NYSEARCH Study for Natural Gas Dispersion and Detection in Residential Environments with HVAC

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SUMMARY

NYSEARCH, a R&D consortium consisting of gas distribution companies across North America with Fire & Risk Alliance, LLC (FRA) performed experimental and modeling work to study the dispersion of Natural Gas in residential structures. The data from this project is being used by the industry to aid in the development of a detector placement standard to facilitate the deployment of methane detectors. One of the recommendations from the study is to further explore the impact of building leakage and HVAC (Heating, ventilation, and air conditioning) on gas concentration throughout the structure volume. In the second phase of the project, with input from NYSEARCH project sponsor(s) and subject matter experts, FRA performed research to examine the dispersion of natural gas within a residential structure with a functioning HVAC system. Testing was completed at the facility with both traditional and open floor plan configurations. Phase I included the following findings and guidance:

- An alarm threshold of 10% LEL resulted in earlier and more widespread detection across all release cases.

- An alarm threshold of 25% LEL resulted in a delayed response in comparison to the 10% LEL and in some cases was never attained, however hazardous conditions were not observed in any location for the duration of the testing. The test was terminated once 60% LEL was reached in the test structure.

- Placement of detectors on the ceiling was preferable, however sensors placed on the wall with the sensing element within 18” of the ceiling also alarmed without significant delay.

- With the sensing element within 12” of the ceiling, the sensor response time was similar.

- Outside of 18” from the ceiling, the sensors showed a significant delay in detection or failed to reach an alarm threshold.

The objective of the Phase II work was to determine if changes to the guidance on sensor placement from the Phase I work was required. In Phase II, over 75 tests were conducted to evaluate the impact of HVAC on the dispersion of gas, gas concentration, and sensor response. The flow rate of methane into the compartment was varied over the test series to simulate different sources: common stove burner flow rates and underground service plumbing. For the testing conducted, methane was released into the enclosure at flow rates of 4.8, 13.3, 71 and 110 SCFH. These rates are identical to those of Phase I dispersion testing. Gas concentration and distribution within the test enclosure was measured over the leakage duration with spot-type electrochemical and metal oxide methane sensors placed throughout the test volume.

EXPERIMENTAL METHODOLOGY

The current study seeks to better understand gas dispersion within residential structures with forced ventilation heating and cooling systems and how this may impact the placement of sensors. This work is a continuation of previous efforts to investigate methane gas dispersion through a residential structure to help guide natural gas sensor development and implementation. The original experimental effort focused on the effect of different leakage sources and structure configurations on the accumulation rate and location of methane within the space. This experimental phase expanded on previous characterizations to include the effect of residential air handling systems on gas dispersion throughout the structure.

A total of 135 full scale gas release tests have been conducted in this project. In recent experimental testing, a fully functional HVAC system was installed within the structure. Vent placement within the structure was intended to provide the flexibility to configure different flow conditions. It included in-floor vents, installed within the sub-floor, in addition to low and high wall registers positioned throughout the various compartments of the floor plan (See Figure 1). For Division 1, supply vent installations were limited to the ceiling level. Each division included an air return intake located near the top of the wall on side ‘A’ of the building.

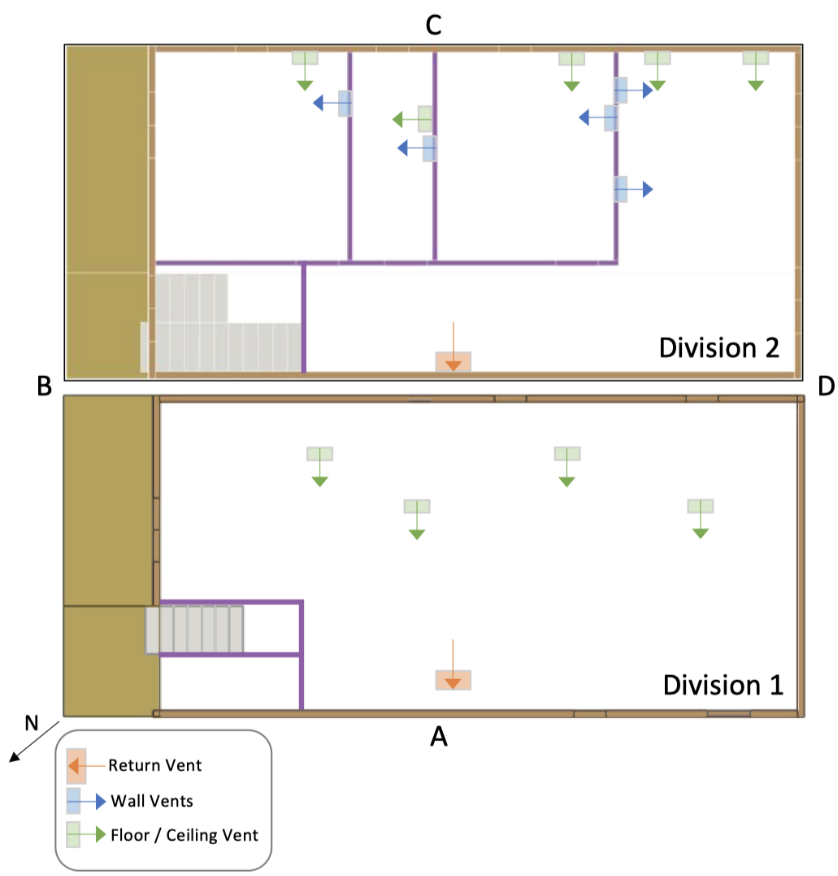

Figure 1: Location of supply vents and return intakes within testing structure.

The installed system was intended to serve the entire structure with a normal operating flow rate of 800 CFM. The designed flow condition assumed flow from the four ceiling vents on Division 1 and five vents on Division 2. For testing conducted on a single division of the structure, the blower speed was set to 33% of the full flow capacity, 396 CFM, and all unused supply vents and return intakes were closed, covered, and taped (See Figure 2) to prevent unintended air circulation within the enclosure. In the test scenarios involving two divisions of HVAC flow, the blower was configured to 66% of the full flow capacity, 792 CFM, and all return intakes were utilized.

The full installed HVAC system was utilized to maintain a conditioned environment for the dispersion measurements with a thermostat setting of 66°F. The no-ventilation condition test, shown in Figure 2 with all vents closed, served as the baseline for each configuration and leakage condition.

Each test configuration examined in this study was run with a sealed no-HVAC condition and at least one active HVAC condition to allow comparison between tests within this experimental effort. Alarm thresholds of 10% and 25% LEL were characterized across all tests conducted to determine the time required for each sensor to register the defined gas concentration. Utilizing sensor coordinates and the times determined from the threshold analysis approach, the alarm time for each sensor was graphically evaluated on the floor plan of the test structure. Alarm histograms were included in the analysis conducted to provide a macro level evaluation of the accumulated number of sensors reaching the alarm thresholds examined as a function of leakage duration.

Figure 2: Installation of HVAC vents within structure; covered for no flow ventilation configuration.

RESULTS

Impact of Vent Openings

Under typical installations, HVAC systems operate in a cyclical manner, conditioning the space over time while cycling the blower and condenser or heating element. Although testing was conducted primarily to examine the effect of an operating HVAC system on the measured concentration of gas within the structure, the mere presence of vent openings on the accumulation of gas within the structure was shown to have an impact on the measured concentration. For a non-operating system with the HVAC vents and intake covered and sealed, 29 of the potential 53 sensors within the volume reached the 25% alarm during the test with a release of 13.3 SCFH. Under similar release conditions but with the vents uncovered, only 8 sensors reached the same 25% threshold indicating that the accumulation of methane in the structure is impacted by an HVAC system, even while not operational. It was further observed that the presence of open vents within the structure appeared to increase the spread of gas from the leakage location toward the return vent which further decreased the measured gas concentration in the general test volume.

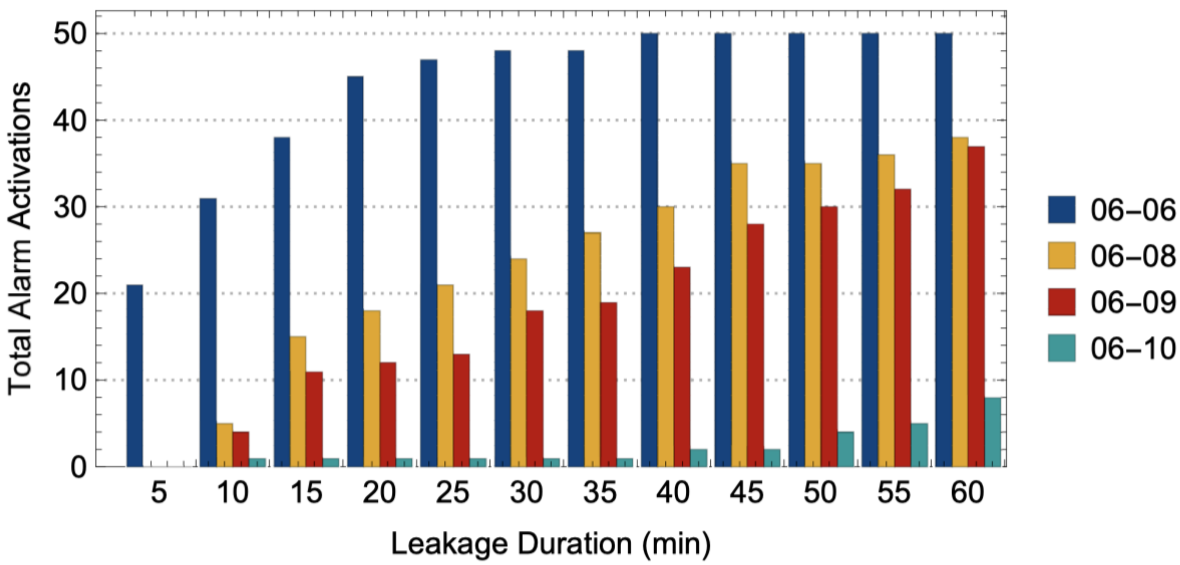

Figure 3: Alarm time histogram comparison of various ventilation conditions at the 10% LEL alarm threshold for a 13.3 SCFH: Tests 06-06 (no vent); 06-08 (low wall vent); 06-09 (high wall vent); 06-10 (floor vent).

Impact of HVAC Operations

Based on testing conducted with an operational system, the HVAC system configuration was observed to have a significant impact on the distribution and accumulation of gas within the test enclosure for all flow rates and alarm thresholds examined. For the initial series of tests conducted, Test Series 06, the flow conditions of “None”, “Low”, “High” and “Floor” were compared to evaluate trends in the alarm activation times and locations for leakages on Division 2 of the structure. For the lowest leakage condition evaluated, 4.8 SCFH, the operation of the HVAC in any configuration resulted in no alarm conditions at the 10% LEL threshold over an hour-long leakage compared to a total of 25 alarm events documented for the baseline test (No HVAC) condition at the same 10% LEL threshold. Examining the alarm activation histogram for the 13.3 SCFH leakage scenario at the 10% LEL alarm threshold (Figure 3), the effect of the different HVAC configurations is apparent.

As shown in Figure 3, depending on the configuration of the HVAC operation, the total alarm activations are reduced to between 16 and 76% of the no-HVAC condition. The HVAC configurations of “low” and “high” wall vents, located nominally 10 inches from the floor and ceiling for tests 06-08 and 06-09 respectively, demonstrate similar effects on the total number of sensor activations observed over the total test duration. Throughout the leakage, the low vents were observed to have the least impact on the number of sensor alarms measured resulting in a total of 38 alarms at the 10% LEL threshold by the end of the test compared to 50 alarms in the baseline testing. The floor vents, located on either side of the leakage source for Test Series 06 configurations, resulted in the most notable reduction in the total number of sensor alarm conditions with just 8 total activations over the hour-long test. At the 25% LEL threshold examined, no alarm activations were measured for any configuration other than the baseline tests with no ventilation, in which all vents were closed and covered.

For all HVAC flow conditions evaluated, a measurable gas concentration was observed by sensors at numerous remote locations, while sensors in the room of origin showed lower concentrations than those in the no HVAC condition. This occurs as the gas is removed from the room of origin and circulated throughout the structure, thereby reducing the concentration in the room of origin, and increasing it in more remote areas when compared to a no HVAC operation. When examining the specific vent orientations, the floor vents appear to provide the most uniform mixing within the space with similar measured concentrations throughout the structure at the end of the leakage duration.

Impact of a Multi-Story Structure

For a multi-story structure with introduction of HVAC, the difference in the number of alarm activations at 10% and 25% LEL thresholds became more apparent. In general, with a functioning HVAC, at lower flow rates (<20 SCFH), the methane sensor activation was delayed in comparison to the No HVAC condition. For the larger leakage rates examined, this difference was negligible at 10% LEL alarm threshold in multi-story test configuration. The difference in alarm activations became more apparent at the 25% LEL thresholds between no ventilation and ventilation tests.

A histogram is presented in Figure 4 for the number of sensor alarms measured at the 25% LEL threshold for one of the higher flow rates tested (71 SCFH) with a range of HVAC conditions. It is observed that the No-HVAC flow condition of Test 10-06 at 71 SCFH leakage rate first shows significantly more alarms than the HVAC conditions until 90 minutes into the test. This is due to the circulation of gas through the HVAC system and transportation delays associated with the door thresholds or header height since the doors opening do not extend to the ceiling. Post the 90-minute mark, the number of alarm activations for the two HVAC configurations begin to exceed the total number of alarms registered by the No-HVAC flow condition as the gas has been uniformly circulated in the structure by that time, aiding the activation of sensors that are even placed away from the source of the leak.

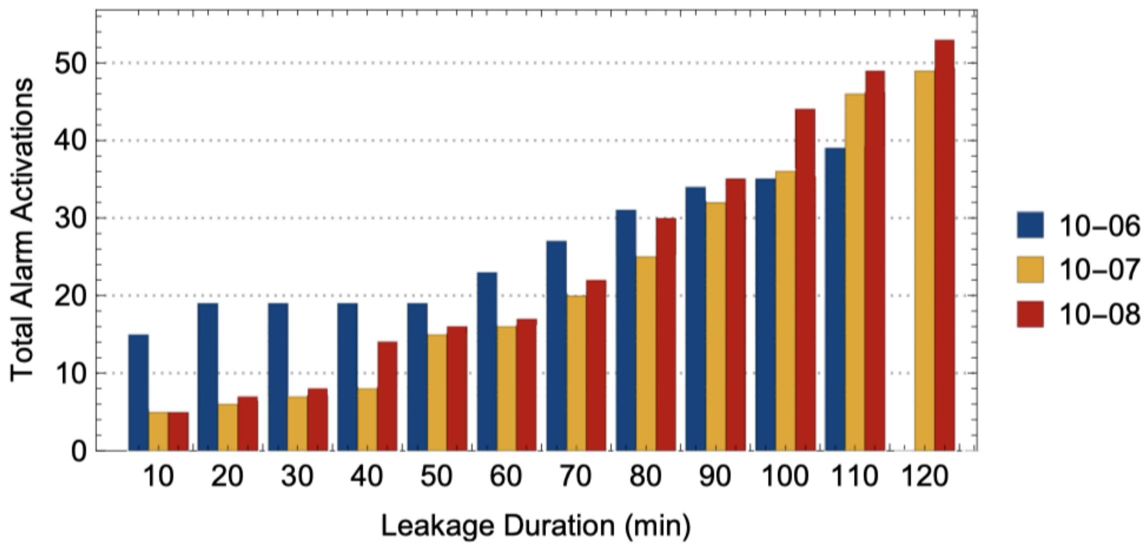

Figure 4: Alarm time histogram for Tests in Series 10 (Multi-story layout) at an alarm threshold of 25% LEL and various HVAC configurations for a 71 SCFH release: 10-06 (none); 10-07 (ceiling/low); 10-08 (ceiling/high).

RECOMMENDATIONS

Based on the Phase II work conducted, the following recommendations are provided regarding ensuring timely sensor response across a broad range of release conditions, structural arrangements, and ventilation conditions. They are as follows:

• Sensors should be installed in rooms with gas fire equipment or piping.

• Sensors should be installed in sleeping areas or communal areas even if gas fired equipment is not present to account for dispersion due to operation of HVAC.

• The LEL threshold for alarm should be 10% LEL. While 25% is still well below the explosive limit the observed delays or lack of detection entirely at the 25% threshold for certain release conditions support moving to a lower threshold that will provide ample notification and alert occupants to a situation that needs to be mitigated.

• Whenever possible, sensors should be located within 18” of the ceiling. While receptacle level sensors alarm more frequently with the HVAC system operating, when it is not operating the sensors are significantly delayed in response or fail to activate when compared to ceiling level sensors.