EXPOSURE TO EMISSIONS FROM SMALL ARMS MUNITIONS

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Aim

- To identify suitable methodologies to measure the combustion products of small arms ammunition (SAA)
- To obtain objective quality evidence (OQE) of Australian manufactured SAA, and determine quantities of toxic and/or carcinogenic products of combustion

Figure 1: Range Testing

Scope

- Small Arms Ammunition ≤ 12.7 mm diameter and in particular, on 5.56mm
- Projectile is matched to the weapon
- For example:
  - F1A1 5.56 mm to EF88A Steyr
  - M855A 5.56 mm to M4 Carbine (See Below)

Figure 2: M4 Carbine

Composition of small arms emissions (Hughes)

- VOCs
  - Aromatics: Benzene, Toluene, Ethyl Benzene, Xylene (BTEX); Styrene;
  - Butadiene
  - Benzonitrile;
  - Polycyclic aromatic hydrocarbons;
- Inorganic gases
  - Asphyxiants - CO, CO_2, HCN;.
  - Irritants - NH_3, HCl, NOx; SO_2;
  - Other - CO_2, O_2; H_2.
- Metals
  - Pb, Cu, Al, Ba, Sb, Zn
- Unburnt propellant
- *Ultrafine Particles (UFPs <100 nm)
- *Soot

Figure 3: SAA emissions

*Other information sources

Recent evidence

- 90% of the particles - aerodynamic diameter of less than <30 nm (nanoparticles).
- 75% of the particulate material in gun smoke had a diameter <0.61 µm, 12 min after firing, which suggests shooters of Pb-free ammunition may be exposed to large quantities of very fine particulate material (Wingfors, 2014).
- Short-term exposure to fumes from firing small arms may induce both pulmonary and systemic inflammation at exposure levels commonly encountered at shooting ranges.
- Reports of symptoms similar to metal-fume fever reported.
- Exposures are within occupational exposure standards.

Rationale for Emissions characterisation

WHS Considerations

- Keeping exposure as low so far as is reasonably practicable (SFARP);
- Section 17, WHS Act requires risks to health and safety be eliminated. If it is not reasonably practicable to eliminate risk, it must be minimised so far as is reasonably practicable.
- To comply with the WHS Act, Defence must ensure that exposure to any hazardous chemical, or any substance with an exposure standard, is kept so low SFARP.
- Possible impacts on performance of shooter;
- Review effectiveness of controls
- Indoor range ventilation based on inhalable sized measurements;

Issues with Exposure Standards

- Occupational exposure standards, in WHS law intended for conventional industrial or occupational environments;
- Not applicable to ultrafine particles;
- "… exposure limits are mostly defined for other exposure conditions and are therefore not applicable as such for military personnel firing ammunition".
- … exposure to mixtures and combinations of chemicals, which is still a rather underdeveloped area in toxicology" (Van Hulst, PARARI, 2018).
- US Army developed Military Exposure Guidelines (MEGs);
- Best practice vs. compliance: e.g. EU approach to acceptable exposures.

Comparison of the surface area of particles with differing diameters

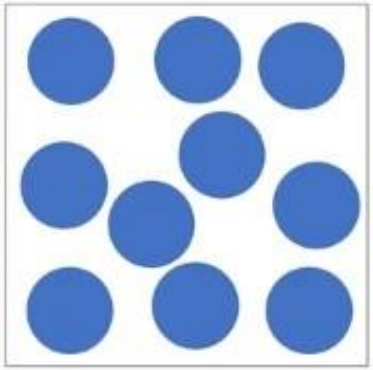
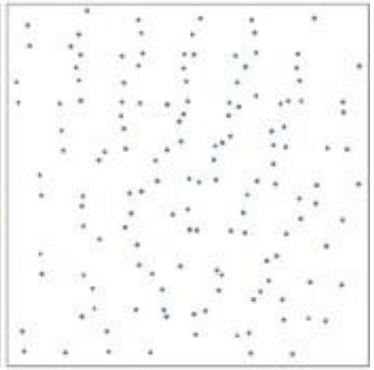
	10 µm (Coarse)	2.5 µm (Fine)	0.1 µm (Ultrafine)
			
Total mass	1	1	1
Particle number	1	64	1,000,000
Surface area per particle	1	0.0625	0.0001
Total surface area per mass	1	4	100
	• Filtered in proximal airway • May irritate skin, mucosa	• Reaches peripheral airway • Cannot enter systemic circulation	• Higher adsorbed toxic material on surface • May enter systemic circulation

Figure 4: Table of differing particle sizes (Hyouk-Soo Kwon, 2020)

Duration of time for which Ultrafine Particles remain airborne

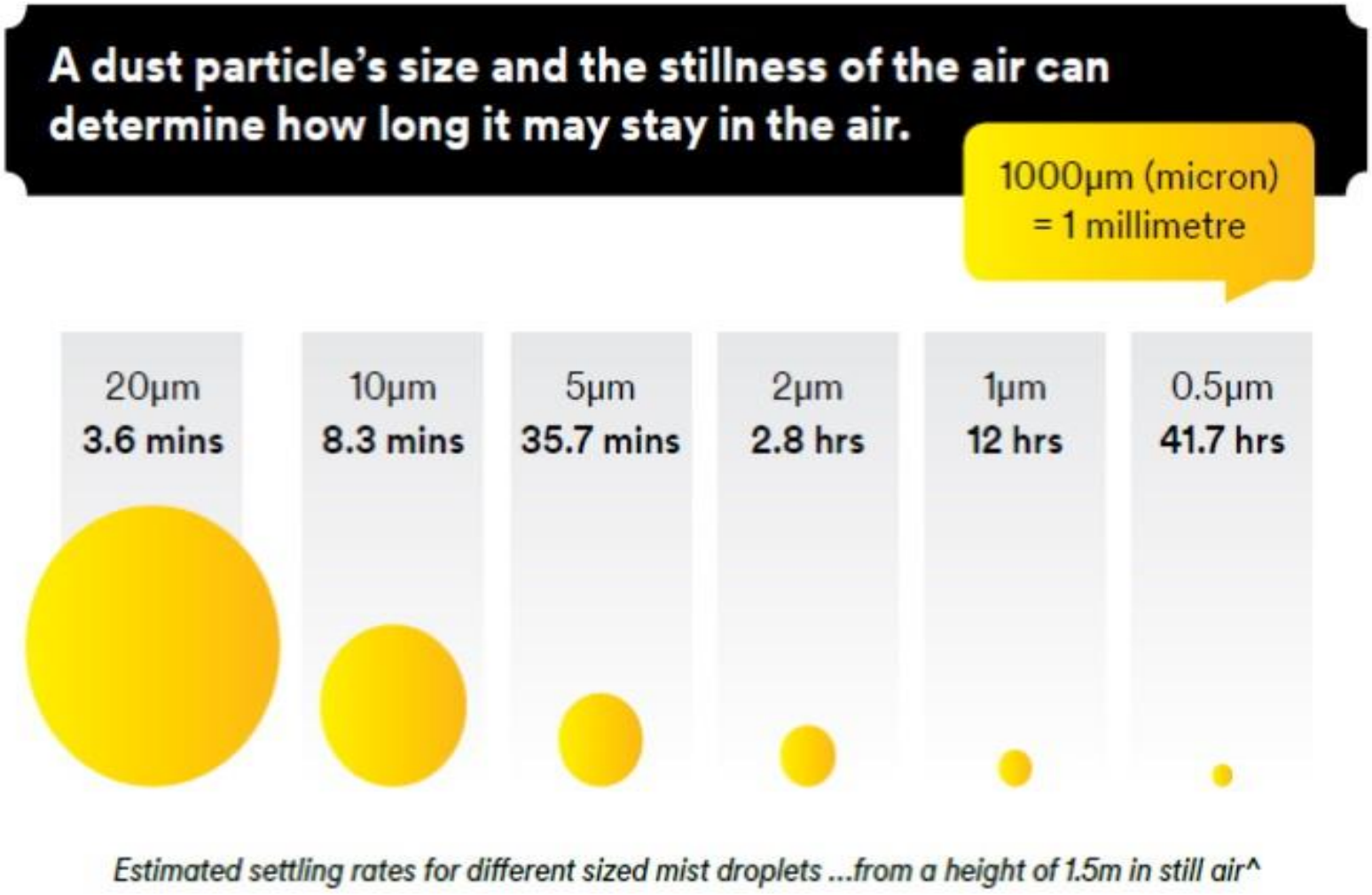


Figure 5: Ultrafine particles duration of time in air (3M, 2020)

Test configurations - considered

Experimental Testing Methods

Chamber Test Method

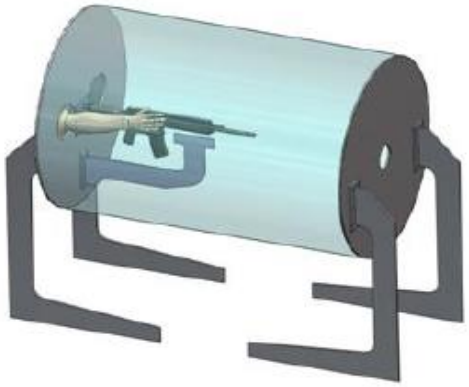


Fig 6 : Chamber Test Configuration (FFI, 2016)

Breathing Zone Test Method

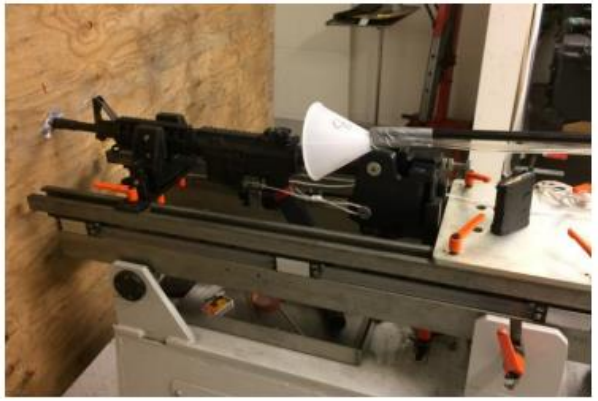


Fig 7: Breathing Zone Test Configuration (DEVCOM Armament Center, 2020)

Test configurations - considered

Chamber Test Method

Pros

- Accurate
- Closed System
- Customisable Environment

Cons

- Time Consuming

Fig 8 : Weapon in chamber test set-up (DEVCOM Armament Center, 2020)

Breathing Zone Test Method

Pros

- Environment Specific Results
- Simple Test Set-Up

Cons

- Time Consuming
- Open System
- Susceptible to Environmental Factors

✓ **Chosen Configuration**

Test Plan

- Chamber Test Method configuration simulated using rig set-up from Swanbourne Barracks

Figure 9: Rig set-up (Hughes, 2009)

Testing scope

- Testing to be conducted at muzzle and ejection port of weapons considered in the program
- Muzzle testing conducted using the test rig below

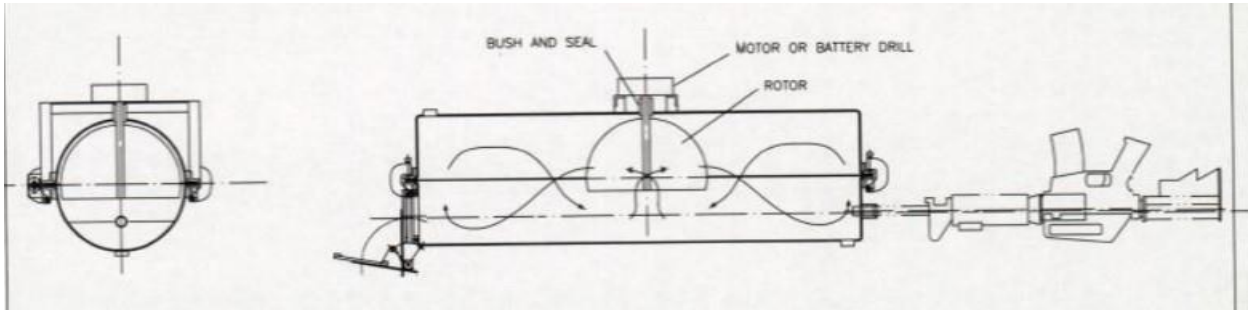


Figure 10: Rig set-up with weapon at muzzle (Hughes, 2013)

- Ejection port testing conducted using a constructed manifold seen below



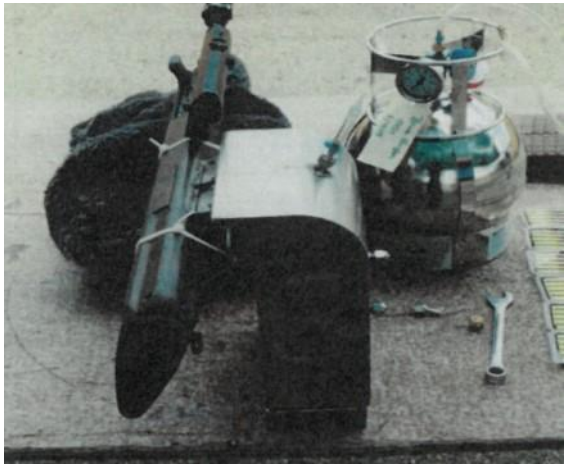
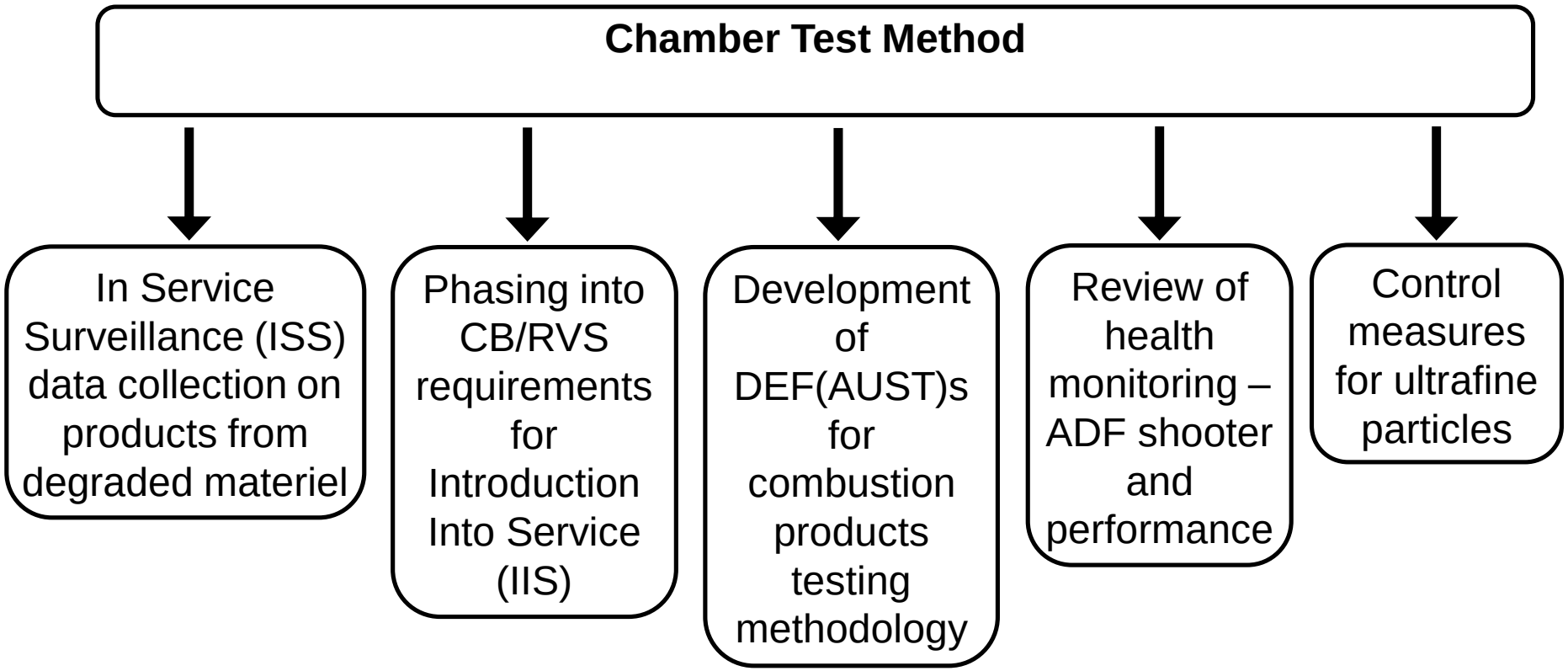


Figure 11: Manifold with weapon at ejection-port (Hughes, 2013)

Proposed Testing

- Proposed testing protocol
  - Control of variables:
    - Weapon-ammunition combinations;
    - With/out suppressor;
    - Consistent ventilation,
    - Constant measurement volume,
    - Relative humidity;
    - Temperature,
    - Identical measuring setup;
    - Position;
    - Consistent number of rounds and
    - Frequency of firing
- Supervision by Expert Range Engineer;
- Sampling & analysis by WA ChemCentre

RECOMMENDED TEST PROGRAM FOR SAA



Questions