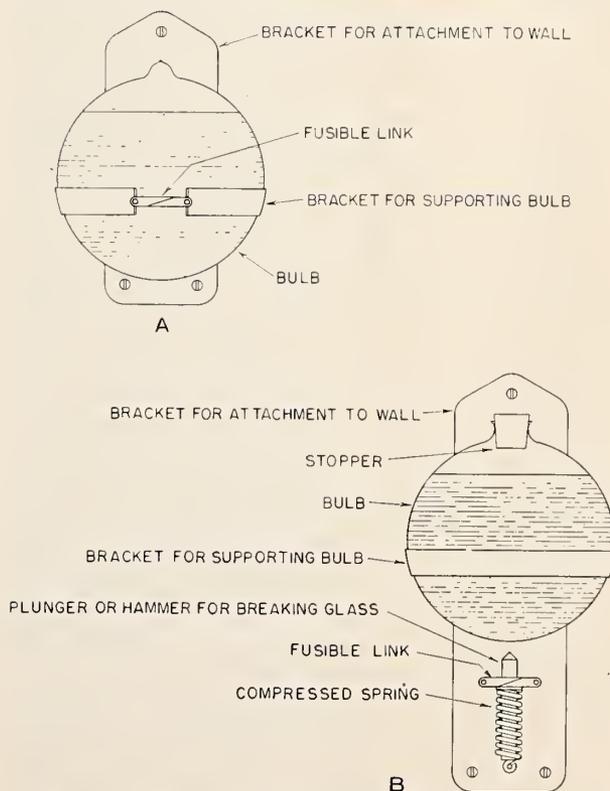


FIGURE 1. General character of two styles of the extinguishers tested. A, Drop-on-floor type; B, Spring-operated type.

TABLE 1. Extinguishers included in the tests

Extinguisher designation	Amount of extinguishing liquid used		Method of operation as hand extinguisher	Temperature at which device was intended to operate when used as automatic extinguisher
	fl oz	qt		
A	14	0.44	Throwing	150
B	14	.44	Sprinkling	160
C	19	.59	do	160
D	24	.75	Throwing or sprinkling	158
E	27	.84	Sprinkling	160
F	32	1.00	Throwing or sprinkling	158
G	56	1.75	-----	170

III. Tests of Devices as Hand Extinguishers

By reason of the nature of the extinguishing liquid employed, devices of the carbon-tetrachloride type when used as hand extinguishers are not suitable for fires in ordinary freely burning materials such as wood, trash, and the like ("class A" fires). The liquid is, however, effective for fires in highly flammable materials such as gasoline, oil, and the like (class B fires).

As the devices tested employed an effective extinguishing medium, the question to be answered in the tests was whether they made available (for class B fires) a sufficient quantity of the liquid and applied it in a sufficiently effective manner to be of practical value. Therefore, to evaluate the effectiveness of the devices, they were tested in comparison with the 1-qt carbon-tetrachloride pump-gun extinguisher, which is the smallest extinguisher of that type generally recognized as acceptable for first-aid fire protection.

For testing extinguishers of the 1-qt carbon-tetrachloride pump-gun type, certain "standard" test fires are commonly used. Among these fires are (1) a fire of 1 gal of gasoline on a 4- by 8-ft floor area, and (2) a fire of 1/2 gal of gasoline on a 4- by 4-ft floor area. For the purposes of comparative tests of the bulb-type extinguishers with the 1-qt pump-gun extinguisher, the second, or smaller, of the two test fires was selected first. This fire can easily be extinguished by the 1-qt pump gun. When (as indicated in the test results given below) it was found that none of the bulb-type extinguishers could extinguish this fire when only one unit was used, trials were made in which a number of units were applied in succession. Further trials were then made in which the area of the test fire was reduced from 4 by 4 ft (16 ft²) to 3 by 3 ft (9 ft²), and the quantity of gasoline from 1/2 gal to 1 qt. It was found by test that this fire could be extinguished with a 1-qt pump gun by the use of less than one-half of its charge. Finally, trials were made in which the area of the original test fire was reduced to a 2- by

2-ft square (4 ft²) with 1 qt of gasoline as fuel. It was found by test that this fire could be extinguished with a 1-qt pump gun by the use of only about one-half of its charge. In the tests on the 3- by 3-ft and 2- by 2-ft-area fires, only one unit was used in each trial. Of these two fires, that on the 2-ft-sq area was the most difficult to extinguish because of the greater depth of gasoline.

The tests were conducted indoors in the Bureau's panel-furnace test building, in a room approximately 84 ft long by 36 ft wide by 30 ft high. The gasoline was confined to the specified area on the concrete floor of the room by an edging constructed of asbestos paste.

1. Results of Tests

The results of the tests of the devices as hand extinguishers are given in table 2.

TABLE 2. Results of tests of the devices as hand extinguishers

Trial	Area of test fire	Extinguisher				Was fire extinguished?
		Designation	Capacity	Method of operation	Number of units used	
Test 1						
1	4×4	A	0.44	Throwing	1	No
2	4×4	B ¹	.44	Sprinkling	1	No
3	4×4	C	.59	do	1	No
4	4×4	D	.75	do	1	No
5	4×4	E	.84	do	1	No
6	4×4	F	1.00	Throwing	1	No
Test 2						
1	4×4	A	0.44	Throwing	5	No
2	4×4	C	.59	Sprinkling	3	Yes
3	4×4	C	.59	do	4	Yes
4	4×4	D	.75	do	2	Yes
5	4×4	D	.75	do	3	Yes
6	4×4	E	.84	do	3	Yes
7	4×4	F	1.00	Throwing	4	No
Test 3						
1	3×3	C ²	0.59	Sprinkling	1	No
2	3×3	C	.59	do	1	No
3	3×3	D	.75	do	1	Yes
4	3×3	D	.75	do	1	No
5	3×3	D	.75	do	1	No
6	3×3	E	.84	do	1	No
7	3×3	E	.84	do	1	No
Test 4						
1	2×2	C ²	0.59	Sprinkling	1	No
2	2×2	C	.59	do	1	No
3	2×2	D	.75	do	1	No
4	2×2	D	.75	do	1	No
5	2×2	E	.84	do	1	No
6	2×2	E	.84	do	1	No

¹ On account of its similarity in design to another extinguisher of larger capacity (extinguisher E), extinguisher B was tried only in the first test on the 4- by 4-ft-area fire.

² Due to the negative results obtained in the previous trials of the devices which were applied as hand grenades, extinguishers A and F were not tried in the tests on the 3- by 3-ft and 2- by 2-ft-area fires.

2. Summary and Discussion of Results

The tests discussed in this paper showed that the bulb-type devices when used as hand extinguishers were less effective than the 1-qt pump-gun carbon-tetrachloride extinguisher. In the first place, the capacity of the devices was, in general, too small to be practically effective and, in the second place, the manner in which the extinguishing liquid was applied made the devices less effective than the pump-gun extinguisher for the same volume of liquid used.

The first test showed that none of the devices put out a relatively simple test fire that the 1-qt pump gun can usually extinguish easily. The second test showed that to put out this test fire, more (in most cases much more) extinguishing liquid was required. The third and fourth tests showed that even with test fires reduced in extent and severity to a point where they could be extinguished easily by not more than one-half of the full charge of a 1-qt pump-gun extinguisher, the devices did not put out the test fires except in the case of one of the units in one of three trials.

With the bulb-type extinguishers, the liquid is not as thoroughly broken up and as readily vaporized as it is with the pump-gun extinguisher, from which the liquid is forcibly projected in a relatively compact stream that changes to a fine spray when it strikes objects in the fire. Furthermore, when the liquid is applied by sprinkling from a container, it cannot be as effectively directed as it can be with the pump gun and, apparently, a considerable portion of the liquid serves to dilute the burning gasoline rather than to cause the formation of a smothering gas blanket.

In the trials in which the test fire was not extinguished, the flames were somewhat diminished during the application of the liquid, but the fuel continued to burn with the production of dense, acrid fumes in great volume. The tests were made in a room with a total volume of approximately 90,000 ft³. When 1 qt of extinguishing liquid was applied in the manner described above, it was found that shortly afterward the fumes became so irritating that the operator was driven from the room, and they became so opaque that it was impossible to distinguish objects at distances greater than 3 or 4 ft.

IV. Tests of Devices as Automatic Extinguishers

The tests of the devices when used as automatic extinguishers were conducted in one of the Bureau's fire-test buildings that contained a single room 29 ft long by 15 ft 3 in. wide by 10 ft 1 in. high. The walls were of brick and the floor and ceiling, concrete. A fireproof partition was erected across the building 13 ft from one end to provide

a test space of 2,000 ft.³ This enclosure contained a single window 3 ft 4 in. wide by 4 ft 10 in. high, with the bottom 3 ft from the floor. It was provided with a fireproof shutter, pivoted horizontally at the center, which was so arranged that it could be set at any given inclination to give the desired ventilation. A tightly fitting door was constructed in the partition to give access to the test space. This door was kept closed when the tests were in progress. The space in the building outside of the test space contained three windows, each 3 ft 4 in. by 4 ft 10 in. and one door, all of which were kept open during the tests.

During each test, the temperature of the air surrounding the extinguishers, as well as the temperature at various other points in the test space, was measured with thermocouples. The progress of the test fires was observed by temperature measurements taken at various points in the paths of the flames.

1. Extinguishers A to F

According to the claims made for fire extinguishers A to F when presented for the tests, the theory of operation was that should a fire occur in the protected space the temperature would rise and the release mechanism would cause the discharge of the carbon tetrachloride, whereupon the liquid would vaporize and be carried by the convection currents over the burning area to smother the fire with an oxygen-excluding blanket. According to this theory, these devices were intended to place a smothering gas blanket locally over a small area of burning fuel and not to provide vapor sufficient to dilute the atmosphere of the protected space to a point where combustion could no longer be possible because of the low oxygen content. This theory excluded the use of the devices for fires in ordinary combustible materials for which carbon tetrachloride when locally applied is not considered suitable, and the fires used in the tests were, therefore, confined to fires of flammable liquids (class B fires).

Because of the danger involved in the handling of gasoline in a small room, oil rather than gasoline was used for the fuel. The oil was a mixture of two parts of light engine oil with one part of kerosene. The fuel was contained in a pan located on the floor. Fires of two sizes were used. The larger of the two consisted of 2 gal of burning fuel in a pan 3 ft sq having 6-in. sides. For the second fire, ½ gal of fuel was used in a pan 2 ft sq having 1-in. sides.

The number of extinguisher units recommended by the makers was one for each 1,000 ft³ of space protected. Accordingly, trials were first made with two units in the 2,000-ft³ test space. Another series of trials was then made, in which the number of units was doubled

(a) Results of Tests

(1) *First test with two extinguisher units.* Extinguisher C was chosen for this test. As shown in table 1, this extinguisher had a capacity intermediate between that of the smallest and the largest extinguishers in the group A to F. In each trial, the two units were mounted $5\frac{1}{2}$ ft above the floor on the vertical center lines of the two end walls of the test space.

In every trial, the test fire pan was on the floor. Trials were first made with the pan at the center of the test space (location *a*), then with the pan next to one of the 13-ft walls directly under one of the two extinguishers (location *b*), and finally with the pan in a corner of the test space (location *c*). The three locations of the pan are shown in figure 2. Location *b* is also indicated in figure 3.

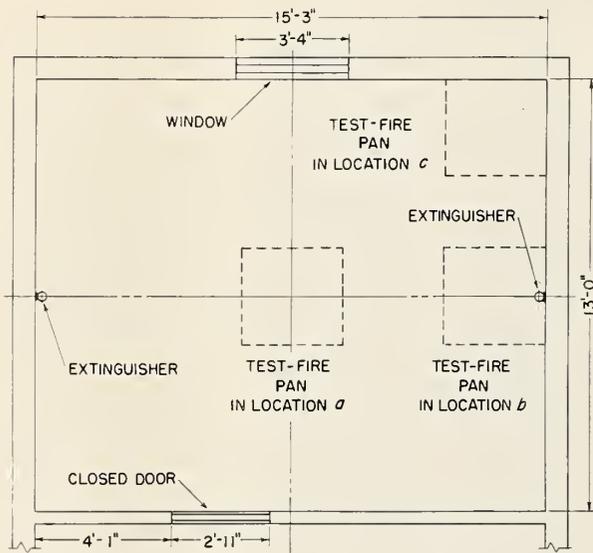


FIGURE 2. Plan for first series of trials of devices A to F as automatic extinguishers.

Two units used; 3-foot-square test-fire pan in trials 1 to 3; 2-foot-square pan in trials 4 to 8.

During these trials, the shutter was tilted so that the ventilation through the window, both above and below the shutter axis, was just enough to permit the fuel in the test space to burn freely. The results of the test are given in table 3.

(2) *Second test with four extinguisher units.* The second test, in which four rather than two extinguisher units were used in each trial, was made because of the negative results shown in the first test. The extinguishers chosen for the second

test were the following: Extinguisher A, one of the two extinguishers having the smallest capacity (0.44 qt) of those tested; extinguisher F, having the largest capacity (1.00 qt); and in one trial, extinguisher E, having an intermediate capacity (0.84 qt).



FIGURE 3. Trial 5, first series of tests of devices A to F as automatic extinguishers.

The test pan was located directly beneath one of the extinguisher units, as shown.

TABLE 3. Results of tests of devices A to F as automatic extinguishers

Trial	Test fire				Extinguisher				Was fire put out by the extinguisher?	Fuel consumed	Duration of fire, extinguishers present	Duration of fire, no extinguishers present
	Fuel		Area of test pan	Location of fire ¹	Designation	Capacity	Number of units used	Number of units which operated				
	Kind	Quantity										
TEST 1												
1	Oil	gal	ft	a	C	qt	2	2	No	Percent	min	min
2	do	2	3×3	b	C	.59	2	2	No	100	14	14
3	do	2	3×3	c	C	.59	2	2	No	100	14	14
4	do	½	2×2	a	C	.59	2	2	No	100	15	14
5	do	½	2×2	b	C	.59	2	1	Yes	100	12	11
6	do	½	2×2	b	C	.59	2	1	Yes	Less than 100	0.7	11
7	do	½	2×2	c	C	.59	2	2	No	Less than 100	.9	11
8	do	½	2×2	c	C	.59	2	1	No	100	14	14
		½	2×2	c	C	.59	2	1	No	100	14	14
TEST 2												
1	Oil	2	3×3	a	A	0.44	4	4	No	100	14	13
2	do	2	3×3	a	F	1.00	4	3	No	100	13	13
3	do	2	3×3	d	A	0.44	4	4	No	100	15	13
4	do	2	3×3	d	E	.84	4	4	No	100	14	13
5	do	2	3×3	d	F	1.00	4	4	No	100	13	13

¹ See figure 2 for test 1, and figure 4 for test 2.

² The ambient temperature at 1 extinguisher was 205° to 210° F for 1½ min and at the other extinguisher, 200° to 250° F for 2½ min.

³ The ambient temperature at the 4 extinguishers for 10 min during the test

was 370° to 415° F, 255° to 310° F, 355° to 410° F, and 245° to 285° F, respectively. ⁴ The ambient temperature at the 4 extinguishers for 10 min during the test was 230° to 300° F, 275° to 310° F, 315° to 355° F, and 230° to 300° F, respectively.

In each trial of the four samples under test, two were mounted on the 15-ft 3-in. wall and two on the partition opposite. The extinguishers were mounted at a height of 5½ ft from the floor and were spaced 3 ft 10 in. from the 13-ft walls, as shown in figure 4.

On account of the nature of the results obtained in the first test, it was not considered necessary in the second test to include all the test conditions covered in the first. Therefore, only one of the two test fires was used, the fire of 2 gal of oil and kerosine in the 3-ft-sq pan. The trials were made at location *a* with the pan on the floor at the center of the test space, and at location *d*, with the pan on the floor adjacent to one of the 13-ft walls.

During the trials, the lower half of the window in the 15-ft 3-in. wall was sealed off, and the shutter was tilted to leave an opening 40 by 20 in. in the upper half. Additional ventilation was provided for these tests by an opening approximately 40 by 20 in. in the fireproof partition opposite. Both openings were above the midheight of the test space, which was a condition recommended by some of the makers of the devices tested. The total area of the ventilating openings amounted to 4 percent of the wall area above the midplane of the enclosed space. Trials with no extinguishers present showed that these openings provided just enough ventilation to permit the test fires to burn freely until the fuel was consumed. The results of these trials are given in table 3.

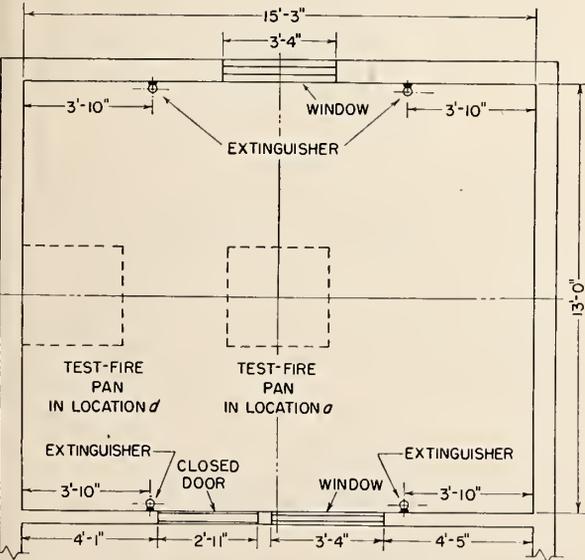


FIGURE 4. Plan for second series of trials of devices A to F as automatic extinguishers.

Four units used; 3-foot-square test-fire pan.

(b) Summary of Results

The tests of the devices in group A to F when used as automatic extinguishers were conducted in a room of 2,000-ft³ capacity in which the ventilation was sufficient to permit the fires to burn freely until all the fuel was consumed. The tests showed that when two extinguisher units (extinguisher C) were used the devices were not effective in extinguishing or checking relatively simple test fires located on the floor, except when a small fire was located directly under one of the extinguishers so that all its liquid was promptly discharged into the pan of burning oil. When the units were doubled in number and located so that no extinguisher was directly above the test fire, the devices (extinguishers A, E, and F) failed to extinguish or check the fires either when they were in the center of the room or against the wall. The thermal release mechanisms of some of the units failed to operate as intended.

2. Extinguisher G

Extinguisher G was in the nature of an installed system that operated on the principle of diluting the atmosphere of the entire protected space to a point where combustion would no longer be possible because of the low oxygen content. The claims for this device did not exclude fires in ordinary freely burning materials, as was the case for the extinguishers in group A to F. Hence, in the tests of this extinguisher, trials were made both on fires of freely burning material (class A fires) and fires of flammable liquid (class B fires).

The ventilating openings in the test space were the two 40- by 20-in. windows used in the second series of trials of extinguishers A to F.

The number of extinguisher units specified by the maker for extinguishing fires in ordinary freely burning materials was one for every 1,000 ft³ of space protected and for putting out fires in gasoline, oil, and like materials, one for every 750 ft³. Accordingly, in the trials on the wood fires, two extinguishers were used and in the trials on the oil fires, three extinguishers. The units were suspended from the ceiling on the longitudinal center line of the test room and were equally spaced, as shown in figures 5 and 6.

(a) Results of Tests

(1) *First test with two extinguisher units on class A fires.* For the class A fires, one of the wood fires frequently employed as "standard" for the 2½-gal soda-and-acid hand extinguisher was used. The fuel for this fire consisted of 78 pine sticks 2 by 2 by 24 in. long. The sticks were arranged in 13 layers. They were laid parallel and about

2 in. apart in each layer. Those of each layer were laid transversely to those of the preceding layer. A cube was thus formed approximately 24 in. on the side, with air channels to afford ready combustion. The cube was built on supports 1½ ft from the floor and was ignited by ½ gal of gasoline in a pan placed 1 ft below the cube. The results of the test are given in table 4.

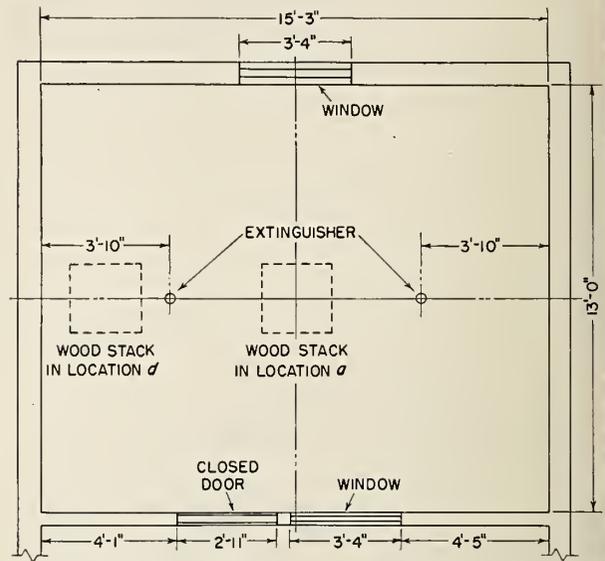


FIGURE 5. Plan for trials of automatic extinguisher G on wood fire. Two extinguisher units used.

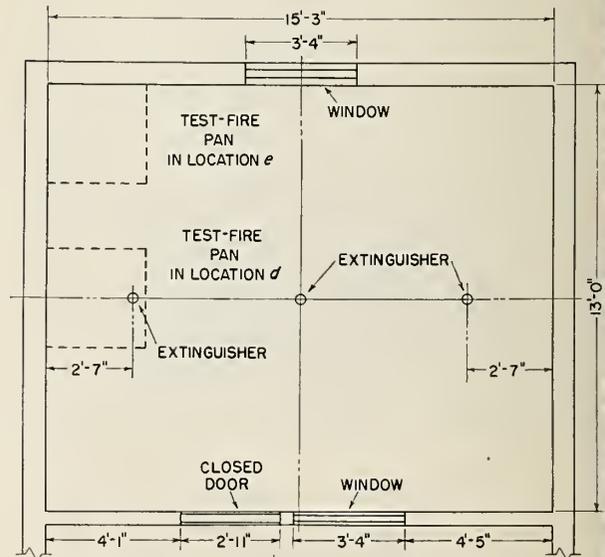


FIGURE 6. Plan for trials of automatic extinguisher G on oil fire on floor. Three extinguisher units used, 3-foot-square test-fire pan.

TABLE 4. Results of tests of automatic extinguisher G (capacity 1¾ qt)

Trial	Test fire				Extinguisher		Was fire put out by the extinguishers?	Fuel consumed	Duration of fire, extinguishers present	Duration of fire, no extinguishers present
	Fuel		Area of test pan	Location of fire ¹	Number of units used	Number of units which operated				
	Kind	Quantity of oil								
TEST 1										
1	Wood ³	gal	ft	a	2	2	No	Percent 100	min 29	min 29
2	do			d	2	2	No	100	30	29
TEST 2										
1	Oil	2	3×3	e	3	4 ²	No	100	13	13
2	do	3	3×3	d	3	5 ³	Yes	40	4	22
3	Oil and wood ³	3	3×3	f	3	3	No	100	6 ²³	6 ²²

¹ See figure 5 for test 1 and figures 6 and 7 for test 2.

² For the wood fires, this was the time when the stack collapsed.

³ See description in text.

⁴ One unit failed to operate, although the ambient temperature at the extinguisher was about 400° F for 8 min.

⁵ One unit discharged only one-half its contents, although the ambient temperature at the extinguisher was 390° to 480° F for over 2 min.

⁶ Duration of oil fire. Wood continued to burn.

(2) *Second test with three extinguisher units on class B fires.* For the class B fires, 2 or 3 gal of the mixture of two parts light engine oil and one part kerosine were used in the 3-ft-sq pan having 6-in. sides. The results of these trials are given in table 4.

The third trial in the second test was made because it appeared probable that, since the fire in the previous trial was located directly under one of the extinguishers, the extinguishment of the fire had been accomplished by a local gas blanket rather than by dilution of the whole atmosphere of the enclosed space. Hence, in the third trial, the same test fire was used, but the pan was placed beneath a wooden bench and about 18 in. off the floor, as shown in figure 7.

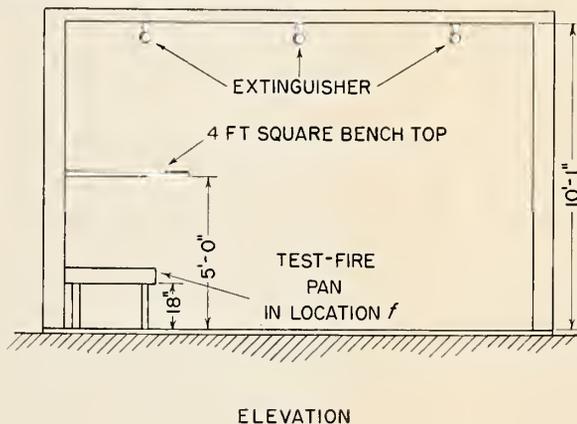
(b) Summary of Results

The tests of extinguisher G were conducted in the same 2,000-ft³ room used for similar tests of the smaller extinguishers. As in those trials, sufficient ventilation was provided to permit the fires to burn freely so that they would not extinguish themselves.

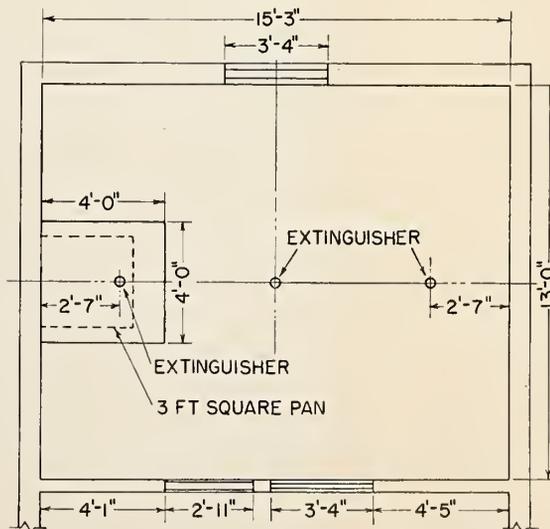
As indicated in table 4, in both of the trials with a fire of freely burning material (class A fire) the extinguisher, when one unit was used for each 1,000 ft³ of space, failed either to extinguish or check the fire.

In the tests with the oil fires (class B fires), in which one unit was used for each 667 ft³, the extinguisher failed to put out or check the test fires in two of the trials and extinguished the fire in one trial. In that trial, the fire was placed directly beneath one of the units.

It appeared probable that, under the conditions of the third trial, the fire was not extinguished by dilution of the atmosphere of the enclosed space but by a local blanketing effect.



ELEVATION



PLAN

FIGURE 7. Plan and elevation for trial of automatic extinguisher G on oil fire in 3-foot-square pan shielded by wood bench.

Three extinguisher units used.

V. Conclusions

The tests indicated clearly that when hand operated the bulb-type carbon-tetrachloride extinguisher, as represented by the samples tried, was distinctly less effective than the 1-qt pump-gun extinguisher, the smallest generally considered acceptable, principally by reason of the manner in which the liquid was applied.¹

The bulb-type devices when employed as automatic extinguishers were not effective in protecting the enclosed space. The seven devices were tested

in the number recommended by the manufacturer, and six of them were also tried in double that number.²

¹ Other types of hand extinguishers recommended for use on fires in flammable liquids (class B fires) are described in the Manual of Fire-Loss Prevention of the Federal Fire Council and the NFPA Handbook of Fire Protection, Tenth Edition. The Manual may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 30 cents a copy. The Handbook is published by the National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.

² Water-sprinkler systems are commonly employed for the automatic protection of enclosed spaces in which the combustibles are of the usual freely burning solids. For flammable-liquid fires in enclosed spaces, automatically operated systems employing carbon dioxide or foam are sometimes installed

WASHINGTON, July 24, 1950.

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