P-1998

NAVEXOS (NRL) 54

REPORT NO. P-1998

DATE February 15, 1943

SUBJECT FR-1998

A GENERAL SURVEY OF THE USE OF METHYL BROMIDE AS A FIRE EXTINGUISHING AGENT

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by
UNLIMITED
ONR

U. S. GOVERNMENT PRINTING OFFICE 16—21906-1

February 15, 1943 NRL Report No. P-1998

NAVY DEPARTMENT

Report on

A General Survey of the Use of Methyl Bromide as a Fire Extinguishing Agent

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 17 Plates - 1

Authorization: BuShips ltr. A93-3(356) of June 13, 1941

Prepared by: Richard L. Tuve, Chemist

Reviewed by: P. Borgstrom, Head Chemist,
Superintendent, Chemistry Division

Approved by: A. H. Van Keuren, Rear Admiral, USN,
Director

Distribution:
BuShips (6)
BuAero (3)
BuY & D (2)
NDRC (2)
Coord R & D (2)
Opnav (2)
CWS (2)
Comm.Gen. S.O.S.
War Dept. (5)

TABLE OF CONTENTS

Page

ABSTRACT

INTRODUCTION
(a) Authorization 1
(b) Statement of Problem 1
(c) General Background of Problem 1
(d) Basic Consideration of Fire-Extinguishing Agents ... 2

METHODS
(a) Qualitative Laboratory Experiments on Methyl Bromide 4

DISCUSSION
(a) Discussion of Factors Involved in Comparison of These Agents 5
(1) Toxicity of the materials 5
(2) Weight of total system of fire protection .. 11
(3) Volume of total system of fire protection .. 12
(4) Ease of operation of the system 12
(5) Maintenance of system and its general reliability and safety 13
(6) Flexibility of installation and application of the system 13
(7) Availability and relative ease of recharging spent containers 14

CONCLUSIONS
(a) General Summary and Evolved Considerations 15
(b) Recommendations on Materials Tested 15
(c) Bibliography 17

PHOTOGRAPHS

Comparison of Two-Pound "Essex, No. 3" Methyl Bromide Extinguisher and Two-Pound Carbon Dioxide Extinguisher ..... Plate 1

APPENDICES

"Industrial Safety" ..... Appendix 1
"Comparative Safety" ..... Appendix 2

ABSTRACT

The dominating characteristics of extinguishers utilizing methyl bromide, carbon tetrachloride and carbon dioxide, are compared and discussed with only general reference to their conditions of application.

Results of qualitative comparative tests on oil fires at the Laboratory using the above materials are given.

Although the present availability of the methyl bromide extinguisher is not too clear a picture, the advantages it possesses in weight and volume per unit effectiveness apparently warrant additional knowledge and study of its limitations under specific requirements of application to fire risks.

INTRODUCTION

(a) Authorization

1. Authority for this survey was granted in a letter from Bureau of Ships to Director, Naval Research Laboratory, A93-3(356) of June 13, 1941.

(b) Statement of Problem

2. The request for comments on the "suitability of methyl bromide in fire-extinguishing systems" contained in the basic letter fortunately did not limit the scope of this investigation to any particular phase of application of this material to fire protection. Therefore, effort has been expended in covering the field in as general a manner as possible, with no emphasis placed on any use to which methyl bromide may be better suited than other existing fire extinguishers.

(c) General Background of Problem

3. The use of methyl bromide as a fire-extinguishing agent apparently stems from an investigation by a British chemist in search of a refrigerant of a non-inflammable character for use in cooling systems in relatively inaccessible places such as a ships' hold. As far back as 1926 methyl bromide was recognized as a successful extinguishing liquid (1) applied in the liquid state directly to the fire. Even previous to this its toxicological qualities had been taken into consideration and numerous experiments had been made in an attempt to disprove its deadliness.

4. Subsequent experiments up to 1933 showed quite clearly by actual trials on different types of fires the efficiency of this material for this purpose.

5. At about this time or shortly thereafter the Essex Methyl Bromide fire extinguisher was merchandized by the National Fire Protection Co. Ltd., of Richmond, Surrey, England.

6. According to information recently secured from domestic fire-extinguisher manufacturing companies, no counterpart of this extinguisher was available in this country at that time, although a company titled "The Stop-Fire Co.," with home offices in France, was said to have attempted the introduction of methyl bromide in the United States up to approximately 1935, at which time the organization ceased business transactions.

7. The larger fire-equipment companies concurrently supplying fire-extinguishers of a similar type and for identical needs have not given adequate attention to the

possibilities of methyl bromide as a commercial product for various obvious reasons. However, it is believed that most of these reasons may be easily negated if sufficient demand were located for a material with such properties.

8. Considerable correspondence was indulged in by this Laboratory before a domestic source of supply for this extinguisher was discovered. The Dominion Merchants Company, Limited, of 533 Bonsecours St., Montreal, Canada, is now manufacturing methyl bromide extinguishers of all types under a license or agreement with the British originators of the Essex Methyl Bromide Extinguisher.

9. As far as can be determined, only one investigation of any size has been undertaken in this country to evaluate the relative merits of methyl bromide extinguishers. This has been conducted by the Civil Aeronautics Administration, Development Section, in cooperation with the National Bureau of Standards. This study was primarily concerned with fires occurring in the engine nacelles of aircraft, and a comparison was made of carbon-dioxide, carbon tetrachloride and methyl bromide as fire extinguishing agents for this purpose. Altho the first phase of this work has been completed, no report has yet become available. It is expected that this report will be quite extensive and will contain much valuable information.

(d) Basic Considerations of Fire-Extinguishing Agents

10. In the application of any fire-extinguishing method or material to any fire resulting from the oxidation of combustible materials where the source of oxygen does not arise from the material itself, two functions must be satisfied before the fire may be considered extinguished.

(1) The oxygen concentration in the air surrounding the flames must be decreased by the addition of some other non-combustible gas or aerosol. This may also be accomplished by cutting off or blanketing the access of the flames to the oxygen of the air.

(2) The temperature of the combustible material must be lowered to a point where additional combustible gases no longer are evolved and it is cooled below the ignition point.

11. The methods and equipment for the extinguishment of different types of fires are many and diverse, but for the purposes of this report the similarity of carbon dioxide and carbon tetrachloride to methyl bromide, both in form and general utility for extinguishing purposes, will be compared.

12. The following table of data is of general interest:

	Methyl Bromide	Carbon Dioxide	Carbon Tetra-chloride
Structure	CH_3Br	CO_2	CCl_4
Molecular Weight	94.9	44.0	153.8
Specific Gravity (liq.)	1.732	1.101	1.595
Vapour Density (Air=1.0)	3.27	1.53	5.31
Boiling Point (°F.)	40.28	-108.4	169.
Freezing Point (°F.)	-135.4	--	-8.7
Specific Heat of Liquid 0°C. (Cals/gram)	.123	.201	.185
Latent Heat of Vaporization at Boiling Point (Cals/gram)	62.06	90.0	46.0
Vapour Pressure 68°F. (p.s.i. absolute)	27.6	810.	1.75
Gas Generation per lb. (cu.ft. at Std. Cond.)	3.7	8.0	2.3
Diffusion Coefficient of Gas (Grams per cm^2 per sec per air)	.097	.142	.076
Percentage Gas or Vapor Recommended for Concentration Method of Extinction	5.	50.	25.

13. It may easily be seen that in the consideration of these three materials their basic physical properties do not show a clear-cut case of superiority in a majority of characteristics for any one compound, and, in attempting to evaluate the position of methyl bromide in an order of efficiency per extinguisher weight or volume, a quite general viewpoint of the various factors contributing to such an efficiency must be observed.

14. Such factors are:

(a) Toxicity of material per se and under conditions of high temperature.

(b) Weight of total system of fire protection.
(c) Volume of total system of fire protection.
(d) Ease of operation of the system.
(e) Maintenance of system and its general reliability and safety.
(f) Flexibility of installation and application of system.
(g) Availability and relative ease of recharging of spent containers.

15. It is the purpose of the following discussion to evaluate methyl bromide, as far as presently available information will allow, in the light of these several viewpoints.

METHODS

(a) Qualitative Laboratory Experiments on Methyl Bromide

16. Extended investigation of methyl bromide fire extinguishers at the Laboratory has not been undertaken. A limited number of purely qualitative tests have been performed to acquaint the writer with the general usefulness of the material.

17. Before the source of a finished methyl bromide fire extinguisher was discovered, the pure compound, as commercially supplied for insecticide use by the Dow Chemical Co. of Midland, Michigan, was the only obtainable material for laboratory examination.

18. This insecticide methyl bromide is packaged in tin cylindrical cans with concave ends to better withstand the pressures developed at room temperatures. Upon puncturing the can with the special tool furnished, the liquid is evolved by virtue of its own vapor pressure and a stream about two feet in length issues from the can and immediately vaporizes into a heavy gas, colorless, and having an odor somewhat similar to carbon tetrachloride in the concentration tested.

19. The liquid evaporates immediately on contact with the skin, cooling and de-greasing the area which it touches, but no other reactions are noted.

20. The extinguishers furnished to us for test by the Dominion Merchants Co. appear to be well-designed units for this purpose (see Plate 1) and our tests with them showed them to be very efficient.

21. On one occasion a simple test was conducted by the use of a pan, approximately 24" x 24", filled with Navy Bunker C fuel oil ignited and allowed to burn for 5 minutes. An attempt to extinguish it with a No. 2 CO_2 extinguisher of comparable size to the methyl bromide extinguisher (see Plate 1) merely served to fan the flames, re-ignition taking place after

coverage of any particular area. Then the Essex Extinguisher was played over the surface, causing complete cessation of the fire in approximately 10 seconds.

22. A second test was made by filling the same pan with about 1 1/2 gal. of aviation grade gasoline and several cotton rags to supply a "wicking" action. This was lighted and attacked after burning 5 minutes with one #2 carbon dioxide extinguisher, this was followed by two #3 Essex methyl bromide extinguishers, and two 1 quart carbon tetrachloride pump-type extinguishers, all of the above used one at a time.

23. In no case was the fire completely extinguished. Several times with each of the different types of material the fire appeared to be nearly extinguished when a "flash-back" would occur resulting in complete ignition of all the gasoline area. (A record of this test was made at the Laboratory on 16 mm. Kodachrome film and this is available to interested personnel at any time.)

24. A large 15 lb. carbon-dioxide extinguisher, equipped with a horn and hose and an open and shut valve, was then opened over the fire and the fire was immediately snuffed out in about 2-3 seconds. Weighing after the test showed that only 1.2 lbs. carbon dioxide was used.

25. The result of this latter experiment brought very much to attention the factor of adequate rate of production of fire-fighting materials to prevent re-ignition. In this case, the gasoline was burning in the open with a very light breeze blowing (around 5 m.p.h.) and the total amount of extinguishant used, pound for pound, in all cases was far in excess of the actual required amount shown by the 1.2 lbs. carbon dioxide released in a large puff by the 15 lb. cylinder.

26. It is possible, however, that other types of Essex extinguishers allow a greater rate of methyl bromide evolution than the #3 type used in the tests.

27. Estimation of the time of exhaustion of 2 lbs. of methyl bromide from the Essex #3 extinguisher is approximately 50 seconds compared with its counterpart in size, the Lux #2, carbon dioxide extinguisher which requires 30 seconds to exhaust 2 lbs. of CO_2.

DISCUSSION

(a) Discussion of Factors Involved in Comparison of These Agents.

(1) Toxicity of the materials.

28. Gas poisoning by inhalation of methyl bromide seems to be a highly over-rated danger and is subject to much contention of opinion.

29. The clinical behavior of subjects of this poisoning is little known, partly because of the very few cases which have been adequately reported and partly because of the restricted use of methyl bromide in any industrial processes. Most of the available information comes from Europe and especially Great Britain where it seems to have achieved wide attention both as a refrigerant and a fire-extinguishant (2, 3, 1). Recent use of methyl bromide as a fumigant in this country, however, has stimulated the search for data concerning its toxicological properties.

30. Certain symptoms seem to be outstanding in this poisoning but it is to be noted that they are common to the response of a number of other organic vapors such as benzene, toluene, etc. to human ingestion.

31. The subject seems to become numb and loses his sense of equilibrium. A paralysis of the legs and arms, (4) and delirium may also follow, depending on the length of time of exposure and the concentration of methyl bromide in the atmosphere breathed.

32. Acute poisoning, from a short and severe exposure, results in a pulmonary edema and lung congestion which leads to bronchial pneumonia. (6, 5, 4)

33. An excellent medical study has been made recently in this country of a manufacturing operation in a plant engaged in the filling and sealing of methyl bromide in glass ampoules used in the fumigation of clothing. (11) The symptoms studied in this report were in most cases due to the effects of low concentrations (35 ppm. or less) of methyl bromide coupled with a long exposure time (8 hr. day, 2 week period).

34. In the manufacturing of these ampoules filled with methyl bromide 90 people were exposed to this low concentration, and mild systemic symptoms of anorexia, nausea and headache occurred in 33 of them. Of these 33 cases a number of them reported other symptoms such as faintness and dizziness and a sensation of loss of muscular control of the eyes following exposure to the gas. All of these symptoms disappeared after cessation of exposure to the methyl bromide and no lingering effects directly attributable to the gas were observed.

35. Additionally, the above investigation describes the toxic effect of the liquid methyl bromide on the skin when exposed for rather short periods. This dermatitis was first thought to be a thermal effect due to the "burning" of the skin exposed to low temperatures but the repeated application of small quantities, probably not sufficient to cause cell damage, gave rise to a chain of characteristically dermatological symptoms. The affected area showed a vesicular burn and itched severely. In some cases eruptions or blisters were

noted of a type similar to "fever blisters." Where exposure was very slight this dermatitis appeared only after a latent period of seven or more days. Treatment with ointment dressings was successful in healing all of these cases.

36. It is interesting to note in this latter phase of the study that the most severe cases of dermatitis occurred in the folds of the skin or where the skin came into contact with a material such as sponge rubber, capable of dissolving small quantities of methyl bromide and giving it off slowly.

37. An important fact must be brought out in regard to the sum of the clinical evidence of this poison and that is that the repeated exposure to threshold concentrations for periods of time sufficient to cause symptoms and reactions of a definite poisoning does not result in any permanent functional or physiological abnormality as long as the subject is removed from the contaminated atmosphere and allowed to recover.

38. It may thus be said that methyl bromide, rather than being a cumulative or severe systemic poison is an asphyxiant and does not necessarily result in an irreparable damage provided the subject is removed from further contact with it and given normal medical attention preventing development of lung complications.

39. The most complete work on the limits of toxicity of the vapor of methyl bromide toward guinea pigs has been done by the U. S. Bureau of Mines and the Public Health Service. (7) This investigation is perhaps best summarized and compared in the manner given by Jacobs (8) who also lists other poisons in the same manner.

	Parts per Million Methyl Bromide	Parts per Million Carbon Tetrachloride	Parts per Million Ethylene Dichloride	Parts per Million Carbon Disulfide
Concentration that kills most animals in a short time	20,000-40,000	50,000-80,000	100,000-200,000	2,000-4,800
Concentration dangerous to life in 30-60 min.	2,000-4,000	24,000-32,000	4,000-6,000	1,000-3,850
Maximum concentration tolerated for 60 min. without serious disturbance	1,000	4,000-13,000	3,500	480-1,000
Maximum concentration for prolonged exposure (8 hrs. or less)	50-170	1,600	1,000	300-390

40. An additional comparison of safety of the above materials is given by Jacobs (8) in citing the "recommended probable safe concentration limits for prolonged or repeated exposures" obtained from different sources:

	PPM Methyl Bromide	PPM Carbon Tetra-chloride	PPM Ethylene Dichloride	PPM Carbon Disulfide
1939-Dalla Valle (U. S. Public Health)	100.	100.	1,000	8.5
1938-Flury	--	31.7	--	3.2
1940-Massachusetts, Dept. of Labor & Ind.	--	100.	100	15.
1939-California, Dept. of Ind. Relations.	--	100.	100	1.
1934-Wisconsin, Industrial Com-mission	--	--	--	1.
-Connecticut, Sanitary Code	--	100.	--	--
1936-Soviet Union	--	--	--	3.2
-U. S. Nat'l Safety Council (Safety Limit)	--	1,000	--	--
1942-California, Dept. of Ind. Relations (9)	--	--	--	15.

41. An excellent study of the toxicity of these related materials was performed by the National Board of Fire Under-writers (10), who were particularly interested in refrigerants.

42. Their method of evaluation of the relative danger of exposure of the gases and vapors studied was by means of a grouping in descending order of toxicity of the gas to laboratory animals using short exposure times as follows:

Group No.	Concentration	Exposure Time	Gas	Results
1	1/2 to 1 % (5000 to 10,000 ppm)	5 min.	Sulfur Dioxide	Lethal or Produces serious injury.
2	1/2 to 1 % (5000 to 10,000 ppm)	30 min.	Ammonia Methyl Bromide	do
3	2 to 2 1/2 %	1 hr.	Methyl Formate Chloroform Carbon Tetrachloride	do
4	2 to 2 1/2 %	2 hr.	Dichloroethylene Methyl Chloride Ethyl Bromide	do
5	(Intermediate between toxicity of Group 4 & Group 6)		"F-11" Carbon Dioxide	do
6	20 %	2 hr.	Freon "F-114"	Do not appear to produce injury

43. This study is also the only one which produces any data on the effect of these materials after they come in contact with flame. In these tests a non-luminous flame from an ordinary gas range was used, compared with the results obtained from exposure of the vapors to oil fires, wood fires and hot metal surfaces. Maximum percentages of toxic decomposition products found are as follows:

Material	Toxic Decomp. Product	Gas Flame	Oil Fire	Wood Fire	Hot Iron Surface
Carbon Tetrachloride	HCl	1.26%	2.83	8.86	.88
	Phosgene	.043	.004	.084	.106
	Chlorine	.00	.00	.013	.058
Methyl Bromide	Hydrobromic Acid	.011	.15	.34	.63
	Carbonyl Bromide	--	.000	.023	.005
	Bromine	.001	.000	.000	.142

44. An initial concentration of 1/2 to 2 1/2% by volume of the gas or vapor was used in their physiological exposure tests, and a continuous duration of exposure of laboratory animals to the decomposition products (as above) of from 5 min. to 1/4 hr. The following comparative listing for this test is given in descending order of "comparative life hazard":

(1) Carbon Tetrachloride
(2) Chloroform
(3) Dichloroethylene
(4) Freon
(5) "F-114"
(6) Ethyl and Methyl Bromide
(7) Ethyl chloride
(8) "F-11"
(9) Methylene Chloride

45. In the light of the foregoing data it is very difficult to draw any just conclusions of their actual extent of comparative toxicity to man of these materials, expecially in view of the large number of different conditions under which methyl bromide, carbon tetrachloride and carbon dioxide may be used to extinguish fires.

46. It appears to be true, however, that at an identical concentration of these materials high enough and with a sufficiently long exposure to cause lethal effects even with the least toxic of them, their order of comparative toxicity is:

(1) Methyl bromide
(2) Carbon Tetrachloride
(3) Carbon Dioxide

47. On the other hand, it must not be overlooked that the highest concentration of these materials which should be necessarily encountered would be that which is necessary to extinguish a fire, which, according to data available, is recommended to be:

Methyl Bromide - 5%
Carbon Tetrachloride - 25%
Carbon Dioxide - 50%

48. At these concentrations the order of comparative toxicity is:

(1) Carbon Tetrachloride
(2) Methyl Bromide
(3) Carbon Dioxide

49. In order to assist the reader in judging this comparative toxicity value, a copy of the data on this subject furnished by the British manufacturers of methyl bromide extinguishers is included in the Appendix. (See Appendix 2)

(2) Weight of total system of fire protection.

50. In making a comparison of the weights of materials necessary to constitute an adequate fire protection of any risk, the amounts of any given liquid or gas to extinguish fire of this risk must be taken into consideration. In the evaluation of this amount of material actual laboratory reproduction of controlled oxidation followed by measurement by weight of the amounts of material required to secure complete extinction is used as a basis for estimation of concentration needed. This "concentration method of extinction" results in the following comparative values:

Methyl bromide (Vapor)-5.% to secure extinction
Carbon tetrachloride (Vapor)-25.% to secure extinction
Carbon dioxide (Gas)-50.% to secure extinction

51. Referring then to the table on page 3 for volumes of gas produced per pound of material, it is easily seen that the follosing weights of materials are equivalent in fire-fighting ability: (assuming other conditions, sucn as cooling effect of the materials on the fire, dissipation of extinguishant due to wind, etc. to be equal)

Methyl bromide - 1.0 lb.
Carbon tetrachloride - 8.04 lb.
Carbon dioxide - 4.62 lb.

52. Obviously, these weights of extinguishant alone represent a considerable advantage for the use of methyl bromide. Coupled with this comparison is one regarding the containers which shows the following data:

	Weight of charge	Weight of cylinder	Ratio of charge weight to cylinder weight
Methyl Bromide #3	2 lbs.	2.62 lbs.	1:1.31
" " #4	4 "	4.25 "	1:1.06
" " #5	8 "	15.00 "	1:1.87
Carbon Dioxide #2	2 "	8.75 "	1:4.36
" " #4	4 "	17.00 "	1:4.25
" " #7	7 "	27.00 "	1:3.86
" " #20	20 "	35.00 "	1:1.75
Carbon Tetrachloride, 1 qt.	3.4 "	3.1 "	1:.91

53. The foregoing data now, when compared with the fire-fighting efficiencies of the three materials, shows the following approximate equivalent weights of installation:

	Wt. of Material	Total Wt. of Installation	Ratio to Methyl Bromide Installation
Methyl Bromide	2. lbs.	4.62 lbs.	1
Carbon Dioxide	10. "	37.0 "	8.0
Carbon Tetrachloride	17. "	32.5 "	7.04

54. This reveals a very great advantage in weight saving if methyl bromide were used either in place of carbon dioxide or carbon tetrachloride; however, it must be always kept in mind that these conclusions are arrived at by assuming practically perfect conditions, such as a closed atmosphere in which to extinguish the fire, proper rate of addition of extinguishant, etc. These conditions may not always be met.

(3) Volume of total system of fire protection.

55. The information available on this question is rather sketchy, however, a rough approximation of these three materials follows from the data and equivalent sizes given in the previous section and from other sources:

	Number Needed	Total Weights	Cylinder Vol. Only (Total)	Ratio to Methyl Bromide Installation
Methyl Bromide#3	1	4.62	111.8 cu.in.	1.
Carbon Dioxide #10	1	37.0	694.	6.2
Carbon Tetrachloride 1 qt.	5	32.5	423.	3.8

56. These figures do not include the volume required by the hose and horn in the case of the carbon-dioxide installation nor is any allowance made for bracket mounting where the extinguisher is required to be set forward at some distance from a wall or upright.

57. An obvious advantage in volume requirements in the case of methyl bromide may be seen if it is again remembered that other conditions must be favorable.

(4) Ease of Operation of the system.

58. This comparison is difficult to make because of the many variations in requirements for the extinguisher, but in general the following may be said:

59. Methyl bromide extinguishers can be easily started, stopped (in case of the SLV types), and controlled with no additional equipment, resources or instructions, it being self-contained and positive in action. (This is also true of carbon-dioxide extinguishers)

60. According to the manufacturer, its operation is not impaired by exposure to low temperatures, high altitudes or other changes in atmospheric conditions.

61. One disadvantage in the method of ejection of the liquid is the necessity for holding some types of these extinguishers in an inverted position with respect to the nozzle. This, to uninitiated personnel is rather difficult to do since the opposite tendency is the natural one, especially during stress as during an actual fire.

62. A brief persual of the manufacturers' literature on these extinguishers as will be found in the appendix will serve to acquaint the reader with this question more fully.

(5) Maintenance of system and its general reliability and safety.

63. The maintenance of fully charged systems of methyl bromide appears to be different from that of a CO_2 system in only one respect; i.e., that of not requiring periodic inspection of cylinders due to the low pressure of nitrogen gas which is used to eject the methyl bromide liquid. This pressure, according to the manufacturers, is some 700 lbs. per sq. in. less in the case of methyl bromide. This is a considerable factor in requiring less frequent inspection but it is not believed to be as advantageous as would be expected since the cylinder would be just as useless with a small leak at 100 lbs. pressure as it would be at 800 lbs. pressure, the factor being one of time of loss of contents rather than insurance against leakage.

64. The design of the Essex extinguisher is such that when a pressure of 800 p.s.i. is reached (this occurs at 350°F. due to the vapor pressure of methyl bromide at this temperature plus the increased pressure of the nitrogen) the copper sealing disc fractures and the liquid is evolved. This condition of high temperature is seldom reached in practice, but constitutes somewhat of a danger due to fumes to personnel nearby unless adequate warning is received.

(6) Flexibility of installation and application of the system.

65. There is little difference in the installation of methyl bromide or carbon dioxide extinguishers for the purpose of "concentration extinction" (enclosed space flooding), excluding the factor of comparative weights and volumes of the two systems. In some instances, however, the use of a liquid

instead of a gas may be of advantage. Additionally, the use of lower pressures and smaller units in methyl bromide systems makes the task of checking the units during inspection periods much easier and quicker.

66. The application of other types of methyl bromide systems for fire protection shows its excellent versatility in that its use is not limited as is water and foam to certain types of fires. This, of course, is true of carbon dioxide and, to a limited extent, carbon tetrachloride.

67. One factor must be carefully considered in all of these installations, however, and that is the speed of generation of an extinguishing atmosphere. Where the calculations for adequate protection may show a great advantage in weight and volume and flexibility of installation, the possibility of "flashback" due to the lower rate of evolution of a large volume of extinguishing gas from methyl bromide may decide against its employment.

68. This factor has become so increasingly evident in fire protection systems that one domestic company markets a type of carbon dioxide equipment which utilizes liquid carbon dioxide, kept at 0°F. in a large central storage tank and piped to the hazard in liquid form in such a manner that large volumes are available for short periods of time.

(7) Availability and relative ease of recharging spent containers.

69. At the present time, no facilities exist in the United States for the recharging of methyl bromide equipment since its merchandising is rather limited to England and, more recently, Canada.

70. It is claimed by a representative of this Canadian concern that plans have been made for production and distribution of the Essex extinguisher somewhere in the New York area as soon as sufficient demand is shown in this country.

71. Information received from this source also indicates that methyl bromide itself is produced by the Dow Chemical Co. in large quantities for use as a fumigant and is readily available.

72. Difficulties of recharging the spent containers of methyl bromide extinguishers would be much the same as those met in the refilling of carbon dioxide, coupled with the obvious advantage of saving in weights and volumes when the Essex extinguisher is shipped to a charging plant.

CONCLUSIONS

(a) General Summary and Evolved Considerations

73. It is beyond the purpose of this report and the experience of the writer to attempt to fit methyl bromide into the general picture of fire protection of Naval materiel and personnel.

74. As has been said before, the employment of methyl bromide extinguishers in preference to other types of available extinguishing systems may only be decided upon after a careful consideration of the characteristics of the risk for which the most efficient fire protection is desired.

75. However, taking a very broad viewpoint of the comparison of methyl bromide with carbon tetrachloride and carbon dioxide, and, in some instances, even foam, fog, or water systems of protection, the advantages in the use of an agent such as methyl bromide which is light in weight, non-destructive in action, easily installed and maintained, small in volume per unit of recommended protection, and fool-proof in operation cannot readily be overlooked.

76. The question of toxicity of methyl bromide will probably continue to be shrouded in doubts and misgivings until sufficient experience and contact with it by unprejudiced personnel has evolved a greater understanding of its limits of exposure and concentrations under working conditions. A basic point in this question is the realization that any material useful in the extinguishment of fire by the mechanism of atmosphere dilution must be, ipso facto, dangerous to life processes in the human organism.

77. The discussion presented in earlier parts of this report shows a comparative factor of economy in weight of one-seventh and one-eighth the total weight of installation if methyl bromide could be directly substituted for carbon tetrachloride or carbon dioxide extinguishers respectively. In the case of volume requirements the saving is in the order of one-fourth and one-sixth.

78. No accurate figures are available as to cost of the Essex extinguisher but one estimate of $15.00 has been made for the No. 3 extinguisher containing two lbs. methyl bromide. Recharging of this type would cost about $4.00, it is believed.

(b) Recommendations on Materials Tested

79. With what limited experience we have been able to collect at this Laboratory, it is believed that the methyl bromide type of extinguisher as available in the "Essex" type

would be advantageously improved by the change of two characteristics of the basic extinguishers tested:

(1) The addition of a suitable odoriferous material such as sulfur-dioxide to the liquid methyl bromide so that exposure of personnel to toxic concentrations of vapors of methyl bromide during or following a fire would be instantly detectable by smell. This would also serve as a warning gas in case of leakage from the cylinder during storage.

(2) The adjustment of the exit nozzle or an increase in pressure on the nozzle during operation so that a better "spread" of the agent and greater flow is obtained per minute. This would achieve a greater "wiping" and "blanketing" action on materials subject to reflash or re-ignition.

(o) Bibliography

(1) Application of the Halogen Derivatives of the Hydrocarbons with Particular Reference to Methyl Bromide - A. Henning Chem. and Industry, Vol. 52, #22, 6/2/33 (British)

(2) Poisoning by Methyl Bromide - F. Rohrer, Vierteljahr Ger. Med. Vol. 60, 51-9(1920)

(3) Poisoning by Methyl Bromide - Loffler and Rutimeyer, Vierteljahr Ger. Med. Vol. 60, 60-7 (1920)

(4) The Response Attending Exposure of Laboratory Animals to Vapors of Methyl Bromide - Irish et al, Jour. Ind. Hygiene and Tox., Vol. 22, No. 6, 218-230, (June 1940)

(5) Toxicological Observations Regarding Several Modern Fire Extinguishants - Joachimoglu, Dent. Med. Wochschrifft, Vol. 56, 785-7(1930)

(6) Chemical Changes of Methyl Bromide in the Animal Body in Relation to its Physiological Effects - Irish, et al, Jour, Ind. Hygiene and Tox., Vol. 23, No. 8, 408-11, (Oct. 1941)

(7) Physiological Response Attending Exposure to Vapors of Methyl Bromide, Methyl Chloride, Ethyl Bromide and Ethyl Chloride - Sayers et al, U. S. Public Health Bull. No. 185(1929)

(8) The Analytical Chemistry of Industrial Poisons, Hazards and Solvents - Jacobs. M.B., Interscience Publishers, Inc. N.Y.C. (1941)

(9) Brief Summary of the Toxicity of Some Common Fumigants - Spencer, H.C., (The Dow Chemical Co.-Midland, Mich.)

(10) The Comparative Life, Fire and Explosive Hazards of Common Refrigerants - Nuckolls, A.H., National Board of Fire Underwriters, (1933)

(11) Methyl Bromide, Local and Mild Systemic Effects - Watrous, R.M., Industrial Medicine. Vol. 11, No. 12 (Dec. 1942)

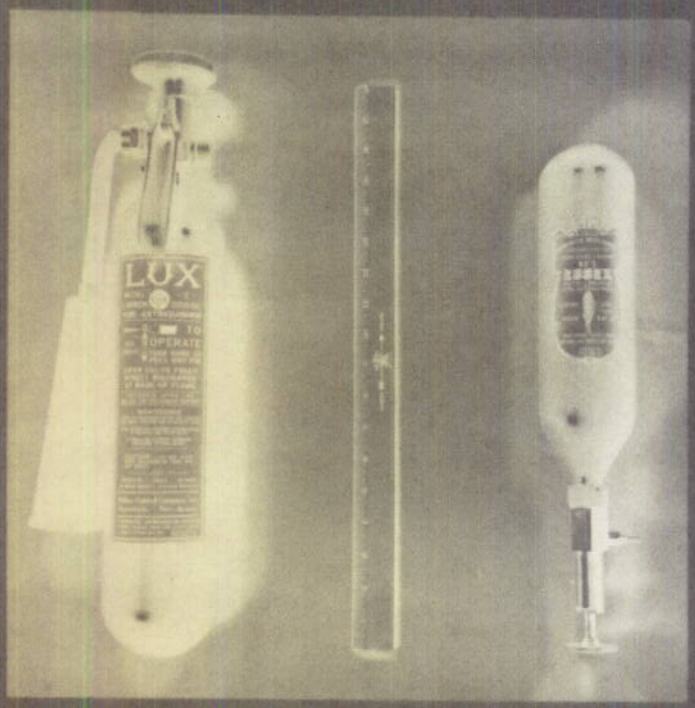


PLATE 1

Industrial Safety

The National Fire Protection Company Ltd
RICHMOND · SURREY
TELEPHONE RICHMOND 2342
TELEGRAMS FIREGUARD RICHMONDSY

INDUSTRIAL SAFETY

A FOREWORD

To Industry, rallying magnificently to the call for ever-increasing production, this third edition of Industrial Safety is offered in the hope that hard-pressed Executives will find therein relief from the prospect of loss of irreplaceable plant, power supplies, or vital materials.

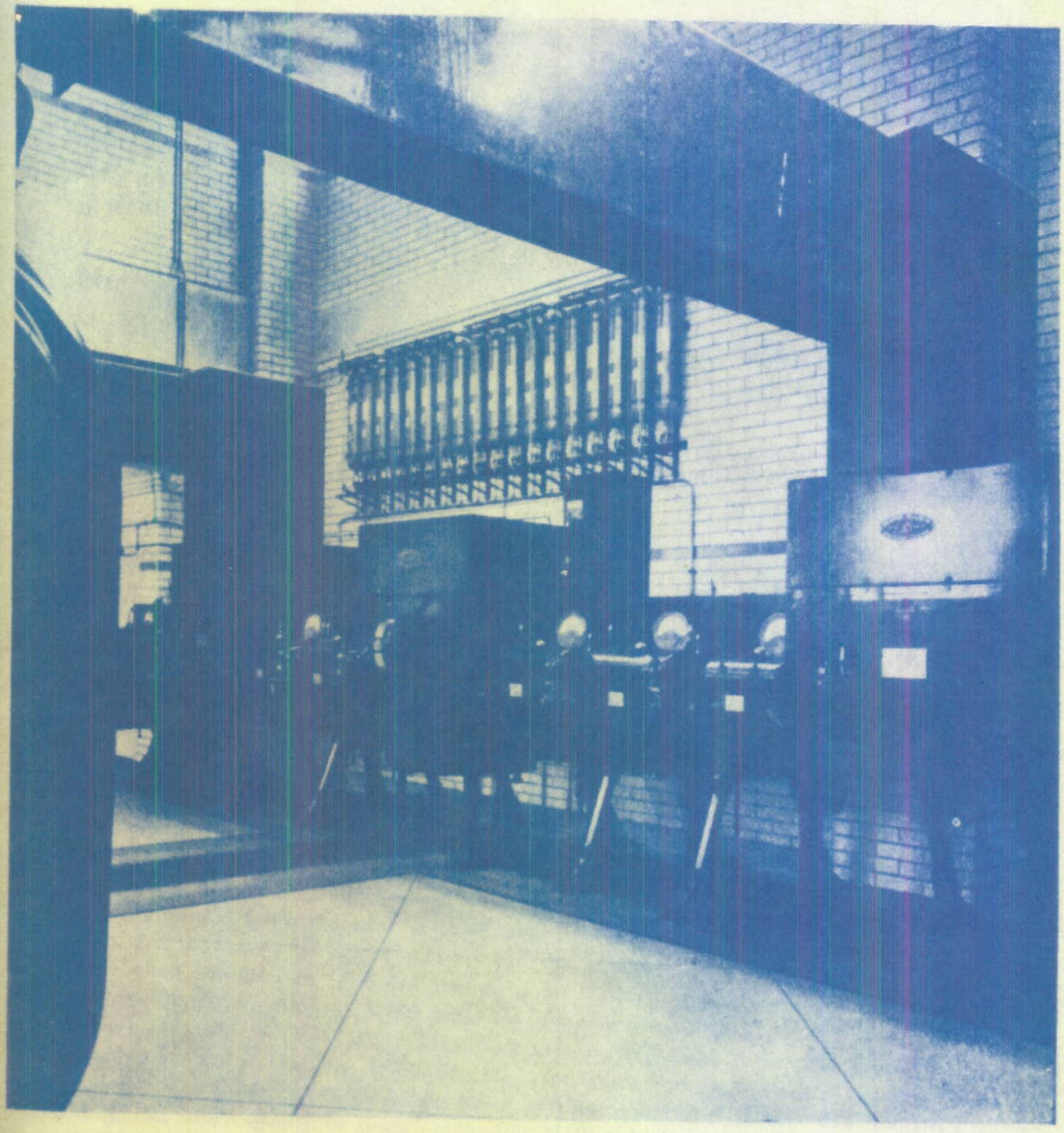
For such risks as we advise it, Methyl Bromide has no peer, but it must be remembered that many of the fires which occur are readily extinguished by water, and for these fires suitable extinguishing equipment is described in our other publications.

Each year of Peace saw at least £12,000,000 worth of property and materials destroyed, irrespective of indirect losses. Of the war time losses no man may speak, but, as Fire Patrols have proved, the greater part of this loss can be avoided, given warning of fire and the "tools to finish the job."

National Fire's contribution to National Service is an open invitation to Industry to place its problems before our Technical Bureau, when we shall be pleased to offer our considered advice.

INDEX

	Page
SELECTION OF EQUIPMENT	4
METHYL BROMIDE—As a Fire Fighting Medium	
Description and Application	4
The Impingement Method	4
The Concentration Method	5
Quantities	5
Practical Advantages	6
Relative Superiority	8
TYPICAL TEST FIRES	10-11
"ESSEX" METHYL BROMIDE—	
Extinguisher Classifications	11
TECHNICAL DATA	12
ELECTRICAL RESISTANCE	12
PRESSURE : TEMPERATURE CURVE—	
Standard Extinguisher Units	13
"ESSEX" STANDARD EXTINGUISHER TYPES—	
Total Discharge	14
Controlled Discharge	15
Remote Control—Lever Bracket	16
"ESSEX" MOBILE TRUCK UNIT—on Test	17
"ESSEX" MOBILE TRUCK UNITS	18-19
"ESSEX" AUTOMATIC INSTALLATIONS	
Mechanically Operated Installations	21
Triple Automatic Unit	22
Electrically Operated Installations	23
Teleflex Control Systems	23-25
Manual Control	23
Automatic Components	24
Indicator Systems and Safety Gear	25
Secondary Equipment	26
Safety Curtains and Screens	27
Selective Distribution	27
Surveys and Service	28
Instructions for Use	28
IS IT TOXIC ?	
Theory	29
Practice	30
METHYL BROMIDE OR CO_2 ?	31
"ELECTRICON" SMOKE DETECTION	32
"NATIONAL" VAPOUR DETECTOR	33
"ESSEX" CUTS PRODUCTION LOSSES	34
"ESSEX" REFILLS	35



A Typical Essex Automatic Installation showing method of mounting cylinders.

SELECTION OF EQUIPMENT

Methyl Bromide, while ultimately the most economical method of protecting such risks as those for which it is advised, should not be used either as an extinguishing or as a preventative agent where simpler as well as less costly media are equally suitable. There is, for instance, no better method of extinguishing a wood fire than by using water with judgment. Applied with skill, a jet of water may sometimes be used successfully to extinguish fires involving volatile and inflammable liquids, although more often it tends only to spread or aggravate the fire.

Methyl Bromide

Methyl Bromide is a stable, colourless and volatile liquid with a boiling point of 4·5° C., which upon release to atmosphere evaporates rapidly to a fire extinguishing gas 3·27 times heavier than air.

In Essex equipment the liquid is sealed in copper or steel cylinders with added nitrogen to increase the pressure to 50 or 100 lbs. per square inch, although in special instances higher pressures may be employed.

Methods of Application

Methyl Bromide is employed as a fire extinguishing agent in two distinct ways. Hand-directed equipment, and certain fixed installations, operate on the "direct impingement" principle. Fully automatic installations generally employ the "concentration" method. Explanation of these terms is given below.

The Impingement Method

Where hand-directed equipment or a fixed installation which is, in fact, the mechanised equivalent of the hand-directed equipment, is employed, the jet (or jets) of Methyl Bromide is directed at the seat of the fire, and thus "impinges" on it. To some extent the jet tends to "beat" out the fire, while the displacement of oxygen by the heavy Methyl Bromide Vapour also adds its quota to the final extinguishing effect. Two further factors are, however, the chief reasons for the superiority of this medium under impingement conditions. The low boiling point coupled with the rather high latent heat of evaporation and the wide range of temperature involved causes an almost instantaneous absorption of heat. This absorption is, by reason of the speed of action, concentrated locally, with the result that ice-crystals are often found where a moment before fire was present. Such is the effect of these combined factors that the fire-fighting rate and capacity of units employing Methyl Bromide is not approached by any other portable equipment.

In addition, there is a secondary effect due to the high local concentration of Methyl Bromide gas. A full description of this effect is given in the following paragraphs.

The Concentration Method

Research has shown that the effect of a proportion of extinguishing gas in the air is not due solely to the dilution of oxygen, nor is the quantity required to secure extinction a function of any of the well-known physical characteristics of the gas in question. Repeated and careful experiments under laboratory conditions show that to secure extinction of a number of test fires (chosen for their difficulty of extinction, but excluding such self-oxidisable fires as occur in electron and magnesium alloys) 29% of CO_2 is required to secure complete extinction. When Carbon Tetrachloride was employed, only 15% was necessary for the same effect, while in the case of Methyl Bromide, in a concentration as low as 3·5% none of the fires were capable of continuing.

The percentage of such gas necessary in dry air to procure extinction is termed the "INHIBITORY FACTOR."

It is upon this Inhibitory Factor that the action of the majority of Essex Automatic Installations is based, since by concentrating the requisite percentage of fire-fighting vapour, any given compartment can be safeguarded from fire, irrespective of the point of outbreak.

Methyl Bromide, while representing the latest development in scientific fire fighting, has, none the less, many years of experience behind its practical application.

The year 1927 saw the first Essex installation on Service aircraft in this country and by 1939 the Governments of some twenty-five countries throughout the world had followed this lead—ample proof of efficiency and reliability. To these must be added thousands of petrol-driven craft for the Services or in private use, while in the industrial field Essex equipment safeguards the highest fire hazards, ranging from Ether, Alcohol and Benzole distilling and processing plant, T.N.T. and Nitro-Cellulose plant, to Radio Transmitters, Electrical Transforming and Switchgear Stations, as well as the routine protection of Cellulose, Paint and Varnish processes and stores, Chemical Stores, etc.

Approximation of Quantities

Where the concentration method is decided upon, the quantity of Methyl Bromide necessary for the protection of an unventilated compartment, assuming the normal concentration of 5%, is as follows :—

Gross Volume Cubic Feet.	Quantity of Methyl Bromide.	Type No.	Working Pressures.
600	8 lbs.	5	50 lbs. per sq. in.
900	12 ,,	5A	100 ,, ,, ,, ,,
1,500	20 ,,	6B	50 ,, ,, ,, ,,
1,800	24 ,,	6	50 ,, ,, ,, ,,
2,100	28 ,,	6D	100 ,, ,, ,, ,,
2,250	30 ,,	6C	100 ,, ,, ,, ,,
2,400	32 ,,	6A	100 ,, ,, ,, ,,

or multiples thereof.

Note.—For comparison with CO_2 on the accepted ratio that 50% of CO_2 will give the same fire-fighting factor as 5% of Methyl Bromide, 105 lbs. of CO_2 is equivalent to 24 lbs. of Methyl Bromide.

Practical Advantages

On fires of the class for which Methyl Bromide is suitable, the rates of extinction obtained, and the sizes of fires which may be fought with hand-controlled apparatus, are not approached with any other comparable equipment. Moreover, the medium evaporates without trace from its liquid state, so that direct damage is absent. It follows that interference with production is reduced to a minimum, a factor vital to-day as never before. While it is equally true that Carbon Dioxide is non-damaging, the physical qualities of this gas leave it at a considerable disadvantage as against Methyl Bromide. Not only must much greater quantity of the former be employed—50% is necessary to give a fire-fighting concentration equivalent to 5% of Methyl Bromide—but the high working pressure of 810 lbs. per square inch involves the use of very heavy steel cylinders. For example, 32 lbs. of Methyl Bromide is contained in a cylinder of some 65 lbs. gross weight and is, in concentration terms, equal to 140 lbs. of CO_2 involving three cylinders weighing some 900 lbs. gross. Even in the smaller hand equipment, the No. 3 Essex Extinguisher weighing 4 lbs. 10 ozs. is, on the concentration basis, approximately equivalent to a 10 lb. CO_2 unit weighing some 50 lbs.

In Automatic installations the Essex equipment can usually be wall mounted out of the way, while the weight of the CO_2 equipment necessitates a floor position. The low weight of the Methyl Bromide cylinders renders them readily removable if an annual check-weighing is desired, although the units are, in fact, **guaranteed for ten years,** and there is no need to have the cylinders tested every two years as is recommended by the Home Office in regard to CO_2 and other high pressure cylinders.

Under stringent conditions the greater density of Methyl Bromide—3·27 as against 1·52 for CO_2 and 1·00 for air—ensures a much greater freedom from gas losses due to updraught, while its diffusion rate is approximately only half that of CO_2. In hand-directed equipment the liquid cooling of Methyl Bromide is again more effective than that of CO_2 snow, while the long steady jet of liquid discharged is more easily directed than is a cloud of gas.

Safety Measures in a Paint Stores

Many well known manufacturers choose Essex Equipment to ensure certain extinction of fires occurring in their stores of inflammable substances.

THE SUPERIORITY OF METHYL BROMIDE

The reasons for the superiority of Methyl Bromide as compared with other media, are as follows :—

METHYL BROMIDE has the following advantages over **FOAM**

1. Non-damaging to machinery and fabrics.
2. Smaller and much lighter apparatus.
3. Much quicker in action.
4. No upkeep costs from periodical re-charging and corrosion.
5. Is not adversely affected by low temperature.
6. No deleterious internal chemical reactions.
7. Clean in action.

METHYL BROMIDE has the following advantages over **CARBON DIOXIDE**

1. Smaller and lighter apparatus.
2. Heavier generated gas, which is much less affected by updraughts and convection currents.
3. Much less gas required for equal effect.
4. Much lower rate of diffusion.
5. No injector action.
6. Guaranteed to remain efficient for a period of ten years.
7. Cylinders need not be periodically pressure tested.
8. Less possibility of explosive mixtures forming.
9. Greater inhibitory effect.
10. Medium discharged as a liquid, not a gas.

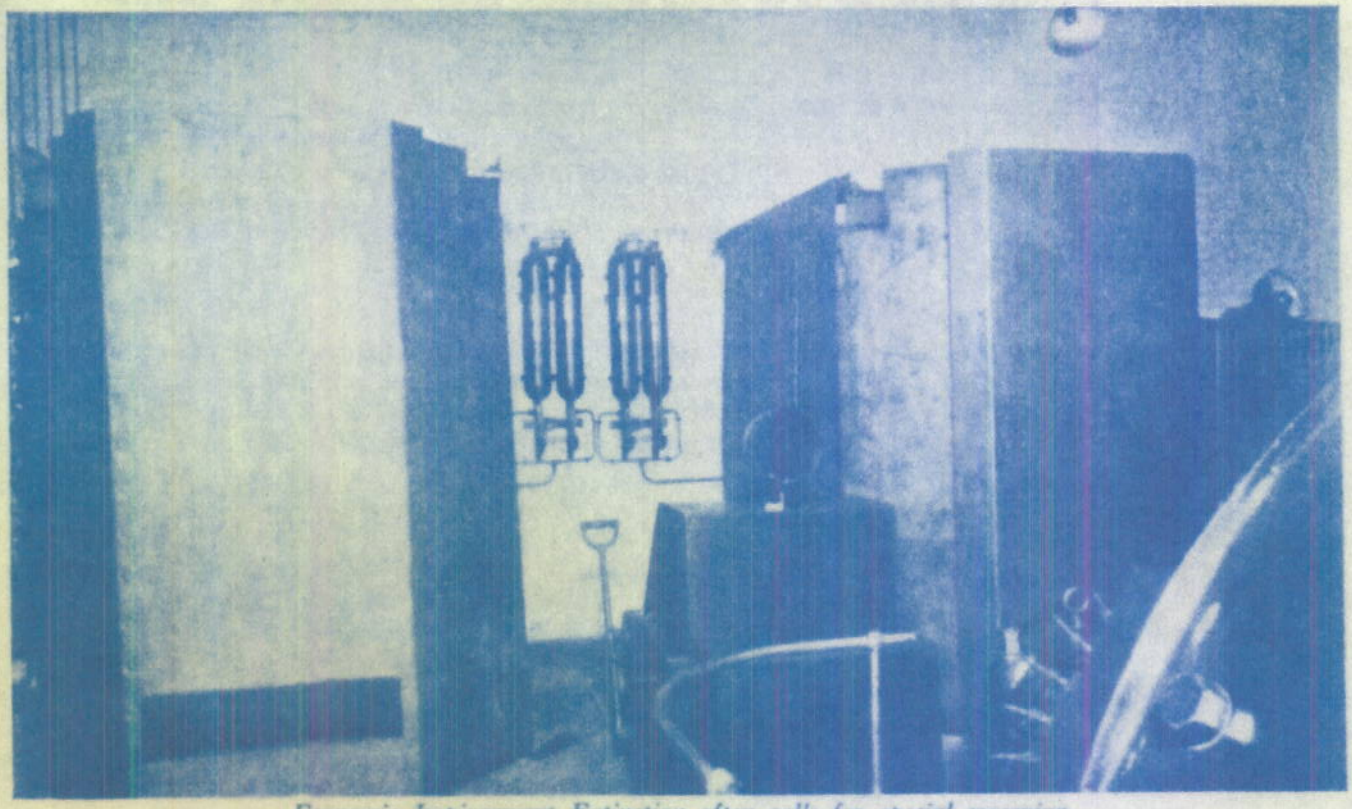
METHYL BROMIDE has the following advantages over **CARBON TETRACHLORIDE**

1. More gas generated per unit weight of liquid.
2. Quicker generation of gas.
3. Less gas required for equal effect.
4. Greater cooling effect, due to lower boiling point.
5. No upkeep costs from leakage or evaporation.
6. Greater electrical resistance.
7. Less dangerous to use (no risk of Phosgene generation).
8. Greater inhibitory effect.

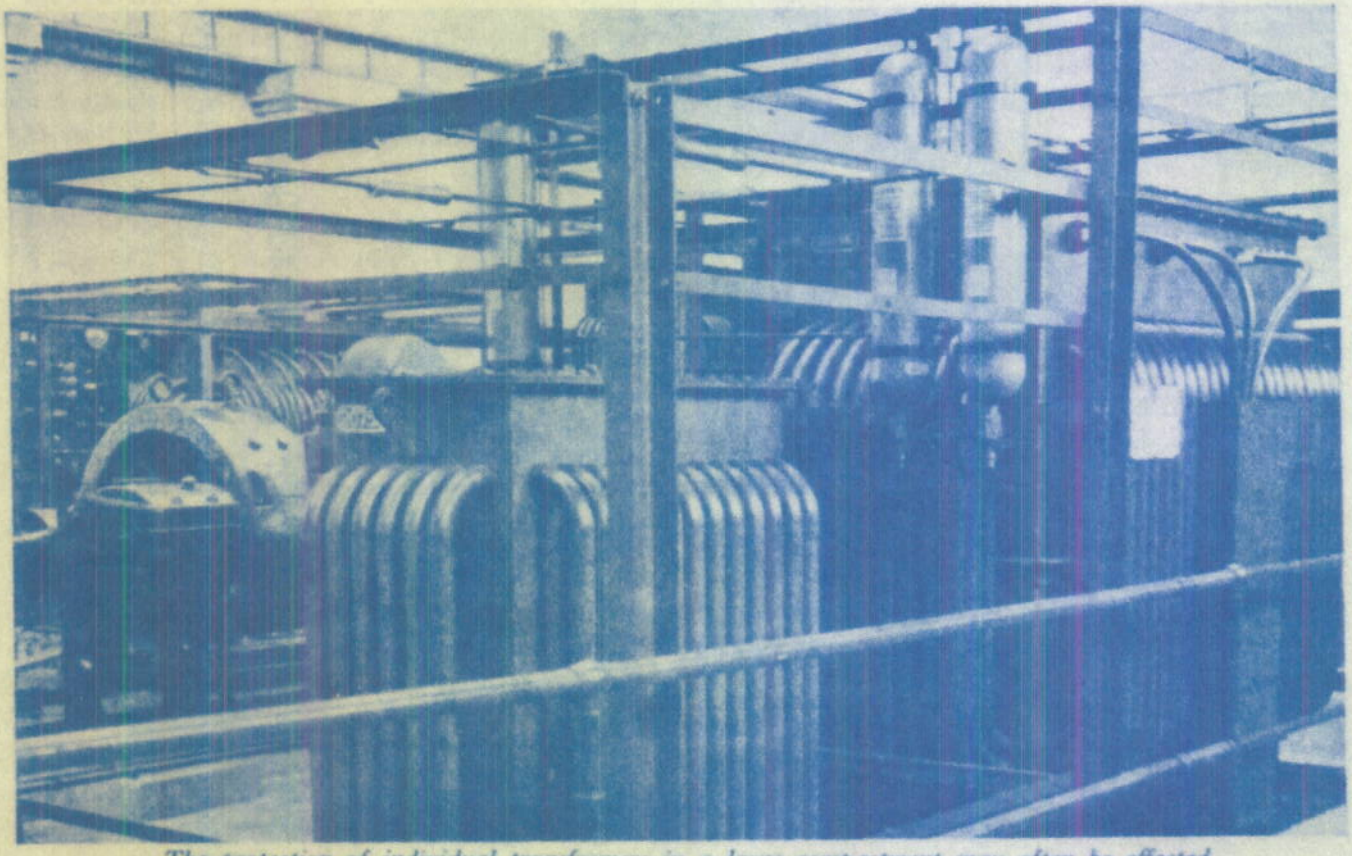
METHYL BROMIDE has the following advantages over **EMULSIFYING WATER SYSTEMS**—

1. Cheaper to install.
2. Self-contained.
3. No pumping plant required.
4. Unaffected by water mains failure (in air raids, frost, etc.).
5. No risk of electrical shock or flash-overs.
6. Eliminates possibility of unatomised water spreading fire and causing "flare-ups".
7. No drying out required. Machinery and plant undamaged.
8. No special drainage necessary.

Impingement Protection



Economic Impingement-Extinction often calls for special screening arrangements as shown here.



The protection of individual transformers in a large compartment may often be effected by treating as separate units.

ARE THESE SOME OF YOUR RISKS?

Petrol?

Three fires each of 2 lbs. of wood wool with 3 pints of petrol in a tray 30" × 40" were attacked after burning for 10 seconds by:—

(a) 2 gallon Foam extinguisher; when empty fire still burning (80 seconds).
(b) Quart C.T.C. extinguisher; when empty fire still burning.
(c) No 3. ESSEX Methyl Bromide extinguisher; fire out in 15·1 seconds.

(R.A.F. Test)

Acetone?

Three separate fires each of a quart of Acetone were extinguished as follows:—

(a) 2 gallon Foam extinguisher—in 53 seconds.
(b) 2 gallon Soda Acid extinguisher—in 50 seconds.
(c) No. 2 ESSEX Methyl Bromide extinguisher—in 5 seconds.

(Fire Brigade Test)

Methylated Spirit?

Three separate fires each consisting of 10 gallons of Methylated Spirits in baths 40" × 18" after ignition were attacked by:—

(a) 2 gallon pressure type C.T.C. extinguisher; fire still burning when the extinguisher was empty (100 seconds).
(b) 2 gallon Foam extinguishers; four extinguishers were used—two simultaneously—but after 5½ minutes the fire was still burning.
(c) No. 5 ESSEX Methyl Bromide extinguisher; out in 8 seconds, using about one-quarter of the contents.

(Public Demonstration)

Cellulose?

In a spray cabinet for motor cars (14' × 15' × 7') trays having an area of 30 sq. ft. containing enamel and cellulose thinners, with soaked waste on the surrounding floor, were ignited and allowed to burn for over 2 minutes. On being attacked by three No. 5 ESSEX Methyl Bromide extinguishers, the fire was put out in 34 seconds.

(Motor Car Factory Test)

Electricity?

A tray 42" × 18" was connected to 230 volts A.C., heaped with rubber covered cable saturated with petrol which was ignited. The fire was extinguished with half the contents of a No. 4 S.L.V. ESSEX Methyl Bromide extinguisher.

(Generating Station Test)

Transformers?

A transformer 5 ft. high, standing amid trays containing 40 gallons of cooling oil having an area of 120 sq. ft., was arranged in a compartment 20' × 20' × 8' high which had been fitted up with two No. 6 ESSEX Methyl Bromide automatic units. A circulating pump continually poured oil over the transformer, while one door and three ventilating holes were provided, all of which were subsequently closed automatically when the unit came into operation upon the fire raising the temperature to 140° F. Ignition was performed by forcing petrol through prepared holes in the walls, and this was lighted by inserting burning waste. Thirty seconds after ignition the extinguishing units automatically came into operation and 12 seconds later the fire was out, while the discharge continued for a further 12 seconds.

(Electrical Engineers' Test)

Fuel Oil?

(a) Forty gallons of fuel oil with an area of 180 sq. ft. were arranged in a tray to represent a ship's bilge, surmounted by a platform of the same size and surrounded by walls representing bulkheads. After being ignited and allowed to burn for 30 seconds, the fire was extinguished by two No. 5 ESSEX Methyl Bromide extinguishers in 39 seconds.

(b) Forty gallons of Fuel Oil in a tray 15′ × 6′ was ignited with added petrol and allowed to burn until the oil was boiling and the tray edges red hot. Extinguished in 16 seconds with a No. 5 S.D.V. ESSEX hand extinguisher weighing only 23 lbs.

(Standard Test Fire)

ESSEX Methyl Bromide equipment may be classified into

1. Hand Directed

(a) Total Discharge Types.
(b) Controlled Discharge Type.
(c) Truck Units-Controlled Discharge Type.

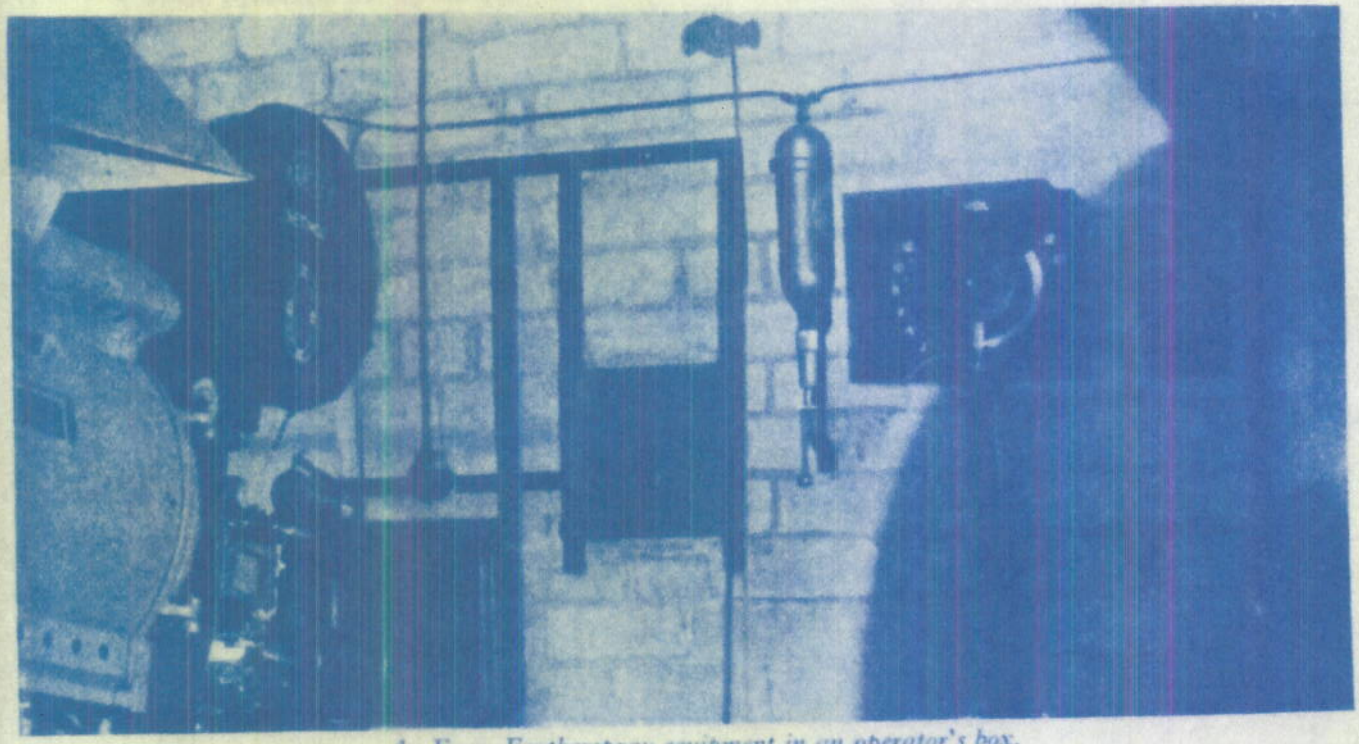
2. Fixed Pipeline systems

(a) Featherspray Type, where the extinguisher can be employed alternatively as a hand-directed appliance, or discharged by a lever on the extinguisher bracket.
(b) Operation by lever on extinguisher bracket only.
(c) Remotely controlled type giving one or more operating positions, through Teleflex or similar control.
(d) Electrical push button type control with solenoid operation.

3. Automatically operated pipeline systems

(a) Mechanical, employing stretched wire and heat fusible links.
(b) Electrical, employing heat, flame or smoke operation.

Remote manual control, alarm systems, etc., can be incorporated in the above.



An Essex Featherspray equipment in an operator's box.

TECHNICAL DATA

Property	Methyl Bromide	Carbon Tetrachloride	Carbon Dioxide
Structure	CH_3Br.	$C\ Cl_4$.	CO_2.
Molecular weight (O=16·0) ...	94·9	153·8	44·0
Specific Gravity (water=1) ...	1·73	1·63	0·77
Vapour Density Air=1·0 at N.T.P.	3·27	5·31	1·52
Boiling Point at 760 mm. ...	4·5°C.	76·7°C.	—78°C.
Melting Point	—93°C.	—30°C.	——
Specific Heat of Liquid at 0°C. Cals/gram.	0·12	0·185	0·20
Latent Heat of Vaporization Cal/grm. at B.P.	62	46	90
Vapour Pressure at 60°F. lbs. per sq. in.	20·0	1·75	810
Gas Generation cubic feet per lb. at N.T.P.	3·7	2·3	8·5
Inhibitory Factor % in dry air ...	3·0	15·0	29
Diffusion coefficient grms/cm²/sec/air	0·097	·076	0·142
Percentage recommended for concentration method of extinction	5	25	50
Relative Toxicity at this strength	8	26	10
Normal Pressure in Cylinders lbs. per sq. in. at 60°F. ...	50/100	80	810
Comparative weights of Automatic installations	1	8	10

ELECTRICAL RESISTANCE

Report by the Faraday House Testing Laboratories.

" The ESSEX Extinguisher submitted was a No. 2 size, and was examined for its suitability for use in coping with electrical fires.

" For this purpose a metal plate was suspended from insulators and connected to the high tension terminal of a transformer, through an instrument for indicating the amount of current flowing.

" The metal case of the Extinguisher was connected to the other terminal of the transformer which was earthed. The jet from the Fire Extinguisher was directed on to the metal plate at a distance of 2½ feet, and the pressure across the transformer terminals increased to 22,500 volts.

" At this pressure there was a current of about 26 micro-amperes flowing.

" This is an extremely small current and represents an impedance of 865 megohms due to the jet of fluid.

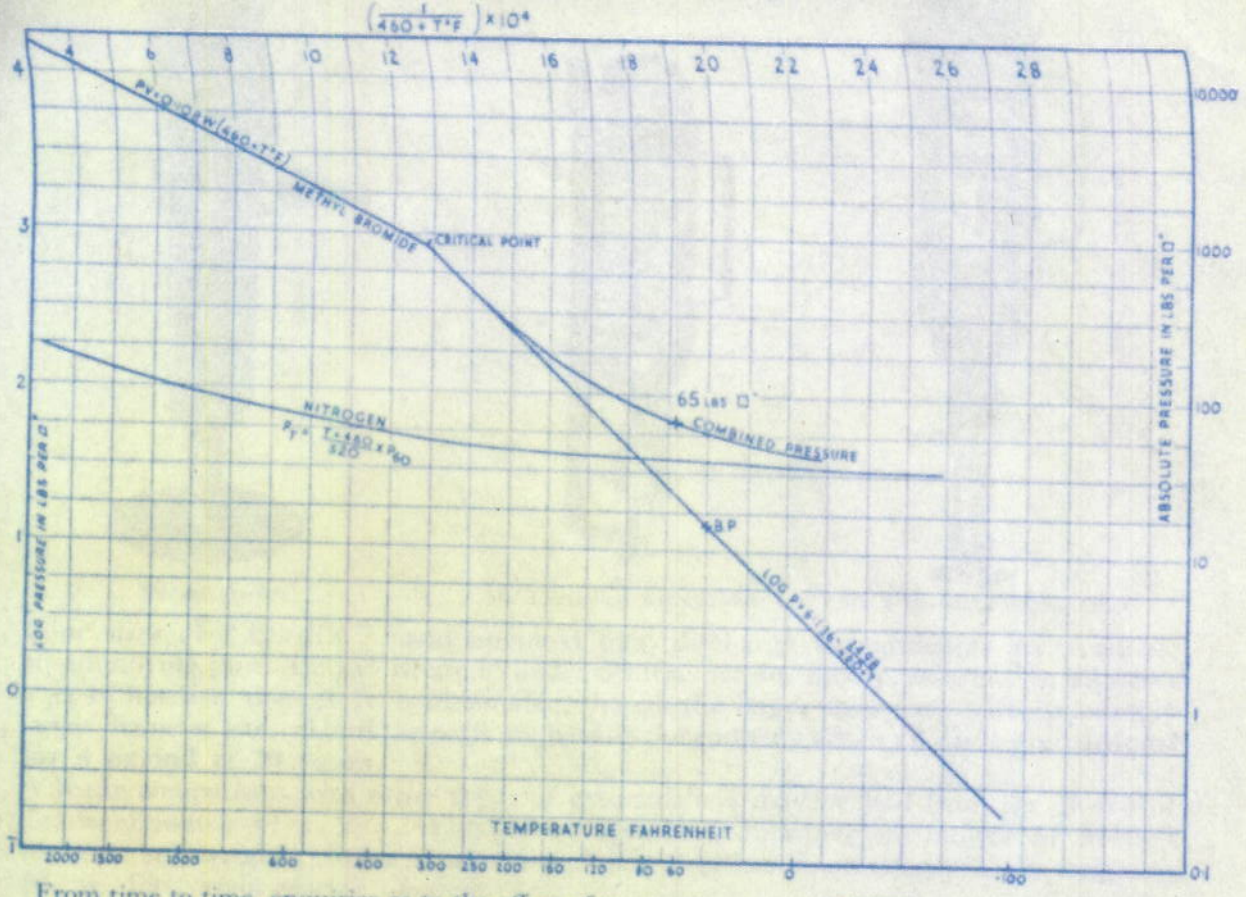
" Such a high resistance should render the appliance safe for use on live electrical wires."

(*Signed*) ALEX. RUSSELL,
Principal.

(*Signed*) A. T. MORRIS,
Superintendent of Testing Laboratories.

NOTE.—This extinguisher contained 80% Methyl Bromide and 20% Pentachlorethane, whereas all ESSEX extinguishers now contain 100% Methyl Bromide giving a greater electrical resistance.

The Effect of Temperature on Methyl Bromide Cylinders



From time to time, enquiries as to the effect of temperature upon ESSEX extinguishers have been made, and as it is desired to provide all needful data, the accompanying graph is reproduced.

Unless temperature or other special conditions require non-standard treatment, ESSEX Methyl Bromide units contain nitrogen gas to bring their gauge pressure to 50 lbs. per square inch at the normal factory temperature of 60° F. Under these circumstances the total pressure will be due to :— Methyl Bromide vapour 20 lbs. per square inch plus Nitrogen 30 lbs. per square inch. Regarding Nitrogen as a perfect gas the **absolute** pressure will vary directly with the **absolute** temperature according to the formula—

$$P_T = \frac{T + 460}{520} \times P_{60}$$

Where **P** = absolute pressure in lbs. per square inch
and **T** = temperature in °F.

the pressure curve of which, plotted logarithmically, is shown above.

Below its critical temperature of 323° F. Methyl Bromide vapour closely follows the formula—

$$\log P = 6.136 - \frac{2498}{460 + T}$$

while above this temperature it may be considered as a perfect gas to which the equation—

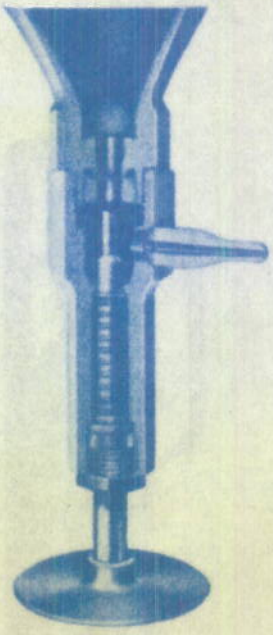
$$PV = 0.108\,W\,(460 + T)$$

may be applied, the resulting curve being indicated in the diagram, the total pressure being the sum of the two individual pressures at any given temperature.

The absolute pressures are plotted on an axis scaled logarithmically against temperature scaled reciprocally and increased by a factor of 10^4 for clarity.

In the case of a No. 6 ESSEX extinguishing unit, the steel cylinder used has a bursting pressure of 2680 lbs. per square inch (representing a temperature of approximately 700° F.), but the copper sealing disc is designed to act as a safety valve under abnormal conditions, and at a pressure of 800 lbs. per square inch (approximately 350° F.) will break down and release the medium through the pipe line.

ESSEX STANDARD EXTINGUISHERS



Plunger Section.

No. 2 Standard Extinguisher

No. 3 Standard Extinguisher

Four sizes of "ESSEX" hand operated total discharge extinguishers are available all employing pure Methyl Bromide under 50 lbs. per sq. inch pressure. In all cases a jet of not less than 20 ft. is obtainable, though the larger sizes have correspondingly larger diameter jets. Until the seals are broken the contents are in all cases **guaranteed for a period of 10 years.**

A ready comparison with other types of extinguishers may be had from the Board of Trade allowance of a No. 2 ESSEX extinguisher containing 20 ounces of Methyl Bromide and weighing 3 lbs. 2 ozs. to replace a 2-gallon Foam extinguisher, weighing 40 lbs., for certain marine hazards.

ESSEX EXTINGUISHERS

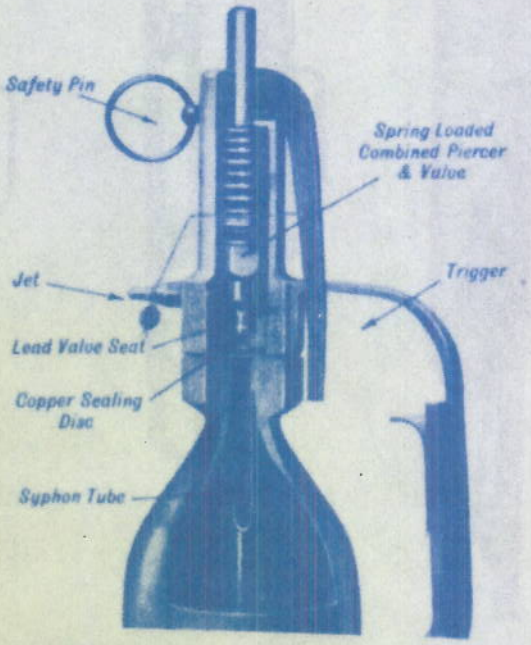
No.	Finish	EXTINGUISHER ONLY: Nett Contents	Weight Full		Overall Height	Dia.	Code	Price	Extinguisher complete with Steel Bracket: Code	Price
			lbs.	oz.						
1	Red Enamel Lacquered Copper Chromium plated	8 oz.	2	4	11"	2"	10 11 12	Prices on application	1010A 1110A 1210A	Prices on application
2	Red Enamel Lacquered Copper Chromium plated	20 oz.	3	2	14"	2½"	20 21 22		2020A 2120A 2220A	
3	Red Enamel Lacquered Copper Chromium plated	2 lbs.	4	10	15¼"	3"	30 31 32		3030A 3130A 3230A	
4	Red Enamel Lacquered Copper Chromium plated	4 lbs.	8	4	15¼"	4½"	40 41 42		4040A 4140A 4240A	

Brackets separately :—

For Extinguisher CODE	10	20	30	40	Code Suffix Letter
Black enamelled steel Enamelled brass Chromium plated	**Prices on application**				A B C

ESSEX CONTROLLED DISCHARGE EXTINGUISHERS

No. 3. SLV Extinguisher



SLV Extinguisher Head

No. 5 SDV ESSEX Extinguisher

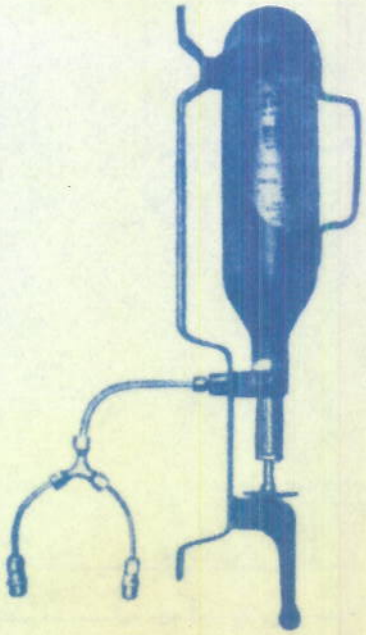
Whereas the standard Essex extinguishers are of the total discharge type, sizes Nos. 3 & 4 are made with spring loaded shut off valves (type SLV) and a larger No. 5 size is made with a special screw down valve.

The SLV type combines the seal of the standard type (bearing a 10 year guarantee) with a trigger control resembling a pistol. The withdrawal of a safety pin releases a spring loaded combined piercer and valve, and pierces the copper sealing disc, at the same time shutting the valve which by trigger operation controls the discharge.

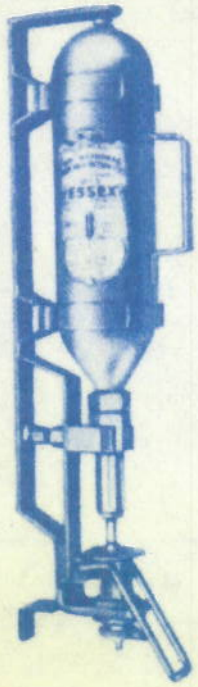
The No. 5 SDV type has no copper sealing disc, but is operated by turning the wheel valve anti-clockwise and opening the additional cock. An 18" length of ¼" bore hose and a leather carrying strap are incorporated. When closing the valve after partial discharge, it is important to screw the valve down hard.

No.	Finish	Code	Nett Contents	Bracket Weight	Height	Extinguisher Weight Full
3 SLV	Red enamelled copper extinguisher with black steel bracket . . .	35	2 lb. 0 oz.	12 oz.	16"	5 lb. 12 ozs.
	Chromium plated ditto	36				
	Extra for brass bracket					
4 SLV	Red enamelled copper extinguisher with black steel bracket . . .	45	4 lb. 0 oz.	14 oz.	17"	8 lb. 12 ozs.
	Chromium plated ditto	46				
	Extra for brass bracket					
5 SDV	Red enamelled steel extinguisher with hose and carrying strap .	50	8 lb. 0 oz.		2' 5"	23 lb.
	Chromium plated (fittings only)	55				
Wall bracket	Black enamelled steel	50A		3 lb.		

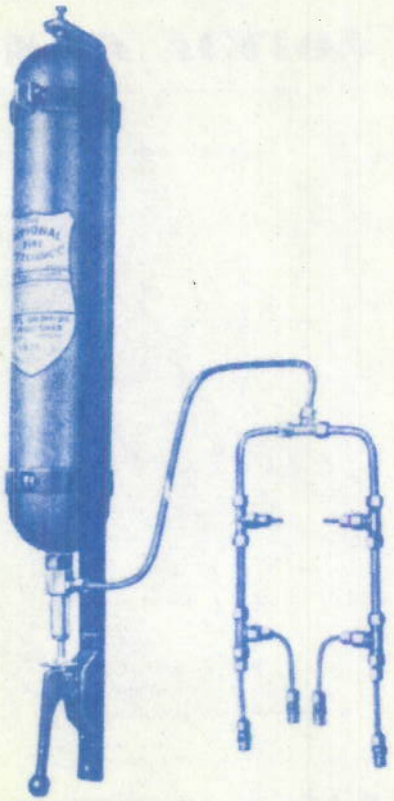
Prices on application.



No. 3 Featherspray Set



Electrical Automatic Featherspray



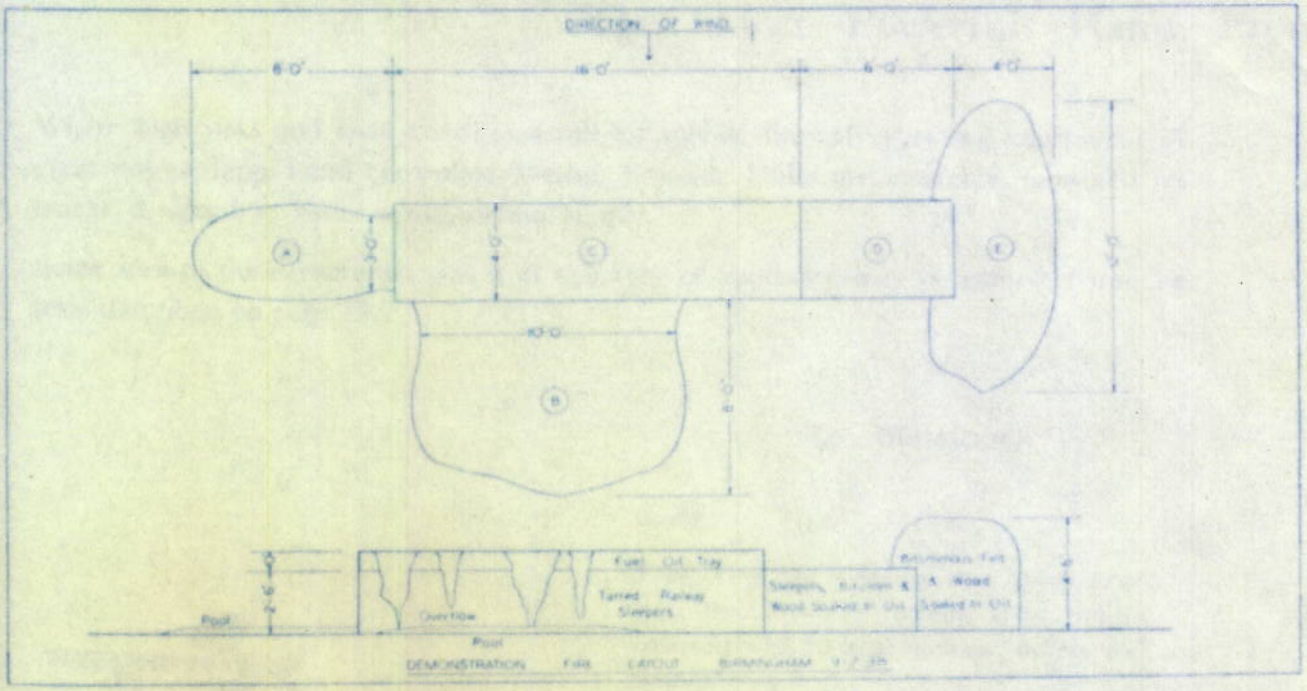
No. 5 Remote Control Set

Essex remote control systems fall into three classes :—
The FEATHERSPRAY equipment comprising a No. 1, 2, 3 or 4 extinguisher held by spring clips to a bracket incorporating a lever. A pipe line system is removably connected to the extinguisher by a rubber gland joint in the bracket into which the extinguisher nozzle fits when in the bracket. This arrangement affords either remote control when the lever is used, or a standard hand extinguisher. Nos. 5 and 6 remote control sets have cylinders too heavy for removal, and the pipe line is permanently connected.
Additional remote control to an automatic installation may be by means of a lever on the bracket, a flexible wire pull system or an electric switch.

No.	Description and Equipment.	Code	Overall Height	Weight Complete lb. oz.
1	Featherspray set with red enamelled extinguisher, black enamelled steel bracket, 8 ft. $\frac{3}{8}$" o.d. copper pipe, 'Y' joint, 2 sprayheads and pipe clips	10FS	15"	3 12
	Do. with chromium plated extinguisher	12FS		
2	Featherspray set with the same equipment	20FS	17"	5 12
	Do. with chromium plated extinguisher	22FS		
2	Electrical automatic set with special cartridge bracket, same pipe equipment and flame sensitive switch ...	20EA	18½"	6 10
3	Featherspray set with the same equipment	30FS	19½"	7 0
	Do. with chromium plated extinguisher	32FS		
3	Electrical automatic set with special cartridge bracket, same pipe equipment and flame sensitive switch ...	30EA	20"	8 0
	Featherspray set with red enamelled extinguisher brass bracket, 24 ft. $\frac{3}{8}$" o.d. copper pipe, 16 ft. $\frac{5}{16}$" o.d. copper pipe, 5 'T' joints, 6 adaptors and 4 sprayheads ...	40FS	20½"	16 0
	Do. with chromium plated extinguisher	42FS		
5	Remote control set with red enamelled extinguisher, black enamelled steel bracket, 36 ft. $\frac{3}{8}$" o.d. copper pipe, 16 ft. $\frac{5}{16}$" o.d. copper pipe, 5 'T' joints, 6 adaptors, 2 unions, 4 sprayheads and clips	51RC	35"	37 0
6	Remote control equipment designed to meet individual needs.			

Prices on application.

AN ESSEX TRIPLE TRUCK IN ACTION



A tray (C) 16′ long by 4′ wide by 10″ deep built of railway sleepers was placed 2′ 6″ off the ground end to end with another erection (D) of well tarred railway sleepers filled with strips of bituminous roofing felt and slats of wood, the whole being well soaked with fuel oil. The tray was then filled with some 2″ of bitumen and tar and was topped to overflowing with fuel oil. This caused a pool (A) some 8′ × 3′ to appear beyond the edge of the tray and a second pool (B) measuring 10′ × 8′ at one side in accordance with sketch above. At the end of the oil soaked bituminous roofing pile, a further mound (E) of bituminous roofing felt with slats of wood again well soaked in fuel oil, measuring 12′ × 4′ high was placed. The demonstration fire was therefore 34 feet long with a maximum width of 12 feet and a maximum height of 4′ 6″.

The whole was simultaneously lit with wood wool soaked in naphtha and was allowed to burn for nearly 10 minutes, until the sleepers were well alight, when an ESSEX Triple Truck (type T 360) was brought into action.

The fire was extinguished in 45 seconds, and did not re-ignite.

It should be noted that a high wind was blowing across this fire during the test.

TEST 2.

The portions in the above diagram marked (A) (E) and contents of (D) were then removed or covered with soil and portions (B) and (C) relit. This fire spread to some of the sleepers of (D) which had been placed too closely for safety, but the whole was easily extinguished by the contents of two and a half No. 5 S.D.V. ESSEX extinguishers.

TEST 3.

The large tray (C) was then relit and was extinguished from a distance of 6 feet with one No. 5 extinguisher.

TEST 4.

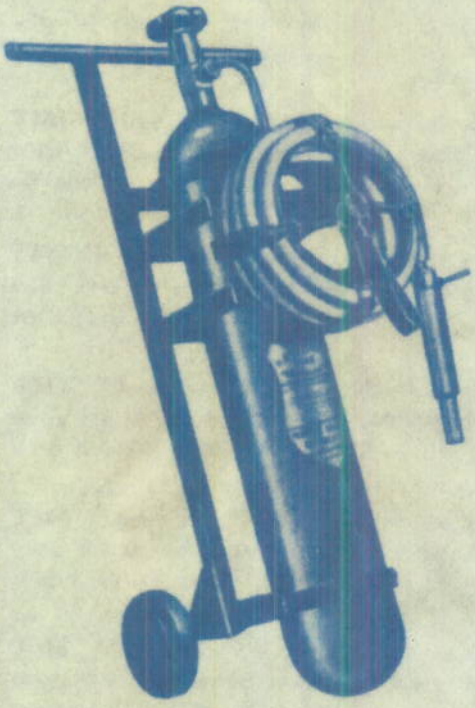
Finally the remainder of the mound (E) to which was added original contents of (D) were relit, and the fire was extinguished by one of the audience.

ESSEX MOBILE

The Most Powerful Hand Propelled

Where high risks and local conditions call for mobile fire-extinguishing equipment of great power, large hand controlled Methyl Bromide Units are available, mounted on trucks designed to make manipulation simple.

Some idea of the exceptional power of this type of appliance may be gained from the tests described on page 17.



Truck T163

Specifications

Code

T160 One No. 6 extinguisher complete on steel truck with 8" compo tyred wheels complete with 20 ft. of hose and nozzle with shut off cock.

T161 One No. 6 extinguisher as above with 30 ft. of hose and nozzle with shut off cock

T163 One No. 6 extinguisher as above with 20 ft. of hose, revolving nozzle and shut off cock.

T164 One No. 6 extinguisher as above with 30 ft. of hose, revolving nozzle with shut off cock.

T260 Two No. 6 extinguishers complete with screw down valves, the cylinders manifolded together with non-return valves, mounted on a steel truck with 8" compo tyred wheels, complete with 20 ft. of hose and nozzle with shut off cock.

T261 Two No. 6 extinguishers as above with 30 ft. of hose and nozzle with shut off cock.

Prices on application

FIRE TRUCKS

Extinguishing Units in the World

Code

T263 Two No. 6 extinguishers as above with 20 ft. of hose and revolving nozzle with shut off cock.

T264 Two No. 6 extinguishers as above with 30 ft. of hose and revolving nozzle with shut off cock.

T360 Three No. 6 extinguishers complete with screw down valves, the cylinders manifolded together with non-return valves, mounted on a truck with 8" compo tyred wheels, complete with 20 ft. of hose and nozzle with shut off cock.

T361 Three No. 6 extinguishers as above with 30 ft. of hose and nozzle with shut off cock.

T362 Three No. 6 extinguishers as above with two 20 ft. lengths of hose and nozzles with shut off cocks.

T363 Three No. 6 extinguishers as above with 20 ft. of hose and revolving nozzle with shut off cock.

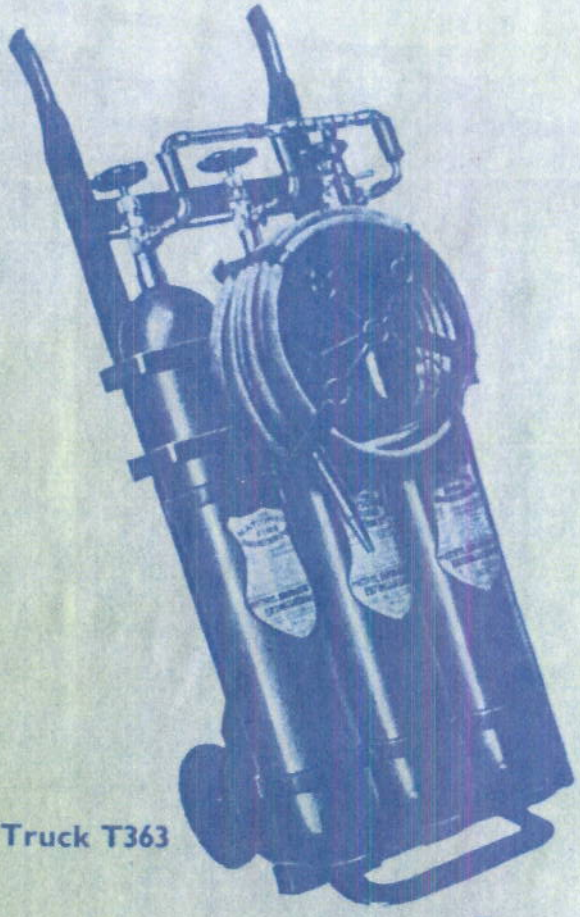
T364 Three No. 6 extinguishers as above with 30 ft. of hose and revolving nozzle with shut off cock.

T365 Three No. 6 extinguishers as above with two 20 ft. lengths of hose and revolving nozzles with shut off cocks.

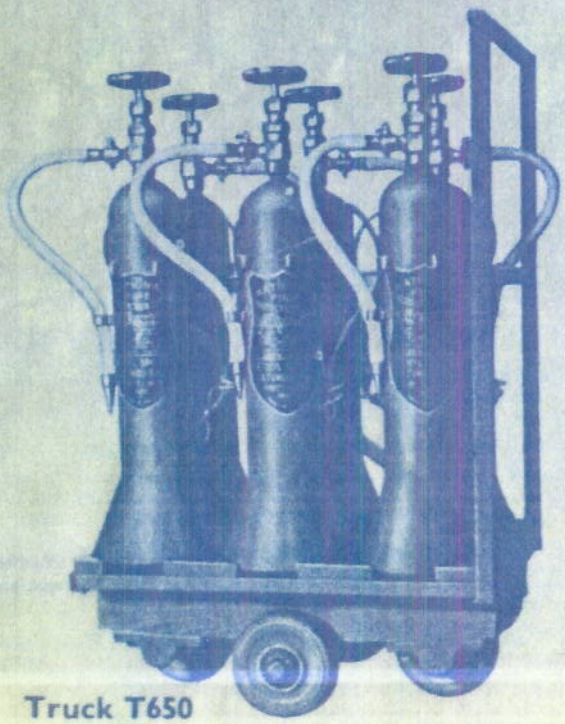
T650 Six No. 5 extinguishers complete with screw down valves carried on a flat type trolley.

Extra for insulator on revolving nozzles.

Prices on application



Truck T363



Truck T650

IRE TRUCKS

Extinguishing Units in the World

Code

T263 Two No. 6 extinguishers as above with 20 ft. of hose and revolving nozzle with shut off cock.

T264 Two No. 6 extinguishers as above with 30 ft. of hose and revolving nozzle with shut off cock.

T360 Three No. 6 extinguishers complete with screw down valves, the cylinders manifolded together with non-return valves, mounted on a truck with 8" compo tyred wheels, complete with 20 ft. of hose and nozzle with shut off cock.

T361 Three No. 6 extinguishers as above with 30 ft. of hose and nozzle with shut off cock.

T362 Three No. 6 extinguishers as above with two 20 ft. lengths of hose and nozzles with shut off cocks.

T363 Three No. 6 extinguishers as above with 20 ft. of hose and revolving nozzle with shut off cock.

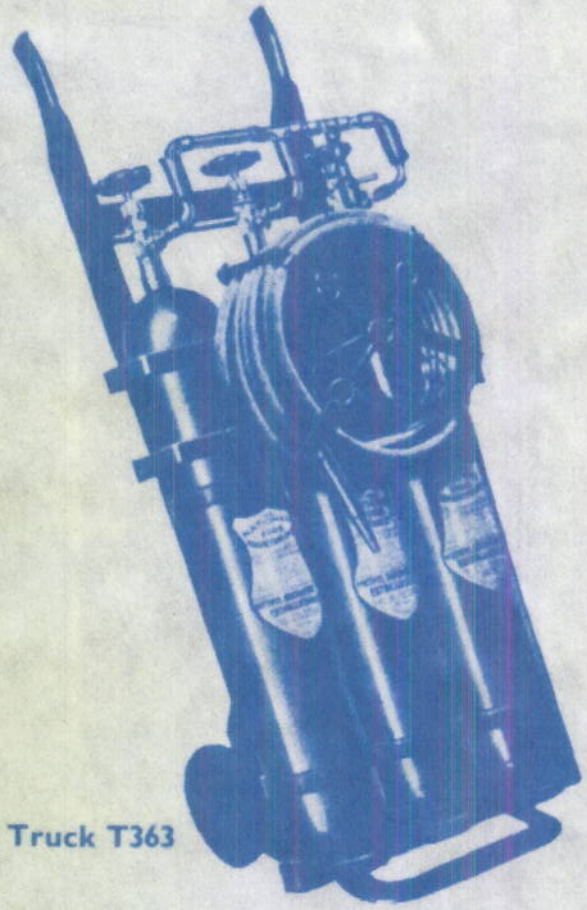
T364 Three No. 6 extinguishers as above with 30 ft. of hose and revolving nozzle with shut off cock.

T365 Three No. 6 extinguishers as above with two 20 ft. lengths of hose and revolving nozzles with shut off cocks.

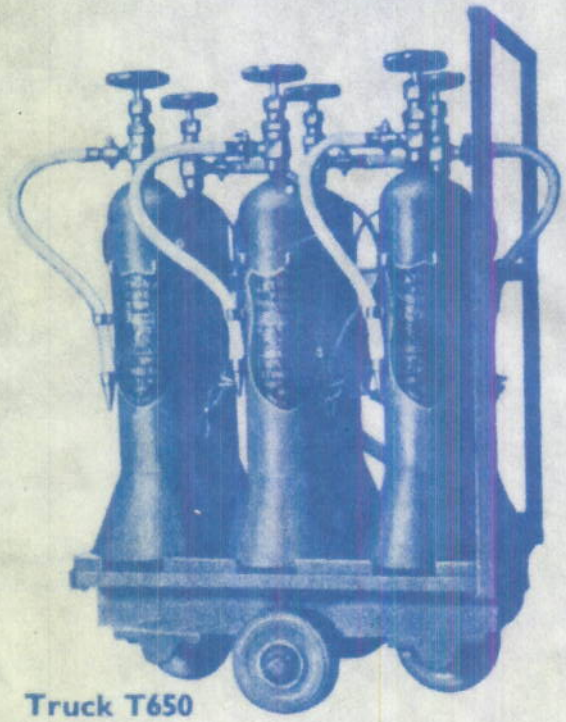
T650 Six No. 5 extinguishers complete with screw down valves carried on a flat type trolley.

Extra for insulator on revolving nozzles.

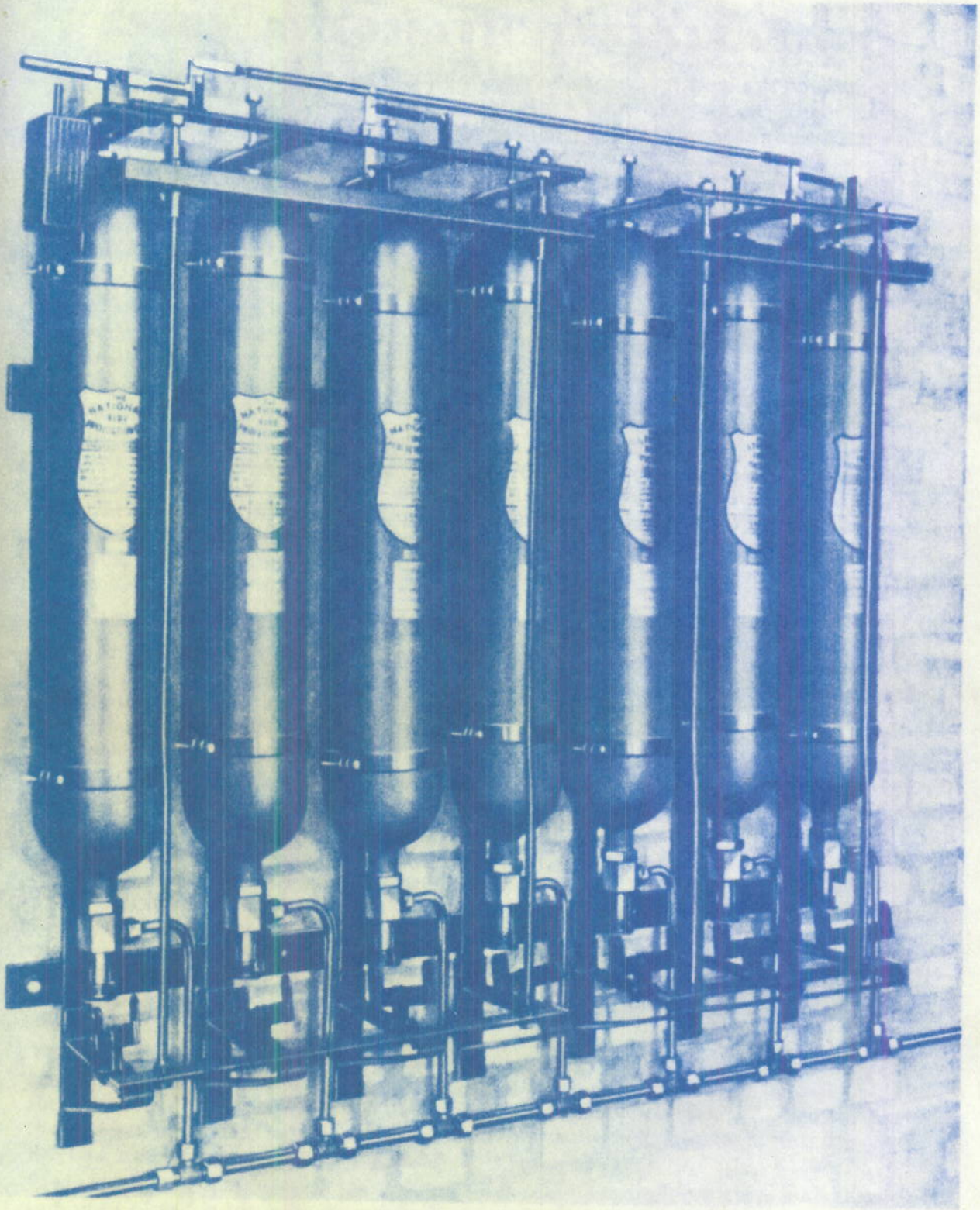
Prices on application



Truck T363



Truck T650



A typical "ESSEX" Automatic Unit arranged for electrical solenoid operation.

ESSEX AUTOMATIC INSTALLATIONS

There are many dangerous fire hazards, such as those in Electrical Power Stations, Chemical Factories and other industries involving high risks which cannot be safely protected by manually-operated extinguishing systems, either because they are normally unattended by personnel, because of the intensity of the fire involved or, more rarely, because of physical conditions precluding satisfactory hand directed attack.

For such situations a variety of ESSEX automatically operated extinguishing installations are available, *each and every instance forming the subject of a special survey* and the adaptation of standard equipment to the particular requirement of the risk.

Exterior hazards, and certain interior hazards localised in large compartments, may be treated independently in such a way that the effect of the Methyl Bromide is somewhat similar to that produced by hand operation, in which case the extinguishing system is termed one of " direct impingement ".

Installations are, however, more usually designed to work on what is known as the *concentration* method. On page 5 it was noted that the addition of 5% of Methyl Bromide vapour to the air not only caused extinguishment of the fire but provided an adequate factor of safety to cover unequal distribution and such leakage as occurs in a nominally unventilated space. Under such conditions, dealt with more fully below, an ESSEX No. 6 Unit containing 24 lbs. of Methyl Bromide is sufficient to safeguard 1,800 cubic feet of space, each pound of medium producing, on release to atmosphere, 3·7 cubic feet of vapour at N.T.P. (See page 12.)

Mechanically Operated Installations

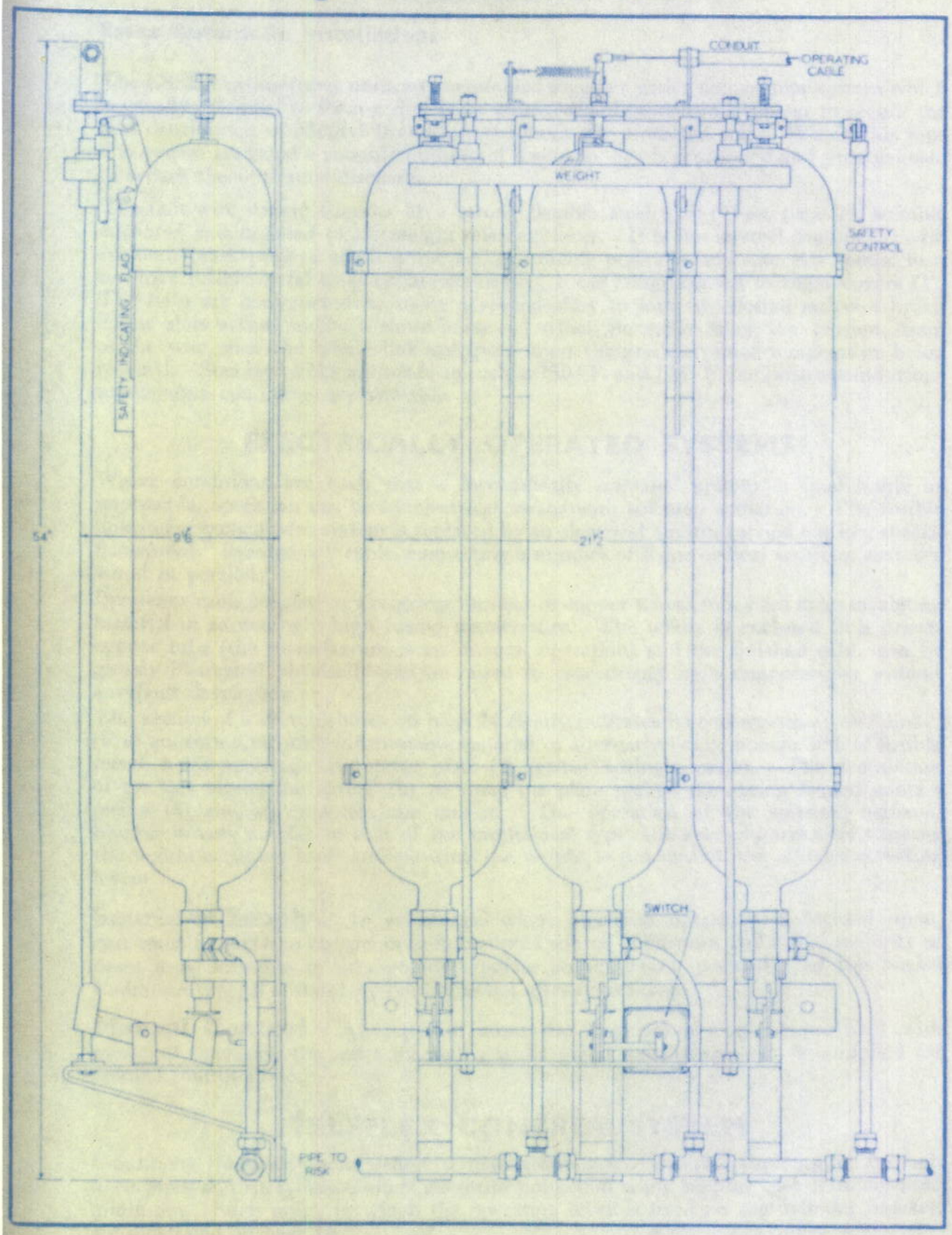
These are normally operated through the agency of low temperature fusible links incorporated in a system of stretched wires, since the essential simplicity of this system contributes largely to its established reliability. A typical extinguisher unit, the head of which is shown on page 22, consists of a solid drawn steel cylinder, tested to 700 lbs. per square inch, containing liquid Methyl Bromide super-gassed to ensure rapid ejection. Content and super-gas pressure are shown on page 5. After filling, the cylinders are gassed at 60° F. to the requisite pressure, and sealed by means of the copper disc seal (11) see page 24.

The method of sealing is so efficient that after passing stringent works tests the cylinders are **guaranteed against leakage or evaporation** for a period of **ten years**, so long as the seal is not pierced. To the cylinder is added an actuating mechanism consisting of a brass body (15) enclosing a seal piercing plunger (13). As will be seen, when this plunger is forced into the body, the copper disc seal is partly cut and then folded back, the plunger is returned by the spring (14) and the content of the cylinder is released to discharge through the screwed orifice (12) at the side of the plunger body, which forms the outlet to the distributing pipeline.

The extinguisher unit is carried in a steel operating bracket which is constructed to accommodate any number from one to six units, which in turn may be assembled to form " banks " of any size. (See illustration, for instance, on page 3.) At the top of the bracket is situated a weight release lever, normally held against spring tension by the taut wire system incorporating the fusible links.

Between this top portion and the rocking lever seal piercing mechanism runs a pair of cadmium plated guide rods upon which the operating weight with its bushes and ball bearings is assembled. This weight is provided with a catch normally engaged by the weight releasing lever, but is otherwise free to fall and actuate the rocking lever mechanism. The latter, upon receiving the impact of the weight, forces the piercer spindles upwards, and so discharges the units. A typical unit is shown on page 22.

Triple Automatic Unit



Essex Automatic Installations

The ESSEX extinguisher units are manifolded together with a copper pipe system which is usually extended to form a ring main arranged and graded in diameter to secure the best distribution of Methyl Bromide throughout the protected area. Within this pipe line system are fitted a suitable number of discharge heads positioned and proportioned to secure the optimum discharge.

The taut wire system consists of a strong flexible steel wire (4) see page 24, suitably anchored and attached to the weight releasing lever. It is run in steel conduit (3) with enclosed brass pulleys at all turns, and at suitable positions and intervals special heat sensitive fusible metal links (2) are connected, these being housed in brass covers (1). The links are constructed by using a special alloy to join two slotted strips of brass. These slots accommodate a short brass rod which normally takes the tension strain of the wire, and the whole link collapses upon the predetermined temperature being reached. Standard links are made to melt at 150° F. and 175° F. but links to suit various temperature conditions are available.

ELECTRICALLY OPERATED SYSTEMS

Where conditions are such that a mechanically operated system is inadvisable or impossible, operation can be by electrical means with solenoid actuation. The fusible link and stretched wire system is replaced by an electrical circuit, carried out in a special flameproof " Pyrotenax " cable, connecting a number of flame or heat sensitive switches wired in parallel.

Pyrotenax cable consists of a requisite number of copper wires embedded in an insulating material of exceedingly high fusing temperature. The whole is enclosed in a drawn copper tube (the manufacture is an integral operation) and the finished cable can be grossly ill-treated physically and/or raised to exceedingly high temperatures without any fault developing.

The section of a switch shown on page 24 clearly indicates its construction. A " link " (5) of guncotton, or other inflammable material, or alternatively a composite link of fusible metal, holds an insulated contact plate (7) against spring pressure. The destruction of the link allows the spring (6) to force the plate against the spring loaded contact pieces (8) and so complete the circuit. The operation of the solenoid actuated bracket is very similar to that of the mechanical type, the solenoid armature tripping the weight retaining lever and allowing the weight to descend on the plunger actuating levers.

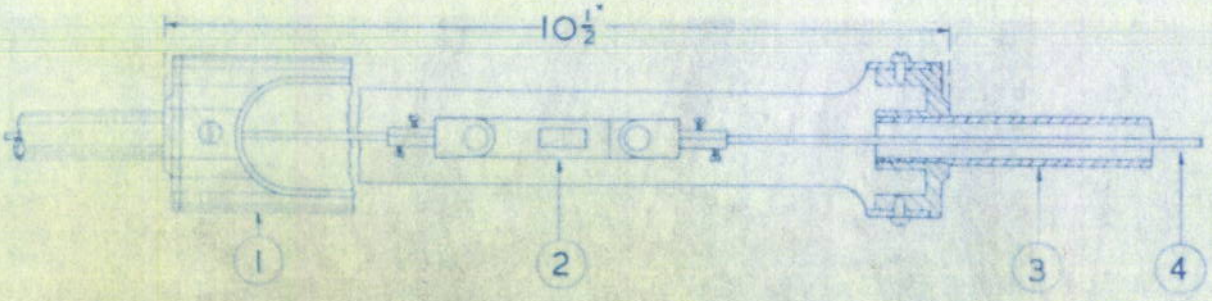
Source of Supply. In every case where electrical operation is decided upon, care must be taken to ensure an uninterrupted source of current, and in the majority of cases it is desirable to arrange for separate accumulators, preferably of the Nickel Cadmium type, if a stand-by battery is not already available.

Manual Control. All types of automatic installations may be provided with means of operating the units manually, while piped installations can be supplied for manual control alone.

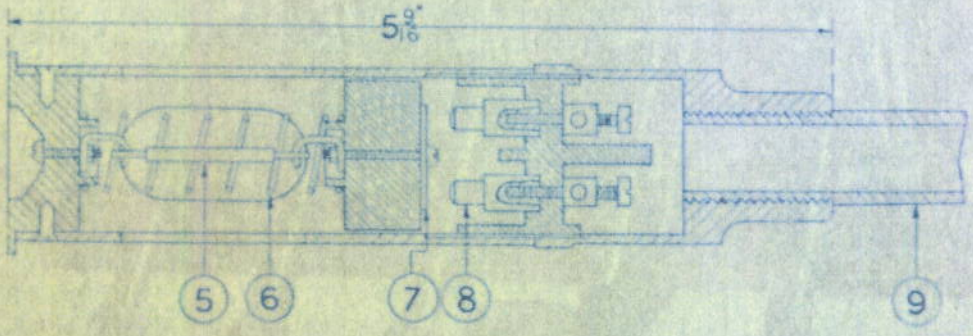
TELEFLEX CONTROL SYSTEM

Conditions frequently arise where a manually-operated system, discharging through fixed pipes and sprayheads, offers adequate protection while keeping cost at an absolute minimum. Such units, in which the operating lever is fixed on the cylinder bracket, are illustrated on page 16.

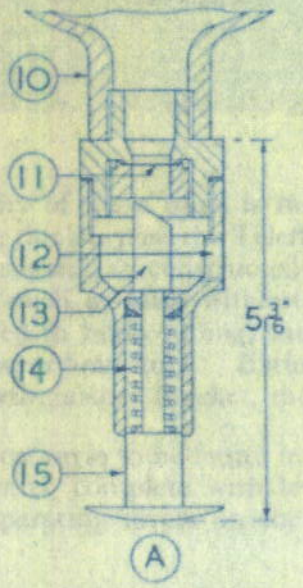
Details of Automatic Components

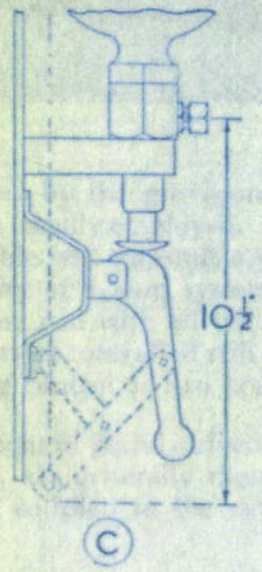


HEAT SENSITIVE FUSIBLE LINK WITH PROTECTIVE GUARD



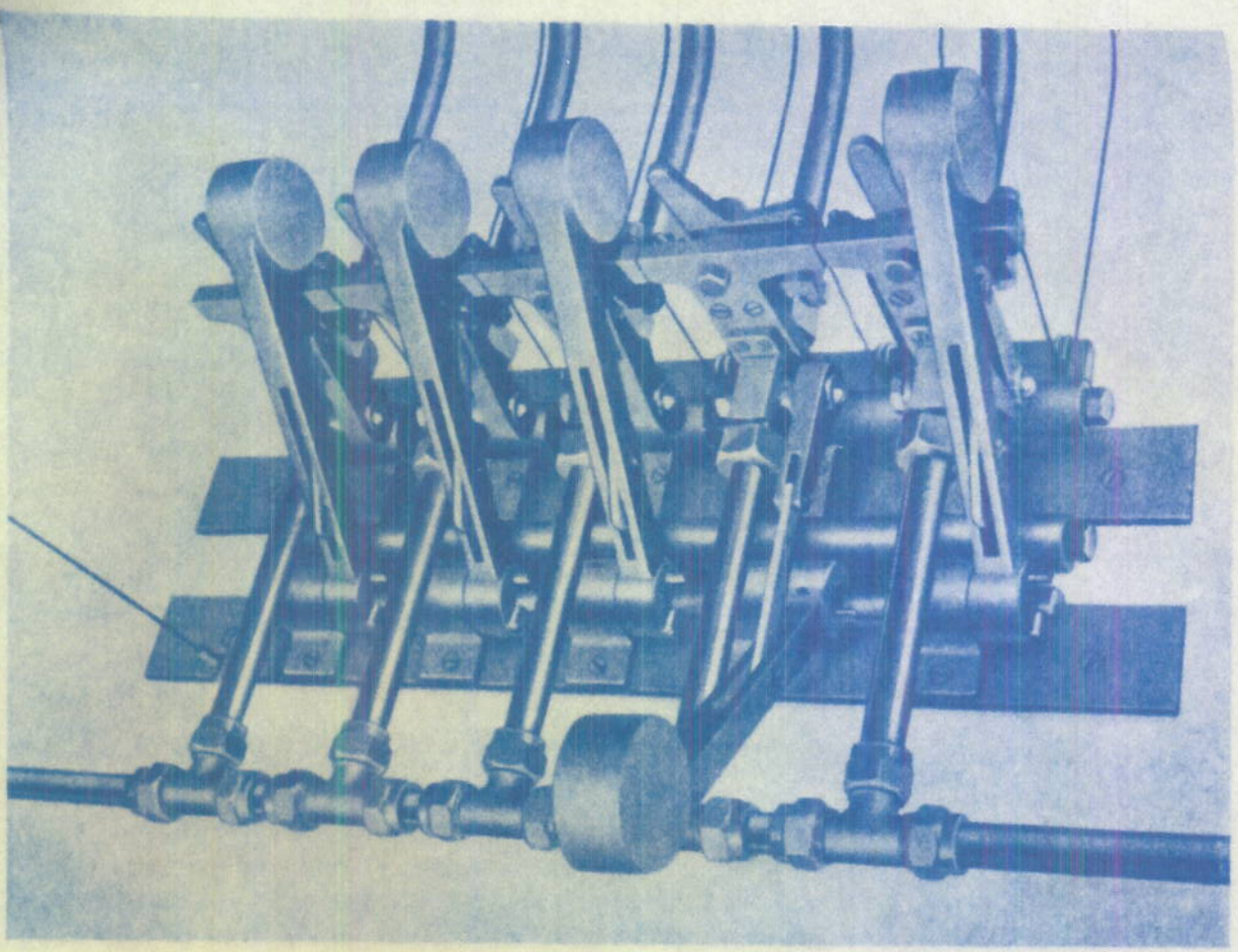
FLAME SENSITIVE ELECTRIC SWITCH





(A) SEAL PIERCING PLUNGER MECHANISM

(C) HAND OR REMOTE OPERATION METHOD

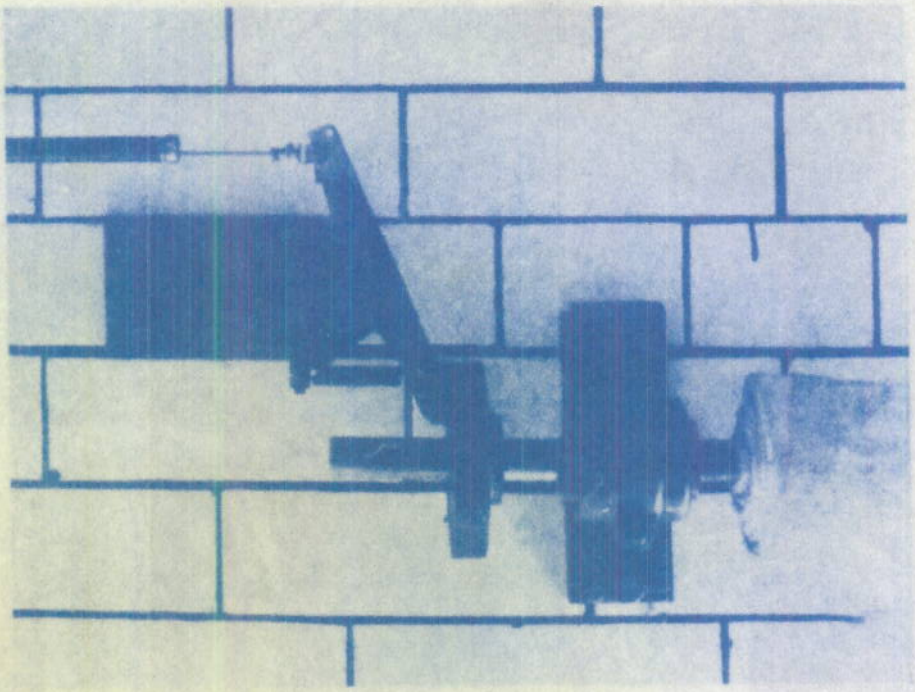


The adaptability of these units is much increased by the provision of positive remote control, and for this purpose the Teleflex system is usually employed. Teleflex is a special form of cable control, so constructed that the cable will transmit a movement in either direction, i.e., push or pull, without the necessity of a loop system. This semi-rigid cable is enclosed in brass tubing, the whole being run with all the ease and simplicity of a small diameter brass tube. Extinguisher units so controlled still retain the operating lever on the extinguisher bracket, thus providing control at two positions.

A typical application is to be found in the equipment of petrol-driven launches where the extinguisher units, complete with lever bracket, are generally mounted in the engine room, while operating levers on the bridge are coupled to the extinguishers through Teleflex cable.

INDICATOR SYSTEMS AND SAFETY GEAR

It is in many cases desirable that the Executive shall be made automatically and immediately aware of an outbreak of fire. Automatic alarms can be incorporated in all Essex Automatic units, warning being given at whichever point desired through lights, bells, etc.



Safety Curtain Release Mechanism

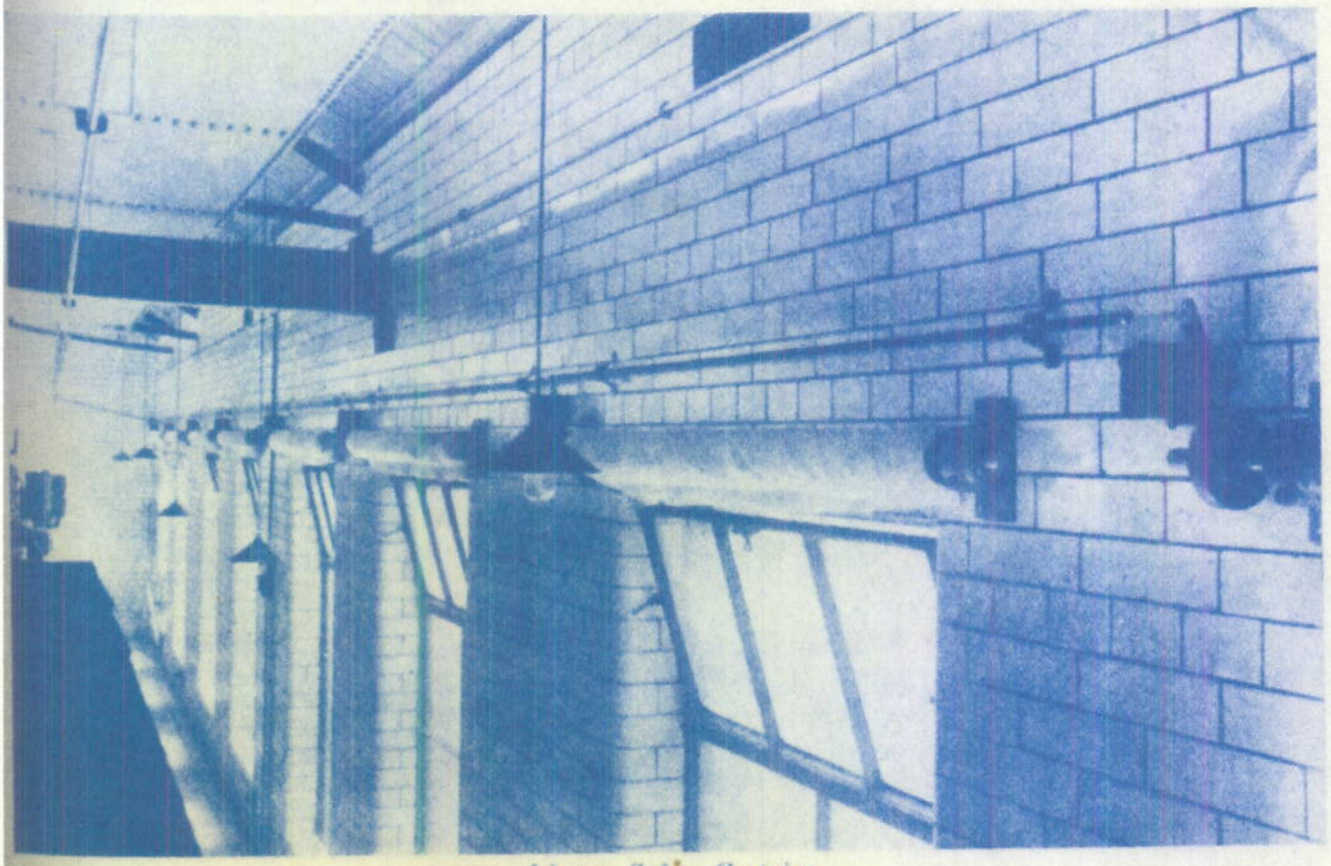
When, for any reason, it is desirable to incorporate a safety device to prevent accidental discharge of equipment—e.g., when plant repairs or removals are being carried out—a safety lever can be incorporated which will prevent the operating weight from falling more than an inch or so. Should the weight drop on to the safety lock, a semaphore signal arm is caused to project from the safety lock, to show what has occurred. Such an arrangement is shown on page 22.

Light signals can be incorporated with this system, to warn the charge-hand that the system has been put out of operation and lines can be run to Executive offices, showing that the gear is at " safety " or that the weight has been tripped while the safety lock is in.

Variations in these alarm systems are provided to suit the particular needs of each client, even to the extent of incorporating Vapour Detector circuits to indicate ventilation of the protected area after discharge.

Secondary Equipment

Switchgear. Switches for the actuation of alarms, the breaking of ventilating fan and other circuits are generally built integrally with the bracket in such a way that they are thrown by movement of the operating lever (see page 22), but may also be arranged elsewhere to meet special conditions.



Asbestos Safety Curtains

SAFETY CURTAINS AND SCREENS

Doors, windows and ventilators often present a problem in safeguarding a compartment, and this can be overcome by the provision of shutters or asbestos curtains operated simultaneously with the extinguishing units. A typical example of this is shown in the illustration above, while the enlargement of the operating mechanism clearly shows its action. Curtains offer a much more satisfactory solution to the difficulty than does the provision of a " gas screen " and are always to be recommended where there is any risk of explosion breaking window panes, etc., and so allowing the gases to dissipate before having done their work. In many instances, as that illustrated on page 9, permanent Durasteel screens are essential to prevent the spread of burning oil and to avoid the undue dissipation of the Methyl Bromide gas.

SELECTIVE DISTRIBUTION

In certain instances it may be permissible, after consideration of all relevant details, to arrange for the protection of a number of adjacent risks by means of a central battery of ESSEX Units. In such a case, an automatic selection valve unit is incorporated, so arranged that the appropriate valve is opened before the extinguisher units are discharged. A typical selection unit is shown on page 25, the lower pipe line being the manifold feed from the Methyl Bromide cylinders, while the five pipe lines in the vertical plane are the feeds to the respective risks.

Where the quantity of Methyl Bromide required is substantially different in various compartments protected by a selective system, the number of ESSEX Units to be discharged may automatically be varied, to ensure the maximum economy in operation.

The primary drawback to the selective system is that if a second outbreak occurs quickly after the first, the extinguisher units may be exhausted. Where desirable, a second battery can be provided, to come into operation after the first has been discharged.

PRELIMINARY SURVEYS AND SERVICE

The loss of vital production, of plant and buildings, and even of life, which may result from outbreak of fire, are factors which to-day need no emphasis.

Protection against fire calls for expert knowledge backed by experience in the *prevention as well as in extinction*. Our engineers are at your disposal, to advise you in these matters, without obligation on your part. Their advice, backed as it is by our very wide range of fire extinguishing equipment of all types, will prove invaluable to those seeking real protection at an economic figure.

INSTRUCTIONS FOR USE OF ESSEX EXTINGUISHERS

Total Discharge Types—Nos. 1—4

Remove extinguisher from bracket, strike knob smartly on floor or ground (this pierces the copper disc seal) and direct jet at base of fire. Keep the jet low—do not invert machine.

Controlled Discharge Types—Nos. 3 and 4 S.L.V.

Remove extinguisher from bracket, remove safety pin by hooking the ring over thumb of left hand (this releases piercer which, under spring pressure, penetrates copper sealing disc). Machine can now be discharged at seat of fire, by raising trigger with forefinger of right hand. After use, drop trigger smartly to shut off delivery.

No. 5 S.D.V.

Unscrew main valve fully, and turn on the quick-action cock with left hand, directing jet at seat of fire with the right hand. After use, shut off quick-action cock and *then* screw down main valve **tightly.**

Truck Units

Generally as for No. 5 S.D.V. On twin or triple truck units, cylinders can be brought into use individually or jointly by opening appropriate main valves.

Refilling
Types 1—4 and 3—4 S.L.V.

Spare charged bottles can be kept in reserve or the machine returned to Works or area depots in exchange for a charged and reconditioned machine which is guaranteed for 10 years. Any Methyl Bromide left in the S.L.V. types will be credited.

Type 5 S.D.V.

Return to works or area depots in exchange for reconditioned and guaranteed machine. Any Methyl Bromide returned will be credited.

Truck Units

Generally as for Type 5 S.D.V. If more convenient return bottle(s) only. On double or triple trucks a full bottle or bottles can be left in place, special non-return valves enabling the truck to be used, even though empty bottle(s) have been removed.

—BUT IS IT TOXIC?

THEORETICAL CONSIDERATIONS

From the efficiency point of view, Methyl Bromide has rightly been proclaimed by experts as the pre-eminent fire extinguishing medium; in fact, it may be said that the only criticism made is that Methyl Bromide is toxic.

"Toxicity" is a somewhat complicated question, which has acquired a publicity value far removed from facts. We have never suggested that Methyl Bromide is an inert substance, or that it can be breathed with safety for long periods at high concentrations. What can be demonstrated is that within the bounds of proper use, it is not only safe to employ but, in fact, harmless to the person.

When using Methyl Bromide by hand extinguishing methods it is most unlikely that the user would be exposed to percentages greater than the order of 0·1% or for periods in excess of a few minutes. Now the effect of a toxic vapour is proportionate not only to the percentage present, but to the period of exposure. Below, we give some figures from independent research, which are, unless otherwise stated, based on *one hour's exposure*.

Methyl Bromide.	Carbon Tetrachloride.	Carbon Dioxide.
4·0% Legge 1930 0·75% Glazer & Frisch 1929 0·19% Beyne & Goett 1934	1·0% Flury 1928 4·8% Legge 1930 2·4%—3·2% Alia	3·0%—4·0% Gaddum 1936 8·0%—10·0% Rapidly fatal. Legge 1930 7·0%—Rapidly fatal. U.S. Navy Regulations
Average of available independent figures.		
0·62%	2·25%	5·0%

It will at once be apparent from the tabulated figures that where hand extinguishers are used the user is never likely to be exposed to a harmful concentration, ignoring altogether the vital time factor, and on page 34 we reproduce a letter which is particularly interesting in this connection.

Moreover, those who propound the argument that Methyl Bromide is toxic lose sight of the fact that both Carbon Tetrachloride and Carbon Dioxide can be rapidly lethal in quite small percentages, as indicated in the preceding table. Granted that these percentages should not be met with through hand discharge of extinguishers, the lower efficiency of these latter media ensures at least a proportionate danger. For example, Methyl Bromide is 3 to 32 times as efficient as Carbon Tetrachloride, while 50% of Co_2 is required to give the extinguishing equivalent of 5% of Methyl Bromide.

If Methyl Bromide is lethal, so, then is Carbon Dioxide or Carbon Tetrachloride.

So far we have dealt with only the raw media, but if we consider fire conditions a very different picture appears. Independent investigation of the by-products of combustion with a series of fires involving Gas Flame, Oil Fire, Wood Fire and Hot Iron, shows, for example, that Carbon Tetrachloride will give off in Phosgene one hundred times the Bromo-Phosgene produced from the fire-fighting equivalent quantity of Methyl Bromide —the proportions of Hydrochloric to Hydrobromic acid may be as high as 500 to 1, and so on. In passing, it should be noted that Carbonyl Bromide (Bromo-Phosgene) is very unstable, and cannot exist under normal circumstances.

Carbon Dioxide, being inherently stable, does not readily break down to form toxic gases, although at high temperatures dangerous percentages of Carbon Monoxide may be released. Carbon Dioxide is, however, a respiratory stimulant and since fires normally produce toxic gases, from Carbon Monoxide upwards, it follows that the presence of Carbon Dioxide will cause these toxic gases to be breathed in much greater quantity. Moreover, it is held by Haldane, among others, that the "physiological effects of Carbon Dioxide in high concentrations appear to be more or less independent of the effects of the want of Oxygen." Nuckolls holds that "Carbon Dioxide is odourless . . . In concentrations, however, much above 10%, the physiological action may be too rapid in producing stupefaction or loss of consciousness to serve as adequate warning."

It must be apparent from these observations that Carbon Dioxide is far from being inert and its reactions on personnel are other than sheer "Oxygen starvation."

From the available figures a toxic factor for Carbon Dioxide of 5% for one hour would seem to be a fair average, and we have already seen the corresponding figure for Methyl Bromide to be 0·62%. Evaluating these in the light of the relative concentrations employed for fire-fighting purposes the toxic index is as **10 for Carbon Dioxide to 8 for Methyl Bromide.** But these figures still make no allowance for the fact that Carbon Dioxide causes an enhanced rate of breathing of any other toxic gases present.

Practical Applications

To the overburdened Manager or Chief Engineer with little time for theorectical considerations, we offer the following points :—

(*a*) Hand-directed Methyl Bromide fire-extinguishing equipment is to-day widely used, even in the triple truck units, without danger to personnel.

(*b*) Automatic units are generally installed over normally unattended risks. Should discharge through fire take place while staff are working in the protected area, visibility is not greatly reduced, the noise of the discharge is negligible and unlikely to produce panic. The vapour has a distinctive, though faint odour, and a normal concentration causes the eyes to water strongly, providing every inducement to seek open air. Unconsciousness may eventually be produced after relatively considerable time lag, preceded by gradually increasing depression and lassitude, usually sufficient to drive personnel to seek fresh air.

With Carbon Dioxide, however, the discharge is accompanied by considerable noise, while the "snowstorm" produced will frequently limit visibility tending to cause loss of sense of direction. Normal fire-fighting concentrations will, with the average man, cause unconsciousness rapidly and without prior warning.

Should the area be imperfectly ventilated after discharge, even quite low concentrations of Methyl Bromide can be smelled. Low concentrations of Carbon Dioxide are, however, completely odourless, while none the less being definitely dangerous.

METHYL BROMIDE OR CO_2?

Very often the choice of the most suitable automatic fire protection lies between the Methyl Bromide and Carbon Dioxide.

The following considerations will assist the judgment of the intending purchaser and enable a choice to be made of equipment best suited to his particular needs.

1. In practice there is little to choose regarding danger from toxicity between the two methods when used for concentration fire fighting. (See L.C.C. Annual Report 1937, Vol. III, Pt. I).

2. The comparative vapour density, i.e., 3·27 (Methyl Bromide), and 1·52 (CO_2) is important since there is less likelihood that up draughts from a fire will dissipate the extinguishing gas before its work is done.

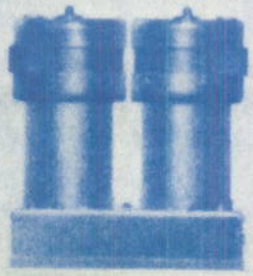
3. The comparative working pressures, i.e., 50 or 100 lbs. per square inch (Methyl Bromide) and 810 lbs. per square inch (CO_2) is another point in favour of the former, inasmuch as the low pressures involved enable lighter apparatus to be used and there is consequently less risk of leakage or failure at the cylinders, pipe joints or fittings. A CO_2 installation when compared with an equivalent Methyl Bromide Equipment, will be at least ten times as heavy. The lower pressure also obviates any risk of injector action occurring for which precautions (which may be rendered void by explosion and in other ways), are necessary when using CO_2.

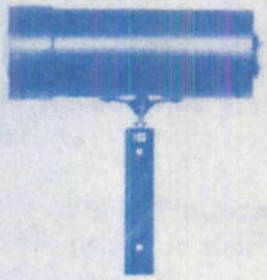
4. The relative diffusion coefficients, i.e. (0·096 Methyl Bromide and 0·142 CO_2), mean that Methyl Bromide diffuses much more slowly than CO_2 and is consequently not so easily affected by draughts or leakages from the protected area.

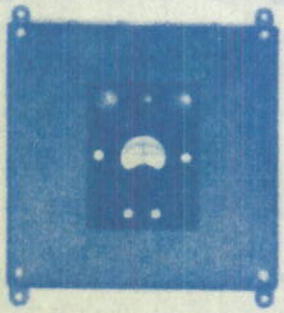
5. The question of bulk is also one which, on occasions, is a serious consideration, and it is of interest to note that the volume required to accommodate a CO_2 plant is approximately four times that needed for the equivalent protection when using Methyl Bromide. With the latter, special concrete bases and/or housing arrangements are unnecessary.

6. Methyl Bromide is contained in cylinders so sealed that they are guaranteed for a period of ten years. Each cylinder is stamped with the weight, and the small number of comparatively light cylinders required makes it an easy matter to check the weights periodically, although this is unnecessary. On the other hand, CO_2 cylinders should be periodically inspected and pressure tested. (Fourth Report—Gas Cylinders Research Committee.)

The "ELECTRICON" Direct Balanced Beam System of Smoke Detection







Smoke almost invariably accompanies an outbreak of fire, and is generally the first indication of danger. The "Electricon" system represents an entirely new departure in the photo-electric method of fire detection by means of this smoke.

The basic principle employed is interception by smoke, even in very small amounts, of a projected beam of light across a space which represents the zone of fire risk concerned.

The consequent diminution of light received by a photocell is registered and utilised to operate audible or visual alarms and even, if desired, to bring into operation automatic fire-fighting equipment. From the illustration it will be seen that the equipment consists of **two** projector lamps, a receiving unit housing the photo-electric cells and a control panel to which these are electrically connected.

The great advantage which the "Electricon" Direct Balanced Beam System has over the earlier single beam systems is that the beams are so interconnected electrically as to maintain balance in spite of mains voltage fluctuation, or reduction in general visibility through fog, conditions which would give an alarm on a single beam system.

The appearance of even a relatively small amount of smoke in either, or both, of the beams will instantly unbalance the electrical receiving circuit and automatically register the appropriate alarm. Each of the beams can operate over a maximum distance of 40 ft. from the receiving unit. Since the two vertical cylinders on this unit can be rotated, the beams can be arranged at any angle to each other, e.g., the system could quite easily be arranged to cover a right angle corridor. The receiving unit would be situated at the turn of the corridor with the beams projecting at right angles to each other.

The equipment itself is extremely robust in construction and requires only the current taken by an ordinary 60-watt lamp to maintain in service. It can also be independently and automatically maintained by auxiliary battery service if this added precaution is desired.

Since this differential system is inherently stable, it can be set to an extreme degree of sensitivity when conditions render this necessary yet the adjustment can be altered if desired.

NATIONAL VAPOUR DETECTOR

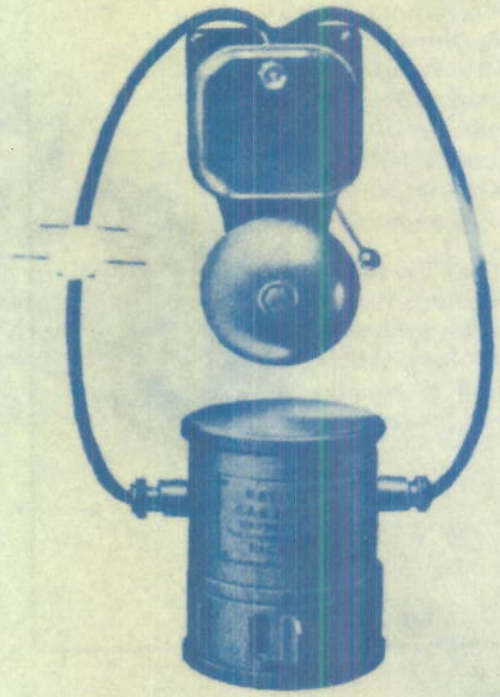
While suitable fire extinguishing apparatus will deal effectively with any fire once an outbreak occurs, it is obviously preferable to prevent the fire in the first instance. Moreover, while such a fire may be extinguished, an explosion will have done its damage before remedial action can be taken.

National Vapour Detectors can be employed to detect the presence of almost all the common gases, and they are particularly suited to the detection of inflammable gases in low concentrations, well below the lower limits of explosive mixtures.

Where the gas to be detected is appreciably heavier than air, the simple **National** Detector Type A can be employed, whose action depends upon the principle that a heavy gas will diffuse more slowly through a membrane than a lighter gas. This type is particularly suited to the detection of petrol vapour, and most hydro-carbon gases (e.g., Butane—Calor gas). It is interesting to note that a cupful of petrol has about the same explosive force as 5 lbs. of dynamite.

Where the gas under consideration is lighter than air and is also inflammable (e.g., Hydrogen) **National** Detector Type B is required. This incorporates a constantly heated palladium wire (4½ watts loading) inside an enclosing membrane.

In both types A and B a partial vacuum is produced and this will make an electric contact by means of a special contracting chamber, thus completing a circuit to a signalling device. Type A is illustrated below.



National Detector unit Type A	Weight Diam. Height Code	4 lbs. 3 ins. 4 ins. ND10
National Detector unit Type B	Weight Diam. Height Code	11 lbs. 5 ins. 8 ins. ND20
Magnet iron-clad weatherproof Bell	Gong diam. Weight Resist. Code	4 ins. 5 lbs. 4 ohms. ND30
Magnet gas tight and flame proof Bell	Gong diam. Weight Resist. Code	6 ins. 6 lbs. 12 ohms. ND40

Prices on application.

ESSEX CUTS PRODUCTION LOSSES

"THE majority of our little fires are put out in a few seconds, but I am sorry to say that we had rather a serious fire in March last, in fact, the worst fire we have had for the past twenty years. The paper we were using on our machine was very dry and gave a static electrical spark across the printing cylinder. This spark ignited the spirit in the ink and No. 1 unit caught fire. The machine was running at a very high speed, the paper travelling from the first unit caught the second unit alight, from the third unit to the fourth, all ablaze in one second. The Fire extinguishers were brought to play on this and in putting this out we used 7 large Fire Extinguishers and 24 medium, and the fire in the four ink ducts was out in just under 2½ minutes.

"Now the weaver in which this fire took place was full of Methyl Bromide fumes and in this weaver there are 80 men and over 200 girls working. After receiving your letter I looked through our Wage cards and I find that not a single person was away from business during the following four weeks. Further, I have not heard one single complaint from any person working in this Weaver, and in the rush and bustle of putting the fire out, many of the fellows who were using the Fire Extinguishers were covered with Methyl Bromide, face, hands, neck and all over them, owing to the fact that some of the men were at the top of the machine, others underneath, and all round, with one ambition to put the fire out. This clearly proved to me that Methyl Bromide fumes do not have any effect on workpeople, or shall I say, did not have any effect on any of our employees.

"I should not hesitate one moment in recommending the use of your extinguisher to any one of my friends who use the same class of spirit in their printing process, and I, personally, would not hesitate in using two or three times the amount of Methyl Bromide to put a fire out if the occasion arose."

Large Printing Works.

ESSEX
METHYL BROMIDE REFILLS

Refill	Finish	Code No.	Nett Contents	Total weight	Length
				ozs.	ins.
No. 1 Sealed and charged container	Red	10R			8½
	Copper	11R	10 oz.	30	8½
	Chromium	12R			8½
Refilling No. 1 container					
No. 2 Sealed and charged container, with handle	Red	20R			10
	Copper	21R	20 oz.	48	10
	Chromium	22R			10
No. 2 Sealed and charged container with handle (old type)	Red Steel	23R	20 oz.	52	10
Refilling No. 2 container					
No. 3 Sealed and charged container, with handle	Red	30R			11½
	Copper	31R	32 oz.	63	11½
	Chromium	32R			11½
Refilling No. 3 container					
No. 3 S.L.V. charged container no handle	Red	35R			11½
	Chromium	36R	32 oz.	66	11½
Refilling No. 3 S.L.V. container					
				lbs.	
No. 4 Sealed and charged container with handle	Red	40R			11½
	Copper	41R			11½
	Chromium	42R	64 oz.	6-14	11½
Refilling No. 4 container					11½
No. 4 S.L.V. charged container no handle	Red	45R			11½
	Chromium	46R	64 oz.	7	11½
Refilling No. 4 S.L.V. container					
Refilling No. 5 S.D.V. extinguisher	Red	50R		26	29
No. 5 Remote Control or automatic sealed and charged container	Red	51R	8 lbs.	18½	22½
	Chromium	53R			22½
Refilling No. 5 Remote control or automatic extinguisher					
Refilling No. 6 S.D.V. extinguisher	Red	61R		67	43½
No. 6 Remote Control or automatic sealed and charged container	Red	63R	24 lbs.	52	28½
	Chromium	65R	24 lbs.	52	28½
Refilling No. 6 Remote control or automatic extinguisher					

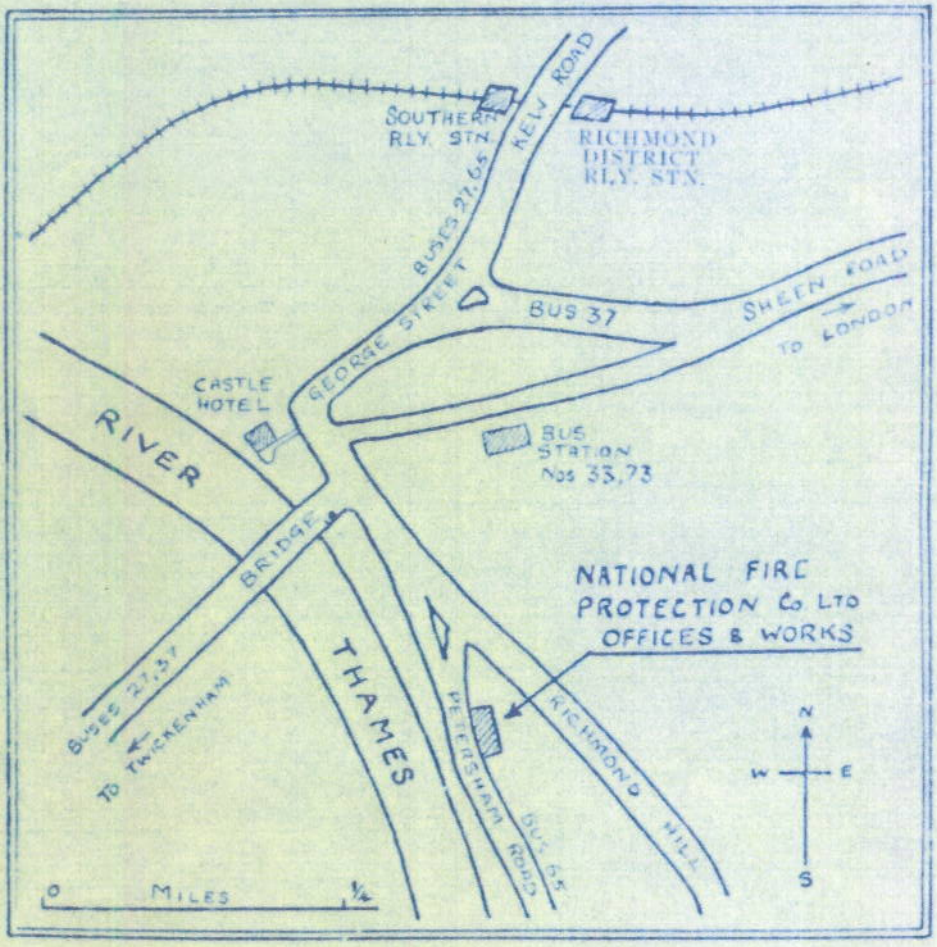
Prices on application.

ESSEX
METHYL BROMIDE REFILLS

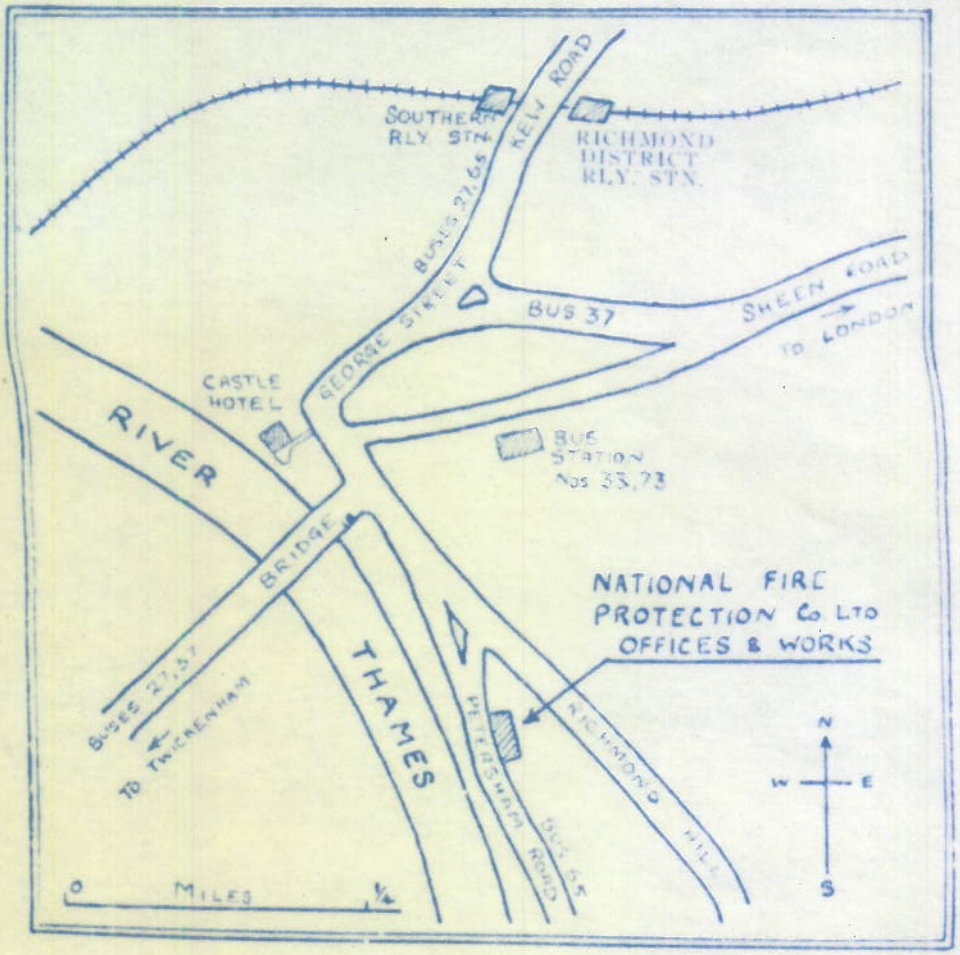
Refill	Finish	Code No.	Nett Contents	Total weight	Length
				ozs.	ins.
No. 1 Sealed and charged container	Red	10R			8½
	Copper	11R	10 oz.	30	8½
	Chromium	12R			8½
Refilling No. 1 container					
No. 2 Sealed and charged container, with handle	Red	20R			10
	Copper	21R	20 oz.	48	10
	Chromium	22R			10
No. 2 Sealed and charged container with handle (old type)	Red Steel	23R	20 oz.	52	10
Refilling No. 2 container					
No. 3 Sealed and charged container, with handle	Red	30R			11½
	Copper	31R	32 oz.	63	11½
	Chromium	32R			11½
Refilling No. 3 container					
No. 3 S.L.V. charged container no handle	Red	35R			11½
	Chromium	36R	32 oz.	66	11½
Refilling No. 3 S.L.V. container					
				lbs.	
No. 4 Sealed and charged container with handle	Red	40R			11½
	Copper	41R			11½
	Chromium	42R	64 oz.	6-14	11½
Refilling No. 4 container					
No. 4 S.L.V. charged container no handle	Red	45R			11½
	Chromium	46R	64 oz.	7	11½
Refilling No. 4 S.L.V. container					
Refilling No. 5 S.D.V. extinguisher	Red	50R		26	29
No. 5 Remote Control or automatic sealed and charged container	Red	51R	8 lbs.	18½	22½
	Chromium	53R			22½
Refilling No. 5 Remote control or automatic extinguisher					
Refilling No. 6 S.D.V. extinguisher	Red	61R		67	43½
No. 6 Remote Control or automatic sealed and charged container	Red	63R	24 lbs.	52	28½
	Chromium	65R	24 lbs.	52	28½
Refilling No. 6 Remote control or automatic extinguisher					

Prices on application.

HOW TO FIND US



HOW TO FIND US



Comparative Safety

The
National Fire Protection Company Ltd
RICHMOND · SURREY
TELEPHONE: RICHMOND 2342
TELEGRAMS: FIREGUARD, RICHMONDSY

Comparative Safety

The National Fire Protection Company Ltd
RICHMOND · SURREY
TELEPHONE: RICHMOND 2342
TELEGRAMS: FIREGUARD, RICHMONDSY

COMPARATIVE SAFETY

The Truth about the Requisite Concentration and the Comparative Toxicity of Fire Extinguishing Gases.

Before considering the important question of Comparative Toxicity of fire Extinguishing media, it is necessary to establish what degrees of concentration are needed in practice.

METHYL BROMIDE.

Typical of a large number of independently attested experiments to determine the amount of Methyl Bromide vapour necessary to procure extinction by the concentration method (*i.e.*, by flooding a compartment with the gas) are the following :—

1. A room of 896 cu. ft. having observation windows, and in size 8′ × 12′ × 9′ 4″ high, had been prepared and fitted up with an internal ring main pipe system carrying six $\frac{1}{8}$″ diameter discharge heads. Placed centrally upon the floor was a tray 18″ × 12″, containing a quart of petrol, and 18″ above this was a heat sensitive metallic fusible link connected to the automatically operated No. 6 ESSEX Methyl Bromide extinguisher. In order to determine the amount of Methyl Bromide actually necessary a hand control valve was fitted additionally, and this was shut off when the fire was seen to be out.
   The weight of Methyl Bromide employed was found to be 9 lbs. 6 ozs. which, on the basis of 3·7 cu. ft. of gas per lb. of Methyl Bromide, gave a concentration of 3·9%.
2. To establish more accurately the concentration of Methyl Bromide required under given conditions, a steel box measuring 2′ × 2′ × 2′ was prepared and fitted with glass inspection windows, hermetically sealed. An electric fan was incorporated internally to secure adequate mixing. Two very small flames from wicks had been provided 2″ and 18″ above the floor. Methyl Bromide was then run in by means of a burette fitted at the top, and so arranged that the liquid could drop on to a tray 2″ below and inside the box, enabling quick volatilisation.
   13·7 c.c. and 13·8 c.c. of Methyl Bromide were required to extinguish the bottom and top flames respectively, which, on the basis that 1 c.c. of liquid Methyl Bromide generates 399·4 c.c. of gas, gives concentrations of 2·42% and 2·43%.

PRINTED IN ENGLAND
Imprimé en Angleterre

3. At this point a previously prepared internal electric heater was switched on and oil dripped on to the red-hot surface. Flames naturally resulted, and Methyl Bromide was run in from the same burette to extinguish them, giving a total volume of liquid Methyl Bromide inserted of 15·8 c.c., or a concentration of 2·8%.

4. Test No. 3 was repeated as a check upon results. Successive quantities as under were run in through the burette until the oil dropping upon the heater should cease to flame.

Results :

6 c.c. or 1·06%	...	...	still burning
12 c.c. or 2·12%	...	...	,, ,,
15 c.c. or 2·65%	...	...	,, ,,
18 c.c. or 3·18%	...	...	no flames

Methyl Bromide vapour is 3·27 times heavier than air and has a diffusion co-efficient of only 0·097 grams. per square cm. per sec. into air. It is ejected from its containing cylinders at a low pressure in liquid form, and a relatively large number of nozzles can be used to ensure either even distribution or alternatively (by judicious positioning of the jets) to secure heavy concentrations in a particular area. To ensure the adequate protection of a hazard in a virtually unventilated area, it has become general practice to design installations to obtain a 5% concentration, the addition of which to the atmosphere does not necessitate any marked escape of air from the compartment concerned. In practice it has been found that this percentage effectively prevents re-ignition of oils, etc., even in the presence of carbonaceous material which may continue to glow for a period before exhausting its retained oxygen.

Where more than nominal ventilation is present, either asbestos curtains or shutters are provided, or the percentage of gas is increased to provide a greater margin of safety.

COMPARATIVE SAFETY

CARBON DIOXIDE.

It has become the established practice of reputable companies advocating the use of CO_2 to supply protective equipment capable of producing a 50% concentration of the gas in nominally unventilated spaces. This is confirmed by Mr. G. Lambert, of the Walter Kidde Co., Ltd. [in association with Messrs. John Kerr & Co.], in a paper given before the Professional Fire Brigades Association at their 1936 (Edinburgh) Conference (page 5).

The wisdom of using this high percentage is borne out by the following test, conducted at the same time as those referred to in the case of Methyl Bromide, from which it will be seen that the character of the fire greatly affects the percentage necessary to secure certain extinction.

A test identical with Test No. 3—Methyl Bromide—was repeated with CO_2, and oil again dripped on to the red-hot heater. After a period, as the flames continued, the cylinder was reweighed, showing that a total of six ounces had been used, or 36%. It was then replaced to continue increasing the concentration until the flames ceased. The rate of insertion was increased and when it was certain that the flames had been extinguished, the cylinder was again weighed, showing a total consumption of eleven ounces, or a concentration of 66%.

From these authentic tests, witnessed by several prominent electrical engineers and Government scientific officers, after taking into consideration the lighter weight of CO_2 (1·5 times heavier than air), its higher coefficient of diffusion (0·142)* and the smaller number of nozzles used, ***it can fairly be concluded that 50% of Carbon Dioxide gives at least no greater factor of safety than 5% of Methyl Bromide.***

American practice, based on considerably more experience with the use of CO_2 than is available in England, is epitomised in the American standard handbook of Fire Protection (Crosby, Fiske & Forster) published under the auspices of N.F.P.A., Boston, Mass., *in which the following rules are given :—*

" the supply of gas required for total flooding systems should be in accordance with the following table :—

16 cu. ft. per lb. of gas, up to 1,600 cu. ft. space protected (*i.e.*, 50% concentration).

* See Appendix 1.

18 cu. ft. per lb. of gas, up to 4,500 cu. ft. space protected (*i.e.*, 44·5% concentration).

20 cu. ft. per lb. of gas, up to 5,000 cu. ft. space protected (*i.e.*, 40% concentration).

22 cu. ft. per lb. of gas, over 5,000 cu. ft. space protected (*i.e.*, 37·7% concentration).

. . . The gas supply (for local application) should be not less than 1 lb. of gas for each 0·7 square foot of liquid surface, and not less than 1 lb. for each square foot of draining boards and other surfaces that may be covered with flammable liquids."

" Where there is a reasonably tight enclosure, the protection of rotary electrical machinery calls for 1 lb. of gas for each 10 cu. ft. of space up to 2,000 cu. ft. and 1 lb. of gas for each 12 cu. ft., and larger spaces. . . . "

" The reduction of the Oxygen content of the air, normally 21%, necessary to prevent fires and explosions, varied with different materials being handled. . . . Table 856 shows the maximum permissible concentration of Oxygen where the inert gas used is carbon dioxide."

Extract from Table 856 :—

" Acetone, maximum permissible Oxygen, ... 15%"
(*i.e.*, an addition of 28·6% of CO_2 to air, plus necessary factor of safety).

" Ethyl Alcohol, maximum permissible Oxygen, ... 15%"
(*i.e.*, an addition of 28·6% of CO_2 to air plus necessary factor of safety).

" Gasolene Vapour, maximum permissible Oxygen, . . . 15%"
(*i.e.*, an addition of 28·6% of CO_2 to air, plus necessary factor of safety).

" Cotton in bulk, to prevent smouldering and re-ignition maximum permissible Oxygen, ... 8%"
(*i.e.*, an addition of 65% of CO_2 to air, plus necessary factor of safety. This would, of course, apply to smouldering insulation, etc.).

In conclusion, it should be emphasised that ***standard practice arises from actual experience*** and that where the safety of life or equipment is concerned, it is folly to procure some slight financial saving at the detriment of the efficiency of the installation purchased.

Relative Toxicity

The "Essex" extinguisher owes its efficiency largely to the choice of Methyl Bromide for the active medium. This efficiency is so great that proof is frequently required before its results can be appreciated, but details of its performance and use may be found in the informative booklet "Industrial Safety". Certain erroneous ideas are prevalent as to the toxic nature of Methyl Bromide in relation to other available fire extinguishing media. It is the subject of this treatise to deal with this question.

Methyl Bromide must be considered as a toxic gas, since inhaled in a concentration and for a time (the product of which is above a certain figure), it is capable of causing death.

Its toxic effects when used under fire fighting conditions have, however, been grossly exaggerated for commercial purposes. In order to bring out the true facts, the following data have been compiled.

For convenience the discussion has been divided into four main sections as under :—

1. The Toxicity of Methyl Bromide. . . . . page 6
2. The Toxic Gases produced by Fire. . . . . page 18
3. The Toxicity of Commercial substances. . . . page 18
4. The Study of the Comparative Practical Toxicity of Fire Extinguishing Media. . . . . page 19

Tabular matter relating to these sections is set out in separate appendices :—

1. Physical data of Fire Extinguishing Gases.
2. Observed Toxicity of Methyl Bromide.
3. Tables, Clinical Research Report.
4. Products of Decomposition from Combustion.
5. Observed Toxicity of various Industrial Chemicals.
6. Observed Toxicity of Carbon Tetrachloride.
7. Calculated Decomposition Products.
8. Observed Toxicity of Carbon Dioxide.
9. Observed Toxicity of Decomposition Products.
10. Bibliography.

SECTION 1.

The Toxicity of Methyl Bromide

Definition.

A toxic substance has been defined as one " which taken into the system, acts in a noxious manner by a means not mechanical, tending to cause death or serious injury ".

In order to avoid ambiguity regarding terminology, the term " Toxic Gas " is herein intended to include all gases which, because of their poisonous or other properties, may cause death or other harm to man if exposed to a concentration of the gas for an appreciable time, while the term " Toxic Factor " is the mean observed percentage at which fatal results have occurred.

Variation of Pathological Reaction.

The pathological reaction of man to various gases varies considerably. For instance, in the case of Methyl Bromide, the reaction is delayed, whereas with some other gases, such as Carbon Dioxide, insensibility is produced before a lethal amount is inhaled. (See also the section " Methyl Bromide and Carbon Dioxide " page 21).

The practical result of this is that whereas a man caught in a discharge of Methyl Bromide may readily escape, in the opposing case he may be prevented from so doing by the quick action of the gas and his inability to see clearly through the resultant cloud.

Observed Toxicity of Methyl Bromide.

Various experiments have been conducted on small mammals to ascertain the toxicity of Methyl Bromide, and the reported results are given in Appendix 2.

In the opinion of Mr. J. H. Gaddum, M.A., M.R.C.A., L.R.C.P., Professor of Pharmacology, University College of London, after investigating many results, the toxic effect of Methyl Bromide is proportional to the product of the concentration of Methyl Bromide and the time of exposure. In order to compare the results with one another, the concentrations marked " * " in the Appendix have all been multiplied by the time of exposure in hours to give the concentrations which would produce equivalent effects with one hour's exposure. Both Sayers *et al.*, and Clark, 1933, concur that this method would give approximately correct results.

COMPARATIVE SAFETY

Reference can also be made to the confidential report of the Civil Airworthiness Committee (No. 153) in this connection.

The mean toxic factor for one hour's exposure (*i.e.*, ignoring results shown untimed and taking the more disadvantageous figures where a period is indicated) is therefore 0·62%.

Toxicity to Man.

It is clearly impossible to know accurately what concentration of Methyl Bromide would result in a man's death if he was exposed to it for an hour, but it would be reasonable to assume that this concentration would be between 0·4% and 0·8%.

Toxicity under Fire Extinguishing Conditions.

In examining the possible danger incurred by the use of a medium for Fire Extinguishing purposes, it is obviously necessary to consider fully the practical conditions under which such a medium is used, while it is also helpful to compare similar aspects of alternative media.

In the absence of undue ventilation, "Essex$_1$" Methyl Bromide fire extinguishing installations are designed to produce an even concentration of 5% in the protected section, as compared with a concentration of the order of 0·1% of Methyl Bromide to which the user of hand-directed appliances is likely to be subjected.

At the former concentration, therefore, it would appear that no untoward results are likely if personnel are exposed to this concentration for a time not in excess of, say, three or four minutes, which should be ample time to escape from the affected area.

The following secondary points should, however, be borne in mind :—

1. "Concentration" installations are almost invariably installed only in such situations as are normally unattended.
2. Safety gear is available, designed to prevent operation while men are working in the area.
3. The weight of the gas is such as to make it tend to sink rapidly to the floor, and so reduce the concentration at head level.
4. Gas detectors are available which would form a satisfactory safeguard against entry when a harmful concentration of gas is present.
5. Each "Essex" cylinder is clearly marked emphasising the necessity of ventilating the space after it has been discharged.

TOXIC TESTS

Fatalities due to Methyl Bromide.

There are, as far as can be ascertained, twelve reported cases of death in the literature of the present century, alleged to be due to Methyl Bromide fumes, the most recent being three cases in Germany and Switzerland (1917), those reported by Rohrer (1920), Loffler and Rutimeyer (1920), Goldschmidt and Kuhn (1920), and a fatality at Portsmouth (1937).

With the exception of the last-mentioned case, none were due to the use of the chemical in fire extinguishing. For example, that of Goldschmidt and Kuhn was due to the bursting of a large copper cylinder containing 78 Kg. of the liquid, the deceased having continued to work in the fumes for a protracted period, while in other cases doubts have been expressed as to the real cause of death.

The Portsmouth case is on a different plane and in view of its interest, a transcript of a report from a paper by Ingman Price (1937) is given below :—

> " A small compartment measuring approximately 40 cu. ft., was protected by an extinguisher containing 8 lbs. of Methyl Bromide. (Incidentally, this was grossly over-protected, but that is beside the point.) In this compartment there were three engines. At the time of the occurrence the hatchway in the roof of the engine compartment was open to the saloon, making a combined volume of 500 cu. ft. What ventilation there was, was secured by a comparatively small opening at one end of the compartment.
>
> " A slight fire occurred in the centre engine and the extinguisher was discharged. It should here be noted that the highest concentration advised by the makers in the most dangerous shore risks is never greater than 5% (in fully enclosed spaces). Allowing for a perfect mixture (which, owing to the weight of the gas, is unlikely), the concentration in the combined compartments was in the neighbourhood of 6% (74% if only the smaller compartment is considered).
>
> " It is almost unbelievable that in that atmosphere a man worked for two hours, but such was the case, and, as a result, he died. His companion worked for the first half hour, went away, and returned, working a total of one and a half hours, and he, too, was taken to hospital, but recovered without ill-effects the next day. This was an exceptional exposure and it is not to be wondered at that fatal results followed."
>
> *Note.*—1 lb. of Methyl Bromide produces 3·7 cu. ft. of gas at N.T.P.

COMPARATIVE SAFETY

Practical Experience with Methyl Bromide as a Fire Extinguishing Medium.

Henning, 1933, exposed himself and two other people to Methyl Bromide in a room of 600 cu. ft. with the doors closed. They poured half a gallon of Methyl Bromide on the floor and stayed for 20 minutes in the room without harm. If the vapours had been evenly distributed, the concentration would have been over 5%, but the vapour has, under normal conditions, a natural tendency to remain near the floor. Henning has been responsible for the manufacture of large quantities of Methyl Bromide for many years, and has had no accidents. He believes that the fatal accidents which have occurred were due to impurities.

CLINICAL RESEARCH ASSOCIATION.—Laboratory Report No. 45623, 1935.

Purpose of the Tests.—With the object of ascertaining if there were any immediate or remote toxic effects from the chemicals used by The National Fire Protection Company, Ltd., in their "Essex" Fire Extinguishers, various tests were carried out in the Laboratories of the Clinical Research Association.

Critical examinations were also performed with a view to demonstrating that the chemicals had no deleterious effects on fabrics and metals in order to show that such articles would not be damaged if accidentally sprayed during a fire.

Varieties of "Essex" Extinguishers employed for Test.—No. 1 cylinder contained 10 ounces of liquid Methyl Bromide with nitrogen gas to produce the requisite pressure for spraying.

No. 2 cylinder contained 8 ounces of liquid Methyl Bromide and 2 ounces of Pentachlorethane. This cylinder was also gassed with nitrogen gas.

Concentration of Vapour produced for the Test.—A small room of 900 cu. ft. capacity furnished with windows and two doors, but with no fireplace or ventilator, was selected for the purpose of these experiments.

In a room such as this, with doors and windows closed, the amount of ventilation is practically negligible and a concentration of approximately 1 part of Methyl Bromide per 381 parts of air would be produced after liberating the contents of No. 1 cylinder.

COMPARATIVE SAFETY

Practical Experience with Methyl Bromide as a Fire Extinguishing Medium.

Henning, 1933, exposed himself and two other people to Methyl Bromide in a room of 600 cu. ft. with the doors closed. They poured half a gallon of Methyl Bromide on the floor and stayed for 20 minutes in the room without harm. If the vapours had been evenly distributed, the concentration would have been over 5%, but the vapour has, under normal conditions, a natural tendency to remain near the floor. Henning has been responsible for the manufacture of large quantities of Methyl Bromide for many years, and has had no accidents. He believes that the fatal accidents which have occurred were due to impurities.

CLINICAL RESEARCH ASSOCIATION.—Laboratory Report No. 45623, 1935.

Purpose of the Tests.—With the object of ascertaining if there were any immediate or remote toxic effects from the chemicals used by The National Fire Protection Company, Ltd., in their "Essex" Fire Extinguishers, various tests were carried out in the Laboratories of the Clinical Research Association.

Critical examinations were also performed with a view to demonstrating that the chemicals had no deleterious effects on fabrics and metals in order to show that such articles would not be damaged if accidentally sprayed during a fire.

Varieties of "Essex" Extinguishers employed for Test.—No. 1 cylinder contained 10 ounces of liquid Methyl Bromide with nitrogen gas to produce the requisite pressure for spraying.

No. 2 cylinder contained 8 ounces of liquid Methyl Bromide and 2 ounces of Pentachlorethane. This cylinder was also gassed with nitrogen gas.

Concentration of Vapour produced for the Test.—A small room of 900 cu. ft. capacity furnished with windows and two doors, but with no fireplace or ventilator, was selected for the purpose of these experiments.

In a room such as this, with doors and windows closed, the amount of ventilation is practically negligible and a concentration of approximately 1 part of Methyl Bromide per 381 parts of air would be produced after liberating the contents of No. 1 cylinder.

TOXIC TESTS

After spraying the contents of No. 2 cylinder into a room of this size, a concentration of approximately 1 part of Methyl Bromide vapour in 476 of air, and 1 part of Pentachlorethane vapour in 4,058 of air would be produced.

Experiments to ascertain if there were any immediate Toxic Effects.—A mouse was placed in a cage at a height of about 4 ft. 6 in. from the floor so as to correspond approximately to the level of a man's head.

A fire was produced on an iron table in the centre of the room from cotton wool soaked with alcohol and commercial spirit. These materials were selected so as to produce a brightly burning and hot flame with a minimum amount of irritating smoke. If the latter had been present to any marked degree, this would have in itself produced an irritant and the effects of the chemical vapours could not have been properly ascertained.

Three members of the Association's staff were in the room at the time of the fire whilst it was being extinguished by No. 1 cylinder containing 10 ounces of Methyl Bromide, and for 5 minutes after. The fire was extinguished with amazing rapidity and as only a small quantity of Methyl Bromide was required to do this, the remainder of the contents of the cylinder was sprayed about the room in order to increase the concentration of the vapour.

The doors and windows of the room were kept shut during the experiment and for 30 minutes after. One door was opened once for a few seconds 5 minutes after the fire to permit exit of the three members of the staff. It was immediately closed again.

These persons suffered no ill-effect apart from very slight irritation of the conjunctiva.

The room was entered after 30 minutes and the slightly pungent odour of the Methyl Bromide was still present, but the mouse appeared to be quite fit.

The room was then thoroughly ventilated and the proceedings repeated, using No. 2 cylinder, which contained 8 ounces of liquid Methyl Bromide and 2 ounces of liquid Pentachlorethane.

The vapour appeared to have a slightly more pungent odour than the pure Methyl Bromide and was somewhat more irritating to the conjunctiva and bronchial mucous membrane, but these effects were not marked.

TOXIC TESTS

After spraying the contents of No. 2 cylinder into a room of this size, a concentration of approximately 1 part of Methyl Bromide vapour in 476 of air, and 1 part of Pentachlorethane vapour in 4,058 of air would be produced.

Experiments to ascertain if there were any immediate Toxic Effects.—A mouse was placed in a cage at a height of about 4 ft. 6 in. from the floor so as to correspond approximately to the level of a man's head.

A fire was produced on an iron table in the centre of the room from cotton wool soaked with alcohol and commercial spirit. These materials were selected so as to produce a brightly burning and hot flame with a minimum amount of irritating smoke. If the latter had been present to any marked degree, this would have in itself produced an irritant and the effects of the chemical vapours could not have been properly ascertained.

Three members of the Association's staff were in the room at the time of the fire whilst it was being extinguished by No. 1 cylinder containing 10 ounces of Methyl Bromide, and for 5 minutes after. The fire was extinguished with amazing rapidity and as only a small quantity of Methyl Bromide was required to do this, the remainder of the contents of the cylinder was sprayed about the room in order to increase the concentration of the vapour.

The doors and windows of the room were kept shut during the experiment and for 30 minutes after. One door was opened once for a few seconds 5 minutes after the fire to permit exit of the three members of the staff. It was immediately closed again.

These persons suffered no ill-effect apart from very slight irritation of the conjunctiva.

The room was entered after 30 minutes and the slightly pungent odour of the Methyl Bromide was still present, but the mouse appeared to be quite fit.

The room was then thoroughly ventilated and the proceedings repeated, using No. 2 cylinder, which contained 8 ounces of liquid Methyl Bromide and 2 ounces of liquid Pentachlorethane.

The vapour appeared to have a slightly more pungent odour than the pure Methyl Bromide and was somewhat more irritating to the conjunctiva and bronchial mucous membrane, but these effects were not marked.

COMPARATIVE SAFETY

The mouse, examined after 30 minutes, was slightly lethargic, but was otherwise quite fit and after a few minutes in fresh air was as lively as its fellow.

In connection with the above experiment, the fact that no doors or windows were opened after the fire was extinguished, renders the conditions of the test rather more stringent than would be the case normally, as undoubtedly the room would be ventilated at once in order to get rid of all smoke and fumes.

(*Note.*—All standard "Essex" Methyl Bromide Extinguishers now contain pure Methyl Bromide with the addition of a small quantity of Nitrogen gas.)

Experiments to ascertain Toxic Effects of a Remote Nature.—Two workers from the factory, "S. J. H." and "J. V. S.," were selected as suitable subjects for test, as they had been employed for 5½ years and 6½ years respectively in filling cylinders with these chemicals.

A blood count was performed on both these men in order to ascertain if there was any indication of aplastic anæmia or of monomucleosis. The former has been found to occur as a result of exposure to carbon monoxide, methane and mustard gas, whilst the latter occurs in tetrachlorethane poisoning (Minot and Smith, 1921).

Both "S. J. H." and "J. V. S." gave normal counts and showed no evidence of any anæmia or monomucleosis. (Reports appended.)

Spectroscopical examination of venous blood from both these men showed no methæmoglobin or sulphæmoglobin, or other abnormal hæmoglobin derivatives. (See Appendix 3.)

Effect on the Skin and Conjunctiva.—When sprayed on the skin a feeling of intense cold is produced similar to that experienced after spraying with ethyl chloride. After a few minutes the skin feels absolutely normal and no ill-effects are noted.

As there is a considerable defatting action, constant exposure would cause some irritation by removal of the protecting greasy substances on the surface of the skin, but doubtless this would clear rapidly on treatment with greasy substances.

As regards the conjunctiva, one of the Association's staff accidentally received some vapour direct on the conjunctiva whilst opening an ungassed cylinder. Beyond slight irritation and burning lasting about 10 minutes, there were no other ill-effects.

These findings show that if a person was accidentally sprayed during a fire no harm would result.

Effect on Fabrics and Metals.—As many substances employed as fire extinguishers produce great damage in the vicinity to fabrics and metals, in some cases more than the fire itself, it was decided to test the effect of the chemicals employed in the "Essex" Extinguishers on silk and cotton fabrics and on stainless and ordinary steel.

These substances were sprayed and immersed in the liquids and a microscopical examination of the silk and cotton fabrics showed no change whatever.

The steel and stainless steel, beyond being cleaned by the contact through removal of the grease on their surfaces, were unaffected and showed no evidence, on examination with a powerful lens, of pitting.

Signed :—D. M. LIVOCK,
Secretary, Clinical Research Association.

Other Independent Tests.

Extract from ("La Prevention du Feu," page 256, September, 1933).

Trials of Extinguishers on a Chassis.—The manufacturer fitted the aeroplane extinguisher (quantity of Methyl Bromide, 1·6 Kg.) on a chassis. The automatic hand control was connected by means of a "Bowden" cable to the percussion point. Two apparatus were placed over an earthenware basin of 1 m. square × 10 cm. deep : 5 litres of petrol and 6 litres of oil were poured into this tank. For a first trial the inflammable liquid, composed of 5 litres of petrol and 5 litres of oil poured into the tank, was fired. After waiting for 30 seconds to let the fire take on a certain importance, the hand control was worked : in about 2 seconds complete extinction was obtained. This time can be considered as the minimum time obtained up to now for an extinction of this importance.

Immediately after extinction, and while the Methyl Bromide gases still remained above the tank, a cage was placed into the tank containing two guinea-pigs, who remained until the gases were dissipated. Although they were absolutely in the midst of the gases, they did not appear to be inconvenienced.

The second test was then carried out in the same way, but adding to the combustibles a layer of rags of 5-6 cm. Extinction was obtained in the same way in about 2 seconds. As before, the animals were placed in the Methyl Bromide gases without any ill-effects on them.

TOXIC TESTS

These findings show that if a person was accidentally sprayed during a fire no harm would result.

Effect on Fabrics and Metals.—As many substances employed as fire extinguishers produce great damage in the vicinity to fabrics and metals, in some cases more than the fire itself, it was decided to test the effect of the chemicals employed in the "Essex" Extinguishers on silk and cotton fabrics and on stainless and ordinary steel.

These substances were sprayed and immersed in the liquids and a microscopical examination of the silk and cotton fabrics showed no change whatever.

The steel and stainless steel, beyond being cleaned by the contact through removal of the grease on their surfaces, were unaffected and showed no evidence, on examination with a powerful lens, of pitting.

Signed :—D. M. LIVOCK,
Secretary, Clinical Research Association.

Other Independent Tests.

Extract from ("La Prevention du Feu," page 256, September, 1933).

Trials of Extinguishers on a Chassis.—The manufacturer fitted the aeroplane extinguisher (quantity of Methyl Bromide, 1·6 Kg.) on a chassis. The automatic hand control was connected by means of a "Bowden" cable to the percussion point. Two apparatus were placed over an earthenware basin of 1 m. square × 10 cm. deep : 5 litres of petrol and 6 litres of oil were poured into this tank. For a first trial the inflammable liquid, composed of 5 litres of petrol and 5 litres of oil poured into the tank, was fired. After waiting for 30 seconds to let the fire take on a certain importance, the hand control was worked ; in about 2 seconds complete extinction was obtained. This time can be considered as the minimum time obtained up to now for an extinction of this importance.

Immediately after extinction, and while the Methyl Bromide gases still remained above the tank, a cage was placed into the tank containing two guinea-pigs, who remained until the gases were dissipated. Although they were absolutely in the midst of the gases, they did not appear to be inconvenienced.

The second test was then carried out in the same way, but adding to the combustibles a layer of rags of 5-6 cm. Extinction was obtained in the same way in about 2 seconds. As before, the animals were placed in the Methyl Bromide gases without any ill-effects on them.

COMPARATIVE SAFETY

1925 *Laboratory Test.*—A test was made to discover any signs of being affected with coughing, headache, anæsthetic symptoms, etc., in a small laboratory of dimensions 12 ft. by 10 ft. by 9 ft., with two men and two women present. For about a quarter of an hour Methyl Bromide was poured on to a lighted gas fire, which, of course, had to be repeatedly lighted. Whitish fumes arose and clung around the ceiling and down to within a foot of the ground. All doors and windows were shut, but no one felt any inconvenience and there were no after-effects. The experiment was carried out at about 2.30 p.m. after the mid-day meal.

1926 *Open-air Test.*—At an open-air test, where from 30 to 40 gallons of Methyl Bromide were projected on to burning petrol and afterwards, when full and partly emptied containers were collected for about half an hour, not one of the persons present noticed any inconvenience.—("Application of the Halogen Derivatives of the Hydrocarbons with particular Reference to Methyl Bromide," from the Journal of the Society of Chemical Industry, June 2nd, 1933.)

Report by Sir Leonard Hill, M.B., F.R.S.

"In order to investigate the physiological or toxic effect, if any, of Methyl Bromide as used in their "Essex" fire extinguishers, The National Fire Protection Company, Ltd., have enabled me to carry out tests on three of their employees, who extinguished fires lit in a small room of approximately 1,700 cu. ft. capacity.

The results of these tests were as follows :—

Test 1.—Doors and windows closed. Some petrol and wood wool in an iron tray were set alight. The flames blazed to the ceiling. The firm's largest hand extinguisher (No. 3), containing 40 ounces of a mixture containing 32 ounces of Methyl Bromide and 8 ounces of a special liquid, was played on to the fire and almost instantly put it out.

Very little of the contents of the extinguisher were required to do this. The rest of the contents were then sprayed about the walls and vapourised.

It was calculated that in a sealed room this would have given a concentration of 66 parts of Methyl Bromide vapour per 10,000 parts of air. As, however, ventilation naturally took place to a certain extent through chinks and crannies of doors and windows owing to the difference of temperature within and without the room,

the concentration was probably rather less than this, but much higher than would be the case in a similar sized room in which a fire occurred under ordinary circumstances.

An extinguisher containing only half the quantity would normally be used in a room of this size, and the door or window (or both) would in all probability be open. After putting out the fire and vapourising the whole of a large extinguisher, the men remained in the closed room for approximately another two minutes, and then came out without showing signs of ill-effect other than some watering of the eyes and coughing, provoked by the fumes of the fire. These symptoms quickly passed off.

Tests of physical efficiency, similar to those employed in the Royal Air Force, were carried out by me on these men both before and after the exposure. No significant difference was found.

Test 2.—Door closed, but two small windows left open. Two pounds of wood wool, with about a quart of petrol, were fired in the same room with the three men inside. The fire was so hot that the men had to turn their backs to it to prevent scorching of the face. This fire was put out with amazing quickness and ease by a spray from another No. 3 extinguisher. The fire was lit once more and again almost instantly put out. The rest of the contents, the larger part, were then sprayed about the room. The men were in the room from the starting of the fires until the completion of this test —approximately two minutes. This second exposure produced some coughing and watering of the eyes, due to the fumes of the fire, but no significant diminution in the physical fitness of the men was shown by the tests which I once more carried out.

Test 3.—In a room approximately 2,190 cu. ft. capacity, the contents of a No. 3 extinguisher were sprayed about the carpets and walls. The door was closed, but two small windows were partly open at the start, but were closed at the end of the spraying. The managing director, the three employees and myself remained inside this room for 15 minutes. The vapour had a sweetish taste and very slightly irritated the conjunctiva of the eye. The tests of physical efficiency applied by me to the other four before and after this exposure showed no significant alteration.

On the following day the three employees, who had thus exposed themselves three times over to the vapour in one morning,

reported fit and well. I myself suffered no ill-effect from the exposure for 15 minutes—a much longer time to an amount of vapour considerably in excess of that which would be required to put out a fire in an ordinary room.

Sir Thomas Legge (the distinguished expert of the Home Office, now retired) has stated that 20–40 parts per 10,000 is a safe concentration of Methyl Bromide vapour to breathe for 30–60 minutes. To exert a toxic effect, the vapour has to be absorbed and reach a certain concentration in the body and this is a slow process. The time it takes to put out a fire with an "Essex" extinguisher and clear out of the room, or throw open the windows and doors, is far shorter than the time required for the vapour to accumulate in the body and exert its toxic action.

From the results of these tests I am of the opinion that "Essex" fire extinguishers can be used in private houses, public buildings, cinemas, factories, etc., and of course in the open air, with perfect safety.

The company's extinguisher puts out a fire by its freezing action, as well as by cutting off the air supply and, owing to the small quantity of vapour required and the great rapidity and clear action, has very great advantages.

A No. 2 extinguisher, which contains only half the contents of the No. 3 used in the above tests, is recommended for ordinary houses, and I am having one of these put in my own home, so convinced am I of its efficiency and safety in use.

In tanks, tunnels, submarines, etc., where there is no natural ventilation, a fire quickly uses up the oxygen in the surrounding air and produces the highly poisonous gas, carbon monoxide. If an extinguisher is used in such a place, the user should escape at once from the proximity of the fire and reach a place where the air is still pure. The use of the company's extinguisher with an oxygen breathing apparatus, such as the Davis submarine escape dress, now carried in British submarines, would, in my opinion, afford a most efficient and safe means of dealing with the danger of fires in submarines.

(Signed) LEONARD HILL.

October 14*th*, 1931.

Letter from the Sun Engraving Co., Ltd., 1935.

" The majority of our little fires are put out in a few seconds, but I am sorry to say that we had rather a serious fire in March last—in fact, the worst fire we have had for the past 20 years. The paper we were using on our machine was very dry and gave a static electrical spark across the printing cylinder. This spark ignited the spirit in the ink and No. 1 unit caught fire. The machine was running at a very high speed and the paper travelling from the first unit caught the second unit alight, from the third unit to the fourth, all ablaze in one second. The fire extinguishers were brought to play on this and in putting this out we used seven large fire extinguishers and 24 medium, and the fire in the four ink ducts was out in just under 2½ minutes.

Now the weaver in which this fire took place was full of Methyl Bromide fumes, and in this weaver there are 80 men and over 200 girls working. After receiving your letter, I looked through our wage cards and I find that not a single person was away from business during the following four weeks. Further, I have not heard one single complaint from any person working in this weaver : and in the rush and bustle of putting the fire out, many of the fellows who were using the fire extinguishers were covered with Methyl Bromide—face, hands, neck and all over them—owing to the fact that some of the men were at the top of the machine, others underneath and all around, with one ambition to put the fire out. This clearly proved to me that Methyl Bromide fumes do not have any effect on workpeople, or, shall I say, did not have any effect on any of our employees.

I should not hesitate one moment in recommending the use of your extinguisher to any of my friends who use the same class of spirit in their printing presses, and I, personally, would not hesitate in using two or three times the amount of Methyl Bromide to put a fire out if the occasion arose."

Extract from Annual Report of the London County Council, 1937, Vol. III (Part I) Public Health.—Fire Extinguishers.

At the request of the Chief Officer, London Fire Brigade, an investigation was carried out as to the relative toxicity of the products from the use of fire extinguishers of the carbon dioxide, carbon

COMPARATIVE SAFETY

tetrachloride, and methyl bromide types. A " standard " fire was generated in a small room by the ignition of wood wool and high tension cable. The fire was then extinguished by the use of one of the extinguishers and samples of the atmosphere in the room at different levels collected at once, and after an interval, by aspiration through glass gas tubes. The contents of the tubes were then analysed to determine the proportion of various toxic gases present, such as carbon monoxide, carbon dioxide, chlorine, bromine, hydrochloric acid, hydrobromic acid, carbonyl chloride and carbonyl bromide. Taking into consideration the results of the analyses and information gained from a research into the available scientific literature on the toxicity of these substances, it was concluded that methyl bromide and carbon tetrachloride, under the conditions of test, can produce acid vapours of such a concentration as would be dangerous in an enclosed space unless a mask were worn. Although carbonyl chloride (phosgene) and carbonyl bromide were not found in appreciable quantity, the possibility of their formation under special circumstances must be borne in mind. In order to extinguish a fire with carbon dioxide, it appears that a concentration of this gas is required which must be regarded as a possible danger in a confined space, unless a mask is worn : the time required to extinguish a fire by this means is also longer than when using methyl bromide. The final opinion expressed was that there is no more risk involved in the use of methyl bromide and carbon tetrachloride extinguishers than when carbon dioxide alone is used. In each case it would be necessary to use a mask if the fire were in a confined space.

SECTION 2.

The Toxic Gases Produced by Fire

Ferguson and Scheflan, 1933, stated :—

" The gases from all types of fires investigated contain toxic constituents in sufficient amount to make breathing the gases dangerous, or even fatal, in a relatively short period. Gases from different materials differ greatly in toxicity. Substances containing nitrogen or sulphur, or both, produce the most toxic gases.

" Of the textiles used for clothing, draperies, etc., cotton and rayon produce the least toxic gases, whereas silk, and especially woollen materials, give off such deadly gases as hydrogen sulphide, hydrocyanic acid, sulphur dioxide, ammonia and carbon monoxide."

It is clearly dangerous to breathe the fumes produced by a fire even when no extinguishing medium has been used upon it.

The composition of gases accompanying smoke produced during the burning of various materials, is given by J. Ivon Graham, M.A., M.Sc., 1931 (see Appendix 4).

SECTION 3.

The Toxicity of Other Substances Used in Industry

In Appendix 5 is given a list of certain chemicals used in industry, the majority of those recorded being of higher toxicity than Methyl Bromide. In considering these, it should be remembered that these substances are in continuous use in manufacturing and other processes.

SECTION 4.

The Comparative Toxicity of Fire Extinguishing Media and their Decomposition Products

No investigation of the toxicity of a substance used for a specific purpose would be considered complete if that of available alternatives was not also studied, nor can the possible effects in practice be deduced if the products of decomposition are ignored.

The two main alternative gas type extinguishing media to Methyl Bromide are carbon tetrachloride and carbon dioxide, the basic toxicity figures of which are given in Appendices 6 and 8.

Methyl Bromide and Carbon Tetrachloride.

In order to establish for practical purposes the relative toxicity of two substances used for the extinguishing of fires, it would seem to be obvious that the relative fire extinguishing efficiency is the first point to be considered.

From the records of a large number of independently certified comparative tests, it can be shown that the proportion by liquid volume of carbon tetrachloride to Methyl Bromide required to extinguish a given fire, varies between ratios of 3 to 1 and 32 to 1. Both these figures are extremes and the practical average is closely in the neighbourhood of 8 parts of carbon tetrachloride equalling 1 part of Methyl Bromide liquid.

Decomposition Products.

The problem of demonstrating the relative harm to which a user may be exposed is somewhat complicated by the various products of decomposition which are always present when an extinguisher is used on a fire. The amount and character of the decomposition products present under laboratory conditions, when the medium is exposed to varying types of flames, have been carefully and exhaustively studied by Nuckolls, 1933 [for the National Board of Underwriters—Fire (U.S.A.), Miscellaneous Hazards No. 2375], who produced comprehensive data on the subject. The mean result of these experiments are shown in Appendix 7, Table I.

These figures are, as they stand, inconvenient for deducing relative toxicity, not only because of the varying percentages of material involved, but also as no correction has been made for the differences in quantity required for extinguishing purposes.

DECOMPOSITION PRODUCTS

From the results of the comparative tests mentioned above, the mean relative fire extinguishing values of the two liquids may be taken to be as 8 is to 1 by volume. The specific gravity of carbon tetrachloride is 1·6326 and that of Methyl Bromide 1·732, and 1 lb. of carbon tetrachloride will produce 2·3 cu. ft. of gas while a similar weight of Methyl Bromide will produce 3·7 cu. ft. of gas. The comparative amount of gas produced by eight volumes of liquid carbon tretrachloride is therefore 4·685 times that produced by one volume of liquid Methyl Bromide. $\frac{8 \times 1{\cdot}6326 \times 2{\cdot}3}{1{\cdot}732 \times 3{\cdot}7} = 4{\cdot}685$

Restating this, one may fairly say that when fire fighting by the impingement method, 1% of Methyl Bromide vapour is equivalent to 4·685% of carbon tetrachloride vapour.

Adjusting to these proportions, therefore, the figures in Table II, Appendix 7, may be calculated from the observed results.

In the average type of fire some of the characteristics of each of the experimental conditions are present and it is, therefore, suggested that if a mean figure for the total decomposition products is taken, as under, this will represent a fair estimate of the comparative amounts produced in practice, *i.e.* :—

	%
Carbon Tetrachloride—	
Mean Hydrochloric Acid (HCl)	2·831
Mean Carbonyl Chloride (Phosgene $COCl_2$) ...	0·0501
Mean Free Chlorine (Cl_2)	0·0357
Methyl Bromide—	%
Mean Hydrobromic Acid (HBr)	0·0825
Mean Carbonyl Bromide (Bromophosgene $COBr_3$)	0·0028
Mean Free Bromine (Br_2)	0·0067

From the observed toxic factors (see Appendices) can be calculated a " toxicity factor " which, while not necessarily being an exact measure of the actual toxicity of the complex mixture of gases resulting from the use of the medium concerned, will nevertheless be a sufficiently accurate indication of the comparative harmfulness likely to result from its use. (See Table III, Appendix 7.)

From these results it will be seen that under fire extinguishing conditions, carbon tetrachloride has a total index of 40·05, whereas

COMPARATIVE SAFETY

Methyl Bromide has a total index of only 3·18, ***and it may therefore fairly be deduced that the latter medium is approximately one-twelfth as dangerous to use.***

In considering this deduction, moreover, it should be remembered that Methyl Bromide is some four times as rapid in extinguishing than Carbon Tetrachloride, and that the user, therefore, is not exposed for an equal time to the action of the gases.[1]

Methyl Bromide cannot decompose directly into carbonyl bromide, the equivalent of phosgene in the bromine series, nor is it greatly affected by catalytic action, or the "Wall reaction", which so strongly affects carbon tetrachloride.

Methyl Bromide and Carbon Dioxide.

The comparative study of the toxicity[2] of Methyl Bromide and Carbon Dioxide is not so well documented as the previous case, but the fact that the reports of the Medical Officers of Health for the Home Office report 27 fatalities between 1913 and 1933 from exposure to the effects of the latter gas may be considered significant, although, as in the majority of cases of Methyl Bromide referred to in "Fatalities with Methyl Bromide", (page 7 et seq) none of these appear to have been caused while the medium was being used for fire extinguishing purposes.

The relative quantities of the two gases necessary for extinguishing a fire by hand-directed methods have not been conclusively stated by independent sources, but it is now the generally accepted practice in the design of "concentration" installations under similar conditions to procure a concentration of 5% in the case of Methyl Bromide and 50% in that of CO_2.[3] The toxic factor of CO_2 has been variously given in accordance with Appendix 8.

Nuckolls (1933), in writing of the harmful effects of Carbon Dioxide, says :—

> "It is not an inert gas physiologically. In mild concentrations (3% to 5% by volume), it acts as a respiratory stimulant."

1. For additional studies of the decomposition products of carbon tetrachloride, see the full reports on the subject by Fieldney, Katz, Kinney and Longfellow, 1920, and Hamilton, 1933. Olsen, 1933, made a denial of the results to which little weight has been given. (Vide Gaddum.)

2. Toxicity, see definition under Part 1.

3. See Lambert, 1936, and generally accepted practice.

DECOMPOSITION PRODUCTS

" Carbon dioxide is odourless, but its physiological effects when breathed in mild or moderate concentrations serve in a measure as a warning of its presence. In concentrations, however, much above 10%, the physiological action may be too rapid in producing stupefaction or loss of consciousness to serve as adequate warning."

" Brown concludes from a study of the effects of comparatively high concentrations of carbon dioxide on man that none of the men could have withstood 10% carbon dioxide in air for longer than 10 minutes without losing consciousness."

Haldane, in " Principles of Respiration," states :—

" Physiological effects of carbon dioxide in high concentrations appear to be more or less independent of the effects of want of oxygen."

It is somewhat difficult from this data to draw a just conclusion, but accepting the mean toxic factor of Methyl Bromide for one hour at 0·62% and estimating that of CO_2 from the available figures to be 5%, ***the relative toxicity would be as 8 is to 10,*** bearing in mind the practical fire extinguishing concentrations.

This conclusion, however, omits two important considerations, the pathological response to the gases and the decomposition products. Carbon dioxide is a respiratory stimulant in its lower concentrations : at 3% for instance, the lung ventilation is increased by 300% (Graham, 1931), and it is reasonable to assume that this will have a definite effect on the rate of absorption of other harmful gases in the atmosphere, such as those from dissociation and the decomposition products of the fire itself. Under certain circumstances, carbon dioxide can be dissociated into its constituents of carbon monoxide and oxygen. This occurs in the presence of great heat and increases rapidly with that heat. The following figures are interesting :—

Temperature Absolute.	*Percentage Dissociation* CO_2.
1000° C.	0·000025
1500° C.	0·0483
2000° C.	2·05
2500° C.	17·6
3000° C.	34·8
3500° C.	83·2

COMPARATIVE SAFETY

These are, of course, laboratory figures, and varying conditions seem to affect the issue. For instance, a rapid stream of carbon dioxide through a porcelain tube heated to 1500° C. shows a dissociation of 0·2%. Carbon dioxide is also decomposed by electric sparks or brush discharge, and at 3 mm. to 5 mm. pressure, 65% is decomposed by the latter. In the case of Methyl Bromide, the extreme rapidity with which it extinguishes fire, coupled with the fact that the equivalent of phosgene, *i.e.*, carbonyl bromide, cannot exist under normal circumstances owing to its instability, leave virtually only the raw CH_3Br vapour and the possible presence of a small quantity of hydrobromic acid to act as toxines.

APPENDIX 1.

TECHNICAL DATA.

Property.	Methyl Bromide.	Carbon Tetrachloride.	Carbon Dioxide.
Structure	CH_3Br.	CCl_4.	CO_2.
Molecular weight (O = 16·0)	94·9	153·8	44·0
Specific Gravity (water = 1)	1·73	1·63	0·77
Vapour Density Air = 1·0 at N.T.P. ...	3·27	5·31	1·52
Boiling Point at 760 mm.	4·5° C.	76·7° C.	—78° C.
Melting Point	—93° C.	—30° C.	——
Specific Heat of Liquid at 0° C. Cals/gram.	0·12	0·185	0·20
Latent Heat of Vaporization Cal/gram. at B.P.	62	46	90
Vapour Pressure at 60° F. lbs. per square inch	20·0	1·75	810
Gas Generation cubic feet per lb. at N.T.P.	3·7	2·3	8·5
Inhibitory Factor % in dry air ...	3·0	15·0	29
Diffusion coefficient grms/cm²/sec/air	0·097	0·076	0·142
Percentage recommended for concentration method of extinction ...	5	25	50
Relative Toxicity at this strength ...	8	26	10
Normal Pressure in Cylinders lbs. per sq. in. at 60° F.	50/100	80	810
Comparative weights of Automatic installations	1	8	10

APPENDIX 2.

OBSERVED TOXICITY OF METHYL BROMIDE.

Authority.	*Date.*	*Subject.*	*Lethal Percentage Concentration by Volume.*	*Period— Actual or Calculated.*
Beyne and Goett ...	1934	Dog	0·14 to 0·19%	1 hour*
Beyne and Goett ...	1934	Rabbit	0·42%	1 hour*
Glazer and Frisch ...	1929	Mouse	0·38 to 1·3%	1 hour*
Glazer and Frisch ...	1929	Cat	0·75%	1 hour*
Legge	1930	—	2·0 to 4·0%	—
Nuckolls	1933	Guinea-pig	0·42 to 1·12%	1 hour*
Nuckolls	1933	,,	0·7 to 1·0%	½ hour
U.S. Health Service ...	—	,,	0·2 to 0·4%	1 hour
Sayers, *et al.*	1929	,,	0·2%	1· hour*
Sayer, Yant Thomas and Berger.	—	,,	0·18%	Somewhat contradictory evidence.

Methyl Bromide : Average observed lethal percentage—0·62%.

* Calculated from observed results.

APPENDIX 3.

REPORT OF BLOOD TEST—CLINICAL RESEARCH ASSOCIATION.

Specimen of Blood, September 25th, 1935.

LABORATORY REPORT NO. 46852.

Hæmoglobin	95%
Red Blood Corpuscles	5,000,000 per c.m.m.
White Blood Corpuscles	11,000 per c.m.m.
Colour Index	0·95

A differential count shows :—

Polymorphs	69%
Lymphocytes	24%
Eosinophiles	2%
Hyalines	5%
Basophiles	None seen.

Reds normal in type.

Mean diameter : 7·2 m.

Platelets occur in normal numbers.

LABORATORY REPORT NO. 46853.

Spectroscopical examination shows no met- or sulph-hæmoglobin.

Specimen of Blood, September 25th, 1935.

LABORATORY REPORT NO. 46854.

Hæmoglobin	100%
Red Blood Corpuscles	5,200,000 per c.m.m.
White Blood Corpuscles	8,000 per c.m.m.
Colour Index	0·96

A differential count shows :—

Neutrophiles	67%
Lymphocytes	28%
Eosinophiles	1%
Hyalines	4%
Basophiles	None seen.

Reds quite normal.

Platelets occur in normal numbers.

Mean diameter : 7·2 m.

LABORATORY REPORT NO. 46855.

Spectroscopical examination shows no met- or sulph-hæmoglobin.

(Signed) D. M. LIVOCK,

Secretary, Clinical Research Association.

APPENDIX 4.

PRODUCTS OF DECOMPOSITION FROM COMBUSTION.

J. Ivon Graham, M.A., M.Sc.

	CO_2%	CO%	O_2%
Wood Fire.—Air supply reduced. Samples taken just above flame	0·93	0·061	19·58
	1·36	0·071	19·18
	2·67	0·098	17·88
Cellulose, burning in enclosed space, flame just extinguished	3·09	Nil	17·93
22 secs. after flame extinguished, glowing just ceased	4·27	0·053	16·25
Repeat test, 26 secs. after flame extinguished, glowing just ceased	6·13	0·071	14·75
Jute, burning in enclosed space— Sample A, glowing	5·18	0·95	14·66
Sample B, just after glowing ceased	1·98	0·20	18·67
Sample C, burning in tube in an air current ...	1·02	0·45	19·68
Coal Fire, 7 ft. Banbury coal, freely burning, little smoke	1·47	0·026	18·71
Air supply cut off, flame out	2·50	0·637	17·24
11 minutes later	2·24	0·913	17·16
Warwickshire coal, 5 mins. after cutting off air supply	3·13	0·406	17·01
Cockshead coal, burning in small tube, thick yellow smoke	8·00	5·86	3·45
Benzol, burning in 12 in. tube closed at one end Thick black smoke just above flame	1·78	0·108	18·25
Petrol, burning in 12 in. tube closed at one end. Black smoke, flame stifled	3·69	0·136	15·52
Paraffin Oil, burning in 12 in. tube, closed at one end. 190 secs. after ignition in black smoke just above flame	2·21	0·129	17·46
Benzol Mixture, fire from 6 gallons, very black smoke	1·62	0·031	18·49
Fire from 4 gallons. Thick black smoke ...	1·06	0·022	19·44
Straw Fire, sprayed with water. Sample from just above flames— Thick, pungent smoke	0·79	0·010	19·85
Pungent fumes causing considerable lachrymation	0·09	0·0008	20·79

OBSERVED TOXICITY OF VARIOUS INDUSTRIAL CHEMICALS.

Substance.	*Observed Lethal Percentage. = Toxic Factor.*	*Authority.*
Acetone	4·6%	Flury.
Ammonia	0·5 to 1·0%	Legge.
	0·5 to 1·0%	Yandell, Henderson and Howard W. Haggard.
Aniline	0·042%	K. B. Lehmann.
Arsenious Chloride ...	1·9%	Bureau of Mines, U.S. Dept. of Interior. 1921.
Arsine	0·025%	Flury.
	0·025%	Legge.
Benzene	1·9%	Legge.
	1·9%	Bureau of Mines, U.S. Dept. of Interior. 1921.
Carbon Disulphide ...	0·48%	Flury.
Chloroform	2·5%	Legge.
Ethyl Chloride	15 to 30%	Bureau of Public Health Service, U.S. Treasury Dept.
Formaldehyde	0·65%	N. Iwanoff.
Hydrofluoric Acid Gas ...	0·002%	Legge.
Hydrogen Fluoride ...	0·066%	Flury.
Hydrocyanic Acid ...	0·03%	Legge.
	0·027%	Flury.
Hydrogen Sulphide ...	0·1 to 0·3%	Legge.
	0·42 to 0·06%	Flury.
Methanol	29%	Flury.
Methyl Chloride	15 to 30%	Legge.
	2 to 2·5%	Bureau of Public Health Service, U.S. Treasury Dept.
Methylene Chloride ...	5·1 to 5·3%	Rambousek.
Nitrogen Tetroxide ...	0·032 to 0·053%	Flury.
*Petrol	2·43%	Legge.
	0·68%	Flury.
Phosgene	0·2%	Legge.
Phosphine	0·04 to 0·06%	Flury.
Phosphorus Pentachloride	1·9%	Bureau of Mines, U.S. Dept. of Interior. 1921.
Phosphorus Trichloride ...	0·0652%	R. Kobert.
Sulphur Dioxide	0·04 to 0·05%	Legge.
	0·0535 to 0·0650%	Flury.
	0·2%	U.S. Chemical Warfare Service.
Toluene and Xylene ...	1·9%	Legge.
	1·9%	Bureau of Mines, U.S. Dept. of Interior. 1921.
Tetrachlorethane	0·73%	Legge.
Trichloroethylene	0·78%	Flury.
Turpentine	0·29%	K. B. Lehmann.

*The toxicity of petrol varies considerably in accordance with its constituents, the chief of which are Hexane and Heptane, but some petrols contain a large proportion of aromatic hydrocarbons, such as benzine, which are usually more toxic. Petrols loaded with lead compounds are excluded from the above.

According to various observers, the toxicity of Aliphatic Hydrocarbons, such as the constituents of petrol, increases with the molecular weight.

APPENDIX 6.

OBSERVED TOXICITY OF CARBON TETRACHLORIDE.

Authority.	*Date.*	*Subject.*	*Toxic Factor.*	*Period—Actual or Calculated.*
Flury	1928	—	1%	Rapidly fatal.
Flury and Zernik ...	1931	Guinea-pig	1·3%	1 hour.
Fuhner	1933	Mouse	1·5%	
Lazarew	1929	Mouse	1·5%	
Legge	1930	? Man	4·8%	1 hour.
Lehmann	1911	Cat	1·8%	
Muller	1925	Mouse	1·5%	
Nuckolls	1933	Guinea-pig	2 to 2·3%	1 hour.
Lehmann	1886		2·4 to 3·2%	½ to 1 hour.

Carbon Tetrachloride.—Average observed lethal percentage—2·25%.

APPENDIX 7.

MEAN OBSERVED DECOMPOSITION PRODUCTS OF CARBON TETRACHLORIDE AND METHYL BROMIDE.

TABLE I.

Exposed to ...	Gas Flame		Oil Fire		Wood Fire		Hot Iron	
Medium ...	CCl_4 %	CH_3Br %	CCl_4 %	CH_3Br %	CCl_4 %	CH_3Br %	CCl_4 %	CH_3Br %
Percentage tested ...	2·326	1·45	5·5	5·4	5·4	2·2	5·5	5·5
Mean Hydrochloric Acid etc.	0·23	—	2·83	—	8·86	—	0·88	—
Mean Carbonyl Chloride ...	0·0172	—	0·0035	—	0·084	—	0·1086	—
Mean Free Chlorine ...	0·041	—	Nil	—	0·013	—	0·058	—
Mean Hydrobromic Acid ...	—	0·007	—	0·15	—	0·34	—	0·63
Mean Carbonyl Bromide ...	—	Nil	—	Nil	—	0·023	—	0·005
Mean Free Bromine ...	—	0·0025	—	Nil	—	Nil	—	0·142

TABLE II.

Calculated Decomposition Products.

	Carbon Tetrachloride. 4·685 %			*Methyl Bromide.* 1 %		
Exposed to ...	HCl %	$COCl_2$ %	Cl_2 %	HBr %	$COBr_2$ %	Br_2 %
Gas Flame ...	0·464	0·0346	0·083	0·004	Nil	0·0017
Oil Fire	2·42	0·0029	Nil	0·027	Nil	Nil
Wood Fire ...	7·69	0·0729	0·011	0·154	0·1004	Nil
Hot Iron	0·75	0·0900	0·049	0·145	0·0309	0·025

TABLE III.

Gas.	*Calculated Percentage of Gas present (G)*	*Observed Toxic Factor (F).*	*G/F = Toxic Index.*
HCl	2·831	0·15	18·9
$COCl_2$	0·0501	0·0025	20·0
Cl_2	0·0357	0·1	0·36
CCl_4	1·772	2·25	0·79
(remainder unchanged).			
Total Toxic Index for CCl_4 ...			40·05
HBr	0·0825	0·15	0·55
$COBr_2$	0·0028	0·0025	1·12
Br_2	0·0067	0·1	0·06
CH_3Br	0·8985	0·62	1·45
Total Toxic Index for CH_3Br ...			3·18

APPENDIX 8.

OBSERVED TOXICITY OF CARBON DIOXIDE.

Authority.	*Date.*	*Subject.*	*Lethal Percentage Concentration by Volume.*	*Period—Actual or Calculated.*
Gaddum ...	1936	Man	3 to 4%	1 hour.
Flury & Zernik	1931	—	5 to 6·7%	Rapidly fatal.
Legge	1930	Man	8 to 10%	Rapidly fatal.
U.S. Navy Regulations.	1930	Man	7%	"Immediate measures necessary."

APPENDIX 9.

OBSERVED TOXICITY OF DECOMPOSITION PRODUCTS.

Substance.	*Observed Lethal Percentage. — Toxic Factor.*	*Authority.*
Bromine	0·55%	Flury.
Carbon Monoxide	0·4%	Legge.
	0·4%	Yandell, Henderson and Howard W. Haggard.
	0·2%	Gaddum.
Chlorine	0·004%	Sayers, Yant, Thomas and Berger.
	0·09%	Flury.
	0·005%	Gaddum.
Hydrochloric Acid Gas ...	0·01 to 0·02%	Legge.
	0·1%	Gaddum.
	0·125 to 0·175%	Flury.
Nitrous fumes	0·025 to 0·075%	Legge.
Phosgene	0·0025%	Legge.

Tobacco smoke is said to contain 0·5% of CO. The exhaust gases of cars from 3·5%, and illuminating gas from 4% to 30%.

APPENDIX 10.

BIBLIOGRAPHY.

Adler-Herzmark (1927), Zbl. Gewerbehyg., **14,** 161.

Beyne and Goett (1934), Arch. de Med. et Pharm. nav., **124,** 409.

Bureau of Mines. Report of Public Treasury Dept., 1921.

Cade and Mazel (1923), Bull. et mem. Soc. Trop. de Paris, **39,** 722.

Chemical Research Association, Laboratory Report 45623.

Clark (1933), " The Mode of Action of Drugs on Cells," Edwin Arnold.

Dufraisse, Vielleſosse and Le Braz (1933), Compt. rend., **197,** 162.

Ferguson and Scheflan, 1933.

Fieldner, A. C., S. H. Katz and S. P. Kinney. Technical Paper 272, Bureau of Mines, U.S. Department of the Interior, 1921.

Fieldner, Katz, Kinney and Longfellow (1920), Journal Franklin Institute, **190,** 542.

Flury (1928), Arch. exp. Path. Pharmak., **138,** 65.

Flury and Zernik (1931), Schadliche Gase, Springer.

Fuhner (1921), Biochem. Z., **115,** 235.

Fuhner (1933), Arch. exp. Path. Pharmak., **97,** 86.

Gaddum, J. H., M.A., M.R.C.A., L.R.C.P., Prof. of Pharmacology.

Glaser and Frisch (1929), Arch. f. Hyg., **101,** 48.

Goldsmidt and Kohn (1920), Zbl. f. Gewerbehyg., **8,** 28.

Graham, J. Ivon, M.A., M.Sc., 1931.

Haldane, " Principles of Respiration."

Hamilton (Alice) (1925), " Industrial Poisons in the United States."

Hamilton (Alice) (1933), Indus. and Engin. Chem., **25,** 539.

Henning (1922), J. Soc. of Chem. Ind., xli, 218 R.

Henning (1933), Chem. and Ind., 462.

Hill, Sir Leonard, F.R.S., October 14th, 1931.

Ingman Price (1937), Fire Fighting and Toxicity. (Prof. Fire Brigades Association.)

Iwanoff, N., " Experimentelle Studien uber den Einfluss Technisch und Hygiensch wichtiger Gase und Dampfe auf dem Organismus." Teil XVI, XVII, XVIII. Arch. f. Hyg., 1911, Vol. 73, p. 308.

Journal of the Society of Chemical Industry. " Application of the Halogen Derivatives of the Hydrocarbons with particular reference to Methyl Bromide." June 2nd, 1933.

Kobert, R. " Kompendium d. Prak." Stuttgart, 1912.

" La Prevention de Feu." Extinction by Carbon Tetrachloride and similar liquids, p. 256, 1933.

Lambert, G. Lux Carbon Dioxide Fire Fighting Appliances in particular relation to Electrical Hazards. P.F.B.A. Conference, 1936.

Lamson, Gardner, Gustafson, Maire, McLean and Wells (1923). J. Pharmacol., **22,** 215.

Lazarew (1922, a.). Arch. exp. Path. Pharmak., **141,** 19.

Lazarew (1929, b.). Arch. exp. Path. Pharmak., **143,** 223.

Legge, Sir Thomas, C.B.E., M.D., " Lessons Learnt from Industrial Gases and Fumes," 1930.

Lehmann (1886), Arch. f. Hyg., **5**, p. 1.

Lehmann (1887), Arch. f. Hyg., **7**, 335.

Lehmann (1911), Arch. f. Hyg., **74**, 1.

Lehmann (1913), Arch. f. Hyg., **75**, 1.

Lehmann. "Experimentelle Studien uber den Einfluss Technisch und Hygienisch wichtiger Gase und Dampfe auf den Organismus." Theil VIII. Arch. f. Hyg., 1899. Vol. 34, p. 321.

Lehmann. "Lehrbuch der Arbeits-und Gewerbehygiene." Leipzig, 1919.

Lehmann (1930), Zbl. f. Gewerbehyg. NF7, 123.

Loffler and Rutimeyer (1920), Viert. f. gerich. Med., **60**, 60.

London County Council Publication. Annual Report of the Council, 1937. Vol. III (Pt. I). Public Health, 75–6.

Medical Officers of Health, Home Office.

Merzbach (1928), Z. f. ges. exp. Med., **63**, 383.

Moller (1933), J. Ind. Hyg., **15**, 418.

Muller (1935), Arch. exp. Path. Pharmak., **109**, 776.

National Research Council and Dow Chemical Co. Report of the Bureau of Mines, p. 30, pp. 31–33, pp. 34–35.

Nuckolls (1933). Report to the National Board of Fire Underwriters, Miscellaneous Hazard No. 2375 for Kinetic Chemicals, Inc.

Olsen (1933). Ind. and Eng. Chem., **25**, 541.

Olsen, Ferguson and Scheflan (1933). Ind. and Eng. Chem., 599, **25**.

Oppermann (1933). Samm. vergift., 4, 157.

Rambousek, J. (Chief State Health Officer, Prague). "Industrial Poisoning," contained in report of Union of Chemical Industry, 1904.

Rohrer, Fritz. "A contribution to the study of the delayed actions of Poisons." Vrtjschr. f. gerichtl. Med. July, 1920. 3rd Series, 60. No. 1, 51–59.

Sayer, R. R., Yant, W. P., Thomas, B. G. H., and Berger, L. B. "U.S. Public Health Bulletin No. 185—Physiological response attending Exposure to Vapours of Methyl Bromide, Methyl Chloride, Ethyl Bromide, and Ethyl Chloride." pp. 4–8, pp. 20–27.

Schumacher and Lenher (1928). Ber. Deutsch. Chem. Ges., **61**, 1671.

Tietze (1933). Arch. f. Gewerbepath. u. Gewerbehyg. **4**, 733.

U.S. Navy Regulations

U.S. Health Service, Public Health Bulletin No. 185.

U.S. Chemical Warfare Service, American University Experimental Station and Washington, D.C.

U.S. Bureau of Mines, 1921. "The permeation of Oxygen Breathing Apparatus by Gases and Vapours." A. C. Fielden, S. H. Katz and S. P. Kinney. Technical Paper 272.

Yandell, Henderson and Howard W. Haggard. "Noxious Gases." Monograph 35, The Chemical Catalogue Co., New York, 1927.