THE APPLICATION OF A HYDROGEN RISK ASSESSMENT METHOD

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ABSTRACT

A comparison of the predicted results from a calibrated CFD model with experimentally measured hydrogen data was made to verify the calibrated CFD model. The experimental data showed the method predicted the spatial and temporal hydrogen distribution in the garage very well. A comparison is then made of the risks incurred from a leaking hydrogen-fueled vehicle and a leaking LPG-fueled vehicle.

INTRODUCTION

The following is brief description of using a Hydrogen Risk Assessment Method (HRAM) to analyze the risk associated with hydrogen leakage in a residential garage. The four-step method is as follows:

1. Simulation of an accident scenario with leaking helium.
2. Calibration of a CFD model, of the accident scenario, using helium data.
3. Prediction of the spatial and temporal distribution of leaking hydrogen using the calibrated CFD model.
4. Determination of the risk incurred by hydrogen compared to a currently used fuel.

EXPERIMENTAL

Steps 1 and 2 were performed for a home refueling station, installed in a residential garage, to test the ability of the CFD model to predict hydrogen concentrations in a single car residential garage. The work was conducted utilizing a half scale model of the garage. The garage employed a vented garage door. The door was designed to provide adequate ventilation for a vehicle parked in the garage leaking hydrogen at a rate of 7200 liters/hr (at full scale). The garage geometry is depicted in Figure 1.

Figure 2 shows the general flow pattern created by the leaking low density gas (either helium or hydrogen). The gases rise over the leak, travel diagonally across the ceiling toward the garage door, exiting through the upper garage door vent. The loss of gases out of the upper vent draws fresh air into the lower vent. These gases flow across the floor toward the rear of the garage.

Experiments were conducted at three gas leakage rates; 900 l/hr, 1800 l/hr, and 2700 l/hr, using both helium and hydrogen. The predictions of the model and the experimental data were in good agreement. Figure 3 shows an example of the comparison of experimental data and computer model results. The data shown is for a hydrogen leakage rate of 2700 l/hr. Sensor location 7 was chosen because that location recorded the highest concentration of hydrogen during the test. The other sensor locations showed similar correlation between experimental and calculated data.

RESULTS

The model was used to compare gas leakage from vehicles stored in residential garages. Leakage from a LPG fueled vehicle was compared to leakage from a hydrogen-fueled vehicle. The comparison was based on a Ford Taurus sized vehicle stored in a single car garage of slightly different dimension, than the home refueling station test, but with the same vented garage door.

The computer model representation of the ventilated garage was run to predict the behavior of a LPG fueled vehicle. The leakage rates chosen for the LPG fueled vehicle were 848.2 liters/hr and 4334 liters/hr. These represent upper and lower bounds on the leakage rate of propane from a fuel line fracture that produced a 7200 liter/hr hydrogen leakage rate. The 848.2 liter/hr flow rate would occur if laminar flow was assumed in the hydrogen and propane leaks being compared. The 4334 liter/hr flow rate would occur if turbulent flow was assumed in the hydrogen and propane leaks being compared. Due to differences in density and viscosity the volumetric leakage rate of propane was lower than that of hydrogen which was 7200 l/hr.

Figures 4-6 show the results after 2 hours of leakage. The figures show surfaces of constant gas concentration that represents the lean limit of combustion. Figure 4 is a plot of the surface of constant 4.1% hydrogen concentration at by volume. 4.1% hydrogen in air is the upward propagating lean limit of combustion for hydrogen-air mixtures (Coward 1961, Hansel 1993, Lewis 1961, and Ordin 1997). This is the lowest concentration of hydrogen considered combustible. The cloud under the front of the vehicle in Figure 4 represents the volume of burnable gas after 2 hours of leakage at 7200 liters/hr. Figure 5 is a plot of the surface of constant 2.1% propane concentration at by volume. 2.1% propane in air is the upward propagating lean limit of combustion for propane-air mixtures (Coward 1961, Hansel 1993, Lewis 1961, and Ordin 1997). This is the lowest concentration of propane considered combustible. The cloud covering almost the entire floor of the garage represents the volume of burnable gas after 30 minutes of leakage at 848 liters/hr. Figure 6 is a plot of the surface of constant 2.1% propane concentration at by volume. The cloud covering the entire floor of the garage represents the volume of burnable gas after 30 minutes of leakage at 4334 liters/hr.

CONCLUSIONS

It can be seen that the volume of combustible gas created by the hydrogen-fueled vehicle is much smaller than the volume created by the LPG fueled vehicle. This was true regardless of which of the two propane flow rates was assumed. It should be noted that the combustible cloud produced by the LPG fueled vehicle was continuing to grow. The volume of combustible gases produced by the hydrogen fueled vehicle had reached steady state after 1 hour as seen in Figure 7. Figure 7 shows the surface of constant 4.1% hydrogen concentration, which is the lean limit of combustion for hydrogen.

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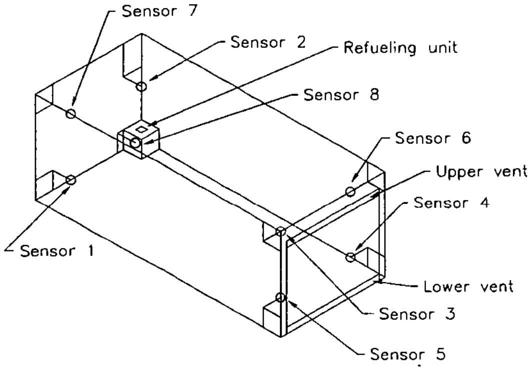

Figure 1 - Half-scale garage geometry

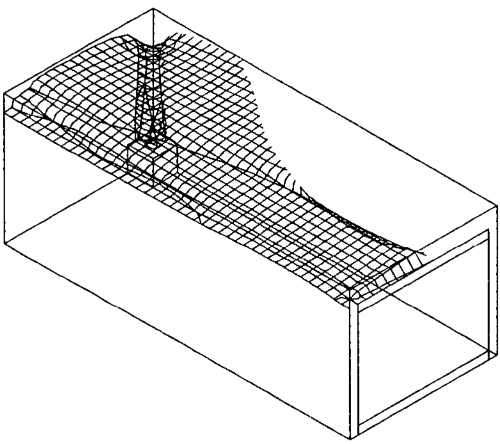

Figure 2 - General flow pattern

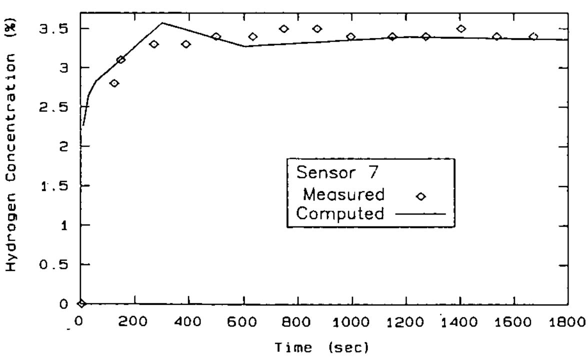

Figure 3 - Hydrogen results comparison (Sensor 7)

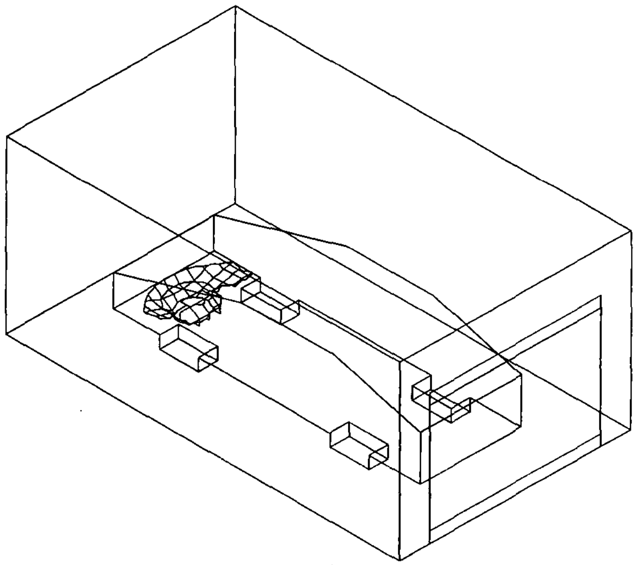

Figure 4 - Surface of constant 4.1% hydrogen concentration after 2 hours of leakage at 7200 liters/hr

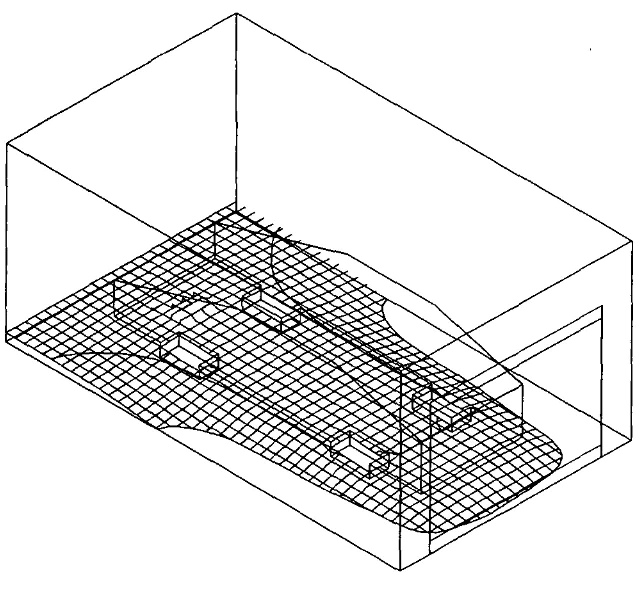

Figure 5 - Surface of constant 2.1% propane concentration after 2 hours of leakage at 848.2 liters/hr

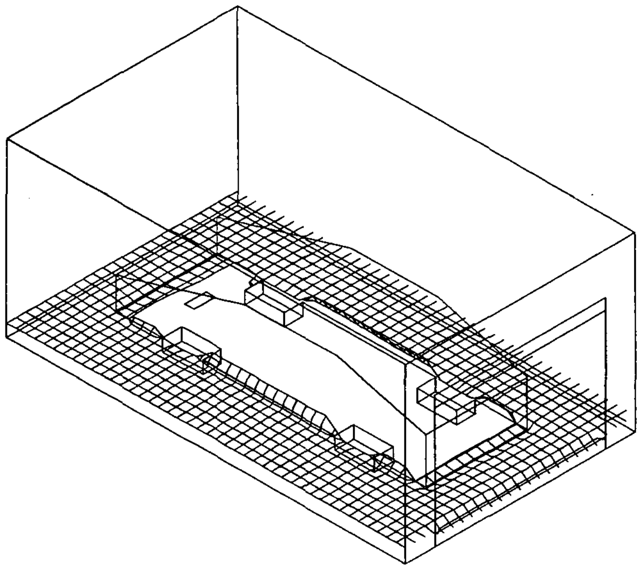

Figure 6 - Surface of constant 2.1% propane concentration after 2 hours of leakage at 4334 liters/hr

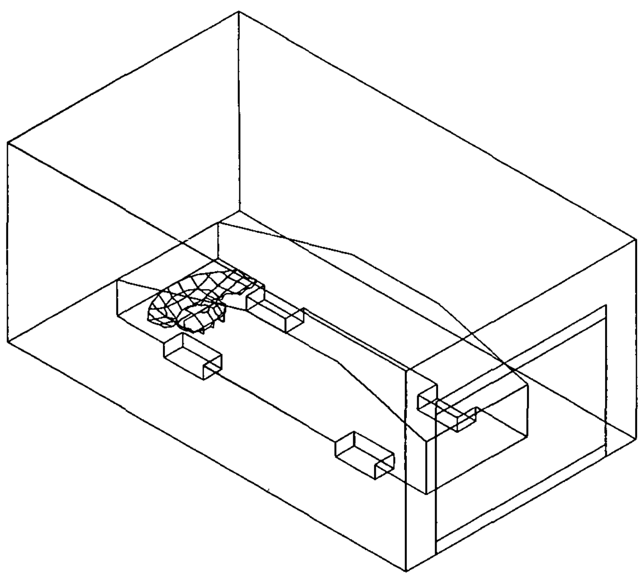

Figure 7 - Surface of constant 4.1% hydrogen concentration at 1 hour