Codes and Standards Analysis

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Objectives

- Quantify ignitability of hydrogen-air mixtures in motion.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

Hydrogen Safety

- C. Validation of Historical Data

Hydrogen Codes and Standards

- B. Competition between ICC and NFPA

Approach

- Design: generate apparatus to produce repeatable hydrogen leaks into the interior of a 5000 square-foot warehouse. Produce experimentally verified computer model of hydrogen cloud formed by leak apparatus.
- Test: locate the boundaries of ignitable cloud formed by hydrogen leak with electrical spark.
- Analyze: compare boundaries of experimentally determined combustible cloud to boundaries of clouds defined by upper propagating lean limit of combustion (4.0% concentration hydrogen) and downward propagating lean limit of combustion (10.0% concentration hydrogen). Determine explanation for observed behavior.
- Design: generate apparatus to produce homogeneous hydrogen-air mixture flows in exhaust ducts.
- Test: test the ignitability of lean homogeneous hydrogen-air mixtures in exhaust ducts.
- Analyze: determine the ignitability of homogeneous hydrogen-air mixtures in exhaust ducts as a function of Reynolds number.

Accomplishments

- Modeling: completed experimentally verified computer model of 20 SCFM hydrogen leak. Leak was directed horizontally and 4 feet above the floor (see Figure 1).
- Design: completed design of sonic throttle experimental apparatus to accurately leak 20 SCFM hydrogen through 0.372 inch diameter orifice in center of 8 foot by 8 foot wall (Figures 2 and 3).
- Examination: examined ignition characteristics of hydrogen cloud formed by 20 SCFM leak (Figure 4).

Future Directions

- Evaluate data taken to date and compare with published data.
- Analyze published data to determine applicability to this research effort.
- Conduct more ignitability tests with hydrogen leaks and flows of hydrogen-air mixtures in ducts.

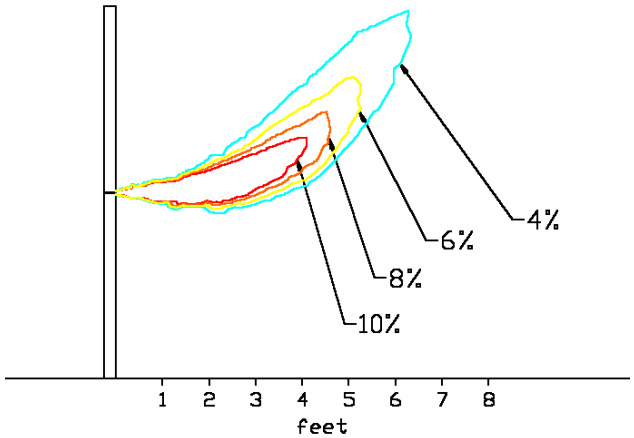

Figure 1. Model Results for 20 SCFM Hydrogen Leak

Figure 3. Leak Test Apparatus

Figure 2. Test Wall for Leaks

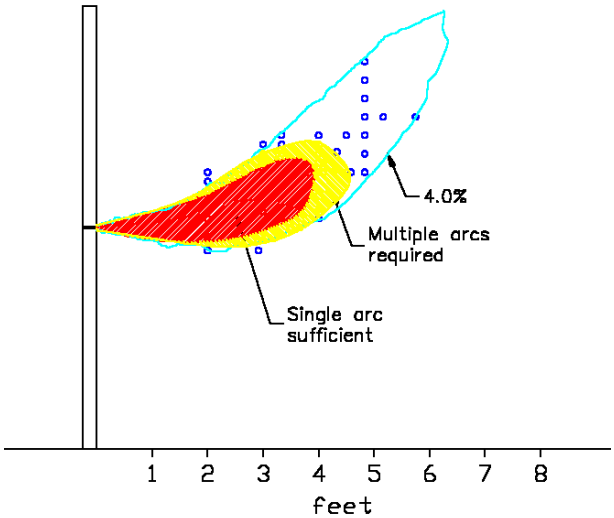

Figure 4. Ignitability of 20 SCFM Hydrogen Cloud

Introduction

Four percent (4.0%) is a commonly quoted value for the lean limit of combustion (references 1-3). This value is then used as an indicator of ignitability in the determination of separation distances and electrical environment classification. Four percent concentration represents the upward propagating lean limit of hydrogen in a quiescent environment. Ten percent concentration represents the downward propagating lean limit of hydrogen in a quiescent environment. The values of lean limit that apply for a moving gas mixture (hydrogen leaks, flow in exhaust ducts) is somewhere between 4.0% and 10%. This work intends to determine what concentrations of hydrogen in air are ignitable under these conditions.

Approach

The approach is to produce a variety of hydrogen leaks and flows of hydrogen-air mixtures in ducts and test their ignitability. Parameters can then be developed to determine how close an ignition source can be to a hydrogen leak and what concentration of hydrogen is ignitable in an exhaust duct.

Results

The first set of test results are depicted in Figure 4. The experimentally verified computer model of a 20 SCFM hydrogen leak shows 4.0% concentration at a distance of 76 inches horizontally from the leak source in the wall. Using the commonly quoted value for the lean limit of combustion, this location should be ignitable. In actuality, the cloud could not be ignited unless the ignition source was 55 inches from the wall. This was true even though the ignition source was 110 millijoules (minimum ignition energy is three millijoules). The ignition source was required to be 47 inches from the wall to ignite the cloud with a single arc. At 55 inches, hundreds of arcs were required to produce ignition.

Conclusions

The separation distance defined by 4.0% hydrogen concentration is 38% greater than the separation distance defined by the actual ignitability of a 20 SCFM hydrogen leak.

References

1. Strehlow, R.A., 1968, Fundamentals of Combustion, International Textbook Company, Scranton, Pennsylvania

2. Lewis, B., and von Elbe, G., 1987, Combustion, Flames and Explosions of Gases, Academic Press Inc., Orlando, Florida

3. Glassman, I., 1987, Combustion, Academic Press Inc., Orlando, Florida