INFLAMMABILITY OF TRICHLOROETHYLENE–OXYGEN–NITROGEN MIXTURES *

G. W. JONES † AND G. S. SCOTT ‡

Explosives Division, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

INTRODUCTION

Trichloroethylene ($CHClCCl_2$) is an important solvent for fats, resins, bitumens, rubber, sulfur, and phosphorus. It is used extensively in dry-cleaning because of its low order of combustibility and has recently been proposed as an inhalation anaesthetic (1). Its physical properties have been described by Carlisle and Levine (2). It is usually considered a noninflammable material; however, substances that are noninflammable when mixed with air are not necessarily noninflammable when mixed with oxygen. Thus, Hewer's statement (1) that "Trichloroethylene . . . is not inflammable under any circumstances, nor will its vapor explode when mixed in any proportion with air, oxygen, or nitrous oxide," requires qualification, especially in anesthesia, where pure oxygen may at times be substituted for air.

This report gives the results of tests made to determine the inflammability of trichloroethylene in various mixtures of oxygen and nitrogen.

The trichloroethylene used was Eastman's No. 1300. The boiling point was given as 86° to 87° C. The specific gravity and refractive index of the sample measured in this laboratory were, respectively, 1.45 and 1.4759 at 25° C.

EXPERIMENTAL

The apparatus and test procedure used by the authors to determine the limits of inflammability have been described in a previous publication (3). In the present tests, oxygen and nitrogen mixtures of known composition were passed from a gas holder through the test liquid.

The vapor pressures used in the calculations of volumetric percentages were taken from a report by Killeffer (4).

RESULTS OF TESTS

The results of tests to determine the lower and upper limits of inflammability in various mixtures of oxygen and nitrogen are given in tables 1 and 2.

The results given in tables 1 and 2 are presented graphically in figure 1. The percentages of oxygen in the mixtures are shown on the vertical axis and the percentages of trichloroethylene on the horizontal axis, while the nitrogen present equals the sum of the oxygen plus trichloroethylene subtracted from 100. The area of inflammability of all possible mixtures of trichloroethylene, oxygen, and nitrogen is defined by the boundary of curve ABCA, all mixtures falling within the area being inflammable.

The limits of inflammability of trichloroethylene-oxygen mixtures are given by the points A and C on line DE. The lower limit of trichloroethylene in pure oxygen is 10.3 per cent by volume, and the upper limit of inflammability is 64.5 per cent, all mixtures between these limits being inflammable.

As nitrogen is added to the oxygen, the limits of inflammability are narrowed, as shown by the graph. When the oxygen content in the final mixtures is reduced below 24.3 per cent all mixtures became noninflammable. Thus, it is seen that trichloroethylene is not inflammable in any mixtures of its vapor with air, since air contains only 20.9 per cent oxygen. However, if ordinary air is enriched with pure oxygen so that the final mixtures contain 24.3 per cent or more of oxygen, inflammable mixtures are produced. The limits of inflammability of trichloroethylene vapor and air enriched with oxygen may be obtained directly from the graph (fig. 1), it being necessary only to determine the percentages of trichloroethylene, oxygen, and nitrogen in the mixtures and then to plot the point on the graph and observe whether the plotted point comes within or outside the inflammable area.

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† Senior chemist.

‡ Associate chemist.

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TABLE 1

DATA FOR LOWER LIMITS OF INFLAMMABILITY OF TRICHLOROETHYLENE-OXYGEN-NITROGEN MIXTURES

Composition of O_2-N_2 mixtures, per cent		Temperature of liquid at lower limit, ° C.	Vapor pressure at lower limit, mm. Hg	Barometric pressure, mm. Hg	$CHClCCl_2$ vapor in final mixture, per cent	O_2 in final mixture, per cent
O_2	N_2					
100.0	0.0	25½	76	739	10.3	89.7
48.7	51.3	27¼	81	737	11.0	43.4
40.4	59.6	30	92	746	12.3	35.4
36.0	64.0	30	92	735	12.5	31.5
33.0	67.0	32	100	750	13.3	28.6
31.0	69.0	[1]	[1]			
30.2	69.8	[1]	[1]			
20.9	79.1	[1]	[1]			

[1] Noninflammable.

TABLE 2

DATA FOR UPPER LIMITS OF INFLAMMABILITY OF TRICHLOROETHYLENE-OXYGEN-NITROGEN MIXTURES

Composition of O_2-N_2 mixtures, per cent		Temperature of liquid at upper limit, ° C.	Vapor pressure at upper limit, mm. Hg	Barometric pressure, mm. Hg	$CHClCCl_2$ vapor in final mixture, per cent	O_2 in final mixture, per cent
O_2	N_2					
100.0	0.0	72	470	728	64.5	35.5
48.7	51.3	58	295	737	40.0	29.2
40.4	59.6	55½	260	746	34.8	26.3
36.5	63.5	52	230	750	30.7	26.3
33.0	67.0	48½	195	744	26.2	24.3
31.0	69.0	[1]	[1]			
30.2	69.8	[1]	[1]			
20.9	79.1	[1]	[1]			

[1] Noninflammable.

The graph shows that trichloroethylene does not have sufficient vapor pressure to give inflammable mixtures with oxygen-nitrogen mixtures at temperatures below 25.5° C. In other words, the dangers of explosions are absent, provided the temperature is kept below 25.5° C. at normal pressures of 740 to 760 mm. Hg.

The graph gives the ranges of inflammability of trichloroethylene vapor in contact with its liquid at various elevated temperatures. It will be observed that over the temperature range of 25.5° to 30° C. the mixtures are only moderately inflammable and then only in the presence of rather high concentrations of oxygen. From 30° C. upward, the maximum range of inflammability is obtained, and, as shown, at a temperature of 45° C., the trichloroethylene has sufficient vapor pressure to give concentrations of the vapor requiring the minimum amount of oxygen. The inflammable mixture requiring a minimum concentration of oxygen contains approximately 25.0 per cent trichloroethylene, 24.3 per cent oxygen, and 50.7 per cent nitrogen.

IGNITION TEMPERATURES OF TRICHLOROETHYLENE

The method used to determine the ignition temperatures of trichloroethylene in air and pure oxygen was essentially the same as that recommended by the Ameri-

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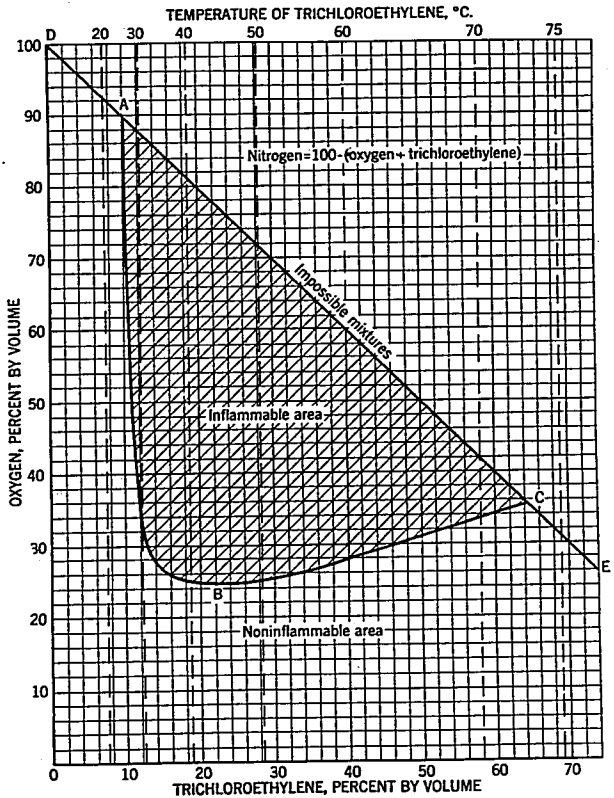

FIG. 1. Inflammability of trichloroethylene-oxygen-nitrogen mixtures.

can Society for Testing Materials (5). Measured volumes of the liquid trichloroethylene were introduced into a 125-cc., flat-bottomed, Pyrex Erlenmeyer flask submerged in a liquid bath maintained at constant elevated temperatures. The bath and flask were heated initially above the predicted ignition temperature, and air or oxygen, as the case might be, was passed through the flask before the trichloroethylene was tested for ignitibility. The temperature of the bath was obtained by a chromel-alumel thermocouple employing the usual potentiometric principles.

The time elapsed, or "lag," from the time the trichloroethylene was introduced until it burst into flame was measured by stop watch. If the trichloroethylene ignited, the bath temperature was lowered slightly and the test was repeated. Thus,

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by trial and error a narrow range of temperature that would just cause ignition was established. The limiting tests made to establish the ignition temperatures of trichloroethylene in air and oxygen are given in table 3.

The ignition-temperature determinations given in table 3 show that trichloroethylene is inflammable in air at high temperatures. It has a minimum ignition temperature of 463° C. in air and 419° C. in oxygen.

TABLE 3

IGNITION TEMPERATURES OF TRICHLOROETHYLENE IN AIR AND OXYGEN

Temperature, ° C.	Trichloroethylene added, cc.	Lag on ignition	Atmosphere	Propagation	Minimum ignition temperature, ° C.
463.0	0.03	4.2	Air	Yes	
463.0	.02	3.8	Air	Yes	
463.0	.04	6.2	Air	Yes	
462.8	.03	5.0	Air	Yes	
462.8	.04	5.0	Air	Yes	
462.8	.03	—	Air	No	463
462.0	.03	—	Air	No	
460.0	.03	—	Air	No	
424.8	.03	4.4	Oxygen	Yes	
419.2	.04	5.6	Oxygen	Yes	
419.0	.04	4.0	Oxygen	Yes	
418.0	.04	—	Oxygen	No	419
417.8	.03	—	Oxygen	No	

CONCLUSIONS

The limits of inflammability of trichloroethylene in pure oxygen are 10.3 per cent for the lower and 64.5 per cent for the upper limit. All mixtures falling within these limits are inflammable.

Trichloroethylene vapor does not form inflammable mixtures with air at ordinary temperatures and pressures.

If air is enriched with oxygen, so that the final mixture contains 24.3 per cent or more oxygen, inflammable mixtures are produced when the amount of trichloroethylene vapor present comes within certain limiting concentrations.

Trichloroethylene below a temperature of 25.5° C. does not have sufficient vapor pressure to produce inflammable mixtures at total pressures of 1 atmosphere or more, even in mixtures containing high concentrations of oxygen.

At high temperatures, trichloroethylene vapor becomes inflammable in air and ignites at 463° C. It ignites in oxygen at 419° C.

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