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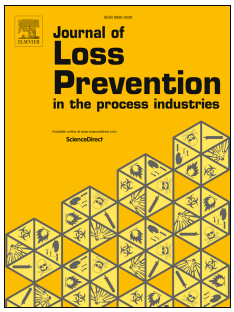

The flammable resistance method for mixture flammability

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The Flammable Resistance Method for Mixture Flammability

Abstract:

Le Chatelier's rule is known for its inability to treat the contribution of a diluent in a flammable mixture. This is not true if we treat the diluent as a flammable resistor with a fictitious lower flammable limit as its signature resistance. Thus the diluent in the mixture can be treated consistently along with other fuels like electrical resistors in parallel. Strictly derived from the thermal balance method, this flammable resistance method has the principle of energy conservation embedded with each energy term additive in the denominator. Like an electrical circuit, the mixture flammable limit serves as the total resistance of a parallel circuit, thereby sharing a simple form with Ohm's Law. This method completes Le Chatelier's rule in dealing with mixtures of multiple fuels and diluents.

Key words:

mixture flammability, thermal balance method, flammable resistance method

1. Background

Since its publication in 1891(Le Chatelier 1891), Le Chatelier's rule (LCR) has been widely used in the field of process safety. However, his version of the rule is "the mixture of limit mixtures is still a limit mixture", which was based on 3 data points (Mashuga and Crowl 2000) and difficult to apply. It was extended by Coward et al.(Coward, Williams et al. 1919)into its present form and protected the process safety industry for almost a century. This rule has an obvious flaw that it cannot deal with the diluent in a gas mixture(Coward and Jones 1952, Zabetakis 1965). If a flammable mixture has one or more diluents involved, a pseudo fuel has to be developed first by pairing fuel and diluent together. Then this rule can be applied to the mixture of pure fuels or pseudo-fuels (Haessler 1988, Crowl and Louvar 2001).

Many efforts were devoted to covering inert species into the estimation scheme. The simplest approach is to artificially impose that the inert gas has a lower flammable limit of infinity(Karim, Wierzba et al. 1985). The purpose in doing so is to have a zero contribution from the nitrogen in the denominator. However, an inert species other than nitrogen may have a non-zero contribution to the mixture. Molnarne et al. (Molnarne, Mizsey et al. 2005) proposed the concept of nitrogen-equivalency factor to generalize the contribution of a non-nitrogen diluent. Their method did extend the Le Chatelier's rule to cover inert species. However, without a fundamental theory in support, they had to resort experimental data for factor adjustment, which results a different factor for each combination of fuel and diluent. This database-dependency limit their method from being a generic rule.

When teaching the analogy between the thermal and the electrical resistance in the first chapter in Drysdale's famous book ((Drysdale 2011), page 40), the author noticed that the classical form of Le Chatelier's rule shares a similar format in both mathematical and physical meaning with Ohm's law. Since the fuel plays a duel role as a heat source and a heat sink, why the diluent cannot do the same thing with a zero contribution on heating? Under this reasoning, a comparable concept of flammable resistance is proposed, with a framework to treat fuel and diluent. Thus we can treat the fuel and the diluent in the mixture consistently. Fortunately, we have the Thermal Balance Method(Ma 2011) , which can be tailored to develop the flammable resistance. Like the