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# Flammability limits of refrigerant mixtures with 1,1,2,2-tetrafluoroethane

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ABSTRACT

Extensive measurements have been made on the flammability limits of two binary mixtures of propane/1,1,2,2-tetrafluoroethane and 1,1-difluoroethane/1,1,2,2-tetrafluoroethane as per the Chinese National Standard GB/T 12474-90. Experimental data for the 1,1,2,2-tetrafluoroethane mixtures were obtained with estimated uncertainties of 0.09 mol% for lower flammability limits and 0.14 mol% for upper flammability limits. All measurements were carried out at atmospheric pressure and room temperatures around 20 °C. It has been found that molar fractions of propane and 1,1-difluoroethane in lower limit mixture decrease when 1,1,2,2-tetrafluoroethane, being itself nonflammable, is added to the mixture. Modification was made to the extended Le Chatelier's formula for interpreting the dilution effect of 1,1,2,2-tetrafluoroethane. It has been found that the extended Le Chatelier's formula using an individual set of parameters can fit the experimental results for flammability limits of propane and 1,1-difluoroethane diluted with 1,1,2,2-tetrafluoroethane well.



## 1. Introduction

The global environmental problem makes it urgent to search for new environmentally friendly refrigerant alternatives in the field of refrigeration and air-conditioning industry. However, it is very hard to find pure substance candidates with appropriate thermophysical performance. Mixed-refrigerants containing hydrofluorocarbons (HFCs) and hydrocarbons (HCs) are currently chosen as the refrigerant substitutes for the traditional chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants. Unfortunately, all the hydrocarbons and some hydrofluorocarbons are flammable. Hence, it is crucial to know the flammability limits of the new substitutable refrigerants from a safety point of view. In fact, the flammability limit is one of the most important indices to evaluate the explosion hazards of flammable gases and vapors.

Experimental study on flammability limit of refrigerant mixture with 1,1,1,2-tetrafluoroethane (R134a), 1,1,1,2,3,3,3-heptafluoropropane (R227ea), or pentafluoroethane (R125) has been reported [1,2]. The critical flammability ratios (CFR) of these mixtures have been determined; the dilution effects of R134a, R227ea, or R125 on the flammability limits of some flammable compounds have been measured. Where, the CFR denotes the minimum molar ratio of diluent to fuel in the mixture which can never be flammable whatever the air concentration is. Recently, it has been found that mixture comprising propane (R290), 1,1-difluoroethane (R152a) and 1,1,2,2-tetrafluoroethane (R134) has good thermophysical characteristics and shows good potential as the new substitutable refrigerant [3]. However, flammability limit data of above refrigerant blend are hardly found in open published literature.

In the present study, an experimental apparatus has been designed and assembled to measure flammability limits. Extensive measurements were carried out for two binary mixtures of R290/R134 and R152a/R134. Moreover, further numerical analysis was made to explain the dilution effect of R134 on the flammability limits of R290 and R152a on the basis of the experimental results. The main purpose of this work is to obtain the flammability limit data and to understand the dilution effect of R134.

## 2. Experimental design

As shown in Fig. 1, the experimental setup in the present study was established based on the Chinese National Standard GB/T 12474-90 [4]. The explosion vessel is a vertical cylindrical tube (1450 mm in length, 60 mm in diameter), which is made of glass so that the flame behavior could be observed visually. The whole explosion tube is placed in a large metal chamber with two glass windows for observation.

A pair of tungsten spark electrodes are positioned a height of 100 mm above the bottom of the tube, and the distance between the two electrodes is 5 mm. An electric spark is initiated by a high-voltage transformer (300 VA/10 kV), and the spark duration is 0.5 s. This induction spark between the couple electrodes is used as the ignition source. The provided energy is sufficient to overcome the minimum ignition threshold. It should be emphasized here that both top and bottom end of the cylindrical tube are

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