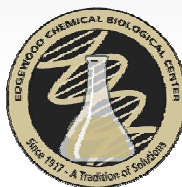


Laboratory Evaporation and Desorption Instrumentation Systems (Wind Tunnels) for Measuring the Environmental Fate of Toxic Chemicals: Comparison of Velocity Profiles with the Earth Surface Layer Profiles

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Outline

- **Atmospheric Simulation**
- **ECBC Agent Fate Wind Tunnels**
 - Microbalance Wind Tunnels
 - Vapor Sample Wind Tunnels, Single Droplet, 5x5-cm Wind Tunnel
- **Comparison of Earth's Surface Layer Velocity Profile to Wind Tunnel Profiles**



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Shrinking Down the Atmosphere

Surface Layer – “Real World”



Lab Chemical
Fume Hood

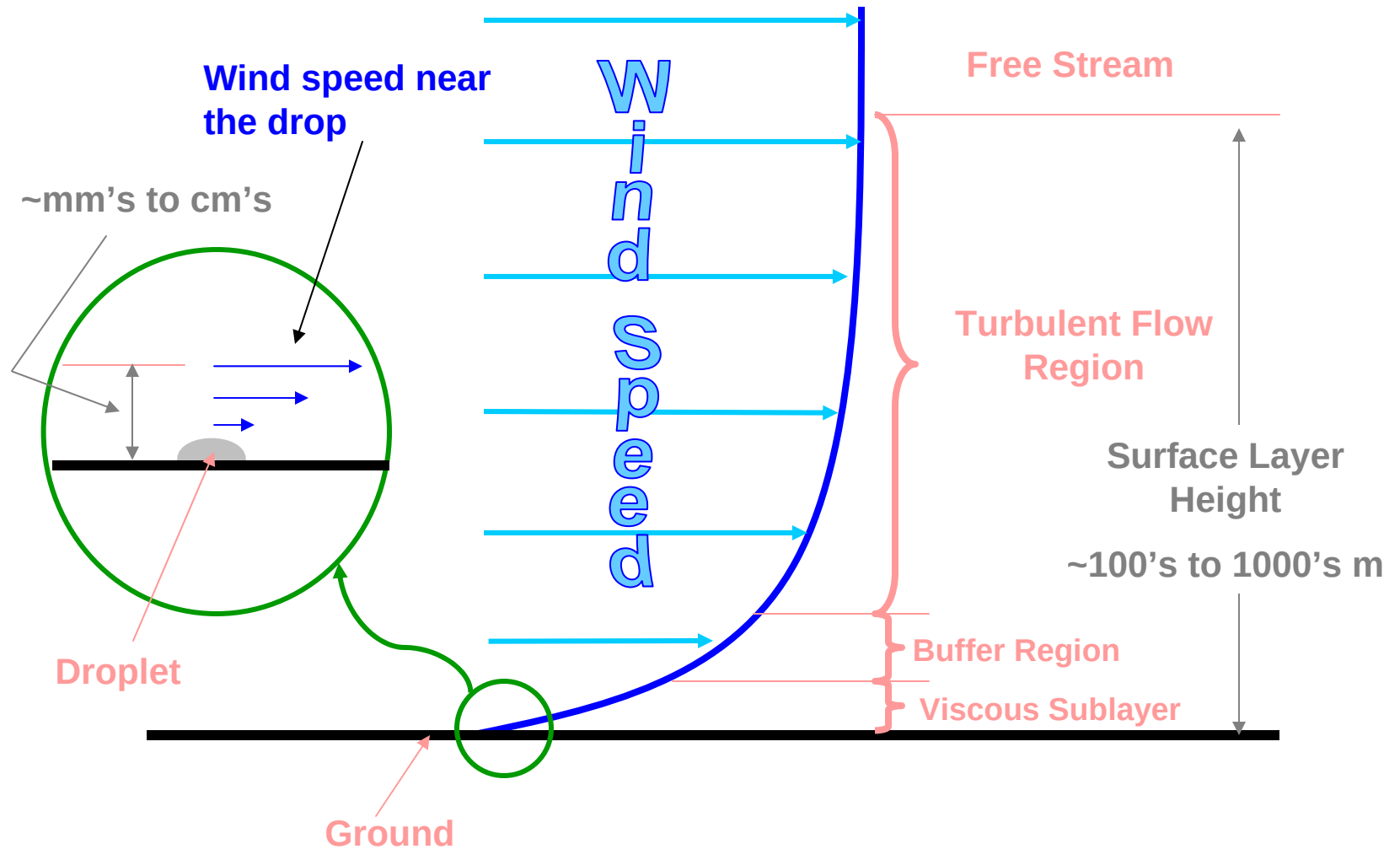


Agent Fate
Wind Tunnel
Test Section



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Atmospheric Surface Layer



Theoretical Vertical Profiles of the Earth's Surface Layer

- Typically described by Frost Curves or a form of the “Law of the Wall”
- Frost Curves or Power-Law Form of the

$$\frac{U}{U_o} = \left(\frac{z}{z_o} \right)^p$$

Where U_o and z_o is the reference altitude and corresponding wind speed. P denotes level of atmospheric mixing

- “Law of the Wall”

$$\frac{u}{u^*} = (u^*) \frac{z}{\nu}$$

Laminar sublayer equation where u^* is the friction velocity, and ν is the air's kinematic viscosity.

$$\frac{u}{u^*} = \left(\frac{1}{\kappa} \right) \ln \left((u^*) \frac{z}{\nu} \right) + B$$

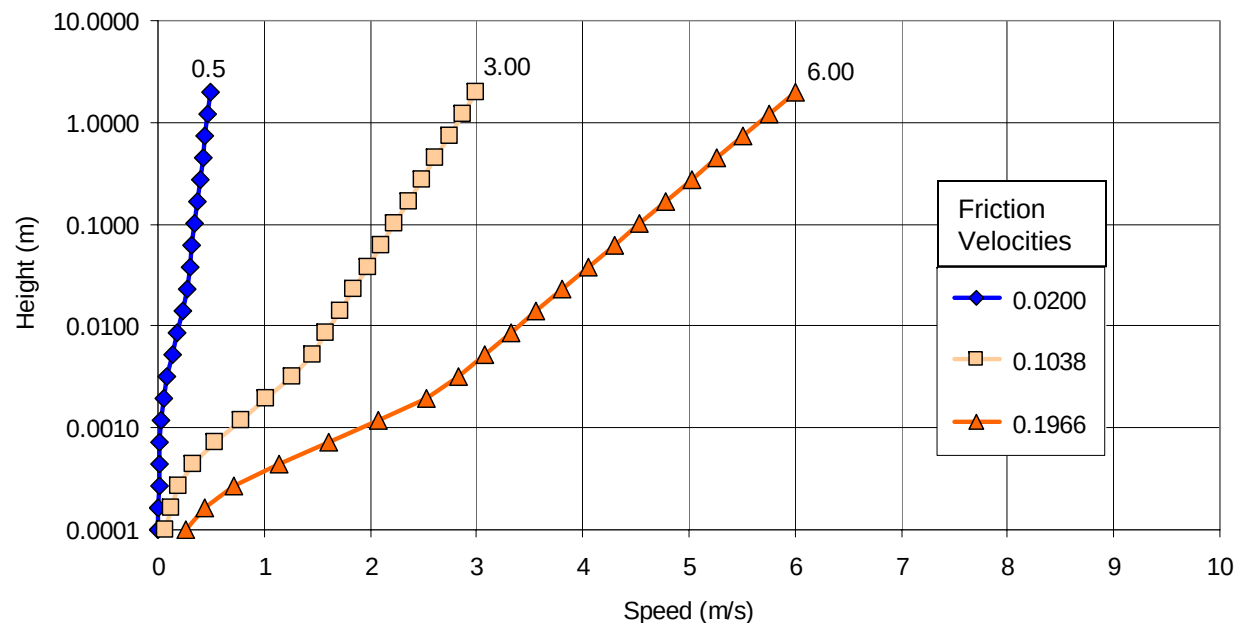
Turbulent region equation where κ is the Von-Karman constant usually = 0.4 and B is a constant ~ 5.5.



Theoretical Surface Layer Approximations

- **Boundary-Layer approximations extended from 2m to near surface**
- **Based on selection of friction velocities to match empirical atmospheric velocities at 2m: 0.5, 3.0 and 6.0 m/s**

Three Friction Velocities (u^*) Yielding
Three Wind Speed vs Height Curves



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Target Velocity Design Specifications

Estimation of 2m Velocities For Two Q600 Flow Rates

		Flow Rates (ml/min)		
		100	1000	
Friction Velocities, u^*		0.007	0.02	Velocities (m/s)
Heights (mm)	1	0.0033	0.03	
	2000	0.154	0.5	

Estimated from
CFD

Adjusted u^* value in to
match the 1mm velocity .
Then estimated 2m
velocity

1000ml/min CFD
estimates matched
the 0.5m/s at 2m
height profiles

TGA 2950 and 5x5 cm Wind Tunnel Target Velocities

Height (mm)	Low (m/s)	Med (m/s)	High (m/s)
1	0.003	0.678	1.882
10	0.222	1.58	3.308
2000	0.5	3.0	6.0



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ECBC Agent Fate Wind Tunnels

- **Microbalance (Thermo-gravimetric Analyzers (TGA))**
 - Single sample pan (model 2950)
 - Dual sample pan (model Q600)
- **Single and Multiple Drop Vapor Sampled**
 - 5x5-cm test section



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ECBC Wind Tunnel Facilities

- **Single drop**
- **Velocity: low, medium and high**
- **Temperature range: 25 to 45 °C currently, 0 to 55 being installed**
- **Humidity range: ~15 to 60% RH**
- **Primary analysis technique**
 - Microbalance: gravimetric
 - 5x5-cm wind tunnel: vapor analysis
- **Additional analyses techniques**
 - Droplet optical imaging
 - Extraction and in situ NMR (Nuclear Magnetic Resonance) analysis
 - HS-SPME (Head Space - Solid Phase Micro-extraction)
 - Others



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Microbalance Wind Tunnels



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Microbalance Wind Tunnels Based on Thermal Gravimetric Analyzers (TGA)

- **TGA's features**
 - Extremely sensitive mass balance ~ 0.1 microgram
 - Temperature control
 - Low air flow rates
 - Record evaporation and desorption of liquid as a function of time
- **Convert TGA to a small wind tunnel by:**
 - Characterize flow field above sample pans
 - Determine flow rate upper limit on TGA measurement sensitivity.



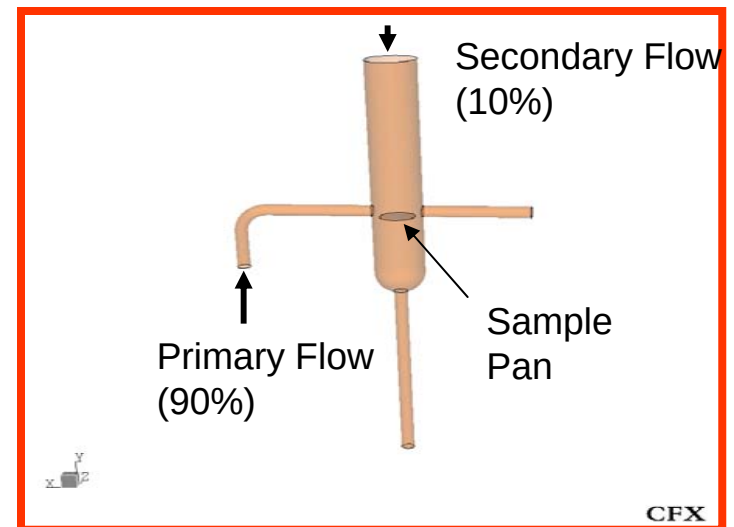
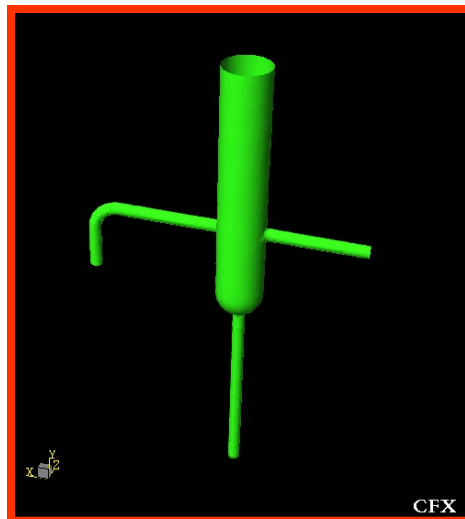
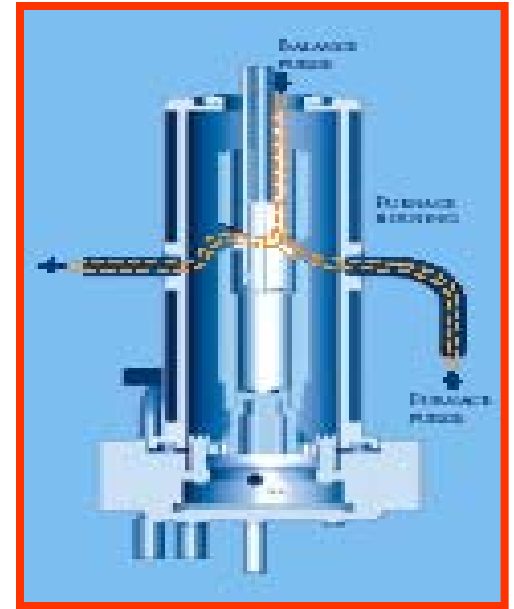
Model Q600
TGA



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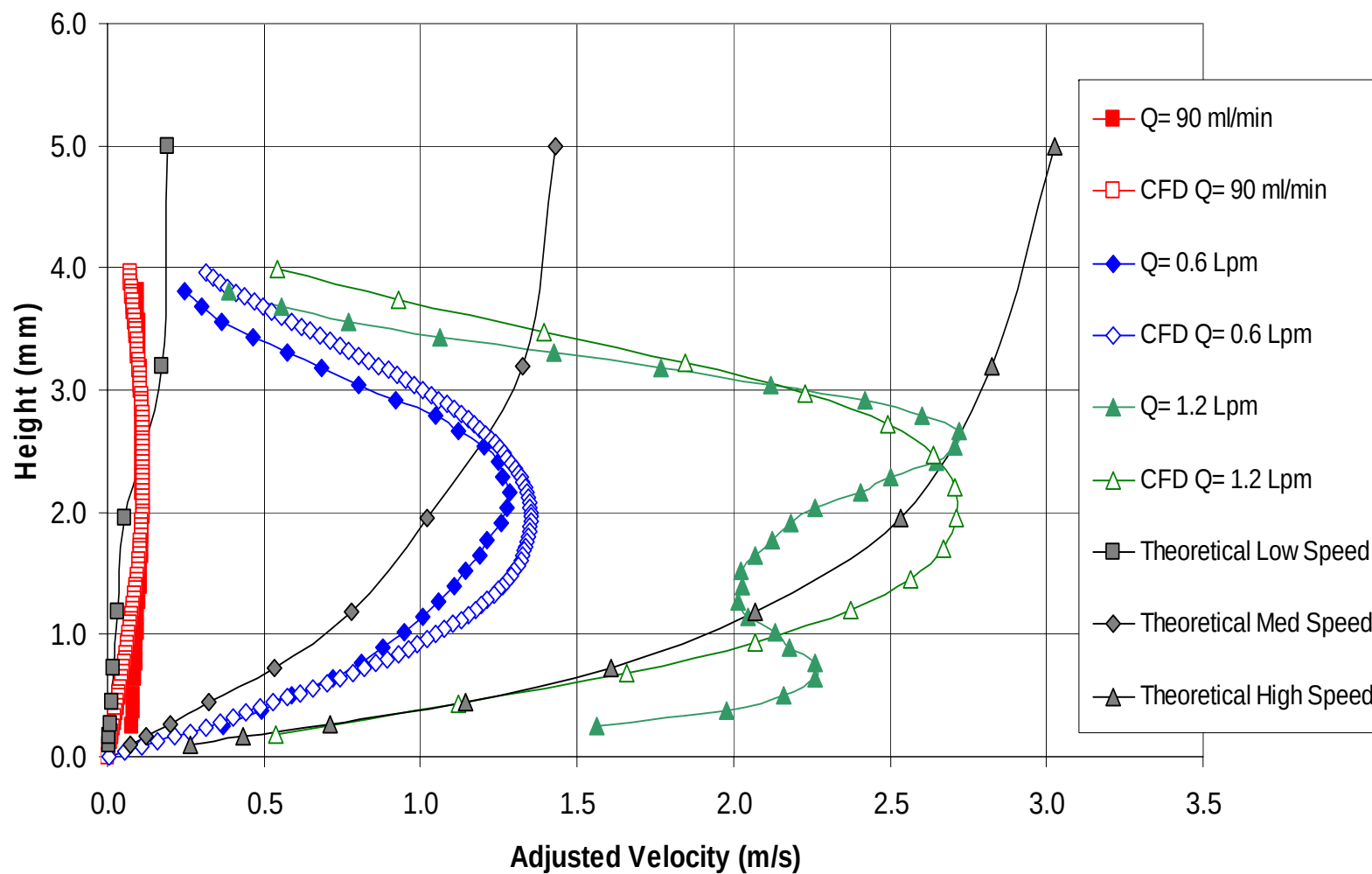
Lab Microbalance Wind Tunnel (TA Instruments Model 2950)

- **Experimental profiles measured in the quartz tube above sample pan**
- **Three flow rates: 0.09, 0.6 and 1.2 Lpm**
 - Measured profiles: no secondary flow
 - Simulated profiles with CFD: above flow rates represent primary flows with 10% secondary flows across entire large tube diameter.
- **Model with and without sample pan**



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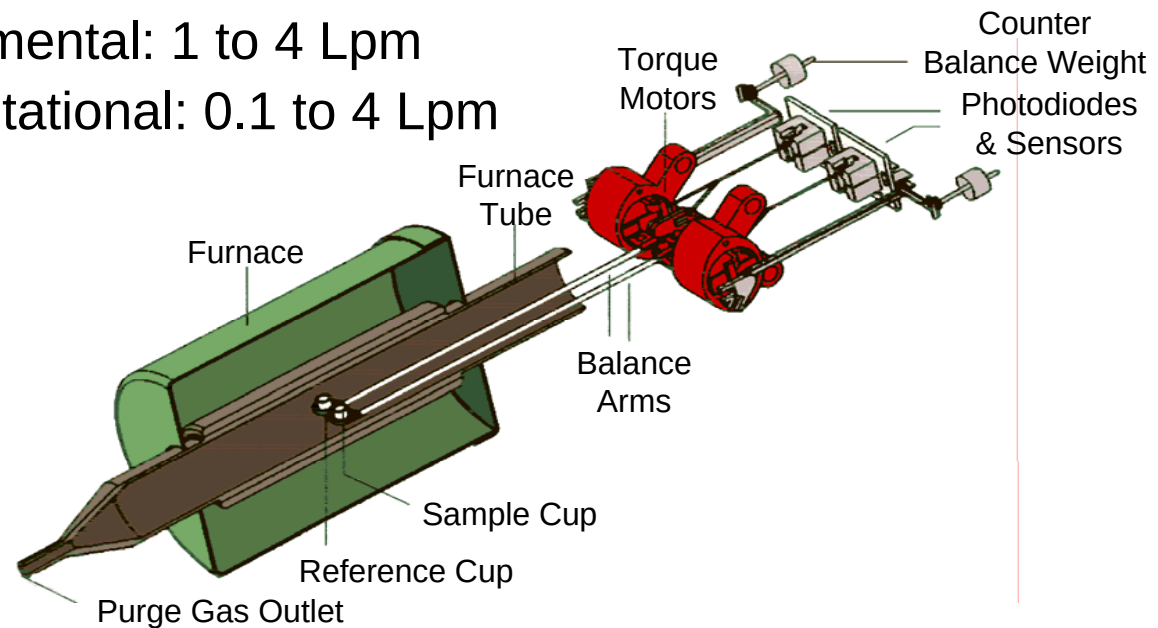
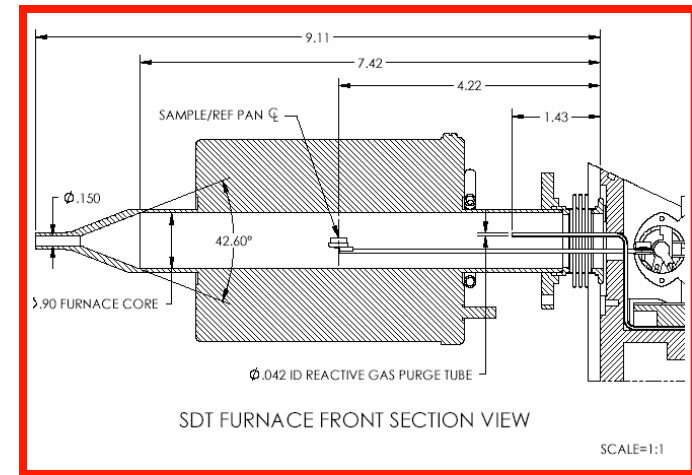
TA Instruments Model 2950 Velocity Profiles



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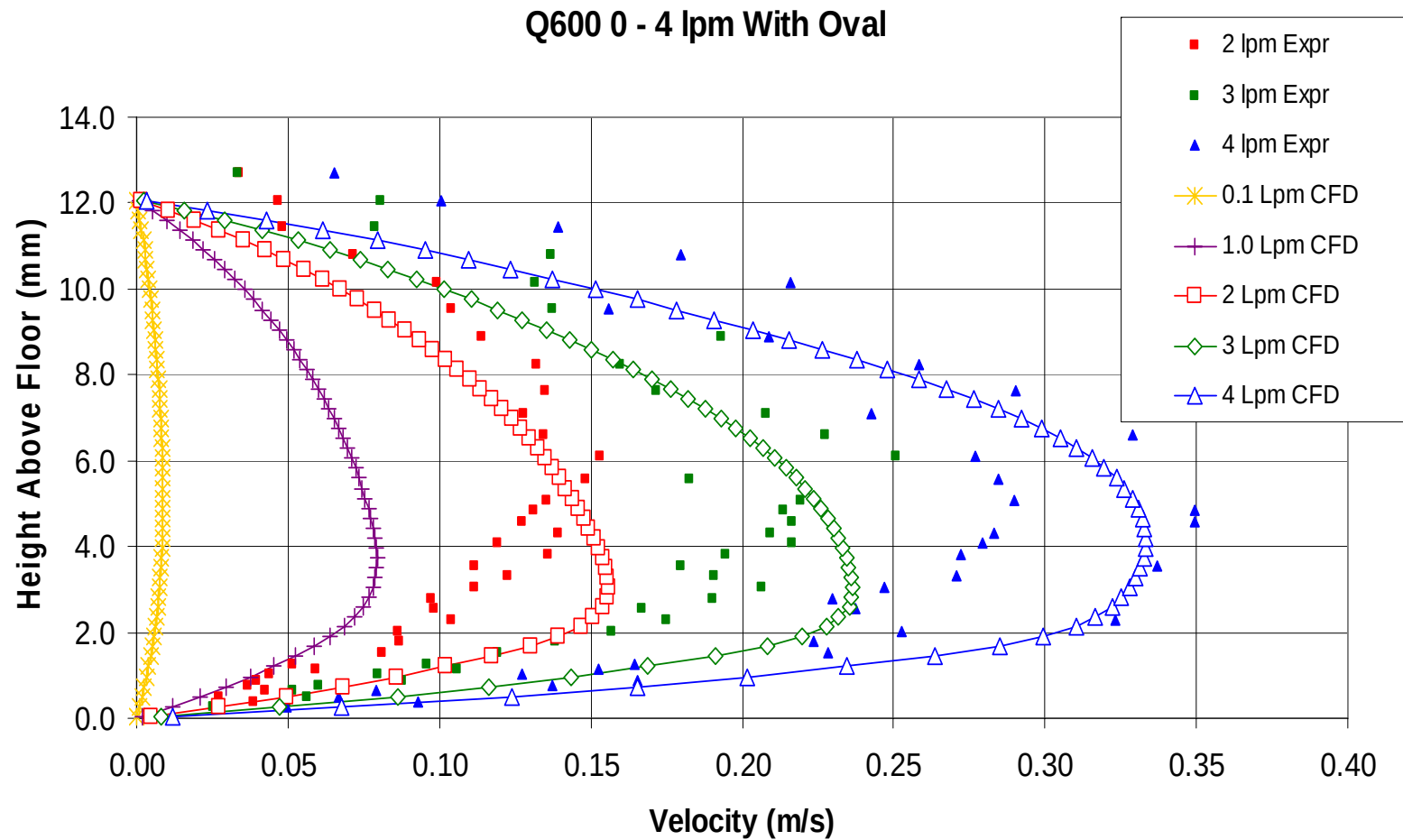
Lab Microbalance Wind Tunnel (TA Instruments Model Q600)

- **Simplify geometry for experimental study**
 - Excluded balance section
- **Simplify geometry for CFD**
 - Excluded balance section
 - Excluded balance rods
- **Range of flow rates**
 - Experimental: 1 to 4 Lpm
 - Computational: 0.1 to 4 Lpm



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TA Instruments Model Q600 Velocity Profiles



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Single Droplet, Vapor Sampled, 5x5-cm Wind Tunnel

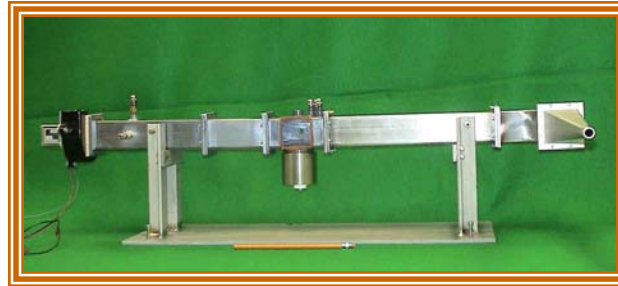


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5x5-cm Wind Tunnel Sections



Blower



Front View



Miller Nelson Transition



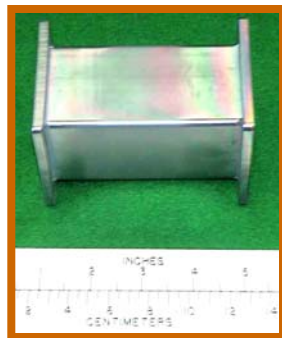
Sampling



Top View



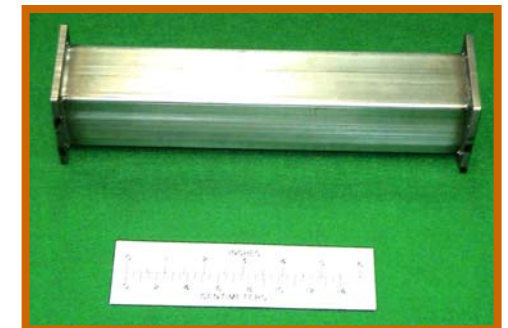
Turning



Static Mixer



Test Section

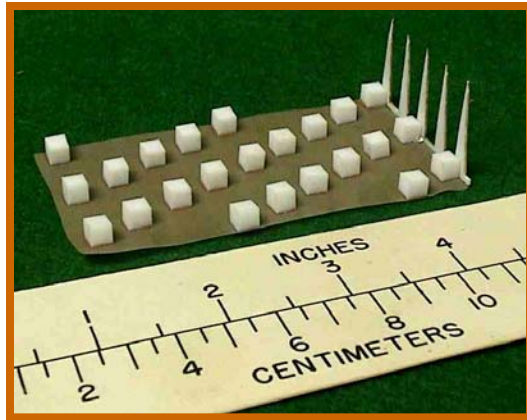


Fetch



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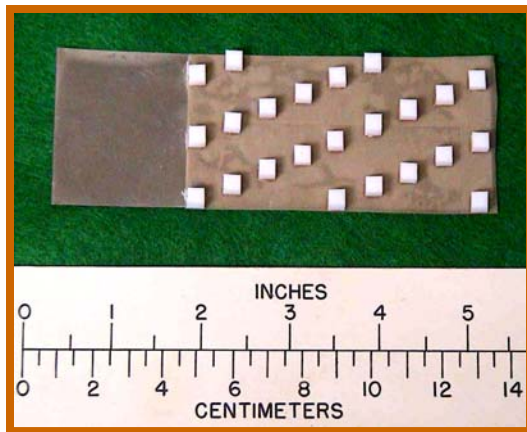
5-cm Wind Tunnel Internal Components



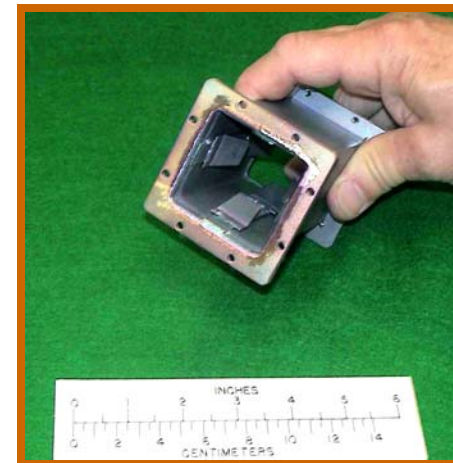
**Turbulence Strakes and
Roughening Blocks**



Adjustable Test Section Piston



Roughening Blocks Only



Static Mixer



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5-cm Wind Tunnel Sections

- **Transition from Environmental Control Unit (Miller Nelson) (1.0-cm diameter) to 5x5-cm wind tunnel**
- **Turning Vane**
 - 90° flow turn
- **Fetch**
 - Smooth
- **Test Section**
- **Static Mixer**
- **Sampling Section**
- **Blower**

Chemical Resistant Coating



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5-cm Wind Tunnel Instrumentation

- **Hotwire anemometer – Velocity near drop**
- **Temperature – Test Section**
- **Static Pressure – Test Section**
- **Humidity – Upstream of Test Section**
- **Chemical Vapor Sampling – Downstream of Test Section**

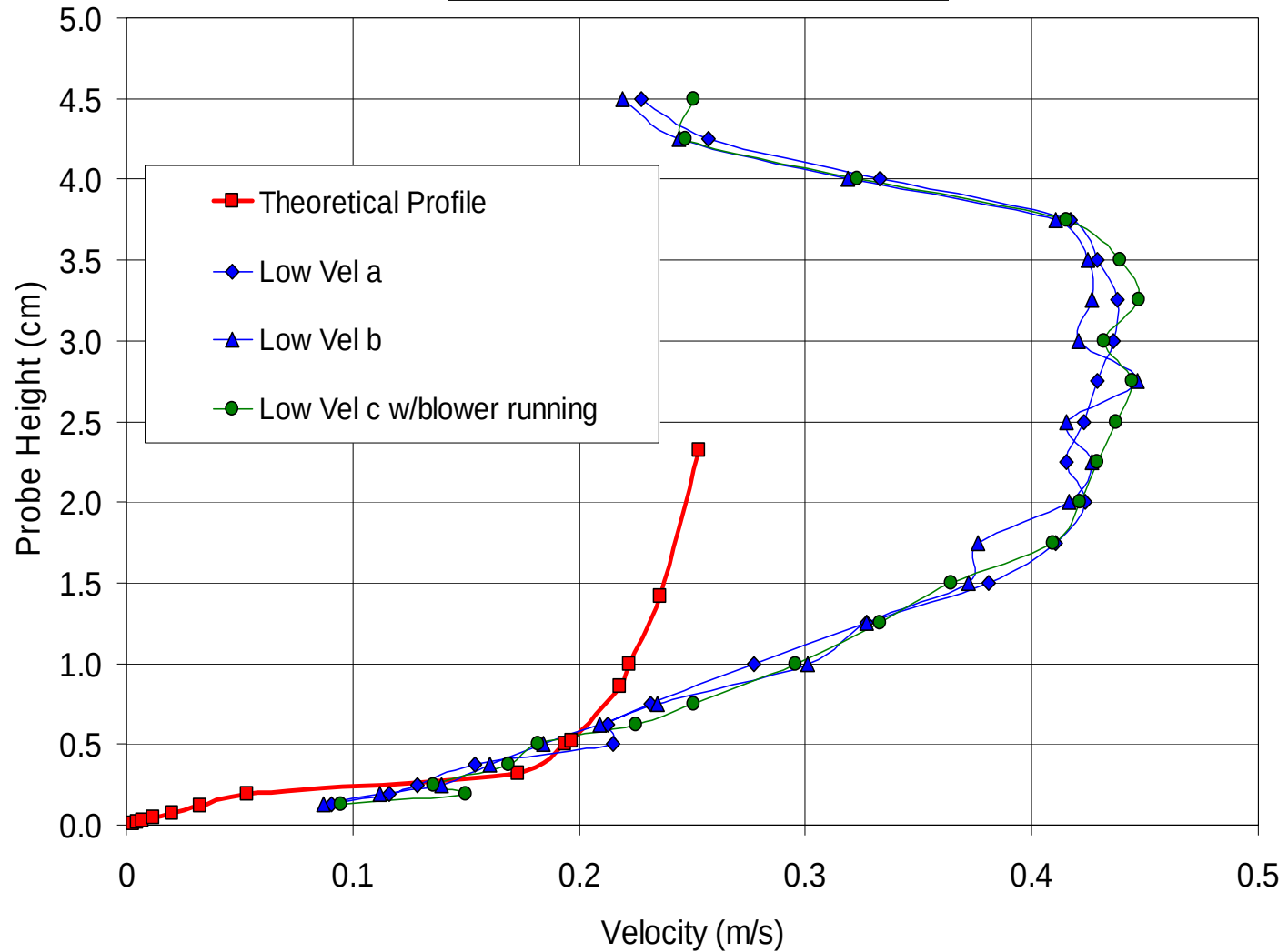


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Low Velocity Comparison

(Q=38 Lpm, T=30 °C, RH=50%, roughening blocks only)

0.5 m/s = 1.8 kph = 1.1 mph

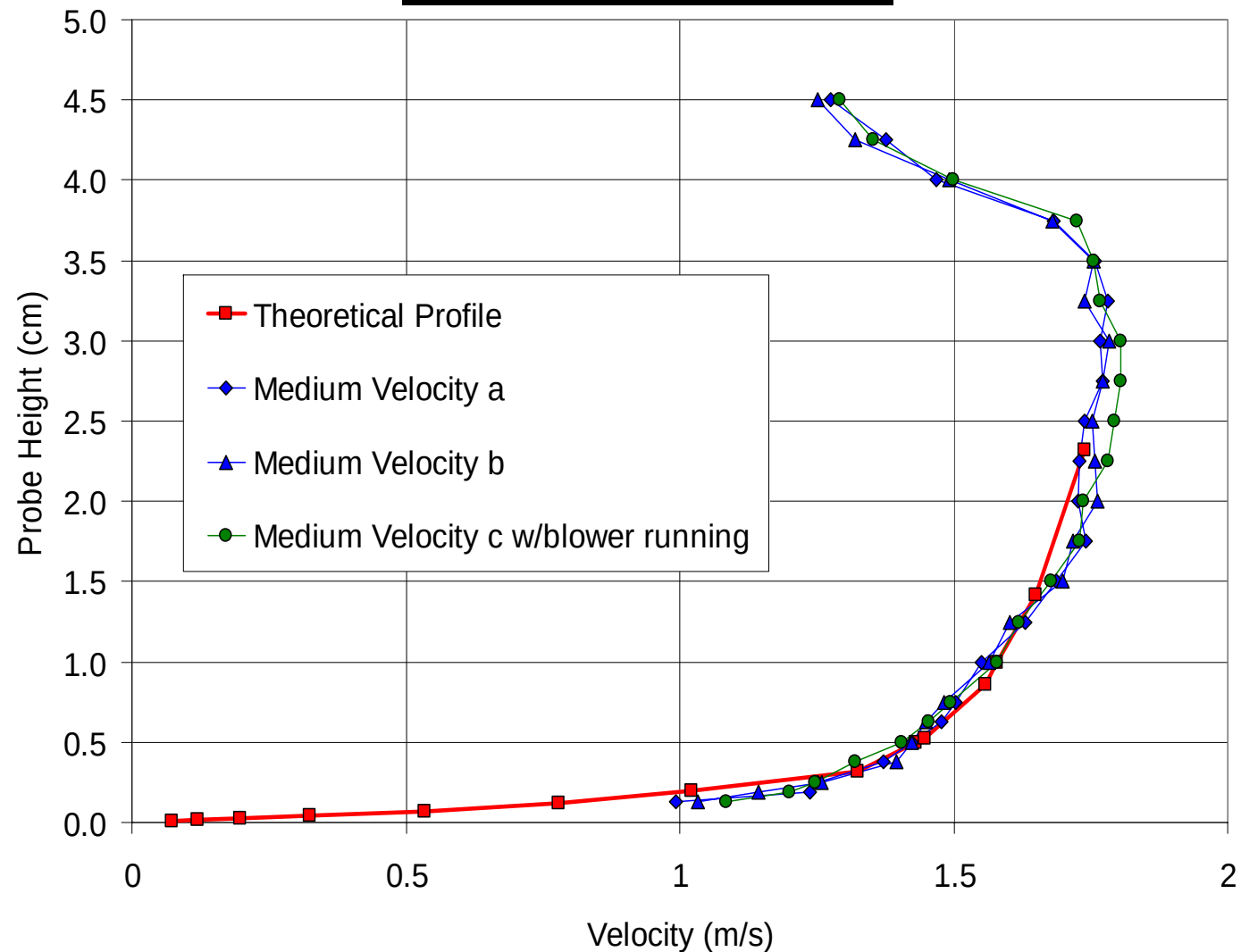


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Medium Velocity Comparison

(Q=185 Lpm, T=35 °C, RH=50%, roughening blocks only)

2 m/s = 7.2 kph = 4.5 mph

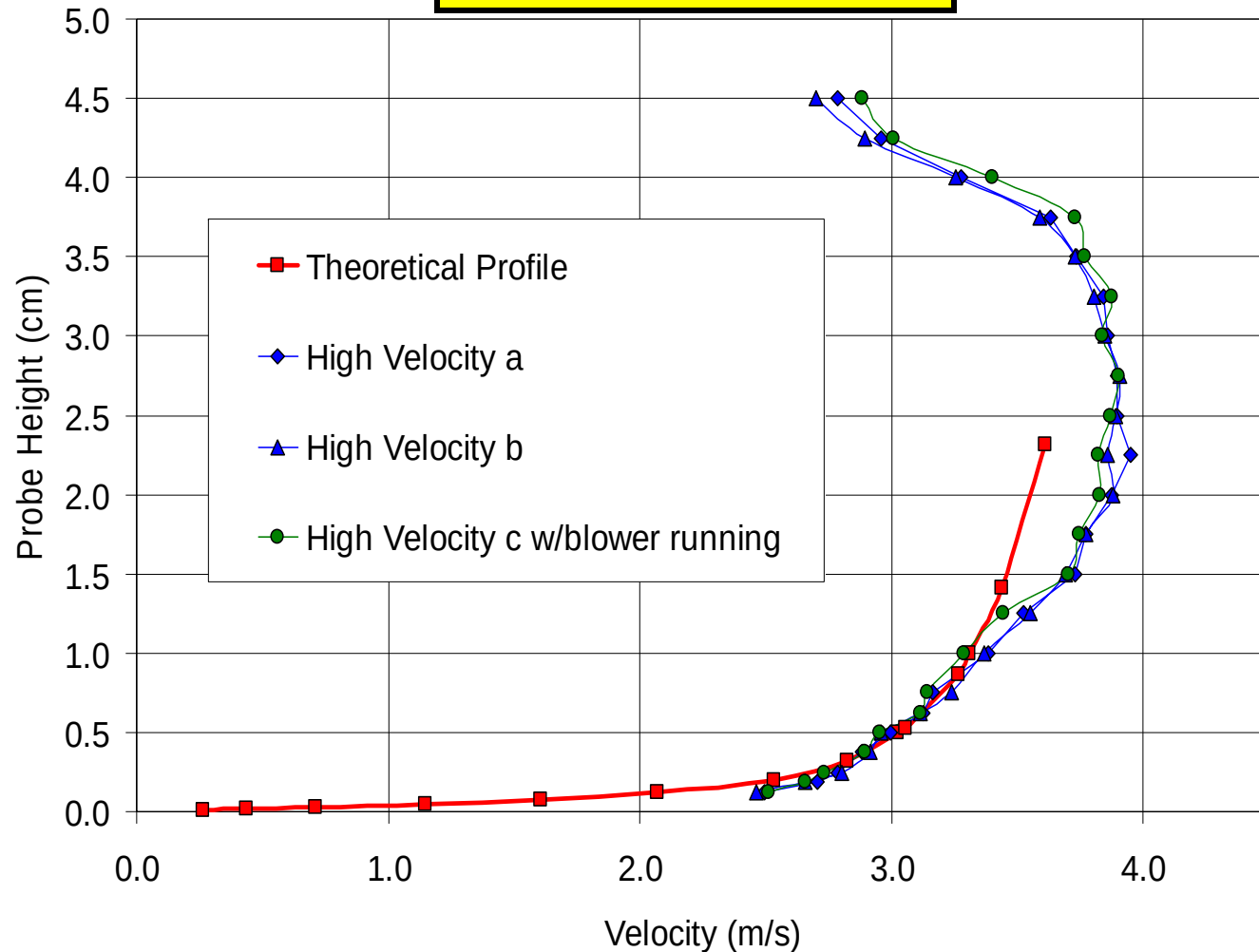


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High Velocity Comparison

(Q=415 Lpm, T=35 °C, RH=50%, roughening blocks only)

4 m/s = 14.3 kph = 8.9 mph



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Summary - Theoretical vs. Experimental Velocity Profiles

- **5-cm Wind Tunnel and 2950 Microbalance Wind Tunnel**
 - Low Velocity: fair agreement from 0.5 cm to surface.
 - Medium Velocity: excellent agreement from tunnel centerline to surface.
 - High Velocity: excellent agreement from 1-cm to surface.
- **Q600 Microbalance Wind Tunnel**
 - CFD runs completed and velocity profiles are being measured



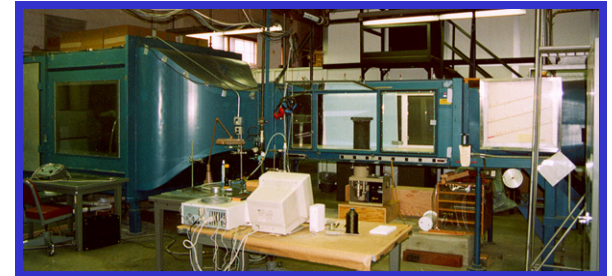
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Target Defeat Team Facilities

Wind Tunnels

- Subsonic Wind Tunnel
 - Aerosol generation capabilities to test Bio Detection systems
- Subsonic Vertical Wind Tunnel
- Transonic Wind Tunnel
- Supersonic Wind Tunnel
- Breeze Tunnel



Compressed Gas Guns

- 25mm diameter, general purpose
- 76mm diameter spinning barrel
- 155mm diameter spinning barrel
- Gator gun for ground impact studies

Other Facilities

- Laboratory Test Fixture for Non-Rigid Payloads Flight Simulator
- Aerosol/Smoke Chamber



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