Gas Mixing Experiments in a Large Enclosure

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ABSTRACT

During some postulated loss of coolant accidents, hydrogen may be produced due to metal-steam reactions and subsequently released through a break in the primary heat transport system into the containment atmosphere. This may lead to the formation of a flammable hydrogen/air/steam mixture. The central issue on post-accident hydrogen management is the predictability of hydrogen distribution under various accident scenarios, whether to support assessments of hydrogen source dilution or the numbers and placement of igniters [1]. Thus far, hydrogen distribution has been predominantly analyzed using "lumped parameter" codes [2]. Due to the assumptions adopted in the lumped parameter approach, there are some limitations to simulate mixing phenomena. The latest version of GOTHIC has incorporated a distributed parameter algorithm to improve its capability. Recently, a k-ε turbulent model and a condensation model were also added to the code. These new features need to be validated using experimental results of relevant scale. Most available data are from experiments designed for validating lumped parameter codes and often do not provide details on the local flow pattern and gas distribution within each compartment. Validation of these state-of-the-art codes requires data from both integrated and separated effects experiments with fine spatial resolution. The goal of this program is to generate gas mixing data which are suitable for validating the new version of GOTHIC.

The facility for this experimental program is the "C Bubble", the former Shielded Loop Room in WR-1 Reactor Facility at Whiteshell Laboratories. It is a 10.3 m by 10.95 m by 8.2 m concrete enclosure with an internal volume of approximately 1000 m^3 and with a wall thickness of 0.45 m. Two different views of the facility are shown in Figures 1 and 2. The size and the wall properties of this facility make it most suitable for the present study. Due to safety reasons, helium instead of hydrogen was used in these experiments. Since the thermal conductivity and the molecular weight for these two gases are very similar, it is expected that helium-air mixing experiments are capable of revealing the key features of hydrogen-air mixing phenomena. It should be noted that the properties of helium and deuterium are almost identical. In the present series of experiments, helium was injected at a constant rate into the facility from a pipe of two different diameters (0.051 m or 0.305 m in diameter) at the bottom (BT), lower-side (LS), or upper-side (US) of the facility (see Figure 1) to simulate a break in the primary cooling system inside a reactor containment building. The facility was maintained at atmospheric pressure during the test by venting through exhaust #6. Since the exhaust is located about 1 m from the floor, only air is expected to be vented out. The objective of this series of experiments was to examine various aspects that can affect the distribution of the injected gas (e.g. effects of obstruction, effects of jet velocity, and effects of the evaluation of the injection point).

Figure 3 shows the helium concentration at five elevations above the injection point (BT). For this experiment, the jet diameter was 0.051 m and the jet velocity was 14.3 m/s. The probe closest to the injection point (P1) measured 55% of helium for almost the whole duration of the experiment. However, the next probe (P2) measured only about 5%. The rest of the probes measured less than 2%. These results show that due to the entrainment of air into the core of the jet, the mixing of helium with the surrounding air is very rapid. Rapid dilution of the injected helium prevents any strong stratification of helium inside the facility. Over the duration of the experiment (10 min.), the helium concentration at the top of the facility never exceeded 2%. Measurements by a second set of probes located 2 m from the first set also show a similar result. Figure 4 shows the measurements by the second set of probes. Within the upper 5 m of the facility, the concentration variation was less than 1%. Capabilities of the facility are further illustrated with results from experiments with other initial and boundary conditions (e.g. injection velocities, injection locations, injection elevations, and presence of obstruction in front of the jet).

References:

1. Koroll G.W., A.P. Muzumdar, M.A. Cormier, and N.G. Hunt, "Hydrogen Management in CANDU Reactors", OECD/CSNI Specialist Meeting on Selected Containment Severe Accident Strategies, Stockholm, Sweden, June 13-15, 1994.
2. Krause M., and P.M. Mathew, "Passive Heat Transport in Advanced CANDU Containment," Proc. Third International Conference on Containment Design and Operation, Toronto, Canada, Vol. 2, Oct. 19-21, 1994.

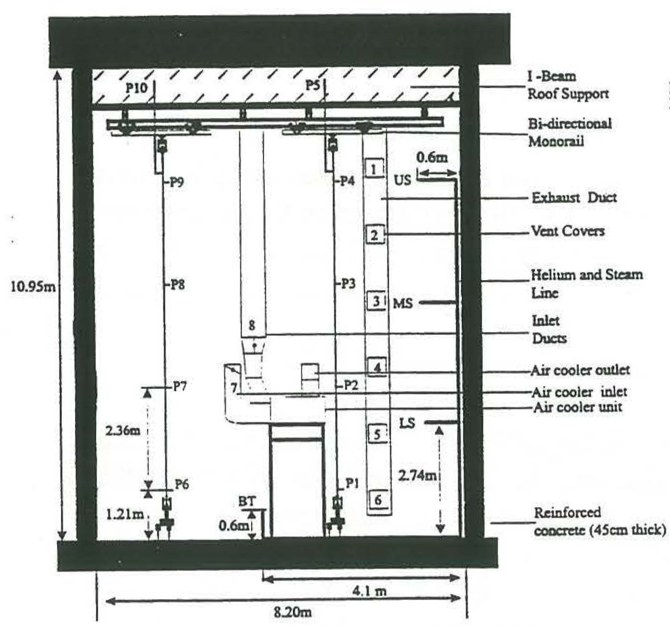


Figure 1: A schematic of the facility (a view of the east wall, from the west wall).

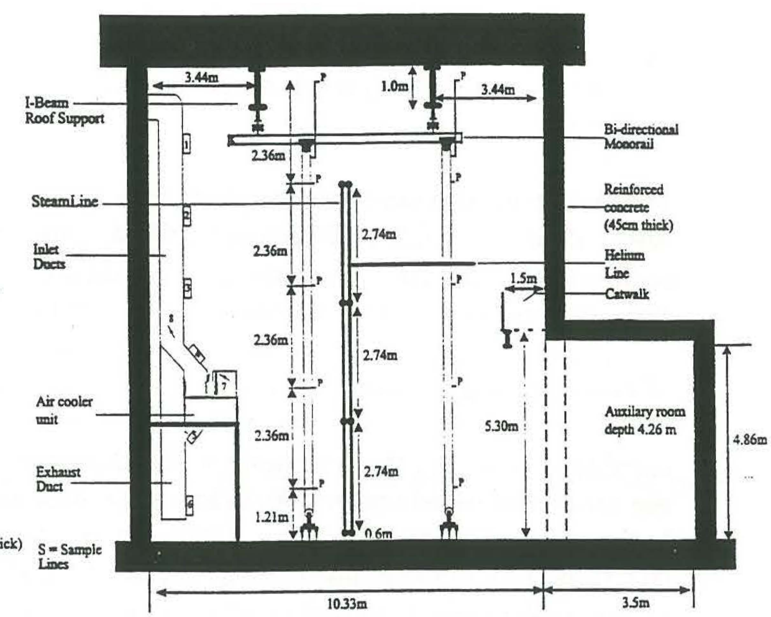
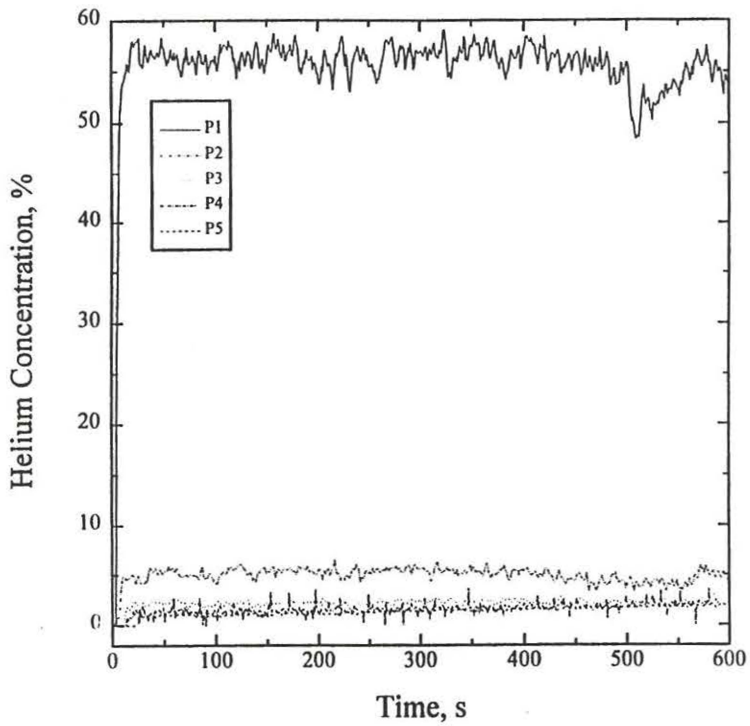
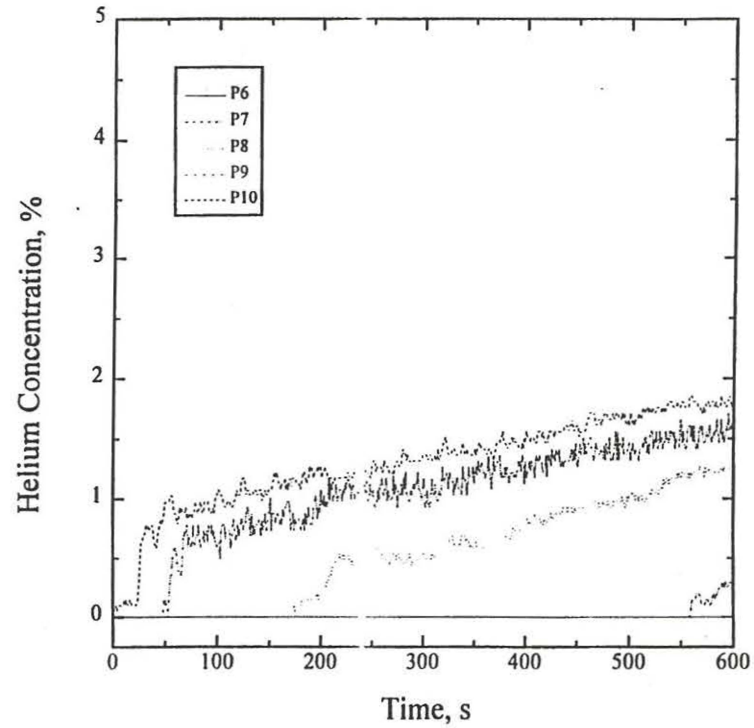


Figure 2: A schematic of the facility (a view of the south wall, from the north wall).



Jet location	Bottom
Volume flowrate	0.029 m^3/s
Jet diameter	0.0508 m
Jet velocity	14.3 m/s

Figure 3: Concentration measurements from probe locations 1 - 5 for the continuous injection of helium from the bottom inlet.



Jet location	Bottom
Volume flowrate	0.029 m^3/s
Jet diameter	0.0508 m
Jet velocity	14.3 m/s

Figure 4: Concentration measurements from probe locations 6 - 10 for the continuous injection of helium from the bottom inlet