AD 654322 8-76-64-103 Final Report cn Fire-Extinguishing Agents under Contract 11 44-009 eng-507 Furdue University July, 1950 Coppe



- Carrier Description

J3893

Purdue Research Foundation and Department of Chemistry

223

Purdue University

W-44-00 FURTSPEFOR ATION ONLY

with

Army Engineers Research and Development Laboratories

Fort Belvoir

Distribution of this document is unlimited.

PROJECT PERSONNEL

Director: Dr. E. T. McBee Supervisor: Dr. Z. D. Welch Research Chemists: Dr. D. D. Micucci Dr. O. R. Pierce Dr. R. A. Sanford Dr. T. R. Santelli Dr. Anthony Truchan Dr. C. E. Wheelock Research Assistants:

E. F. Barnos C. D. Caldwell V. A. Fauver Eva Colsom Mary M. Kruder G. C. Lindenborg J. M. Mockford F. P. Palopoli Mary L. Riethof D. D. Smith Clara Stuckey G. F. Ulrich R. A. Wells

Circumstances did not permit a continuity of effort on the part of the research chemists and research assistants from the beginning of the project in September, 1947 to its termination in June, 1950. The research assistants were part-time employees and in general they were Purdue Students.

ż

TABLE OF CONTENTS

•

Abstract
Introduction
Flammable Areas
Effect of Halogen Containing Compounds
Table I
Fig. 2
Fluorine Atom in CF4, Fig. 3
Weight Effectiveness vs. Molar Effectiveness
Table II. 17
Effect of Temperature
Apparatus for the Determination of Flammability Limits at Various Temperatures
Plats 1
Effect of Temperature on the Peak in the Flammability Curves 23 Isobutane and Bromotrifluoromethane at ~78°C., Fig. 5
Effect of Flammable Materials
Chemicals Boiling Below -100°C. at Normal Pressure Table V

Page Effect of Binary Mixtures of Halogen Compounds - 30 43 Mixtures of Pentane, Methyl Bromide and Sulfur Hexafluoride 45 Pentane Fig. 19..... 44 6% Pentane 45 Mixtures of Pentane, Methyl Bromide and Perfluorobutane 46 47 48 Mixtures of Pentane, Methyl Bromide and Ethyl Bromide 49 Mixtures of Pentane, Ethyl Bromide and Methyl Louide 50 51 52 Nixtures of Pentane, Ethyl Bromide and Nethylene Chloride 53 54 55 Mixtures of Pentane, Ethyl Bromide and Chlorotrifluoromethane 56 57 58 Mixtures of Pentane, Carbon Tetrafluoride and Trichloromethylene 59 60 61 Binary Mixtures of Halogen Compounds, Table VII. . . . 62 64 Effect of Pressure on Peak in the Flammability Curves. Heptane and Bromotrifluoromethane at 200 mm Hg., Fig. 37 . 65 at 300 mm Hg., Fig. 38 . 66 at 400 mm Hg., Fig. 39 . 67 at 500 mm Hg., Fig. 40 . 68 Heptane and Methyl Bromide at 200 mm Hg., Fig. 41. . . . 69 at 300 mm Hg., Fig. 42. . . . 70 ٠ at 400 mm Hg., Fig. 43. . . 71 at 500 mm Hg., Fig. 44. . . . 77 Heptane and Dichlorodifluoromethane 78 at 200 mm Hg., Fig. 45. . 79 at 300 mm Hg., Fig. 46. . at 400 mm Hg., Fig. 47. . 80 at 500 mm Hg., Fig. 48. . 81 Table VIII 82 64 . . .

ii

Page 64 83 Corrosive Action under Aqueous Conditions, Table X 85 84 Stability at 392°F (200°C.) for 30 days, Table XI. . . . 86 Corrosive Action at 200°F. (93°C.) Table XII 60 Stability of Halogen-containing Compounds to Metals 91 Resistivity Measurements 93 Resistivity of Fluorocarbons, Table XIV. 94 94 Combustion Apparatus, Fig. 49. 95 Summary of Analysis of Products of Combustion, Table XV. . 98 Pyrolysis Studies 99 Relation of Flammability Peak to Per Cent Decomposition of Pyrolysis Studies in the Presence of Air. 101 Analytical Data of Pyrolysis of Halogen Compounds and Air Behavior of Halogen Compounds in an Electric Arc. 105 Relationship Between Dielectric Constant and log of Flamm-Relationship Between Dielectric Constant and the Reciprocal Relationship Between Dielectric Constant and the Flammabil-Relationship Between Vapor Density and Flammability Peak, Relationship Between Vapor Density and the Reciprocal of Relationship Between Vapor Density and the Log of the . . . 108 . . .

Tost	Materials (Continued)	ra
1634	Dibromodi Auoromethane	11
	Tribromo fluoromethana.	11
	Remochlandifluowmuthane	11
		11
	WINGFOIDHE	11
		11
		11
	Dibromomethane	11
	Bromochloromethane	ü
	Methyl Bromide	Ц
	Methyl Iodide	П
	Hexafluoroethane	ບ
	1,2-Dibromotetrafluoroethane	11
	Tetrafluoro-1,2-diiodoethane	1)
	2-Brcmo-1,1,1-trifluoroethane	1)
	1,2-Dibromo-2-chloro-1,1,2-trifluoroethane	12
	1,2-Dibromo-1,1-difluoroethane	12
	2-Bromo-1-chioro-1.1-difluoroethane	1:
	1-Bromo-2-chloroethane	1:
	Ethyl Bromide.	1
	Ethyl Todide	1:
	2 2-Difluoroviny hromide	1
	Vinw hoomide	ĩ
		1
		1
		1
	2-promo-1-chicoro-1,1-dilluoropropane	1
	1-bromo-2,2-difiuoropropane	1.
	1-Bromopropane	1
	2-sirsmopropane	1.
	Perfluorobutane.	1
	Cctafluorocyclobutane	Ľ
	Benzotrifluoride	1
	Perfluoro(ethylcyclohexane).	Ľ
	Perfluoro(1,3-dimethylcyclohexane)	1
	Perfluoro(1,4-dimethylcyclohexane)	1
	Heptadecafluoro(N.N-diethylproplyamine).	Ľ
	Ethyl Trifluoroacetate	1
	Nitrogen Trifluoride	1
	Silicon Tetrachloride	1
	Hydrogen Bromide	1
	Hydrogen (h)orida.	î.
	nyarogen objeriaes e e e e e e e e e e e e e e e e e e	1
	Combra Diavida	1
		1.
		Ŧ
Perfo	rmance Tests	12
	Weight Effectiveness, in Percent. of Selected Agents	
	Against Class B and C Fires. Table XVIII	12
	Correlation Between Performance Test and Peaks in the	
	Flammability Curves.	1
		-

~

iv

4

....

Final Summary Report

September 1, 1947 to June 30, 1950

An

Research at Purdue University

Purdue Research Foundation and Department of Chemistry in cooperation with Army Engineers Research and Development Laboratories

FIRE EXTINGUISHING AGENTS

Abstract

Negotiations between the Army Engineers Research and Development Laboratories resulted in Contract No. W44-009 eng - 507 for conducting studies, research and investigations leading to the development of a fire extinguishing agent with fire fire-fighting characteristics equal to or superior to methyl bromide. Although fluorine containing compounds were of a great deal of interest to this project, the investigation was not limited to a study of the applicability these compounds as fire extinguishing agents.

A literature search revealed that no systematic study had been made of compounds to be used as fire extinguishing agents. In general, a proposed compound was tested by putting out fires under specified conditions. Such a test method was obviously not suited for rating research samples of a few grams of material.

A laboratory screening test of compounds for their fire inhibiting properties was set up by determining the limits of flammability of mixtures of fuel, (<u>n</u>-heptane) air, and the proposed extinguishing agent. The peak in the curve obtained by plotting data concerning the flammability of mixtures was considered as a measure of the flame artinction properties of the test compound. This hypothesis was later shown to be valid by tests conducted at Fort Belvoir. Dibromodifluoromethane heads the list of the thirty-one compounds found to be more effective than methyl bromide on the basis of this test. When the comparisons were made on a weight basis instead of a volume basis only eight compounds were found to be more effective than methyl bromide.

It was found that in a given homologous series of compounds, the effectiveness in fire extinction properties increases with an increase in molecular weight. No apparent relationship could be found between the fire extinction properties and molecular weight of compounds chosen at random.

As part of a program of determining the effectiveness of elemental composition of a compound in decreasing the flammability of mixtures of air and <u>n</u>-heptane, several non-carbon compounds were studied. Halides of silicon, sulfur, and boron have flame inhibition properties which are greater than those for the corresponding carbon halides. The properties of these non-carbon halides rule them out as suitable fire extinguishing agents. Subsequent research should include a study of methods leading to the preparation of organic polyhalides containing sulfur, silicon and boron as an additional element.

The effect of a halogen substituent upon the fire extinction properties of carbon compounds was studied in some detail. The order of increasing effectiveness is $F \leq Cl \leq Br \leq I$. There are, however, some anomalies to this generalization which cannot be satisfactorily explained. For example, the alkyl iodides are more effective flame inhibiting agents than the corresponding alkyl bromides, but the perfluoroalkyl iodides may or may not be as effective as the corresponding perfluoroalkyl bromides.

The replacement of a bromine atom for a fluorine atom in carbon tetrafluoride greatly increases the effectiveness of the resulting compound, bromotrifluoromethane, in decreasing the flammability of mixtures containing air and <u>n</u>-heptane. Subsequent replacements of bromine for fluorine results in the formation of compounds which are more effective as fire extinguishing agents, however, this increase in effectiveness is not a linear relationship.

Unsaturated compounds were found, in general, to be ineffective in decreasing the flammability of mixtures of air and <u>n</u>-heptane. Tetrafluoroethylene was found to burn in air. 2,2-Difluorovinyl bromide was found to be as effective as methyl bromide. The (perfluoroalkyl)benzenes, such as benzotrifluoride were found to be flammable in air.

The effect of temperature upon the coordinates of the peak in the flammability curves was determined at $-78^{\circ}C_{\cdot}$, $+26^{\circ}C_{\cdot}$, and $+145^{\circ}C_{\cdot}$ The order of effectiveness, based upon the volume per cent of the halogen compound in the mixture, is the same at the three temperatures. The flammable areas obtained at $-78^{\circ}C_{\cdot}$ were found to be quite irregular. It was also found that as the temperature increases, the peak in the flammability curve also increases.

The standard fuel used for rating the various fire retarding agents with respect to one another was <u>n</u>-heptane. When the standard fuel, <u>n</u>-heptane, was replaced by a different fuel a qualitative parallel relationship exists between the fire retarding agents. Other fuels investigated included diethyl ether, pentane, benzene acetone, ethyl acetate, and methanol.

The possibility of using a mixture of compounds as a fire extinguishing agent was also investigated. Several binary mixtures of

2.

halogen compounds were used as fire retarding agents on mixtures of <u>n</u>-pentane and air. This preliminary study indicated that in certain instances the use of a mixture of halogen-containing compounds is advantageous. The actual effectiveness appeared to be characteristic of the particular mixture used. Hence no generalizations could be made regarding choice of constituents in the mixture.

As a continuation of a study of the effect of variables on the flammable limits of mixtures containing air, <u>n</u>-heptanc, and a halogen compound, the flammable areas at subatmospheric pressures of 200, 300, 400, and 500 mm. Hg were determined. For mixtures containing methyl bromide as the flame inhibiting agent, not only is the flammability peak lowared with a decrease or increase in pressure from 400 mm. Hg but in general the flammable area lies within the area found at 400 Hg pressure. When trifluoromethyl bromide was used as the flame inhibiting agent the peak in the flammability curve was essentially the same at 300, 400, and 500 mm. Hg pressure and lower at 200 mm. Hg pressure. In the case of dichlorodifluoromethane, the peaks are equivalent at 300 and 400 mm. Hg pressure and lower at 200 mm. Hg pressure. These examples are too few to warrant drawing any conclusions concerning the effect of pressure on the flammable areas.

An accelerated stability test of various halogen compounds to iron, copper, aluminum, brass and magnesium was performed. Tests were conducted at reflux temperatures at 200°F. (93.3°C.) and at 392°F. (200°C.) under anhydrous and aqueous conditions. Small strips of the test metal werenoted for corrosion and loss in weight. Data show that halogen compounds are less stable toward aluminum than to either brass, copper, iron or magnesium. There appears to be no significant difference between the stability of these compounds to brass and to copper. The compounds are most stable to iron. The fluorocarbons are the most stable and the monohaloalkanes the least stable.

Restivity measurements show that for practical purposes fluorocarbons are non-conductors of electricity and hence would be suitable for use in combating electrical fires.

A knowledge of the behavior of halogen compounds under conditions favoring decomposition is of interest in the interpretation of data relating to the toxicological properties and corrosive action. Accordingly, several halogen-containing compounds were introduced into a flame resulting from the combustion of propane in air and the products of decomposition studied. A special burner was designed so that the materials introduced and products formed could be quantitively measured. The halogen compound was : "jected to the flame in either of two ways. The halogen compound w first premixed with the propane stream before burning or the air stream before burning. Considerable soot was formed except when carbon tetrafluoride and sulfur hexafluoride were used. Then only trace amounts were noted. The amount of soot obtained was always a little less than the amount of carbon present in the halogen compound introduced. This suggests that soot formation arises

3.

ethane are about equivalent in effectiveness.

Unsaturated compounds were found, in general, to be ineffective ir decreasing the flammability of mixtures of air and <u>n</u>-heptane. However, 2,2-diflucrevinyl bromide (CF₂ = CHBr) was found to be unexpectedly effective. The peak in the flammability curve was 9.7%.

Tetrafluoroethylene was found to be flammable in air. The lower limit of flammability lies between 16.0 and 16.3% and the upper limit between 43.0 and 44.0%. These limits are for the upward propagation of flames. The flames resulting from combustion of mixtures whose compositions were in the region of the lower limit were pale blue in color and no smoke was present. The flames resulting by burding mixtures of tetrafluoroethylene and air having a composition in the region of the upper limit of flammability were red and much soot was formed.

Mixtures of <u>n</u>-heptane, air and nitrogen trifluoride were found to be explosive when ignited. The violence of the combustion reaction was increased as the percentage of nitrogen trifluoride was increased to 70% where further testing was stopped. These results were unexpected since nitrogen trifluoride is a stable compound and relatively inert. As a result of these tests it was concluded that nitrogen trifluoride was of no further interest as a fire extinguishing material.

The (perfluoroalkyl)benzenes, benzotrifluoride, bis(trifluoromethyl)benzenes and l-(pentafluoroethyl)-4-(trifluoromethyl)benzenes, were eliminated from further consideration when they were found to be flammable, The ring halogenated derivatives of these compounds were not studied because of their low vapor pressure.

<u>Weight Effectiveness vs. Molar Effectiveness</u>. The method used for the determination of the flame extinction properties of halogencontaining compounds is based upon the volume percentage of the agent in a mixture of vapors. While this procedure provides a convenient means for evaluating the compounds and correlating the results, the weight effectiveness becomes significant from an economic viewpoint since these materials are usually sold on the weight basis. It is also important to consider the weight of material required for fire protection. In general, this point is more significant in cases where aircraft is concerned than in other cases.

A comparison is made in Table II between the weight effectiveness of a halogen compound as a fire extinguishing agent and the volume effectiveness of these same compounds. The following equation was used in calculating the weight of halogen compound equivalent to the volume percentage of the halogen compound at the peak in the flammability curve. Grams of Extinguisher = 100 liters

Extinguisher = $\frac{100 \text{ liters}}{22.4 \text{ liters}}$ x Mol. Wt. of Extinguisher x Vol.% Extinguisher at

Peak. The calculations are based on 100 liters of gaseous mixture at 0°C. and one atmosphere of pressure. It will be noticed that some compounds which have a low flammability peak are found to be less effective on a weight basis than others with a high flammability peak and vice versa. It is interesting to note that on the volume basis, thirty-one of the compounds tested are better than methyl bromide; whereas, on a weight basis, only eight compounds are more effective than methyl bromide.

ţ

Table II

ы., ы

۴,

ţ

. . ..-

SUMMARY OF COMPOUNDS EVALUATED AS FIRE EXTINGUISHING AGENTS (Room Temperature)

1944 - 1945 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 - 1946 -

Compound		Peak in Flamability		Order Effect	r of tive-
Formula	Name	Curve, %	Extinguisher.g.	* <u>Vol.</u>	<u>Wt.</u>
CBr ₂ F ₂	Pibromodifluoromethane	4.2	39•37	<u>basis</u> 1	basis 6
CBrsF	Tribromofluoromethane	4.3	51.96	2	17
CF ₃ CHBrCH ₃	2-Bromo-1,1,1-trifluor propane	0- 4.9	38.71	3	4
CBrF ₂ CBrF ₂	1,2-Dibromotetrafluoro ethane	- 4.9	56.87	4	22
CF2ICF2I	Tetrafluoro-1,2-diiodo ethane	5.0	79.01	5	37
CH ₂ Br ₂	Dibromomethane	5.2	40.39	6	7
CF3CF2I	Pentafluoroiodoethane	5.3	58.19	7	26
CF3CH2CH2Br	3-Bromo-1,1,1-trifluor propane		42.67	8	11
CH3CH2I	Ethyl iodide	5.6	39.00	9	5
CF3CF2Br	Bromopentafluoroethane	e 6.1	54.16	10	18
CH ₃ I	Methyl iodide	6.1	38.67	11	3
CBrF ₃	Bromotrifluoromethane	6.1	40.57	12	8
CH 3CH 2Br	Ethyl bromide	6.2	30.15	13	1
CH2BrCF2CH3	1-Bromo-2,2-difluoro- propane	6.3	44•69	14	13
CClF ₂ CHBrCH ₃	2-Bromo-1-chloro-1,1- difluoropropane	6.4	55 . 38	15	20
CHBr ₂ F	Dibromofluoromethane	6.4	54.85	16	19

* These values were obtained by calculations assuming 100 liters of gaseous mixture at 0°6. and one atmosphere of pressure.

.

 $(x_1,y_2,\dots,y_n) \in \{x_1,y_2,\dots,y_n\}$

ì

Table II (Continued)

ţ.,

i

,

:

×*

۰.

Concound	F	Peak in Lammability		Orde Effe	er of ctive-
Formula	Name	Curve, %	Extinguisher.g.*	Vol. bas:	. <u>Wt.</u> is basis
CBrF ₂ CH ₂ Rr	1,2-Dibromotetrafluoro- ethane	6.8	68.0	17	
CF ₃ CH ₂ Br	2-Bromo-1,1,1-trifluoro	- 6.8	19 66	18	16
C_7F_{16} $C_6F_{11}C_2F_5$	Perfluoroheptane Perfluoro(ethylcyclo-	7.5	129.91	26	49
• • • • •	hexane)	6.8	121.42	19	46
1,3-C ₆ F ₁₀ (CF ₃) ₂	Perfluoro(1, 3-dimethyl- cyclohexane)	6,8	121,42	26	47
1,4-C ₆ F ₁₀ (CF ₃) ₂	Perfluoro(1,4-dimethyl- cyclohexane)	6.8	121.42	21	48
CF ₃ I	Trifluoroiodomethane	6.8	59•5	22	27
CH2BrCH2Cl	1-Bromo-2-chloroethane	7.2	45.69	23	14
CC1F ₂ CH ₂ Br	2-Bromo-1-chloro-1,1- difluoroethane	7.2	57.69	24	24
C ₆ F ₁₁ CF ₃	Perfluoro(methyl- cyclohexane)	7.5	117.18	25	45
CH ₂ BrCl	Bromochloromethane	7.6	43.93	27	12
CHBrF ₂	Bromodifluoromethane	8.1.	49.12	28	15
CC1F2CC12F	1,1,2-trichlorotri- fluoroethane	9.0	75.3	29	36
CBrClF ₂	Bromochlorodifluoro- methane	9.3	68.71	30	31
HBr	Hydrogen bromide	9.3	33.62	31	2
CH ₃ Br	Methyl bromida	9.7	41.13	32	9
CF ₂ =CHBr	2,2-Difluorovinyl bromic	ie 9.7	61.92	33	28
n-C ₄ F ₁₀	Perfluoro n-butane	9.8	104.12	34	44

 These values were obtained by calculations assuming 100 liters of gaseous mixture at 0°C, and one atmosphere of pressure.

Table II (Continued)

Compound		Peak in Flammability	E	Order ffectiv	of veness Wit.
Formula	Name	Curve, %	Extinguisher.g.*	blols	basis
SiCl ₄	Silicon tetrachloride	9.9	75.1	35	35
CBrF ₂ CBrC1F	1,2-Dibromo-2-Chloro-1 1,2-trifluoroethane	10,8	133.5	36	50
CC1FgCC1F2	1,2-dichlorotetrafluor ethane	0- 10,8	82.4	37	40
CC14	Carbon tetrachloride	11.5	79.0	38	38
CF3CHC1CH3	2-chloro-1,1,1-tri- fluoropropane	12.0	70 .99	39	33
CF3CH2CH2C1	3-chloro-1,1,1-tri- fluoropropane	12.2	72.16	40	34
CClF3	Chlorotrifluoromethane	12,3	57.38	41	23
CF ₃ CF ₃	Hexafluoroethane	13.4	82+55	42	41
CCl ₂ F ₂	Dichlorodifluoromethan	e 14.9	80.4	43	39
CHC13	Chloroform	17.5	93.3	44	42
CHF ₃	Trifluoromethane	17.8	55.6	45	21
CHCLF ₂	Chlorodifluoromethane	17.9	69.12	46	32
C4F8	Octafluorocyclobutane	18.1	161 .61	47	53
SF ₆	Sulfur hexafluoride	20.5	133.6	48	51
BF ₃	Boron Trifluoride	20.5	62.05	49	29
PCl ₃	Phosphorous trichloride	e 22.5	138	5 0	52
нсі	Hydrogen Chloride	25.5	41.55	51	10
CF4	Carbon tetrafluoride	26	102.1	52	43
CO ₂	Carbon dioxide	29.5	57.94	53	25

* These values were obtained by calculations assuming 100 liters of gaseous mixture at 0°C. and one atmosphere of pressure.

,

•

·· · .)

₩,

,

Effect of Temperature. The effect of temperature upon the coordinates of the peak in the flammability curves and the flammable areas was determined. Since it was desired that one of the temperatures be at least as low as -50° C. it was necessary to choose materials for this study which have a vapor pressure at -50° C. sufficiently high to obtain mixtures having the desired concentrations, as the test procedure is based upon the measurement of the flammability of a mixture of vapors. Methane was investigated first as the flammabile material, but it was observed that the flame was not always luminous. Isobutane was found to be satisfactory in all respects as the flammable material. Methyl bromide, bromotrifluoromethane and chlorotrifluoromothane, sulfur hexa-fluoride and carbon tetrafluoride were chosen for use as the flame inhibitors.

The apparatus used was similar to the one previously described except that the combustion tubes were izmersed in a constant temperature bath as shown by photograph in Plate I and by diagram in Figure 4. The Pyrex combustion tube (A) was 51 mm. inside diameter and 120 cm. long. The rubber stopper (B), held on by atmospheric pressure, sealed the upper end of A. The lower end of A was connected by means of 8 mm. Pyrex tubing (C) to the gas mixing system. The upper end of A was connected to the gas mixing system by means of E. The gas mixing system consisted of the mercury piston (G) and the one-way check valves (F). Thus, when the mercury rose and fell in G, the gas mixture in A was circulated and thoroughly blended into a homogeneous mixture. Relay (J) and solenoids $(I_1 \text{ and } I_2)$ controlled the pump action in G by regulating the flow of compressed air into the mercury reservoir (H). Tube A was connected to the manifold (L) through stopcocks (D and N₅). Manometer (M) was used to measure the pressure in A. A vacuum pump and sources for dry air, fuel, and halogen compound were connected to L through stopcocks (N_1, N_2, \dots) N_3 , and N_4 respectively). The electrodes (0) used for ignition, were made of number 29 gauge platinum wire and were connected to the high voltage terminals of a Model-T Ford induction coil (not shown). The constant temperature bath (P) was constructed of one-sixteenth inch sheet copper and was lagged with 1.5 inches of magnesia (not shown). For elevated temperatures the bath was filled with oil which was heated by 250-watt nichrome wire immersion heaters (not shown). For low temperatures, the bath was filled with trichloroethylene and cooled with Dry Ise.

The apparatus was operated as follows: Tube A was evacuated by the vacuum pump by closing and opening appropriate stopcocks. Fuel, extinguisher, and dry air were introduced in order of increasing vapor pressure. The composition was calculated from the partial pressure of each component as noted on the manometer (M). Clamp (Q) was opened and the pump (G) was allowed to operate until thorough mixing had occurred. The mixing time was determined by several preliminary runs. After mixing, the mixture was fired and a positive result was recorded if the flame traveled the whole length of the tube A. Before the next run the system was flushed with air by opening stopcock K.

Coordinates for the peak in the flammability curves for mixtures of the halogen compounds with air and isobutane at $-78^{\circ}C_{\circ}$, $+26^{\circ}C_{\circ}$ (room temperature) and $+145^{\circ}C_{\circ}$ are summarized in Table III. The flammable areas at -78° , $\pm 26^{\circ}$ and $\pm 145^{\circ}C_{\circ}$ are shown in Figures 5-18 inclusive. The order of effectiveness, based upon the amount of halogen compound in the mixture, is the same at $-78^{\circ}C_{\circ}$ as at $\pm 26^{\circ}C_{\circ}$. The order is as follows.

. ₽



e i te ka i developmente pre

•



FIG. APPARATUS FOR THE DETERMINATION OF FLAMMABILITY LIMITS AT VARIOUS TEMPERATURES

Figure 4

22.

Table III

EFFECT OF TEMPERATURE ON THE PEAK IN THE FLAMMABILITY CURVES

Temperature, °C.	-78		+26		+145		
. وي وي کارني _{ال} او اين او	Peak in flammability curve		Peak in flammability curve		Peak in flammability curve		
Halogen Compound	Halogen Compd.%	C4H10.5	Halogen Compd.,%	C.H10.%	Halogen Compd.,	C4H109%	
CBrF ₃	3.25	4+5	4.7	4.6	7.3	4.0	
CH 3Br	3.75	3.5	6.75	4.0	8.3	4.0	
CC1F3	8,25	3.5	10 .7 5	4.25	12.8	4.0	
SF6	12.75	5.0	15.75	5.0	17	5.5	
CF4	18.25	5.0	23.75	4.0	14	3.5	

n an sagar 2 ▲

ŗ









25.







į

irr



Figure 9 Effect of Temperature on Peak in the Flammability Curves

١



29.

Figure 10 Effect of Temperature on Peak in the Flammability Curves

<u>نه</u>

<u>ः वि</u>



JWNTON X8 INJOJJ 'JNVLNBOS/ Figure 11 Effect of Temperature on Peak in the Flammability Curves



١.

51.

44

日本の時間にあるというです。



<u>.</u> -

۶.,

•

1997 -

÷.

JUNTON LE LNJJJJJ SURTUROSI Figure 13 Effect of Temperature on Peak in the Flammability Curves



Figure 14 Effect of Temperature on Peak in the Flammability Curves

and always of the second second



Figure 15 Effect of Temperature on Peak in the Flammability Curves

¥.

:





.



1

٦,

Figure 17 Effect of Temperature on Peak of the Flammability Curves

٩,



JWNTON LE INED LEG 'SNVLNEDOS' Figure 18 Effect of Temperature on Peak in the Flammability Curves

> مىيەرىيە بەرمەر يېلى بەر يېسى. ق

37.

- 1. bromotrifluoromethane
- 2. methyl bromide
- 3. chlorotrifluoromethane
- 4. sulfur hexafluoride
- 5. carbon tetrafluoride

At 145°C, the order of decreasing effectiveness is bromotrifluoromethane, methyl bromide, chlorotrifluoromethane and carbon tetrafluoride.

As shown in Figures 5-9, the curves defining the fammable areas at -78*C. are quite irregular. The flammable area for mistures of air, chlorotrifluoromethane and isobutane is unique since it is divided into two regions. None of the mixtures containing 2% chlorotrifluoromethane burned. There is a constriction in the flammable area for mixtures of bromotrifluoromethane, isobutane and air at 1% bromotrifluoromethane. There is a slight indentation in the curve showing the flammable area for mixtures of carbon tetrafluoride, isobutane and air. There is no evidence of such phenomena in the curves showing the flammable areas with the other halogen compounds. Likewise there is no evidence of such a constriction in any of the flammable areas determined at room temperature using heptane as the flammable material. Since a zone of non-combustion was found to exist with isobutane and chlorotrifluoromethane at low temperatures, the region above the peak in the flammability curve for mixtures of air, chlorotrifluoromethane and isobutane at +26°C. was explored to determine whether a second flammable area could be found. No area of combustion was found even with concentrations of 40% chlorotrifluoromethane. With one exception, the data in Table III support the hypothesis that the percentage of halogen compound in the mixture of air, flammable material and halogen compound at the peak in the inflammability curve increases as the temperature increases. Carbon tetrafluoride appears to be more effective in reducing the flammability of mixtures of air and isobutane at 145°C. than at 26°C or at -78°C.

Effect of Flammable Materials. This research project was undertaken to find a superior fire extinguishing agent for use in combating fires resulting from flammable liquids and/or electricity. Early in the research program, it was demonstrated that, in general, the types of materials being investigated for possible fire extinguishing agents were nonconductors Since heptane vapors were used in the evaluation of electricity¹⁰. studies, it seemed wise to undertake a project to determine whether or not a parallel relationship exists between the abilities of halogen containing compounds to reduce the flammability of mixtures of air and heptane and mixtures of air with other flammable materials. Fontane, benzene, ethanol, diethyl ether, acetone and ethyl acetate were chosen as the combustibles after a consideration of availability and volatility as well as flammability. Methylene dibromide, ethyl bromide, methyl bromide, sulfur hexafluoride, carbon tetrafluoride, and bromotrifluoromethane were chosen as the flame inhibitors. These materials were chosen because of their availability and, on the basis of previous tests, because a wide range of effectiveness is represented by these materials. Data are summarized in Table IV which show the peak in the flammability curve for the various combustibles mixed ith air and with the selected halogen containing compound.

It can be concluded from the data in Table IV that a qualitative parallel relationship exists between the abilities of halogen containing compounds to reduce the flammability of mixtures of air and heptane and mixtures of air with other flammable materials. Those points which spear to be more or less effective than expected have been checked and found to be accurate within experimental error.

Effect of Binary Mixtues of Halcgen Compounds. Developments have emphasized the need for a fire extinguishing agent applicable for use at temperatures ranging upward from -54°C. (-65°F.). A single material which could be used over the entire temperature range would be desirable. One requirement of such a material is that it have a vapor pressure sufficiently high at the low temperature to propel itself from the container to the fire. The vapor pressure of chlorotrifluoro-methane (b.p. -78° C) is too low at -54° C. to carry the extinguishing agent any appreciable distance from its container 22. Therefore, it seems probable that a substance should have a boiling point of -100°C. or lower if it is to be a self-propelling fire extinguishing agent at -54°C. Chemicals selected from a group of about ten thousand arganic and inorganic materials having a normal boiling point below -100°C. are listed in Table V. An examination of this list shows that those known materials which may be of interest as a fire extinguishing agent are limited to a small group comprising of helium, neon, nitrogen, argon, krypton, nitric oxide, carbon tetrafluoride, nitrogen trifluoride and xenon.

Carbon tetrafluoride has been shown to be more effective with respect to fire extinction properties than nitrogen. It is believed that there is no great difference in effectiveness between nitrogen, helium, neon, argon, krypton, and menon. The choice would depend upon performance tests, availability and economics.

Nitric oxide has favorable physical properties but its chemical properties are unfavorable. One reaction may be summarized as follows:

 $2NO + O_2 ----- 2NO_2$ $3NO_2 + H_2O ----- 2HNO_3 + NO_3$

The first reaction may be advantageous since oxygen is being consumed, but the second reaction would be disadvantageous because of the corrosive nature of nitric acid produced by the reaction of nitrogen dioxide with water.

In view of the relatively few compounds available with boiling points below -100°C., it seems evident that a higher boiling substance(s) will have to be used along with a propellant. Such a material should have a freezing point below -54°C. and should be relatively non-viscous at -54°C. If the fluid is a mixture of substances, the freezing point of one or more of the components may be somewhat higher than -54°C. i

Table IV

· · _• ·

*

*

÷.

.

2*

EFFECT OF FLAMMABLE MATERIALS

Flammable Materials	Halogen Compound	CH ₂ Br ₂	CBrFj	C ₂ H ₅ Br	CH ₃ Br	SF ₆	ÇF4
С7Н16		5.2	6.1	6.2	9 •7	20.5	26
C5H12		6.8	6.3	6.3	8.4	19.8	20.4
C ₆ H ₆		7.3	4.3	8.2	8-4)	18.3	23.6
C ₂ H 5OH		5.7	3.7	5.2	6.2	10.6	19,8
(C ₂ H ₅) ₂ O		7.7	6.3	7.3	7.2	21.8	22.4
CH 3 COCH 3		5.7	5.3	5.3	7.3	16.4	18.7
CH3CU2C2H5		4.3	4.6	6.3	é .8	17.5	21.4

Table V

. س

HEMICALS BOILING BELOW -100°C. AT NORMAL PRESSURES

Name	Formula	<u>B.P.,°C.</u>	M.P., °C.	Mol.Wt.	Remarks
Helium	He	-208.9	<-27 2	4	
Hydrogen	Hz	-252.7	-259.1	2	Flammable
Neon	Ne	-245.9	-248.7	20	
Nitrogen	N2	-195.8	-209.9	28	
Carbon Monoxide	co	-192	-207	28	Flammable, highly toxic
Fluorine	F2	-187	-223	38	Extremely reactive
Argon	A	-185.7	-189.2	40	
Oxygen	02	-183	-218.4	32	Supports combustion
Fluorine Oxide	F ₂ 0	-167		54 E	elieved highly toxic
Methane	CH4	-161.4	-182	16	Flammable
Krypton	Kr	-151.8	-169	84	
Nitric Oxide	NO	-151	-161	30	
Carbon Tetrafluoride	CF.+	-128	-184	88	
Silane	SiH4	-112	-185	32	Ingnites spontaneously
Ozone	03	-112	-251	48	Favors combustion
Nitrogen Trifluoride	NF ₃	-110	-210	71	
Xenon	Xe	-109	-140	131	
Ethylene	C ₂ H ₄	-103.9	-169	28	Flammable
Boron Trifluoride	BF ₃	-101	-127	68	Hydrolyzes readily
The possible need for using a mixture of compounds for a fire extinugishing agent was mentioned in the preceding paragraphs. Accordingly, research was initiated to determine the effectiveness of binary mixtures of halogen containing compounds in decreasing the flammability of mixtures containing <u>n</u>-heptane, air and halogen compounds. Data obtained in this preliminary study are summarized in Table VI. These data indicate that in certain instances the use of a mixture of halogen containing compounds is advantageous.

In subsequent studies pentane was used as the flammable material to avoid certain irregularities in the data believed to result from the condensation of the heptane from the mixture. The concentration of combustible material was maintained constant in this study. Pentane concentrations of 2.5, 4 and 6% were used with each mixture of halogen compound. The data are plotted in Figures 19-36 inclusive. The straight line in each plot represents the curve expected if the relationship between the flame inhibition activities of the two extinguishing agents were arithmetical. Mixtures of ethyl bromide and methyl iodide follow this line at a pentane concentration of 4% (Fig. 26). At a pentane concentration of 2.5% (Fig. 25) the curve lies below the line for mixtures of ethyl bromide and methyl iodide containing 65-100% ethyl bromide, indicating that the mixture in this region is more effective than calculated. The curve lies above the line for mixtures containing from 35-100% methyl iodide (0-65% ethyl bromide), indicating that in regions the mixture is less effective than calculated from the consideration of the effectiveness of the two components. At a pentane concentration of 6% (Fig. 27), the entire curve lies below the straight line. At pentane concentrations of 2.5%, 4% and 6% (Figs. 28, 29 and 30), the curves for mixtures of ethyl bromide and methylene chloride lie below the straight line, indicating a synergistic effect in all pentane concentrations of this binary mixture of halogen compounds. This is the only mixture investigated which shows enhancement of effectiveness in all concentrations of the hydrocarbon. A summary of the effect of the mixtures is given in Table VII.

The evaluation of mixtures of carbon tetrachloride and trichloroethylene was performed, in response to a request from representatives of ERDL. This request was made since a mixture comprising 70% carbon tetrachloride and 30% trichloroethylene has been recommended for use as a fire extinguishing fluid. In general on the basis of tests with pentane, it can be stated that a mixture comprising 70% carbon tetrachloride and 30% trichloroethylene are not the most effective that can be obtained by mixing the two compounds. In choosing the composition of such a mixture consideration must be given to economic factors and freezing point characteristics as well as effectiveness. Should the 70-30 composition represent the optimum from the cost consideration and the freezing point characteristics, then a sacrifice in effectiveness may be justified.

Table VI

• ••

EFFECT OF BINARY MIXTURES OF HALOGEN COMPOUNDS IN DECREASING THE FLAMMABILITY OF MIXTURES CONTAINING AIR AND <u>n</u>-HEPTANE

	Peak in Flammability Curves				
Compound A	$(H_2Br_2, \%)$	Compound A,%	Mixtu Obs.	calc.*	
CBr ₃ F	5.2	4.3	5.3	4.8	
C ₆ F ₁₁ C _{.2} F ₅	5.2	6.8	5.4	6.0	
CH ₃ CH ₂ Br	5.2	6.2	5 .7	5.7	
CC34	5.2	11.5	7.2	8.4	
CHC13	5.2	17.5	9.3	11.4	

(% $CH_2Br_2 = \%$ Compound A)

يودد بالمتقايد ف

* Calculated Value = $\frac{\text{% CH}_2\text{Br}_2 + \text{% Compound A}}{2}$

-

- -



î Ş

.

÷

Figure 19 Effect of Hinary Mixtures in Decreasing the Flammability of Air and Pentune





Y CAR



1

Figure 21 Effect of Binary Lixtures in Decreasing the Flequet 11ty of Air and Fentene



۰.



÷ ₩ ₩

* 羅海

. . .





.

E.





· ****

中には御御とてい



LN30232 3WN70A JUNLXIW NO22400200000000 Figure 25 Effect of Binary Mixtures in Decreasing

igure 25 Effect of Sinary mixtures in Decreasing the Flammability of Air and Fentane

ļ

₹,



LNJOYJA JWN70A JYNLXIW NOSYVJOYOYOYA Figure 26 Effect of Binary Mixtures in Decreasing the Flambolility of Air and Pentane ÷.



Figure 27 Effect of Binary Mixtures in Decreasing She Flammability of Air and Pentane

80

-





Figure 29 Effect of Linery Mixtures in Decreasing the Fleamability of Air and Pentene





and the second second

n Mennetter Li

Viñ N

ية. وتوقيقها ال n nyaéngan alaw Nyaéta - Mathematical States (Second States) - Second States) - Second States) - Second States (Second States) - Second States) - Seco - Second States) - Second State

and a second second second

why set the

¥



 $M_{12}^{(1)} = M_{12}^{(1)} + \frac{1}{2} \sum_{i=1}^{n} \frac{1}{i} \sum_{i=1$

 $\frac{1}{2} \int dx dx$



ţ

e.,



•

د المراجع المرا المراجع المراجع





:

Table VII

BINARY MIXTURES OF HALOGEN COMPOUNDS

Mixture	Pentane, S	Effect
CH 3Br-SF6	2.5	Synergistic over 40 to 100% SF ₆ ; less effective over other concentrations
	4.0	Synergistic over entire range
	6.0	Synergistic over entire range
~{ ₃ Br-C ₄ F ₁₀	2.5	Less effective than calculated over entire range
	4.0	Synergistic over entire range
	60	Synergistic over entire range
CH ₃ Br-C ₂ H ₅ Br	2.5	Less effective than calculated
QH3I-C2H5Br	2.5	Synergistic for C _{2H5} Br concentrations of 65-100%; less effective than cal- culated at other concentrations
	4.0	Follows curve calculated
	6.0	Synergistic over entire range
CH ₂ Cl ₂ -C ₂ H ₅ Br	2.5	Synergistic over entire range
	4.0	Synergistic over entire range
	6.0	Synergistic over entire sange
CC1F3-C2H5Br	2.5	Synergistic at CClF ₃ concentrations of 55-100%; less effective at other concentrations
	4.C	Synergistic at CClF ₃ concentrations of 40 to 100%; less effective at other concentrations
	6.0	Follows calculated curve 75 to 100%; less effective at other concentrations
CC14-CC12=CC1H	2.5	Synergistic for CCL4 concentrations of 30-100%; loss effective at other concentrations.

Table VII (Continued)

Mixture	Pentane, \$	<u>Effect</u>
	4	Synergistic for CCL, concentrations of 70 to 100%, less effective than calculated at CCL, concentration of 28-70% and synergistic at con- centration of 0 to 24% CCL.
	6	Less effective at concentrations of CC14 from 45-100%; More er as effective for CC14 concentrations of 0-45%

63.

Effect of Pressure. As a continuation of a study of the effect

of variables on the flamma'le limits of mixtures containing air, n-heptane and a halogen compound, the flammable areas at subatmospheric pressures and at room temperature were determined for these mixtures wherein methyl bromide, trifluoromethyl bromide, and dichlorodifluoromethane were used as the halogen compounds. The areas obtained at pressures of 200, 300, 400 and 500 mm. Hg. pressure are shown in Figures 37-48, inclusive. Data showing peaks in the flammable areas are summarized in Table VIII. For mixtures containing methyl bromide as the flame inhibiting agent it can be seen that not only is the flammability peak lowered with a decrease or increase in pressure from 400 mm. Hg., but that in general the flammable area lies within the area found at 400 mm. Hg pressure. But when triflucromethyl bromide was used as the flame inhibiting agent the peak in the flammability curve was essentially the same at 300, 400 and 500 mm. Hg pressure and lower at 200 mm. Hg pressure. In the case of dichlorodifluoromethane, the peaks are equivalent at 300 and 400 mm. Hg pressure and lower at 200 and 500 mm. Hg pressure.

These examples are too few to warrant drawing any conclusions concerning the effects of pressure on the flammable areas.

Stability Tests

Specifications of the desired fire extinguishing fluid require a compound stable under any climatic condition for long periods of time. An accelerated test is desirable in a program in which a number of conditions was used in predicting the behavior of the compounds when stored. Iron, copper, aluminum, brass and magnesium were chosen for use in these studies because they are commonly encountered in materials of construction.

Stability at Reflux Temperature. Tests were conducted to show the stability of halogen compounds being investigated to iron filings, and copper powder. The experiments were conducted aluminum powder as follows: A 10 ml. sample of halogen compound was refluxed with the finely divided metal for 100 hours. The liquid was then tested for unsaturation with a solution of potsssium permanganate in a cetone and the aqueous extract for halide ions using the zirconyl-alizarin "Red S" test for fluoride ion and aqueous silver nitrate for bromide and chloride ions. The test was followed with another in which 10 ml. of distilled water was added to the mixtures of organic compound and metal and the resulting mixture refluxed for 100 hours. Tests for halide ions and unsaturation were carried out as described previously. The results of these tests are summarized in Table IX. The data show that in general the compounds are quite stable to both iron and copper under the conditions of the test. Decomposition was observed with wet bromochloromethane, (not shown in Table IX) 1-bromo-2-chloroethane and carbon tetrachloride in contact with both iron filings and copper powder.



Figure 37 Ffrest of Fressure on Peak in the Flemmability Curves



Figure 38 Effect of Pressure on the Peak in the Flammability Curves

<u>ب</u>هر



Figure 39 Eff of of Pressure on Peak in the Flammability Curves



Figure 40 Effect of Pressure on Peak in the Flemmability Curves



ing angeneration of the second s



8 •

and the second second

Figure 42 Effect of Pressure on Peak in the Flammebility Curves

×*



Figure 43 Effect of Pressure on Peak in the Flammability Curves

+

2

•

7





• •

. .

• ..

Carrier.

Figure 45 Effect of Pressure on Peak in the Flammability Curves



× ¥

¥*

Figure 46 Effect of Pressure on Peak in the Flammability Curves





. .

i



۱.

Figure 48 Effect of Pressure on Peak in the Flammability Curves

81

.

in the

÷

• ft

÷.

1

÷.

5

-

の日本の見たいできる

Table VIII

THE EFFECT OF PRESSURE ON THE PEAK IN THE FLAMMABILITY CURVE

Commund	N	Curve. & Halogen Compound	
- Versieven Fd	Pressure, mn. Hg		
CH₃Br	200		
	400	5+8	
	300	6.6	
	400	9.7	
	500	7.2	
CBrF ₃	200	1. 3	
	300	4.5	
	400	6 1	
	500	6.3	
CCl ₂ F ₂	200	13 /	
	300	1/ 0	
	400	14.0	
	F CO	14.7	
	500	13.4	
Table IX

Record

CORROSIVE ACTION OF HALOGEN COMPOUNDS AT REFLUX TEMPERATURE (TIME, 100 HOURS)

	A	nhydrous	Hydr	ous
Compound	Unsatn.	Halide Ions	Unsatn.	Halide Ions
Perfluoroheptane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	-	-
Perfluoroethylcyclo-				
hexane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	~	-
Iron Filings	-	-	-	-
Perfluoro-1,4-dimethyl				
cyclohexane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	-	-
Perfluoromethylcyclo-				
hexane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	•	-
Perfluoronaphthalana				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	-	-
Perfluoroindane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	-	-
Carbon Tetrachloride				
Copper Powder	-	-	-	+
Aluminum Powder	-	-	-	+
Iron Filings	-	~	-	+
Dichloromethane				
Copper Powder	-	-	-	-
Aluminum Powder	-	-	-	-
Iron Filings	-	-	-	-
1-Bromo-2-chloroethane				
Copper Powder	-	-	•	•
Aluminum Powder	-	-	+	+
Iron Filings	-	•••	+	+
+ Indicates positive to	estsi - ind	licates negative	tests.	

83.

a -:.

- î -

Another series of tests were conducted in which carbon tetrachloride (with and without an inhibitor) and bromochloremethane were treated in the following manner: A mixture comprising 15 ml. of the test compound and 15 ml. of distilled water was refluxed for 100 hours in the presence of polished and weighed strips of copper, aluminum and iron. The results of these experiments are summarised in Table X. These data indicate that carbon tetrachloride is more corrosive to copper and iron than bromochloromethane. In all three cases the eliminum strip was consumed.

<u>Stability at Elevated Temperatures</u>. A series of experiments were conducted in which the test compounds were heated in contact with strips of metal at 392°F. (200°C.). Only the materials boiling above about 50°C. were used in this study and these compounds were chosen to show the effects, if any, of structural relationships on instability.

The procedure used in this study was as blows: Polished and weighed strips of the metal and 20 ml. of the halogen compound were sealed in ampoules (Carius tubes). The tubes were inserted in iron pipes which, in turn, were placed in an oven beated at 392°F. After 30 days, the tubes were allowed to cool to room tomperature and then opened. The physical appearance of each strip was noted. After removing coatings from the strips which had corroded, the strips were reweighed and changes in weight compared with the original value were recorded. This study was initiated to show the stability of halogen compounds to aluminum, copper and iron, common materials of construction. After this study was initiated it was requested that brass strips be substituted for copper strips. Data are summarized in Table XI.

Compounds showing marked instability to the metals at 392°F. were heated in contact with the same metals at 200°F. In addition, experiments were conducted in which the halogen containing compounds were heated in contact with magnesium ribbon at 200°F. Data from these experiments are summarized in Table XII. Experiments with magnesium deviated from the experiments with the other metals in one respect, namely, after two weeks at 200°F. the ampoule was removed from the oven, cooled to room temperature, and the contents examined visually. Those ampoules in which there was little or no attack on the magnesium were returned to the oven for a second period of heating.

The compounds have been divided into four groups, according to the weight change in the metal. Group A contains those compounds in which the weight change was less than 0.01 g. Group B contains those compounds in which the weight change was between 0.01 and 0.1 g. Group C contains those compounds in which the weight change was greater than 0.1 g. and less than complete consumption of the metal. Group D contains those compounds in which the metal was completely consumed. The stability of halogen-containing compounds toward metals according to these classifications are summarized in Table XIII. Data show that

84.

States Press

Table X

...

<u>- مړ</u>

CORROSIVE ACTION AT REFLUX TEMPERATURE, UNDER AQUEOUS CONDITIONS (TIME = 100 HOURS)

....

<u>c</u>	Campound	Weight of M Original	etals, g. Final	Change i	n Weight
Carbon	Tetrachloride				
	Copper	1.8449	1.7271	-0.1178	7
	Aluminum	1.2891	0.0000	-1.2891	100
	Iron	3.4522	2.4549	-0.9973	29
Carbon (wit	Tetrachloride th inhibitor)				
• -	Copper	1,8289	1.7306	-0.0983	5
	Aluminum	1.2921	0.0000	-1.2921	100
	Iron	3.2768	2.1348	-1.1420	32
Bromoci	nloromethane				
	Copper	1.7705	1.7652	-0.0053	nil
	Aluminum	1.3454	0.0000	-1.3454	200
	Iron	3.4169	2,8851	-0.5308	16

Table XI

• •

a the state of the state

يەن

STABILITY AT 392°P. (200°C.) FOR 30 DAYS

		Weight of M	atale o.	Change i	n Weig	h t.
	Compound	Original	Final		<u> </u>	<u>Appearance</u>
Carbon '	ob iro [dost.to]					
(with	inhibitor)					
、	Copper	1.8297	0.0000	-1.8297	- 100	Completely corroded
	Aluminum	1.1894	0.0000	-1.1894	-100	Completely corroded
	Iron	3.0947	0.0000	-3.0947	-100	Completely corroded
Carbon '	Tetrachloride					
(without	t inhibitor)					
•	Copper	1.7005	0.0000	-1.7005	-100	Completely corroded
	Aluminum	1.4000	1.3567	-0.0433	-3	Grav coating
	lron	2.8319	2.7562	-0.0757	-3	Black coating
DJ - 1 - 1					-	U
DICUTOL	ometnane	1 000			3.00	
	Copper	1.7005	0.0000	-1.7005	-100	black, completely corroded
	Aluminum	1.4190	1.3393	-0.0797	-6	black coating
	Iron	3.1027	3.0785	-0.0242	-8	black coating
Bromoch.	loromethane					
	Copper	1.8078	0.0000	-1.8078	-100	Completely corroded
	Aluminum	1.1758	0.6501	-0.5257	-45	Corroded
	Iron	2.7196	2.7351	+0,0156	+1	Red coating
Dibromo	nethane					
2221 020	Conter	1.7856	0.0000	-1.7856	~ 100	Completely corroded
	Aluminum	1.1824	0.7041	-0.4783	-40	Corroded
	Iron	3.2240	3.1121	-0.1119	-34	Red coating
1 1 0 0						-
fluor	richiorotri-					
	Copper	1.8443	0,9085	-0.9358	- 51	Grav coating
	Aluminum	1.1920	1,1920	0.0000	0	Slight discoloration
	Iron	3.0530	3.0530	0.0000	ō	Slight discoloration
1. D	2 -12					
1-promo-	-2-cnioroetnane	3.0160	A 88.40	0.000	(0	
	copper	1. (4)7	0.7750	-0.9727	-00	Black coating
	Aliminum	1.4380	1.3188	-0.1192	-8	Black coating
	Iron	3.2271	3.1982	-0.0289	- 1	Black coating
1,2-Dib: ethan	romotetrafluoro- e					
	Copper	1.7443	1.5442	-0.2001	-11	Grav coating
	Aluminum	1.4465	0.0000	-1,4465	0	Gray, completely
	Iron	2.9080	2.9043	-0.0037	nil	corroaed Black coating

86.

l

. _ i

Table XI (Continued)

STABILITY AT 392°F. (200°C.) FOR 30 DAYS

· • • •

	Weight of m	etals, g.	Change in	Weis	ht
Compound	Original	Final	<u></u>		Appearance
3-Bromo-1,1,1-tri-					
fluoropropane					
Copper	1.7581	1.6965	-0.0616	-3	Gray coating
Aluminum	1.2280	1.2280	C-0000	0	No discoloration
Iron	3-1935	3.1841	-0.0 094	nil	No discoloration
2-Bromo-1.1.1-tri-					
fluoropropane					
Copper	1.6717	1.5705	-0.1012	-6	Black coating
Aluminum	1,3970	0.0000	-1,3970	0	Completely corroded
Iron	3.2663	3.2510	-0.0153	nil	Black coating
Brass	3.5531	3.5198	-0.0333	-1	5
Perfluoroheptane					
Copper	1.6055	1.6055	0.0000	0	No change
Aluminum	1.4428	1.4601	+0.0173	0	Slight tarnish
Iron	2.7258	2.7258	0.0000	ō	No change
Brass	3.8199	3.8253	+0.0054	nil	
Perfluoroethyl cyclo- hexane)					
Copper	1.6861	1.6861	0.0000	0	No change
Aluminum	1.4149	1.4327	+0.0178	0	Slight tarnish
Iron	3.1050	3.1050	0.0000	0	No change
Brass	4.0718	4.0772	+0.0054	nil	U
Perfluoro(1, 3-dimethyl- cyclohexane)					
Copper	1.6838	1.6854	+0.0016	nil	Slight tarnish
Aluminum	1.3945	1.4041	+0.0096		Slight tarnish
Iron	2.8250	2.8256	+0.0006	nil	Slight tarnish
Brass	4.0095	4.0112	+0.0017	nil	
Perfluoro(1,4-dimethyl- cyclohexane)					
Copper	1.7371	1.7371	0.0000	0	No change
Aluminum	1.3883	1.4062	+0.0179	-	Slight tarnish
Irvin	3,1313	3.1318	+0.0005	nil	No change
Brass	3.9070	3.9094	+0.0024	nil	
Perfluoromethyl- cyclohexane)					
Copper	1.6209	1.6209	0.0000	0	No change
Aluminum	1.48 3	1.5062	+0.0234	-	Slight tarnish
Iron	2.9908	2,9908	0.0000	0	No change
Brass	3.8367	3.8424	+0.0057	nil	U U

187.

÷

÷

1.

•

•

١

Table XI (Continued)

STABILITY AT 392°F. (200°C.) FOR 30 DAYS

ž

	Weight of M	letals, g.	Change i	n Weig	ht .
Compound	Original	Final	<u>g.</u>	\$	Appearance
Perfluoronaphthalane					
Copper	1.7350	1,7350	0.0000	0	No change
Aluminum	1.4029	0.0000	-1.4029	-100	Black, completely corroded
Iron	2.9379	2.9379	0.0000	0	No change
Perfluoroindane					
Copper	1.6678	1.6678	0.0000	0	No discoloration
Aluminum	1.4031	1.4175	+0.0144	+1	Black coating
Iron	3.8083	3 .8 083	0.0000	0	No discoloration
Methyl bromide					
Copper	1.8437	1.8698	+0.0261	+1	Slight discoloration
Aluminum	1.2145	1,2145	0.0000	0	No discoloration
Iron	2,8084	2,8130	+0.0046	nil	Slight discoloration
Trifluoromethane					
Copper	1.7830	1.7830	0.0000	0	No discoloration
Aluminum	1.2572	1.2572	0.0000	0	No discoloration
Iron	3.1043	3.1043	0.0000	0	No discoloration
Bromotrifluoromethane					
Copper	1.8290	1.8398	+0.0108	+1	Slight discoloration
Aluminum	1.2101	1,2110	+0.0009	nil	No discoloration
Iron	3.1116	3.1170	+0.0054	nil	Slight discoloration
Chlorotrifluoromethan	e				
Copper	1.8625	1.8625	0.0000	0	No discoloration
Aluminum	1.1830	1.1830	0.0000	0	No discoloration
Iron	2.9177	2.9177	0.0000	0	No discoloration

8e,

Ì

Table XII

_

. .

.....

CORROSIVE ACTION AT 200°F. (93°C.)

	Time	Weight of H	etals, gi	Change in	Weigh	t
Compound .	Dave	Original .	Final	<u></u>	\$	Appearance
Carbon Tetrachloride	30					
Conner	~	1.8331	1.7821	-0.0510	-3	Black costing
Aluminum		1.2198	0.6127	-0.6021	-1.9	Black coating
Twop		2 2201	3 2718	-0.0506	-2	Red costing
		2 01 5 2	2 0001	-0.0076	- <u>-</u>	Hed coatting
Drads		3.7173	2.7004	-0.0070	11TT	
Carbon Tetrachloride (with inhibitor)	30					
Copper		1.8828	1.5780	-0,3048	-16	Black coating
Aluminum		1.1596	0.0000	-1.1596	-100	Completely cor-
Iron		3.3024	2.7677	-0.5347	-14	Red coating
1-Bromo-2-chloroethane	30					
Copper		1.7733	1.7485	-0.0248	-1	Black coating
Aluminum		1.2397	0.0000	-1.2397	-100	Completely cor-
Tara		2.2377	3 2255	-0 0122	n41	Black costing
Banes		2 9955	2 0770	-0.0076	n11	prack maching
Magnostra		2+70JJ	2.7117		1111	De 11
Haghestur		0.9001	0.9117	-0.0110	Ŧ	buit
2-Bromo-1,1,1-trifluoro	-					
propane	- 30					
Copper		1,8174	1.8174	0.0000	0	No discoloration
Aluminum		1.3880	1.3880	0.0000	0	No discoloration
Iron		3,6006	3.6006	0.0000	0	No discoloration
Brass		2.6455	2.6444	-0.0011	nil	
1,2-Dibromotetrafluoro- ethane	30	I				
Copper		1.8552	1.8552	0.0000	0	No discoloration
Aluminum		1.1781	1.1761	0.0000	Ó	No discoloration
Iron		3.4582	3.4582	0.0000	0	No discoloration
Brass		3.806/4	3.8053	-0.0011	nil	
1,3-Dibramo-2,2-difluor	0- 32					
propine						
Copper		1 20/2	1 10/0			.
Aluminum		1,1001	1.1003	+0.0002	nii	Bright
Iron		2.0950	2.0859	-0.0098	nil	Corroded
brass		3.7418	3.7412	-0.0006	nil	Slight, dull
Magnesium		1,2002	1.2199	+0.0197	2	Dull, coate:
1,2-Dibdotetrafluoroeth	ane l	4				
Copper					-	
Aluminum		1.3998	1.3843	-0.0155	1	Dull, pitted
Iron		2.9675	2.8798	-0.0877	3	Dull, pitted
Brass		3.7823	3.7513	-0.0310	1	
Magnesium		1.1434	1.2344	+0.0960	8	Dull, pitted

89.

•

١

ļ

Table XII (Continued)

•

CORROSIVE ACTION AT 200°F. (93°C.)

Compound	Time Days	Weight of Original	Metals, g. Final	Change in Wei	ight <u>Appearance</u>
Ethyl Bromide	a.	2.4042	2.3914	-0,0128	a Badly corroded
Aluminum Iron		1.1212	0 .9 076	-0.2136	Badly eatmn
Brass Magnesium		3 .804 0 1.1886	3.7921 1.2760	-0.0119 +0.0874	Corroded Coated
Ethyl Iodide	Ħ				
Copper Aluminum Iron		2.9471 0.7314	2.9304 0.1138	-0.0167 -0.6176	Corroded Eaten away
Břass Magnesium		3 .46 65 1.2098	3.4413 1.2628	-0.0252 +0.0530	Corroded Coated
Perfluoroheptane	27	0.8763	0.8803	+0.0040	Shiny
Perfluoro(methyl- cyclohexane)	27	0.8368	0.8420	+0.0052	Shiny
Perfluoro(ethyl- cyclohexane)	27	0.8763	0.8803	+0 ₄0040	Shin y
Perfluoro(1,3-di- methylcytlohexane)	27	0.8408	0.8467	+0.0059	Shiny
Perfluoro(1,4-dimethyl- cyclohexane)	27	0.8530	0.8607	+0.0077	Dull
Perfluoronaphthalane	27	0.8883	0.8973	+0.0090	Dull
1,1,2-Trichlorotri- fluoroethane	14	0.9140	0.9346	+0.0208	Dull, pitted brittle

-

....

•

Table XIII

and the second second

STABILITY OF HALOGEN-CONTAINING COMPOUNDS TO METALS (Unless otherwise indicated, contact time = 30 days)

COMPOUND	ALUI	TNUM	BR	ASS	CO	PPER	IR)N	M.GNI	SIUM
	392' F	200°F	392°₽	200°F	392°F	200° F	392°F	200"F	392*F	200°F
			На	locarbo	กร					
C7F1A	B	~	Å	-	A	-	A	-	-	AЗ
CAFTICFS	В	-	Α	-	A	-	i.	-	-	A 3
CAFTICF2CF3	В	-	A	-	A	-	A	-	-	A3
$1.3 - C_4 F_{10} (CF_3)_2$	В	-	A	-	A	-	А	-	-	A 3
$1.4 - C_6 F_{10} (CF_3)_2$	В	-	A	-	A	-	A	-	-	A ³
C10F18	D	-	-	-	A	-	A	-	-	A 3
CC1_FCC1F2	A	-	-	-	С	-	A	-	-	B1
CBrF2CBrF2	D	A	-	A	С	A	A	A	-	-
CF2ICF2I	-	Cl	-	B	-	-	-	Bı	-	-
CCI4	В	С	-	В	D	В	В	В	-	
			Halo	h ydro ca	rbons					
CF 1CH 2CH 2Br	A	-	-	-	В	-	В	-	-	-
CFaCHBrCHa	D	A.	В	A	C	A	В	A	-	***
CH2BrCF2CH2Br	+	A ⁴	-	A''	-	-	-	B4	-	B4
CH2BrCH2C1	С	D	-	A	С	В	С	В	-	B
CH2BrCl	С	-	-	-	D	-	В	-	-	-
CH ₂ Br ₂	С	-	-	-	D	-	C		-	-
CH ₂ Cl ₂	B	-	-	-	D		В	-	-	-
CH ₃ CH ₂ Br	-	Ç2	-	B ²	-	-	-	C2	-	P 2
CH ₃ CH ₂ I	-	C2	-	B5	-	-	-	Cs	-	Bs

1 Contact time = 14 days

- 5

- 2 Contact time = 11 to 15 days
- 3 Contact time = 27 days
- 4 Contact time = 32 days

۵,

91.

the compounds are less stable toward aluminum than to either brass, copper, iron or magnesium. There appears to be no significant difference between the stability of these compounds to brass and to copper. The compounds are most stable to iron.

As a class of compounds, the fluorocarbons are the most stable of the compounds investigated, and the monohaloalkanes the least stable. The halohydrocarbons containing halogen atoms on adjacent carbon atoms were less stable than the halohydrocarbons containing halogen atoms in the 1-3 position. This is illustrated by the fact that 2-bromol,l,l-trifluoropropene was less stable than 3-bromo-l,l,l-trifluoropropene. This type of instability is to be expected, since dehalogenation is one of the expected reactions between a metal and a halohydrocarbon. This roaction occurs more readily when the halogen atoms are on adjacent carbon atoms than when there is a carbon atom between the two carbon atoms holding the halogen atoms.

The halogan compounds proved to be more stable to the metals at 200°F. than at 392°F. This was expected, since, in general, the rate of a reaction doubles each time the temperature is increased by 10°. Carbon tetrachloride containing an inhibitor, was more corrosive at 392°F than carbon tetrachloride containing no inhibitor. Perhaps the inhibitor decomposed under the conditions of the tests.

Of the liquid compounds other than fluorocarbons tested at 392°C., 3-bromo-1,1,1-trifluoropropant was the least corrosive while the carbon tetrachloride containing an inhibitor was the most corrosive.

Resistivity Measurements

A meterial useful in extinguishing electrical fires should be a non-conductor. Accordingly, apparatus was assumbled for use in resistivity measurements. A Westinghouse Power Factor Cell (cell constant 396) and a General Radio Megohm Bridge, type 544-B, Serial No. 842, were available for use in making these measurements. Results of the determination are summarized in Table XIV. Resistivity measurements were limited to the fluorocarbons. The data obtained show that the fluorocarbons tested are, for practical purposes, non-conductors and hence would be suitable for use in combating electrical fires. It is believed that the other compounds shown to be of interest as fireextinguishing agents are equally effective as insulators.

Attempts were made to determine the resistivity of bromotrifluoromethane following the same procedure used for the liquid fluorocarbons. Values ranging from 1×10^{10} to 1×10^{44} were obtained. When results were obtained which were variable the project was discontinued for lack of time. The data obtained indicate that bromotrifluoromethane is a non-conductor of electricity.

92.

ç

Table XIV

RESISTIVITY OF FLUOROCARBONS

Campound	<u>Resistivity, ohm cm.</u>
Perfluordmethylcyclohexane)	4 x 10 ¹⁴
Perfluordethylcyclohexane)	1 x 10"
Perfluoroindane	2×10^{14}
Perfluoro-n-heptane	2 x 10 ¹²
Perfluoromaphthalane	4 x 10 ¹³

93.

.

Products of Decomposition

The major part of the study of fire extinguishing agents at Purdue University was concerned with the determination of the flammable limits of mixtures of air, <u>n</u>-heptane and a halogen-containing compound. A plot of these data on coordinate paper showed graphically the flammable area for the three component mixtures. The peak in the curve defining this flammable area serves as a measure of the flame inhibition characteristics of the compound in question.

A knowledge of the behavior of compounds under conditions favoring decomposition is of interest in the interpretation of data relating to the toxicological properties and corrosive action. For compounds with favorable flame inhibition characteristics, this knowledge is also of interest in the advancement of the theoretical understanding of flame extinction. Decomposition in (a) a flame, (b) "hot zone" and (c) electric arc are of particular importance in a project relating to fire extinguishing agents. Therefore, in the final phases of this investigation, attention was directed to a study of the behavior of compounds chosen because of their flame inhibition characteristics under these conditions.

<u>Flame Decomposition Studies</u>. The apparatus that was used for the determinations of flammable limits was not suitable for a study of the products of combustion because the quantities of materials involved were insufficient for a total analysis. Therefore, a combustion apparatus was assembled as shown diagramatically in Figure 41.

Compressed air was regulated by the needle valve 1 to maintain a constant flow as indicated by the calibrated flowmeter 4. Propane was released from the cyclinder by means of the needle valve 2 to maintain the desired flow as shown by the calibrated flowmeter 5. The fire retarding agent was released by the needle valve from the cylinder 3 which was of 20 51. capacity. Flowmeter 6 was used to maintain a constant gas flow from cylinder 3; however, the quantity of retarding agent used was determined by difference in weight of the cylinder before and after the experiment. The burner barrel 8 was the top of an ordinary laboratory Bunsen burner, 10.7 cm. tall, 1.0 cm. inside diameter, and wall thickness of 0.1 cm. The burner was held in place by the piece of quarter inch copper tube 7. The combustion zone was at the top of the burner. The mixture was ignited by means of the spark coil 14 and electrodes 7 and 13. The flame can be observed through the small mica window 9 and the mirror 10. The large Pyrex test tube 11, 10 cm. in diameter and 18 inches deep, made an air tight seal with the rubber stopper 12. The chimney 15 was made from a piece of stainless steel tube 14 cm. long and 6 cm. in diameter. The large goose-neck 16 was made of nickel tubing 4 cm. in diameter. The bonds in the nickel tubing and nickel-stainless steel connections were welded. The choice of the nickel tubing was arbitrary and based upon material readily available. To aid in dismantling the apparatus for cleaning, flanges 17 and 19 were provided with neoprene gaskets held in place by small bolts. The 2-liter, stainless steel beaker 18 containing



Figure 49

20 ml. of distilled water collected most of the soot and a large proportion of the combustion products soluble in water. The water level in 13 must not be higher than the lower edge of 16 in order to avoid large gas bubbles which would effect the flame at 8. The gas from 18 passed by means of the stainless steel tube 20, 8 mm. inside diameter, into the 1-liter, stainless steel beaker 21 containing 600 ml. of distilled water. The lower and of 20 at 22 had small holes drilled in the walls in order to disperse the gas bubbles into a fine stream for thorough contact with the water and also to maintain a constant gas pressure at 8. The gas stream leaving 21 was free of corrosive hydrogen fluoride, but a Pyrex glass scrubbing tower 23 was provided for taking out residual scluble products that may have gotten past 18 and 21. The cold finger traps 24 were chilled with Dry Ice-trichloroethylene mixture for removal of elemental halogen or other condensible products. Samples of gas were withdrawn at 26 for analysis on a Burrell gas analyser. The last traces of soot settled out in the tube 25, 100 by 5.2 cm. The gases then passed through the West Test meter 27 and was vented to the hood at 28.

The propane and air flows were adjusted so that the resulting flame was luminous but not smokey. The halogen compound was added (as a gas) to the propane stream or to the air stream through a T-tube so as to be premixed before burning.

In all runs the flow rates of propane and air were adjusted at 0.238 and 7.18 moles per hour respectively. After the mixture was burning steadily, the fire retarding agent was introduced slowly in increasing amounts until the flame tended to go out. The amount of the fire retarding agent was then decreased slightly and the combustion was allowed to burn for the desired time. At the completion of a run, the apparatus was dismantled and the soot in 15 and 16 was brushed loose for weighing. The contents of the scrubbers 18, 21, and 23 and of the cold fingers 24 were filtered by suction and thoroughly rinsed with distilled water. The soot was dried at 110°C. and weighed. The filtrate was diluted to 2000 ml. from which aliquots were taken for chemical analysis.

Analysis data for the combustion products of several halogen compounds are summarized in Table XV.

Analytical Procedures. - Aliquots of the scrubbing solutions were taken for analysis at the completion of each run. Chloride and/or bromide ion was determined gravimetrically by precipitation with silver nitrate 19. Fluoride ion was determined gravimetrically by precipitation as calcium fluoride 29.

A Burrell De Luxe Build-Up Model J gas analyser was used for the analysis of the gaseous mixture coming from the water scrubbers 5. Carbon dioxide was absorbed in 30 per cent aqueous potassium hydroxide. Illuminants or unsaturated organic compounds were absorbed in 30 per cent oleum. Oxygen was determined by absorption in alkaline sodium hydrosulfite. Hydrogen was determined by oxidation to water. Carbon monoxide was determined by oxidation to carbon dioxide followed by absorption of the carbon dioxide in a 30 per cent potassium hydroxide solution. Total paraffins or saturated hydrocarbons were analysed by catalytically oxidizing to water

and carbon dioxide. Mitrogen was determined by difference.

Samples of gas were collected for analysis with respect to organic constituents according to the procedure which follows:

A quantity of gas, 38 to 76 liters, was scrubbed with 30 per cent potassium hydroxide and then with aqueous sodium hydrosulfite to remove carbon dioxide and oxygen, respectively. Carbon dioxide was removed to facilitate later rectification, and oxygen was removed to avoid a possible explosion hazard. The gas was passed from the scrubbers through a trap cooled with liquid nitrogen which condensed all of the organic components along with some residual oxygen and a little nitrogen. This mixture was then rectified on the Podbielniak Hyd-Robot low temperature fractionating column. In all cases, there was a large forerun of non-condensable material consisting of oxygen and nitrogen. The quantities of the various components present were calculated from the resulting rectification curves.

The results of these rectifications may be summarized as follows:

Run No. 12. - It was found that approximately 4% of carbon tetrafluoride was destroyed when it was premixed with propare and then burned in air. This value was obtained by analysis of the fluoride ion present in the hydrolysis solution. The object of this experiment was to see how much of the carbon tetrafluoride could be recovered from the combustion products by rectification. Propane and carbon tetrafluoride ware first premixed before burning in air. Flow rates of propane, carbon tetrafluoride, and air were 0.238, 0.244, and 7.18 moles per hour, respectively. After burning and stripping off the non-condensable material carbon tetrafluoride was present to the extent of 0.072 mole per 76 liters of gas. This corresponds to 63 per cent of the carbon tetrafluoride originally introduced.

Run Nos. 17 and 18. - Nineteen liters of gas collected from each run were combined for the rectification. A trace of ethane, b.p. range -87 to -88°C. was indicated. No trace of dibromodifluoromethane was found, thus indicating that it was completely decomposed.

Run No. 19 - For this experiment, 76 liters of gas were collected and three fractions were isolated. Methane, b.p. $-166^{\circ}C.$, was present to the extent of 0.0031 mole per 76 liters of gas and ethane, b.p. -86 to $-87^{\circ}C.$ was present to the extent of 0.0047 per 76 liters of gas. The third fraction, b.p. $-136^{\circ}C.$, is of unknown composition, and was present to the extent of 0.0015 mole per 76 liters of gas.

Run No. 20 - Only carbon tetrafluoride was present to the extent of 0.184 mole per 76 liters of gas. This corresponds to 56 per cent of the carbon tetrafluoride originally introduced.

Discussion of Results. - Table XV presents a summary of the results of analysis of the products of combustion. In all cases, considerable soot formation occurred except for carbon tetrafluoride and sulfur hexafluoride where only trace amounts were noted. The amount of

			9 5									
	E.	B	ъ	805	P.C	acr	13.6	14	16 ^a	180	1961	ہ ھ
Run Number	9	8	ת	2		2	2	. 55	5 03	5 63	61.7	14.8
Air, Moles	7,18	7,18	7.78	6.82 0.226	8,26 0,274	4°139		0,151	0,167	0,187	0,138	0.492
Propane, moles		CH-B-	CHrF.	CRCLF	CC1F,	CF.	C 3F6	SF6	CBr2F2	CBr2F2	CH _j Br	
Halogen compound	-	0,0918	573.	175.	ن . ا کر	0,223	0,155	ر. مرا	671		ر در ار 100 م	1.42 7 1.67
Combon a (cplcd_)		1,10	1,02	2,10	1,439	2,673	6,766	20 00	1, 748	0.379	10.6	108.7
Total halogen, g. (calcd.	~ ~	7_34	11.57	12,82 57	80 9	10243 35	40°02		24	47	35	124
Combustion time, minutes	2	3	8		5							
Combustion Products							ļ					
Analytical Data												
Scrubbing Solutions	;		1520-1	0 300/	0 510	9 Trace	0,7506	Trace	2,2551	0,7949	0.6613	0.1365
Soot,g.	None				6		91.48					
Carbon, K							0.86					
Hydrogen, 🎜		F 5	74.7		ν ν	7 0.605	4 22,85	16.64	3,14	1.74		1.32
Fluoride ion, g.			4.01)		5 E 5 C 7 C	80	•	•				
Chloride ion, g.						2			13.95	6.750	6 . 453	
Bromide ion, g.		8, 365		11.02	3 9.5	95 0 <u>.605</u>	1 22.85	16.64	17.09	8.49	6.453	1.32
Total halide ion.g.		202								•		
Gassous Mirtures after												
Water Scrubbers,												
% by volume			<i>C</i> ⁷ <i>c</i>		v o	05 8 0	10.48	5.31	4.33	5,20	5.58	10.40
Carbon dioxide	3. 38	×	¥ ~				0 0	000	0.49	0,36	0.51	0,10
Illuminnts	0,12	0.20			ייי קיי קיי	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	6.26	37.6	11.36	0.84	4-88	2.40
Oxygen	14.51	15.51			יי קר גינ			210	1.99	1.70	1,12	0.70
Hydrogen	0	*0°0	200		5 -				0.33	0,10	0°°0	0*0
Carbon Monoxide	0,16	3							0.95	0800	8.1	0.46
Total paraffins	0,50	0.85	0,20		5°8				80.55	85,00	86.49	85.54
Nitrogen	81.33	80.08	20% 7	79.0	<u>61. 11</u>	a 199 65		2 0444	for hir	n ing.		
a The propane and halog	en compo	und wer	e premi: emixed	med before	ore ente anterine	the com	bustion :	zone for	burming			
peniction and Tin ent d	by diff	erence	and may	contair	9008	inert flu	orine co	mpounds.				
												98

. Frie

2

۲.

BULLARY OF ANALYSIS OF PRODUCTS OF COURDSTION

Table XV

- A HAR AND A

. . .

soot obtained was always a little less than the amount of sarbon present in the halogen compound introduced. This suggests that soot formation arises from the halogen compound and not from the propane, a point which could be checked by burning a halogen compound containing labeled carbon. The analysis for total halide ion gives the degree to which the halogen compound is decomposed. Due to the hydrolytic action of the water scrubbers, only total halide ions were determined. Possible halogen compounds such as carbonyl halides or easily hydrolysed organic halides were not determined qualitatively or quantitatively since their structure would be destroyed by passing through water. From the results of Table XV it is apparent that all of the halogen compounds except carbon tetrafluoride tested are largely decomposed. The percentage decomposition of the halogen compound when premixed with the propane stream can be determined by dividing the calculated total halogen introduced into the tdal halide ion found by analysis of the combustion products. In Table XVI flammability peaks and per cent decomposition are tabulated for the halogen compounds tested when premixed with the propane stream. Halogen compounds having low values for the flammability peaks have high values of per cent decomposition with the exception of dibromodifluoromethane.

Halogen compounds containing bromine or chlorine in addition to fluorine were largely destroyed and since those compounds having strong fire retarding characteristics contain bromine and/or chlorine in addition to fluorine, it can be expected that they will be largely destroyed in a flame. Dibromodifluoromethane appears to be an exception to that observation since it has a flammability peak of 4.2 but is decomposed to the extent of 69 per cent (%) as determined by the quantity of halide ion formed.

In the case of sulfur hexafluoride, no total sulfur balance was obtained but free sulfur, sulfur dioxide, and hydrogen sulfide were identified. The concentration of hydrogen sulfide in the gas stream was of the order of 5 x 10^{-4} grams per liter.

There appears to be very little difference in the results obtained by introducing the halogen compound with either the air or the propane.

Examination of the results of the gas analysis in Table XV shows that the introduction of the halogen compound to the propane-air mixture is accompanied by a decrease in the completeness of combustion as evidenced by increases in the amounts of illuminants, hydrogen and carbon monoxide produced. Two exceptions are noted. Carbon tetrafluoride and octafluoropropane seem to enhance the degree of combustion as noted by the large increase of carbon dioxide produced.

<u>Pyrolysis Studies</u> - Three types of experiments were conducted in this category; namely, heating the halogen compound, in the presence of and in the absence of air, at 800°C. in an iron pipe heated to 800°C. and heating the halogen compound in a platinum tube at 800°C. in the absence of air. Details of these experiments are as follows:

99.

A

100.

.

ţ

÷

.

1

Table XVI

•

.

۰.

RELATION OF FLAMMABILITY PEAK TO PER CENT DECOMPOSITION OF HALOGEN COMPOUNDS

Halogen Compound	Flammability Peak	Decomposition, \$
CBr ₂ F ₂	4.2	69
CBrF ₃	6.1	100
CH ₃ Br	9.7	114
CC1F3	12.3	87
CHCLF2	17.9	93
C ₃ F ₈	-	80
SF6	20.5	73
CF4	26	4

Pyrolysis Studies in the Presence of Air. An iron pipe, 20 inches long and five-eights inch inside diameter, was loosely packed with about 10 grams of coarse steel wool. A 12-inch, electrically heated tube furnace was used for heating the iron pipe at $800^{\circ} \pm 10^{\circ}$ C. The temperature was measured by a thermocouple placed near the conter of the tube and on the outside between the tube wall and the heating elements. Air and the halogen compound were premixed before passing through the hot zone. In the case of liquid halogen compounds, boiling near room temperature and over, premixing was done by passing a measured amount of air through the compound in a test tube. The loss of weight of the test tube gave the amount of halogen compound used. Gaseous compounds were measured by means of calibrated flowmeters. The products from the hot tube were passed directly into a receiver cooled by liquid nitrogen. All of the organic components were condensed along with some air. At the completion of a run, the entire contents of the cold trap were rectified on a Podbielniak Hyd-Robot low temperature fractionating column.

.

والمتركف والمواصحين

Air and the helogen compound were protected from moisture but no special precautions were taken to dry the gases before pyrolysis. It was assumed that ordinary compressed air and commercial helogen compounds were sufficiently dry for all practical purposes.

The halogen compounds chosen for the pyrolysis studies contained no hydrogen in their structure. The reason for this choice was based upon the fact that there would be no hydrogen helide, expecially hydrogen fluoride, formed as a result of the pyrolysis. Hence, the gaseous pyrolytic products could be rectified directly without any danger of corroding glass apparatus.

The pyrolysis products were analysed for the organic components present in the gas stream, carbonyl halides, and carbon dioxide and oxygen. The organic components present were analysed by condensing all of the pyrolytic products in a trap cooled with liquid nitrogen and then rectifying the contents of the cold trap as already mentioned above. From a comparison of known boiling points and gas densities, the identity of the unknown fractions could be determined in most cases. The quantity of each fraction present was calculated from the rectification chart which is automatically plotted by the Podbielniak instrument.

The following procedure was used for the quantitative determination of carbonyl halides: Air and the halogen compound were passed into the hot zone as already described. Gasecus products were led through a dry Pyrex Wool filter to remove iron compounds suspended in the gas stream and then into an absorption train similar to the one described by Yant and coworkers.³³ The train consisted of a layer of calcium chloride for drying the gas, a layer of amalgamated tin for removal of elemental halogen, and a layer of mossy zine for removal of hydrogen halides. The gas then entered the carbonyl halide absorption bulbs containing water saturated with aniline and sym-diphenylures. A Wet Test meter following the absorption bulbs recorded the liters of gas passed

through. Carbonyl halides were converted to sym-diphenylures by reaction with the aniline. The sym-diphenylurea was filtered on tared Gooch crucibles was dried at 70°C. and weighed. The sym-diphenylurea was then dissolved out with 5 milliliters of warm, absolute ethanol into a tared weighing bottle. The alcohol was evaporated at room temperature and the residue was dried at 70°C. and weighed as sym-diphenylurea. The Gooch crucible was also dried at 70°C. and reweighed. The loss in weight was used as a check for the analysis. Melting points and qualitative chemical analysis of the sym-diphenylurea were made to check the purity of the product. In all cases, only traces of halogen were detected in the symdiphenylurea and the melting point found varied from 224 to 239°C. The literature value for sym-diphenylurea is 238-239°C. The amount of carbonyl halides was calculated from the weight of sym-diphenylurea as parts per million on a gas volume basis at temperatures and pressures of experimental conditions. No attempt was made to identify the exact formula of the carbonyl halide that was formed. Depending upon the halogen compound undergoing decomposition, there is a possibility of various carbonyl halides being produced and the values reported hers represent the summation of all.

In addition to the determinations of organic components and carbonyl halides, an analysis was made on some of the products using for carbon dioxide and oxygen a Burrell Gas Analysis Apparatus of the Orsat type. The values found are reported in Table XVII, along with other data for these experiments.

Rectification analyses for several of the products arc as follows:

Pyrolysis No. 3 - Carbon tetrafluoride was the only organic compound present.

Pyrolysis No. 4 - Dichlorodifluoromethane was recovered to the extent of 43.1 per cent. A second fraction boiled at -82.0°C. and had a molecular weight of 104 as determined by a gas density determination. The compound is chlorotrifluoromethane and was present to the extent of 19.3 per cent of the dichlorodifluoromethane originally introduced. A third compound boiled at -125°C. and was present in a trace amount only. The latter compound is probably carbon tetrafluoride. In addition to these compounds, a few grams of an organic solid was found at the exit end of the iron pipe. The solid was purified by sublimation and its melting point and qualitative chemical analysis were determined. The compound melted in the range 181-189°C. in a sealed tube and contains chlorine but no fluorine. The compound was established to be hexachloroethane.

Pyrolysis No. 5 - The pyrolysis of 0.274 mole of dibromodifluoromethane and 0.174 mole of air through an iron pipe at 800°C. resulted in the formation of a compound having a boiling point of -57°C. and a molecular weight of 149 as determined from the gas density. The structure of this compound was not established. The pyrolysis was also accompanied by the liberation of elemental bromine which was converted to an equivalent amount of iodine and then

and the second second

4.

Table **XVII**

			Iron at	ROO-C.						
Fyrolysis Number	~	4		\$	19 0	6	10	t‡	32	
Helogen Commund	CF.	CC1,F,	CBr ₂ F ₂	C,F	CBrF.	CH ,Br	CC1.	CBrF2CBrC1F	CC1F ₃	
Kolas	0_278	0.176	0.274	0 248	0,200	0.228	0.116	0.051	0.175	
clean.	۲	1_06	3,29	0.744	².51	1,368	0.696	0,382	1.31	
	0.347	0_347	174.0	117.7	0.174	0.347	0, 347	0.277	0.277	
oleit tre	4	2,08	2,08	2,08	2,08	2,08	2,08	2.08	2 . 0%	
Aralytical Data										
Pvrolvais Gas Vol. liters	0.6	9.57	6.76	15.3	10.5	8 . 3	7,16	5.6	8.5	
sym. Diphenylures, grams	, pu	0.0254	0,0044	0.0497	0,0012	Traca	0,056	0°0017	0,0515	
Carbonyl Halide.P.P. M. of								1	•	
Gag on Volume basis	None	344	84	422	15	Trace	1035	40	726	
Carbon Dioxide, t by vol.	6.0	3 •0	л . 0							
Oxygen, % by vol.	12.0	1. 6	1.4	г . 3						
Original Halogen Compound										
Recovered	93.2	43.1	0°0	6 7 0						

Analytical Data of Pyrolysis of Halogen Compounds and Air over

103.

١

titrated with a standard sodium thiosulfate solution. By calculation, it was found that a total of 0.733 g. of elemental bromine was formed. No dibromodifluoromethane was recovered.

Pyrolysis No. 6 -The pyrolysis of 0.121 mole of octafluoropropane and 0.347 mole of air through an iron pipe at 800°C. resulted in the recovery of 67.0 per cent of the octafluoropropane introduced. Trace amounts of compounds boiling at -86°C. and -79°C, were also present but not identified.

Pyrolysis Studies in the Absence of Air - The same apparatus was used for these experiments that was described for pyrolysis experiments in the absence of air. The amount of halogen compound used was determined by the difference in weight of a small steel cylinder before and after the experiment. The pyrolysis products from the hot zone were condensed in a trap cooled by liquid nitrogen. Generally only one pass was made through the hot zone. The product in the trap cooled with liquid nitrogen was enclysed for breakdown products by fractional distillation on the Hyd-Robot Low Temperature column.

Dichlorodifluoromethane - The pyrolysis of 0.307 mole of dichlorodifluoromethane through the iron pipe resulted in the formation of four breakdown products. Carbon tetrafluoride b.p. -130°C., was present to the extent of 0.004 mole. Chlorotrifluoromethane b.p. -82°C., was present to the extent of 0.121 mole. The recovery of dichlorodifluoromethane was 0.004 mole. A fraction boiling at -95°C. was present to the extent of 0.004 g. mole and material boiling above -18°C. was present to the extent of 0.003 mole. These materials were not identified.

The pyrolysis of dichlcrodifluoromethane (0.164 mole) through a platinum tube at 800°C. resulted in the recovery of 0.119 mole of dichlcrodifluoromethane. No other products were detected.

Octafluoropropane - The pyrolysis of 0.100 mole of octafluoropropane through the iron pipe at 800°C. resulted in the formation of 0.004 mole of unidentified material boiling at -80°C. The recovery of octafluoropropane was 0.082 mole.

The pyrolysis of 0.183 mole of octafluoropropane through a platinum tube at 800°C. resulted in the recovery of 0.164 mole of octafluoropropane. No other products were detected

Chlorotrifluoromethane - The pyrolysis of 0.363 mole of chlorotrifluoromethane through a plotinum tube at 800°C. resulted in the recovery of 0.320 mole of chlorotrifluoromethane. No other products were detected.

Bromotrifluoromethane. - Bromotrifluoromethane (0.171 mole) was passed through the platinum tube at 800°C. six times by distilling the product back and forth. Upon analysis of the final product, the recovery of bromotrifluoromethane was 0.114 mole. Elemental bromine was present to the extent of 0.003 mole. An unidentified material boiling at -91° C. was present to the extent of 0.007 mole.

Carbon Tetrafluoride - The pyrolysis of carbon tetrafluoride (C.180 mole) through a platinum tube at 800°C. resulted in the • recovery of 0.135 mole of carbon tetrafluoride. No other products were detected. It can be concluded from this series of experiments that decomposition of the halogen compounds is less extensive in the absence of air than in the presence of air. Also, more extensive decomposition is obtained in the iron tube.

Behavior of Halogen Compounds in an Electric Arc. - The object of this research was to determine the breakdown products formed by the fire extinguishing agent when subjected to an electric arc. To accomplish this, the following apparatus was constructed: A piece of Pyrex tubing, 24 mm. in diameter and 26 cm. long, was constricted in the middle to an inside diameter of 1 cm. Platinum electrodes were sealed into the tube wall in such a manner that the gap between the electrodes was directly across the constricted part. A separate cold trap was connected to each end of the Pyrex tube by means of ground glass ball joints to make an air tight seal. The system was also connected to a mercury manometer, one end of which was open to the atmosphere so that the internal pressure during the arcing process could be measured at all times. The spark source was a Model-T Ford spark coil having eight volts D.C. on the primary. For the experiments described herein, the electrode gap was 0.4 to 0.5 cm.

A quantity of the fire extinguishing agent was distilled into the system and condensed into one of the cold traps fooled with liquid nitrogen. Liquid nitrogen was chosen as a cooling medium to make certain that no possible decomposition products would escape from the system. By distilling the compound back and forth from cold trap to cold trap, the vapors were forced through the arc. After arcing, the contents of the system were analysed by rectification on the Podbielniak Hyd-Robot low temperature fractionating column.

Octafluoropropane - Octafluoropropane was subjected to five passes through the arc. Etcaing of the Pyrex tube was noticed. On rectification, the bulk of the material was found to be octafluoropropane. A trace of material boiling at -81°C. was also found.

Methyl Bromide. - Methyl bromide was subjected to a single pass. Some soot formation was noticed on the surface of the electrodes. No elemental bromine was found. On rectification the bulk of material was found to be methyl bromide. A trace of material boiling at -74 °C. was also found.

Dibromodifluoromethane. - Dibromodifluoromethane was subjected to five passes. A small quantity of elemental bromine was liberated as a result of the arcing. On rectification, the bulk of the material was dibromodifluoromethane. A trace of material boiling at -70° C. and a trace boiling at -55° C. were also found. Carbon Tetrafluoride. - Carbon tetrafluoride was subjected to seven passes. G_n rectification, only carbon tetrafluoride was found.

Bromotrifluoromethane. - Bromotrifluoromethane was subjected to seven passes. A small quantity of elemental bromine was formed as a result of the arcing. On rectification, the bulk of material was bromotrifluoromethane. A trace of material boiling at -109°C. Was also found.

Toxicity

No attempt has been made at Purdue to determine the toxicity of the substances under investigation.

The Freens have been studied extensively and, in general, they are considered to be non-toxic. Fluoroform (Freen 23) has been shown to produce no ill effect upon a guinea pig when the test animal was subjected to an atmosphere comprising 80% trifluoromethane and 20% oxygen⁹.

As a part of a cooperative research program at Purdue University a number of fluorine-containing compounds have been made avilable for evaluation as anesthetics. Many of the compounds tested have been shown to possess desirable anesthetic properties.²⁴ Among these compounds are 2-bromo-and 3-bromo-1,1,1-trifluoropropane.

The literature contains information concerning the life hazards of several materials of interest as fire-extinguishing fluids. This information may be summarized as follows:

Compound	Classification	Reference
CH 3Br	2	30
CCI4	3	30
ChCi ₃	3	30
CH2BrC1	3	31
CH ₃ CH ₂ Br	4	30
ω_2	5	30
CCI ₃ F	5	30
CCl ₂ F ₂	6	30
CCLF2CCLF2	6	30

The classifications have been defined in the following manner:

"Group 1--Gases or vapors which in concentrations of the order of 1/2 to 1 per cent for durations of exposure of the order of 5 min. are lethal or produce serious injury: sulphur dioxide.

"Group 2--Gases or vapors which in concentrations of the order of 1/2 to 1 per cent for durations of exposure of the order of 1/2 hr. are lethal or produce serious injury: ammonia and methyl bromide.

"Group 3--Gases or vapors which in concentrations of the order of 2 to 2-1/2 per cent for durations of exposure of the order of 1 hr. are lethal or produce serious injury: methyl formate, chloroform, and carbon tetrachloride.

"Group 4--Gases or vapors which in concentrations of the order of 2 to 2-1/2 per cent for durations of exposure of the order of 2 hr. are lethal or produce serious injury: dichlorethylene, methyl chloride, and ethyl bromide.

"Group 5--This group includes gases or vapors much less toxic than Group 4 and (a) more toxic than Group 6: monofluorotrichloromethane ("F-11") and carbon dioxide---and (b) those which available data indicate classifly as either Group 5 (a) or Group 6: butane, ethane, and propane.

"Group 6--Gases or vapors which in concentrations up to at least about 20 per cent by volume for durations of exposure of the order of 2 hr. do not appear to produce injury: dichlorodifluoromethane ("Freon") and dichlorotetrafluoroethane ("F-114")."

Struck and Plattner²⁷ have reported that perfluorobutane is without anesthetic activity and that it is toxic in concentrations greater than 25%. No ill effects were observed in concentrations of about 5%. Perfluorocyclopentane was found to be more toxic than perfluorobutane.

A study of the toxicological properties of several of the compounds possessing the more favorable flame inhibition properties has been initiated at the Toxicology Branch of the Army Chemical Center. A formal report covering toxicity studies has not been issued.

Physical Properties

A library research project was initiated to determine whether or not a correlation exists between the flame inhibition properties of a compound and its physical characteristics. An attempt was made to find all of the physical characteristics reported for several gases. Materials chosen for this library study may be grouped into three classifications, namely, inert gases, flammable gases and gases supporting combustion. Representative materials in each of these groups are as follows:

Inert_Gases

argon	krypton	chlorotrifluoromethane
helium	xenon	dichlorodifluoromethane
nitrogen	carbon dioxide	trifluoromethane
neon	methyl bromide	carbon tetrafluoride

Flammable Gases

methane ethane acetylene

Gases Supporting Combustion

oxygen chlorine fluorine

The appendix of this report contains tables showing data obtained in this search. Numerous attempts have been made to correlate the physical data reported in the Appendix(Tables 1 to 147 inclusive) with flame inhibition properties as indicated from the peak in the flammability curves. However, no correlation is apparent. Some of the relationships considered which were more promising than others are shown in Figures 50 to 55 inclusive. These figures show the relationship of vapor density and dielectric constants to flammability peaks.

It is our conclusion as a result of this library search that there are insufficient physical data reported for any given series of compounds to make a correlation feasible.

Test Materials

During the course of this research it has been the policy to use compounds of high purity. Whenever possible materials available from commercial supply houses have been used. Other materials were synthesized in the laboratories at Purdue following procedures which seemed most expedient. The following paragraphs summarize the source of the test compounds used on the project. Details are omitted from procedures described in the literature.

<u>Freons</u> - The following Freons were obtained from Kinetic Chemicals, Inc. and were used without further purification:

Dichlorodifluoromethane (Freon 12),	b.p.,	-30°C.
Chlorotrifluoromethane (Freon 13),	b.p.,	-82°C.
Chlorodifluoromethane (Freon 22),	b.p.,	-40°C.
Trifluoromethane (Freon 23),	b.p.,	-82.2°C.
1,1,2-Trichlorotrifluoroethane (Freon 113)b.p.,	46.5°C.
1,2-Dichlorotetrafluoroethane (Freon 114)	b.p.,	3.6°C.
Tetrafluoroethylene (Freon 1114)	b.p.,	-76.3°C.

<u>Carbon tetrafluoride</u> (b.p. -128°C.) was prepared by the vaporphase fluorination of carbon tetrachloride with silver difluoride. Before using, the carbon tetrafluoride was purified by rectification on a Podbielniak Heli-Grid low temperature column. In addition, carbon tetrafluoride was obtained from the New Products Division, Minnesota Mining and Manufacturing Co., St. Paul, Minnesota.



Figure 57 Relationship between Dielectric constant and Flammsbility Peak

109.

500



•

i i

. .



DIELFOTRIC CONSTANT & 10⁻³ Aigure 52 Gelationstir between Dielectric Constant and Flarmability reak

3

111.

.: *.



112.

7

Figure 53 Relationship between Vapor Density and Flammability Peak



Figure 54 Relationship between Vapor Density and Flammability Peak



114.

1

Figure 55 Relationship between Vapor Density and Flammability Peak

<u>Carbon tetrachloride</u> (Fire Extinguishing Grade) was made available through the courtesy of the Purdue Physical Plant.

<u>Bromotrifluoromethane</u> (b.p. -60° C.) was prepared by the thermal bromination of trifluoromethane (Freen 23)³. The reaction was carred out at 600°C. in a glass tube packed with glass beads.

1. CHF₃ + Br₂ +++++++++++ CBrF₃ + HBr

Also a part of the bromotrifluoromethane was supplied by the Army Engineers.

<u>Trifluoroiodomethane</u>. (b.p. $-22.5^{\circ}C_{\cdot}$) was pre-ared from carbon tetraiodide and iodine pentafluoride, following a procedure described by Emeleus and coworkers⁶. Reactions involved in this synthesis are illustrated by equations 2, 3, and 4:

> 2. $CCl_4 + CH_3I \rightarrow Alcl_3 \rightarrow CI_4 + CH_3Cl$ 3. $I_2 + F_2 \rightarrow IF_5$ 4. $CI_4 + IF_5 \rightarrow CF_3I + I_2$

The procedure used in the preparation of carbon tetraiodide was adapted from the one described by Soroos and Hinkamp²⁶. The techniques involved are illustrated by the following example: Two hundred and sixteen grams (1.4 moles) of carbon tetrachloride and 936 g. (6,6 moles) of methyl iodide were mixed in a 2-liter, 3-necked flask equipped with a motor driven stirrer, a brine-cooled condenser, and a nitrogen inlet. Before mixing, the carbon tetrachloride and the methyl iodide were dried by distilling from anhydrous aluminum chloride. Aluminum chloride mole, 4. g.) was added to the solution and the flask flushed with dry nitrogen for 10 minutes. The mixtue was heated rapidly to 42°C. (about 10 minutes), and the temperature maintained at 42°C. uctil only a small amount of methyl iodide remained in the flask (approximately 60 minutes). Then 400 ml. of 20% sodium bisulfite was added to the reaction mixture in the flask. The mixture was filtered and the residue washed with copious amounts of sodium bisulfite solution. The carbon tetraiodide was placed in a crystallizing dish and washed with distilled water. The wet carbon tetraiodide was placed in a vacuum desicator and dried for several days. Seven hundred and two grams (1.35 moles) of dried carbon tetraiodide was obtained, representing a yield of 97% based on the carbon tetrachloride used.

Indine pentafluoride (b.p. 97° C.) was prepared by direct union of the elements, indine and fluorine. In a typical experiment, 1.5 lb. of indine was placed in a nickel tube, 36 in. long and 1 in. in diameter, surrounded by a water jacket. Fluorine from 3 cells operated at 30 amperes was passed into the tube for a period of 6 hours, at the end of which time the indine pentafluoride was distilled from the reactor. The distillation was conducted in an atmosphere of fluorine. Approximately 500 g. of indine pentafluoride was obtained, representing a yield of 84%, based upon the indine charged to the reactor.

Trifluoriodomethane was prepared from carbon tetraiodide by a helogen exchange reaction using iodine pentafluoride. In a typical experiment, 160 g. of theroughly dried carbon tetraiodide was placed in a 2-liter, 3-necked flask equipped with a mercury sealed stirrer, a dropping funnel, and a condenser connected in series with a receiver cooled by a mixture of Dry Ice and trichloroethylene. The flask and its contents were cooled to 0°C. and 60 g. of iodine pentofluoride was added dropwise during a period of 30 minutes. No change in temperature was observed during the period in which iodine pentafluoride was added. The mixture was heated to 90-100°C. within 45 minutes, during which time large quantities of vapors were evolved. The products from 3 such experimonts were combined, and approximately 60 g. of trifluoroiodomethane was obtained representing a yield of 33%. Yields as high as 65% were obtained in later experiments. In conducting these experiments, it was observed that the desired reaction does not proceed if the reagents are not anhydrous.

Other experiments which were tried and which were not productive of the desired trifluoroiodomethane include the halogen exchange reaction between carbon tetraiodide and antimony trifluoride, in the presence of and in the absence of antimony pentachloride. Carbon tetraiodide was recovered. These experiments were conducted under conditions known to give the desired halogen exchange reaction with carbon tetrachloride and with carbon tetrabromide.

<u>Dibromodifluoromethane</u> (b.p., 24.5°C.) was prepared in accordance with the following sequence:

5. $3CBr_4 + 2SbF_3 \longrightarrow 2CBr_2F_2 + 2SbBr_3$

Two hundred grams of carbon tetrabromide was ground with 500 g. of antimony trifluoride and the mixture was placed in a 3-necked flask fitted with a stirrer and a water condenser. The temperature of the condenser water was adjusted to about 25°C. to permit the distillation of dibromodifluoromethane from the reaction mixture as formed. The reaction mixture was heated, with stirring, to 120°C. until all of the halogenated methanes had been distilled off and collected in receivers cooled in ice water. The product was washed with ice cold sodium hydroxide solution and then with ice water. After drying over anhydrous sodium sulfate, it was rectified and 74 g. of dibromodifluoromethane was obtained. There was a residue of about 7°g. of tribromofluoromethane which apparently had been entrained through the water condenser.

<u>Tribromofluoromethane</u> (b.p. 106°C.) was prepared in accordance with the following equation:

6. $3CBr_4 + SbF_3/Br_2 \longrightarrow 3CBr_3F + SbBr_3$

Carbon tetrabromide (200 g.) was mixed with 400 g. of antimony trifluoride and the mixture was placed in a 3-necked flask equipped with a Hirschberg stirrer and an air-cooled condenser which was connected in sories with receivers cooled by wet ice and by Dry Ice. About 5 ml. of bromine was added to the mixture in the flask and the mixture was warmed with stirring to 100°C. Tribromofluoromethane distilled from the reaction flask as formed and collected in the ice cooled receiver. The material was we shed with a cold concentrated sodium hydroxide solution and dried over anhydrous sodium sulfate. Upon rectification at atmospheric pressure, there was obtained 79 g. of tribromofluoromethane representing a yield of 49%.

<u>Bromochlorodifluoromethane</u> (b.p., -6°C.) was obtained by thermal bromination of chlorodifluoromethane (Freen 22). The reaction involved may be illustrated by the following sequence:

7. CHClF₂ + Br₂ +++++++ CBrClF₂ + HBr

A Vycor tube, 5 cm. by 2.5 cm., was packed with Kimble glass beads 5 mm. in diameter. This reactor was placed in an electric furnace and heated to 570°C. Chlorodifluoromethane was introduced below the surface of liquid bromine maintained at a temperature of 40-50°C. The mixture of bromine and chlorodifluoromethane was then passed into the reactor. The effluent gases were scrubbed with aqueous sodium hydroxide (20%), dried by anhydrous calcium chloride and finally condensed in a receiver cooled by Dry Ice. Upon rectification of the product which collected in the receiver there was obtained 43 g. of chlorodifluoromethane, 77 g. of bromochlorodifluoromethane and 47 g. of dibromodifluoromethane.

Chloroform (b.p. 61.2°C.: m.p. -63.5°C.) was obtained from the Dow Chemical Company. It was used without further purification.

<u>Bromodifluoromethane</u> (b.p. -14.5°C.) was obtained from the Army Engineers and was used without further purification.

<u>Dibromofluoromethane</u> (b.p. $65^{\circ}C_{\circ}$) was prepared in accordance with the following equation:

8. 3CHBr₃ + SbF₃/Br₂ ++++++++ 3CHBr₂F + SbBr₃

Bromoform (CHBr; 253 g.) was mixed with antimony trifluoride (330 g.) and the slurry was poured into a 3-necked flask equipped with a stirrer and an air-cooled condenser connected in series with a receiver cooled by wet ice and by Dry Ice. About 5 ml. of bromine was added and the mixture was heated with stirring to 110°C. Dibromofluoromethane distilled from the reaction vessel as formed and collected in the ice-cooled receiver. The distillate was wambed with cold concentrated sodium hydroxide solution and dried over anhydrous sodium sulfate. Upon rectification at atmospheric pressure, there was obtained 64 g. of dibromofluoromethane representing a yield of 46%.

Dichloromethane (b.p., 40-41°C.) was obtained from the Eastman Kodak Company and used without further purification.

<u>Dibromomethane</u> (b.p. 98.5°C) was obtained from the Columbia Organic Chemicals Inc. This material was rectified before using. <u>Bromochloromethane</u> (b.p. 68-69°C.) was obtained from the Michigan Chemical Company and from the Columbia Organic Chemical, Inc. These materials were used without further purification.

<u>Methyl Bromide</u> (b.p., 4.5°C.) was obtained from the Mathieson Company and used without further purification.

<u>Methyl Iodide</u> (b.p., 42.4°C.) was obtained from the Paragon Testing Laboratories and used without further purification.

<u>Hexafluoroethane</u> (b.p. -78°C.) was made available for test purposes on this project after it was obtained on another project as a by-product in the synthesis of chlcropentafluoroethane by the reaction between 1,1,2-trichlorotrifluoroethane and silver difluoride.

<u>1,2-Dibromotetrafluoroethane (b.p. 46.4°C.) and Bromopenta-</u> <u>fluoroethane (b.p., -23°C.)</u> were prepared in accordance with the following reaction sequence:

9. CF2=CF2 + Br2 ++++++ CBrF2CBrF2

10. 2CBrF₂CBrF₂ + 2AgF₂ ++++++ 2CF₃CBrF₂ + 2AgF + Br₂

1,2-Dibromotetrafluoroethane was prepared by the addition of bromine to tetrafluoroethylene following the procedure described by Ruff²⁵. The following example is illustrative of the technique used. Bromine vapors and tetrafluoroethylene were mixed in a reaction chamber illuminated with one 200 Watt incandescent lamp. The rate of introduction was such that the bromine color disappeared as a result of addition to tetrafluoroethylene. After 3 moles of bromine had been utilized, the crude product was washed with cold sodium hydroxide solution to remove excess bromine. The organic product was then steam distilled, dridd over calcium chloride and rectified. Six hundred and forty-three grams of 1,2-dibromotetrafluoroethane was obtained, representing a yield of 83% based on bromine consumed.

Lead tetrafluoride was tried for the halogen exchange reaction to convert 1,2-dibromotetrafluoroethane to bromopentafluoroethane. However, after several attempts proved unsuccessful, efforts were directed to the use of the more active silver difluoride. In the first experiment with silver difluoride, 75 g. of 1,2-dibromotetrafluoroethane was passed over silver difluoride maintained at a temperature of 110°C. The time required for the addition of the organic material was one hour. The effluent gases were passed from the reactors into a receiver cooled by wet ice and then into a receiver cooled by Dry Ice. Approximately 10 ml. of product collected in the Dry Ice-cooled receiver. There was some evidence indicating that the dibromotetrafluoroethane decomposed to give bromine and tetrafluoroethylene. A second experiment was conducted in which 75 g. of the dibromotetrafluoroethane was passed over silver difluoride at 75°C. The time for introducing the 1,2-dibromotetrafluoroethane was 0.5 hour. Approximately 20 ml. of product was obtained from

-
this experiment. The products from these two experiments were combined, scrubbed free of bromine by bubbling through sodium hydroxide, and dried by contacting the vapor from the scrubber with phosphorus pentoxide. Rectification on a low temperature column gave 28 g. of bromopentafluoroethane boiling at -23°C.

Pentafluoriodoethane (b.p., 16-16.5°C) Emeleus and coworkers⁶ reported the preparation of pentafluoroiodoethane by the reaction of iodine pentafluoride with acetylenetetraiodide. After a consideration of available materials and reactions involved, it was decided to prepare a quantity of this compound for testing with respect to fire extinction properties by the reaction of iodine pentafluoride with tetrafluoro-1,2diiodoethane. Several experiments were performed and the following example may be considered typical of the techniques involved: Fifty grams of tetrafluoro-1,2-diiodoethane was placed in a one-liter, 3-necked flask equipped with a stirrer, a dropping funnel, and a condenser connected in series to a wash bottle containing a 5% solution of sodium hydroxide and a receiver which was cooled by a mixture of Dry Ice and trichloroethylene. Thirty-one grams of iodine pentafluoride was added dropwsie over a period of 15 minutes. The mixture was heated to 70°C. within 20 minutes, during which time a small amount of gas was evolved. The temperature was then raised rapidly to 75°C. (about 5 minutes) and maintained at 75 to 82°C. until the evolution of gases ceased. Approximately 24 g. of pentafluoroiodoethane, boiling at 16-16.5°C., was obtained. This represents a yield of 69%.

<u>Tetrafluoro-1,2-Diodeethane</u> (b.p., 112°C.) was prepared by adding iodine to tetrafluoroethylene, according to the procedure of Reasch²² and illustrated by the following sequence:

11. $CF_2 = CF_2 + I_2 \xrightarrow{} CF_2 I CF_2 I$

One pound of iodine and one pound of diethyl ether were mixed in a 2-liter iron autoclave. After securing in position, the autoclave and its contents were heated to 60°C. Then portion of the ether was discharged to remove the air which was in the autoclave and tetrafluoroethylene was added from a cylinder to a pressure of 330 lb./sq. in. The autoclave and its contents were rocked for 7 hours, during which time a pressure drop of 30 lb./sq. in. Was observed. Tetrafluoroethylene was added at frequent intervals during the next 48 hours, so that a pressure of 330 lb./sq. in. was maintained. After discharging the fixed gases, the autoclave was opened, and the contents were poured onto crushed ice. No free iodine was present. The organic material was steam distilled from a sodium thiosulfate solution. The diethyl ether was removed by distillation at atmospheric pressure, and the 1,2-diodotetrafluoroethylene was distilled at reduced pressure.

<u>2-Bromo-1,1,1-trifluoroethane</u> was prepared in accordance with the following sequence:

12. $CH_2C1CHCl_2 + NaOH \rightarrow CH_2=CCl_2 + NaCl + H_2O$

13. CH2=CCl2 + Br2 + ++++++++ CH2BrCBrCl2

14. $CBrCl_2CH_2Br + HF/SbCl_5 \rightarrow CF_3CH_2Br$

In brief, this process involved the dehydrochlorination of 1,1,2-trichloro-ethane to form 1,1-dichloroethane which was converted to 1,2dibromo-1,1-dichloroethane by the reaction with bromine. 1,2-Dibromo-1,1-dichloroethane was converted to 2-bromo-1,1,1-trifluoroethane using the hydrogen fluoride in the presence of antimony pentachloride. This latter step represents a modification of a procedure described in the literature.¹⁴

<u>1,2-Dibromo-2-chloro-1,1,2-trifluoroethane</u> (b.p., 93-94°C.) was obtained from the Army Engineers and was used without purification.

<u>1,2-Dibromo-1,1-difluoroethane</u> (b.p. 94; m.p. -56.5°C.) was obtained from the Army Engineers and was used without further purification.

<u>2-Bromo-l-chloro-l,l-difluoroethane</u> (b.p., 68°C.) was prepared from vinylidene chloride in accordance with the following sequence:

15. $CCl_2=CH_2 + Br_2 \rightarrow \cdots \rightarrow CBrCl_2CH_2Br$

16. $CBrCl_2CH_2Br + SbF_3/SbCl_5 + CClF_2CH_2Br + SbBr_3$.

Bromine was added dropwise to an equivalent amount of vinylidene chloride contained in a 3-liter, 3-necked flask. The rate of addition of bromine was controlled by the rate of the reaction as evidenced by the disappearance of the color of bromine from the contents of the flask. After the reaction was essentially complete, the product was washed with dilute sodium hydroxide to remove excess bromine and then with water. The dried product, essentially 1,2-dibromo-1,1-dichloroethane, was used in subsequent fluorinations.

A one-liter, 3-necked flask was fitted with a Hershberg stirrer and a Vigreaux column. 1,2-Dibromo-1,1-dichloroethane (300 g.) and antimony trifluoride (260 g.) were mixed in the flask and then antimony pentachloride (25 g.) was added slowly with stirring. The mixture was heated rapidly and the product allowed to distill from the flask. The distillate was treated with a small amount of sodium bisulfite and steam distilled. The organic layor was washed with water and dried over anhydrous sodium sulfate. Upon rectification there were obtained 51 g. of 2-bromo-1-chloro-1,1-difluoroethane and 110 g. of 2-bromo-1,1-dichloro-1-fluoroethane representing a 245 conversion of 1,2-dibromo-1,1-dichloroethane to 2-bromo-1-chloro-1,1-difluoroethane.

<u>1-Bromo-2-chloroethane</u> (b.p. 106.7°C.) was obtained from the Eastman Kodak Company and was used without further purification.

<u>Ethyl Bromide</u> (b.p. 38.4°C.; m.p. -117.8°C.) was obtained from the Dow Chemical Company and used for test purposes without further purification. <u>Ethyl Iodide</u> (b.p. 72.4°C.; m.p. -117.8°C.) was obtained from Columbia Organic Chemicals, Inc. The material was used for determination of fire extinction properties without purification.

<u>2.2-Difluorovinyl bromide</u>. (b.p. +6°C.) was prepared by the dehydrochlorination of 2-bromo-1-chloro-1,1-difluoroethane as illustrated in the following equation.

17. $CClF_2CH_2Br + NaCH \rightarrow CF_2=CHBr + NaCl + H_2O$

2-Bromo-1-chloro-1,1-difluoroethane was added dropwise to an alcoholic solution of sodium hydroxide at 60°C. The solution was contained in a 1-liter, 3-necked flask equipped with a dropping funnel, a stirrer and a reflux condenser. Difluorovinyl bromide distilled from the reaction mixture as formed and collected in a receiver cooled by a mixture of Dry Ice and trichloroethylene. The difluorovinyl bromide was purified by rectification. Due to the rapidity with which difluorovinyl bromide undergoes polymerization, the purified material was stabilized with hydroquiunone.

Vinyl bromide (b.p. 16°C.) was prepared in accordance with the following sequence:

18. $CH_2BrCH_2Br + KOH/C_2H_5OH \rightarrow CH_2=CHBr + KBr + H_2O$

A solution of potassium hydroxid in ethanol was charged into a 3-necked, round-bottom flask equipped with a dropping funnel, a motor driven stirrer and a reflux condenser. The reflux condenser was connected in series with a receiver cooled by web ice. 1,2-Dibromoethane was added dropwise from a separatory funnel and the vinyl bromide, distilling cut as formed, was collected in a receiver cooled by ice. Vinyl bromide was purified by rectification through a low temperature column.

2-Chloro-1,1,1-trifluoropropane (b.p. 30°C.) and 3-chloro-1,1,1trifluoropropane (b.p. 45°C.) were prepared by the chlorination of 1,1,1trifluoropropane¹³.

<u>2-Bromo-1,1,1-trifluoropropane (b.p. ?6.5°C.) and 3-bromo-1,1,1-</u> trifluoropropane (b.p. 62°C.) were prepared in accordance with the following sequence:

> FeCl₃ 19. $CH_2ClCRClCH_3 + Cl_2 \xrightarrow{\text{recl}_3} CHCl_3CHClCH_3 \rightarrow HCl$ 20. $CHCl_2CHClCH_3 + NaCH \xrightarrow{\text{rec}_3} CCl_2=CHCH_3 + NaCl \rightarrow H_2O$ 21. $CCl_2=CHCH_3 + 3HF \xrightarrow{\text{rec}_3} CF_3CH_2CH_3 + 2HCl$ 22. $CF_3CH_2CH_3 + Br_2 \xrightarrow{\text{rec}_3} CF_3CHBrCH_3 + CF_3CH_2CH_2Br + HDr$

1,2-Dichloropropane (propylene chloride was chlorinated in the liquid phase and in the presence of ferric chloride to produce polychloropropanes, a large proportion of which was 1,1,2-trichloropropane. 1,1-

121.

Dichloropropene was prepared from the 1,1,2-trichloropropane by dehydrochlorination using aqueous sodium hydroxide. 1,1-Dichloropropene was converted to 1,1,1-trifluoropropane by treatment with an excess of hydrogen fluoride at autogenous pressure and at about 125°C. The thermal bromination of the trifluoropropane at about 600°C. resulted in the formation of a mixture containing both 2-bromo- and 3-bromo-1,1,1-trifluoropropane¹⁶.

2-Bromo-1,1,1-trifluoropropane can also be prepared by the fluorination of 1,2-dibromo-1,1-dichloropropane with antimony trifluoride containing elmental bromine ccording to the reaction sequence outlined in equations 23 and 24.

23. $CCl_2 = CHCH_3 + Br_2 \rightarrow CBrCl_2CHBrCH_3$

24. CBrCl_CHBrCH_3 + SbF_3 - Br2 - CF_3CHBrCH_3 + SbBrCl_2

<u>2-Bromo-l-chloro-l,l-difluoropropane</u> (b.p. 68°C.) was prepared by the fluorimation of 1,2-dibromo-l,l-dichloropropane with antimony trifluoride and elemental bromine. The reactions involved may be illustrated by the following sequence.

25. $CCl_2=CHCH_3 + Br_2 \longrightarrow CBrCl_2CHBrCH_3$

26. $CBrCl_2CHBrCH_3 + SbF_3 \rightarrow Br_2 \rightarrow CClF_2CHBrCH_3 + SbBrClF$

<u>1-Bromo-2,2-diFluoropropane</u> (b.p., 76°C.) was prepared in accordance with the following sequence:

27. $CH_2ClCHClCH_3 + KOH \rightarrow CH_2=CClCH_3 + KCl \rightarrow H_2O$

28. $CH_2 = CClCH_3 + Br_2 + \cdots + CH_2BrCBrClCH_3$

29. Gl₂BrCBrClCH₃ + SbF₃/Br₂ + + + CH₂BrCF₂CH₃ + SbBr₃.

2-Chloropropene (CH₂=CClCH₃) was prepared by the dehydrochlorination of 1,2-dichloropropane following a procedure described by Reboul²³.

A one-liter, 3-necked flask was equipped with a mercurysealed stirrer and a dropping funnel. The flask was surrounded by icewater and then charged with 1.44 moles of 2-chloropropene. Liquid bromine (1.44 moles) was added dropwise from the separatory funnel. After the reaction was essentially complete, the flask was fitted with a condenser set downward for distillation. Then a mixture of antimony trifluoride (1.44 moles) and bromine (1.44 moles) was added to the contents of the flask. The mixture was heated with stirring until the flask was free of bromine vapors. The product which collected in the ice-cooled receiver was steam distilled from aqueous sodium hydroxide. After drying, the product was rectified. Seventy-six grams of 1-bromo-2,2-difluoropropane was obtained.

CARLES & STORES

<u>1-Bromopropune</u> (t.p. 70.8°C.; m.p. -109.9°C.) used for test purpose was obtained from Halogen Chemicals, Inc. and used without further purification.

2-Bromopropene (b.p. 48.4°C.; m.p. -125°C.) was obtained from the Halogen Chemicals Company. It was used without further purification.

<u>Perfluorobutane</u> was prepared by the fluorination of 1-bromobutane with silver difluoride at temperatures ranging from 200-300°C. The product from the fluorination was washed with a sodium hydroxide solution to remove acidic materials and then with a solution of potassium permanganate to remove unsaturated compounds. The perfluorobutane was dried prior to rectification on a highly efficient column.

Octafluorocyclobutane (FC-318) (b.p. -5°C.; m.p. -48°C.) was obtained as a research sample from the Jackson Laboratories of the E. I. duPont de Nemours Co., Inc. This material was used without purification.

Benzotrifluoride (b.p. 102.5°C.) was obtained from the Hooker Electrochemical Company.

<u>Perfluoro(ethylcyclohexane)</u> (b.p. 99.5°C.) perfluoronaphthalane, (b.p. 140°C.) perfluoroindane (b.p. 116-117°C.), perfluoro(methylcyclohexane) (b.p. 75-76°C.) and perfluoroheptane (b.p. 82.4°C.) were propred by the flucrimation of ethylbenzene, naphthalene, indene, toluene, and <u>n</u>-heptane respectively.^{1,4,11,18} These reactions were carried out in the vapor phase using silver difluoride as a fluorinating agent. The hydrocarbon was fluorinated with the silver difluoride at 200-250°C. and then the product from the first pass recycled over silver difluoride at 300-350°C. Cobalt trifluoride could have been used with equal facility. However, a higher temperature would have been required to insure complete conversion to a saturated, hydrogen-free material.

<u>Perfluorc(1.)-cimethylcyclohexane</u>) was prepared according to the following sequence.



123.



Commercial xylene is a mixture comprising essentially <u>m</u> (about 70%) and <u>p</u> (about 20%) xylenes²¹. This mixture contains some o-xylene as well as some ethylbenzene. In order to obtain perfluoro(1,3-dimethylcyclohexane) free of isomeric materials the sequence outlined in equations 30-34, inclusive, was followed in accordance with procedures described previously,^{1,11,12,13,17,21}



Para xylene from the Oronite Chemical Company was chlorinated photochemically to produce 1,4-bis(trichloromethyl)benzene, (m.p. 112°C.) which was purified by recrystallization. The 1,4-bis(trichloromethyl)benzene was treated with hydrogen fluoride and antimony pentachloride at room temperature to produce 1,4-bis(trifluoromethyl)benzene which was converted to perfluoro(1,4-dimethylcyclohexane) by vapor-phase fluorination with silver difluoride. <u>Heptad cafluoro(N.N-diethvlpropylamine)</u> was obtained from the Minnesota Mining and Manufacturing Company as a research sample. It was used as such without purification.

<u>Ethyl trifluoroacetate</u> (b.p., 61.7°C.) was prepared by the simultaneous hydrolysis and esterification of sodium trifluoroacetate. The reactions involved in this synthesis may be illustrated by the following sequence:

39. $CF_3CO_2Na + H_2SO_4 + C_2H_5OH + + + + + CF_3OO_2C_2H_5 + NaHSO_4 + H_2O_4$

In carrying out the reaction, an excess of both sulfuric acid and ethanol was used and the reaction was forced to completion by the continuous distillation of the product from the reaction mixture. The distillate was treated with anhydrous calcium chloride at 0°C. to remove residual alcohol and distilled from a small amount of phosphorus pontoxide.

<u>Nitrogen Trifluoride</u> (b.p. -110°C.) was prepared by the vaporphase fluorination of ammonia using silver difluoride. Nitrogen trifluoride was purified by scrubbing with aqueous alkali, drying and rectifying.

<u>Silicon tetrachloride</u> (b.p. 57.6°C.; m.p. -70°C.) was obtained from the Stauffer Chemical Company and was used without further purification.

<u>Hydrogen bromide</u> (b.p. -67° C.) was prepared by the reaction between bromine and tetralin. In the preparation of hydrogen bromide 135 ml. of bromine added slowly to an excess of tetralin contained in a Florence flask. The gas evolved was dried by passing it through calcium chloride and collected in traps cooled by Dry Ice. To prevent bromine from pessing over with the reaction product an ice trap was utilized together with water cooling of the reaction flask.

<u>Hydrogen Chloride</u> (b.p. -85°C.) was obtained from the Hanshaw Chemical Company and used without further parification.

<u>Phosphorus Trichloride</u> (b.p. 75.9°C.) was obtained from the Mallinckrodt Chemical Company and used without further purification.

Carbon Dioxide was obtained from the Liquid Carbonic Company.

<u>Other Materials.</u> Most of compounds evaluated with respect to their fire axtinction properties have been either halocarbons or halohydrocarbons. The desirability of preparing and evaluating representative compounds from other classes of materials is evident from an inspection of the few data available from the evaluation of such compounds. Considerable effort has been directed to the preparation of fluorinated derivatives of ether, sulfides, silicones and amines. The proposed methods of synthesis of these compounds and a discussion of the progress and failures to date are reported herein.

125.

Fluorinated Ethers. It was decided to attempt the preparation of fluorinated dimethyl ethers by two methods which are described by the following equations:

> 40. $CF_{3}I + NaOCH_{3} + CH_{3}OCF_{3} + NaI$ 41. $2CF_{3}I + Ag_{2}O + CF_{3}OCF_{3} + 2AgI$ 42. $CH_{3}OH + HCl + CH_{2}O + ClCH_{2}OCH_{3} + H_{2}O$ 43. $ClCH_{2}OCH_{3} + Cl_{2} + C_{2}H_{2}Cl_{4}O$ 44. $C_{2}H_{2}Cl_{4}O + SbF_{3} + C_{2}H_{2}F_{4}O + C_{2}H_{2}ElF_{3}O$ 45. $C_{2}H_{2}F_{4}O + Cl_{2} + Cc_{2}Cl_{2}F_{4}O$ 46. $C_{2}H_{2}ClF_{3}O + Cl_{2} + Cc_{2}Cl_{3}F_{3}O$ 47. $C_{2}Cl_{2}F_{4}O + MF_{x} + Cc_{2}Cl_{2}F_{4}O + Cc_{2}ClF_{5}O + Cc_{2}Cl_{5}O + Cc_{2}Cl_{5}O + Cc_{2}F_{6}O + Cc_{2}ClF_{5}O + Cc_{2}F_{6}O + Ccc_{2}F_{6}O + C$

The method of equations 40 and 41 represents the more direct approach and accordingly experiments were performed in which an attempt was made to react trifluorcmeinyl iodide with sodium methoxide and with silver oxide. The reactions when carried out in Carius tubes usually ended with the demolition of the tubes, indicating the formation of hexafluoroethane. One experiment was conducted in a small nickel autoclava. Forty grams of trifluoroiodomethane, 26 g. of silver onlde and 20 g. of methanol were placed in a small nickel autoclave and heated av 50°C. for 96 hours and then at 100°C. for 24 hours. The autogenous pressure had reached 600 lb./sg. in. at 100°C. and was 200 lb./sg.in. at room temperature. The subsclave was connected to a series of traps and the valve was opened. No gas was collected in the Dry Ice traps and upon heating the autoclave a q inity of methanol was conjected. The autoclave was opened and the solid was removed. The solid material gave a positive test for silver iodide but also seemed to have hydrogen fluoride occluded on the surface. The fact that there was a pressure increase during the reaction and yet no gas was collected in the Dry Ice traps indicated that a more complicated reaction had taken place than expected from equation 41. It appears that a metallic surface is not beneficial to the desired reaction. Since no glass lined autoclave was available and since only small quantities of materials could be used in the Carius tubes it was decided to abandon this approach.

The synthesis concerned with the preparation of the polychlorinated dimethyl others as the intermediates was considered the next logical approach to the preparation of the desired polyfluorinated dimethyl others. Monochloromethyl other was chosen as the starting material and four kilograms were prepared by the directions given in Organic Synthesis⁷. The next step in the preparation of fluorinated methyl others was the preparation of polychlorinated methyl others from the monochloromethyl other. Booth: mentioned the preparation of polychlorinated methyl ethers but does not give experimental details. It was found that in the presence of carbon tetrachloride and ultraviolet radiation further chlorination of monochloromethyl ether with chlorine could be achieved. A typical preparation is as follows: Three hundred grams of monochloromethyl ether was placed in a large glass tube 4 feet long and 2 inches in diameter and equipped with cooling coils, a gas dispersion disc and a reflux condenser. Two hundred and fifty grams of carbon tetrachloride was added and chlorine was passed into the solution for 20 minutes at -15°C., and for 16 hours at approximately 35 to 40°C. The solution was dried with calcium chloride and fractionated. There was obtained 300 grams of polychlorinated dimethyl ether boiling at 128 to 130°C, and 100 grams of dichloro(dimethyl ether) boiling at 102 to 105°C. It has not been determined if the higher boiling fraction is the tri- or tetrachloro(dimethyl ether). There are conflicting reports in the literature as to the boiling points of the two materials.

Booth² gives the preparation of fluorinated dimethyl ethers by the reaction of antimony trifluoride with the polychlorinated methyl ethers. Three hundred grams of the polychlorinated ether was placed in a 500 ml., round-bottom, 3-necked flask equipped with a stirrer, a condenser and a nitrogen inlet. Five hundred grams of antimony trifluoride was added and the mixture was heated at reflux for several hours. There was obtained 25 grams of material boiling at 30-31°C. and 7 grams of material boiling at 53°C. This would indicate that the starting material was trichloro(dimethyl ether) since the boiling points correspond to these given by Booth for trifluoro(dimethyl ether) and chlorodifluoro-(dimethyl ether.)

Fluorinated Sulfides. Among the sulfur compounds desired for evaluation ... ith respect to their fire extinction properties were the following: CClF₃S, CF₃SF₅, CF₃SF, CF₃SCF₃, and (CF₃)₂SF₄. The proposed mothods of synthesis of these compounds are given by the following unbalanced equations:

49. $CS_2 + Cl_2 + CCl_3 + CCl_3 + CCl_3 + CCl_2 + Ccl_3 + Ccl_3 + Ccl_2 + Ccl_3 + Ccl_4 + Ccl_2 + Ccl_4 + Cccl_4 + Ccl_4 + C$

57. $C_2H_2F_4S + Cl_2 \rightarrow \cdots \rightarrow C_2Cl_2F_4S$

58. C2C12F4S + SbF3 + ++++++ C2F6S

59. $Gi_3SCH_3 + HF_{\pm} \rightarrow \cdots \rightarrow (CF_3)_2S + CF_3SF_5 + (CF_3)_2SF_4$

Several attempts were made to prepare thiocarbonyl perchloride (CCl₃SCl) without success by the method given in Organic Synthesis⁸. No explanation has been found and this particular synthesis has been abandoned.

The chlorination of dimethyl sulfide has been done by Moos²⁰. However, upon chlorination of dimethyl sulfide, products were obtained whose boiling points were different from these given by Mcos.

Fluorinated Amines. In order to make the study on amines more complete, it was decided to attempt the preparation of perfluoro(trimethyl amine). Ten experiments were performed in which trimethylamine was fluorinated to various degrees by passing the compound over fluorides consisting of ether lead tetrafluoride, cobolt trifluoride or silver difluoride. The experiments were varied with respect to temperature and time of contact. From the ten experiments approximately 70 grams of a material boiling at 30-33°C. and analyzing for 6.9% N, 19.4% C and 1.6% H as compared to 6.33% N, 16.28% C and 0% H for perfluoro(trimethylamine) was obtained. This material was recycled over cobalt trifluoride at 180-200°C. The resulting product was rectified on a low temperature column. Seven fractions were obtained and are as follows:

Weight of distillate (g.)	Boiling Range (°C.)
Less than 1.0	below -15.0
5.0	-14.0 to +7.0
5.0	+7.5 to 15.0
9.0	15.0 to 27.0
Less than 1.0	27 to 40
1.9	40 to 65
7.5	65 to 70

Since these experiments were not indicative of better results, further work was abandoned.

Performance Tests

Early in this research program it was mutually agreed that large scale tests should be conducted at Fort Belvoir and not at Purdue. This report would not be complete without including results of some actual tests. These results, supplied by the research group at Fort Belvoir, are summarized in Table XVIII. An inspection of these data in this table bear out the conclusion that bromofluerocarbons are effective fire extinguishing agents. The correlation between the peak in the flammability curve (Table I) and the behavior of these materials in extinguishing a two fire is not readily apparent. However, if the

1.0

TEC 4 N. Belvoir, Ft. Belvoir, Va.

.

مړ

Weight Effectiveness, in Percent, of Selected Agents Against Table AVIII

			Class P	24-in. Tu	ą	Class B	24-in. Tu	b Fire.	Class C 2-	ערע. א גרעי
			Fire, 4	gent at 80	O psig	Agent a	t 400 peig	Initial	Cotton Fra	te Fire,
			Bure. ^a	aracuarge		Dischar	go Pressur	3 9	Initial Di	CC raig scharge
			Tc ext 1	agulsh	"Veight	To exti	ngulsh	Weight	Pressure,	•
			Jvg. Wt.	ivg.	Eff. ct-,	Avg. Wt.	. ³ vg.	different.	To extingu	1sh Telet
		, ,	lgent	Time	asoucat .	lgent	Time	iveness	lvg. Ht.	Avg. Briach-
	Franto	Holon No	(20)	(Sec)	(F)	(20)	(Sec)			
Dibromodif luoromethene	CF.Br.	1202	3.6	1.9	148	6.6	1.6	120	20	
Bromotrifluoromethane	CF,Br	1301	7.7	i n	146	7.60	n n	1050	15.6	4.7 126
Carbon dioxide	6 0	•	9.1	5.2	124	9 <u>.</u> 1	5.2	88	j2+ 8	•
Dibromotetrafluoroethane	CF2BrCF2F	Br 2402	10.5	'N	101	10,8	د . ۲	74	19,85	4 4 6
Dichlorodifluoromethane	CF2C12	122	10.8	Ē	104	12	4.1	8	$(2i)^{\dagger}$	(10) ¹ (74) ¹
lethyl bromids	CH ,Br	1001	11.3	3.4	100	8°0,	2 ° 1	100	20	5 100
Ethyl bromide	C2H3Br	2001	11.7	2 . 8	96	.(91)	(2.5) ^a	(50) ^d	:	••••
Methyl iodide	CHJI	10001	11.7	2,8	96	•	•	•	•	••••
Chlorobromomethene	CH_CIBr	TIOT	12.7	2.7.	99	•	•	:	•	***
Carbon tetrachloride		7 01	(15)	, (E)	(15)	11.4	2°0	8	32+8	•
Perfluoro tacthyl-		•				•	,	a .	6	
eyel cherene)	C F 11CF3	CN(M)	:		•• • 7	(77) _a	(⁽ ⁽ ⁽	»(EC)	324.0	•
bromochiorodilluoro-						4	1			
ne thene	CF2CIBr	IIZI	:::::::::::::::::::::::::::::::::::::::	:	:	10.7	2°9	75	••••	***
Dibromodifluoroethane	CF2BrH2B1	333		-		72	2.2	8		
a. Agents were discharge	ed from a 2	12-10	• CO e	rt ingui she	r charged	with 2 lb.	of agent,	and then	pressurized	wi th
nitrogen at 70°F. Ca	arbon dioxi	ide disc	harge pi	Gessure in	all cases	swas appro:	ximately 8	OC psig.		
b. Methyl bromide taken	яв 100%									
c. Five tests										
d. Six failures in the l	10 testas d	lata rec	orded as	Ce average	values fo	or successf	il extinei	ishments (only.	

; ò ø រំខំនេះសំ

Three failures in the result and record Three failures in 5 tests; see above (d) Not effective in combatting the fires.

Ś 4

129.

product of the time required for extinguishment and quantity of meterial required is compared with the peak in the flammability curve (Table XIX), There is a qualitative relationship.

It is noted that the method of application influences the effectiveness of a given substance is a fire-extinguishing agent. Perhaps a closer correlation would have been obtained between small scale tests and large scale tests if all large scale tests had been conducted using conditions for the application which had been demonstrated as being most effective for the compound in question. ÷.

ż

131.

Table XIX

. •

.

.

.

THE CORNELATION BETWEEN PERFORMANCE TEST AND PEAKS IN THE FLAMMABILITY CURVES (Class B Tub Fire)

/ ·ent	Tine and	Quantity, oz.	Product	Flammability Peak, \$
	•	Agent at 800 psig.		
CBr ₂ F ₂ CBrF ₂ CBrF ₂ CBrF ₃ CH ₃ I C ₂ H ₅ Br CH ₂ BrC1 CH ₃ Br CO ₂	1.9 2 3 2.8 2.8 2.7 3.4 5.2	7.6 10.5 7.7 11.7 11.7 12.7 11.3 9.1	14.44 21.00 23.10 32.76 34.29 38.42 47.32	4.2 4.9 6.1 6.1 6.2 7.6 9.7 29.5
		Agent at 400 psig.		
$\begin{array}{c} CBr_2F_2\\ CBrF_2CBrF_2\\ CBrF_3\\ CBrF_2CH_2Br\\ CBrC1F_2\\ CH_3Br\\ CC1_4\\ CC1_2F_2\end{array}$	1.4 2.3 3.0 2.2 2.3 2.1 2.0 4.1	6.6 10.8 7.6 12 10.7 8.0 11.4 12	9.24 24.84 22.80 26.40 24.61 16.80 22.80 49.20	4.2 4.9 6.1 6.8 9.3 9.7 11.5 14.9

. .

- Benner, Benning, Downing, Irwin, Johnson, Linch, Parmalee and Wirth, Ind. Eng. Chem., 19, 329 (1947).
- 2. Booth, U. S. Paten 2,066,905 (Jan. 1937).
- 3. Brice, Pearlson and Simons, J. Am. Chem. Soc., 69, 968 (1946).
- 4. Burford, Fowler, Mamilton, Anderson, Weber and Sweet, Ind. Eng. Chem., <u>39</u>, 319 (1947).
- 5. Burrell Manual for Gas Analyst, Catelog 80, Burrell Technical Supply Co. 1936_ 42 Fifth Ave., Pittsburgh, Pa.
- 6. Emcleus, Bunho, Hazeldine, and Kerrigan, J. Chem. Soc., Dec. 1948, 2188.
- 7. Gilman, ed., ''Organic Synthesis'', Vol. 1, p. 377, New York, John Wiley and Sons, Inc., 1941.
- 8. Ibid., p. 506.
- 9. Henne, J. Am. Chem. Soc., 59, 1200 (1937).
- 10. Jones and Gilliland, Bureau of Mines, Report of Investigations 3871, April 1946.
- 11. McBee and Bechtol, Ind. Eng. Chem., 39, 380 (1947).
- 12. McBee, Bolt, Graham and Tebbe, J. Am. Chem. Soc., <u>69</u>, 947 (1947).
- 13. McBee and Frederick, J. Am. Chem. Soc., 71, 1490 (1949).
- 14. McBee, Hass, Bittenbender, Wessner, Toland, Hausch and Frost, Ind. Eng. Chem., <u>39</u>, 409 (1947).
- 15. McBee, Hass, Thomas, Toland and Truchan, J. Am. Chem. Soc., <u>59</u>, 944 (1947).
- 16. McBee, Hass, Toland and Truchan, J. Am. Chem. Soc., 69, 944 (1947).
- 17. McBee, Hass, Weimer, Rothrock, Burt, Robb and Van Dyken, Ind. Eng. Chem., 39, 298 (1947).
- McBee, Holten, Evans, Alberts, Welch, Ligett, Schreyer and Krantz, Ind. Eng. Chem., <u>39</u>, 310 (1947).
- Mellon, "Methods of Quantitative Chemical Analysis", New York, Thomas Y. Crowell Co., 1937.

20. Moos and Flichtinger, C. A., <u>43</u>, 4624 (1949).

21. Murray, Beenblossom and Wojcik, Ind. Eng. Chem., 39, 302 (1947).

ļ,

- 22. Private Communication, E R D L Personnel.
- 23. Raasch, U. S. Patent 2,424, 667, (July 29, 1947).
- 24. Reboul, Ann. Chim., 14, 464 (5) (1878).
- 25. Robbins, J. Pharmacol, <u>E6</u>, 197 (1946).

3²*

- 26. Ruff, Anorg. Allgem. Chem. 910, 173 (2003).
- 27. Soroos and Hinkamp, J. Am. Chem. Soc., 67, 1642 (1945).
- 28. Struck and Plattner, J. Pharmacol, Exp. Therap., <u>68</u>, 217 (1940).
- 29. Threadwell and Hell, "Analytical Chemistry", 9 th. ed., Vol. 2, pp. 397-8, 405, New York, John Wiley and Sons, 1942.
- 30. Underwriters Laboratories Report on "Comparative Life, Fire, and Explosion Hazards of Common Refrigerants." Miscellaneous Hazards No 2375. November 13, 1933.
- 31. Underwriters Laboratories Inc., Bulletin of Research No. 42, August, 1948, "The Life Hazards and Nature of the Product Formed When Chlorobromomethane Extinguisher Liquid is Applied to Fires."
- 32. Williams, Barrett and Larson, Bureau of Mines Bulletin 270 (1927).
- Yant, Olsen, Storch, Littlefield and Scheflon, Ind. Eng. Chem., Anal. Ed., <u>9</u>, 20-25 (1936).

Appendix

The desirability of having all of the data obtained during the course of research on this project is apparent. Consequently, detailed information not pertinent to the discussions in the body of this report are collected in the appendix. Tables are included which show the flammability of various mixtures. Whenever possible plots are included showing the flammable areas of the various mixtures. The data obtained in the literature search for physical properties of several gares are summarized in tabular form in this section.

In the tables showing the flammability, + indicates that the misture burned, i.e. the flame travelled to the top of the tube; - indicates that the mixture did not burn or if the mixture ignited, the flame did not travel to the top of the tube.

134.

1. 1. A. 1.

-535

FLAMMABILITY OF MIXTURES OF <u>n</u>-HEPTANEY AIR AND DIBROMODIFLUOROMETHANE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volu	<u>18 %</u>	Result
C ₂ H ₁ A	CBr ₂ F ₂	C7HIE	CBr ₂ F ₂	
8	8	2.0	2.0	-
8	12	2.0	3.0	-
12	8	3.0	2.0	+
12	12	3.0	3.0	-
16	ß	4.0	2.0	+
1:	6	3.0	1.5	+
8	4	2.0	1.0	-
16	6	4.0	1.5	+
20	4	5.0	1.0	+
14	8	3.5	2.0	+
22	6	5,5	1.5	-
14	10	3.5	2.5	+
14	12	3.5	3.0	+
12	10	3.0	2.5	-
10	6	2.5	1.5	-
18	6	4.5	1.5	+
22	2	5.5	0.5	+
10	4	2.5	1.0	+
22	4	5.5	1.0	+
16	12	4.0	3.0	+
18	10	4.5	2.5	+
16	14	4.0	3.5	+
18	12	4.5	3.0	+
16	16	4.0	4.0	-
18	16	4.5	4.0	+
20	14	5.0	3.5	-
18	18	4.5	4.5	-
24	4	6.0	1.0	+
20	8	5.0	2.0	+
14	<u>l</u> 4	3.5	3.5	-

.

ŧ

135.

FLAMMABILITY OF MIXTURES OF <u>n</u>-HEPTANE, AIR AND TRIBROMOFLUOROMETHANE (Total Pressure = 400 mm. Hg)

Pressure.	mm. Hg	Volu	ne 1	Result
C7 18	CBr ₃ F	C7H18	CBr ₃ F	
8	8	2.0	2.0	-
8	12	2.0	3.0	-
10	8	2.5	2.0	+
10	12	2,5	3.0	-
12	16	3.0	4.0	+
10	10	2.5	2.5	-
12	20	3.0	5.0	-
12	18	3.0	4.5	-
14	18	3.5	4.5	-
16	14	4.0	3.5	-
18	10	4.5	2.5	-
14	14	3.5	3.5	-
20	6	5.0	1.5	-

136.

. . .

. .

/

Table 3

τ.

×*

FLANMAPILITY OF MIXTURES OF n-HEPTANE, AIR AND 2-BROMO-1,1,1-TRI-FLUORO-FROPANE

Pre	sourc, ar. Hg		Volu	1me 1	Result
n-C-H.a	C.H.BrF.	Total	n-C-Hia	CaH.ErFa	
4.0	4.0	100	1,0	1.0	-
5,0	8.0	400	1.3	2.0	-
6.0	6.0	3 97	1.5	2.0	+
8.0	9.0	396	2.0	2.3	-
9.0	9,0	400	2.3	2.3	+
9.0	12.0	400	2.3	3,0	<u>+</u>
9.0	14.0	396	∂.3	3.5	-
10.0	14.6	398	℃ •5	3.5	+
11.0	16.0	4 0 0	2.8	4.0	+
14.0	20.0	4 (注)	3.5	5.0	-
14.0	19.0	4.00	3.5	4.8	+
15.0	0,21	400	3,8	4 . 8	<u>+</u>
16.0	18,0	400	4.0	4.5	-
16.0	17.0	397	4.0	4.0	+
18.0	15.0	398	4.5	3.8	-
18.0	14.0	400	4.5	3.5	+
19.0	10.0	400	4.8	2.5	<u>+</u>
20.0	8.0	400	5.0	2.0	-
20.0	7.0	400	5.0	1.8	-
20.02	6.0	400	5.0	1.5	<u>+</u>
20.0	4.0	3 98	5.0	1.0	+
21.0	4.0	400	5.3	1.0	-

PLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 1,2-DIMRONO TETRA- FLUOROETHANE (Total Pressure = 400 mm. Hg)

Press	ure. ma. Hg	Volume	<u>%</u>	Result
D-CaHIA	C2Br2F4	CaH1	C.Br.F.	
7.0	4.0	1.8	1.0	+
6.0	4.0	1.5	1.0	-
7.0	8.0	1 . R	0.0	+
7.0	6.U	1.8	1.5	-
7.0	10.0	1.8	2.5	+
8.0	12.0	2.0	3.0	<u>+</u>
9.0	14.0	2.3	3.5	Ŧ
10.0	16.0	2.5	4.0	<u>+</u>
11.0	18.0	2.8	4.5	-
14.0	18.0	3.5	4.5	+
15.0	19.0	3.8	4₀ 8	+
15.0	20.0	3.8	5.0	-
17.0	18.0	4.3	4.5	+
18.0	16.0	4.5	4.0	
20.0	14.0	5.0	3.5	-
21.0	10.0	5.3	2.5	+
21.0	8.0	5.3	2.0	+
22.0	8.0	5.5	2.0	-
19.0	14.0	4.8	3.5	+

- -

138.

Ì

1

1

í

í

13

- 7

Pressu	re. mm. Hg.	Vol	ume, %	Result
Callin	CF_1CF_1	CoH1 a	CF_ICF_I	
16	16	4.0	4.0	+
20	16	5.0	4.0	+
16	18	4.0	4.5	+
12	16	3.0	4.0	+
24	16	6.0	4.0	-
8	16	2.0	4.0	+
16	24	4.0	6.0	-
12	24	3.0	6.0	-
16	20	4.0	5.0	-
12	20	3.0	5.0	-
12	18	3.0	4,5	+
20	18	5.0	4.5	-
8	18	2.0	4.5	-
14	19.2	3.5	4.8	+
6	16	1.5	4.0	-
14	20	3.5	5.0	-

FLAMMABILITY C: MIXTURES OF <u>n</u>-HEPTANE, AIR, AND 1,2-DIIODOTETRAFLUOROETHANE (Total Pressure = 400 mm. Hg)

FLAMMABILITY	OF	MIXTURES	OF 1-HL	TT.	NE.	AIR,	AND	DIEROMOMETHANE
		(Total H	Pressure		400	mm.	Hg)	

Pressure.	mm Hg	Volum	9. \$	
n-C-H16	CH _o Br _g	n-CoH10	CH_Br_	Regults
14.0	16.0	3.5	4.0	٠
12.0	20.0	3.0	5.0	
15.0	16.0	3.8	4.0	-
11.0	20,0	2,8	5.0	+
18.0	10.0	4.5	2.5	-
6.0	14.0	1.5	3.5	-
7.0	14.0	1.8	3.5	+
8.0	16.0	2.0	4.0	+
7.0	12.0	1.8	3.0	+
6.0	10.0	1.5	2.5	-
6.0	8.0	1.5	2,0	-
8.0	18.0	2.0	4.5	-
6.0	4.0	1.5	1,0	+
9.0	20.0	2.3	5.0	+
10.0	21.0	2.5	5.3	-
17.0	10.0	4.3	2.5	+
20.0	4.0	5.0	1.0	-
19.0	4.0	4.8	1.0	+

.

140.

•

Pressure	. mm. Hg.	Volum	0. <u>%</u>	<u>Result</u>
GoH2.	CF_CF_I	C-H14	CF3CF3I	
12.0	16.0	3.0	4.0	*
12.0	20.0	3.0	5.0	+
10.0	18.0	2.5	4.5	-
12.0	24.0	3.0	6.0	-
14.0	20,0	3.5	5.0	-
12.0	22.0	3.0	5.5	-
10.0	14.0	2.5	3.5	-
16.0	14.0	4.0	3.5	+
10.0	10.0	2.5	2,5	-
20.0	10.0	5.0	2,5	+
10.0	6.0	2.5	1.5	-
18.0	16.0	4.5	4.0	+
24.0	10.0	6.0	2.5	+
18.0	18.0	4.5	4.5	+
26.0	10.0	6.5	2.5	-

1

FLAMMABILITY OF MIXTURES OF N-HEPTANE, AIR, AND PENTAFLUORO-IODOETHANE

ł

*

1.2

Sec.

· . . .

.

142.

Table g

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR, AND 3-BROMO-1,1,1-TE-FLUOROPROPANE (Total Pressure = 400 mm. Hg)

Pressure	a. mm. Hg	Vo	lume, 🕺 🔄	Result
n-C ₇ H ₁₆	CaH_BrFa	n-Collin	C3H4BrF3	
12.0	16.0	3.0	4.0	+
13.0	16.0	3.3	4.0	-
12.0	18.0	5.0	4.5	-
6.0	18.0	1.5	4.5	+
16.0	10.0	4.0	2.5	+
6.0	20.0	1.5	5.0	+
18.0	10.0	4.5	2.5	-
6.0	21.0	1.5	5.3	+
5.0	20.0	1.3	5.0	_
8.0	21.0	2.0	5.3	-
5.0	22.0	1.5	5.5	-
5.0	21.0	1.3	5.3	
5.0	14.0	1.3	3.5	+
10.0	20.0	2.5	5.0	-
±.0	10.0	1.0	2.5	-
10.0	19.0	2.5	4.8	+

بم توبع ومدين الداني ب

1

:

<u>_</u>*

FLANGEBILITY OF MIXTURES OF n-HEPTANE, AIR AND ETHYL IODIDE (Total Pressure = 400 mm Hg)

(Total	Pressure	= 400	ma.	HE I
--------	----------	-------	-----	------

Pressure	ma Hg	. Volu	<u>ne 🦸</u>	Result
C-7H18	C _p H ₅ I	C ₇ H ₁₆	C2H5I	
12	16	3.0	4.0	•
12	20	3,0	5.0	+
12	24	3.0	6.0	-
12	22	3.0	5.5	-
10	22	2.5	5.5	+
1.4	22	3.5	5.5	-
10	24	2.5	6.0	
14	18	3.5	4.5	-
8	24	2.0	6.0	-
16	14	4.0	3.5	-
8	22	2.0	5.5	+
16	10	4.0	2.5	+
6	16	1.5	4.G	+
20	8	5.0	2.0	-

143.

İ

FLAMMABILITY OF MIXTURES OF n-HEPTINE, AIR, AND BROMOPENTAFLUOROETHANE (Total Pressure = 400 mm. H.)

Pressure. mm. He		Volume %		Page 14
C7H16	CF3CF2Br	C7H16	CF3CFgBr	AUGHLL
14	20	3.5	5.0	_
12	20	3.0	5.0	-
16	20	4.0	4.0	
20	20	5.0	5.0	•
16	16	4.0	4.0	-
20	16	5.0	π.ο Λ Ω	+
14	16	3.5	4.0	-
10	16	4.5	4.0	+
12	16	3.0	4.0	+
18	20	4.5	4.U	+
17.2	22	7. 17	5.0	-
16	22	4+0	5.5	-
10	18	4.0	5.5	+
16	20	2.0	4.5	-
19.2	16	4.0	5.0	+
16	26	4.8	4.0	+
10	16	4.0	6 . 5	-
15.2	10	2.5	4.0	+
2	64 1 c	3.8	6.0	-
14	10	2.0	4.0	-
14	20	3.5	5.0	+
10	24	4.2	6.0	-
10	24.8	4.0	6.2	-
12	20	3.0	5.0	+

. . . .

144.

<u>د</u> ^

<u>第</u> 2014年・

Ì

i

A SAN AL BOARD

. .

the print and

. -

.*

Pressure. ma. He		Volum	8. 5	
D-C-HIA	CHAL	n-C-Hia	CH-I	Result
14.0	12.0	3,5	3.5	-
13.0	12.0	3.3	3.0	*
12.0	16.0	3.0	4.0	+
8.0	20.0	2.0	5.0	•
13.0	16.0	3.3	4.0	-
8.0	18.0	2.0	4.5	+
8.0	16.0	2.0	4.0	+
9.0	22.0	2.3	5.5	+
7.0	16.0	1.8	4.0	-
9.0	23.0	2.3	5.8	-
8,0	22.0	2.0	5.5	+
7.0	6.03	1.8	5.0	-
10.0	20.0	2.5	5 .0	+
8.0	23.0	2.0	5.8	-
11.0	20.0	2.8	5.0	+
12.0	20.0	3.0	5.0	+
14.0	12.0	3.5	3.0	+

FLANMABILITY OF MIXTURES OF n-HEPELNE, AIR AND METHYL IODIDE (Total Pressure = 400 mm. Hg)

1

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND PROMOTRIFLUORO-METHANE

(Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume	Volume, ž		
n-C-H1A	CRrF3	n-C-HIE	CBrF ₂	<u>kesult</u>	
5.0	0.0	1.3	0.0	-	
6.0	0.0	1.5	0.0	+	
28.0	0.0	7.0	0.0	+	
29.0	0.0	7.3	0.0	-	
11.0	a:.0	2.8	6.Ĵ	-	
13.0	24.0	3.3	6.0	-	
6.0	8.0	1.5	2.0	-	
7.0	8.0	1.8	2.0	+	
8.0	16.0	2.0	4.0	-	
9.0	16.0	2.3	4.0	+	
20.0	U . U	5.0	2.0	-	
16.0	16.0	4.0	4.0	-	
12.0	24.0	3.0	6.0	+	
12.0	25.0	3.0	6.3	-	
10.0	20.0	2.5	5.0	+	
13.0	23.0	3.3	5.8	-	
9.0	20.0	2.3	5.0	-	
15.0	16.0	3.8	4.0	+	
19.0	8.0	4.8	2.0	+	
14.0	20.0	3.5	5.0	+	
24.0	4.0	6.0	1.0	-	

.

🗶 en el en el 🖡

.

146.

Î

÷

🕈 🍋 (1944)

FLUMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND ETHYL BROWIDE (Total Pressure = 400 mm. Hg)

*

Pressur	essure.mm. Hz Volume \$		ume 🐔	<u>Result</u>
C7H18	CH3 CH2Br	C7II16	CH3CH3Br	
24	16	6.0	4.0	-
2	16	0,5	4.0	-
20	16	5.0	4.0	-
6	lċ	1.5	4.0	•
18	16	4.5	4. 0	+
÷.	16	1.0	4.0	+
19.2	16	÷.8	֥0	-
5.2	16	1.3	4 .0	-
18	32	4.5	8.0	-
14	32	3.5	8.0	-
14	24	3.5	6.0	-
6	24	1.5	6.0	-
10	24	2.5	6.0	+
12	24	3.0	6.0	-
8	24	2.0	6.0	+
10	26	2.5	6.5	-
11.2	24	2.8	1.0	+
7.2	24	1.8	6.0	-
6	25.2	2.5	6.3	-
9.2	25.2	2.3	6.3	+
8	25.2	2.0	6.3	_
9.2	26	2.3	6.5	-

.

147.

₽.

ł

. . . .

.

÷

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 1-EROMO-2,2-DIFLUOROPROPANE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		1	olume#	<u>Result</u>
C7H18	CH2BrC 2CH3	C7H18	CH2BrCF2CH3	
4	4	1.0	1.0	-
4	3	1.0	2.0	-
8	4	2.0	1.0	+
8	8	2.0	2.0	+
8	12	2.0	3.0	+
6	Ļ.	1.5	1.0	+
6	8	1.5	2.0	+
6	12	1.5	3.0	+
8	16	2.0	4.0	+
4	16	1.0	4.0	+
4	12	1.0	3.0	+
2	16	0.5	4.0	-
4	20	1.0	5.0	-
4	24	1.0	6.0	-
6	20	1.5	5.0	+
6	24	1,5	6.0	+
6	28	1.5	7.0	-
8	32	2.0	8.0	-
8	28	2.0	7.0	-
12	24	3.0	6.0	+
12	28	3.0	7.0	-
8	26	2.0	6.5	-
12	26	3.0	6.5	-
16	26	4.0	6.5	-
14	26	3.5	6.5	-
16	24	4.0	6.0	-
10	24.8	2.5	6.2	+
14	24	3.5	6.0	-
26	12	6.5	3.0	-
8	25.2	2.0	6.3	-
22	12	5.5	3.0	-
8	24	2.0	6.0	+
18	12	4.5	3.0	+

148.

. j

ł

*

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 2-BROMO-1-CHLORO-1,1-DIFLUCROPROPANE

(Total Pressure = 400 mm. Hg)

Preasure	e. mn. Hg.	Vol	uno. 1	
n-Calla	C-H_BrClF3	n-C-H1A	C-H-BrClF-	Rosult
10.0	20.0	2.5	5.0	+
14.0	16.0	3.5	4.0	-
12.0	20.0	3.0	5.0	-
8.0	24.0	2.0	6.0	+
10.0	22.0	2.5	5.5	+
10.0	24.0	2.5	6.0	-
8.0	25.0	2.0	6.3	-
4.0	20.0	1.0	5.0	+
·÷•0	24.0	1.0	6.0	+
6.0	25.0	1.5	6.3	+
5.0	26.0	1.5	6.5	-
3.0	24.0	0.8	6.0	-
4.0	25.0	1.0	6.3	-
3.0	16.0	0.8	4.0	-
13.0	16.0	3.3	4.0	+
4.0	10.0	1.0	2.5	+
18.0	8.0	4.5	2.0	-
16.0	8.0	4.0	2.0	+
3.0	10.0	0_8	2.5	-
2.0	4.0	0.5	1.0	-

149.

₩.

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND DIBROMOFLUOROMETHANE (Total Pressure = 400 mm. Hg)

Pressure	, mm, Hg	Volu	me f	Result
C7H1A	CHBr ₂ F	C7H18	CHBr ₂ F	
12	2 0	3.0	5.0	+
6	12	1.5	3.0	-
12	28	3.0	7.0	-
12	24	3.0	6.0	-
8	12	2.0	3.0	-
12	23	3.0	5.75	+
10	12	2.5	3.0	+
10	24	2.5	6.0	-
28	12	7.0	3,0	-
14	24	3.5	6.0	-
20	12	5.0	3.0	-
10	22	2.5	5.5	-
16	12	4.0	3.0	+
14	22	3.5	5.5	+
18	12	4.5	3.0	+
13	24	3.25	6.0	+
13	25	3.25	6.25	+
16	22	4.0	5.5	-
13	26	3.25	6.5	-

150.

1

مدرد (۱

~ 8

-

ないいますい

FLAMABILITY OF MIXTURES OF n-HEPTANE, AIR, AND 1,2-DIBROMO-1,1-DIFLUOROETHANE (Total Pressure = 400 mm. Hg)

Vo	lunc, 1	
n-C-H1.	CBrF ₂ CH ₂ Br	<u>Result</u>
1.0	5.0	-
4.0	4.0	+
1.0	2.0	-
4.0	5.0	+
2.0	5.5	-
4.0	6.0	-
2.0	5.0	+
5.5	2.0	-
2.0	6.0	-
3.0	6.5	+
5.0	4.0	-
3.0	7.0	-
2.5	6.5	-
3.5	6.5	-

151.

Teble 18

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 2-BROMO-1,1,1-TRIFLUOROETHANE (Total Pressure = 400 mm. Hg)

Pressure, mm. He		Volum	Volume. \$		
n-C-H18	CF ₃ CH ₂ Br	n-C-H1A	CF ₃ CH ₂ Br		
29.0	5.0	7.3	1.5	+	
29.0	7.0	7.3	1.8	-	
27.0	10.0	6.8	2.5	+	
28.0	10.0	7.0	2.5	-	
26.0	12.0	6.5	3.0	-	
25.0	12.0	6.3	3.0	+	
25.0	14.0	6.3	3.5	+	
22.0	18.0	5.5	4.5	-	
21.0	18.0	4.3	4.5	+	
19.0	22.0	4.8	5.5	-	
18.0	22.0	4.5	5.5	+	
16.0	26.0	4.0	6.5	+	
11.0	26.0	2.8	6.5	+	
13.0	27.0	3.3	6.8	-	
10.0	22.0	2.5	5.5	+	
9.0	18.0	2.3	4.5	-	
9.0	18.0	2.3	4.5	-	
9.0	10.0	2.3	2.5	-	
10.0	10.0	2.5	2.5	+	
9.0	6.0	2.3	1.5	-	
8.0	4.0	2.0	1.0	-	
9.0	4.0	2.3	1.0	+	

.

٠.

152.

į

4

1.

Pressure, mm. Hg			Volume. %		Result
n-C-H1A	CaF11CoFE	Total	n-C-H1A	CaF11C2F5	
5.0	5.0	500	1.0	1.0	-
30.0	5.0	500	6.0	1.0	+
6.0	5.0	499	1.2	1.0	+
31.0	5.0	500	6,2	1.0	+
5.0	10.0	499	1.0	2.0	+
4.0	10.0	499	0.8	2.0	-
5.0	15.0	501	1.0	3.0	+
4.0	15.0	502	0.8	3.0	
24.0	в.0	401	6.0	2.0	+
6.0	20.0	503	1.2	4.0	-
25.0	8.0	401	6.2	2.0	-
7.0	20.0	50 0	l.4	4.0	+
24.0	12.0	401	6.0	3.0	-
10.0	25.0	503	2.0	5.0	-
23.0	12.0	400	5.8	3.0	+
11.0	25.0	501	2.2	5.0	+
22.0	16.0	399	5.5	4.0	-
10.0	24.0	400	2.5	6.0	-
21.0	16.0	399	5.3	4.0	+
11.0	24.0	401	2.7	6.0	+
18.J	18.0	349	5.2	5.2	-
9.0	21.0	300	3.0	7.0	-
16.0	17.0	340	4.7	5.0	-
15.0	17.0	340	4.4	5.0	+
9.0	20.0	300	3,0	6.7	+
12.0	18.0	300	4.0	6.0	+
10.0	20.0	300	3,3	6.7	
13.0	18.0	300	4.3	6.0	-
11.0	20.0	300	3.7	6 .7	+
12.0	21.0	310	3,9	6.8	-

FLANMABILITY OF MIXTURES OF n-HEPTINE, AIR AND PERFLUCROETHYL-CYCLOHEXANE

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND PERFLUCRO-1,3-DIMETHYLCYCLOHEX JE (Total Pressure = 400 mm. Hg)

Pressure, mm. He		Volume d		
n-C-H18	CaFi (CFa).	A-Collie	CoFrolOFale	Result
25.0	4.0	£ 7		
23.0	12 0	0.0	1.0	+
99 A	16.0	5.8	3.0	+
~~ ••	16.0	5.5	4.0	•
20.0	16.0	5.0	4.0	-
18.0	22.0	0.0	4.0	+
13.0	50.0	4.0	5.5	+
-0.0	27.0	3.3	6.8	+
3.0	24.0	2.3	6.0	
7.0	16.0	1.8		+
6.0	16.0	1.00	4.0	+
4.0	-0.0	Ce L	4.0	-
5 0	4.0	1.0	1.0	_
0.0	4.0	1.3	1.0	-

. . .

154.

1

ہ تھی 1 1
Table gl

ŧ

1

FLAMMABILITY OF MIXTURES OF n-IEPTANE, AIR AND TERFLUCRO-1,4-DIMETHYLCYCLOHEXANE

Pressure. ma. Hg		Vo			
n-C-H1	$C_{a}F_{10}(CF_{T})_{0}$	Total	n-C-H1A	CoFin(CF3)2	Result
3.0	6.0	239	1.0	2.0	-
20.0	3.0	300	6.7	1.0	+
4.0	6.0	300	1.3	2.0	+
21.0	3.0	300	?.J	1.0	-
4.0	12.0	300	1.3	4.0	-
17.0	9.0	302	5.6	3.0	+
5.0	12.0	299	1.7	4.0	+
18.0	9.0	300	6.0	3.0	-
7.0	15.0	30 0	2.3	5.0	+
13.0	15.0	300	4.3	5.0	+
6.0	15.0	30 0	2.0	5.0	+
14.0	15.0	302	4.6	5.0	+
5.0	15.0	300	1.7	5.0	-
15.0	15.0	299	5.0	5.0	-
7.0	18.0	301	2.3	6.0	-
16.0	15.0	300	5.3	5.0	-
8.0	18.0	301	2.7	6.0	+
19.0	6.0	300	6.3	2.0	-
11.0	21.0	300	3.7	7.0	-
18 .0	6.0	3 00	6.0	2.0	+
11.0	20.0	303	3.6	6.6	+
14.0	19.0	300	4.7	6.3	-
9.0	20.0	302	- 3.0	6.6	+
13.0	19.0	299	4.3	6.3	-
9.0	21.0	307	2.9	6.8	-
16.0	12.0	300	5.3	4.0	-
5.0	5.0	499	1.0	1.0	-
15.0	12.0	300	5.0	4.0	+
6.0	5.0	499	1.2	1.0	+
13.0	. 18.0	300	4.3	6.0	+
15.0	17.0	299	5.0	5.7	-
59 ° 0	ن.	401	7.2	0.0	+
15.0	17.0	305	4.9	5.6	-
30.0	0 . 0	405	7.4	0,0	-

155.

1

ŧ

FLAMIABILITY OF MIXTURES OF N-HEPTANE, AIR AND TRIFLUORO-IODOMETHANE (Total Pressure = 400 mm. Hg.)

Regult	18 %	Volu	Pressure, mm. Hg.	
ALMAN A	CF3I	C7H16	CF3I	C7H16
+	5.0	3.0	20,0	12.0
-	7.0	3.0	28.0	12.0
-	6.0	3.0	24.0	12.0
•	6.5	3.0	26 .0	12.0
-	6.5	2.5	26.0	10.0
Ŧ	6.5	3.5	26.0	0 14
-	7.0	2.5	28.0	10.0
-	5.0	4.0	20.0	16.0
+	0.0 6 6	2.0	26.0	8.0
-	5.0	2)	20.0	8.0
•	5.0	5.0	20.0	20.0
*	5.0	1.5	20.0	6.0
-	2.U	5 0	20.0	24.0
-	5.0	3.7	24.0	8.0
+	0.0	2.U 5.5	20.0	22.0
+	5.0	0.0 7 E	24.0	14.0
+	6.0	3.5	24 0	18.0
.	6.0	£•5	COR & C	

.

156.

÷

-

Ŧ

Pressure. sa. Hg		Volum			
CH_C1CH_Br	n-C-H	Total	CH_C1CH_Br	n-C-H1A	Result
6.0	4.0	353	1.7	1.1	•
6.0	20.0	300	2.0	6.7	-
6.0	3.0	300	2.0	1.0	-
6.0	19.0	300	2.0	6.3	-
12.0	3.0	300	4.0	1.0	-
6.0	18.0	300	2.0	6.0	-
12.0	* •V	300	4.0	1.3	+
6.0	16.0	300	2.0	5.3	-
18.0	4.0	300	6.0	1.3	+
6.0	14.0	310	1.9	4.5	+
18.0	3.0	300	6.0	1.0	-
6.0	15.0	299	2.0	5.0	-
21.0	4.0	300	7.0	1.3	-
12.0	11.0	301	4.0	3.7	_
12.0	10.0	299	4.0	3.3	+
21.0	5.0	301	7.0	1.7	+
18.0	8.0	300	6.0	2.7	-
23.0	5.0	301	7.7	2.0	-
16	7.1	3.1.	6.0	2.3	+
10. 0	6.0	300	7.3	2.0	-
22. 91 0	7 0	300	7.0	2.3	-
01 0	F 0	300	7.0	2.0	-
00.0	5.0	300	7 • V 7 • K	1.7	_
22.0	0.U	300	1.0	1. # f 5. 5	•
3.0	10.0	300	1.0	5.0	-
3.0	TR*0	300	T+A	0.0	-

. .

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 1-BROMO-2-CHLORO-BTHLINE

į

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 2-HRCMO-1-CHLORO-1,1-DIFLUOROETHANE (Total Pressure = 400 mm. Hg)

Pressure. mm. Hg		Vc	Result	
C7H18	CC1F2CH2Br	C7H18	CC1FgCH2Br	
8	8	2.0	2.0	•
8	12	2.0	3.0	+
12	8	3.0	2.0	+
8	16	2.0	4.0	-
8	20	2.0	5.0	-
12	16	3.0	4.0	+
12	20	3.0	5.0	+
12	24	3.0	6.0	+
12	28	3.0	7.0	+
12	36	3.0	a.0	-
12	44	3,0	11.0	-
12	32	3,∪	8,0	-
16	28	4.0	7.0	-
12	30	3.0	7.5	-
16	24	4.0	6.0	+
14	30	3.5	7.5	-
20	20	5.0	5.0	-
14	28	3.5	7.0	-

158.

FLAND BILITY OF MIXTURES OF n-HEPTANE, AIR AND PERFLUCEOMETHYL-CYCLOHEXANE

Pressure, ma. Hg		le le	Vol		
n-C-H1	CaFts CFT	Totel	n-C-H1 A	C-F1+CF3	Result
27 .0	15.0	501	5.4	3.0	+
28.0	15.0	500	5.6	3 . 0	-
6.0	20.0	502	1.2	4 . Û	-
7.0	20.0	500	1.4	4.0	+
12.0	35.0	500	2.4	7.0	_
13.0	35.0	499	2.6	7.0	+
14.0	38.0	520	2.7	7.3	+
14.0	38.0	500	2.8	7.6	-
14.0	37.0	500	2.8	7.4	+
11.0	30.0	500	2.2	6.0	-
12.0	30.0	50J	2.4	6.0	+
9.0	25.0	504	1.8	5 . 0	+
21.0	30.0	500	4.2	6.0	+
8.0	25.0	498	1.6	5.0	-
12.0	33.0	500	2.4	6.6	+
22.0	30.C	5 00	4.4	6 . J	-
19.0	33.0	488	3.9	6.8	+
18.0	35.0	505	3.6	6.9	+
19.0	35.0	495	3.8	7.1	-
16.0	37.0	499	3.2	7.4	-
16.0	36.0	502	3.2	7.2	+
5.0	10.0	500	1.0	2.0	+
4.0	10.C	499	0,8	2.0	-
6.0	20.0	500	1.2	4.0	-
7.0	20.0	499	1.4	4.0	+
5.0	15.0	50)	1.0	3.Û	-
6.0	15.0	502	1.2	3.0	+
24.0	24 .C	500	4.8	4.8	-
23.0	24.0	50C	4.6	4.8	+
5.0	5.0	500	1.0	1.0	+
4.0	5.0	501	8,0	1.0	-

159.

i

.

7

----- **4**

į

:

ł

160.

Table 26

FLANMABILITY OF MIXTURES OF n-HEPTANE, AIR, AND n-PERFLUORO-HEPTANE (Total Pressure = 400 mm. Hg)

. .

Prescure, mg. Hg		Volu	no, %	
ACKONT &	B-C-7	n-Calls	D-C-FIA	Result
28.0	4.0	7.0	1.0	•
24.0	12.0	6.5	3.0	-
22.0	16.0	6.U 5.5	3.0	•
18.0	24.0	4.5	6.0	◆
13.0	26.0	3.8	6.5	<u>−</u> 1 ◆
10.0	16.0	3.3 2.5	6.0 3.0	+
7.0 6.0	8.0	1.8	2.0	* *
6.0	8.0 4.0	1.5	2.0	-
5.0	4.0	1.3	1.0	+

,

Te'18 27

.

36

FL.MM.BILITY OF MIXTURES OF n-HEPTANE, AIR AND BROMOCHLORO-METHANE

Pressure, mm. Hg			Volum		
n-C-H1A	CH_BrCl	Total	n-C-HIA	CH_BrC1	Result
9.0	20.0	499	1.8	4.0	-
10.0	20.0	501	2.0	4 . Ŭ	+
11.0	55.u	498	2.2	7.0	+
10.0	55.J	507	2.0	6.9	-
23.0	15.0	505	4.6	3.0	-
22.0	15.0	502	4.4	3.0	+
18 .0	25.0	500	3.6	5.0	+
19.0	25.Ŭ	497	3.8	5.0	-
14.0	35.0	496	2.8	7.1	+
15.0	35.0	495	3.0	7.1	-
13.0	37 .0	512	2.5	7.2	÷
12.0	36.0	502	2.4	7.2	+
12.0	38.J	498	2.4	7.6	-
12.0	37.0	505	2.4	7.3	+
10.0	37.0	492	2.0	7.5	+
11.0	38 C	502	2.2	7.6	••

· •

FLAMMABILITY OF MIXTURES OF N-HEPTANE, BROMODIFLUORC-METHANE AND AIR (Total Pressure = 400 mm. Hg)

•**

Pressure, mm. Hg.		Volu	Results	
C7H18	CHBrF ₂	C7H16	CHB1F2	
16.0	32.0	4.0	8.0	+
12.0	24.0	3.0	6.0	+
20.0	24.0	5.0	6 • V	-
16.0	40.0	4.0	10.0	-
20.0	16.0	5.0	4.0	-
16.0	36.0	4.0	9.0	-
12.0	32 .Û	3.0	8,0	-
8.0	24.0	2.0	6.0	-
20.0	8.0	5.0	0 . S	-
12.0	28.0	3.0	7.0	-
8.0	8.0	2.0	2.0	+
20.0	32.0	5.0	8.0	-
20.0		5.0	1.0	+
32.0	0.0	8.0	0.0	-

162.

K

÷ Ì

19

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND 1,1,2-TRICHLORO-FLUORDETH, NE

PT	essure, ma. H	is	Volu	лие 🐔	
n-C-HIA	C.Cl.F.	Total	n-C-His	CoClaFa	Result
5.0	5.0	500	1.0	ίJ	-
6.0	5.0	500	1.2	1.0	+
5.0	10.0	500	1.0	2.0	-
6.0	10.0	1 99	1.2	2.0	-
6.0	10.0	500	1.2	2. û	-
7.0	10.0	500	1.4	2.0	+
7.0	15.0	499	1.4	3.0	-
8.0	20.03	500	1.6	4.0	Blew off
					safety cap
28.0	2.0	409	6.9	0.5	+
28.0	4.0	399	7.0	1.0	-
27.0	4.0	400	6.7	1.0	+
27.0	8.0	400	6.7	2.0	-
26.0	8.0	400	6.5	2.0	+
26.0	12.0	399	6.5	3.0	+
27.0	12.0	401	6.8	3.0	-
26.0	16.0	400	6.5	4.0	-
25.0	16.0	404	6.2	4.0	-
24.0	16.0	401	6.0	4.0	+
6.0	16.0	399	1.5	4.0	+
22.0	20.0	400	5.5	5.0	+
6.0	2L.	200	1.5	5.0	-
23.0	20.0	401	5.7	5.0	-
7.0	21.0	400	1.7	5.2	-
5.0	15.0	400	1.3	4.0	-
20.0	24.0	400	5.0	6.0	+
8.0	20.0	399	2.0	5.0	+
10.0	24.0	403	2.5	6.0	+
21.0	24.0	399	5.2	6.0	-
9.0	25.0	400	2.3	6.2	+
17.0	28.0	400	4.3	7.0	+
8.0	24.0	400	2.0	6.0	-
18.0	28.0	400	4.5	7.0	+
10.0	28.0	400	2.5	7.0	+
9.0	28.0	400	4.7	7.0	+
19.0	28.0	401	2.2	7.0	+
8.0	28.0	400	2.0	7.0	-
21.0	28.0	400	5.2	7.0	-
12.0	32.0	401	3.0	8.0	+
16.0	32.0	400	4.0	8.0	+
12.0	34.0	400	3.0	8.5	-
16.0	34.0	399	4.0	8.5	+
16.0	36.0	401	4 .Ŭ	9.0	+
10.0	31.0	399	2.5	7.7	+

Table 29 (continued)

• •

يو اليو

Pressure, mm. Hg			Vol		
n-C-H1	C2Cl3F3	Total	n-C2H1A	C ₂ Cl ₃ F ₃	Result
16.0	38 .0	400	4.0	9.5	-
10.0	32.0	400	2.5	8.0	-
20.0	32.0	407	4.9	7.9	-
12.0	33,0	406	3.0	8.1	+
19.0	32,0	400	4.7	8.0	-
12.0	33.C	401	3.0	8.3	+
18.0	32.0	400	4.5	8.0	•
16.0	37.0	406	4.0	3.1	_
17.0	25.0	400	4.3	8.8	_
20.0	28.0	400	5.0	7.0	
18.0	28.0	400	4.5	7-0	•
18.0	35.0	411	4.4	8.5	-
19.0	28.0	400	4.8	7 0	-
14.0	35.0	400	3.5	28	•
20.0	28.0	399	5.0	75	-
14.0	34.0	400	3.5	8.5	-

••

164.

-

1

-

î: ·

FL.LM. BILITY OF MIXTURES OF n-HEPT., NE, .IR .ND BROMOCHLORO-DIFLUCROMETH., NE (Total Pressure = 4.0 mm. Hg)

Pressure. ma. Ha		Vol	Result	
C ₇ H ₁₀	CBrClFg	C7H18	CBrCli	
8	24	2.0	6.Ū	+
20	24	5.0	6.ù	+
8	32	2.0	8.0	-
12	28	3.0	7.0	+
4	24	1.0	6.0	-
8	28	2.0	7.0	+
6	24	1.5	6.Û	-
12	32	3.0	8,0	+
8	30	2.0	7.5	-
14	34	3.5	8.5	-
12	36	3.0	9.0	+
16	32	4.0	8.0	-
10	34	2.5	8.5	-
12	38	3.0	9.5	-
18	34	4.5	8.5	-
14	34	3.5	8.5	-
20	28	5.0	7.0	-
6	12	1.5	3.0	-

.

.

165.

ł

₩, . .

. .

FLAMMABILITY OF MIXTURES OF N-HEPTANE, AIR, AND HYDROGEN BROWIDE (Total Pressure = 400 mm. Hg.)

Pressure, mm. Hg.		Volu	<u>Result</u>	
C7H18	IBr	C7H16	HBr	
16.0	40.0	4.0	10.0	-
24.0	40.0	6.Q	10.0	-
16.0	20.0	4.0	5.0	+
24.0	20.0	6.0	5. 0	-
16.0	28.0	4.0	7.0	+
0.0غ	20.0	5.0	5.0	-
16.0	32.0	4.0	8,0	-
8.0	20.C	2.0	5.0	-
16.0	36.0	4.0	9.0	+
12.0	20.0	3.0	5.0	+
12.0	38.0	3.0	9.5	_
20.0	36.0	5.0	9.0	-
16.0	38.0	4.0	9.5	-
12.0	36.0	3.0	9.0	-
24.0	4.0	6.0	1.0	-
8.0	8.0	2.0	50	•

166.

لوجن

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND METHYL BROMIDE

Pressure, mm. Hg		Hg	Volume %		
n-C-His	CH-Br	Tot 1	n-C-HIA	CH ₃ Br	Result
6.0	20.0	498	1.2	4.0	-
7.0	20.0	508	1.4	3.9	+
6.0	40.0	500	1.2	8,0	-
7.0	40.0	500	1.4	8.0	+
10.0	43.0	500	2.0	8.6	+
10.0	44.0	501	2.0	8.8	-
15.0	27.0	500	3.0	5.4	+
15.0	30.0	499	3.0	6.0	-
17.0	25.0	500	3.4	5.Q	-
16.0	25.0	504	3.2	5.0	+
13.0	35.0	498	2.6	7.0	-
12.0	35.0	500	2.4	7.0	+
11.0	40.0	501	2.2	8.0	-
10.0	40.0	501	2.0	8.0	+
8.0	46.0	501	1.6	9.2	+
8.0	47.0	499	1.6	9.4	-
7.0	48.0	501	1.4	9.6	+
7.0	49.0	500	1.4	9,8	-
25.0	9.0	503	5.0	1.8	+
26.0	9.0	503	5.2	1.8	-

167.

t

ł

.

ر میں

FLAMMABILITY OF MIXTURES OF N-HEPTANE, AIR AND DIFLUORO-VINYL HRCMIDE (Total Pressure = 400 mm. Hg.)

Pressure. mm. Hg.		Volu	Result	
C7H16	CF2=CHBr	C7H18	CT2=CHBr	
8,0	24.0	2.0	6.0	+
20.0	24.0	5,0	6.0	-
4.0	24.0	1.0	6.0	-
16.0	24.0	4.0	6.0	-
4.0	36.0	1.0	9.0	-
12.0	24.0	3.0	6.0	+
8.0	28.0	2.0	7.0	+
10.0	32.0	2.5	8.0	+
12.0	28.0	3.0	7.0	+
10.0	36.0	2.5	90	+
10.0	40.0	2.5	10.0	-
10.0	38.0	2.5	9.5	+
12.0	38.0	3.0	.8.5	-
8.0	38.0	2.0	9.5	-
20.0	10.0	5.0	2.5	-
20.0	14.0	5.0	3.5	-
20.0	6.0	5.0	1.5	-

w ...

168.

48.90

5

X

:

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND PERFLUCROBUTANE

Pressure. mm. Hg		Volume 4			
<u>n-C-H.</u>	CaF10	Total	n-C-Han	CEFIC	Result
30.0	4.0	400	7.5	1.0	-
23.0	4.0	400	7.2	1.0	+
29.0	8.0	400	7.2	2.0	-
28.0	8.0	400	7.0	2.0	+
24.0	16.0	40 0	6.0	4.0	-
23.0	16.0	401	5.7	4.0	+
20.0	23.0	4 0 0	5.0	5.7	+
21.0	24.0	402	5.2	6.0	-
20.0	29.0	400	5.0	7,2	-
19.0	29.0	400	4.7	7.2	+
17.0	35.0	402	4.2	3.7	-
13.0	32.Ū	400	4.2	8.5	+
13.0	39.0	400	3.3	9.7	+
5.0	40.0	400	3.3	10.0	-
4.0	4.0	400	1.2	1.0	-
4.0	4.0	401	1.0	1.0	+
4.0	12.0	398	1.0	3.0	+
5.0	12.0	400	1.2	3.0	-
5.0	20.0	400	1.2	5.0	+
6.0	20.0	399	1.5	5.0	-
7.0	26.0	400	1.7	6.5	+
8.0	26_0	400	2.0	6.5	-
8.0	31.0	400	2.0	7.7	+
9.0	31.0	400	2.2	7.7	-
11.0	35.0	401	2.7	8.7	+
11.0	36.0	40 0	2.7	9.0	+

169.

•••

÷

÷

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND SILICON TETRACHLORIDE (Total Pressure = 400 mm. Hg)

to darge men

A LANCE COMPACT REPORT

Pressure, sa. Hg		Volume \$		Result
C7H10	C7H10 SiCl4	C7H16	SiCl4	
16	32	4.0	8.0	+
12	24	3.0	6.0	+
20	24	5.0	6.0	+
16	34	4.0	8.5	+
10	24	2.5	6.0	-
12	36	3.0	9,0	+
14	36	3,5	9.0	+
16	36	4.0	9.0	-
14	38	3,5	9.5	-
12	38	3.0	9.5	+
12	40	3.0	10.0	-
10	40	2.5	10.0	-
10	38	2.5	9.5	-

.

. .

1

· ····

FLANMABILITY OF MIXIURES OF n-HEFTANE, AIR, AND 1,2-DIBROMO--2-CHLORO-1, 1-DIFLUCROETHANE

(Total Pressure = 400 mm. Hg)

<u>n-Calla</u>	CBrF_CBrC1F	Result
2.0	4.0	+
2.0	5.0	+
2.0	6.0	*
2.0	7.0	+
2.0	8.0	+
2.0	9,0	-
2.5	9.0	-
3.0	9.0	+
3.0	9.5	-
3.5	9.0	+
4,0	9.3	+
3.5	9.5	•
3.5	10.0	+
4.0	10.0	-
4.5	9.0	+
1.5	8.0	-
5.0	9.0	+
1.5	5.0	-
5.5	9.0	-
3.5	10.0	+
3.5	10.5	+
3.5	11.0	_

and and a second and

4

FL MAM ABILITY OF MINTURES OF <u>p-HEPTINE</u>, AIR AND 1,2-DICHLOROTETRAFLUOROETHANE (FREON 114) (Total Pressure = 4CO mm. Hg)

Pressure, ma. Hg		V	Volume 1	
C7H16	CC1F2CC1F2	C7H16	CC1F2CC1F2	
8	4	2.0	1.0	+
10	8	2,5	2.0	+
6	8	1,5	2 0	-
8	12	2 0	3_0	+
8	8	2.0	2_0	+
6	12	1.5	3.0	-
8	16	20	4.0	+
8	20	2.0	5.0	-
8	24	2 0	6.0	-
10	20	2.5	5.0	· _
10	26	2.5	6.5	-
12	20	3.0	5.0	+
14	24	3.5	6.0	+
12	29	3.0	7,25	+
20	24	5.0	6.0	+
12	36	3.0	· 9,0	+
16	32	4.0	8,0	+
12	40	3.0	10,0	+
20	32	5 0	8.0	+
12	44	3.0	11_0	-
12	42	3.0	10 5	+
20	32	5 0	8.0	+
14	42	3.5	10 5	-
10	42	2.5	10.5	-
24	32	6.0	8.0	-
12	41	3.0	10 25	+
22	32	5,5	8,0	+
24	22	6,0	5,5	+
26	22	7.0	5,5	-

. ..

172.

1

Sandyana a series and a series of the

FLAMM BILITY OF MIXTURES OF <u>n-HEPTANE</u>, AIR AND CARBON TETRACHLORIDE

Pressure, mm, Hg		Volu	Volume %		
n-C-H	<u>CC1.</u>	Total	$n - C_{\eta}H_{1.6}$	CC 1	Result
7.0	20.0	493	1.4	4.1	+
6.0	20_0	522	1,2	3.8	-
8.0	30_0	517	1,5	5,8	-
7.0	30.0	517	1.4	5.8	+
13.0	50,0	531	2.4	9.4	-
14.0	50 0	536	2.6	9.3	+
13.0	46.0	409	3.2	11.2	+
13.0	47.0	406	3.2	11.6	-
21.0	45.0	468	4.5	9.6	-
20.0	45.0	192	4.1	9.2	+
29.0	20 0	506	5.7	3.9	+
30 0	2 0 0	509	5,9	3,9	-

٠

۰.

.

.. مرتقت

FLAMMABILITY OF MIXTURES OF n-NEPTANE, AIR AND 2-CHLORO-1,1,1-TRI-FLUOROPROPANE (Total Pressure = 400 mm. Hg)

Pressu	re, m, Hg	Volu	ne. %	
n-C2H46	CF3CHC1CH3	n-CaH16	CF,CHC1CH,	My sult
22.0	16.0	5.5	4.0	_
4.0	16.0	1.0	λ 0	•
2,0	16.0	0.5	1 0	
12,0	32.0	3 0	8.0	-
14,0	32.0	3.5	e 0	•
8.0	10.0	20	10.0	-
6.0	10 0	1.5	10,0	-
<u>6</u> 0	11 0	1.0	10.0	*
00	32 0	1.0	11.0	+
60		₽ •Q	8,0	-
	44.0	1.5	11.0	+
4.0	48.0	1,0	12_0	-
0.0	46.0	1.5	11.5	+
0.0	42.0	0,0	10.5	+
6,0	47.0	1.5	11.8	-
4.0	47.0	1.0	11.8	+
0,0	28.0	0.0	7.0	-
7,0	44.0	1.8	11 0	-
0_0	29.0	0 0	73	-
0,0	43.0	0 0		•
3.0	44.0	0.8	11 0	-
1.0	24.0	0 2	TT*0	-
21 0	16.0		0.0	+
	10. V	2.3	4.0	+

174.

,

Table	40
	- 30

÷.

.

1

1

...

FLUMMEBILITY OF MIXTURES OF n-NEPTANE, AIR WND 2-CHLORO-1,1,1-TRI-FLUOROPROPANE (Total Pressure = 400 mm. Hg)

Pressure. m. Hg		Volu		
n-C-Has	C.H.CIF.	n-C7H16	C.H_CIF.	Result
22.0	12,0	55,5	3.0	-
21,0	12.0	5,3	3.0	+
14.0	28.0	3.5	7.0	-
13.0	28.0	3.3	7 0	+
4.0	44.0	1.0	11.0	+
16.0	20.0	4.0	5.0	+
1.0	36.0	0.3	9.0	+
0.0	36.0	0.0	9.0	-
17 0	20 0	4.3	5.0	-
	10 0	0 0	10 0	-
	18 D	10	12 0	_
10		03	11.0	-
20	18.0	0.5	12.0	-
	40,0	1.0	11 5	*
2.0	40,0		12 2	-
2.0	49.0	0.5	14,3	-
3.0	46,0	0,8	11.2	Ŧ
1.0	48.0	0,3	12.0	-
3.0	48.0	0.8	12.0	+
3.0	49.0	`0 ,8	12,3	-
1,0	28,0	0,3	7,0	-
3,0	20_0	0,8	5 . 0	+
2_0	28.0	0,5	7.0	+
2.0	20,0	C, 5	5.0	-
10,0	36,0	2.5	9,0	-
9.0	36.0	2.3	9,0	+

FLAMMABILITY OF MIXTURES OF n-MEPTINE, MR AND CHLOROTRIFLUOROMETHANE (FREON 13) (Total Pressure = 4C0 mm, Hg)

. .

Pressure, mm. Hg		Volume		
n-C2H16	CC1F,	n-C2H16	CC1F1	<u>Regult</u>
12.0	48.0	3.0	12.0	+
14.0	48.0	3.5	12.0	-
12.0	50.0	3.0	12.5	-
14.0	44.0	3,5	11.0	+
10.0	40 0	2.5	10.0	-
20.0	24.0	5 0	6.0	+
21.0	24.0	5.3	6.0	-
11.0	48.0	2.8	12.0	-
13.0	48.0	3.3	12,0	+
13.0	50.0	3.3	12.5	-
7.0	24.0	1.8	6.0	+
60	21.0	1.5	6.0	+

176.

į

たまます

2

-

÷≣ ∖

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND HEXAFLUOROETHANE (Total Pressure = 400 mm, Hg)

Pressure, Hg		Volu		
n-CoH16	C ₂ F ₆	n-C2H16	C ₂ F ₆	Result
24.0	20,0	6.0	5.0	+
6.0	2,0	1.5	5.0	-
25.0	20 0	6.3	5.0	-
7.0	20 0	1.8	5.0	+
8.0	40.0	2.0	10,0	-
9.0	40 0	2.3	10 0	+
10,0	52.0	2.5	13.0	-
10,0	48.0	2.5	12_0	-
16.0	44.0	4.0	11_0	-
11.0	48.0	2 8	12.0	+
16.0	40.0	4.0	10,0	+
17.0	40.0	4.3	10_0	. •
14.0	48.0	3.5	12_0	+
12.0	54.0	3.0	13.0	-
15.0	48.0	3.8	12 0	+
14.0	50.0	3.5	12.5	-
13.0	52.0	3.3	13.0	-
12.0	53.0	3.0	13,3	+

FLAM ABILITY OF MIXTURES OF n-HEPTANE, AIR AND DICHLORODIFLUOROMETHANE (FREON 12) (Total Pressure = 400 mm, Hg)

Pressure, mm. Hg		Volume. X		
n-C281A	CC12F2	B-Cailan	CC1 ₂ F ₂	Result
6.0	32.0	1.5	8.0	+
20.0	32.0	5.0	8.0	-
6.0	16.0	1.5	4.0	+
22.0	16,0	5.5	4.0	-
21.0	16.0	5.3	4.0	+
19.0	32.0	4.8	8.0	+
5.0	16.0	1.3	4.0	-
5.0	32.0	1.3	8.0	-
18.0	44.C	4.5	11.0	+
19.0	44.0	4.8	11.0	-
12.0	44.0	3.0	11.0	+
18.0	52.0	4.5	13.0	-
17.0	52.0	4.3	13.0	+
14.0	58.0	3.5	14.5	•
11.0	44.0	2.8	11.0	-
14.0	59.0	3.5	14.1	_
16.0	58.0	4.0	34.5	
18.0	58.0	4.5	14.5	-
16.0	60.0	4.0	15.0	-
10-0	38.0	2 6	1)•U	-
9.0	38.0	2 2	7•2	•
17.0	59.0	4+J	7 •7	-
T.L+O	20.0	4.5	上4+5	÷

178.

i

100

and the

e n**er ei**nterstersterstellige

£ 🖕

ŝ

3

1

FLAMMABILITY OF MIXTURES OF <u>n</u>-HEPTANE, AIR AND CHLOROFORM

(Total Pressure = 400 mm. Hg)

Pressure. mm. Hg		Volume %		
C7H16	CHC13	C7H16	CHC13	Result
8	4	2,0	1.0	-
.8	8	2.0	2.0	+
12	4	3.0	1.0	+
8	12	2.0	3.0	+
8	16	2.0	4.0	+
8	20	2.0	5.0	-
8	24	2.0	6.0	-
12	20	3.0	5.0	+
12	48	3.0	12.0	+
12	24	3.0	6.0	+
12	52	3.0	13.0	+
16	56	4.0	14.0	÷
12	60	3.0	15.0	+
12	68	3.0	17.0	-
12	72	3.0	18.0	-
12	64	3.0	16.0	+
16	60	4.0	15.0	+
12	66	3.0	16.5	+
16	64	4.0	16.0	+
20	60	5-0	15.0	+
24	36	6.0	9.0	+
14	68	3-5	17.0	+
28	68	7.0	9.0	-
14	7 2	3.5	18.0	-
14	70	S+5	17.5	+
16	68	4.0	17.0	-
20	64	5.0	16.0	-

179.

د. ورياريهم

1

Ļ

<u>.</u>

FLAMMABILITY OF MIXTURES OF <u>n</u>-HEPTANE, AIR AND TRIFLUOROMETHANE (FREON 23) (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume %		
n-C-H16	CHF ₃	n-C ₇ H ₁₆	CHF3	Result
24.0	16.0	6.0	4.0	-
5.0	24.0	1.3	6.0	+
4.0	24.0	1.0	6.0	-
22.0	16.0	5.5	4.0	+
6.0	40.0	1.5	10.0	+
18.0	40.0	4.5	10.0	-
4.0	40.0	1.0	10.0	-
16.0	40.	4.0	10.0	+
14.0	60.0	3.5	15.0	-
12.0	60.0	3.0	15.0	+
6.0	56.0	1,5	14.0	+
10.0	68.0	2.5	17.0	+
8.0	68.0	2.0	17.0	+
12.0	68.0	3.0	17.0	+
6.0	68.0	1.5	17.0	-
10.0	71.0	2.5	17.8	-
12.0	71.0	3.0	17.8	-
8.0	71.0	2.0	17.8	-
13.0	68.0	3.3	17.0	

180.

:

÷ -

*

;

:

 \mathbf{r}

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND CHLORODIFLUOROMETHANE (FREDN 22) (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg	Vol	ume. \$	
n-C7H16 OHCLF2	<u>n-C₇H_{1.6}</u>	CHC1F2	Result
24.0 16.0	6.0	4.0	-
4.0 16.0	1.0	4.0	+
20.0 28.0	5.0	7.0	+
3.0 16.0	0.8	4.0	
23.0 16.0	5.8	4.0	+
4.0 28.0	1.0	7.0	+
21.0 28.0	5.3	7.0	-
18.0 40.0	4.5	10.0	+
19.0 40.0	4.8	10.0	-
4.0 40.0	1.0	10.0	+
3.0 28.0	0.8	7.0	-
3.0 40.0	0.8	10.0	-
6.0 60.0	1.5	15.0	+
5.0 60.0	1.3	15.0	-
12.0 66.0	3.0	16.5	+
13.0 66. 0	3.3	16.5	-
12.0 68.0	3.0	17.0	-
10.0 72.0	2.5	18.0	-
11.0 70.0	2,8	17.5	-
10.0 71.0	2.5	17.8	+
8.0 70.0	2.0	17.5	+
16.0 52.0	4.0	13.0	-
6.0 68.0	1.5	17.0	-
7.0 68.0	1.8	17.0	+
8.0 71.0	2.0	17.8	-
4.0 52.0	1. 0	13.0	-
15.0 52.0	3.8	13.0	+
5.0 52.0	1.3	13.0	+

.

•

ر-م

.

FLAMMABILITY OF MIXTURES <u>n-HEPTANE</u>, AIR AND CCTAFLUCROCYCLOBUTANE (FC-318) (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume \$		Result
C7H16	C ₄ F _R	C7H16	C ₄ F ₈	
8	8	2.0	2.0	+
8	12	2,0	3.0	+
8	16	2.0	4.0	+
8	20	2.0	5.0	+
8	24	2.0	6.0	+
8	28	2.0	7.0	+
8	32	2.0	8.0	+
8	36	2.0	9.0	+
8	40	2.0	10.0	+
8	44	2.0	11.0	+
8	48	2.0	12.0	+
8	60	2.0	15.0	+
8	72	2.0	18.0	+
12	72	3.0	18.0	-
8	80	2.0	20.0	
8	76	2.0	19.0	-
10	76	2.5	19.0	-
10	74	2.5	18.5	-
8	74	2.0	18.5	-
14	64	3.5	16.0	-
6	36	1.5	9.0	-
16	52	4.0	13.0	-
6	16	1.5	4.0	+
20	36	5.0	9.0	+
4	12	1.0	3.0	+
26	24	6.5	6.0	+
4	24	1.0	6.0	-
28	24	7.0	6.0	+
30	30	7.5	7.5	-
2	12	0.5	3.0	-

182.

to pille

ŧ

1

i

i

...

ŝ

a Marine in the second state and the second
FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND SULFUR HEXAFLUCRIDE

Pressure. mm. Hg		Volume	*	
n-C-H16	SFA	n-C2HIA	SFA	Result
26.0	16.0	6.5	4.0	+
6.0	16.0	1.5	4.0	-
27.0	16.0	6,8	4.0	+
7.0	16.0	1.8	4.C	+
8.0	32.0	2.0	8.0	+
7.0	32.0	1.8	8.0	-
10.0	48.0	2.5	12.0	+
9.0	48.0	2.3	12.0	-
10.0	60.0	2.5	15.0	-
22.0	48.0	5.5	12.0	-
21.0	48.0	5.3	12.0	+
11.0	60 . 0	2.8	15.0	+
26.0	32.0	6.5	8.0	-
24.0	32.0	6.0	8.0	+
12.0	72.0	3.0	18.0	-
22.0	60.0	5.5	15.0	_
13.0	72.0	3.3	18.0	+
21.0	60.0	5.3	15.0	•
20,0	72.0	5.C	18.0	+
21.0	72.0	5.3	18.0	-
16.0	82.0	4.0	20.5	-
18.0	80-0	4.5	20.0	+
18.0	81.0	4.5	20.3	-
16.0	81.0	4.0	20.3	+
20.0	80.0	5.0	20.0	+
14.0	° 80 ∎0	3.5	20.0	+
13.0	80.0	3.3	20.0	-
21.0	80 .0	5.3	20.0	-
14.0	81.0	3.5	20.3	+
14.0	8 2.0	3.5	20.5	-
20.0	81.0	5.0	20.3	-

FLAmmeBILICY OF MIXTURES OF n-HEPTANE, AIR AND BORONTRIFICORILE (Total Pressure = 400 mm. Hg.)

and the second secon

~1

Pressure	mm. Hg	Volu	me 🖇	Results
C7H16	BF ₃	C7H16	BF ₃	
8.0	8.0	2.0	2,0	+
20.0	16.0	5.0	4.0	+
16.0	24.0	4.0	6.0	+
4.0	8.0	1.0	2.0	-
16.0	32.0	4.0	8.0	•
24.0	16.0	6.0	4.0	+
16.0	100.0	4.0	25.0	-
28.0	1(.0	7.0	4.0	-
16.0	80.0	4.0	20.0	+
8.0	24.0	2.0	6.0	-
16.0	84.0	4-0	21.0	-
24.0	32.0	6.0	8.0	-
12.0	80.0	3.0	20.0	-
12.0	64.0	3.0	16.0	+
20.0	80.0	5.0	20-0	
10.0	64.0	2.5	16.0	•
20.0	64.0	5.0	16.0	-
6.0	64.0	1.5	16.0	-
16.0	64.0	4.0	16.0	•

.

184.

ţ

į

1

;

Table Cu

24

.

.

١

14

FLAMMAPILITY OF MIXTURES OF n-HEPTANE, AIR AND PHOSPHOROUS TRICHLORIDE (Total Fressure = 400 mm, Hg.)

Pressure	e. mm. <u>Hz.</u>	Volum	ne 🕱	Results
C7H16	PC13	C7H16	PCI3	
16.0	24.0	4.0	6.0	+
16.0	48.0	4.0	12.0	+
16.0	52.0	4.0	13.0	+
16.0	80.0	4.0	20.0	**
16.0	60.0	4.0	15.0	-
16.0	56.0	4.0	14.0	+
20.0	56.0	5.0	14.0	-
12.0	56.0	3.0	14.0	+
12,0	60.0	3.0	15.0	+
12.0	64.0	3.0	16.0	+
12.0	68.0	3.0	17.0	+
12.0	72.0	3.0	18.0	+
12.0	76.0	3.0	19.0	+
12.0	80.0	3.0	20.0	+
12.0	88.0	3.0	22.0	+
12.0	100.0	3.0	25,0	-
12,0	46.0	3.0	24.0	-
12,0	92.0	3.0	23.0	-
8.0	88.0	2.0	22.0	-

186.

....

Table 51

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND HYDROGEN CHLORIDE (Total Pressure = 400 mm. Hg.)

Pressure, mm. Hg.		Volume 发		Results
C7H16	HC1	C7H16	HCL	
12.0	40.C	3.0	10.0	+
12.0	80.0	3.0	20.0	+
12.0	120.0	3.0	30.0	-
12.0	100.0	3.0	25.0	+
12.0	112.0	3.0	28.0	-
8.0	80.0	2.0	20.0	+
12.0	104.0	3.0	26.0	-
4.0	80.0	1.0	20.0	-
16.0	100.0	4.0	25.0	-
16.0	£0.0	4.0	20.0	-
8.0	100.0	2.0	25.0	-
20.0	40.0	5.0	10.0	+
4.0	24.0	i.0	6.0	-
24.0	40.0	6.0	10.0	-

187.

ŧ

ŧ

مبا

.

Table 52

. . .

۰.

•

.

• .

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND CARBON FETRAFLUORIDE (Total Pressure = 400 mm. Hg)

المراجع ومتحد ومتعادين والمراجع

Pressure, MM. Hg		Volum	e 🔏	
$n-C_2H_{16}$	CF	n-C7H16	CF	Result
29.0	8.0	7.3	2,0	+
30.0	8.0	7.5	2.0	-
28.0	20.0	7.0	5.0	+
29.0	20.0	7.3	5.0	-
24.0	36.0	6.0	9.0	+
25.0	36.0	6.3	9.0	-
21.0	48.0	5.3	12.0	+
21.0	52.0	5.3	13.0	t
16.0	72.0	4.0	18.0	- +
14.0	84.0	3.5	21.0	Ŧ
12.0	92.0	3.0	23.0	±
5.0	100.0	1.3	25.0	ŧ
4.0	84.0	1.0	21.0	÷
4.0	64.0	1.0	16.0	
4.0	44.0	1.0	11.0	
4.0	20.0	1.0	5.0	
3.0	12.0	0.8	3.0	-
3.0	8.0	0.8	2.0	-

.

- --

a+..

FLAMMABILITY OF MIXTURES OF n-HEFTANE, AIR AND CARBON DIOXIDE (Total Pressure = 400 mm. Hg)

Pressure mm. Hg		Volume %		
n-C ₇ H ₁₆	002	n-C2H16	<u>C02</u>	<u>Result</u>
3.0	4.0	0.8	1.0	-
3.0	12.0	0,8	3.0	-
3.0	16.0	0,8	4.0	-
4.0	32.0	1.0	8.0	+
3.0	32.0	0.8	8.0	-
4.0	64.0	1.0	16.0	•
4.0	80.0	1.0	20.0	+
6.0	100.0	1.5	25.0	Ŧ
5.C	100.0	1.3	25.0	-
12.0	116.0	3.0	29.0	+
12.0	118.0	3.0	30.0	-
16.0	96.0	4.0	24.C	+
20.0	80.0	5-0	20.0	-
23.0	40.0	5.8	10.0	+
24.0	S. 0	6.0	2.0	-

138.

1.

ł

-

. . .

: 2

:

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND BROMOTRIFLUOROMETHANE AT ~78°C.

Volu	ne. X	
C ₄ H ₁₀	CBrF ₃	Results
3.5	1.5	-
3.5	2.5	-
5.5	1.0	-
6.0	1.0	-
5.5	2.0	-
6.0	2.0	-
5.0	1.0	-
5.0	2,0	+
4.0	1.0	-
4.5	1.0	+
3.5	0.5	-
4.0	0.5	+
5.0	0.5	+
5.5	0.5	+
5.0	1.5	+
6.0	0.5	+
6.5	0.0	200
6.5	0.5	-
2.5	0.0	+
3.0	0.0	+
2.0	2.0	-
2.5	2.0	-
3.0	2.0	-
3.5	2.0	+
3.0	4.0	-
3.5	4.0	-

189.

ļ

.

- **-**

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND BROMOTRIFLUOROMETHANE AT 26°C

Volume, \$		D14
<u>64810</u>	<u>UBIL 1</u>	Results
3.5	1.5	-
3.5	2.5	-
5.5	1.0	-
6.0	1.0	-
2.0	0	
2.5	0	-
2.5	2.0	-
3.0	2.0	-
3.5	2.0	+
3.5	4.0	+
4.0	4.0	-
4.5	4.0	-
3.5	3.0	-
4.0	3.0	+
3.5	3.5	-
4.0	3.5	-
4.5	3.5	
5.0	3.5	-
4.5	3.0	+
5.0	3.0	+
5.5	3.0	-
6.0	3.0	-

190.

ويتساويه والمحاجب وال

ł

į
FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND BECHOTRIFLUOROMETHANE AT +145°C

المراجعة المراجع المراج المراجع
Vclume, %		
Cullin	CBrF ₁	Results
2.5	1.0	+
3.0	2.0	+
2.0	1.0	-
2.5	1.0	+
2.5	2.0	+
3.0	2.0	+
2.0	2.0	-
2.5	3.0	-
3.0	3.0	-
3.5	3.0	-
4.0	3.0	-
4.5	3.0	~
3.0	4.0	-
4,0	4.0	-
6.0	3+5	+
5.0	3.5	+
5.0	3.0	+
5.0	4.0	+
4.5	4.0	+
6.0	4.0	+
4.5	5.0	+
5.0	5.0	+
4.0	5.0	+
4.0	6.0	+
3.5	5.0	+
3.5	6.0	+
3.0	5.0	-
3.0	6.0	-
3.5	7.0	-
4.0	7.0	+
4.0	7•5	-
4.5	7.5	-
4.5	7.0	-
5.0	7.0	-
5.5	5.0	+
6.0	5. 0	-
6.5	3.0	+
7.C	3.0	-
7.G	2.0	+
7.5	2.0	+
8.0	2.0	-
8.5	2.0	-
8.0	1.0	-
8.5	1.0	-
9.5	0.0	-
10.0	0.0	-

• •

a gran a com a

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND METHYL BROMIDE AT -78°C

Volume	≥ _%	
C ₄ H ₁₀	CH 3Br	Results
4.5	3.5	-
4.0	<u>í.</u> 0	-
4.0	3.0	-
4.5	3.0	-
4.0	2.0	*
4.0	3.0	-
4.5	2.0	•
5.0	2.0	•
5.5	2.0	
6.0	2.0	
6.0	10	, ,
6.5	10	+ +
4.0	2.0	+
4.0	2.0	-
3.0	4.0	-
3. 0	4.0	-
2+2	4.0	-
2.0	1.0	-
3.0	1.0	-
5.5	1.0	+
4.0	1.0	+
2.5	2.0	
2.5	3. C	-
3.0	3.0	+
3.5	3.0	+
3.0	3.5	+
3.5	3•5	+
2.5	3.5	
4.0	3.5	+

192.

in the second second

1 -

į

i

ž.

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND METHYL BROWIDE AT 26°C

Volume, %		
CaHao	CH 3Br	Results
1.0	4.0	+
3.0	4.0	-
1.0	5.0	-
3.0	5.0	+
1.0	1.0	-
6.5	1.0	-
5.5	1.0	+
2.0	1.0	+
4.0	6.0	+
4.0	5.0	+
4.0	7.0	+
4.0	8.0	-
4.0	7.5	-
4.0	3.0	+
5.0	3.0	-
5.0	4.0	-
5.0	6.0	+
5.0	5.0	-
5.0	8.0	-
5.C	7.0	-
4.0	6.0	+
4.0	10.0	-
4.0	9.0	-
2.5	5.0	+
4.0	8.0	-
2.0	5.0	-
6.0	2.0	+
4.0	7.0	-
7.0	2.0	-
4.0	6.5	-
3. 0	6.C	+
5.0	6.0	-

ł

•

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND METHYL BROMIDE AT +145°C

•

Volum C ₄ H ₁₀	CH ₃ Br	Results
1.0	0.0	-
0.5	0.0	-
1.5	0.0	-
1.0	0.0	-
2. 0	0.0	-
1.5	0.0	-
2.5	0.0	-
3.0	0.0	-
3.5	C•O	+
4.0	0.0	+
6.5	0.0	+
7.0	0.0	+
7.5	0.0	+
8.0	0.0	+
9.0	0°•C	+
10.0	0.0	-
4.0	2.0	+
4.5	2.0	+
3.5	2.0	-
3.5	4.0	+
3.0	4.0	-
2.5	4.0	-
3.0	6.0	-
3.5	6.0	-
3.0	5.0	-
4.0	5.0	-
4.5	5.0	+
4.5	5.5	+
4.0	5.5	-
4.0	6.0	+
4.0	7.0	+
4.5	7.0	+
4.5	6.0	+
4.5	8.0	+
3.5	7.0	+
3.5	8.0	+
3.0	7.0	+
3.0	8.0	-
3.5	9.0	-
4.0	8.0	-
5.0	8.5	-
5.0	9.0	-
4.0	8.0	+
4.0	8.5	-

194.

ł

j,

÷

:

i

4

Ser Law

Ver La Com

195.

۲

1

1

Table 59(Cont'd)

ан I.

-

.

•

Volume, %		
C.H10	CH Br	Results
5.5	B _∎ O	-
6.0	₿.0	-
5.0	7.0	+
5.5	7.0	-
5.5	6.0	-
6.0	6.0	-
5.0	5.0	+
5.5	5.0	-
5.5	3.0	+
6.0	3.0	+
6.5	3.0	+
7.0	3.0	-
7.0	2.0	+
7.5	2.0	-
7.0	1.0	+
7.5	1.0	+
5-0	4.0	+
5.5	4.0	+
4.5	1.0	+
4.5	3.0	+
6.5	<i>i</i> 0	-
8.0	1.0	-

Table 60 FLAMMABILITY OF MIXTURES OF ISCBUTANE, AIR AND CHLOROTRIFLUOROMETHANE AT -78°C

-

.

Volume, %		
C4H10	CCLF 3	Results
4.0	2.0	-
4.5	2.0	-
3 . C	2.0	-
3.5	2.0	-
2.0	2.0	-
2.5	2.6	-
3.0	2.0	-
6.0	1.5	+
4.0	2.0	-
4.5	2.0	-
7.0	1.0	-
7.5	1.0	-
6.5	1.0	-
6.5	7.0	-
6.0	1.0	+
6.5	2.0	-
6.0	2.0	-
6.0	0.0	+
5.5	2.0	-
6.5	0.0	+
5.0	2.0	-
7.5	0.0	-
4.5	2.0	-
7.0	0.0	-

196.

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND CHLOROTRIFLUCROMETHANE AT 26°C.

Volume. 8		
C.H10	CC1F.	Results
3.0	6.5	-
3.5	7.0	+
3.0	8.0	-
3.5	8.0	+
2.0	3.0	-
2.0	5.0	-
2.5	3.0	_
2.5	5.0	-
4.5	7.0	-
4.5	9.0	-
3.0	9.0	-
3.5	9.0	- .
4.0	9.0	-
4.5	9.0	-
4.0	8.5	-
4.5	8.5	-
450	10.5	+
4.5	10.5	+
5.0	10.5	-
5.5	10.0	-
3.5	10.0	-
3.5	10.5	-
5.0	10.0	+
5.0	12.0	-
4.0	10.0	+
4.0	12.0	-
4.5	10.0	+
4.5	12.0	-
5.0	5.0	-
2.2	6.0	-
4.7	5.0	+
5. 0	4.0	+
2+2	3.0	+
2.2	4.0	+
5.0	4.2	+
5 5	4.0	+
2+2 6 5	4+2	+
65	4.0	-
6 5	∠ ∎U 6 0	+
7.0	2.0	
6.0	2.0 6.0	•
7.5	2.0	•
1•2 6.0		
	7.0	-

. .

÷

Table 61 (Cont'd)

۰.

Volum	ie, %	
CuH10	CC1F1	Results
5.5	9.0	•
5.5	13.0	-
6.0	6.5	+
6.0	3.0	+
6.5	3.0	+
6.5	6.5	+
7.0	3.0	-
7.0	6.5	-

j,

ě

÷.

ļ

7able 62

.

•

.

•

FLAMMABILITY OF MIXTURES OF ISOHUTANY, AIR ARC (HLCROTRIFLUOROMETHANE AT +145°C

Volume, X		
Collin	CC1F ₁	Results
1.5	0.0	-
2.0	0.0	-
2.0	0.0	+
2.5	0.0	+
1.5	2.0	-
2.0	2.0	-
2.5	2.0	+
3-0	2.0	+
2.0	4.0	-
2.5	4.0	+
2.0	6.0	-
2.5	6.0	
2,5	6.0	-
3.0	6.0	+
3.0	8.0	-
3.5	8 . C	-
4.0	8.0	+
4.5	8.C	+
4.0	10.0	+
4.5	10.0	4 ,
3.0	10,0	-
3.5	10.0	+
3.5	12.0	-
4.0	12.0	+
3.5	13.0	-
4.5	2.0	+
4.5	6.0	+
4.5	14.0	-
5.0	14.0	-
4+5	13.0	-
5.C	13.0	-
4.0	12.5	+
4.5	12.5	-
3.5	13.0	+
4.0	13.0	-
4.5	12.0	+
5.C	12.0	-
5.C	10.0	+
5.5	10.0	+
6.0	8.0	+
6.5	8.0	-
6.0	6.0	+
6.5	6.0	-
6.0	4.0	+
6.5	4.0	+
7.5	2.0	+
8.C	2.0	+

Volume, %		
Cullin	CCLF.	Results
9.5	0.0	+
10.0	C.G	+
6.0	10.0	-
5.0	11.0	+
3.5	12.0	+

•

ł

「たち」 .

> 13. 2

۰. .

.

-

r .

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND SULFUR HEXAFLUORIDE AT -78°C

Volum	0,%	
C.H10	SF	Results
3.0	0.0	+
5.0	10.0	+
4.5	10.0	+
4.0	10.0	-
5.0	12.0	+
4.5	12.0	+
4.0	12.0	-
4.0	14.0	-
4.5	14.0	•
4.5	16.0	-
3.0	4.0	+
3.0	6.0	+
2.5	0.0	-
2.5	2.0	-
3.0	2.0	-
2.0	6.0	-
2.5	6.0	-
5.0	11.0	-
5.0	12.0	-
4.5	12.0	-
4.5	12.5	-
3.5	, 0 . 0	-
3.5	0.0	+
3.5	0.0	+
4.5	11.0	-
5+5	14.0	-
5.0	14.0	-
5.0	13.0	-
4.5	13.0	-
5.0	12.5	-
4.5	12.5	-
3.5	0.0	+
3.5	0.0	+
5.5	12.0	-
6.0	12.0	-
5.0	11.0	-
5.5	11.0	-

. .

201.

1

PLAMMABILITY OF MIXTURES OF ISOPUTANE, AIR AND SULFUR HEXAFLUORIDE AT 26°C.

Volum	e, %	
C.H10	SF6	Results
1.0	4.0	-
4.0	4.0	+
2,0	4.0	-
3.0	4.0	-
2.5	4.0	-
6.0	4.0	+
2.0	0,0	+
0,8	0.0	-
1,0	0.0	+
7.0	0.0	-
0.5	0,0	-
6.0	0.0	+
6.0	0.0	+
6.5	0.0	+
4.0	13.5	+
7.0	5.0	+
2+U 5 5	18.0	-
2+2	14.0	+
1.5	17.0	-
5.5	15.0	+
5.0	16.5	.▲
4.5	16.0	+
3.5	13.0	+
6.0	13.0	-
3.0	10.0	-
5.0	11.0	+
5.0	12.0	+
5.0	13.0	-
5.0	14.0	+
4.5	11.0	-
4.5	12.0	-
3.5	0.0	-
3.5	0.0	+
4.0	0.0	-
4.0	0,0	+
4.0	0.0	+
4.0	0.0	+
5.0	12.0	+
4.5	12.0	-
5+U E .E	8.0	-
2+2	9.0	-
4.0	0.0	+
4.0	8.0	* _
5.0	8.0	-
٤.0	6.0	+

.....

.

n -----

ş

•

.

.

.

r :

FLAMMABILITY OF MICTURES OF ISOBUTANE, AIR AND SULFUR HEXAFLUORIDE AT +145°C

Volum	e, %	
Callin	SFA	Results
2.0	2.0	-
2.5	2.0	-
3.0	2.0	+
3.5	2.0	+
3.5	4.0	+
4.0	4.0	+
3.5	8.0	+
4.0	8.0	+
2.5	4.0	+
2.5	8.0	-
3.5	12-C	-
4.0	12.0	+
4.0	14.0	+
4.5	14.0	+
3.5	14.0	-
5, C	14.0	+
4.0	16.0	-
4.5	16.0	-
5.0	18.0	-
2.2	18.0	-
4.2	17.0	-
5.0	17.0	-
2.U	10.0	+
6.0	16.0	+
6.0	16 5	+
5.5	17 0	+
6.0	17.0	-
6.5	16.0	-
7.0	16.0	-
6.5	14.0	-
7.0	14.0	-
6.5	12.0	•
7.Č	12.0	-
ز ب	10.0	+
7.0	10.0	•
8.0	10.C	-
7.5	10.0	-
7.0	8.0	-
7.5	8.0	+
8.0	6.0	-
8.5	6.0	-
7.5	6.0	+
7.5	3.0	+
3.C	10.0	-
3.5	10.0	-
2.0	6.0	-
2,5	6.0	-

×۲. . . ۱۱۰

1

í

Table 66

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND CARBONTETRAFLUORIDE AT -78°C

<u>Volum</u>	e, %	
Callin	<u>CC14</u>	Results
6.0	18.0	-
7.0	18.0	-
5.5	18.0	-
2.2	18.5	-
3.0	0.0	+
5.0		*
5.0	15.0	-
4.5	135	₹
5.5	13.5	+
4.0	10.0	+ ▲
6.0	16.0	-
5.5	10.0	+
6,0	10.0	-
6.5	10.0	-
5.5	8.0	+
6.0	8.0	+
6.5	8.0	+
7.0	8.0	+
7.5	8.0	+
6.5	9.0	+
7.0	9.0	+
7.5	9.0	+
8.0	7.0 8.0	+
8.0	9.0	-
7.0	6.0	-
7.5	6.0	-
6.5	6.0	+
7.0	7.0	-
6.5	4.0	-
7.0	4.0	-
6.0	4.0	+
2.2	4. 0	+
6.5	2.0	+
4.5	2.0	+
3.5	12.0	+
4.5	7.0	÷
4.5	10.0	+ +
4.5	3.0	•
4.5	5.0	• •
2.5	6.0	-
3.0	6.0	+
2.5	6.0	-

• 1247 - •

Table 66 (Cont'd)

Volume	. 8	
C.HIG	<u>CF</u>	Results
2.5	10.0	-
3.0	10.0	+
3.5	10.0	+
2.5	14.0	-
3.0	14.0	*
3.5	14.0	-
4.0	14.0	_%
4.5	14.0	-
5.0	14.0	+
4.5	18.0	-
5.0	18.0	+
4.5	22.0	-
5.0	22.0	-
4.5	14.0	-
4.5	18.0	-
5.0	22.0	-
6.0	22 . 0	-
6.5	22.0	-
7.0	22.0	-
4.5	20.0	-
5.0	20.0	-
5.0	20.0	-
6.0	20.0	-
7.6	20.0	-
8.0	20.0	
5.0	19.0	-
5.5	19.0	-

205.

÷

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND CARBONTETRAFLUORIDE AT 26°C

.

Volume	. \$	<i>A1 ~</i> 0 0
C4H10	CF	Results
6.5	10.0	-
6.5	14.0	-
6.0	13.0	+
6.0	16.0	-
2.2	16.0	-
2.2	18.0	-
5.0	16.0	-
55	15.0	-
1. 5	15.0	-
5.0	15.0	+
5.0	18.0	•
4.5	18-0	-
4.5	20.0	-
4.0	21.0	-
4.5	21.0	+
4.5	22.0	-
5.0	22.0	-
2.5	9.0	+
3.0	9.0	+
2.5	13.0	-
3.0	13.0	+
2.5	15.0	•
3.0	15.0	+
2.5	18.0	-
3.0	18.0	-
3.U 2.E	12.0	+
2.0	12.0	+
3.5	14.0	+
1.5	14.0	+
2.0	0.0	-
4.0	23.0	•
7.5	4.0	-
4.0	23.5	+
7.5	5.0	+
8.0	1.0	-
8.0	2.0	-
8.0	3.0	-
7.0	4.0	+
7.0	6.0	+
7.0	8.0	-
0.5	8.0	+
0.) 6 0	11.5	-
6.0	T5.0	•
5.0	20	•
5.5	5.0	+
5.0	2.0	÷

، مر

--

206

and the second
--

•

ł

.

.

FLAMMABILITY OF MIXTURES OF ISOBUTANE, AIR AND CARDONTETRAFLUORIDE AT +145°C.

Volum	e, 1	
CAHIO	CF	Results
3.0	0.0	+
3.5	0.0	+
2.5	0.0	+
2.0	0.0	+
1.5	0.0	-
1.0	0.0	-
9.0	0.0	+
9.5	0.0	+
2.0	3.0	-
2.5	3.0	+
2.0	6.0	-
2.5	6 .0	+
2.5	9.0	-
3.0	9.0	+
3.0	12.0	+
3.5	12.0	+
2.5	15.0	-
3.0	15.0	-
2.5	12.0	-
3.5	15.0	-
3.5	18.0	-
4.0	18.0	-
4.5	18.0	-
5.0	18.0	-
4.0	15.0	-
4.5	15.0	-
3.5	13.5	+
4.0	13.5	-
2.5	13.5	-
3.0	13.5	-
4.0	12.0	+
4.5	12.0	+
5.0	12.0	+
5.0	13.5	-
5.5	12.0	+
6.0	12.0	-
5.5	13.5	+
5.5	15.0	-
6.0	9.0	-
6.5	9.0	-
7.0	6.0	-
7.5	6.0	-
7.0	3.0	+
7.5	3.0	+
4.0	3.0	+
4.0	9.0	+
2.0	1.5	-
2.5	1.5	÷

Í

. . . .

FLAMMABILITY OF MIXTURES OF PENTANE, AIR AND METHYLENE DIBROMIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg			Volume %		Result
$C_{5}H_{12}$	CH2Br2		C5H12	CHgBr2	
10	04	1	2 O	6.0	•
2	8		2.0	2.0	•
12	32		3.0	8.0	+
6	8		1.5	2.0	-
12	28		3.0	7.0	-
24	12		6.0	3.0	-
12	22		3.0	5.5	+
12	26		3.0	6.5	-
10	26		2.5	6.5	•
14	24		3.5	6.0	-
10	28		2.5	7.0	-
18	16		4.5	4.0	. –
8	26		2.0	6.5	-
18	12		4.5	3.0	+
8	16		2.0	4.0	· •

FLAMMABILITY OF MIXTURES OF PENTANE, AIR AND BROMO-TRIFLUORGJETHANE (Total Pressure = 400 mm. Hg)

Pressure, ma. Ha.		Volum	1e. 9	Result	
C6H12	CF ₃ Br	C5H12	CF3Br		
12	16	3.0	4.0	+	
16	16	4.0	4.0	+	
12	22	3.0	5.5	+	
16	20	4.0	5.0	+	
12	26	3.0	6.5	-	
16	26	4.0	6.5	-	
12	24	3.0	6.0	+	
1;	24	3.5	6.0	+	
10	24	2.5	6 . 0	-	
14	26	3.5	6.5	-	
8	20	2.0	5.0	-	
16	24	4.0	6.0	-	
8	16	2.0	4.0	-	
20	20	5.0	5.0	-	
10	16	ະ.5	4.0	-	
20	16	5.0	4.0	-	
10	14	2.5	3.5	+	
20	12	5.0	3.0	+	
8	12	2.0	3.0	-	
20	8	5.0	2.0	+	
8	8	2.0	2.0	-	
20	÷	5.0	1.0	+	
8	-1	2.0	1.0	+	
20	0	5.0	0.0	-	
24	12	6.0	3:0	-	
24	8	6.0	8:0	-	
24	· _	6.0	ĭ.0	+	

.

١

Pressure, mm. Hg.		Volume, A		Result
C _B II	C ₂ H ₅ Br	C5H12	C ₂ H ₅ Fr	
12	16	3,0	4.0	+
12	24	3.0	6.0	-
12	28	3.0	7.0	-
12	20	3.0	5.0	-
12	22	3.0	5.5	-
12	28	3.0	4.5	_
lû	20	3.5	5.0	+
10	22	2.5	5.5	+
4	12	1.0	3.0	-
10	24	2.5	6.0	- +
6	12	1.5	3.0	+
8	26	2.0	6.5	+
6	18	1.5	4.5	+
10	26	2.5	6.5	_
6	26	1.5	6.5	_
8	30	2.0	7.5	_
12	22	3.0	4.5	-
8	28	2.0	7.0	-
16	10	4.0	2.5	-
22	4	5.5	1.0	•

FLAMMABILITY OF MIXTURES OF FENTANE, AIR AND ETHYL BROMIDE (Total Pressure = 400 mm. Hg)

141

ŝ

FLALMABILITY OF MIXTURES OF PENTANE, AIR AND METHYL BROMIDE (Total Pressure = 400 mm. Hg)

Pressure. mm. Hg		Volu	Regult	
C6H12	CH ₃ Br	C5H12	CH3Br	
4	12	1.0	3.0	-
28	12	7.0	3.0	-
6	12	1.5	3.0	-
24	12	5.0	3.0	-
8	12	2.0	3.0	+
12	21	3.0	6.0	+
20	12	5.0	3.0	+
12	32	3.0	8.0	+
22	12	5.5	3.0	-
12	34	3.0	8.5	-
16	24	4.0	6.0	+
10	32	2.5	8.5	+
18	24	4.5	6.0	-
8	36	2.0	9.0	+
8	24	2.0	6.0	+
8	32	2.0	8.0	+
6	24	1.5	6.0	-
8	34	2.0	8.5	-
10	34	2.5	8.5	-
10	35	2.5	8.75	-

.

V,

FLAMMABILITY OF MIXTURES OF PENTANE, AIR AND SULFUR HEXAFLUORILE (Total Pressure = 400 mm. Hg)

Prossure. mm. Hg		Volume. S.		Result
C ₅ H ₁₂	SFG	C5H12	CF6	
12	72	3.0	18.0	-
16	76	4.0	19.0	+
12	70	3.0	17.5	+
16	78	∉.0	19.5	-
25	76	5.0	19.0	•
14	75	3.5	19.0	+
18	7C	4.5	19.0	-
14	78	3.5	19.5	+
18	72	4.5	18.0	+
14	80	3.5	20.0	-
10	56	2.5	14.0	-
20	68	5.0	17.0	-
8	30	2.0	8.0	+
22	52	5.5	13.0	+
10	32	2.5	8.0	+
24	52	6.0	13.0	-
6	32	1.5	8.6	-
28	24	7.0	6.0	-
26	24	6.5	6.0	-
24	24	6.0	6.0	+

·

;

ź

• • ≇a: •

FLAMMABILITY OF MIXTURES OF PENTANE, AIR AND CARBON TETRAFLUORIDE (Total Pressure = 400 mm, Hg)

Pressure. mm. He		Volumo 4			
C5H12	CF4	C5H12	CF4	<u>Result</u>	
12	72	3.0	19.0		
14	72	3.5	10.0	+	
12	80	3.0	10.0	+	
19	80	7.0	20.0	-	
12	26	U+C 7 A	20.0	+	
1.	AP	3.0	19.0	+	
16	80	3.5	0. SS	-	
14	20	4.0	\$0 . 0	-	
18	0	3.5	21.0	-	
14	72	4.5	16.0	-	
10	82	3.5	20.5	_	
10	60	4.5	15.0		
10	72	2.5	18.0	-	
18	52	4.5	13.0	-	
10	6C	2.5	15.0	+	
10	52	2.5	1% 0	-	
6	40	1.5	10.0	+	
16	72	4.0	10.0	-	
6	28		13.0	-	
9	00	1.0	7.0	-	
	20	2 • V	7.0	+	

۰.

213.

₩. _1

Pressure. mm. Hg. Volume, ⋦ Result CeHe CH_2DT2 C₆H₆ CH2Br2 12 2.5 ΰ 0 ÷ 12 28 **3.0** 7 ٠ 30 0 30 6 7.5 12 3.0 3.0 8 12 2.0 15 28 7.0 2.5 12 -1 3.0 1.0 14 28 7.0 3.5 6 12 3.0 1.5 36 9.0 0 5.0 0 8 2Ó 2.0 3. ٤.5 ÷U 0 18 20 4.5 š.0 10 20 2.5 5.0 16 20 4.0 5.0 5.0 12 20 3.0 t 14 20 3.5 5.0 18 12 4.5 3.0 22 12 3.0 5.5 _ 20 12 5.0 3.0 _

FLAMMABILITY OF MIXTURES OF BUNZENE, AIR AND METHYLENEDIUS 'I F (Total Pressure = 400 mm, Hg)

1

- [

يد فد

1

2

i

FLAMMABILITY OF MIXTURES OF BENZENE, AIR AND HROMOTRI-FLHOROMETHANE (Total Pressure = 400 mm. Hg)

Fressure, mm. Hg		<u>Volume, %</u>		Recult
Calle	CBrF3	CeHe	CPrF	
12	20	3.0	5.0	-
16	20	÷.0	5.0	-
20	20	5.0	5.0	-
16	16	4.0	4.0	+
24	2 0	. 6.0	5.0	-
16	18	4.0	4.5	+
18	3.8	4 •Ē	4.5	-
20	16	D .C	4.Ŭ	-
18	16	4.5	4.0	-
14	16	3.5	4.0	+
14	18	3.5	4.5	-
12	16	3.0	4.0	+
10	14	2.5	3.5	+
10	16	2.5	4.0	+
12	18	3.0	4.5	-
10	18	2.5	4.5	-
18	14	4.5	3.5	+
22	12	5.5	3.0	+
2 8	10	7.0	2.5	+
32	6	8.0	1.5	+
28	12	7.0	3.0	+

.

•

215.

4

FLAMMABILITY OF MIXTURES OF BENJENE, AIR AND ETHYL BRONIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume, 🐔		Resul	
C ₆ H ₆	C2H5Br	C ₅ H ₆	C2HBBr		
12	24	3.0	6.0	•	
12	32	3.0	8.0	-	
12	28	3.0	7.0	+	
12	30	3.0	7.5	-	
10	30	2.5	7.5	Ŷ	
14	È	3.5	7.5	-	
10	. .?	2.5	0.3	+	
16	2	4.0	6.0	+	
10	34	2.5	8.5	-	
25	2 5	5.0	5.0	-	
8	34	2.0	8.5	-	
24	12	6.0	3.0	-	
8	26	2.0	6.5	-	
18	20	4.5	5.0	-	
16	26	4.0	6.5	-	
20	10	5.0	2.5	+	
8	14	2.0	3.5	+	
32	0	8.0	0	+	
6	14	1.5	3.5	+	
4	0	1.0	0	-	
6	0	1.5	0	-	
4	14	1.0	3.5	-	
8	0	2.0	0	-	
12	0	3.0	0	+	

216.

-

5. **3**. 1.

1

÷ŝ,

i

÷

FLANDABILITY OF MIXTURES OF BENZENE, AIR AND METHYL BROWLDE. (Total Prussure = 400 mm, Hg)

Pressure, mm. Hp		Volu	Result	
C.H.	CH ₃ Br	CeHe	Cli ₃ Br	
12	24	3.0	6.0	*
ß	16	2.0	4.0	-
12	32	3.0	8.0	+
10	16	2.5	4.0	•
12	40	3.0	10.0	-
8	8	2.0	2.0	-
12	36	3.0	9.0	-
24	16	6.0	4.0	+
12	34	3.0	8.5	-
28	16	7.0	4.0	-
14	32	3.5	8.0	-
32	10	8.0	2.5	+
10	32	2.5	8.0	+
26	16	6.5	4.0	-
8	32	2.0	8.0	-
16	24	4.0	6.0	+
10	34	2.5	8.5	_
18	24	4.5	6.0	-

· ·

217.

ł

FLAMMABILITY OF MIXTURES OF BENZENE, AIR .ND SULFUR HEXA-FLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume, #		Result
C ₅ H ₆	SF6	CoHe	OF8	
16	80	4.0	20.0	-
12	80	3.0	20.0	-
10	80	2.5	20.0	-
12	78	3.1	19.5	-
10	76	2.5	19.0	-
12	74	3.0	18.5	-
10	72	2.5	18.0	-
12	70	3.0	17.5	-
10	70	2.5	17.5	-
12	66	3.0	16.5	-
10	62	2.5	15.5	-
12	58	3.0	14.5	-
16	58	4.0	14.5	+
20	58	5.0	14.5	+
16	70	9.0	17.5	-
20	64	5.0	16.0	+
16	66	9.0	16.5	+
20	6 6	5.0	16.5	+
14	64	3.5	16.0	+
20	72	5.0	18.0	-
14	68	3.5	17.0	-
20	68	5.5	17.0	+
18	70	4.5	17.5	+
24	68	6.0	17.0	•
18	74	4.5	18.5	_
26	68	6.5	12.0	_
24	72	6.0	18.0	-
18	72	4.5	18.0	-
12	45	3.0	12.0	
10	24	2.5	6.0	•
28	52	6-5	13.0	•
8	24	2.0	10.V	•
30	52	7.5	13.0	-
30	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	7.5	13.0	-
~-	~	/ •U	7.0	+

.

· · · · ·

ł

FLAMMABILITY OF MIXTURES OF MENZENE, AIR AND CARBON TETRAFLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volum	6, %	Result
C ₈ H ₈	CF4	C ₆ H ₆	C₹ <u></u>	
14	76	3.5	19.0	+
12	80	3.0	20.0	+
14	80	3.5	20.0	+
12	88	3.0	22.0	-
14	88	3.5	22.0	+
14	62	3.5	23.0	-
12	84	3.0	21.0	+
1:	90	3.5	22.5	+
16	88	4.0	22.0	-
18	60	4.5	20.0	
10	80	2.5	20.0	-
16	80	4.0	20.0	+
10	64	2.5	15.0	+
20	64	5.0	16.0	+
24	48	6 . C	12.0	+
28	40	7.0	10.0	+
28	48	7.0	12.0	+?
2;	64	6.0	16.0	-

ł

N

1 *. .

7

Table 81

FLAMMABILITY OF MIXTURES OF ETHANOL, .. IR .. ND METHYLENE DIBROMIDE (Total Pressure = 400 mm. Hg)

Pressure. mm. Hg		Volume &		Result
C2H5OH	CH ₂ Br ₂	C2H5	CH2Br2	
32	12	8.0	3.0	+
32	20	8.0	5.0	+
28	28	7.0	7.0	-
32	24	8.0	6.Ú	-
32	22	8.0	5 .5	-
28	22	7.0	5.5	-
34	20	8.5	5.0	-
30	20	7.5	5.0	+
28	16	7.0	4.0	+
30	22	7.5	5.5	+
20	10	5.0	2.5	-
3 0	24	7.5	6.0	-
24	12	6.0	3.0	-

FLAMABILITY OF MIXTURES OF ETHANOL, AIR AND BROMG-TRIFLUOROMETHANE (Total Pressure = 400 mm. Hg)

Prossure. mm. Hg		Volume. &		Recult
CgHeOH	CF ₃ Br	C2H5OH	CF3Br	
28	εū	7.0	5.0	-
32	20	8.0	5.0	-
28	16	7.0	- ≨ ∎0	-
32	16	8.0	4.0	-
36	16	9.0	4.0	-
36	14	9.0	3.5	+
32	14	8.0	3.5	-
40	14	10.0	3.5	-
34	14	8.5	3.5	-
38	14	9.5	3.5	-
40	;	10.0	0	+
32	10	8	2.5	-
40	10	10.0	2.5	-
32	6	8.0	1.5	-
40	6	10.0	1.5	-
32	4	8.0	1.0	-
40	4	10.0	1.0	-
32	0	8.0	0	· •
40	2	10.0	0.5	+

.

,

| 4. 4.

ł

FLAMMABILITY OF MIXTURES OF ETH/NOL, AIR AND ETHYL BPONIDE (Total Pressure = 400 mm, Hg)

Pressure, mm. Hg		Volum	Volume %	
C2H5OH	CplinBr	C2H5OH	C_2H_6Br	
32	12	8.0	3.0	*
32	20	8.0	5.0	+
32	24	8.0	5.0	-
32	22	8.0	5.5	-
30	22	7.5	5,5	-
34	22	8.5	5.5	-
28	20	7.0	5.0	+
36	20	9.0	5.0	-
28	22	7.0	5.5	-
24	20	6.0	5.0	-
22	16	5.5	4.0	+
20	12	5.0	3.0	+
20	8	5.0	2.0	+
26	20	6.5	5.0	-

ž,

1

4

1.74

•

FL, MMABILITY OF MIXTURES OF ETHANOL, AIR AND METHYL BROMIDE (Total Pressure = 400 mm, Hg)

Pressure, mm. Hr.		Volum	10, X	Result	
C2HBOH	Cit _a Pr	C2H5OH	CH3Br		
12	24	3.0	6.0	-	
32	24	8.0	6.0	+	
32	28	8.0	7.0	-	
20	32	5.0	8.0	-	
20	28	5.0	7.0	-	
28	28	7 .C	7.0	-	
20	20	5.0	5.0	_	
32	26	8.0	6.5		
36	26	9.0	6.5	-	
28	24	7.0	6.0	-	
20	12	5.0	3.0	-	
40	14	10.0	3.5	-	
28	20	7.0	5.0	+	
36	14	9.0	3.5	+	
36	22	9.0	5.5	-	
24	16	6.0	9.0	+	

.

١

.

FLUMMABILITY OF MIXTURES OF ETHANOL, AIR AND SULFUR HEXA-FLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, Mm. Hg		Volume. %		Roault
C2H5OH	SF6	C ₂ H ₅ OH	SF6	
20	64	5.0	16.0	
20	16	5.0	4.0	
32	64	8.0	16.0	-
24	16	6.0	4.0	-?
32	48	8.0	12.0	~.
28	16	7.0	÷.0	+
32	32	8.0	8.0	+?
48	12	12.0	4.0	+
32	40	8.0	10.0	-
32	36	8.0	9.0	+
28	76	7.0	9.0	+
28	40	7.0	10.0	+
24	40	6.0	10.0	-
24	16	6.0	4.0	+
28	44	7.0	11.0	-
40	32	10.0	8.0	-
56	16	14.0	4 0	<u>ـ</u>

224.

Ř.

FLIMMABILITY OF MIXTURES OF ETHANOL, AIR AND CARBON-TETRAFLUORILE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume	Ve au 1+	
C2HBOH	CF4	C2H5OH	CF4	<u>nesare</u>
20	80	5-0		
24	80	6.0	50 0	-
25	80	7.0	20.0	
32	80	8.0	20.0	-
28	74	7-0	19 6	-
32	76	8.0	10.0	•
28	68	7 0	10.0	+
32	78	8.0	10 5	-
28	6 0	7.0	19.0	+
34	78	8.5	10.5	-
36	80	9.0	50 0 19 D	+
24	32	5.0	20.0	~
34	80	8.5	20.0	-
28	32	7 0	20.0	-
36	72	9.0	0.0	-
30	32	7.5	10.0	-
36	56	9.0	0.0	-
30	6 0	5.0 7.5	14.0	+
40	40	10 0	15.0	+
3 C	32	7.5	10.0	+
44	40	11 0	0.0	-
32	32	8.0	10.0	-
30	78	7 5		-
36	32	9.0	19.0	-
30	68	7 S	0.8	+
20	0	7.U 5.0	17.0	+
32	12	5.0		-
28	0	0.0	3.0	+
24	0	r.U 6 m	0	+
28	8	0.0	0	+
22	õ	7.0	2.0	+
24	ň	0.0 C	- 0	+
	0	0.0	2.0	-

225.

1

Ń

FLAMMABILITY OF MIXTURES OF DIETHYL ETHER, AIR AND METHYLENE DIERCMIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volune, 7		Result
$(C_2H_6)_20$	CH2Br2	$(C_2H_5)_2O$	CH2Br2	
12	10	3.0	4.0	•
12	24	3.0	6.0	+
12	28	3.0	7.0	+
12	32	3.0	8.0	-
12	36	3.0	9.0	_
12	30	3.0	7.5	-
10	30	2.5	7.5	-
14	30	3.5	7.5	+
10	24	2.5	6.0	-
14	32	3.5	8.0	-
10	16	2.5	4.0	+
16	30	4 .0	7.5	-
24	20	6.0	5.0	-
24	12	6.0	3.0	+
18	24	4.5	6.0	-

226.

ţ

1 ¢

i

ł
-

FL.MM.BILITY OF MIXTURES OF LIETHYL THEM, AIR AND FROMOTRI-FLUCROMETIENE (Total Pressure = 400 mm. Hg)

. .

t91	Pressure	= 400	mr.	ng)
-----	----------	-------	-----	-----

Pressure, mm. Hg		Volum: 4		Result
$(C_2H_5)_2C$	CF ₃ Br	(C216)	r ، آو 7	
12	20	3.0	5.0	-
15	20	4.0	5.0	+
20	20	5.0	5.0	+
16	24	4.0	6.0	+
20	24	5.0	6.0	-
16	28	4.V	7.0	-
16	30	4.0	7 •5	-
14	24	3.5	6.0	-
16	26	4.0	6.5	-
18	24	4.5	6.0	+
12	16	3 . û	4.0	-
18	26	4.5	6.5	-
12	12	3.0	3.0	-
20	22	5.0	5,5	+
12	8	3.0	2.0	+
24	£ΰ	6.0	5.0	-
14	22	3.5	5.5	-
24	16	6.0	4.0	+
14	16	3.5	4.0	+
28	12	7.0	3. C	+?
32	10	8.0	2.5	-

•

.

227

.

Í

FLUMABILITY OF MIXTURES OF DIETHYL ETHER, AIR .ND ETHYL BROMIDE (Total Pressure = 400 mm. Hg)

.7

Pressure. mm. Hg		Vol un	4. F	Result
$(C_2H_5)_2C$	C ₂ H ₆ Br	(C2H5),C	C ₂ H ₅ Br	
12	24	3.0	6.0	+
8	10	2.0	2.5	-
12	28	3.0	7.0	-
10	10	2.5	2. •5	+
16	32	4.0	8.0	-
18	24	4.5	6.0	-
16	28	4.0	7.0	-
16	24	4.0	6.0	-
10	20	2.5	5.0	+
14	24	3.5	6.0	-
10	24	2.5	6.0	+
12	26	3.0	6.5	
10	26	2.5	6.5	+
22	12	5.5	3.0	+
10	28	2.5	7.0	+
24	12	6.0	5.0	+
10	30	2.5	7.5	-
26	12	6.5	3.0	+
26	12	6.5	3.0	+
28	12	7.0	3.0	+
32	12	8.0	S .0	+
36	10	9.0	× 0	

228.

1

ł

FLIMMABILITY OF MIXTURES OF DIETHYL ETHER, AIR AND METHYL HROMIDE (Total Pressure = 400 mm. Hg)

$\frac{\text{Pressure.}}{(C_2 H_5)_2 U}$	CH ₃ Br	Voluno (Colle)er	ž CH ₃ Br	Result
12	12	3.0	3.0	+
36	12	9.0	3.0	+
8	12	2.0	3.0	-
38	12	9.5	3.0	-
10	12	2.5	3,0	-
12	24	3.0	6.0	+
12	36	3.0	9.0	-
12	44	3.0	11.0	-
12	32	3.0	8.0	-
1.	30	3.5	7.5	-
12	28	3.0	7.0	+
16	26	4.0	6.5	-
12	30	3.0	7.5	-
25	25	6.25	6.25	+
10	20	4.0	5.0	+
2.	20	6.0	5.0	+
36	16	9.0	∕÷.₀0	-

229.

۶.

230.

ł

1

é

i.

Manager and

Table 91

é.

FLAMMABILITY OF MIXTURES OF DIETHYL FTHER, MIR AND SULFUR HEX.FLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume,	4.	Result	
$(C_2H_5)_20$	SF6	$(C_2H_5)_2O$	3F6		
20	40	5.0	10.0	+	
10	12	2. 5	3.0	+	
20	56	5.0	14.0	+	
20	72	5.0	18.0	+	
12	56	5.0	14.0	+	
20	80	5.0	20.0	+	
12	76	3.0	19.0	-	
20	88	5.0	22.0	-	
12	68	3.0	17.0	-	
20	84	5.0	21.0	+	
12	66	3.0	16.5	-	
20	86	5.0	21.5	+	
12	60	3.0	15.4	-	
24	84	6.0	21.0	-	
16	76	4.0 .	19.0	+	
24	76	6.0	19.0	+	
36	48	9.0	12.0	-	
32	48	8.0	12.0	-	
22	88	5.5	22.0	-	
28	48	7.0	12.0	+	
18	88	4.5	22.0	-	
36	16	9.0	4.0	+	
16	84	4.0	21.0	-	

.

FLAMMABILITY OF MIXTURES OF DIETHYL ETHER, AIR AND CARBON-TETRAFLUORIDE (Total Pressure = 400 mm. Hg)

Fressure, n	nn. Hg	Volume	×.	Result
(C ₂ H ₅) ₂ 0	CF4	$(C_2H_{f_1})_2O$	CF ₄	
10	16	2,5	4.0	+
38	16	9.5	4.0	-
8	16	2.0	4.0	-
34	16	8,5	4.0	-
14	26	3.5	£.5	+
30	16	7.5	4.0	+
10	26	2.5	6,5	+
26	36	6.5	9.0	+
10	36	2.5	3.0	+
30	36	7.5	U.C	+
10	44	2.5	11.0	-
28	60	7.0	15.0	-
12	52	3.0	13.0	+
24	60	6.0	15.0	_
12	80	3.0	20.0	_
22	60	5.5	15.0	+
16	80	4.0	. U.U	+
20	80	5.0	19.0	+
16	84	4.0	21.0	+
38	0	9.5		+
16	88	4.0	22.0	_
14	84	3.5	21.0	-
18	84	4.5	21.0	+
20	84	5.0	21.0	_
18	8.3	4.5	22.0	+
18	30	4.5	22.5	_

.

N

23).

Teble 93

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND METHYLENE-DIBROMIDE (Total Pressure = 400 mm. Hg)

Pressure,	mm. He	Volume. A		Perult	
CH3COCH3	J12512	CH_COCH3	CH ₂ Br ₂	<u>nesui t</u>	
20	16	5.0	4 ()		
20	20	5.0	4,0 5 0	+	
16	16	4.0	5.0	+	
20	24	4. 0	4.0	+	
12	16	0.0	6.0	-	
20	50 90	3. U	4 .0	-	
16	20	5.0	5,5	+	
18	20	4.0	5,0	-	
22	22	4.5	5 . 5	+	
18	26	5.5	5,5	+	
22	24	4.5	6.0	-	
₩∾ 0.4	24	5.5	6.0	_	
44 10	22	6.0	5.5	_	
12	12	3.0	3.0	_	
28	16	7.0	4.0	-	
28	14	7.0	3.5	-	
36	8	9.0	2.0	+	

- . .

232.

•

2.4

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND BROMOTRI-FLUOROMETHANE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume. %		Result
CH3COCH3	CF ₃ Br	CH3COCH3	CF ₃ Br	
20	20	5.0	5.0	-
24	20	6.0	5.0	-
20	16	5.0	4.0	+
24	16	6.0	4 • Û	+
20	18	5.0	4.5	-
24	16	6.0	4.0	+
24	18	6.0	4.5	_
28	16	7.0	4.0	+
28	20	7.0	5.0	+
28	22	7.0	5.5	_
32	20	8.0	5.0	
26	20	6.5	5.0	-
30	20	7.5	5.0	-
16	16	4.0	4.0	-
3 2	1.6	8.0	4.0	+
16	12	4.0	5.0	-
36	14	9.0	3.5	_
16	8	4.0	2.0	-
16	4	4.0	1.0	_

233.

234.

Table 95

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND ETHYL BROMIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hr.		Volum	9 <u>, %</u>	Result	
CH3COCH3	C ₂ H ₅ Br	CH3COCH3	C2H5Br		
20	16	5.0	4.0	+	
20	20	5.0	5.0	ł	
16	20	÷.0	5.0	+	
20	24	5.0	6.0	~	
16	24	4.0	6.0	-	
20	22	5.0	5.5	-	
18	22	4.5	5.5	-	
14	とし	3.5	5.0	+	
24	20	6.0	5. 0	_	
14	22	3.5	-5	+	
16	22	4.0	5.5	+	
14	24	3.5	5.0	-	
28	16	7.0	2 . U	-	
28	12	7.0	` • -	+	
32	8	ರ 🗚 0	2.0	+	
32	12	8.0	3.0	~	

والمستر وراب

1 . i

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND METHYL BROMIDE (Total Pressure = 400 mm. Hg.,

Pres. urc. mr. lig.		Volume, 5		Result
CH3COCH3	Cli ₃ Br	CH3COCH3	CH ₃ Br	<u> </u>
12	0	3.0	0	-
16	0	4.0	0	+
32	õ	8.0	õ	+
14	Ō	3.5	Ő	+
44	Ō	11.0	ō	+?
16	12	4.0	3.0	+
48	0	12.0	0	+?
14	12	3.5	3.0	+
20	24	5.0	6.0	+
52	$\hat{\mathbf{u}}$	13.0	0	+?
14	24	3.5	6.0	-
12	12	3.0	3.0	-
20	28	5.0	7.0	+
24	28	6.0	7.0	-
20	32	5.0	8.0	-
16	28	4.0	7.0	_
20	30	5.0	7.5	-
28	24	7.0	6.0	-
36	14	J. E	3.5	-
28	20	7.0	5.0	-
32	14	8.0	5.5	-
28	16	7.0	4.0	_
32	8	8.0	2.0	+
29	20	6.0	5.0	+
	-			•

235.

1

į

- '

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND SULPHUR HEXA-FLUORIDE (Total Pressure = 400 mma. Hg)

Pressure, mm. Hg		Volume, &		Result
CH3COCH3	SF6	CH3COCH3	SFB	
20	20	5.0	5.0	+
14	12	3.5	3.0	+
20	28	5.0	7.0	+
12	12	3.0	3.0	+
20	36	5.0	9.0	+
10	12	2.5	3.0	-
20	64	5.0	16.0	+
20	72	5.0	18.0	-
12	36	3.0	9.0	-
16	36	4.0	9.0	-
20	68	5.0	17.0	
22	64	5.5	16.0	+
18	64	4.5	16.0	-
24	61	6.0	16.0	-
16	36	4.0	9.0	?
22	68	5.5	17.0	-
18	52	4.5	13.0	-
24	52	6.0	13.0	÷
18	40	4.5	10.0	_
26	52	6.5	13.0	+
18	32	4.5	8.0	-?
30	52	7.5	13.5	+
18	16	4.5	4.0	-?
36	6 0	9.0	15.0	+
4 4	4 8	11.0	12.0	+
18	16	4.5	4.0	+
4÷	52	11.0	13,0	-
18	24	4.5	6.0	÷
40	60	10.0	15.0	+

236.

1

1.4.5

··• ± ...

•

FLAMMABILITY OF MIXTURES OF ACETONE, AIR AND CARBON TETRA-FLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg.		Volume,	2	Result
CH-COCH-	CF	CH3COCH-	CF.	
20	72	5 . Ú	18.0	-
16	72	4.0	15.0	-
24	72	6.0	18.0	-
20	64	5.0	16.0	+
20	68	5.0	17.0	-
24	68	6.0	17.0	+
28	72	7.0	18.0	+
32	72	8.0	18.0	-
28	76	7.0	19.0	-
32	68	8.0	17.0	-
28	74	7.0	18.5	_
32	64	8.0	16.0	-
14	48	3,5	12.0	-
32	56	8.0	14.0	-
14	40	3.5	10.0	-
32	48	8.0	12.0	+
16	40	4.0	10.0	+
36	44	9.0	11.0	-
40	40	10.0	10.0	-
36	36	9.0	9.0	-
36	28	9.0	7.0	+
26	74	6.5	18.5	+
26	76	6.5	19.0	-

.

237.

ł

FLAMMABILITY OF MIXTURES OF LITHYL ACETATE, AIR AND METHYLENE-LIBROMIDE (Total Pressure = 400 mm. Hg)

د. در روهه دو روسید از محود اف

Pressure. mm. Hr.		Volume,	ÿ	Result	
CH3CO2C2H5	CH2Br2	CH_CO_C_H_	OH_BR-		
16	0	4.0	0	+	
12	0	3.0	0	+	
3 8	0	9.0	0	+	
٤	0	2.0	0	-	
44	0	11.0	0	•	
10	0	2.5	0	-	
36	20	9.0	5.0	_	
12	12	3.0	3.0	_	
36	12	9.0	5.0	_	
14	12	3.5	3-0	_	
36	-~	9.0	1.0	-	
16	12	4.0	3-0	-	
36	2	9.0	0.5	- +	
16	16	4_0	()) ())	-	
16	20	4.0	5.0	-	
24	16	5 0	3.0	-	
28	16	v 0	1.0	•	
24	20	6 O	5.0	-	
26	10	2 U	3.0	-	
20	19	5.0		•	
24	10	5.0	4.0 • E	-	
20	10	0.0	4±•0	-	
20	14	2.V 5.5	3.0	+	
16	10	0.0	··• • U	+	
10	8	••	2.0	-	
<i>22</i>	10	5.5	4.5	-	
32 00	0	8.0	1.5	+	
20	16	5.0			

238.

Table 1CO

and and a second se

· · · · · · ·

FLAMMABILITY OF MIXTURES OF LTHYL ACETATE, AIR AND BROMO-TRIFLUOROMETHANE (Total Pressure = 400 mm. Hg)

Pressure. mm. Hg		Volume	Result	
CH_CO, CoHe	CBrF ₃	CHaCOndath,	CBrF ₃	
16	2-1	4.0	6 . 0	-
12	4	3.0	1.0	-
16	16	4.0	4.0	-
32	4	8.0	1.0	+?
24	16	6.0	4.0	-
32	8	8.0	2.0	+
20	12	5.0	3.0	-
32	12	8.0	3.0	+
16	32	4.0	8.0	_
32	16	8.0	4.0	
36	16	9.0	4.0	-
32	24	8.0	6.0	-
30	14	7.5	3.5	+
36	12	9.0	3.0	-
30	16	7.5	4.0	-
28	16	7.0	4.0	+
26	16	6.5	4.0	+
28	18	7.0	4.5	-
26	18	6.5	.5	+
26	20	6.5	5.0	-
24	14	6.0	3.5	+
20	8	5.0	2.0	+

239.

•

.

đ

FLANSABILITY OF MIXTURES OF ETHYL ACETATE, AIR AND ETHYL BROWIDE (Total Pressure = 400 mm. Hg.)

Pressure, mm. Hg.		Volume	. %	Result
CH1CO2C2H5	CoHe Br	CH3CO2C-H5	CoHaBr	
24	16	6.0	4.0	•
24	20	6.0	5.0	
28	18	7.0	4.5	-
24	18	6.0	4.5	-
16	10	ن. 4	2.5	-
20	16	5.0	4.0	+
12	4	3.0	1.5	*
20	18	5.0	4.5	•
12	10	3.0	2.5	-
16	16	4.0	20	*
28	16	7.0	4 0	+
16	20	4.0		+
32	16	8.0	U • U	+
16	24	4.0	4.0	-
12	20	3.0	5.0	-
16	22	4.0	5.5	•
12	22	3.0	0+0 E E	+
14	24	35	0+0	+
12	24	3.0	6 •U	-
36	10	0.0	6.0	+
12	26	3.0	2.5	-
36	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	0.0	6.5	-
48	0	3.U 19 ()	1.5	+
52	Ŭ	12.0	0	+?
	0	10.0	0	+?

240.

.

t

1

FLAXMABILITY OF MIXTURES OF ETHYL ACETATE, AIR AND METHYL BROWIDE (Totel Pressure = 400 mm. ng)

Pressure. mm. Hg		Volume,	Result	
CHaCO2C215	<u>CH_Br</u>	CH CU2C2HE	CH Br	
2.	20	6.0	5.0	+
20	20	5.0	5.0	+
24	22	6.0	5.5	-
20	22	5.0	5.5	-
18	22	4,5	5.5	+
20	24	4.5	6.0	+
12	8	3.0	2.0	-
18	26	4.5	õ.5	+
14	8	3.5	2.0	+
18	28	4.5	7.0	-
14	16	3.5	4.0	+
16	28	4.0	7.0	-
14	22	3.5	5.5	
16	26	4.0	5.5	-
32	18	8.0	4.5	-
2 8	20	7.0	5.0	-
32	14	8.0	3.5	-
32	10	8.0	2.5	-
32	ò	8. 0	1.5	+
28	12	7.0	3.0	+

211.

Table 103.

.

e*..

FL MAABILITY OF MIXTURES OF ETHYL ACETATE, AIR AND SULFUR HEXAFLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume, A		Result
CH_CO_C_H_	SF	CH3CU2C2H5	SFa	
12	24	3.0	6.0	-
24	24	6.0	6.0	+
12	12	3.0	3.0	?
24	32	6.0	8.0	+
12	12	5.0	3.0	-
24	÷0	6.0	10.0	+
14	12	3.5	3.0	+
24	56	6.0	14.0	-
16	24	4.0	6 .ŭ	+
24	48	€0	12.0	+
18	40	4.5	10.0	+
÷0	24	10.0	6.0	-
24	52	6.0	13.0	+
32	24	0.8	6.0	+
20	52	5.0	13.0	+
28	52	7.0	13.0	+
28	52	7.0	13.0	+
20	56	5.0	14.0	+
2	50	5.0	15.0	+
32	44	8.0	11.0	-
20	68	5.0	17.0	- .
36	24	9.0	6.0	-
20	64	5.Ŭ	16.0	-
16	56	4.0	14.0	
16	64	4.0	16.	
16	68	4.U	17.0	
12	64	3.0	16.0	
16	72	4.0	18.0	

.

242.

į

;

i

.

.

FLAMMABILITY OF MIXTURES OF ETHYL ACETATE, "R AND CARBON TETRAFLUORIDE (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume.	Result	
CH-CO-C-H-	<u>OF4</u>	CHaCúgCells	CFA	
20	72	5.0	18.0	+
24	72	6.0	18.0	-
16	72	4.0	18.0	+
50	76	5.0	19.0	+
20	72	3.0	18.0	-
20	80	5.0	20.2	+
16	76	4.Ŭ	19.0	+
20	84	5.0	21.0	+
16	80	4.0	<u>ລຽ</u> ບ	-
20	88	5.0	22.0	-
12	56	3.0	14.0	-
12	90	3.0	10.0	-
20	86	5.0	21.5	-
14	40	3.5	10.0	Ý
18	84	4.5	21.0	-
22	84	5.5	21.0	-
24	<u>04</u>	6.0	16.0	+
26	60	7.0	15.0	

243.

•

•

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR, TRIBROMOFLUORO-METHANE ..ND METHYLENE DIBROMIDE (Total Pressure = 400 mm. Hg)

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	esult
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	+
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	-
	+
	+
	-
18 6 6 4.5 1.5 1.5	÷
10 10 10 2.5 2.5 2.5	-
14 9 9 3.5 2.25 2.25	+
14 11 11 3.5 2.75 2.75	-
22 6 6 5.5 1.5 1.5	
18 8 8 4.5 2.0 2.0	-
24 4 6.0 1.0 1.0	-
6 4 4 1.5 1.0 1.0	-
20 5 5 5.0 1.25 1.25	-
8 4 4 2.0 1.0 1.0	
22 3 3 5.5 0.75 0.75	-
10 4 4 2.5 1.0 1.0	+
20 3 3 5.0 0.75 0.75	-
8 2 2 2.0 0.5 Ú.5	+
20 2 2 5.0 0.5 0.5	+

244.

÷

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR, EETHYLENE DIBROMIDE AND PERFLUOROETHYLCYCLOHEXANE (Total Pressure = 400 mm. Hg)

...

Pressure, mm. Hg Volume			Volume 🛠	e % Result		
C-H1A	CH_Br2	CaF18	CoH1 A	CH2Br2	CaF15	
12	14	14	3.0	3.5	3.5	-
12	10	10	3.0	2.5	2.5	+
8	6	6	2.0	1.5	1.5	+
12	12	12	3.0	3.0	3.0	-
4	6	6	1.0	1.5	1.5	-
12	11	11	3.0	2.75	2.75	-
6	6	-	1.5	1.5	1.5	+
10	10	13	2.5	2.5	2.5	+
22	6	٢.	5.5	1.5	1.5	-
16	8	8	4.0	2.0	2.0	+
14	10	10	3.5	2.5	2.5	+
16	10	10	4.0	2.5	2.5	+
8	10	10	2.0	2.5	2.5	+
18	10	10	4.5	2.5	2.5	-
6	10	10	1.5	2.5	2.5	-
14	11	11	3.5	2.75	2.75	-
16	11	11	4.C	2.75	2.75	-

.

245.

. .

¢

.

:

FL-MMABILITY OF MIXTURES OF n-HEPLINE, AIR, ETHYL BROMIDE WITH METHYLENE DIBROMIDE (Total Pressure = 5. ma. Hg)

Result	Volume 🛠 Result		Volume 🛠			Pressure, mm. Hg		
	CH_Br_	C2H5BT	C7H1A	CH_Br_	CoHe Br	Ç7H16		
+	2.0	2.0	3.0	8	8	12		
-	1.5	1.5	5.0	6	6	20		
-	3.0	3.0	3.0	12	12	12		
-	1.5	1.5	4.0	6	6	16		
+	2.75	2.75	3,0	11	11	12		
-	2.0	2.0	2.0	8	8	8		
+	2.5	2.5	3.5	10	10	14		
-	2.0	2.0	2.5	8	8	10		
+	1.0	1.0	2.0	4	4	8		
-	2.0	2.0	3.0	8	8	12		
-	1.0	1.0	1.0	' 3	4	4		
-	2.0	2.Û	3.0	8	8	12		
-	1.0	1.0	1.5	4	4	6		
+	75•0	0.75	4.0	3	3	8		
+	2.0	2.0	3.0	8	8	12		
+	0.75	J.75	5.0	3	3	20		
-	3.0	3.0	3.5	12	12	14		
	0.75	0.75	6.0	3	3	24		
-	2.87	2.07	3.25	11.5	11.5	13		
+	0.75	0.75	5.5	3	3	22		
+	2.75	2.75	2.75	11	11	11		
-	2.75	2.75	3.75	11	11	15		

246.

Table 108.

aar -

FL.MMABILITY OF MIXTURES OF n-HEPTAME, AIR, CARBON TETRA-CHLORIDE AND METHYLENE DIERCHIDE (Total Pressure = 400 mm. Hg)

Pressure, mm, Hg			Volume 🛸			Result
CoH16	CH2Br2	<u>CC1</u>	C7H1B	CH2Br2	<u>CU1.</u>	
12	10	10	3.0	2.5	2.5	+
6	3	3	1.5	ύ .75	პ.7 5	-
12	13	13	3.Ú	3.25	3.25	+
8	3	3	2.0	0.75	0,75	+
12	16	16	3.0	4.0	4.0	-
2 L	6	6	5 <u>.</u> 0	1.5	1.5	+
12	14	14	3 .0	3.5	5.5	+
24	6	6	6.0	1.5	1.5	-
12	15	15	3.0	3.75	3.75	-
16	11	11	4.0	2.75	2.75	+
10	14	14	2.5	3.5	3.5	+
18	11	11.	4.5	2.75	2.75	+
8	14	14	2.0	3.5	3.5	-
20	11	11	5,0	2.75	2.75	-
10	15	15	2.5	3.75	3.75	-
8	10	10	2.0	2.5	2.5	+
14	14	14	3.5	3.5	3.5	_
6	10	ن1	1.5	2.5	2.5	-

.

247.

• • • · · · · · · · · · · · · ·

, 1

FLAMAABILITY OF HIXTURES OF n-HEPTANE, AIR, METHYLENE DI-EROLIDE AND CHLOROFORM (Total Pressure = 400 mm. Hg)

Pressure, mm. Hg			1	Volume 🐔		
C7H1A	ChiCl ₃	CH_Br_	C-H1 A	CHC1 -	CH ₂ Br ₂	
12	6	6	3,0	1.5	1.5	+
12	10	10	3.0	2.5	2.5	+
12	14]4	3.0	3.5	3.5	+
12	18	18	3.0	4.5	4.5	+
12	22	22	3.0	5.5	5.5	-
12	26	26	3.0	6.5	6.5	-
12	20	20	3.0	5.0	5.0	-
12	19	19	3.0	4.75	4.75	-
10	18	18	2.5	4.5	4.5	-
14	18	18	3.5	4.5	4.5	-
8	1'	1	2.0	2.5	2.5	-
20	12	12	5.0	3.0	3.0	-
8	7	7	2.0	1.75	1.75	-
22	8	8	5.5	2.0	2.0	-
8	4	4	2.0	1.0	1.0	*
24	4	4	6.0	1.0	 1.u	-
20	4	÷.	5.0	1.0	1.0	-

248.

1

6 N

e ...

ដ	
Table	ļ

•

service in the later

nc, & Mo, S	OF KIXTURES 85%576 15%CH ₃ Br Volume, 3	OF FENT.JT. Result	IR. ETHYL 7 955F6 259CH JBr Volumo, &	BROWIDT. Result	NT SULFUR H 5U%SF6 50%CH3BT Yolumi, 5	EX. FUURTIE Josult
ŝ	5 . U	*	7 •5	ı	2.0	÷
ũ	5 •5	÷	0 • 8	ł	7.5	•
2	6 . 0	ł	ł		8.v	•
រ	6. 25 0	٠	ı		8.5	ı
2	•		ł		9 . C	٠
C	1		1. U	+	•	
0	ı		1.5	+	,	
2	ł		2°.C	+	1	
J	3		2•5	+	1	
ſ	•		3.0	ł	•	

and the second se

249.

•

*

.

2**0** -

Teble.110 (Continued)

k Kesult																•	•	ŧ	8	ı	1	ı		25
Volume, *	1	I	ł	1	ł	3	ł	1	١	1	١	ł	3	•	•	5.0	ល ្ ល	6 و (6 . 5	2°0	9°.	8 . 5		
Result	÷	*	÷	ł	+	ı	·	3	•	8	ł	l	ı	1	•									
20%26 75%CH3Br Volumo, %	5.0	0.0	7.5	0°.0	6 . 5	8.75	ට " 6	12°0	5.0	ភ.ភ	6.0	2	7.5	0"6	11. 0	·	•	·	ı	•	ı	ı		
C ₆ H ₁₂ Volume, 9	5.0	20	20 0 0	5 ° 0	5.0 N	0.0°	50°	2°2	4	4.0	4.0	4.0	0.4	4.0	0.4	6 °C	6 C	, j		6.0	6.0	6.0		

.

:

1 1-1-1-1-1Ì

i

1

ж Эк Эк	luș Volume,	kesult	」、「こ、「CAF」) 」と、らた Chg BF Volume 一番	husult	75, 04710 253, 04310 Volure: 4	Kceult
5	5°C	٠	0.0	÷	6.5	+
ı.	0*4	٠	7.5	÷	7. C	+
	7.5	•	B . U	ı	7.5	+
.0	9-6	I	Ð		8 . .	ł
1 c	8.5	1	ı		ı	
	٦ • 6	ł	·		•	
	3.5	÷	8. U	٠	3.5	+
	5°.C	•	8 . 5	,	5.0	+
	6.0	•	•		5 . 5	+
	7.5	•	ı		6. C	+
-	9°C		1		3	+
-	9 •2	÷	1		7.0	ı
-	lu.u	•	J		ı	
	1.5	+	ı		ı	
-	0.1L	1	1		ı	
ŕ	12.5	I	I		ı	
	4 • C	+	3.5	+	J.~	+
	5.5	+	√ •₽	ı	1.5	•
	6.U	ł	•		2.	•
	6.5	ı	٠		2.5	1
-	0. 6	ı	8		3.0	1
-,	8.5	ı	ł		4 °5	1

Table III

. . .

.

*

.

251.

Ň,

٧.

. .

ŧ

11.00

ς.

Tuble 111 (Continued)

in the second

csult	+	1			+	•	1			•	+	1				
25% C4F10 75% CH3Br VolueJ, %	7.0	7 5	6°0	1	4 °C	4 °5	5.0	. 1	.1	3		1.5	•	3	1 1 1 1	-
Result	+	•	+	I	+	•	↓	•	1	1	+	+		1	1	
50% C4F10 50% CH3Br Volume, %	6 • 5	0°4	7.5	0.8	4 •5	5.0	5.5	6.0	6.5	8.0	0.5	1.	1.5	2°.0	2.5	
C ₆ H ₁ 2 Volume, %	2.0	2.5	2 •5	2.5	4 °Ū	4 °Ú	4°0	4.0	4 °.	4 •Ü	6 •Ú	6.0	6.0	6 . Ú	6.0	
	C6H1250% C4F1025% C4F10Volume, %50% CH3BrResult75% CH3BrVolume, %Volume, %Volume, %	C6H12 50% C4F10 Result 25% C4F10 Result 25% CH3Br Result 25% CH3Br Result Result 25% CH3Br Result Result 25% CH3Br Result Result 25% CH3Br Result Result	C6H12 50% C4F10 Result 25% C4F10 Volume, % 50% CH3Br Result 75% CH3Br Volume, % Volume, % Volume, % 2.5 6.5 + 2.5 7.0 +	Colume Support Support C4F10 Result 25% C4F10 Volume % 50% CH3Br Result 75% CH3Br Result Volume % Volume % 7.0 + 2.5 7.0 + 7.0 + 2.5 7.0 + 7.5 - 2.5 7.5 + 8.0 -	Colume Support Support Support Support Support Result	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CeH12 50% C4F10 Result 25% C4F10 Result 75% CH3Br Result 7.5% CH3Br 8%	C6H12 50% C4F10 Result 25% C4F10 Result 75% CH3Br Result 7.5 Result 8.0 9.0 9.0 <th< td=""><td>$\begin{array}{cccccccccccccccccccccccccccccccccccc$</td><td>C6H12 50% C4F10 Rosult 25% C4F10 Volume, % 50% CH3Br Rosult 75% CH3Br 2.5 Volume, % Nolume, % Result 2.5 7.0 Result 7.5 + 2.5 7.0 Result 7.5 + + 7.5 2.5 7.0 8.0 + 7.5 + + 1.4 Result 2.5 7.0 8.0 + 7.5 + + 1.4 1.4 1.4 1.4 2.5 4.0 6.0 -</td><td>C6^{H12} 50% C4F10 Result 25% C4F10 Result 75% C4F3Br 80.0 75% C4F3Br 80.0</td><td>C6H12 SUX C4F10 Result SUX C4F10 Result Re</td><td>C6^H12 50% C4F10 Rosult 25% C4F10 Rosult 75% CH₂Br 80% CH₂Br<</td><td>Colume, A 50% C4F10 Result Result Result Result Part (H3Br Pr Part (H3Br Pr</td><td></td></th<>	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	C6H12 50% C4F10 Rosult 25% C4F10 Volume, % 50% CH3Br Rosult 75% CH3Br 2.5 Volume, % Nolume, % Result 2.5 7.0 Result 7.5 + 2.5 7.0 Result 7.5 + + 7.5 2.5 7.0 8.0 + 7.5 + + 1.4 Result 2.5 7.0 8.0 + 7.5 + + 1.4 1.4 1.4 1.4 2.5 4.0 6.0 -	C6 ^{H12} 50% C4F10 Result 25% C4F10 Result 75% C4F3Br 80.0 75% C4F3Br 80.0	C6H12 SUX C4F10 Result SUX C4F10 Result Re	C6 ^H 12 50% C4F10 Rosult 25% C4F10 Rosult 75% CH ₂ Br 80% CH ₂ Br<	Colume, A 50% C4F10 Result Result Result Result Part (H3Br Pr Part (H3Br Pr	

252.

	Rcsult		+	+		8	I.		+	+	1		3	+	!	•	ſ	·	I		
U ETATL BRU LAL	oc.ov vz.ctr 17.5% Cii ₃ Br Volume. %		5.0	6.0		0.0	· · · ·	ı	2°.C	3.5		2. 4	4.5	1.0		C• T	\$\$	2	0.0	1	
BRCATUE AN	Result		+	1		1		•	+	+		3	ł	+	4	F	1	I		,	
ANE. UR. METHYL	90.3% C2HEBT 9.2% CH3Br Volume 5	2 10117 101	5 .0	ن ر ل) ^ (0	•	1	ເ ເ ເ ເ ເ เ เ	۲		3.5	5.0			. . .	1.5		N.C.	5 2	
KTURES OF PENT	Result		+	•	•	+	•	1								:		9 ²			
FL. NM. BILITY OF MI	100% C ₂ H ₆ Br Volume, %		د ۲		4 °U	4.5	5.0	0.6			1) .	1		1	1	1	•	
	C ₆ H ₁₂ Volumo, %		Ľ	N • 0	2°2	2.5	2.5		2	D• 7	4°C	C.A		0•4	6 . U	f.J		0.0	6.0	6.0	

253.

Table 113 (Continued)

																	, s	
		Result		4	Þ	+.	t	I	+	1	+	1	1	+	1	6.		
ETHYL BROWIDE	40% CalleBr	60% CH3Br	Volume. %	Ľ	0.0	9°C	6.5	0.0	3.0	3.5	Q.4	5.0	. 0•9	1.0	1.5	2°0	1	
BROMIDE AND		Result			•	÷	1	J	+	•	1	ı			t			
AIR. METHYL	50% C.H.Br	50% CH3Br	Volumo, %	i i	5.5	5.75	6.0	6 . 5	2.5	6 4	4.25	4 °5	1	2.0	3•Ĵ	1		
TRES OF PENTANE		Result		/						+	•		1	•	•	10	I	
	FLAMMADILLIS VE MAAA	33 1/3% CH ₃ Br	Volume. 5		•	1			0.0		5°.5	4.0	6.0		1.0	1.5	3.0	
		C ₅ H ₁₂ Volume. \$			L C	2 4	รัก วัก	วู แ		2 •4	0 C # -	0.0	, ,	· · · ·		0°9		

254.

BRUMIDE	Regult		+	÷	1	1	I		÷		÷	ł	ı	+		•	ł	ı
ROMIDE NO ETHYL	15% C2H3Br 85% CH3Br Volume, %	3. 1.	~ ~ ~	7.0	2.5		0°8		3_0		••	4° 0	5.5	0_5			н , У	2,5
UR. ENTL	Result	-	ŀ	+	+		ı		+		ŀ	+	,	+	+	·	۱	•
RES OF FENT ME.	20% C ₂ H,Br 80% CH,Br Vclume, %	C Y	.	ද ී ර	6.5		n•/.	•	3.0	2	•	4°C	4.5	0.5	0,1	- 1 	1 • 2	3 ° 0
TLITY OF MIXT	Result	•	•	+	+		•	•	,		ł	1		٠	1		•	3
FL MAN UF	د 25% C2H5Br 75% CH3Br ۲۰۵۱یسو، %	5		6° C	6 . 5	с, г г		C"/	3.5	7-7		د 0°	1	5°0	2.5			ر، ز
	GeH12 Volume, «	2.5	•	Z •5	5°.	ۍ م	1 1 1		4 • 0	4.	, r) (‡	0°4		و د د	6 (

.....

Table 112 (Cont'rued)

255.

.

۰.

-

ļ

	DHR	Result
Ie	AIR.	
Tab	PENT INB	CH Br
	5	
	MIXTURES	lt 9.
	е Ч	Resu
	FL 106 ABILITY C.H.Br	CH JBr

C.H.1.	10% C.H.Br		5 Ja C - H Br				
Volume, 🦿	90% CH3Br Volume, %	Result	94.8% CH3Br Volume, %	Result	Volume,	Regult	
3 6	L						
		+	n•/.	+	5°0	+	
C •2	7 . 0	+	•		7.0	+	
2 . 5	י י גי	•	1		7.5	+	
2,5	0 8	,	1			• •	
2.5	ŀ		ı		. u		
2.5	•		ı				
4. F	3_0	+	2.5	÷	2 2 2		
4. Ú	4.0	t	0	• 1		+ 4	
0.4	4.5	ı	3.5	1		+ 4	
4•C	5 ° 0	1	4.0	:	2 ° C	- 4	
6 . 0	1.0	+	J_O	+			
6, C	1.5	,	1.5	ı		• •	
0 •	2 . 0	I	•		1.5	• •	
6, C	3.0	1	1) (
					•		

256.

lupij. Remit	+ 8 8 9 9 + + + 1 8 8 9 4 7 4 8 8 8 8
BROMIDE AND METHYL 50% CH ₃ I 50% C ₂ H ₅ Br Volume, %	៷៷៹ឩ៰៓៓៹៲៷ <i>៷</i> ៷៹៷៹ឩ៰៶៹៷៷៹ឩ ៷៷៰៰៰៰៰៰៷៷៰៰៰៷៰៰៰៰៰
AIR, ETHYL H Regult	+ + + + + +
IXTURES OF PENT-WE. 73.9% CH3 1 26.2% C2H5Br Volume. %	ພາກທາງຊະພະແທບພາງ ລີພະພາກທາງພາງ ດ້ວາມເລີ່ອງກາວກາວ ທີ່ກ່ວາວດ້າວດີ
<u>BILITY OF 10</u> Regult	+ + + + + + + + + + + + + + + + + + + +
FLAKIN 1005 CH 3 1 Velume, 7	60400040 00700000 00700000
GsHız Volume, ₹	พพพพพอออยุออรรรรธดอ. ธรอ พพพพพอออยุออรรรรธดอ. ธรอ

. ¥

257.

· ·

.

۰.,

σ
ō
3
5
42
8
0
O
مب
m
-1
-
Q
<u></u>
A,
ø
F-1

, ICDIDE		Result	*	+	+	+	8	+	ı	ł	ŧ				+	+	1		ł				
ETHYL BRCHIDE UN HETHYL	1(C ^{-d} C ₂ H ₅ Br	Volume, 🧭	0 *	4.5	2 •0	5.5	6°0	3. 0	3.5	4°0	5 . C	ı	•	ı	0-1- 0-1-	in (0 5 5	่าง	\ • I	•	·		
CF SUITURES OF PENTINE. JIR.	I I	zH5 Regult e. *	.5	•	•	•		+ 0.	+	+ •	+ 0	•	•	•	+	،	•			1	•		
FLAGABLLITY	254 6	لم Volum	5	6	JC				-	2	ω.	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	7	2			(4)		1 1		1		
	C.H.	Volume,	2.5	2,5	2.5	2,5	2.5	4.0	4.0	4.0	0.4	7	4°C	, * *	0°9	0 9	6. 0	0 . V	0 v	50	ວ • 9		

258.

ł

ł

Contraction of the local distribution of the

BRCALDE	Regult								÷	÷	Ŧ	ł	۲	1		۲	ł	1	ł			
DICHLARIDE AND ETHYL	50⊈ CH ₂ CI ₂ 50⊈ C₂H ₅ Br	Volume, 🐔	ı	•	1	•	8	,	4 . 5	5.0	5.5	6	7.0	10.0	ł	1.5	2.0	3° C	4.C			
R. METHYLENE I	Result		÷	+	+	1			+	+	+	÷	•	•	L	+	+	+		•	,	•
CF PENT INE, AII	75% CH ₂ C12 25% C ₂ H ₅ Br	Volume 🏅	1 5 .0	16.0	16,5	17.0	•	1	5 . C	7.0	7.5	8 . 5	0°6	4	14°C	2. ز	2,5	ວ ຕ	3.5	4° 0	5 ,C	10°0
Y CF MIXTURES	Result		+	+	+	+	+	ŧ	+	+	+	1										
LI LIN MULTI	100 ≠ CH2C12 Volume. ≴		7 C	11.0	13.0	15.0	16.0	17.0	S. C	10 0	15.0	20.0	•	ı	I							
	C ₅ H12 Volume. %		2.5	2.5	2.5	5	3	2.5	7-0	4.0	0 7	4.0	0.4	4.0	4.0	e c	С У	0°0	6, C	6.0	0	6°0

. -

Table 114

259.

· ·

.

į

٠

. **.**

,		
ND ETHTL BRCHIDE	Regult	+ 1 1 1 1
R. METHYLENE DICHLORIDE 1	100% C2H Br Volume, %	・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・
LES OF PENT INE. AI	Result	* + + + 1 + + + + + + + + + + + + + + +
FL Acid ABILITY OF MIXIUF	25年 CH_2C1_ 75% C_ ² H5Br Volume, 发	៹ _៱ ៱៹៹៵៷៷៹៹៵៲៹៹៰៹ ៰៝៸៷៰៷៰៓៸៷៰៰៰៰៰៰៰៰៰៰៰៰
	C5H1≥ Volume, %	๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛๛

260,

311	
Table	

IFTUC RUMETH WE		Kegult	÷		,	ł	Ł	I	•	+	ŧ	ŧ	ŧ	£	ŀ	•	+	+	ŧ	•	ł	1	Ŧ	
BROWIDE ND CHLCACTR	50% CCIF2	Volume, Z	8 ° C	ဒီ	8,5	0 °6	9,5	10,0	5.5	6°0	6 <u></u> 5	7.0	3°C	10.0	12.0	18.0	J.C	1 . 5	5°C	3.0	5.0	0.01) 	
VIR, ETHYL	ŕ	TLESULT	+	+	+	+	ı	ı	•	+	•	3	ı	ı			+	,	ł	I	•	I	1	
ES CF PENT NE.	75% COLF	Volume.	4°C	6 ° 0	7.0	7.5	0 ° 8	16.0	5 . 0	ن 8	8,5	0.6	9• 5	10.0	ı	•	1.0	1 . 5	2 . (ک ہ5	3.0	7-1	10_0	
CF AIXTUR	c	result	•	ı	·	ı	·	+	+	+	+	ł	+	ı	ł	1								
FL 45 (BILIT	ICCX CCIF,	% '9UNTO1	6 . 0	7.0	د	3 °6	9 ° 2	10.0	0°6	9 . 5	10°C	11.6	12.0	12.5	13.0	14.0								
	C, 112	volume,	2.5	۲.5	2.5	2°2	2.5	2°2	4,0	4°C	4"C	4-1	7 •C	7 •C	4.0	4 •C	6 .0	ن. م	5 .C	5 .0	و* ن	6 .0	5.0	•

a and a second a seco

.

-

261,

١

1

•

f t

• ...

Table 115 (Continued)

																									2(
THYL, BROKIDE ND CHLOROTRIFILUC ROMETH INE	Regult	•	*	•	•	1	•	•	+	*	•	•	•	•	•		. 1	• +	•	•	•	•	•		
LITY OF MIXTURES OF PENT INE, AIR, E	25% CC1F3 75% C2H4Br	2.0	ے : 8	\$.°*	0°6	10.0	o ม	14,0	5.0	2°0	7.5	6°9	8,5	0.6		2 2 2 2 2		1.5	2°0	یں ہے۔ ا	3.0	2.0	0 *7		
FL Add BIL	C₅H ₁₂ Volume, ″	\$2 \$2		2.5	2,5	2.5	2 . 5	ي. ح	4. C	4 •0	4°C	ر چ	4 . C	5		- C 	ت د نه ا	- C - C - C - C - C - C - C - C - C - C	6 , í	ن ح ل	D U	0 0 0			

262.

<u>ب</u>

ADeline -

× . . .

:
•
- E & I 7
20°0 19°0 20°0
•
) g
। বি ক ক ক ক

263.

x

İ

-

Table 116 (Continued)

Result 80% C_HC1 Result Volume, 7 Result Result Volume, 7 Result Result Result Result Result Volume, 7 Result Result Result Result Result Volume, 7 Result Result Result Result Result Result Result Result<	1	FLAMABILITY	OF MIXTURES C	DE PENTANE, AIR.	CARGON TETRACH	LCRIDE WD 1.1.2 TRJ 1000 C.HC1.	ICHLC RC ETHYLENE
+ + + + + + + + + + + + + + + + + + +	X C2HC13		Result	Volume.	Result	Volume, 2	Result
 ++,,, 4 <l< td=""><td>10_0</td><td></td><td>+</td><td>15.0</td><td>÷</td><td>5.0</td><td>•</td></l<>	10_0		+	15.0	÷	5.0	•
+	12.0		+	16,0	+	10,0	•
 + + + + + + + + + + + + + + + + + + +	14 .0		+	17,0	+	11.0	•
· · · · · · · · · · · · · · · · · · ·	14.5		ı	17.5	+	12°C	•
+ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	15.0		ı	18.0	+	13.5	•
+ 1	•			14_5	+	15 . 0	
+ 1	ı			19.0	ı	18.0	•
+ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	٠			19.5	•	1 9 •0	•
+ 1 - 6 - 6 - 6 - 6 - 6 - 6 - 6 - 6	ł			20°C	ı	50° C	·
+ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	•			•		21.0	
 ・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・	15.5		+	9*5	+	10°C	•
 1 1<	16.0		ł	10.0	•	11.0	÷
	8			12.0	+	11.5	+
	•			12.5	+	12.0	•
	·			13.0	+	13 ° C	+
	I			13.5	÷	17°C	•
	ı			14.0	•	15.5	•
	I			•		16 . 0	•
	ł			1		17.0	ŧ
				ı		18 .C	•
1 1 1 1 1 1 10,0 10,0 10,0			I	•			+
			•	8		5.00	•
			1	ł			•
-			9				• •
	i			٠		16.0	ŧ

-

264.

. 1

į

, ;

ł

.

•

FLAMMABILITY OF MIXTURES OF n-HEPTANE, MR, AND METHYL BROWIDE (Total Pressure = 100 mm, Hg.)

	Volume, A	
<u>n-Heptane</u>	Acthyl Bromide	Result
3	4.5	-
2.~	3	-
2.0	£ . ບ	-
3.0	2.0	-
2.~	1.0	-
4	1.J	-
3.0	∂ ∎5	-
4	J.5	-
5.J	-	-
10.0	-	-
9.0	-	-

165.

ំ 🚺 🕺 🚺 🖓 ខេត្តកំពុទ្ធ

1.

 A second sec second sec

266.

Table 118

FLAME.BILITY OF MIXTURES OF n-HEPTANE, AIR, AND METHYL BROWIDE (Total Pressure = 200 mm. :ig.)

٧n	1	າມ	e	£
Y 🖌	-		•	•

<u>n-Heptane</u>

*

<u>Methvl</u>	Bromido	Result

3.0	5	+
2,0	5.4	-
3.0	5.5	-
2.~	4.0	-
4.Ú	5.4	~
2.0	3.0	+
4.0	3.0	+
1	1.0	-
2.5	5.5	+

Flammability of mixtures of n-Hoptane, Air, and Sothyl Bromide. (Trtal Pressurem300 rm, Hg.)

:

<u>م</u>ر ا

· · · · · · · · · · · · · · · · · · ·	Volunc, %	D
n-Heptene	Methyl Bromido	Result
2.0	6 . 0	-
2.0	5.0	+
3.0	5.0	-
2.0	5.5	+
1.0	5.0	-
1.5	5.5	-
2.5	5,5	+
1.5	3.0	+
2,5	6.0	+
4.0	3.0	-
2.5	6.5	+
3.5	3.0	+
2.5	7.0	-
1.0	3.0	<u>+</u>

ļ

	Volune, %	
n-Heptene	Mothyl Bromido	Rosults
1.5	10	-
2,0	7.0	-
1.5	9.5	-
1.5	9.0	-
4.0	3.0	-
1.5	7.0	+
1.5	8.0	-
1	7.0	-
1.5	7.5	-
4.0	2.5	+
1.0	3.0	-
6.0		+
1.0	1.0	-
7.0		+
1.0		-
8 . C		
1.5		+
2.5	5.0	+

i

ž

Flarmability of mixtures of n-Heptone, Air, and Bromstrifluoromethane. (Total Pressure=200 mm. Hg.)

	Volumo 2	
n-Heptene	Bromotrifluoromethane	Results
3.0	5.0	8.7
3.0	3.0	+
3.0	4.0	-
2.0	3.0	E.)
3.0	3,5	+
3.5	3.0	
2,5	3.5	+
3.5	3.5	-
2,5	4.C	+
2.5	4.5	~
4.0	1.5	+
5.0	1.5	-
2.0	1.0	+

. مع

269.

Į

lable 122

n-Heptane	Volume. & Bromotrifluoromethane	Result
3.0	5.0	+
3.5	4.0	-
3.0	5.5	+
2.0	6 .0	-
3.0	6.0	+
1.5	2.0	-
3.5	6.0	-
3,0	6.5	-
2.5	6.0	-
2.0	2.0	+
4.5	2.0	+
5,C	2.0	+
5.5	2.0	+
6.0	5.0	-

•

FLAMMABILITY OF MIXTURES OF n-HEPTANE, .IR, .CD BROMOTRIFLUOROLETAANE (Totol Pressure = 300 mm, Hg.)

j,

Protect
 N

Ţ

FLAMMAEILITY OF MINTURES OF n-HEPTANE, AIR, AND BROMOTHIFLUORO-METHANE (Total Pressure = 500 mm. Hg)

	Volume, 4	
<u>n-Heptane</u>	Bromotrifluoromothene	Result
3.0	6.5	-
3.0	6.0	+
1.5	3.0	-
2.5	6.0	-
3 .5	6.0	+
2.0	3.0	+
3.5	6.5	-
4.0	6.0	-
5.0	3.0	-
4.0	4.5	-
4.0	3.0	+
5.0	1.5	+
4.5	3.0	-
6.5	1.5	-

ł

271.

.

· .

PHYSICAL DATA FOR GASES SUPPORTING COMBUSTION

Table 124

<u>Material</u>	Chlorine	Oxygon	Fluorine
Boiling Point, °C.	~34.6 (10,42,79) ~33.6 (42)	-183.0 (11,42) -182.7 (23,25)	-187. (11,23,42)
Melting Foint, °C.	-101.6 (11,42,79) -102, (23) -103.5 (79)	-218.4 (11,42) -218. (23) -218.8 (25)	-233. (10,23,42 79)
Molecular Weight	35 .457 (11) 35.46 (23)	16.000 (11) 16 (23)	19.000 (11) 19.0 (23)
Critical Temperature, °C.	141 (23) 144 (79)	-118 (23) -118.8 (79)	-129.1 (8)
Critical Pressure, atm.	83.9 (23) 76.1 (79)	49.7 (79) 50.0 (3)	55 (8)
Critical Density, g./cc.	0.5739 (79) 0.573 (79)	0.430 (79) 0.6044 (23)	
Heat of Fusion,	0.812 kg.cal/g.s (42) 3.40 kg.joules/g atom (79) 96.1 joules/g.(a m.p.) (79)	atom 0.053 kg.cal/g. atom (42) 5.	0.19 kg. cal/g.atom at b.p. (42) 0.8g-joules/ g.atom (79)
Triple Point, "A	417.1 at 76.1 atm. (59)	54,3 (25)	l atm. P. 50° (52)
Dencity STP Liquid, (g./l.) Vapor	3,214 (23,79) 2,491 (23)	1.4290 (23) 1.1053 (23)	1.695 (23,79) 1.26 (23)
Hoat of Vaporization atom (at t.p.)	n 10.0kg, joules/g. (79) 2.39kg.cal/g.aton (42)	1630.7 <u>+</u> 1.5 cal/molc (24) n 50.97 cal/kg. (23)	

- -

, **R**, - 1

يەل يە **ئ**ەر

Thermal Conductivity x 105	Temperature, •A
Cal./sec./cm./•A	ىرى بىرىنى <u>مەمىرىكى مەرمىيە بىرىمىيە بىرىمىيە بىرىمىيە بىرىمىيە بىرىمىيە بىرىمىيە بىرىمىيە بىرىمىيە ب</u> ىرىپەر ب
1.701	80
1.72	81.7
1,930	90
2,159	100
2,387	110
2:614	120
2.840	130
2.064	140
3,287	150
3,508	160
3,728	170
3,946	180
4.162	190
4,292	194.7
4.375	200
4,584	210
4,730	220
4.993	230
5,194	240
5.392	250
5 . 586	260
5,780	270
5,70	273
5,970	280
6.159	290
6 . 350	300
6 . 547	310
6 . 798	320
6.954	330
7.164	340
7,378	350
7,594	360
7.182	370
7,427	373
8 . 033	390

.

ł

×.

THERMAL CONDUCTIVITIES FOR OXYGEN (29)

273.

ΰ.

Tablo 126

Heat Capacities for Oxygen

Cp-cal/mole/*A (78)	(5)	Temperature *A
6 .961		200
6 . 970		250
7.017	7,019	a1, 468
7.019	7.021	300
7.194	7.194	±00
7.429	7.430	500
7.670	7.669	600
7,885	7,882	200
8.064	8,062	600
8,212	8,211	900
8,335	8,335	1000
8,440	8.439	1100
8.530	8,528	1200
8.570	-	1250
8.608	8,606	1300
8.676	8.675	1400
8.739	8,739	1500
8.885	• •	1750
9.024		2200
9.035		2500
9.518		3000
9-711		3500
9.879		4000
10.003	ميوا المسموي	4500
10.105		5000
		~~~~

274.

ł

-----

.

-

ł

:

'Inble 127

# Heat Capacities for Chlorino (6)

Cp-cal/mole/•A Tomporture •A 0.89 1.87 15 20 2,90 25 3.97 30 5.73 40 6.99 50 8.00 60 8.68 70 9.23 80 9.71 90 10.10 100 10.47 110 10.87 120 11.29 130 11.73 140 12.20 150 12,68 160 13,17 170

.

ł

÷ مړ

275.

,

•. . .

Thermal Conductivity, cal./cm, sec.	Temperature, •A	Ref.
1.851	66.53	54
2,035	94.55	34
2.113	98.02	34
2,774	127.22	34
2.861	130.99	34
3.166	144.56	34
3,316	151.24	.34
3.676	167.25	34
4.051	185.17	34
4.488	205.38	34
4.981	229.36	34
5.408	250.87	34
5.819	272.07	34
6.175	290,90	34
6.828	323.86	34
7.201	341.99	34
7.547	357.63	34
7.956	376.30	34
5.768	273.1	78
5.83		37
5.839		35
5.89		55
5.89		31
5.90		18

.

## THERMAL CONDUCTIVITIES FOR OXYGEN

.

Material	Ethane	Acetylene	Methane
Eoiling Point, °C	-88.3 (11) -89.1 (81) -89.0 (28) -93. (23) -88.9 (42) -88.62(79)	-83.6 (16) -83.8 (38) -85. (23) -82.9 (42) -85.0 (79)	-161.5 (11,79) -161.37(70) -161.4 (16) -164. (38) -165. (23) -161.1 (42)
Welting Point, °C	-172. (42) -171. (23) -172. (11) -183.2(16) -183.23(81) -172.2 (42)	-81.8 (11,38) -81.0 (16,23)	-184. (11,23,38) -182.5 (16) -184.4 (42)
Molecular Weight	30.27 (11)	26.04 (11)	16.04 (11) 16.03 (82)
Critical Tempera- ture, °C	32.27 (2) 32.2 (79) 32.1 (23)	36.1 (16) 36. (79)	-82.4 (70) -82.8 (16) -82.1 (79) -82. (82)
Critical Pressure, atm.	49.0 (23) 45.8 (16) 48.2 (2) 48.8 (79)	61.7 (79) 62. (16)	45.8 (16,79,82)
Critical density, g/cc.	0.220 (79) 0.203 (2,16)	0.230(79) 0.231(16)	0.1615 (30,91) 0.162 (10)
Heat of Fusion, cal/mole	682.9 (at b.p.) (81) 682 (25)		224 (25)
Triple Point, 🖌	89,9 (25)	81.5 (79)	

### PHYSICAL DATA FOR SOME FLAMMABLE GASES

277.



## Table 129 (Cont'd)

## PHYSICAL DATA FOR SOME FLAMMABLE GASES

<u>Material</u>	Ethene	Acetylene	Nethene
Vapor Density (g./l.) at STP	1.0494 (23)	0.92 (23)	0.415 (16)
Liquid Density (g./1.)			0.415 (23)
Heat of Vaporization, cal/mole	3415 <u>+</u> 4 (81)		2036 <u>+</u> 2 (24) (-173.6°C.)
cal/g	1 <b>16.9</b> (at b.p.)	(16)	138.3 (16) (at b.p.)

the second second second second second second second second second second second second second second second s

٠.

18 ph 13

Pthane $6.57$ - $92.4$ $10$ $6.51$ - $93.1$ $40$ $6.55$ - $93.3$ $40$ $6.55$ - $93.3$ $40$ $6.55$ - $97.4$ $40$ $6.56$ - $97.4$ $40$ $6.64$ - $99.6$ $40$ $6.64$ - $99.6$ $40$ $7.72$ - $134.1$ $40$ $7.10$ - $143.0$ $39$ $7.43$ - $163.0$ $39$ $7.43$ - $191.1$ $42$ $8.02$ - $193.0$ $39$ $ 11.834$ $272.07$ $41$ $9.406$ - $286.1$ $42$ $ 12.733$ $302.70$ $42$ $ 12.59$ $296.16$ $5$ $ 12.65$ $300.0$ $5$ $ 27.66$	Materials	C _v , cal/mole	C _p , cal/sole	Temporature •A	Ref.
6.51       - $93.1$ $40$ $6.55$ - $91.3$ $40$ $6.59$ - $97.4$ $40$ $6.60$ - $92.6$ $40$ $6.64$ - $92.6$ $40$ $6.64$ - $100.5$ $40$ $7.72$ - $134.1$ $40$ $7.10$ - $145.0$ $39$ $7.43$ - $191.1$ $42$ $8.02$ - $192.0$ $39$ $ 11.834$ $272.07$ $41$ $9.408$ - $286.1$ $42$ - $12.733$ $302.70$ $42$ - $12.733$ $302.70$ $42$ - $12.733$ $302.70$ $42$ - $12.59$ $298.16$ $5$ - $12.59$ $298.16$ $5$ - $12.59$ $298.16$ $5$ - $12.58$ $300.0$ $5$ - $27.66$ $900.0$ $5$	Ethane	6.57	-	92.4	÷0
6.55         - $93.5$ $40$ $6.55$ - $91.3$ $40$ $6.55$ - $97.4$ $40$ $6.60$ - $97.4$ $40$ $6.60$ - $98.4$ $40$ $6.64$ - $92.6$ $40$ $7.72$ - $134.1$ $40$ $7.43$ - $163.0$ $39$ $7.43$ - $163.0$ $39$ $7.43$ - $193.0$ $39$ $7.43$ - $193.0$ $39$ $7.43$ - $12.733$ $302.70$ $41$ $9.408$ - $286.1$ $42$ - $12.733$ $302.70$ $41$ $ 12.65$ $300.0$ $5$ $ 12.65$ $300.0$ $5$ $ 12.65$ $300.0$ $5$ $ 27.68$ $900.0$ $5$ $ 27.68$		6.51	-	93.1	40
6.55       - $9:.3$ $40$ $6.59$ - $97.4$ $40$ $6.60$ - $98.4$ $40$ $6.64$ - $100.5$ $40$ $7.72$ - $134.1$ $40$ $7.72$ - $134.1$ $40$ $7.10$ - $143.0$ $39$ $7.43$ - $163.0$ $39$ $6.13$ - $191.1$ $42$ $8.02$ - $193.0$ $39$ $ 11.834$ $272.07$ $41$ $9.406$ - $286.1$ $42$ $ 12.733$ $302.70$ $42$ $ 12.59$ $298.16$ $5$ $ 12.59$ $298.16$ $5$ $ 12.65$ $300.0$ $5$ $ 12.66$ $500.0$ $5$ $ 12.66$ $500.0$ $5$ $ 25.62$ $600.0$ $5$ $ 28.71$ $700.0$ $5$		6.55	-	93 <b>.5</b>	40
6.59         - $97.4$ $40$ $6.60$ - $98.4$ $40$ $6.64$ - $99.6$ $40$ $7.72$ - $134.1$ $40$ $7.10$ - $135.0$ $39$ $7.43$ - $163.0$ $39$ $7.43$ - $163.0$ $39$ $6.13$ - $191.1$ $42$ $8.02$ - $193.0$ $39$ $ 11.834$ $272.07$ $41$ $9.406$ - $2866.1$ $42$ $ 12.733$ $302.70$ $42$ $ 12.733$ $302.70$ $42$ $ 12.59$ $2986.16$ $5$ $ 12.55$ $300.0$ $5$ $ 12.55$ $300.0$ $5$ $ 21.54$ $600.0$ $5$ $ 21.34$ $600.0$ $5$ $ 27.66$		6.55	-	91.3	40
6.60         -         98.4         40           6.64         -         99.6         40           7.72         -         134.1         40           7.72         -         134.1         40           7.10         -         143.0         39           8.13         -         163.0         39           8.13         -         191.1         42           8.02         -         193.0         39           -         11.834         272.07         41           9.408         -         286.1         42           -         12.733         302.70         42           -         12.739         355.62         41           -         14.589         364.78         41           -         12.65         300.0         5           -         12.65         300.0         5           -         12.45         300.0         5           -         12.64         400.0         5           -         29.31         1000.0         5           -         27.66         900.0         5           -         32.00         1250.0		6.59	-	97.4	40
6.64         -         99.6         40           5.64         -         100.5         40           7.72         -         134.1         40           7.10         -         143.0         39           7.43         -         165.0         39           8.13         -         191.1         42           8.02         -         195.0         39           -         11.834         272.07         41           9.408         -         286.1         42           -         12.733         302.70         42           -         12.59         298.1         42           -         12.59         298.16         5           -         12.65         300.0         5           -         12.65         300.0         5           -         12.645         300.0         5           -         12.645         300.0         5           -         25.62         900.0         5           -         25.62         900.0         5           -         27.66         900.0         5           -         32.00         1250.0		6.60	-	98.4	40
6.64         -         100.5         40           7.72         -         134.1         40           7.10         -         143.0         39           7.43         -         163.0         39           8.13         -         191.1         42           8.02         -         193.0         39           -         11.834         272.07         41           9.408         -         286.1         42           -         12.733         302.70         42           -         12.733         302.70         42           -         12.59         298.16         5           -         12.65         300.0         5           -         12.65         300.0         5           -         12.65         300.0         5           -         12.65         300.0         5           -         21.34         600.0         5           -         21.34         600.0         5           -         29.31         1000.0         5           -         29.31         1000.0         5           -         32.00         1200.0		6.64	-	99.6	40
7.72       -       134.1       40         7.10       -       143.0       39         7.43       -       163.0       39         8.13       -       191.1       42         8.02       -       193.0       39         -       11.834       272.07       41         9.408       -       286.1       42         -       12.733       302.70       42         -       12.733       305.82       41         -       12.59       298.16       5         -       12.59       298.16       5         -       12.65       300.0       5         -       12.66       400.0       5         -       12.66       900.0       5         -       23.71       700.0       5         -       29.31       1000.0       5         -       29.31       1000.0       5         -       32.00       1250.0       5         -       33.10       1250.0       5         -       34.05       1300.0       5         -       34.45       288.1       42         -<		6.64	-	100.5	40
7.10-143.039 $7.43$ -163.039 $8.13$ -191.142 $8.02$ -193.039-11.834272.0741 $9.408$ -288.142-12.733302.7042-13.719335.8241-12.59298.165-12.65300.05-15.68400.05-18.66500.05-21.34600.05-25.82800.05-29.311000.05-32.001200.05-33.101250.05-34.051300.05-34.051300.05-84.47288.142-9.49283.123Acetylene29.12-202.142-10.452291.142		7 .72	-	134.1	40
7.43-163.039 $8.13$ -191.142 $8.02$ -193.039-11.834272.0741 $9.408$ -288.142-12.733302.7042-13.719335.8241-14.589364.7841-12.59298.165-12.65300.05-15.68400.05-15.68400.05-21.34600.05-25.82900.05-29.311000.05-32.001200.05-34.051300.05-34.4891400.05-34.491400.05-34.491400.05-8.47288.616-9.49283.123Acetylene29.12-202.142-10.452291.142		7.10	-	143.0	39
8,13       - $191,1$ $42$ $8,02$ - $193,0$ $39$ - $11,834$ $272,07$ $41$ $9,408$ - $288,1$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,733$ $302,70$ $42$ - $12,59$ $298,16$ $5$ - $12,65$ $300,0$ $5$ - $23,71$ $700,0$ $5$ - $27,68$ $900,0$ $5$ - $29,31$ $1000,0$ $5$ - $34,05$ $1200,0$		7 .43		163.0	39
8.02       -       193.0       39         -       11.834       272.07       41         9.408       -       288.1       42         -       12.733       302.70       42         -       13.719       335.82       41         -       13.719       335.82       41         -       12.59       298.16       5         -       12.65       300.0       5         -       15.68       400.0       5         -       15.68       400.0       5         -       18.66       500.0       5         -       21.34       600.0       5         -       27.68       900.0       5         -       29.31       1000.0       5         -       29.31       1000.0       5         -       32.00       1200.0       5         -       34.05       1300.0       5         -       34.05       1300.0       5         -       34.489       1400.0       5         -       34.49       288.6       16         -       9.49       283.1       23 <tb< td=""><td></td><td>8,13</td><td>-</td><td>191.1</td><td>42</td></tb<>		8,13	-	191.1	42
-11,834 $272.07$ 419.406- $288.1$ 42-12,733 $302.70$ 42-13,719 $335.62$ 41-14,589 $364.78$ 41-12,59 $298.16$ 5-12,65 $300.0$ 5-12,65 $300.0$ 5-18,66 $500.0$ 5-21.34 $600.0$ 5-23.71 $700.0$ 5-27.68 $900.0$ 5-27.68 $900.0$ 5-23.00 $1200.0$ 5-32.00 $1200.0$ 5-34.05 $1300.0$ 5-34.89 $1400.0$ 5-9.49 $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		8.02	-	193.0	39
9.408- $288.1$ $42$ -12.733 $302.70$ $42$ -13.719 $335.82$ $41$ -14.589 $364.78$ $41$ -12.59 $298.16$ $5$ -12.65 $300.0$ $5$ -15.68 $400.0$ $5$ -18.66 $500.0$ $5$ -21.34 $600.0$ $5$ -23.71 $700.0$ $5$ -27.68 $900.0$ $5$ -29.31 $1000.0$ $5$ - $32.00$ $1200.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $34.89$ $1400.0$ $5$ - $9.49$ $283.1$ $42$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	11.834	272.07	41
-12,733 $302.70$ $42$ -13,719 $335.82$ $41$ -14,589 $364.78$ $41$ -12,59 $298.16$ $5$ -12,65 $300.0$ $5$ -15,68 $400.0$ $5$ -18,66 $500.0$ $5$ -21,34 $600.0$ $5$ -23,71 $700.0$ $5$ -27,68 $900.0$ $5$ -29,31 $1000.0$ $5$ -32,00 $1200.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $34.89$ $1400.0$ $5$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		9 • 408	-	288.1	42
- $13,719$ $335,82$ $41$ - $14,589$ $364.78$ $41$ - $12,59$ $298,16$ $5$ - $12,65$ $300.0$ $5$ - $15,68$ $400.0$ $5$ - $18,66$ $500.0$ $5$ - $21,34$ $600.0$ $5$ - $23.71$ $700.0$ $5$ - $25,82$ $800.0$ $5$ - $27,66$ $900.0$ $5$ - $29.31$ $1000.0$ $5$ - $32.00$ $1200.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $6.4512$ $6.451$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	12.733	302.70	42
- $14,589$ $364,78$ $41$ - $12,59$ $298,16$ $5$ - $12,65$ $300,0$ $5$ - $15,68$ $400,0$ $5$ - $18,66$ $500,0$ $5$ - $21,34$ $600,0$ $5$ - $23,71$ $700,0$ $5$ - $25,82$ $800,0$ $5$ - $27,66$ $900,0$ $5$ - $29,31$ $1000,0$ $5$ - $32,00$ $1200,0$ $5$ - $33,10$ $1250,0$ $5$ - $34,05$ $1300,0$ $5$ - $34,05$ $1300,0$ $5$ - $ 8,47$ $288,1$ $42$ $6,4512$ $8,45$ $288,1$ $42$ - $9,49$ $283,1$ $23$ Acetylene $29,12$ $ 202,1$ $42$ - $10,452$ $291,1$ $42$		-	13,719	335.82	41
- $12.59$ $298.16$ 5- $12.65$ $300.0$ 5- $15.68$ $400.0$ 5- $18.66$ $500.0$ 5- $21.34$ $600.0$ 5- $23.71$ $700.0$ 5- $27.68$ $900.0$ 5- $29.31$ $1000.0$ 5- $29.31$ $1000.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $8.47$ $288.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$		-	14.589	364.78	41
-12.65 $300.0$ 5-15.68 $400.0$ 5-18.66 $500.0$ 5-21.34 $600.0$ 5-23.71 $700.0$ 5-25.82 $800.0$ 5-27.66 $900.0$ 5-29.31 $1000.0$ 5-32.00 $1200.0$ 5-33.10 $1250.0$ 5-34.05 $1300.0$ 5-34.89 $1400.0$ 5-8.47288.616-9.49283.123Acetylene29.12- $202.1$ 42-10.452291.142		-	12.59	298.16	5
- $15.68$ $400.0$ 5- $18.66$ $500.0$ 5- $21.34$ $600.0$ 5- $23.71$ $700.0$ 5- $25.82$ $800.0$ 5- $27.68$ $900.0$ 5- $29.31$ $1000.0$ 5- $30.75$ $1100.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	12.65	300.0	5
- $18.66$ $500.0$ $5$ - $21.34$ $600.0$ $5$ - $23.71$ $700.0$ $5$ - $25.82$ $800.0$ $5$ - $27.68$ $900.0$ $5$ - $29.31$ $1000.0$ $5$ - $32.00$ $1200.0$ $5$ - $32.00$ $1200.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $34.89$ $1400.0$ $5$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	15.68	<b>400.</b> 0	5
- $21.34$ $600.0$ $5$ - $23.71$ $700.0$ $5$ - $25.82$ $800.0$ $5$ - $27.68$ $900.0$ $5$ - $29.31$ $1000.0$ $5$ - $29.31$ $1000.0$ $5$ - $30.75$ $1100.0$ $5$ - $32.00$ $1200.0$ $5$ - $32.00$ $1200.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $6.4512$ $6.45$ $298.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	18,66	500.0	5
- $23.71$ $700.0$ $5$ - $25.82$ $800.0$ $5$ - $27.68$ $900.0$ $5$ - $29.31$ $1000.0$ $5$ - $30.75$ $1100.0$ $5$ - $32.00$ $1200.0$ $5$ - $33.10$ $1250.0$ $5$ - $34.05$ $1300.0$ $5$ - $34.89$ $1400.0$ $5$ - $34.89$ $1400.0$ $5$ - $8.47$ $288.1$ $42$ $6.4512$ $6.455$ $288.1$ $42$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	21.34	600.0	5
- $25.82$ $800.0$ 5- $27.68$ $900.0$ 5- $29.31$ $1000.0$ 5- $30.75$ $1100.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $298.1$ $42$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	23.71	700.0	5
- $27.68$ $900.0$ 5- $29.31$ $1000.0$ 5- $30.75$ $1100.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	25.82	800.0	5
- $29.31$ $1000.0$ 5- $30.75$ $1100.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $5.92$ $7.963$ $195.1$ 42 $6.4512$ $8.45$ $288.1$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	27.68	900.0	5
- $30.75$ $1100.0$ 5- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5Methane $5.104$ $7.20$ $158.1$ $42$ $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	29.31	1000.0	5
- $32.00$ $1200.0$ 5- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5- $34.89$ $1400.0$ 5Methane $5.104$ $7.20$ $158.1$ $42$ $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	30,75	1100.0	5
- $33.10$ $1250.0$ 5- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5Methane $5.104$ $7.20$ $158.1$ $42$ $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	32.00	1200.0	5
- $34.05$ $1300.0$ 5- $34.89$ $1400.0$ 5Methane $5.104$ $7.20$ $158.1$ $42$ $5.92$ $7.963$ $195.1$ $42$ $6.4512$ $8.45$ $288.1$ $42$ - $8.47$ $288.6$ $16$ - $9.49$ $283.1$ $23$ Acetylene $29.12$ - $202.1$ $42$ - $10.452$ $291.1$ $42$		-	33,10	1250.0	5
-       34.89       1400.0       5         Methane       5.104       7.20       158.1       42         5.92       7.963       195.1       42         6.4512       8.45       288.1       42         -       8.47       288.6       16         -       9.49       283.1       23         Acetylene       29.12       -       202.1       42         -       10.452       291.1       42		-	34.05	1300.0	5
Methane       5.104       7.20       158.1       42         5.92       7.963       195.1       42         6.4512       8.45       288.1       42         -       8.47       288.6       16         -       9.49       283.1       23         Acetylene       29.12       -       202.1       42         -       10.452       291.1       42		-	34 .89	1.400.0	5
5.92       7.963       195.1       42         6.4512       8.45       288.1       42         -       8.47       288.6       16         -       9.49       283.1       23	Methane	5.104	7.20	158.1	42
6.4512       8.45       288.1       42         -       8.47       288.6       16         -       9.49       283.1       23         Acetylene       29.12       -       202.1       42         -       10.452       291.1       42		5.92	7.963	195.1	42
-       8.47       288.6       16         -       9.49       283.1       23         Acetylene       29.12       -       202.1       42         -       10.452       291.1       42		6.4512	8.45	288.1	42
- 9.49 283.1 23 Acetylene 29.12 - 202.1 42 - 10.452 291.1 42		-	8.47	288.6	16
Acetylene 29.12 - 202.1 42 - 10.452 291.1 42		-	9.49	283.1	23
- 10.452 291.1 42	Acetylene	29.12		202.1	42
	-	-	10.452	291.1	42

ì

#### HEAT CAPACITIES OF FLAMMABLE GASES

279.

*

## Table 131

# DIVILICATRIC COMETANTS OF TOUS GASES

Material	Dielectric Constant	Pressure, Hg	Temperature, ^A	Ref.
Oxygen	1,000,503,3	760	273	31
	1.000,799	1217	291.1	50
	1.000,862	2863	291.1	50
	1,000,5)5	763	291.7	50
	1.000,986	1507	291.7	50
	1.001,314	2035	291.7	50
	1.000,504	765	292.6	50
	1.000,841	2873	292.6	50
	1.004.241	6610	294.4	50
	1.002,781	<b>395</b>	294.6	50
	1.001,889	2955	295.1	50
	1.004,263	6675	295.4	50
	1.003,388	5352	296.1	50
Chlorine	1.9	760	274.1	13
	2.0	760	274.1	22
	1.97	760	274.1	49

. .

Materials	c _p /c _v	Temperature, °A	Ref.
Methene	1.47	158.1	42
	1.35	199.1	42
	1.31	288.1	42
	1.316	284.1 to 300.1	23
Ethane	1.22	288.1	
	1.21	323.1	42
	1.19	373.1	42
Acetylene	1.31	202.1	79
-	1.26	288 .1	79
	1.28	191.1	42

ł

# RATIO OF Cp/Cv FOR SOME FLAMMABLE GASES

Ì

Material	Thermal Conductivity $\pi$ 10 ⁵	Temperature, *A	Rof.
	Cal/cm./sec./°A		
Acetylene	4.40	2 <b>73.1</b>	29
Ethane	2.727	202.7	29
	4.306	273.1	29
	7.673	373.1	29
Methane	2.248	81.5	29
	2.272	90	33
	2.536	100	33
	2,800	110	33
	3,065	120	33
	3.331	130	<b>3</b> 3
	3.595	140	33
	3,860	150	33
	4,128	-	33
	4.396	170	33
	4.667	180	33
	<b>4 .94</b> 0	190	33
	4,940	197.5	29
	5.216	200	25
	5.496	210	63
	5.778	220	30
	6.063	230	30
	6.351	240	30
	6.643	250	- 3
	6.940	260	33
	7.242	270	33
	7.200	273.1	29
	7.549	280	33
	7.862	290	33
	8.186	300	33
	8,518	310	33
	8.862	320	33
	9,219	330	33
	9.590	340	33
	9.978	350	33
	10,372	360	33
	10.797	370	33
	11.220	380	33

----

- - --

### THERMAL CONDUCTIVITIES FOR SOME FLAMMAHLE GASES

282.

靐

r sin anna santaire a'

Material	Dielectric Concient	Yomperature,	Pressure,	Ref.
<i>siothane</i>	1.01918	0	20	75
	1.04044	0	40	75
	1.06439	0	60	75
	1,09082	0	80	75
	1.1198	0	100	75
	1.0134	100	20	75
	1.02750	100	40	<b>7</b> 5
	1.04164	100	60	75
	1.05615	100	80	75
	1.07113	100	100	75
	1.09005	100	125	75
	1.1089	100	150	75
	1.1275	100	170	75
Ethane	1.0015			73
Acetylene	1.00134			73

1

**.,**#*

DIELECTRIC CONSTANTS OF SOME FLAMMABLE GASES

PHYSICAL DITI FOR SCHE INERT GISTS

Krypton	-152,9 (11) -151,7 (23) -151,8 (33,42)	-169.0 (23,42) -157.0 (11) -157.1 (33)	83.7 (11,42,82) 82.92 (23)	0,36 kg.c31/g., 1tor (42)	115.94 ± (3 at 209.39 m. (.48)	
Hellum	-268.9(11, 33, 42) -268.884(61) -267.0(23)	-272,2 (11) (26, 45:) -272,2 (33,42)	4, cc3 (11,42) 3,99 (23)	C.835 cal/ at 2.5 ^v 1 (69) 1.035 cal/ at 3 ^v 1 (69) 1.365 cal/ at 3.5 ^v 1 (69) at 3.5 ^v 1 (69)	5.19 au 2.26 atm. ( <b>59)</b>	
Årgon	-185.7 (11, 33,42) -186.1 (23) -185.76 (45)	-190_0 (79) -189_2 (79) -188_C (23)	<b>39,944</b> (11) <b>39,94</b> (72) <b>39,91</b> (92) <b>39,8</b> 8 (23)	265.2 cal/rolo at 3.6 (21) 28.1 Jouleag. (79) 0.268 kg-cal/g.atom (42)	83,93 at 517 mm, (4) 83,85 at 516,3 mm, (12) 83,8 at 515,65 mm, (12) 83,55 at 760 mm, (24) 83,81 at 521,4 mm, (44) 33,5 at 760 mm, (57)	
ula ter ial	Boiling Point, C ^{eC} .	Melting Point, CoC.	Wolecular Weig <b>ht</b>	Hoat of Fusion	Triple Point, C.a.	

• •

----

Table 135 (Cont'i.)

4

Physical Data For Some Incrt Gases

Msterial	Neon	Nitrogen	Lenop	Carbon Diorida
Boiling Point, CCC.	-245 <b>.</b> 9 (11,33,42) -239 (23) -246 (25)	-195.8 (42) -195.8 (11) -195 (23) -194.4 (10)	-109,1 (23) -109,1 (22) -107,1 (11)	-78,2 (25) -78,5 (11)
Welting Point, OvC,	-248,67 (11,33,42) -252, (23)	-209.86 (42) -2 5 6 (11) -211. (23) -210.06 (25)	-112, (11) -140, (22) -140, (23) -111,74, (25) -140, (33)	-56,6 (11) at 5,2ata. -57,5 -25:
Kdlecular Weight	20,183 (11) 20,183 (42) 20,2 (23)	14,008 (42) 14,01 (23) 14,08 (11)	131.3 (11,42) 130.2 (23)	(111 10,44
Heat of Pusion kg.cal/g. atom cal/mole	0,057 (42)	0,0851 (42)	0,490 (42) 0,548 (25)	0,196 (25) 1900,3 at 215.4 (21)
Iriple Point, Oc.	-248,1 (25)	-209,9 (25)	-16.6 (59) (58.2 atm.)	-31,1 (59) (73 atm.)
-				

★ kcal/∎ole

١

; |

.

285.

Table 135 (Cont'd.)

120,914 (42) 120,92 (11) Cluoro methane -30 (9) -24**.**8 (7) -29.8 (42) 8.2 (l) -29.8 (70) -127 (11) -155 (51) -155 (42) Dichlorodi-* ļ 4.44 (42) 4.5 (38) (757.6 ma. Hg) - 93. 66 (11,19) - 93. (38) - 92.77 (42) 94.95 (11,19) 1.429 (19,25) 3.56 (11,19) bromide 11 uiethyl Physical Data For Some Inert Gases fluorone thare 104.47 (11) -80,5 (70) -82, (56) -81,5 (60) (11,6) 08-Chlorotri-(11) 181-(66) 081-1 -183.6 (25,49) -128,5 (70) -126 (43) Carbon tetra--184 (30) -186 (65) -183.6 (25) 519.69 (11) 0.167 (25) -130 (70) fluoride -82.2 (at 23 : atm.) (11) * cal/g. Trifluoro--90 (70) -90 (70) -82 2 (32) -81 (17) -82 (47) -163 (11) -163 (32) -160 (68) 70.02 (11) methane Triple Point, OvC. kg. cel/mole Point, Ouc. Welting -Point, °C, . Molecular Mater181 Boiling Heat of Weight Puston

286

; ;

; 4

٩

**;** 

.

٠

.

PHIBICAL DATA FOR SO IE INERT GASES

Material	Argon	Hellum	K rypton	Néon
Gritical Tarperature, OvC.	-117.4 (23) -122.4 (79,82) -122 (79)	-266 (23) -267,91 (33,72) -267,9 (29)	-63.1 (82) -62.5 (33) -65.5 (23)	-205.0 (23) -228.7 (33) -228.65 (82)
Critical Fressure, atm.	48.0 (79) 47.96 (33) 47.966 (82) 52.9 (23)	2,26 (33) 2,75 (29) 2,161 (82)	54. 3 (23, 33) 54. (8)	28.86 (43.82) 29.0 (23) 25.9 (79)
Critical Density, g./cc.	0,531 (79) 0,53078 (22)	0,066 (29) 0,06930 (82) 0,125 (81) 0,0693 (79)	0.78 (79,82)	0.4835 (82) 0.484 (79)
Heat of Vaporization kg.cal./g.atom cal.g. cal.mole	38,93 (24)	0.024 (at b.p.) (42) 5.5 (69) 	2,2 (b,p,) (42)	0.416 (b.p.) (42) 
Liquid Density,g./ml.	1	8		c*1035 (52)
Vapor Density,g./liter as compared to uir	1.7824 (42) 1.7732 (79) 1.3796 (23) 1.379 (79)	0,1785 (42) 0,1348 (23)	3,708 (42) 2,868 (23,33)	0, 40434 (11) 0, 4044 (23)

287.

ļ

pnide			(7		2222	28220	288 <b>.</b>
ne thr br			<b>42,</b> 66,15		1.73 (53) 1.755 at 1.750 at 1.830 at 1.830 at	1.955 at 95 at 95	1. 940 at 1
Carbon Dioxide 31,2 (23)	73.0 (27,79)	0,46 (23,79)		2481 (at (~C.) (46)	ł		1,5291 (23)
Xenor 16,5 (33) 16,7 (82)	58,22 (82) 58,2 (33)	1.154 (82) 1.155 (79) 3.06 (33)	3.20 (42)				4.525 (33) 4.526 (23)
Nitregen -147.1 (79) -146.0 (23)	35.5 (79) 35.0 (23)	0.3110 (79) 0.44 (23)	0,669 (42) 0,04745 (-195,640,				1,2506 (3) 0,9673 (23)
Material Critical Temperature, OvC.	Critical Pressure, atm.	Critical Density, g/cc.	Heat of Vaporization, Kg.cal/g.atom cal/g. cal/g.	Liquid Density E./ml. at vC.			Vapor Density, g. A. compared to air

,

Table 135(Contid.)

.

··· :

ł

÷

:

.

Dichlerodi- fluorogethene	115.5 (70) 111.7 (42) 111.5 (77)	39.4 (42)	40.4 (70) 4840 (-29.8) (7) 4100 (23°C,) (7) 3960 (28°C,) (7)	5.44 (42) 4.709 (26) 4.21 (42)
Chlorotrifluorcaethum	30. (70) 38.8 ( <i>5</i> 7)	1	-35.8 (64) 	3,430 (26) 
Carbon tetrafluoride	-49 (70)	1	31.°C (70) 2927 (71) 3209 (at 273.1 (.	3°451 (26)
Triflyoromethane	15. (70) 32.9 (28)	46, (28)	53,42 (70)	e e e e
	Critical Temperature, OC.	Critical Pressure, atm.	Heat of Veporization, kg. cal/kg. cal/mole at °C.	Vapor Density g./1. compared to air

Table 136 (Cont'd.)

.

289.

į

:

290,

### Table 137

### THERMAL CONDUCTIVITIES OF INERT GASES

Material	Thermal Conductivity x 10 ⁵ <u>Cal/sec./cm./°A</u>	Temperature, °A	Ref.
Argon	1.42	<b>90.</b> 5	29
· U	3.88	273.1	29
	5.037	373.1	29
Helium	6.0	3.3	60
	5.13	20.8	29
	15.34	80	33
	14.84	81.4	29
	16.43	90	33
	17.51	100	33
	18,53	110	33
	19.64	120	33
	20,63	130	33
	21.71	140	33
	22.73	150	33
	23.73	160	33
	24.72	170	33
	25-63	180	33
	26-63	190	33
	27.56	200	33
	28.49	210	33
	29.39	220	33
	30,28	230	33
	31,15	240	33
	32.00	250	33
	32.83	260	33
	33-65	270	33
	33.6	273.1	29
	34 - 45	280	33
	35-23	290	33
	36.00	300	33
	36-74	310	23
	37.46	320	33
	38-15	330	32
	38,81	340	33
	39-44	350	33
	40.05	360	33
	40.62	370	33
	39,85	373.1	29
	41,17	380	33
Neon	4.99	91.7	33
HOOL	8-79	198.7	33
	10.87	273.1	33
	13.44	378.9	33
Yanon	1.94	273.1	15
Venon	1 0 C T		

The second

.

سندريل ملا

Material	Thermal Conductivity x 105 Ccl/sec./cm./°A	Temperature, °A	Ref.
Nitrogen	1.829	81.7	29
-	4.305	198.7	29
	5,68	273.1	29
	7.18	373.1	29
Krypton	2.12	273.1	15
Curbon dioxide	1.984	180	33
	2.126	190	33
	2,546	194.6	29
	2.272	200	33
	2.424	210	33
	2.580	220	33
	2.741	230	33
	2.907	240	33
	3.077	250	33
	3.251	260	33
	3.429	270	<b>3</b> 3
	3.393	273.1	29
	3.611	280	33
	3.796	290	33
•	3.964	300	33
	4.175	310	33
	4.371	320	33
	4.571	330	33
	4.777	340	33
	4.988	350	33
	5.202	360	33
	5.416	370	33
	5.06	373.1	29
	5.630	380	33
	14.20	819 <b>.1</b>	29
Methyl bromid	e 1 <b>.7</b> 4	277.7	33

:

۰.

;

Table 137 (Continued)

5

Ń

	DILLS OTRIC CONST	Prossure	Temp.	
Meterial	Dielectric Constant	mm, Hg.	A	Ref.
Carbon	1.000862	714	294.1	76
dioxide	1.000862	722	294.1	76
	1.000873	724	294.1	76
	1.000929	763	291.1	76
	1.001449	1203	292.6	76
	1.001548	1275	292.1	76
	1.002145	1747	292.1	76
	1.002367	1946	292.6	76
	1.002377	1959	294.1	76
	1.002421	1997	292.6	76
	1,003042	2486	291.3	76
	1.003074	2511	292.6	76
	1.003595	2868	291.1	76
	1.004057	3329	294:1	76
	1,005540	4494	293.5	76
	1,008667	5384	294.4	76
	1.007452	5986	294.1	76
	1,007608	6088 🗯	293.5	76
	1.0280	25.79	296,15	50
	1.0343	.30 <b>.</b> 48 [¥]	298,15	50

*These values are expressed in atmospheres.

292.

:

. ....

:

-

**₩**. ¥

## Table 139 (Cont'd)

4

5

:

٠.

80%

## DIELECTRIC CONSTANTS OF INERT CASES Pressure

Mark and a		TTCSSRL6		
Material	Dielectric Constant	atm.	Temp A.	Rof.
Cerbon	1.0415	35.24	200 15	50
dioxide	1.0494	70 00	230+10	50
	1.0585	-14 65	1	50
	1.0707	50 17		50
	1.0838	54.62		50
	1.1022	59.33	1	50
	1.1317	65.14		50
	1.02486	25.80	390 AI	50
	1.03578	35.26	UCC OL	50
	1.04566	42.91		50
	1.06343	54.67		50
	1.07513	1 21		50
	1.08574	66 d's c		50
	1.09712	71 97	i i	50
	1.11124	76.53		50
	1.12444	80.74	í	50
	1.15457	00.12		50
	1.01951	24 75		50
4	1.04457	51 72	372.80	50
	1.06939	D1+70 DA 25		50
	1,13914	193 50		50
	1,18008	146.90		50
	1,20654	140.20		50
Helium	1,000,072 8	100.51		50
	1,000,068,4+0,0	00 000 5	•	80
Neon	1.000.1%	00,000,5	873•T	31
	1,000,1274+0.0	00 000 5	-	80
Argon	1,000,550	00,000,5	273.1	31
0	$1.0005451 \pm 0.0$	00 000 5	-	60
Krypton	1.000.838	00,000,5	273.1	31
Xenon	1,001,351			80
Methyl bromide	9.97			80
	10.42		273.1	53
	10.91		263.1	53
	11.43		253.1	53
	12-00		245.1	53
	19 67		233.1	53
	13.39		223.1	53
	14 07		213.1	53
	1/ 02		203.1	53
	16 Ag		193.1	53
	10.0C		183.1	53
	1 ( • <del>5</del>		173.1	53

.

١

293.

# Heat Capacities of Nitrogen (73)

cp-cal/mole/°A	Temporature 'A
6.957	200
6.959	250
6.960	298.15
6.961	300
6.991	400
7.070	500
7.197	600
7.351	700
7.512	800
7.671	900
7.816	1000
7.947	1100
8.063	1200
8.116	1250
8.165	1300
8.253	1400
8.330	1500
8.486	1750
8.602	2000
8.759	2500
8.862	5000
8.934	3500
8,984	4000
9.036	4500
9.076	5000

•

294.

•

小田の

1 F 7

## Table 141.

.

2

## Heat capabilian of general a rhon dioxido

co-cal/mole/A	Temperature, A	Ref.
8,827	292 <b>.</b> 9	41
8.374	298.16	78
8.894	50 <b>0.</b> 0	78
9.240	331.86	41
2.503	358.4	41
¥•595	367.72	41
9.871	400.0	78
10.662	500.0	78
11.311	600.0	78
11.849	700.C	78
1:	800.0	78
12.678	900.0	78
12.995	1000.0	78
13.260	1100.0	78
13.49	1200.0	78
13.59	1250.0	78
13.68	1300.0	78
13.85	1400.0	76
13.99	1500.0	78
14.30	1750.0	78
14.50	2000.0	78
14.80	2500.0	78
15.00	3000.0	78
15.2	3500.0	76
		. •

295.

/. =

## 296.

## Table 142

# Heat Capacities of solid carbon dioxide

cp-cal/mole/°A	Temperature. A	Hef.
0 540	15	27
1 995	20	
2137	25	
3.093	30	
3,912	35	
4-690	40	
5.435	45	
6.095	50	
7.178	60	
1.110	70	
4 5,82	80	
6.1.05	90	
9.530	100	
0 015	110	
10 30	120	
10.67	130	
11 04	140	
11.39	150	
11,00	160	
148(7	170	
ቷይቃይ <i>ተ</i> ጉባ <b>ይገ</b>	180	
	190	
13.01	***	

w. . N.

ł

Diff.

#### HEAT CAPACITIES REPORTED FOR METHYL TROMIDE

Cp. Cal/mole/*A.	Temperature. "A	Ref.
1.54	15	6
° <b>.5</b> 6	20	6
3.60	25	6
4.54	30	6
6-37	40	6
7.93	50	6
9.16	60	6
10.02	70	6
10.79	80	6
11.42	90	6
11.92	100	6
12.34	110	6
12.67	120	ö
12.96	130	6
13.21	140	6
13.44	150	6
13.88	160	74
10,18	298.1	74
11.07	350	74
11,96	400	74
13.60	<b>50</b> 0	74
15.05	600	74
16.27	700	74
17.30	800	74
18.24	900	74
19.06	1000	74
19.78	1100	74
20.41	1200	74

F.

### HEAT CAPACITIES FOR DICHLORODIFLUOROMETHANE

. . .....

.

•-- -- --

C Cal/mole	C cal/mole	Temperature,	<u>ante</u>
10.32	12.31	173.1	36
11.27	13.25	198.1	36
12.16	14.15	223.1	36
13.01	15.00	248.1	36
13.82	15.80	273.1	36
11.57	16.56	298.1	36
15.25	17.24	323.1	36
15.92	17.90	348.1	36
16.51	18.50	373.1	36
17.06	19.04	398.1	36
17.55	19.54	423.1	36
18.01	20.00	448.1	36
18.43	20,41	473.1	36
14.82		273.1	20
16.87		523.1	20
17.37		373.1	20
18.32		423.1	20
19,10		473.1	20
19.74		523.1	20
29,34		573.1	20

298.

Surger and the second

-

í

÷.

£
#### Table 145

:

.

۰.

## HEAT CAPACITIES OF TRIFLUOROMETHANE (28)

## (Cal./moles at "A)

<u> </u>	Temperature, "A	Co	Temperature, *A
11.37	250	16.2.	450
12.01	273.1	16.68	473.1
12.68	298.1	17.15	500
12.73	300	17,95	550
14.02	350	16.65	600
14.58	373	19.27	650
15.19	400		

#### Table 146

## HEAT CAPACITIES FOR CARBON TETRAFLUORIDE (20)

## (Cal./mole at °A)

<u></u> Cv	Temperature, °A	
11.23	273.1	
12.74	323.1	
14.09	373.1	
15,27	423.1	
16.30	473.1	
17.18	523.1	
17.94	573.1	

299,

1 %, 4

## Table 147

۴.

THE RATIO  $C_p/C_v$  FOR SOME INERT GASES

Material	C _p /C _v	Temperature, *C.	Ref.
Nitrogen	1.41		23
	1.47	-181	42
	1.404	15	42
Helium	1.652		33
	1.660	-180	42
Argon	1.76	-180	42,79
-	1.668	15	42
	1.65	15	79
rypton	1,68	19	42
Neon	1.64	19	42
Dichlorodi-	1.138		42
fluoromethane	1.139	25	42
Methyl bromide	1.27	18	42
Carbon dioxide	1.37	-75	42
	1.310	1	42
	1.304	15	42
	1.281	100	42
	1.235	400	42
	1.195	1000	42
	1.171	2000	42
	1.2995	4-11	23
Xenon	1.66	292	63

300.

... . .

4 1

----



1

٠

Figure 100 ,Flammable Area

JUNTON X8 LNJJZJZ * YOUVA JNYLUJH-4



A.HEPTANE, PERCENT BY VOLUME

Figure ).01 Flammable Area

302.

ļ



_____

ALPTANE, PERCENT BY VOLUME

Figure 102 Flammable Area

303.

. * *

9 Ò INERT COMPOUNDS , PERCENT BY VOLUME 8 7 CK 3.81 6 ct² 5 5 AREA ŋ FLAMMABLE 2 Ø ~ S Ю N * 0

HEPTANE , PERCENT BY VOLUME

Figure 103 Flammable Area





Figure 104 Flammable Area





Figure 105 Flammeble Area

306.

INERT COMPOUNDS, PERCENT BY VOLUME

R.



÷

HEPTANE, PERCENT BY VOLUME

Figure 106 Flammable Area



Figure 107 Flammeble Area



-HEPTANE VAPOR, PERCENT BY VOLUME

Figure 108 Elammeble Area

ł



SWATON LA LNESSES . PERCENT BY VOLUME

Figure 109 Flammable Area

310.



ł

Figure 110 Flammable Area

JAULON YA TNIJAIA, PERCENT BY VOLUME



AMULON YA TNZJAZA, AOGAY ZNATAZH-A

Figure 111 Flammable Area

•

1.1.1

312.

STREET ASTREET



4

۰**,** ۴

JWNTON LE LNJJJJJ' YOCKN JNVLJJH-4

Figure 112 Flammable Area

9 0 Ø 2 v CH3Br 5 4 AREA N **L**J FLAMMABL N Ś 4 2 ~ 9 Ó Ю -

# JWN70N X8 LNJJH-4 Figure 113 Flammable Area

. س^ر م 314.

INERT COMPOUNDS, PERCENT BY VOLUME

and the second second second second second second second second second second second second second second second



÷.



Figure 114 Flammable Area

315.

•



INERT COMPOUNDS, PERCENT BY VOLUME

2

JWNTON LE LNJJYJ' YOUN JNYLJJH-"

1

1 -

Figure 115 Flammable Area



1.12

٢



Figure 116 Flammable Area

317.

1



318.

- - K. fr to

. •





1



Figure 119 Flammable Area

INERT COMPOUNDS, PERCENT BY VOLUME



## AMUICY YE TN30939 , BAY VOLUME

Figure 120 Flammeble Area



A-HEPTANE VAPOR, PERCENT BY VOLUME

Figure 121 Flammable Area

The John sector

INERT COMPOUNDS, PERCENT BY VOLUME



Figure 122 Flammable Area

325.

INERT COMPOUNDS, PERCENT BY VOLUME



Figure 123 Flammable Area





¥



Figure 125 Flammable Area

x

~



THE LAND AND LAND BELLEN BY NOTAME Area

9 0 1 Ø CH Br , ~ v 0 Ĥ 5 4 FLAMMABLE AREA Ю N 1 0 4 ~ Ю 2 ю 5 0 -

1

7

4

# HEPTANE, PERCENT BY VOLUME

Figure 127 Flammable Area

328.

INERT COMPOUNDS, PERCENT BY VOLUME



SWNTON YA TNESSA, ROGAN SNATAH-A

**, 4** 

Figure 128 Flammeble Area

### LITERATURE CITED

.

1

£

1.	Awherry, Phil. Mag., <u>31</u> , 247-53 (1941)
2.	Beattie. Gang-Jen, and Simard, J. Am. Chem. Soc., <u>64</u> , 924-5 (1938).
3.	Booth, U. S. Patent 2,066, 905 (Jan. 1937)
4.	Born, Ann. Physik, <u>69</u> , 473-504 (1922)
5.	Brichemedde, Moskow, M., et. al., J. Res. Nat'l. Bur _o Stand., <u>37</u> , 263-79 (1946).
6.	Bruchsch, and Ziegler, Waldeman, J. Chem. Phys., 10,740-3 (1942).
7.	Buffington, and Floischer, Ind. Eng. Chem. 23, 1290-2 (1931).
8.	Cady, and Hildebrand, Am. Chem. Soc., <u>52</u> , 3839-43 (1930).
9.	Calfee, and Smith, U.S. 2,417,059 (March 11, 1947)
10.	Castell, Phys. Chem. Tables, 1902
11.	Chemical Rubber Company, Handbook of Chemistry and Physics 31st edition, 1949.
12.	Clusius, Z. Physik Chem., <u>B31</u> , 459-474 (1936).
13.	Coolidge, Ann. Physik, <u>69</u> , 125 (1899).
14.	Crommelin, Commun. Phys. Lab. Univ. Leiden, 119a, (1911).
15.	Curie, and Lepaye, Compt. rend., <u>193</u> , 842-3 (1931).
16.	Less, Physical constant of the principal hydrocarbon. Texas Company 4th edition (1943).
17.	Downing, Benning, and McHarness, U.S. 2,413,695 (Jun. 7, 1947.)
18.	Dukins, Proc. Roy. Soc. (London) <u>A143</u> , 517 (1934).
19.	Egan, and Kemp, J. Am. Chem. Soc., <u>60</u> , 2097-101 (1938).
20.	Euchen and Bertram, Z. Physik Chem. B31, 361-81 (1936).
21.	Euchen and Hauch, Z. Physik Chem., 134, 161-177 (1928).
22.	Evershein, Ann. Physik, 13, 492 (1904).
23.	Fowle, Smithsonian Physical Tables, Smithsonian Institution, 6th edition 1916.

24.	Frank, and Clusius, Z. Physik. Chem., <u>B42</u> , 215-421 (1939).
25.	Frick Chem. Lab., Annual Tables of Physical Constants, 1941.
26.	Fuoss, J. Am. Chem. Soc., <u>60</u> , 1633-7 (1938).
27.	Giangue, and Egan, J. Chem. Phys., 5, 45-54 (1937).
28.	Glockler, and Edgell, J. Chem. Phys., 9, 224-31 (1931)
29.	Gmelin, Handbuch der Anorganischen Chomie, <u>B and I</u> , Berlin (1926).
30.	Grosso, and Cody, Ind. Eng. Chem. 39, 367 (1947).
31.	Hector, Grant and Wounly, Phys. Rev., <u>69</u> , 101-5 (1946).
32.	Henne, J. Am. Chem. Soc. <u>59</u> , 1200-2 (1937).
33.	Hopkins, "Chapters in the Chemistry of the Less Familiar Elements", Stipes Publishing Co., Champaign, Ill., 1939.
34.	Johnston, and Grilly, J. Chem. Phys., 14, 233-8 (1946).
35.	Jones, Chem. Rev., <u>22</u> , 4 (1938).
36.	Justi and Langer, Z. Tech. Physik, <u>21</u> , 189-94 (1940).
37.	Kannuluik, and Martin, Proc. Roy. Soc. (London) <u>4144</u> , 496 (1934).
38.	Kempf and Kutter, Schmelzpunktstabellen (1928).
39.	Kistiakowsky, and Nazmi, J. Chem. Phys., 6, 18-24 (1938).
40.	Kistiakowsky, Lacker, and Stitt, J. Chem. Phys., 7, 289-96 (1939).
41.	Kistiakowsky and Rice, Chem. Phys. 7, 281-8 (1939).
42.	Lange, Handbook of Chemistry, 6th edition, 1946.
43.	Lebesu, Compt. rend. 191, 939-40 (1930).
44.	Linie, Ann. Thysik, 56, 546 (1895)
45.	MacLeod, Trans. Faraday Soc., <u>41</u> , 122-6 (1945).
46.	MacLeod, Trans.Faralay Suc., 43, 169-72 (1937).
47.	McBee, Ind. Eng. Chem. <u>39</u> , 236-7.
48.	Mathius, and Crommelin, 7th Congr. intern. Froid, 1st. comm. intern, Rapports et Commun., <u>June</u> , <u>1936</u> , 96-102.

Ċ

ł

- 49. Menzel and Manry, Z. anorg. allgom. Chem. 210, 257-63 (1933).
- 50. Mickels and Klurekoper, Physics. 6, 586-90 (1939).
- 51. Midgley, Ind. Eng. Chcm. 22, 542-5 (1930).

- 52. Moissan and Dewar, Compt. Rend., 136, 641-3 (1903).
- 53. Morgan and Lowry, J. Phys. Chem., 34, 2385-2432 (1930).
- 54. Navy Report, A General Survey of the Use of Methyl Bromide as a Fire Extinguishing Agent.
- 55. Northdurft, Ann. Physik, 28, 137 (1937).
- 56. Nutting and Petrie, U.S., 1,961,622, (Jun. 5, 1934)
- 57. Olszewshi, Trens., Roy. Soc. (London) A186, 253-7 (1895).
- 58. Onnes, Proc. Roy. Acad. of Sciences of Amsterdam, 168, 678 (1912).
- 59. Pickering, Bureau of Standards, Scientific Papers. No. 511 (1926).
- 60. Plank, Z. Jes. Kalt. Ind., 49, 77-9 (1942).
- 61. Podulnick, Analytical Determination and Testing, Chap. IV, Butane-Propane Handbook (1942).
- 62. Predvoditelev, Z. Physik, <u>36</u>, 557-62 (1926).
- 63. Ramsay, Proc. of Roy. Soc. (London), <u>A86</u>, 100 (1912).
- 64. Ramsay and Travers, Trans. Roy. Soc. (London), A197, 47-89 (1901).
- 55. Reyrolle and Co. Limited, British Patent 525, 244, (Fob. 20, 1940.)
- 66. Riedel, Chem. Zt. <u>65</u>, 287 (1941).
- 67. Riedel, Z. Ces. Kulte Ind. <u>48</u>, 89-92 (1941) Chem. Zentr. <u>I. 33</u>.
- 68. Ruff, Ber. <u>69B</u>, 279-308 (1936).
- 69. Satterly, Rev. Modern Phys. <u>8</u>, 347-57 (1936).
- 70. Seger, Dic Chemie 55, 58-59 (1942).
- 71. Simons, and Block, J. Am. Chem. Soc. <u>61</u>, 2962-66 (1939).
- 72. Soroos and Hinhamp, J. Am. Chem. Soc., <u>67</u>, 1642, (1945).
- 73. Smcle, Ann. Physik, 60, 625 (1897).
- 74. Stevenson and Beach, J. Chem. Phys. 6, 25 (1938).

332.

. A

- 75. Uhlig, Kirkwood and Kuyes, J. Chem. Phys., I, 155-9 (1933).
- 76. Van Itterbeck and Spaepen, Physica II, 43-8.
- 77. Veziri, Z. Gos. Kalte-Ind. 50, 17, 20 (1947).
- Wagmun, Kilpatrick, Taylor, et al., J. Res. Nat'l. Bur Stand. <u>34</u>, 143-61 (1945).
- 79. Washburn, ed., " International Critical Tables" New York, McGraw-Hill Book Co., Inc., 5 80 (1926).
- 80. Watson, Rao., and Ramaswamy, Proc. Roy. Soc. (London), <u>A132</u>, 569-85 (1931)
- 81. Witt, and Kemp., J. Am. Chem. Soc. 59, 273-6 (1937).
- 82. Woolsey, J. Am. Chem. Soc. 59, 1577-8 (1938).

353.

٩