# Methyl Bromide and Sulfuryl Fluoride Gas Leakage Rates from Structures

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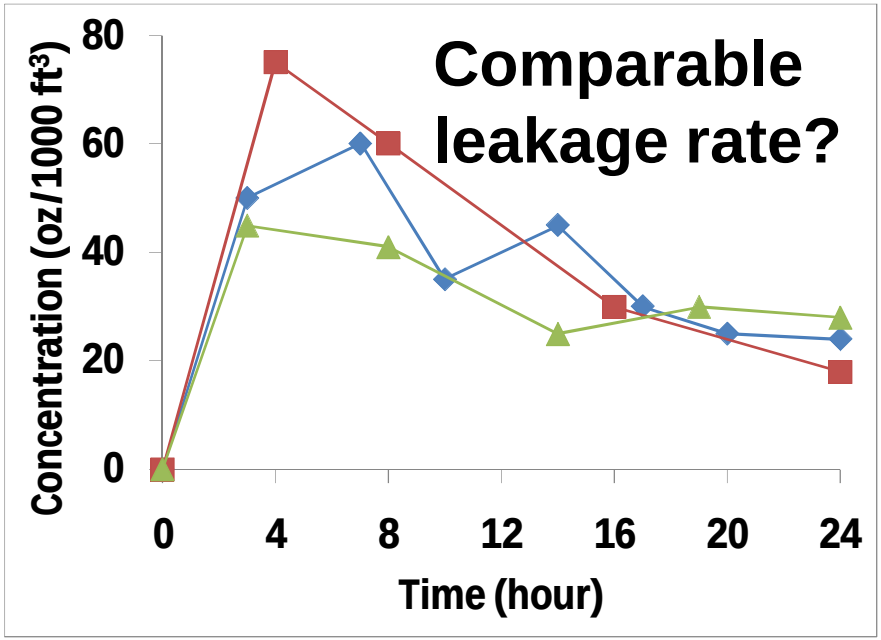
A Hands-on Workshop on Methyl Bromide Alternatives, May 11-13, 2010

# Introduction

- During typical structural fumigations, do MB and SF show different gas dynamics (for example leakage rates and gas distribution)?
- Problem – when the two gases are compared, environmental conditions generally are not analyzed in details and sealing quality is assumed the same



# Introduction

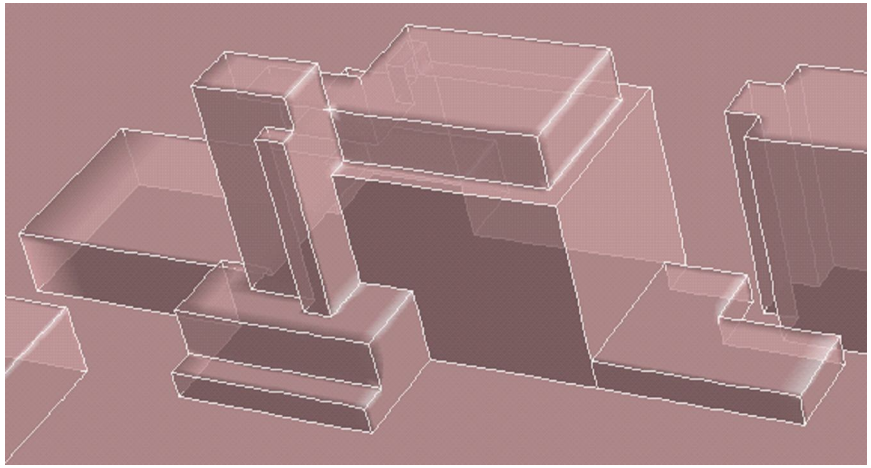
- Research at Purdue University and Kansas State University
  - Fumigation experiments and simulations for the past six years and continuing
  - A number of fumigation experiments in flour mills
  - Computer models of the fumigation process

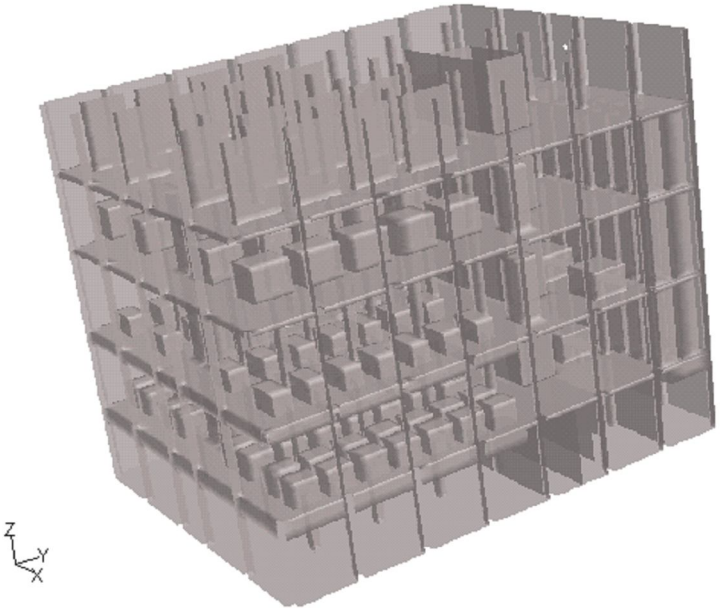
# Fumigation Simulations

- Chayaprasert, W., D.E. Maier, K.E. Ileleji and J.Y. Murthy (2008). *Development and validation of Computational Fluid Dynamics models for precision structural fumigation*. Journal of Stored Products Research. 44: 11-20
- Chayaprasert, W., D.E. Maier, K.E. Ileleji and J.Y. Murthy (2009). *Effects of weather conditions on sulfuryl fluoride and methyl bromide leakage during structural fumigation in a flour mill*. Journal of Stored Products Research. 45: 1-9

# Model

- Based on a commercial reference flour mill
- Takes into account leakages created by wind and buoyancy forces
  - Input: weather conditions, type of fumigant, amount released, etc.
  - Output: gas concentration readings

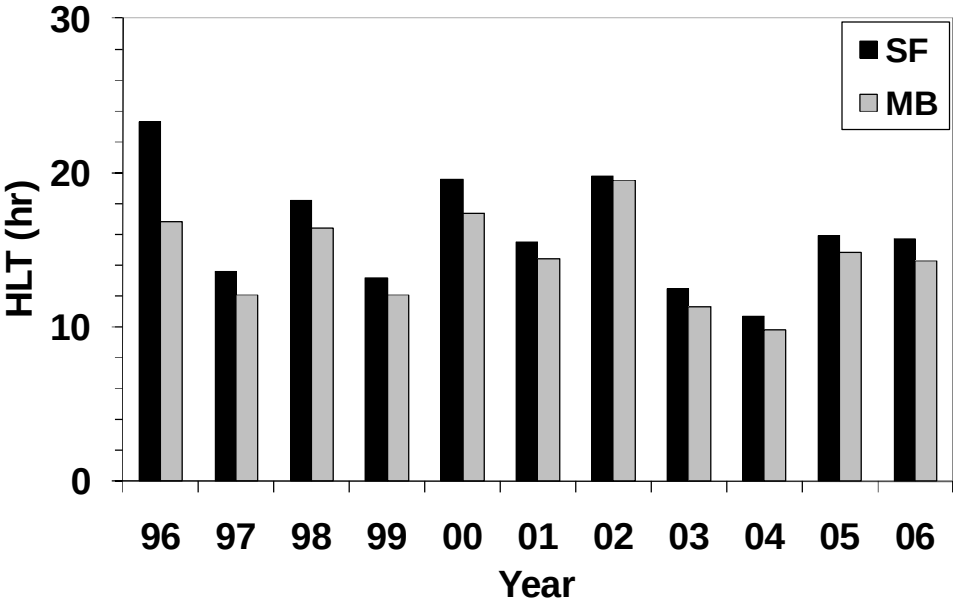


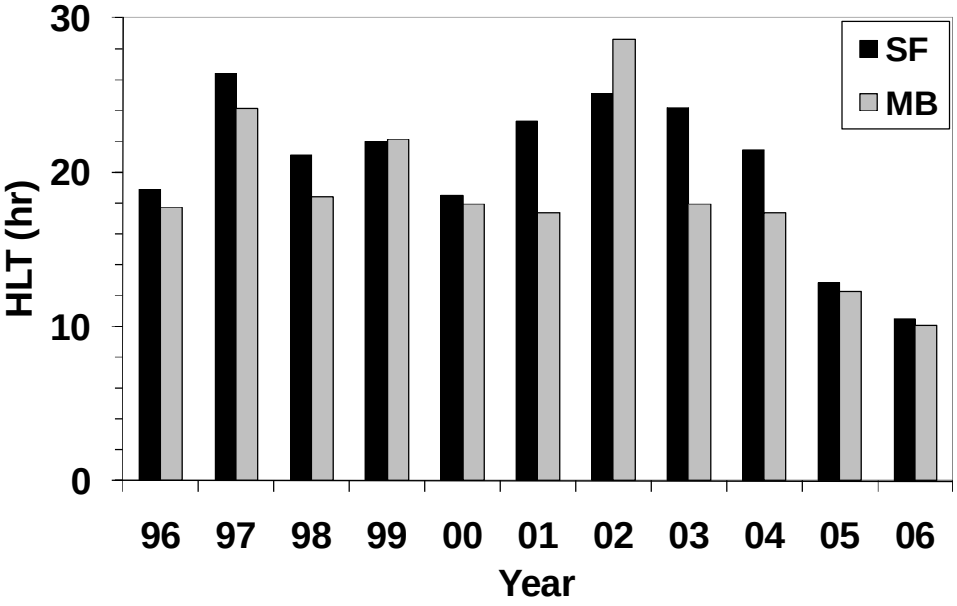


# Simulations

- MB and SF fumigation simulations performed with hourly average weather data around the Independence Day and Labor Day of 1996 – 2006
  - 11 MB fumigations on each of Independence and Labor Days
  - 11 SF fumigations on each of Independence and Labor Days
- Fumigation practices were the same
  - Gas introduction and monitoring locations
  - Sealing quality
  - Exposure time

# Half-Loss Time



# Findings

- Leakage rates (i.e., half-loss time) largely depends on weather conditions during fumigation
- Under the same weather and sealing conditions, leakage rates of MB and SF are similar

→ These findings were based on computer simulations

→ Would we obtain similar findings in actual fumigations?

# Experiments at Hal Ross Flour Mill

- As many controlled parameters as possible
- Two MB and two SF fumigations in one single building
- Almost identical sealing quality verified by building pressurization tests
- Continuous weather condition and gas concentration monitoring

| **Fumigation #** | **MB1** | **SF2** | **MB3** | **SF4** |
|---|---|---|---|---|
| **Starting time** | **6:40 PM May 6th** | **6:00 PM May 27th** | **2:50 PM Aug 11th** | **2:45 PM Aug 19th** |
| **Exposure (hr)** | **~24** | **~24** | **~24** | **~24** |

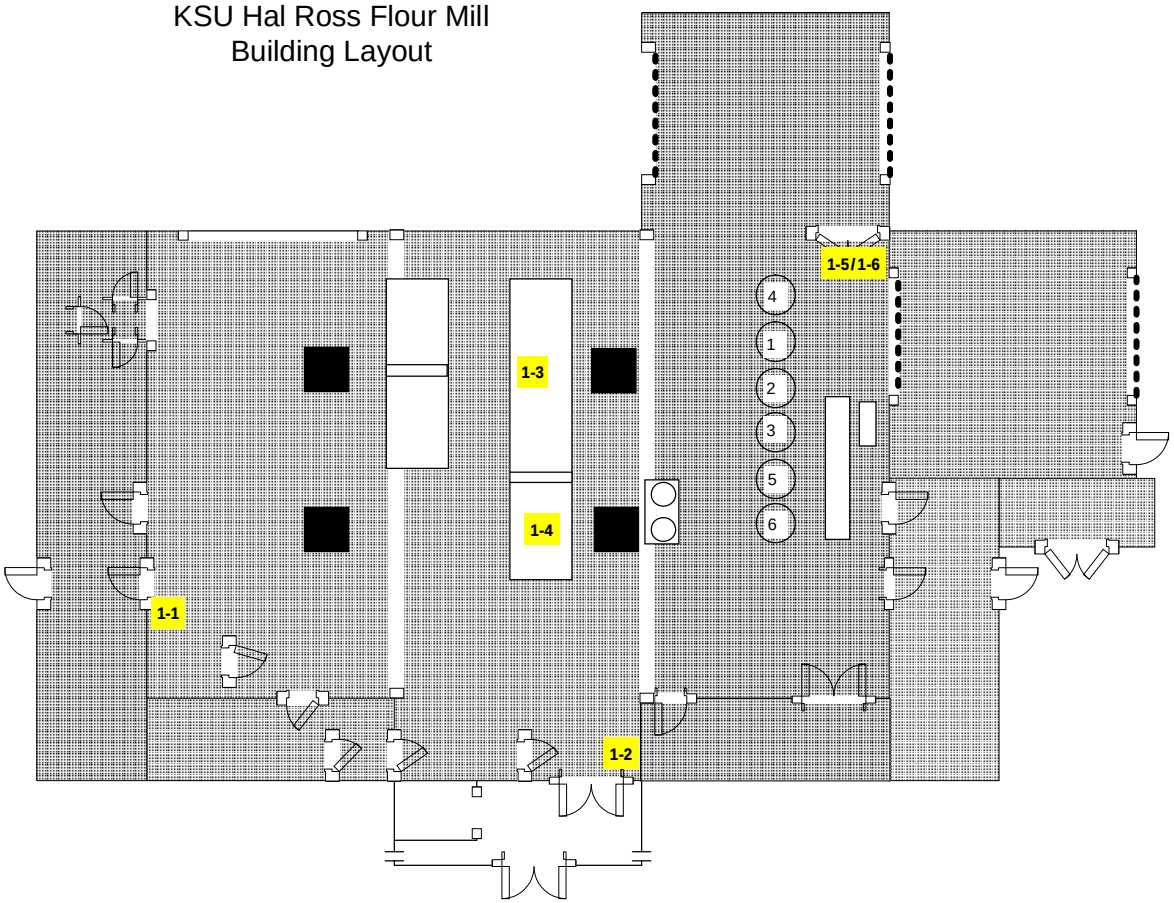
# Experimental Setup

- Weather station (temperature, RH, wind, solar radiation, barometric pressure)
- Temp/RH logger (one point on each floor)

# Experimental Setup

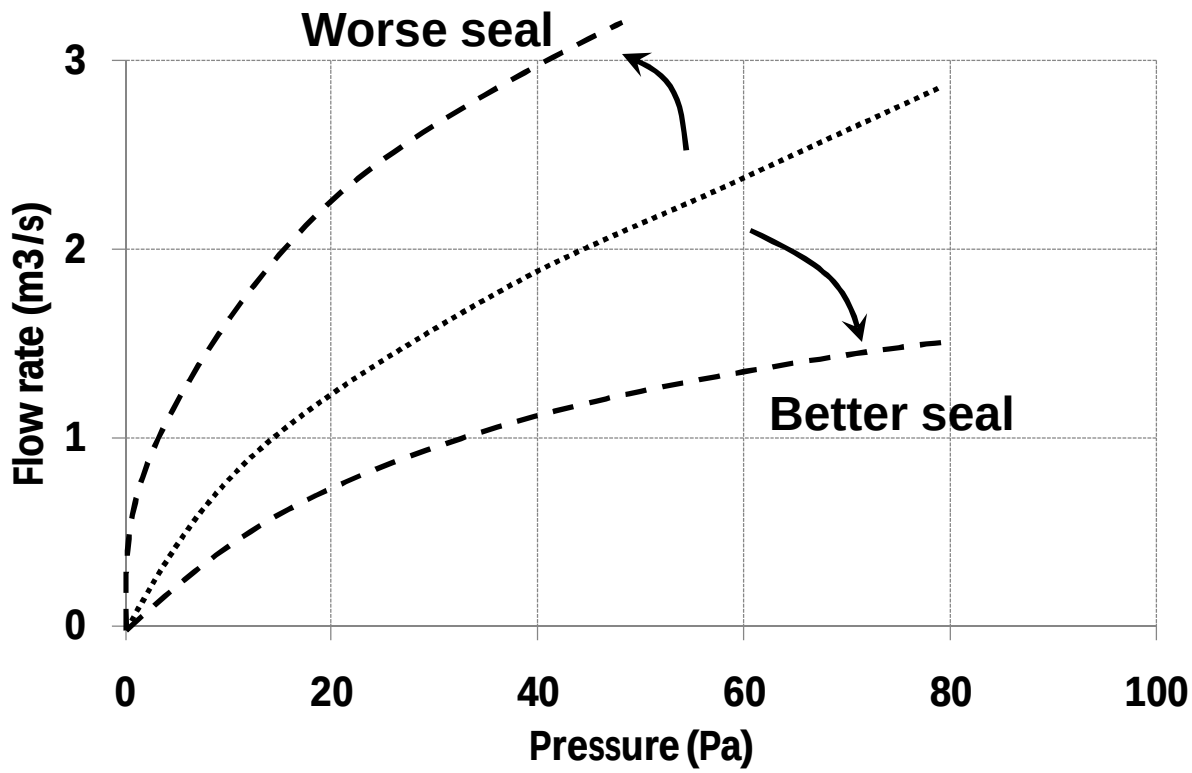
- Gas concentrations continuously monitored at 6 locations evenly distributed on each floor

KSU Hal Ross Flour Mill
Building Layout



# Pressurization Test

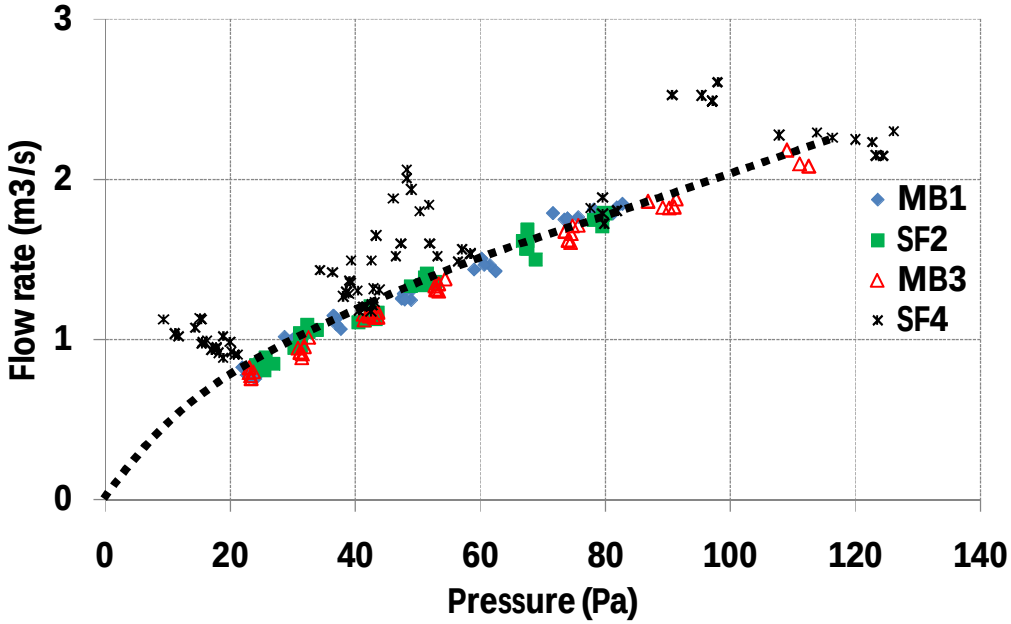
- Flow rate VS Pressure
  - Good seal → Lower flow rate at any given pressure



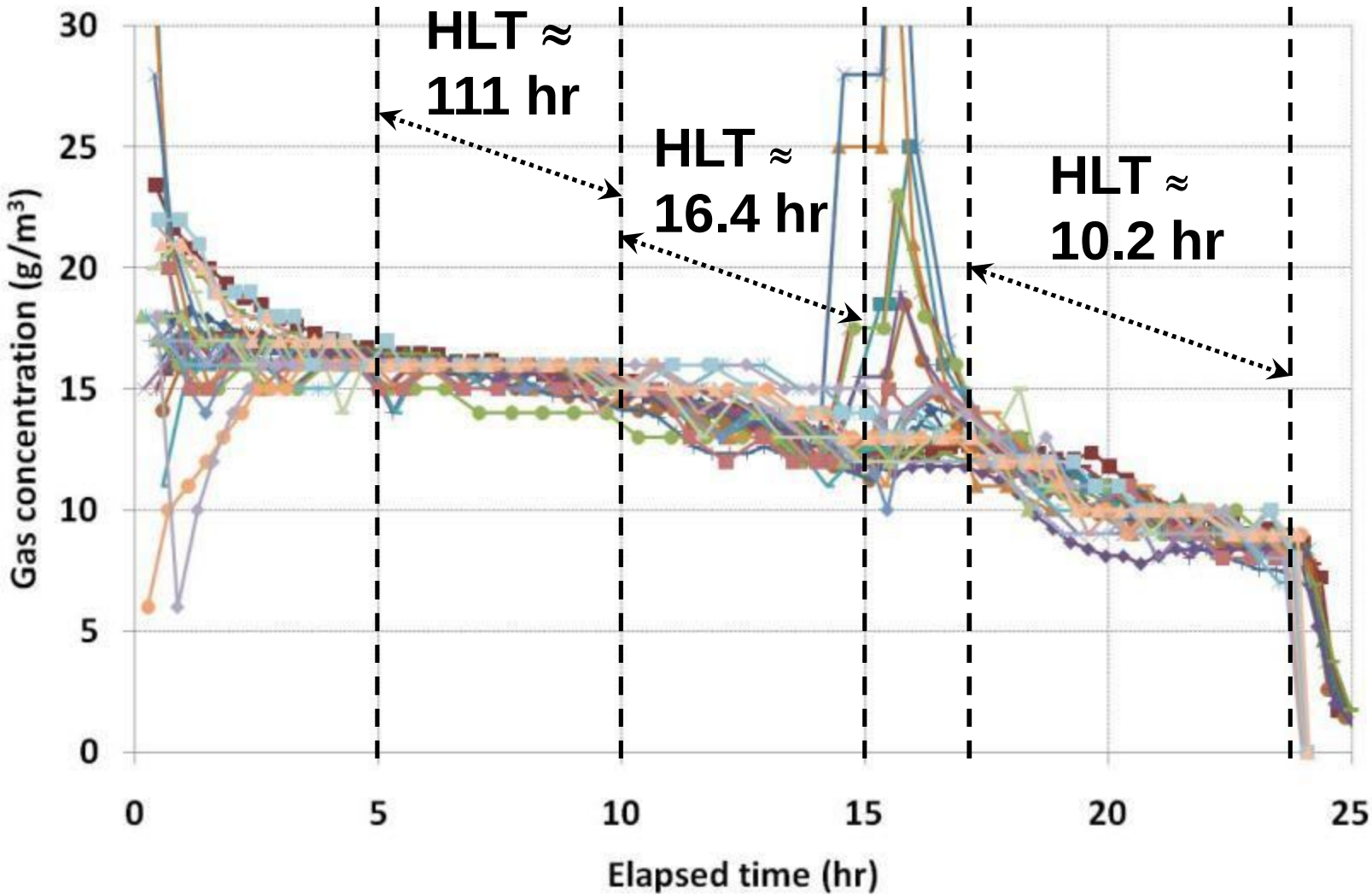
# Pressurization Test

- Sealing quality of MB1, SF2 and MB3 fumigations was identical
- Pressure test result of SF4 experiment was adversely affected by strong outdoor wind

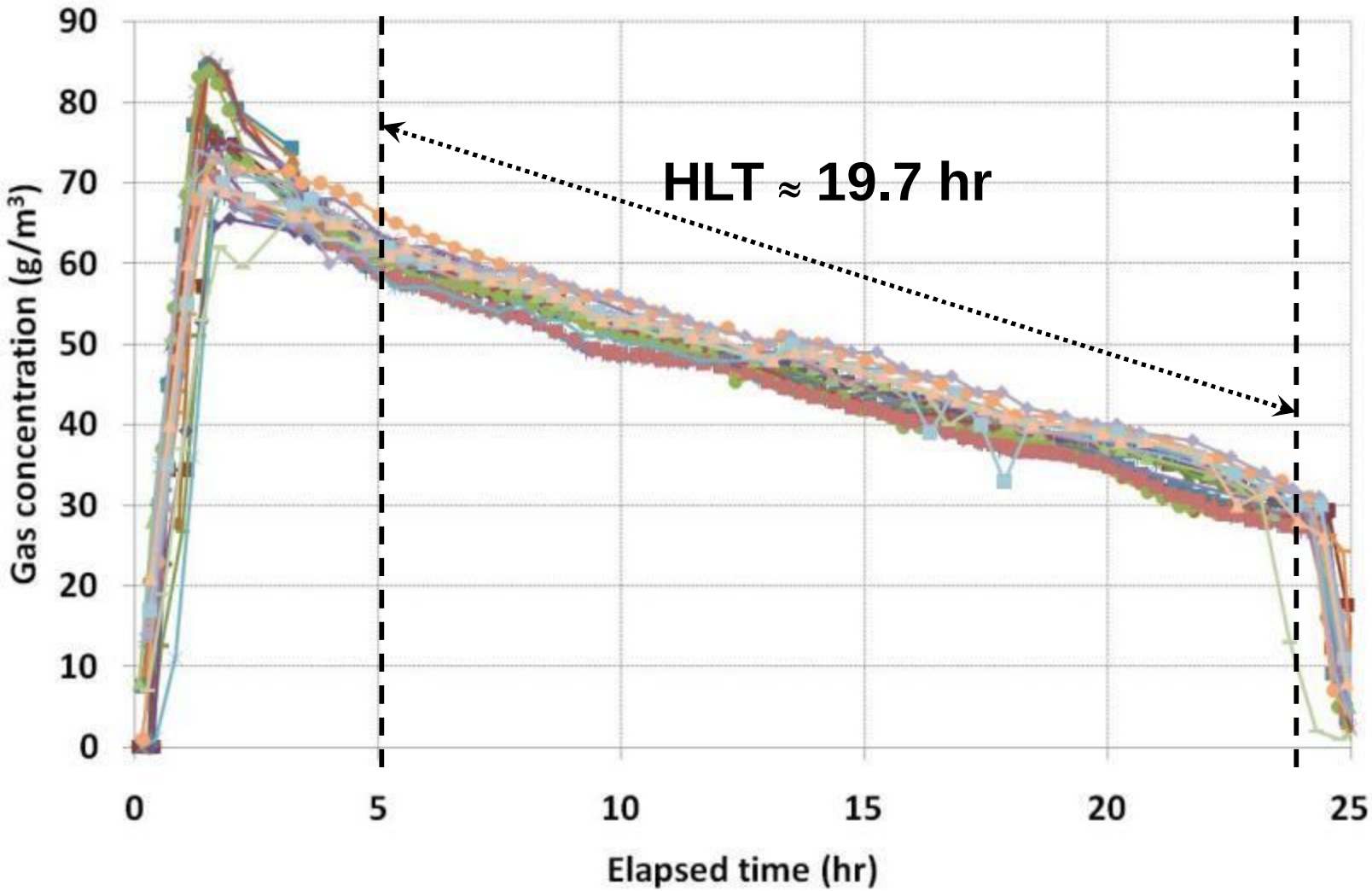
→ Assuming best sealing quality of SF4 experiment, sealing quality of all fumigations was the same



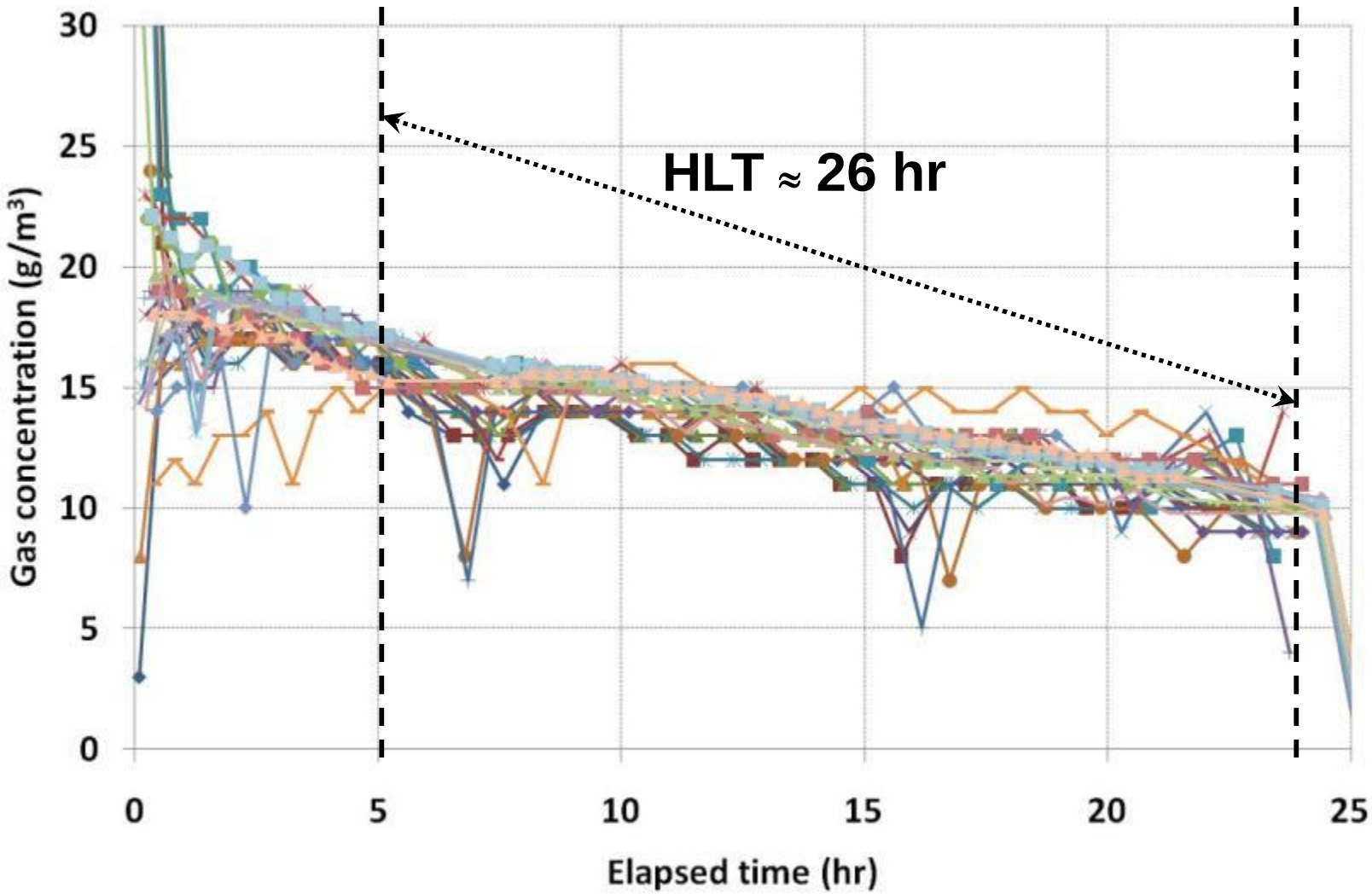
# Gas Concentration: MB1



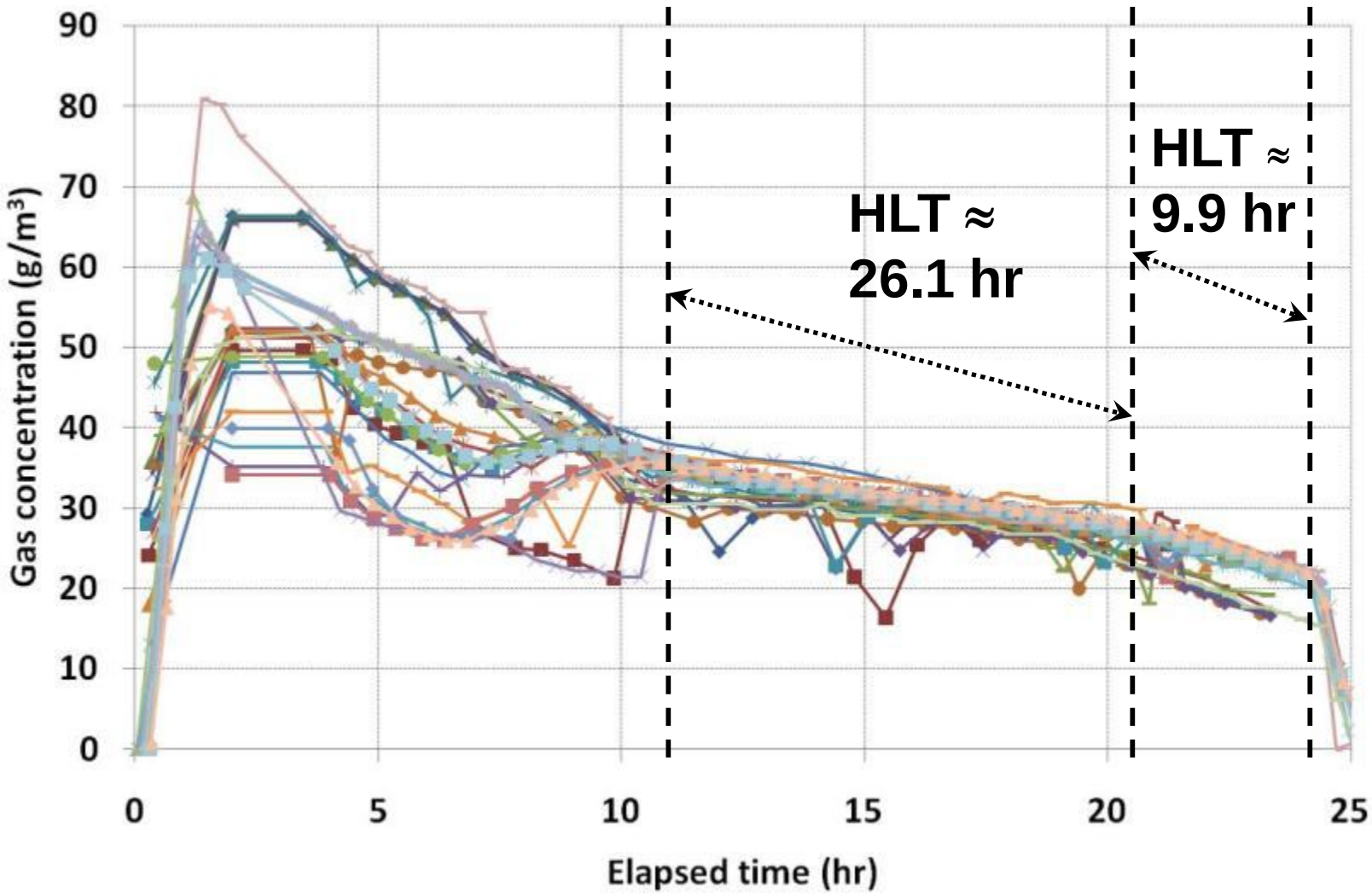
# Gas Concentration: SF2



# Gas Concentration: MB3



# Gas Concentration: SF4



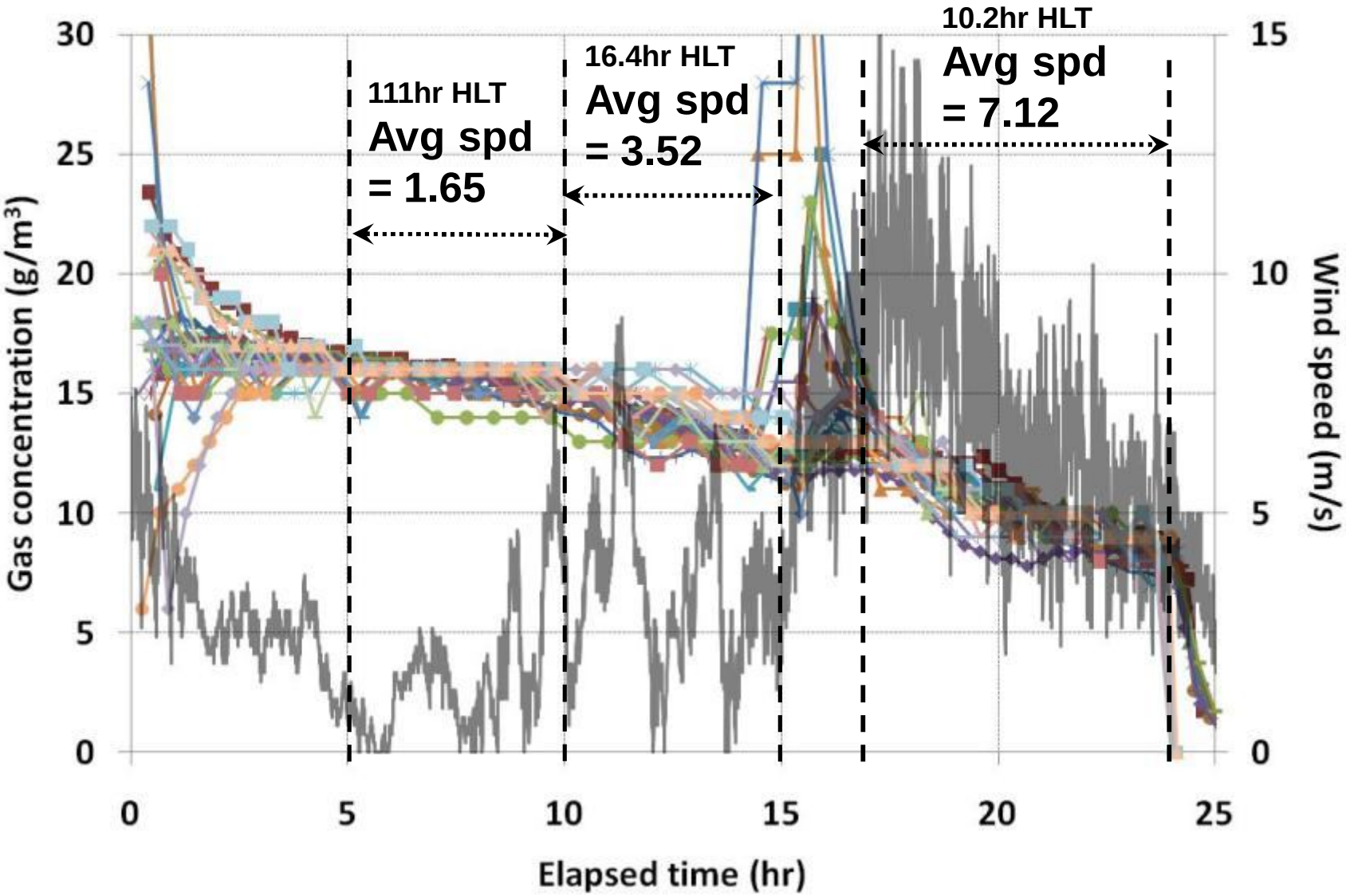
# Discussion

- Both MB and SF were evenly distributed throughout the building
- Both MB and SF fumigations showed varying HLTs
- Sealing quality was the same, but different HLTs were observed

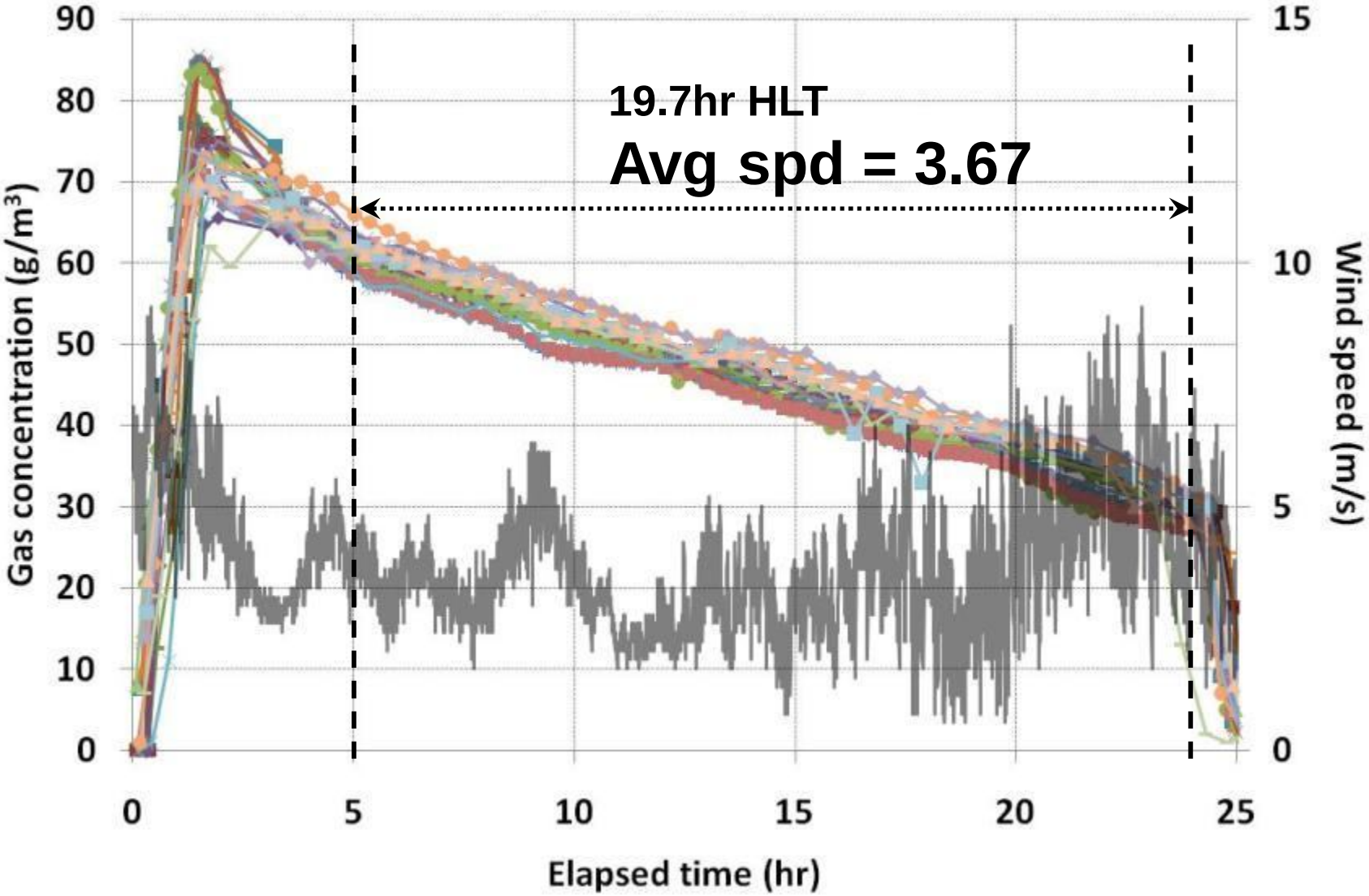
→ What caused these differences?

→ Can the weather data explain this?

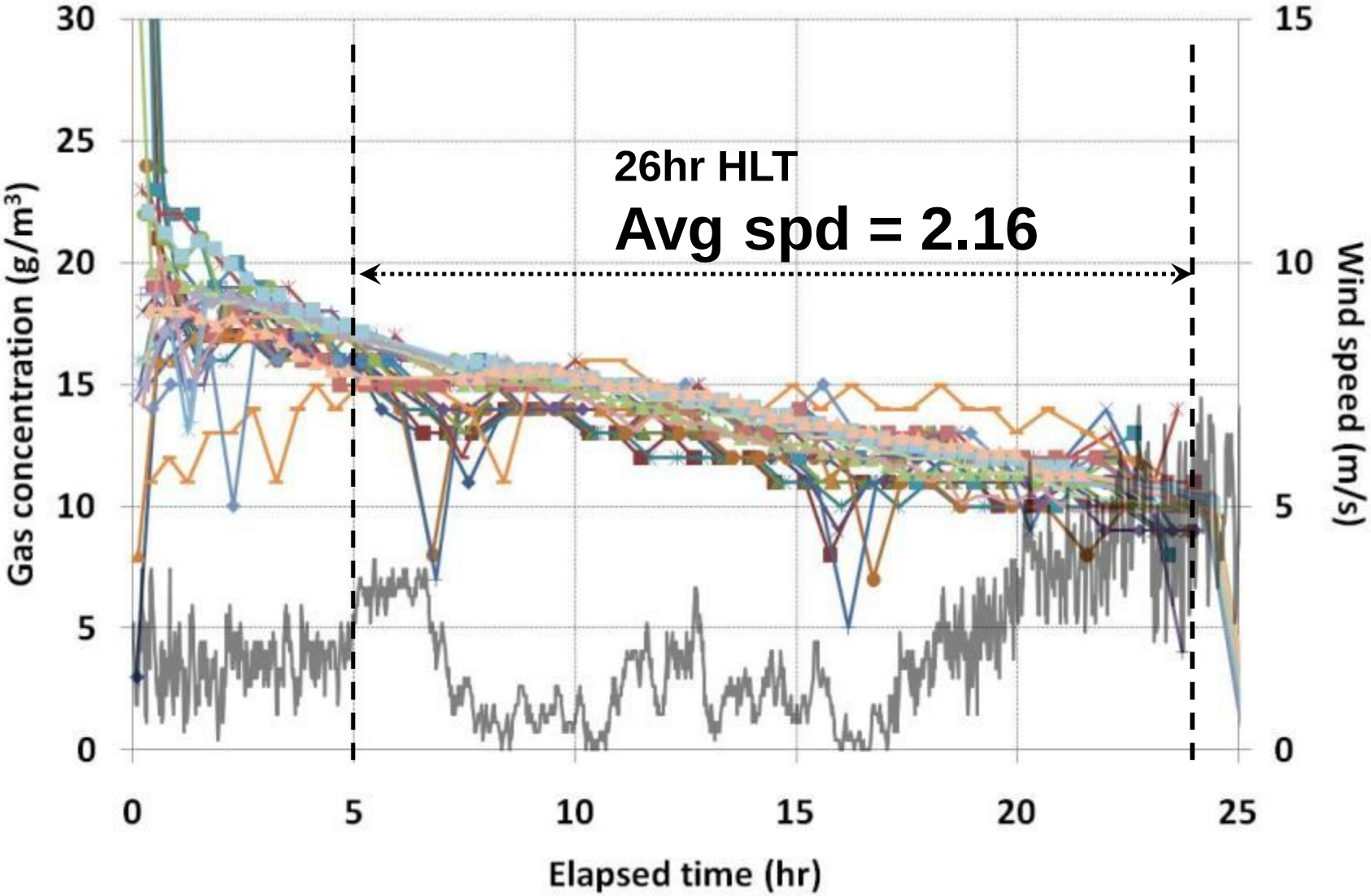
# Gas Concentration: MB1



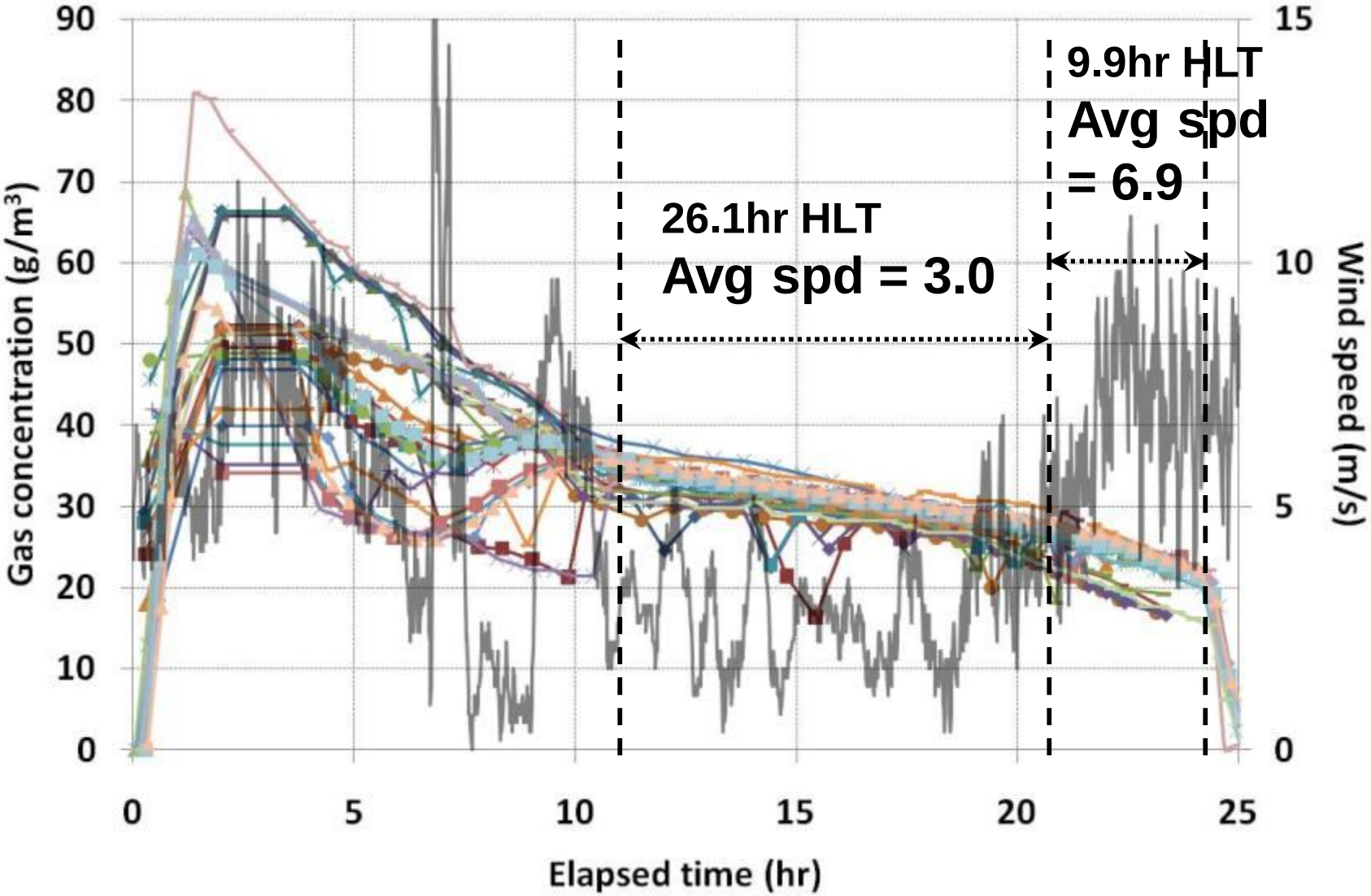
# Gas Concentration: SF2



# Gas Concentration: MB3



# Gas Concentration: SF4

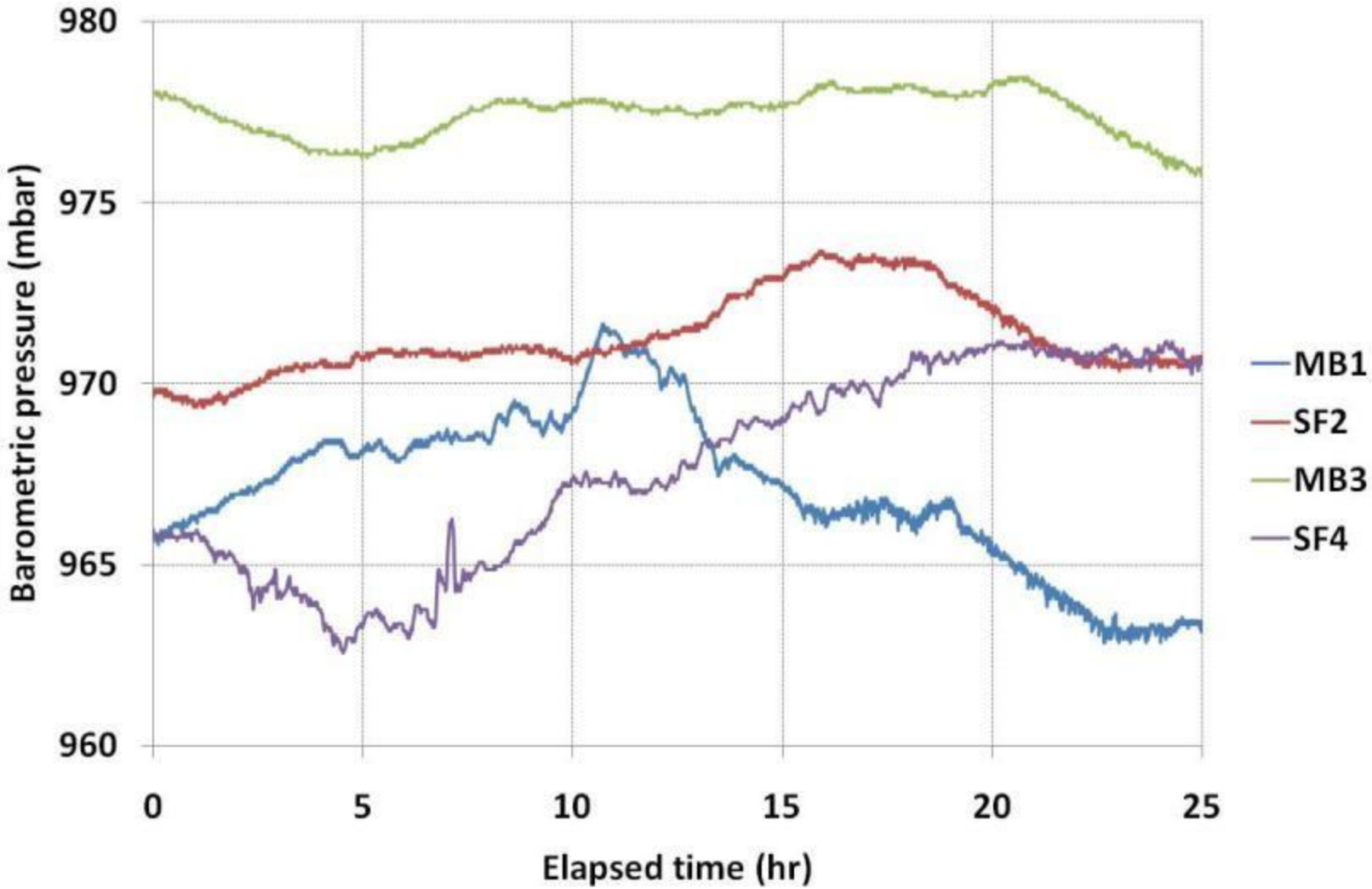


# Discussion

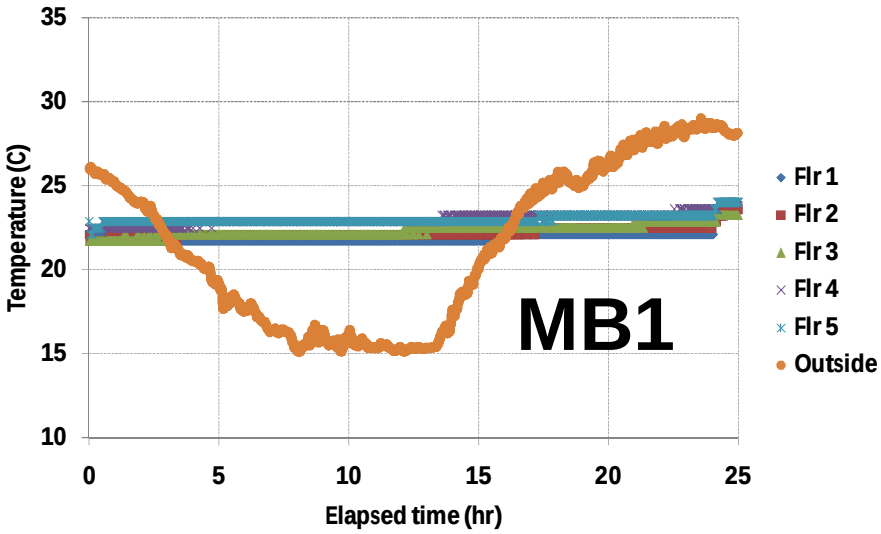
- Wind speed data are consistent with the observed HTLs
- Small fluctuations of wind could not be picked up by gas monitoring

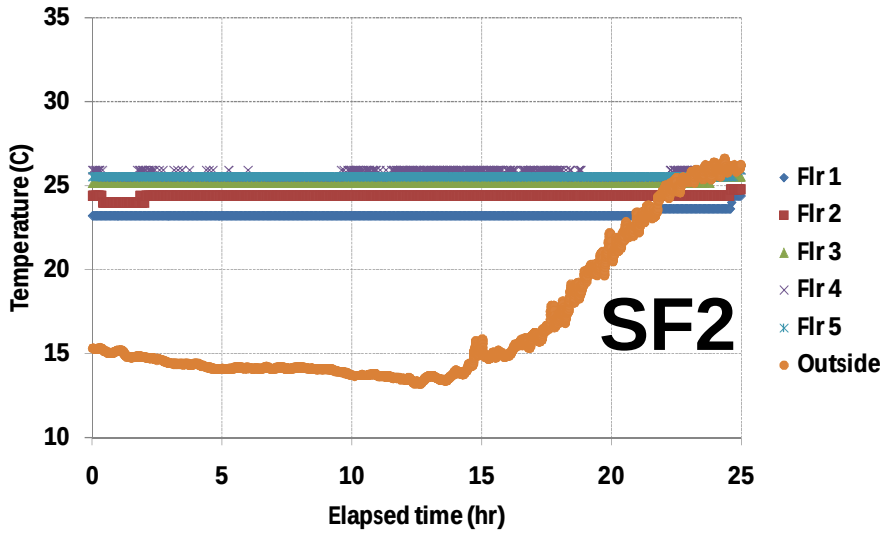
→ How about buoyancy and barometric pressure pumping forces?

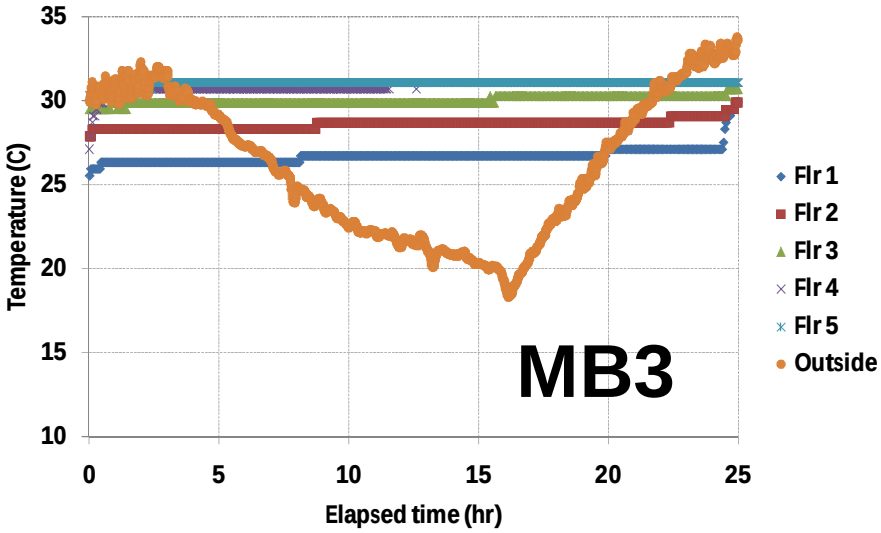
# Barometric Pressure

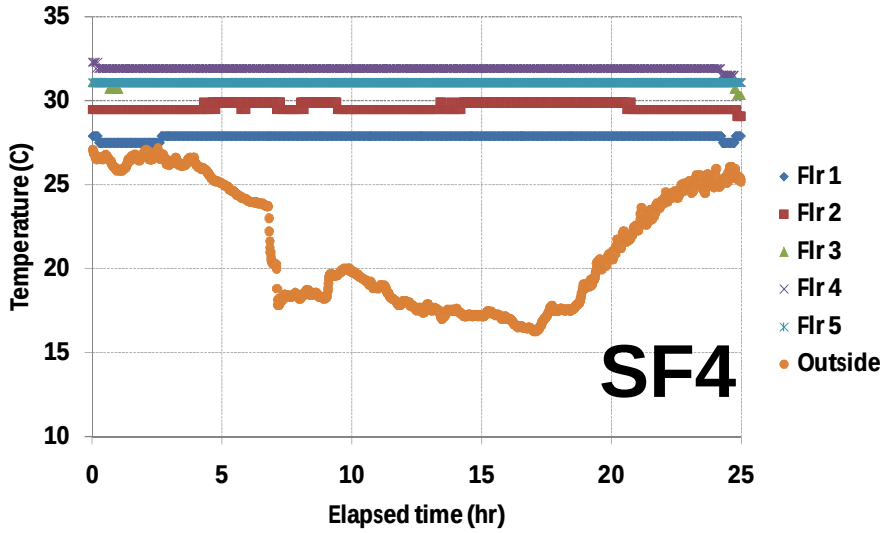


# Temperatures

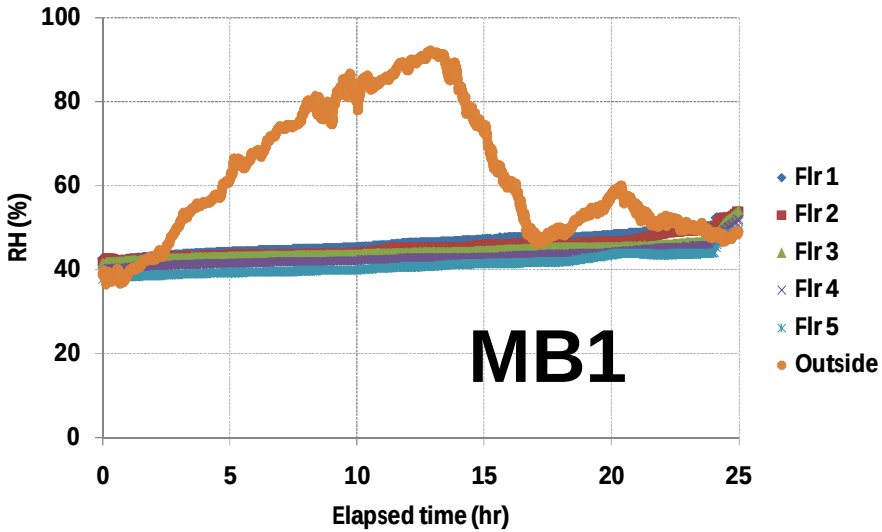


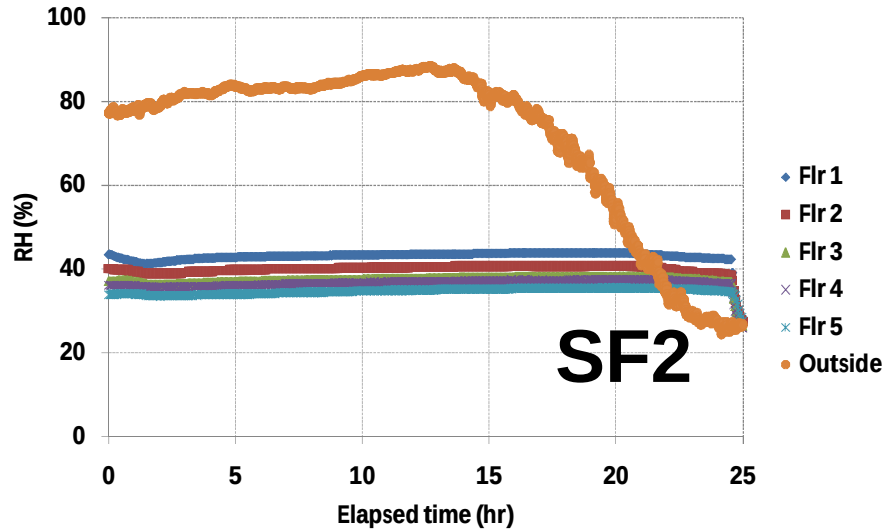



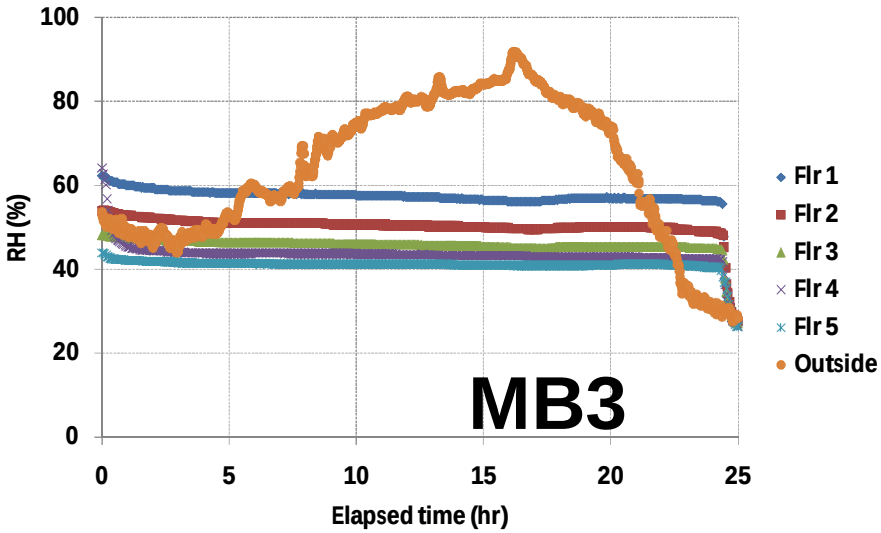



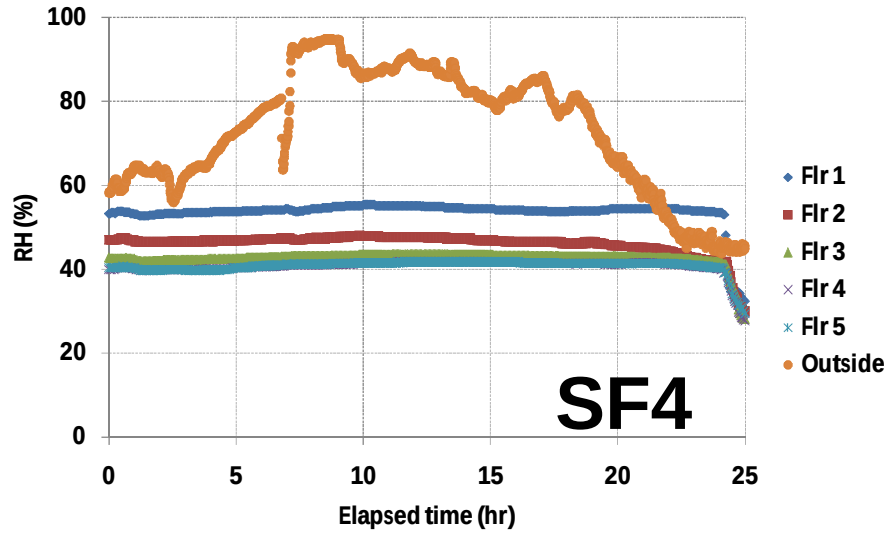



# Relative Humidity

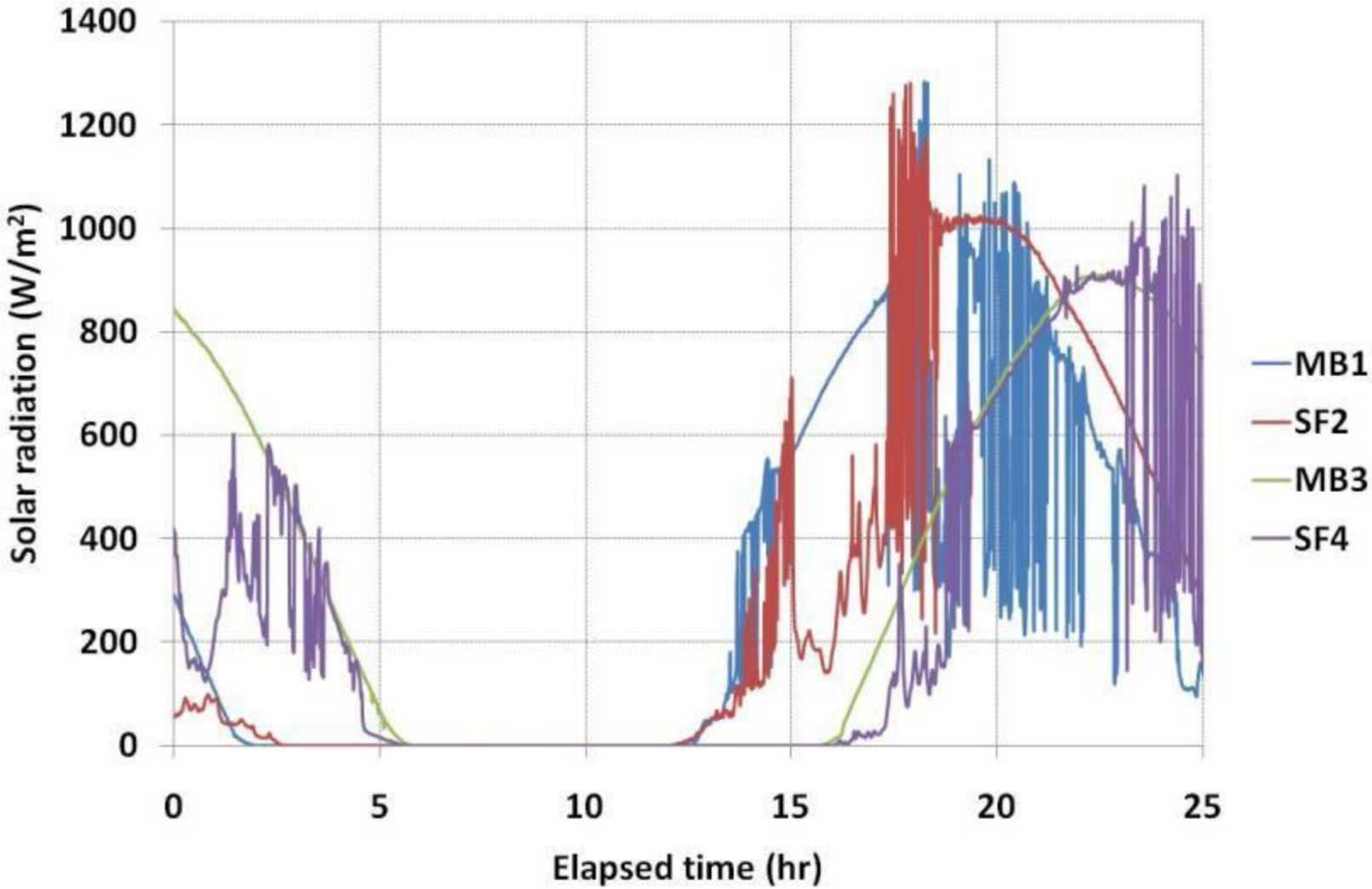


# Solar Radiation



# Discussion

- Clear-cut correlations between buoyancy and pressure pumping forces and HLTs could not be established
  - Their effects might be overshadowed by the wind effect
  - More data analyses will be conducted after the final set of experiments
- Despite variations in outside temperature, RH and solar radiation, inside temperatures and RHs were relatively stable
  - Relatively airtight building
  - The heat transfer, generation and accumulation rates were balanced
  - Similar observations can be expected for buildings with the similar airtightness level

# Summary of Results

| | MB1 | SF2 | MB3 | SF4 |
|---|---|---|---|---|
| Starting time | 6:40 PM May 6th | 6:00 PM May 27th | 2:50 PM Aug 11th | 2:45 PM Aug 19th |
| Exposure (hr) | 24 | 24 | 24 | 24 |
| Total gas used (kg) | 181 (400 lb) | 567 (1250 lb) | 159 (350 lb) | 511 (1125 lb) |
| Inside temp (C) | 22 - 23 | 23 - 26 | 27 - 31 | 28 - 32 |
| Outside temp (C) | 15 - 29 | 14 - 26 | 19 - 34 | 16 - 27 |
| Inside RH (%) | 39 - 50 | 34 - 44 | 40 - 60 | 40 - 55 |
| Outside RH (%) | 37 - 91 | 25 - 88 | 30 - 90 | 45 - 95 |
| Avg wind spd (m/s) | 1.65, 3.52, 7.12 | 3.67 | 2.16 | 3.0, 6.9 |
| HLT (hr) | 111, 16.4, 10.2 | 19.7 | 26 | 26.1, 9.9 |
| Ct product (g-hr/$m^3$) | 283 - 327 | 923 - 1191 | 268 - 318 | 663 - 1003 |

# Findings

- Fumigation experiments at Hal Ross Mill confirmed the previous findings
- SF and MB showed similar gas distribution and leakage characteristics
  - Inside gas distributions were dominated by circulation fans
  - Leakage rates were influenced by environmental conditions
  - For these particular experiments, wind was the dominating factor

# Findings

- Sealing effectiveness can be determined by pressurization testing ahead of a fumigation
  - By itself, it cannot predict HLT
  - It can differentiate a "well" vs "poorly" sealed facility

→ How can we use the pressurization test to predict HLT more accurately?

# Superposition

- Quadratic superposition method
- Used by the HVAC industry to quantify air infiltration in houses for energy saving and in-door air quality purposes

$$Q = \sqrt{Q_s^2 + Q_w^2} = \frac{A_L}{1000}\sqrt{C_s \Delta t + C_w U^2}$$

$$HLT = \frac{V}{Q}\frac{\ln(2)}{3600}$$

# Superposition

Leakage due to stack effect

Stack coefficient

Equivalent leakage area

Wind coefficient

?

Total leakage rate

$$Q = \sqrt{Q_s^2 + Q_w^2} = \frac{A_L}{1000}\sqrt{C_s \Delta t + C_w U^2}$$

Temperature difference

Wind velocity

Leakage due to wind effect

Could be estimated by pressurization test and computer simulation

Thank You