GHD Design

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Understanding the Mechanical Ventilation in a Modern Urban Operations Live Fire Facilities

Welcome

Topics covered

Importance: Mechanical ventilation is crucial to limit exposure to harmful particulates and gases.

Challenges: Designing ventilation systems involves managing turbulent airflow and room complexity.

Testing: Testing provides reliable data using well-known techniques and realistic scenarios.

CFD Limitations: CFD models need more data for validation and can't fully solve the problem yet.

Results: Mechanical testing showed contaminant levels below allowable limits in various scenarios.

Why is mechanical ventilation design of internal live fire facilities important?

Limit exposure to heavy metal particulates

Limit exposure to noxious gases

Maximise training time

Minimise accumulation of dust inside the facility (secondary exposure)

Reduce cost to build

Reduce the noise of ventilation systems (secondary hazard)

Challenges in Designing Ventilation Systems

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What are the challenges in designing internal ventilation systems?

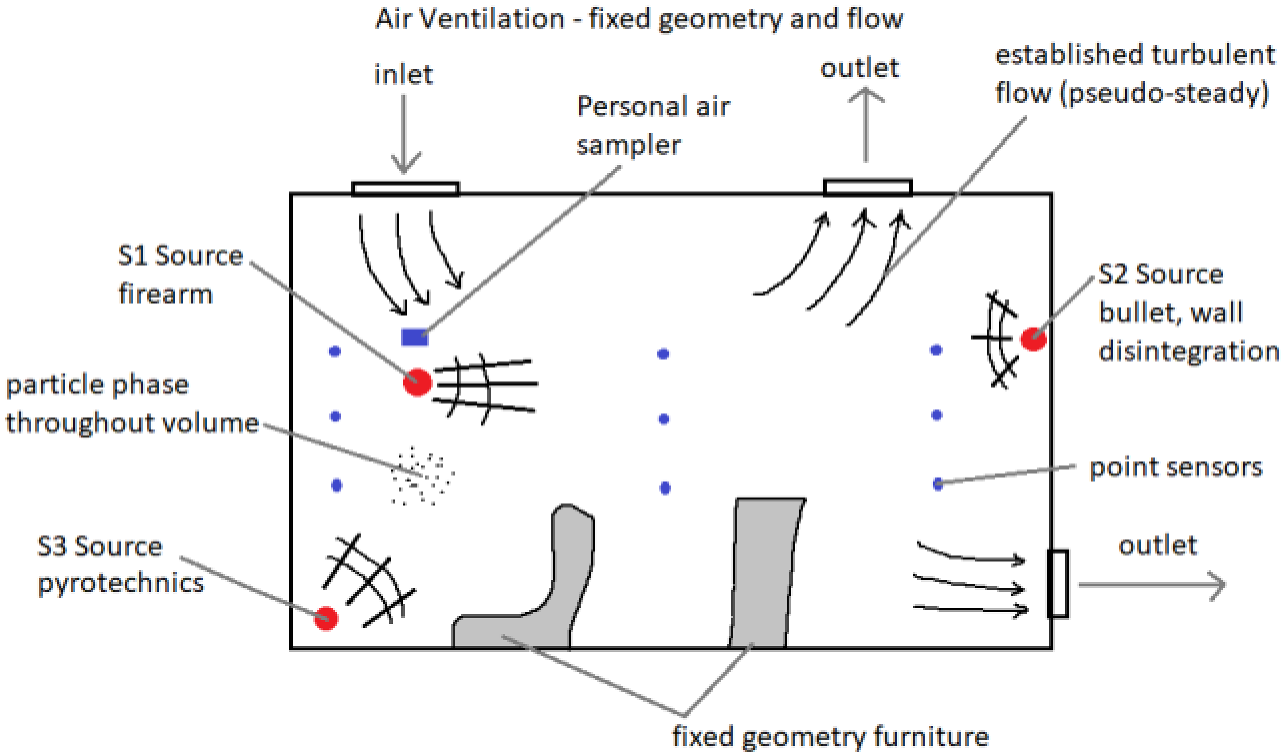
Airflow inside rooms and around inlet ducts is turbulent

Achieve laminar flow inside the room

Disturbance of airflow by people and weapons fire

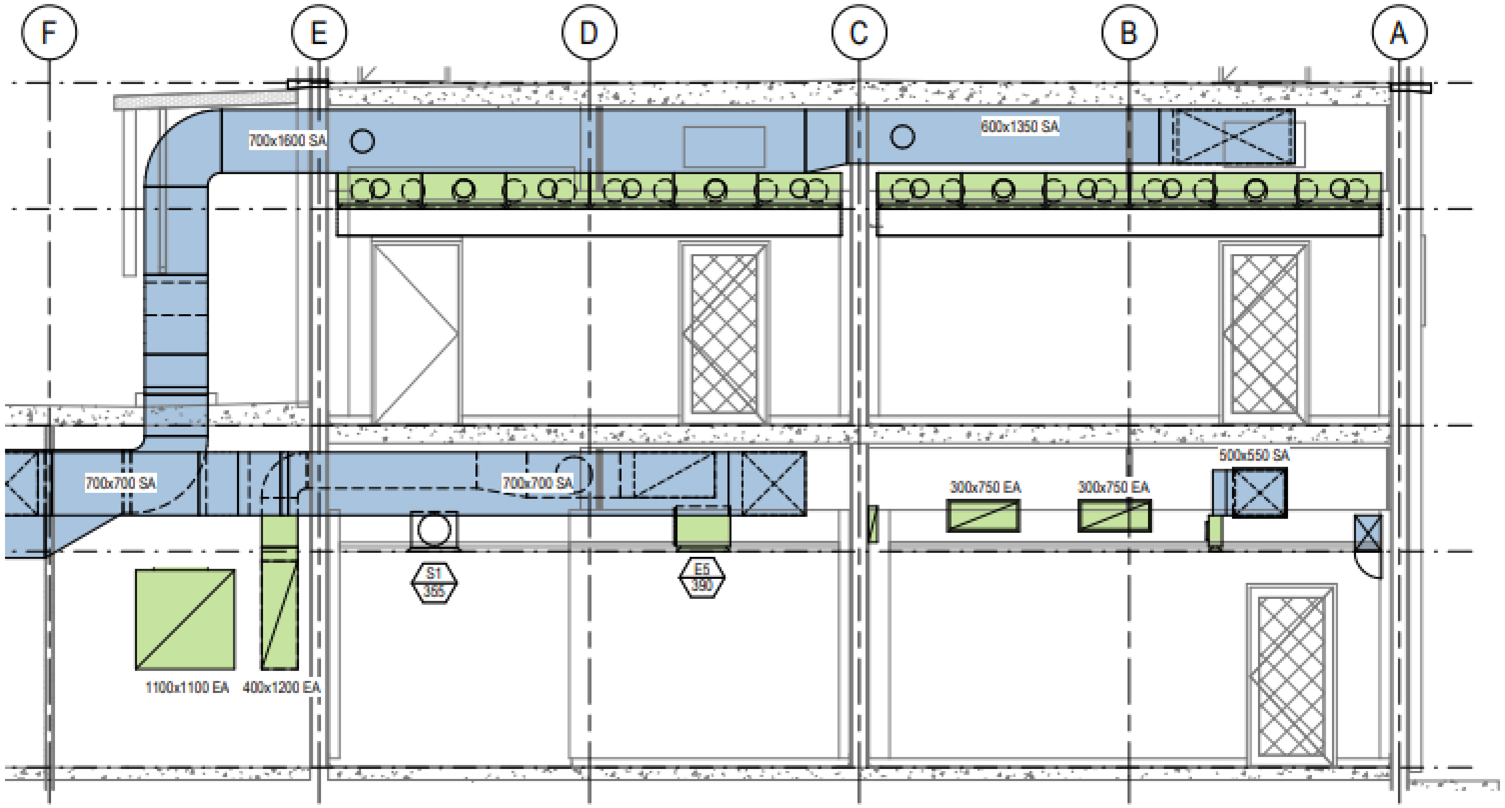
Complexity of the rooms means no airflow model is the same

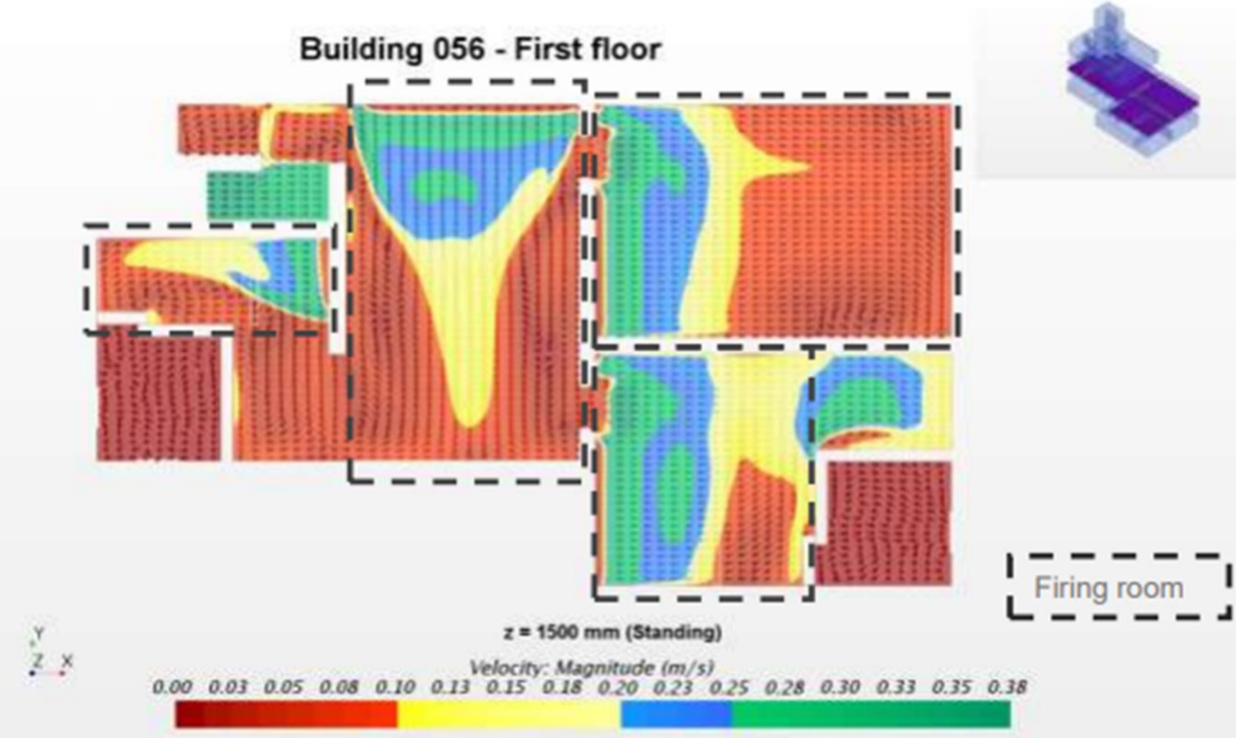
Rate of airflow affects turbulence



Why test internal ventilation

- providing as much reliable, relevant and “design useful” information and direction as possible
- using well-known and trusted multi-phase flow measurement techniques
- considering well-known UOLFF layouts and soldier training scenarios
- meeting a reasonable budget





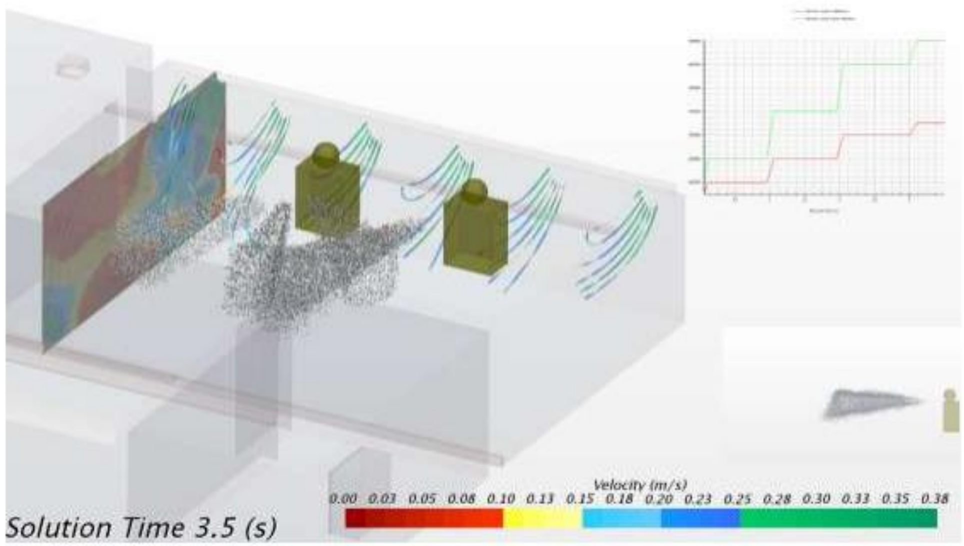


Figure 5-6 plume analysis | Time=3.5 second | seventh round shot

Computer Fluid Dynamic modelling verses testing

CFD (at this stage) can't provide a complete picture of the problem

Information on the size and speed of particles leaving the weapons is not known

Over time CFD modelling may assist in design – but we need more data to validate models

Mechanical Testing and Methodologies

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Mechanical Testing

Mechanical testing conducted in a mock up facility in Greenbank Training Area from 14 Dec – 18 Dec 2020 and 2 Feb – 12 Feb 2021

- Primary contaminants considered were copper dust, mist and fume generated by frangible munitions.
- Also measured dust and silica (due to design of the facility).
- Used data collated to calculate 8 hr TWA over a 8 hr day / 5 day working week.
- Based on user firing scenario
- Sampled both ‘breathing zone’ and static air samplers.
- 6 samples of each scenario taken.
- Final results <TWA

Mechanical ventilation testing conducted at Greenbank Training Area from 7 – 9 Dec 2021.

-Same scenario as previous testing, but blank and alternative frangible were test fired.

- Only the worst case scenario of the previous tests were used.
- Copper, lead and silica dust were measured.
- All results were less than allowable TWA

Mmechanical Testing

Mechanical ventilation testing conducted at Greenbank Training area from 29 November to 7 December 2023

- Testing was conducted on a new ventilation model (top down)
- Firing internally to external targets was introduced (fire through a window)
- Lead, copper and carbon monoxide was measured.
- Testing was 'exaggerated' – real life use would be less.

Future testing

- Use personal samplers during real training scenarios in actual facilities to 'certify' the facility

Example mechanical ventilation test development

- Developing a test plan
- Construction of the mockup facility
- Test the ventilation system
- Set up sampling devices
- Conduct of the test
- Analysis and reporting

Development of test plan

Number of rounds to be fired based on expected training serials

Where are the firers located in the room (when will they fire)

Where are the safety staff located

Who else is exposed

What happens after weapon is fired (where do personnel move and when)

Development of test plan

Consideration of the flow of air / particles

Modelling use of the facility based on user training need

‘Worst case’ scenarios

Firing must be enough to trigger sensors

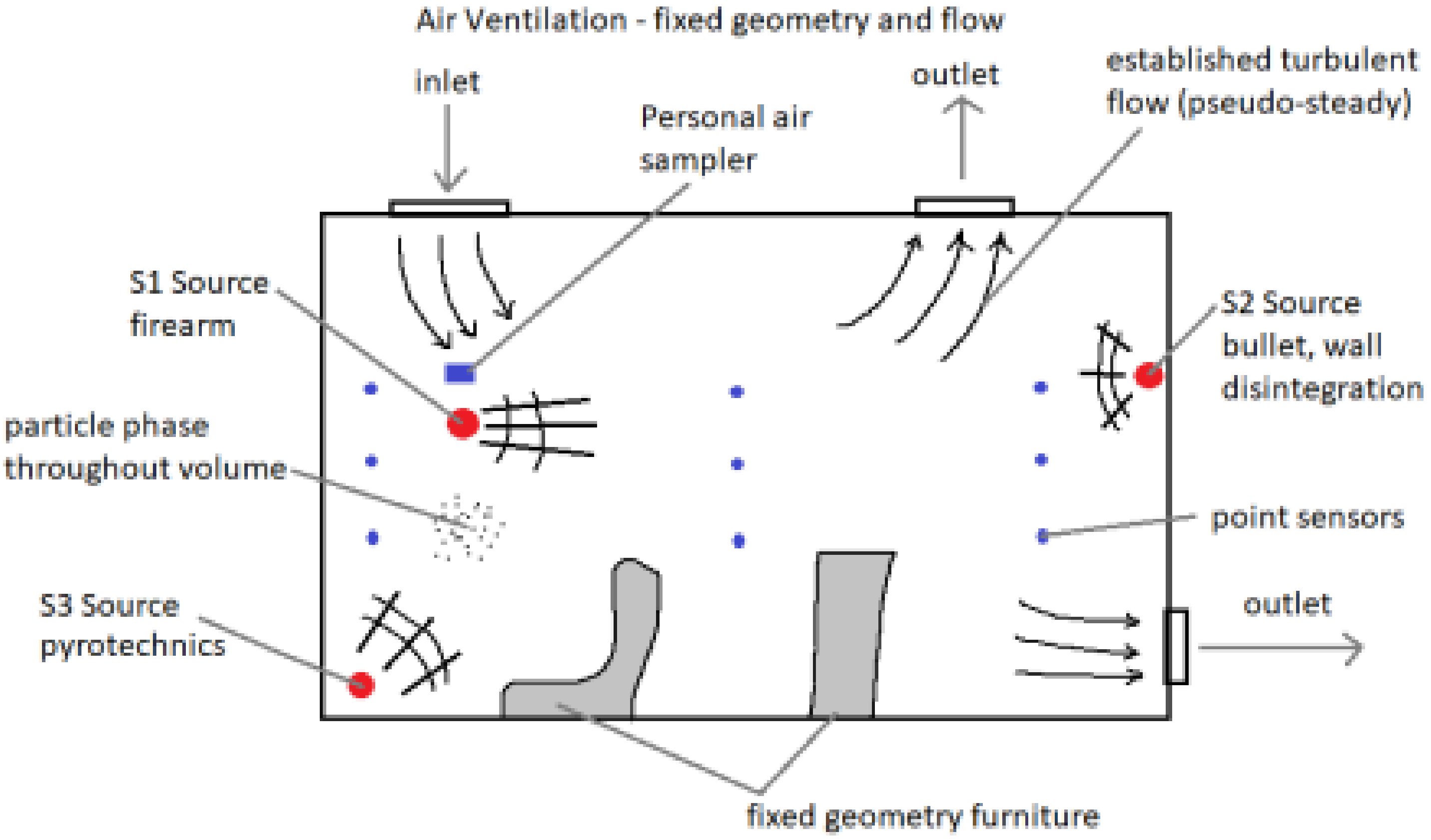

Figure 3 General Layout of Test Firing Range

Setup and Execution of Testing

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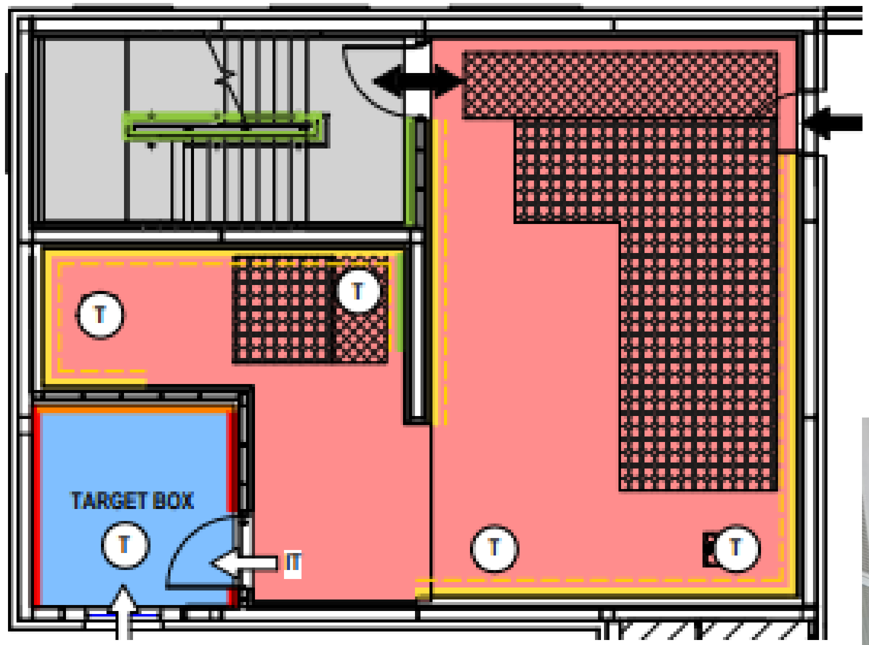
Construction of Mockup Facility



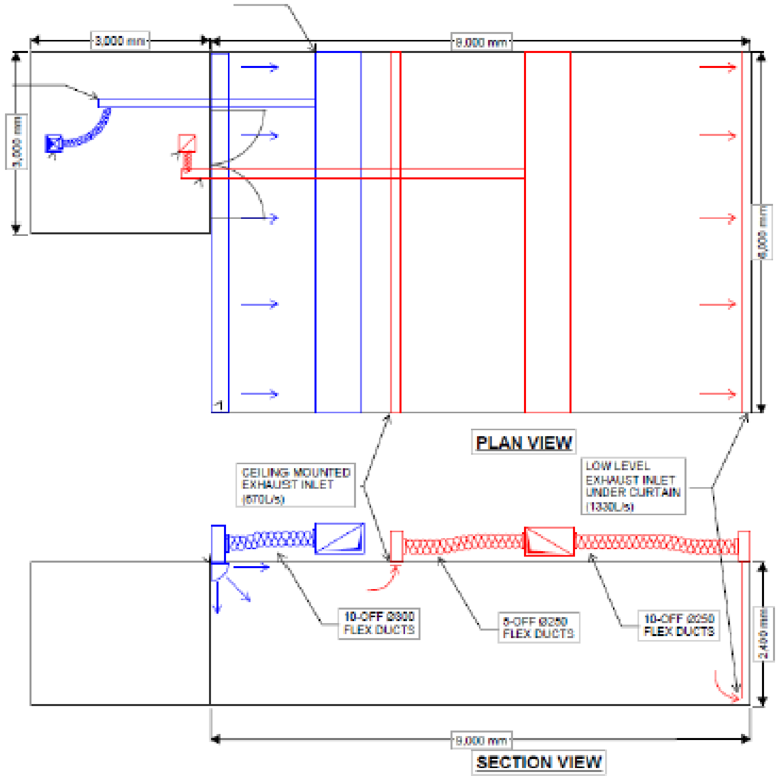


Figure 2 - Proposed mechanical layout

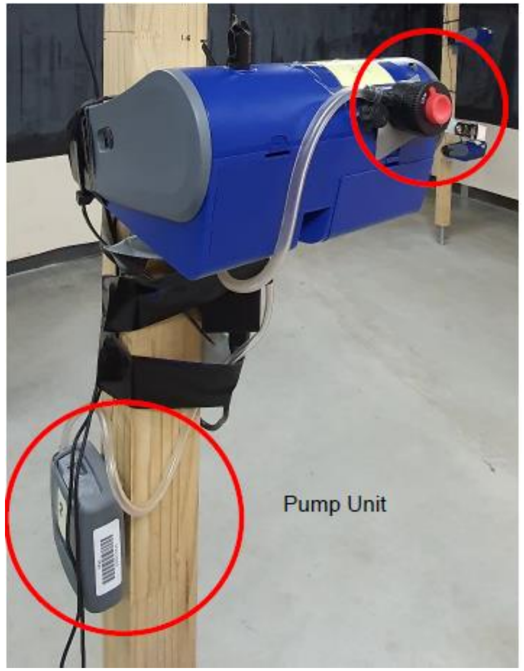
Setting up samplers

Carbon monoxide samplers

Weather anemometer

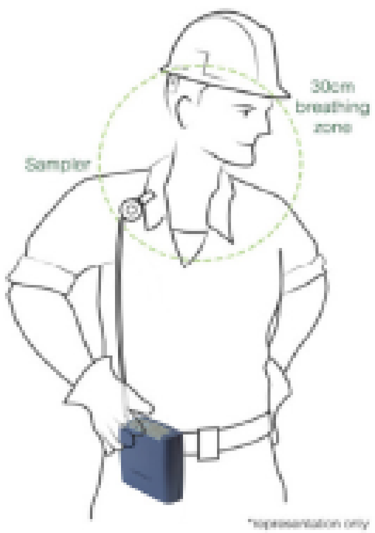
Static Air Samplers

AirChek XR5000



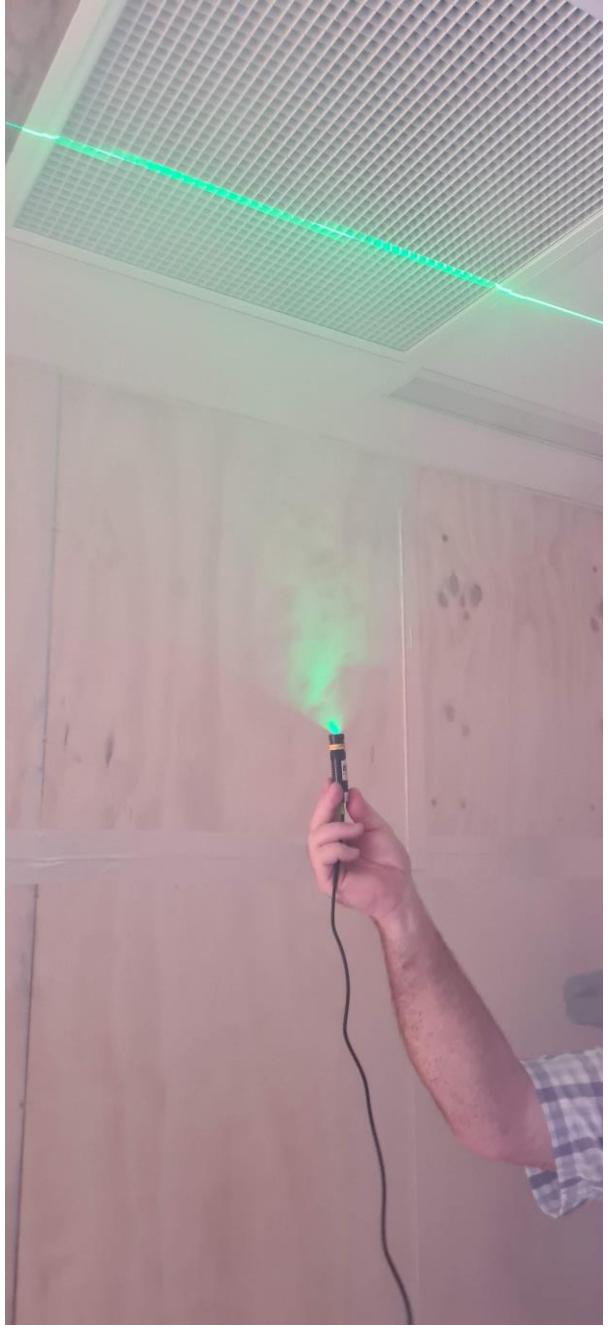
Particulate air samplers

DustTrakDRX 8533 real time sampler



IOM Multi-dust Sampling Head with 25 mm filter cassette 55 g

Testing ventilation system



DustTrak Analysis

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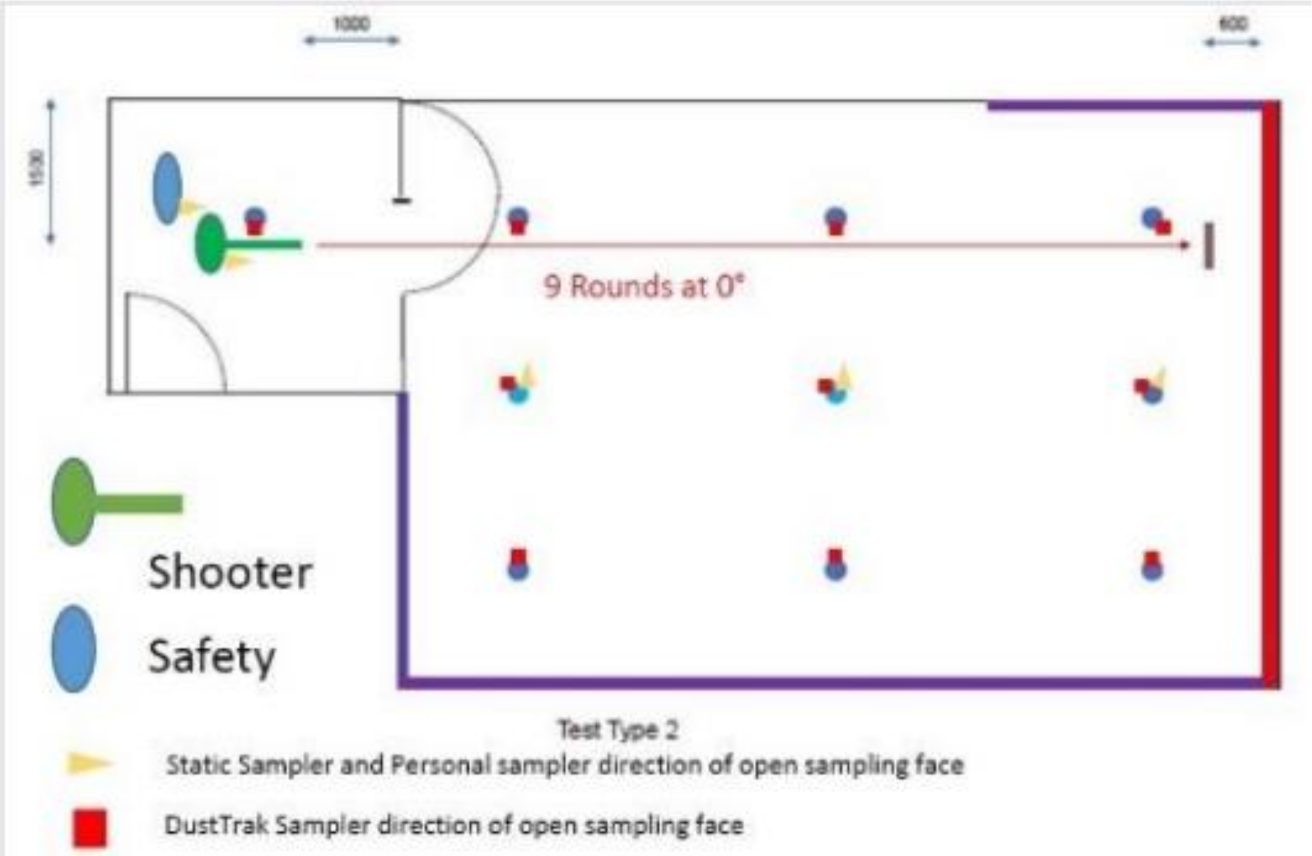
DustTrak Analysis

DustTrak data recorded:

- At **33** points within test facility – spacial data
- At one reading per second
- Giving time varying sample concentration (mg/m3)
- For 4 particle sizes **1.0, 2.5, 4.0, 10.0** PM (μm dia) and Total
- Around 300,000 data points

Example

- **TEST 2, the Serial 2, 2.5 PM** at Sample Post A at 2.1 m **initially**

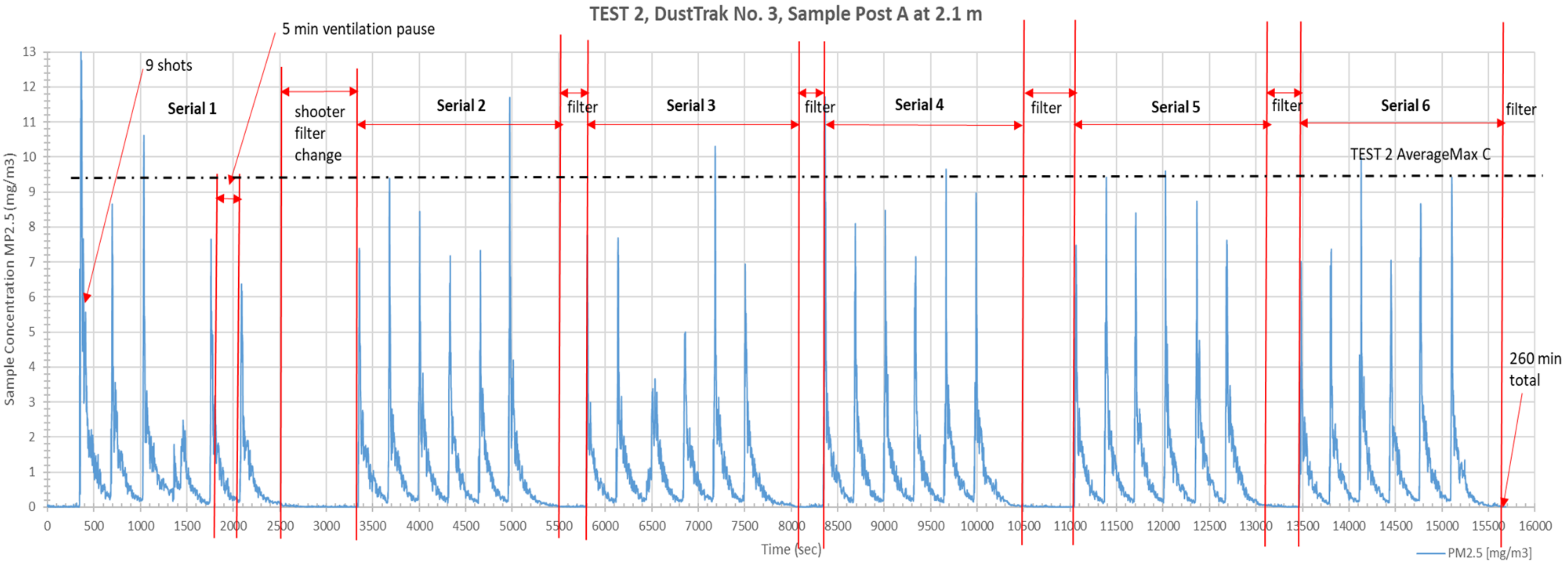


DustTrak Analysis

TEST 2, 2.5 PM at Sample Post A at 2.1 m

6 Serials of 9 rounds each, 5 min ventilation pause (air-con to clear room)

Max concentration from firing of 9 rounds – **clear peaks from firing particulates**

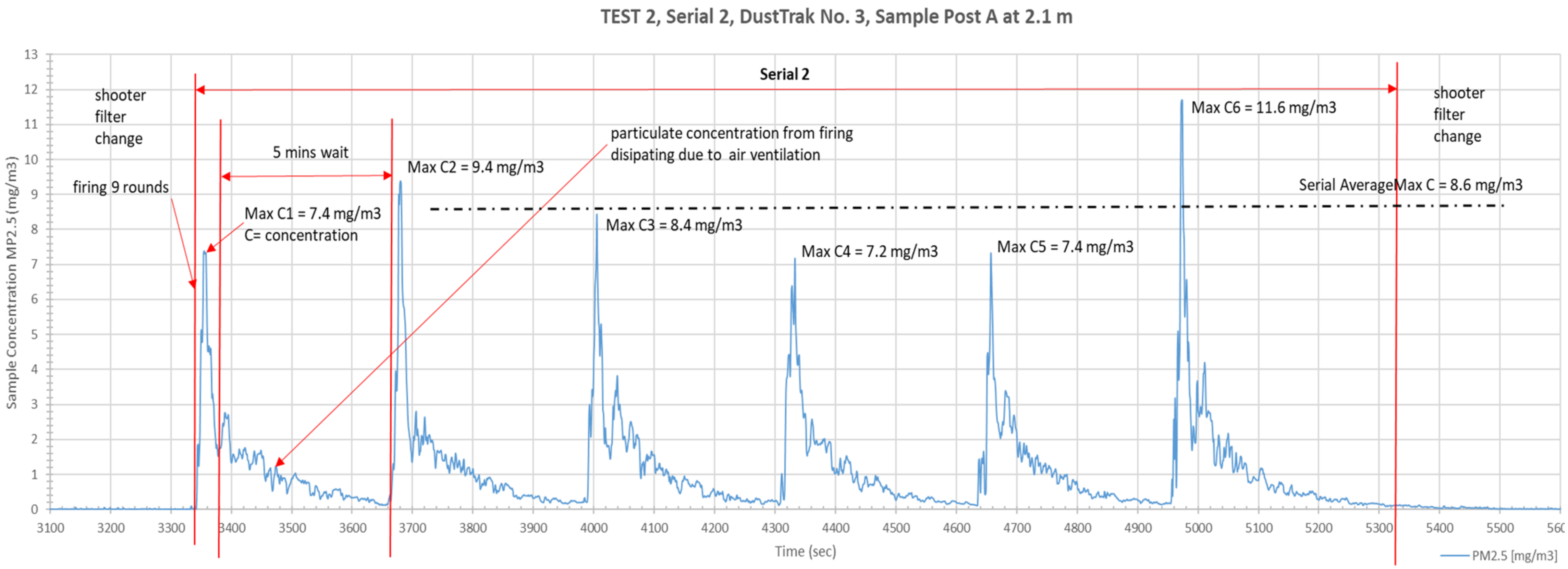


Dust Track Analysis

TEST 2, **Serial 2**, 2.5 PM at Sample Post A at 2.1 m

6x9 rounds each, 5 min ventilation pause

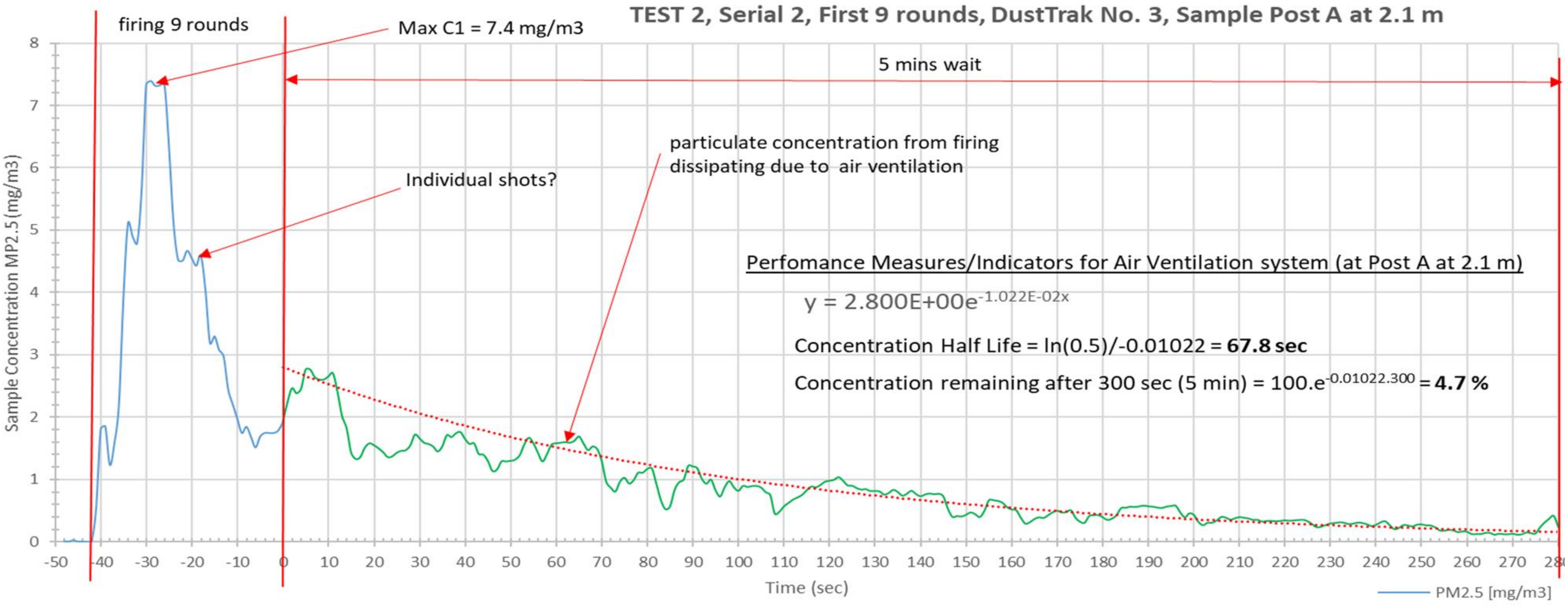
Max concentration after/during rounds – **some variation in max (statistically stable-good)**



Dust Track Analysis

TEST 2, Serial 2, **First 9 rounds**, 2.5 PM at Sample Post A at 2.1 m

Shows 9 rounds firing – **then particulates dissipate as air-con removes particles from room**



Dust Track Analysis

TEST 2, Serial 2, **First 9 rounds**, 2.5 PM at Sample Post A at 2.1 m

Fit exponential curve to particulate dissipation period

Sample Concentration of particle phase varies exponentially due to air-con action

Exponential curve = direct measure of ventilation system performance (at Sample Post A)

Performance measures/indicators for Air Ventilation System

- y = concentration (mg/m3), x = time (sec)
- Half life – time to reduce particle concentration by half = **67.8 sec**
- Concentration remaining after 300 sec (5 min) = **4.7 %**
- Available at **33** locations in test room

$$y = 2.800E{+}00e^{-1.022E-02x}$$

Key air-con performance measures

Very hard to measure

Dust Track Analysis

DustTrak Measurements/Indicators at 33 points throughout Test Room

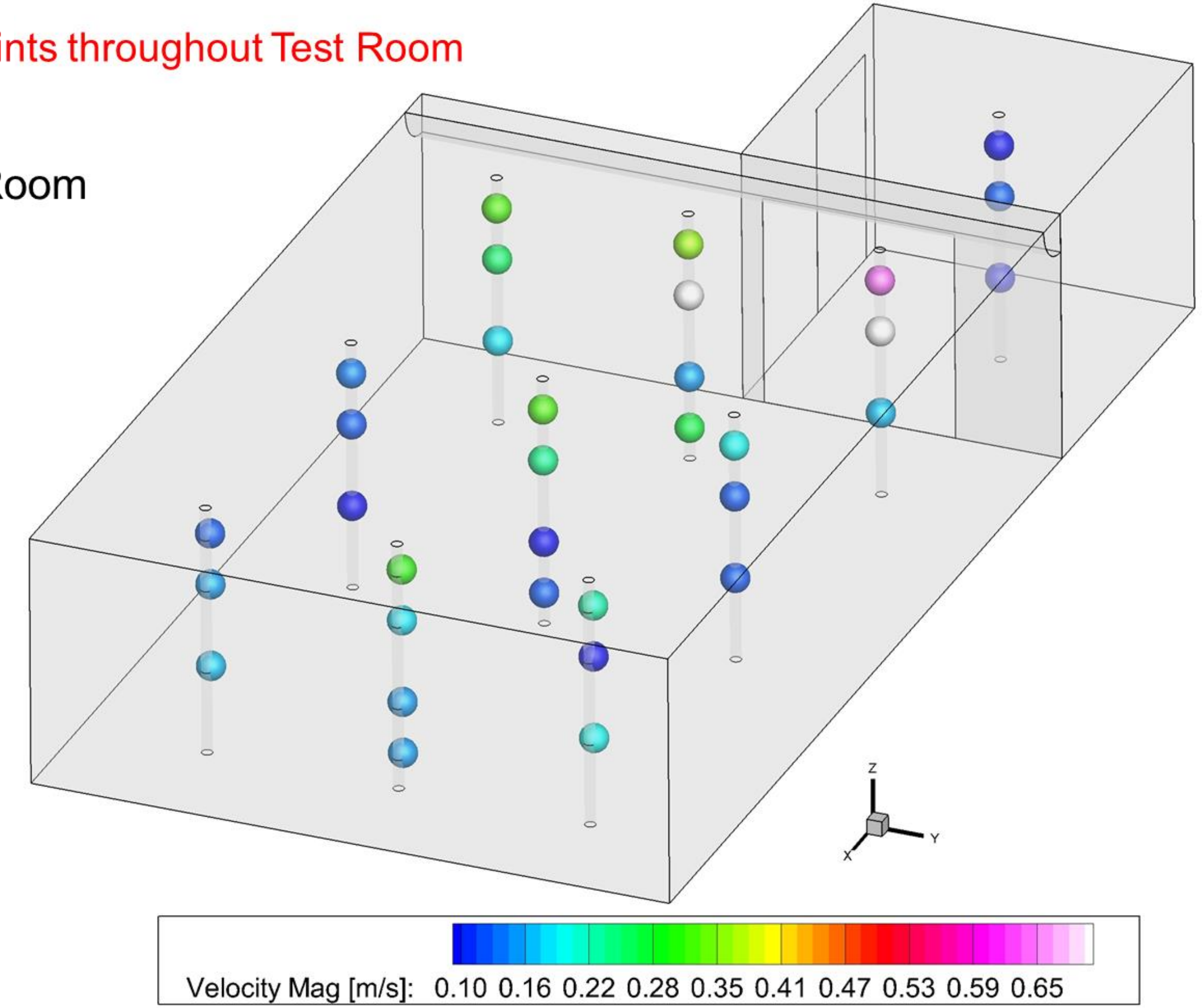
How to best display 3D Data?

Display 3D DustTrak Data, within Test Room

Example of 3D Data Presentation

Velocity Measurements at 33 Points

- Taken 4th Feb 21 (anemometer)
- Higher V near Air-con inlet
- Lower V towards back of room
- Highest V near doorway anti-room

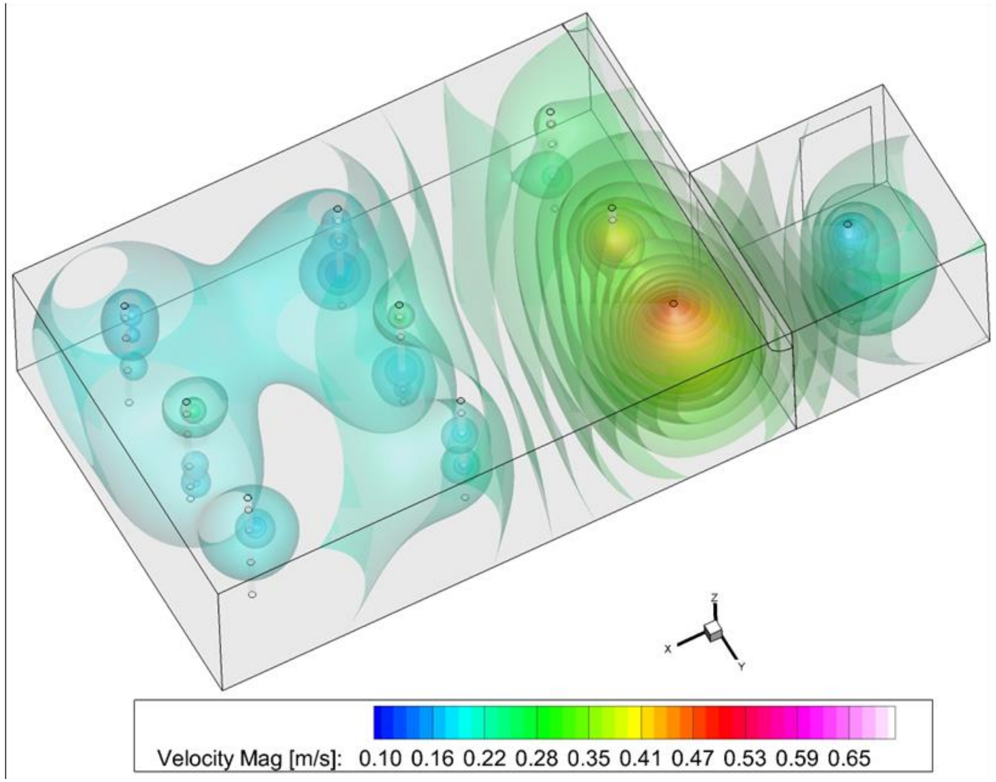


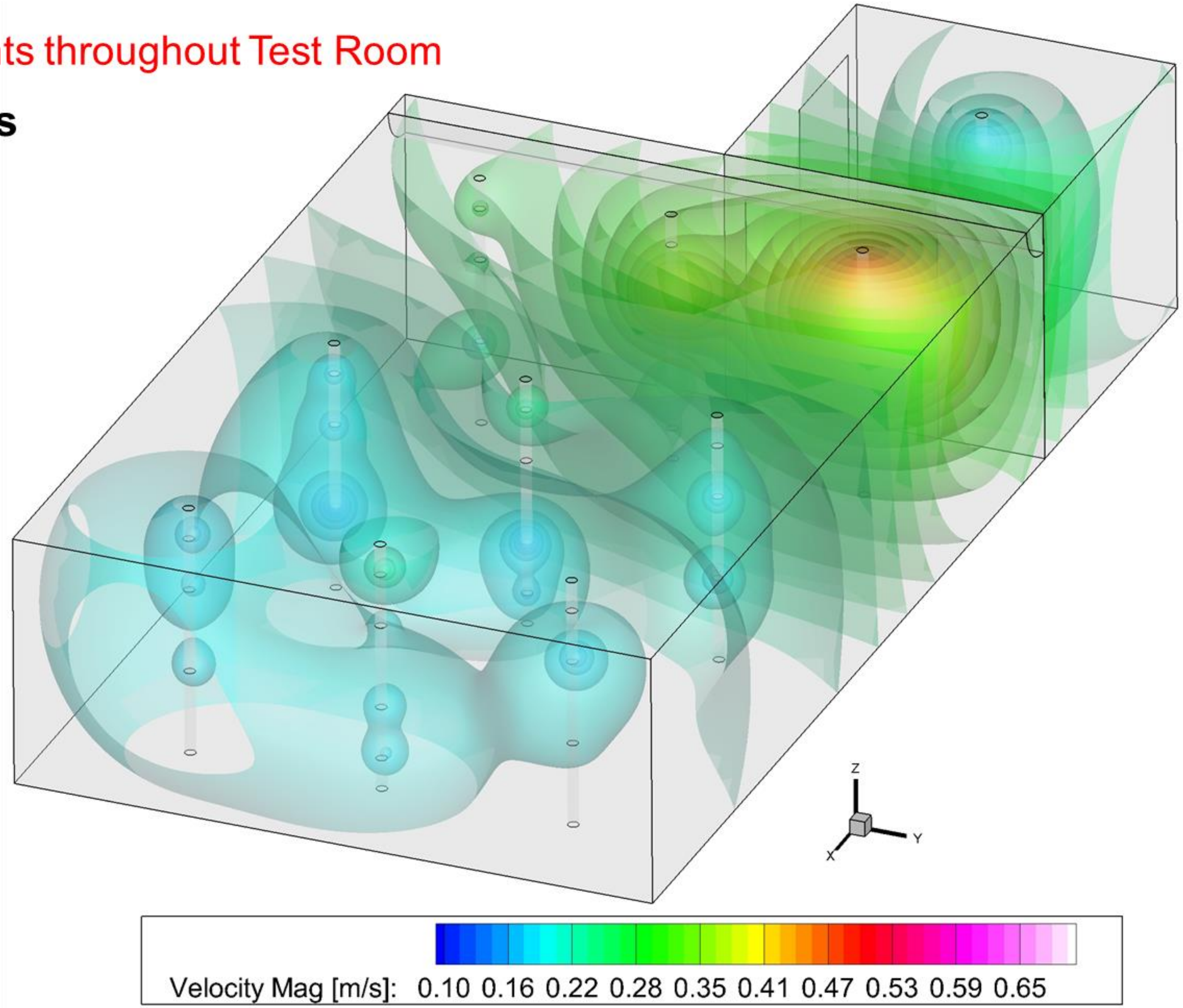
Dust Track Analysis

DustTrak Measurements/Indicators at 33 points throughout Test Room

Data IsoContours – **interpolated contours**

- High V near doorway anti-room
- Can be hard to "see" – good for some data





Dust Track Analysis - Conclusion

33 DustTraks captured considerable detail for the firing particle – air flow

Including:

- Firing and how the particulates spread around the Test Room
- How the Air Ventilation System performs in extracting the particulates – how long it takes!
- Which regions of Test Room are cleared first
- Key Performance Measures/Indicators for the Air Ventilation System

This data was presented as tables, and 3Dimensionally (interpolated)

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Personal Sampling and Other Considerations

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Personal Sampling

- Mass copper / silica / filter paper
- Converted to concentration based on 24 shots / firer and 72 for safety supervisor
- Shooter – 24 shots / 2 hrs with 6 hrs no exposure
- Safety – 72 shots / 6 hrs with 2 hrs no exposure
- Calculate TWA and compare to standards

Results found that exposure did not exceed standards.

Example results – Test 2		
Identifier	Personal Shooter, 6 C	Based on 54 shots / serial
Time of sampling	38	min
Flow rate	3	l/min
Air Volume	0.1140	m3
Dust	0.12	mg/filter
Dust	1.1	mg/m3
Silica	0.01	mg/filter
Silica	0.09	mg/m3
Copper	0.028	mg/filter
Copper	0.24	mg/m3

Other considerations for testing

Cleaning

– Cleaning was conducted at:
  - Mock-up construction completion
  - During testing
  - Disassembly of mock-up

Live fire or remote firing systems

Time required to conduct

- Set up time (establish sampling equipment)
- Data collection between test serials
- Cleaning of facility
- Modification of mockup facility

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Summary and Conclusion

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Summary

This presentation discussed:

Importance of testing to validate ventilation models

How CFD modelling can and cannot assist

What testing has been conducted

An example mechanical testing process

- What to test
- Where to test
- How to collect samples
- Other considerations when establishing mechanical testing

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✱ Thank You

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