WHITE PAPER

ANSUL®

Inerting Concentration Study

Inergen®

INERGEN® Clean Agent Fire Suppression System

Conducted by Factory Mutual Research Corporation

tyco Fire Protection Products

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 Form No. F-9343-04

Introduction

In August of 1992, Ansul Fire Protection commissioned a series of tests through Factory Mutual Research Corporation (FMRC) to determine the inerting requirements for methane/air and propane/air mixtures by an ANSUL® inerting mixture of nitrogen, argon and carbon dioxide.

Purpose

Explosibility testing was performed to determine the inerting requirements of the supplied ANSUL mixture with both propane and methane in the FMRC 5.1-liter sphere. The inerting mixture was identified as INERGEN® agent containing 52% nitrogen, 40% argon, and 8% carbon dioxide.

Test Apparatus

The testing was carried out in the FMRC 5.1-liter explosion vessel which is shown in Figure 1. It consists of a spherical stainless steel shell built in two halves and joined at the equator by a clamping arrangement. The vessel is routinely used for explosion testing and can operate at pressures up to 600 psi (4136 kPa). Several penetrations are provided for instrumentation feed-throughs and to connect an ignition source to firing circuitry. In addition, an internal stirrer is available to ensure mixing of gaseous components introduced in the vessel. By use of an electrically powered mantle, the test apparatus can be heated to temperatures up to 752 °F (400 °C).

The explosion vessel is routinely used at FMRC for measuring the explosibility limits and the reactivity of gaseous mixtures. Bottled air is normally used as the oxidizer. In these experiments, the components are introduced in the vessel in sequence in amounts determined by the partial pressure method. They are allowed to mix and finally are ignited, typically by a 19-Joule spark. The time evolution of the pressure in the test vessel resulting from the explosion is monitored with a pressure transducer and recorded by a suitably fast data acquisition system.

Schematic – FMRC 5.1 Liter Explosion Vessel

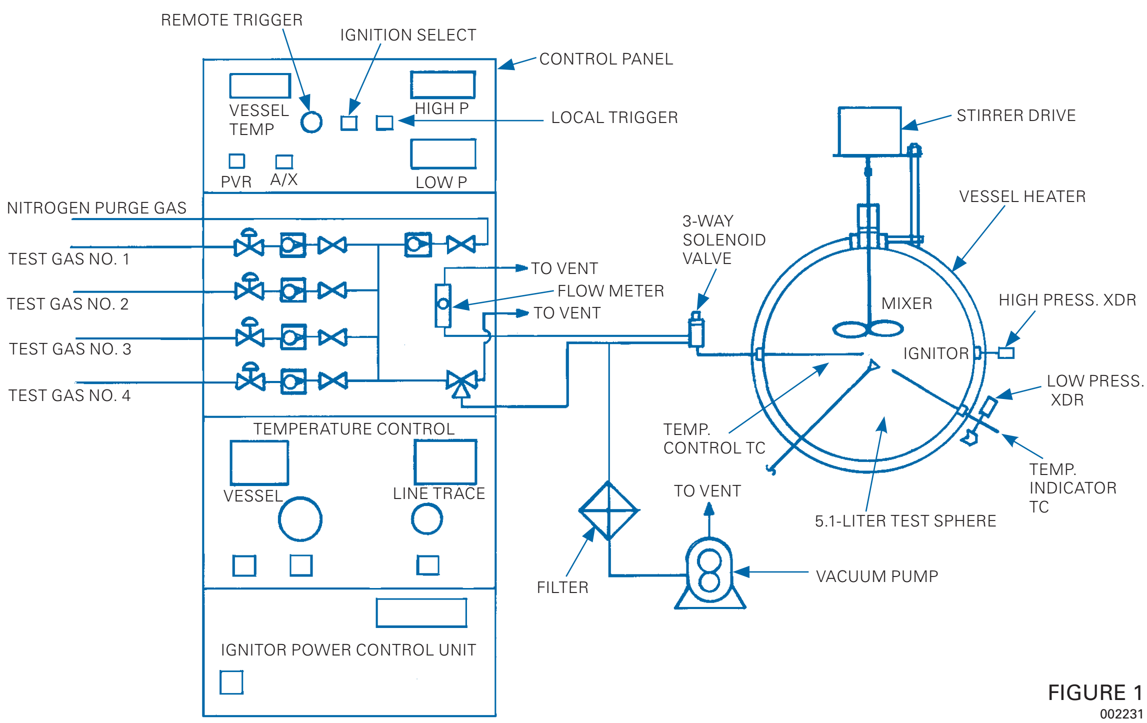

FIGURE 1
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For reactivity testing, the pressure traces from those tests where ignition of the mixture has been achieved are then analyzed to extract three parameters: 1) peak explosion pressure (p_{max}); 2) maximum normalized rate of pressure rise (K_G); and 3) burning velocity (u_{10}). The peak explosion pressure and the normalized rate of rise are calculated directly from the pressure trace as follows:

$$K_G\text{-}V^{1/3}\left(\frac{dp}{dt}\right)_{max}$$

(V is the volume of the test vessel and (dp/dt) max is the maximum rate of pressure rise achieved in the explosion.)

The burning velocity, u_{10}, is obtained from the initial portion of the pressure-time trace, using a procedure which involves applying a cubic fit to the pressure curve and then interpreting the fit with the help of a formula based on a simple flame propagation model.

For the determination of explosibility limits, tests are performed using procedures aimed at providing substantial compliance with the ASTM E-681 standard. The main differences between this standard and the FMRC test procedure are in the type of ignition source, and the criterion used to define explosibility. Tests carried out to determine the explosibility limits of mixtures of known behavior (methane, propane, ethylene, ammonia with air), have given results in good agreement with literature values. When disagreement is observed, it is generally found to be in a conservative direction, i.e., the FMRC procedure may yield slightly broader explosibility limits. This is probably due to the use of a relatively strong ignition source and, more importantly, to the adoption of restrictive criteria to identify the occurrence of flame propagation.

Test Procedure

The testing was performed using a 0-300 psia PSI Tronics pressure transducer to monitor pressure rise. A bare junction 1/16 inch diameter sheathed thermocouple was installed in the vessel with the junction located in the equatorial plane at 3/4 radius from the center of the vessel or 1 in. (25 mm) from the vessel wall. The outputs of the thermocouple and transducer were recorded on a strip chart recorder. Ignition was by a 19-Joule spark. The oxygen content of the combustion air was found to be 21.4% (by volume). Concentrations of mixtures of the inerting blend with air and fuel were chosen in the vicinity of estimates made for the inerting requirement of the blend with each fuel (propane and methane).

In the test procedure, a mixture is considered explosive if it produces a pressure rise of 0.3 psi or greater, and/or a measurable temperature rise. Pressure excursions of 0.2 psi and temperature rises of 2 °C can be reliably detected by the instrumentation. The approximate location of the boundary of the explosibility range is determined by plotting the explosion pressure from tests that have displayed a weak reaction. Data used for this determination are taken from sets where either the concentration of one component or a ratio of two components is held constant. The separation between reactive and non-reactive mixtures is determined at the point where the pressure curve starts to rise rapidly from near-zero (<0.3 psi) values. Based on this procedure, the lower and upper explosive limits (LEL and UEL) of methane in air have been determined to be 4.95 and 16.05% as compared to the published values[1] of 5.0 and 15.0%. Similarly, in the case of propane, measured values for LEL and UEL of 2.07% and 10.5% compare with published values of 2.1% and 9.5%.

Results

The data obtained from the tests are shown in Figures 2 and 3 for the methane/air and the propane/air cases respectively. As can be seen from the figures, most of the data points were obtained near the nose of the explosibility envelope, given the fact that the objective of the testing was to determine the inerting requirements of mixtures of the two fuels in air by the ANSUL mixture. In the case of methane, additional points were taken along the lower boundary of the explosive region to further verify proper operation of the instrumentation and test procedures.

The minimum inerting requirement for the tested mixtures was found to be 44% (by volume) for the methane/air system, and 50% for the propane/air system.

Summary

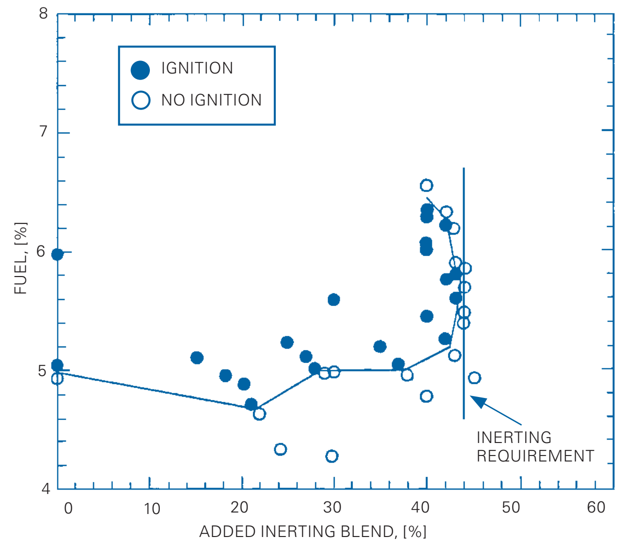
The measured inerting requirements by the ANSUL blend for the two mixtures tested can be compared with calculated values, based on published data[1] for the inerting characteristics of nitrogen, argon and carbon dioxide. In the case of the methane/air system, application of Le Chatelier's law yields a calculated value of minimum concentration for inerting of 40.4%, as opposed to 44% obtained in the measurements. For the case of propane, the calculation yields 44.8%, as compared to an experimental value of 50%. These results are in reasonable agreement and tend to confirm the already mentioned conservatism of the criterion used in the FMRC procedure to determine achievement of ignition.

Another factor that can explain part of the discrepancy between the experiment and the calculated inerting requirement is the fact that the bottled air used in the tests contained 21.4% oxygen. The correction to be applied to the data to convert the results to the case of air with 20.95% oxygen can be found by assuming that the marginal condition for ignition corresponds to a constant oxygen concentration. **On this basis, the measured inerting requirements of 44 and 50% for methane and propane in air with 21.4% O_2, would become 42.8% (43.0%) and 48.9% (49.0%) in standard air with 20.95% O_2.**

Note: Testing conducted by Factory Mutual Research Corp. (FMRC) does not, in any way, indicate their endorsement of the product.

[1] Zabetakis, M. G., "Flammability Characteristics of Combustible Gases and Vapors," Bulletin 627, U.S. Bureau of Mines (1965)

Explosibility Curve For Methane – Air – INERGEN Agent (% Air = 100% – % CH4 – % INERGEN)



EXPLOSIBILITY DATA FOR MIXTURES OF METHANE, AIR AND ANSUL INERTING BLEND (INERGEN).

FIGURE 2
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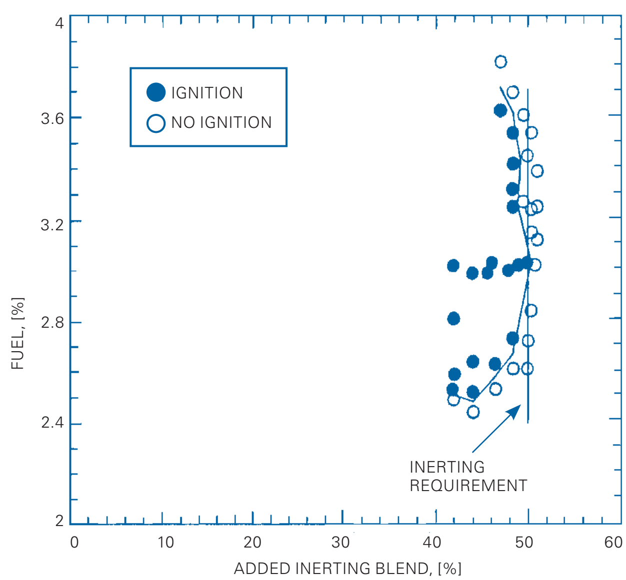
Explosibility Curve For Propane – Air – INERGEN Agent (% Air = 100% – % C3H8 – INERGEN)



EXPLOSIBILITY DATA FOR MIXTURES OF PROPANE, AIR AND ANSUL INERTING BLEND (INERGEN).

FIGURE 3
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