Breeze Tunnel Testing of Collective Protection Tent Systems

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Introduction and Methods

Introduction

First responders and warfighters must be protected against chemical warfare agents (CWAs) and biological warfare agents (BWAs). Groups are protected in collective protection (CP) areas such as a tent, vehicle, building, or ship. Passive CP structures are protected by barrier materials, filter materials, and closures. Active CP structures feature additional protection by drawing air in through a filter and using overpressure of filtered air to exclude agent.

Due to surety safety and cost, CP structures may not be tested outdoors with agent. Simulants, however, may be used. The results of simulant tests may be combined with agent-simulant relationships (discussed in the companion poster), to predict how the CP structure would behave if challenged with agent on the battlefield.

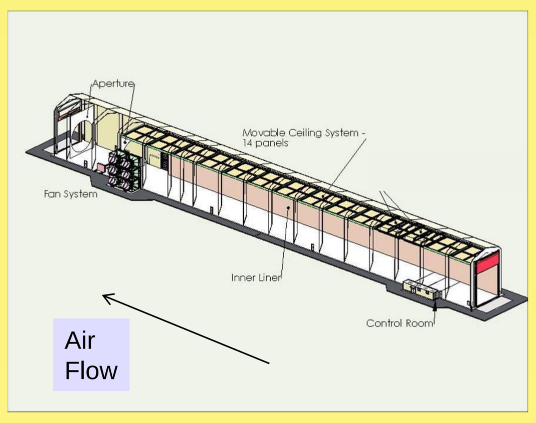
A US Department of Defense (DoD) program funded testing of five tent systems at Dugway Proving Ground (DPG). Active and passive systems were tested. Each system under test (SUT) was tested at different orientations.

There were three types of trials. In an airflow trial, no simulant was disseminated, but the airflow around the SUT was profiled in detail. In a biological simulant (bio) trial, the SUT was challenged with an aerosol of viable *Bacillus atrophaeus* (BG) spores. In a chemical simulant trial, the SUT was challenged with vapor of a simulant.

A minimum challenge concentration × time (*Ct*) was specified for each trial. *Ct* was calculated during the trial by integrating the challenge concentration over time. Simulant concentration and environmental conditions were measured every few minutes at several locations outside and inside the SUT. Reliability, availability, maintainability, SUT control settings, entries and exits, test incident reports, and other logistic data were collected for each SUT but are not reported here.

Methods

Trials were performed in the Joint Ambient Breeze Tunnel (JABT) at DPG from April to August 2012. The JABT is a large breeze tunnel that operates at ambient temperature and pressure. The working length is 100 m, the width is 10 m, and the ceiling height can be adjusted from 4 m to 12 m.



One door of the JABT was closed. Large fans drew air in from the open end, through the JABT. Air was expelled through high-efficiency particulate air (HEPA) filters. Trials were stopped (or not started) and the JABT was closed when the exterior wind exceeded 5 m/s or lightning was observed within 10 miles.

In each trial, the SUT was placed approximately 100 m from the entrance of the JABT near the JABT centerline. The SUT was setup at the specified orientation. Additionally, active SUTs were leak tested to ensure that the supply and return air hoses did not leak, and the filters were seated correctly.

Outside air was drawn into the JABT and out the SUT. Tunnel flow speeds were controlled at 2 or 5 m/s. Simulant concentration was measured inside and outside the SUT at several locations. Barometric pressure, temperature, and relative humidity (RH) were measured inside the JABT. Wind speeds and directions outside the JABT were measured. Airflow entering the active SUT was measured. Differential pressure (ΔP) between the outside and inside of each SUT was measured. Personnel used disposable gloves, foot baths, and other precautions to reduce simulant tracked into the SUT.

Procedures and Conditions

Airflow

Several 3-D sonic anemometers were placed around the SUT, 1 to 3 m above the JABT floor. Three anemometers were located upwind of the SUT to characterize the incident airflow. Anemometers were placed within 1 m of the SUT on each side and downwind of the SUT, to characterize airflow around the SUT. Raw data were collected at 10 Hz. Airflow velocity components were measured across the JABT, along the JABT, and upwards.

Bio

Viable BG spores were milled, fluidized, and loaded into a hopper. Air was blown past the vibrating hopper into the JABT; the flow carried BG to the SUT.

Aerosol includes disseminated particles and ambient outdoor aerosol. A particle may contain no, one, or many viable BG spores. The mean number of viable BG spores per particle depends on conditions.

Aerodynamic particle sizers® (APS™, TSI Inc.) were placed in the JABT outside the SUT to measure total aerosol challenge. APS™ were also placed inside the SUT to measure aerosol penetration. Each APS™ measured a histogram of aerosol size, with 52 bins from <0.523 μm to >10 μm. The histogram was collected every six seconds. Each SUT was challenged with air containing approximately 4000 particles of BG per liter for ten minutes.

All-glass impingers (AGIs) were placed outside the SUT to measure the viable aerosol challenge. Each AGI drew air through a tube into a vial containing growth solution. Every two minutes, a carousel was rotated to draw air into a fresh vial. After the trial, vials were returned to the laboratory. The solution from each vial was cultured, diluted, and counted to determine the concentration of viable BG spores in the air at two-minute intervals.

Slit to agar samplers (STAs) were placed inside the SUT to measure viable BG penetration. Air was drawn through a narrow slit. Aerosol impacted on an agar plate, which was slowly rotated to continuously expose fresh agar. The agar plate was removed, cultured, and counted to determine the concentration of viable BG spores as a function of time.

Chemical

Liquid simulant was pumped into the JABT through nozzles driven by unheated compressed air. Simulant vapor was disseminated at concentrations in the range 100 to 250 mg/m³ for approximately 30 min. Typically, 20 to 60 kg of simulant was used per trial.

Vapor concentration was measured outside the SUT every six seconds using Gasmet™ Fourier transform infrared instruments, previously calibrated using a known vapor concentration.

Vapor concentration was measured inside the SUT every five minutes using MINICAMS® miniature gas chromatographs (OI Analytical), previously calibrated by injecting a known mass of simulant. A five-point, triplicate calibration curve was used. MINICAMS® were frequently checked to ensure that they were still in calibration. Two MINICAMS® were used alternately; one sampled air while the other analyzed. After each trial the MINICAMS® and heated sample lines were cleaned but some vapor remained.

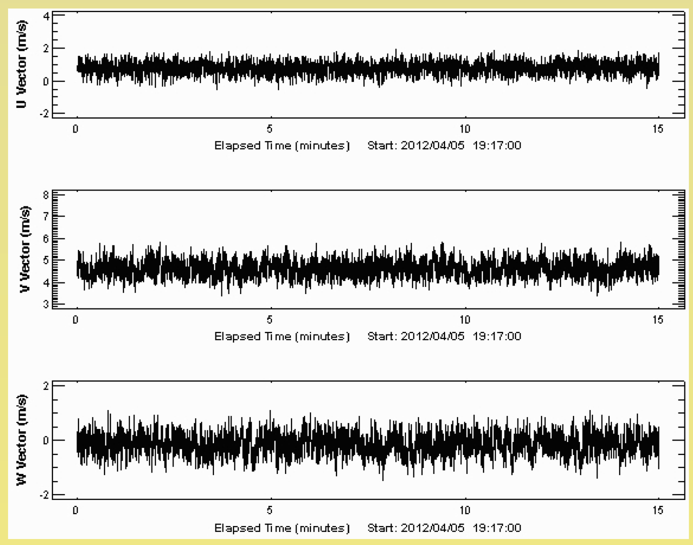
The total mass of vapor entering the SUT during the trial was measured by drawing air through solid sorbent tubes (SSTs). Before each trial, the analysis laboratory prepared tubes spiked with a known mass of simulant. The spiked tubes were exposed alongside and in parallel with the sample tubes. SSTs were then analyzed offline.

Preliminary Analysis

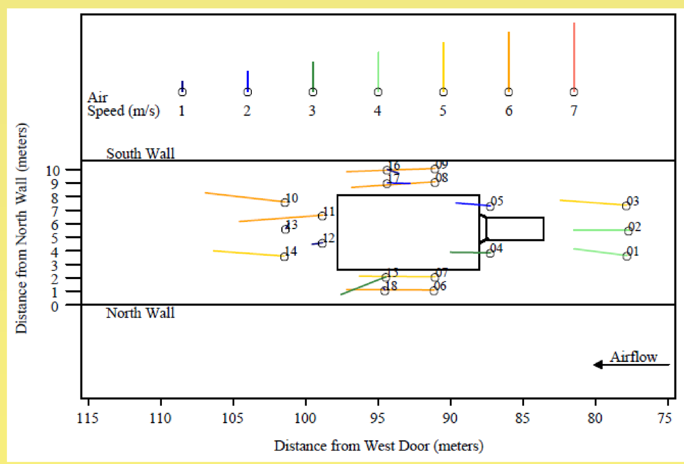
Airflow

Example data sets are presented. Analysis is continuing.

Raw data were reviewed and then averaged to 1 Hz. Tunnel flow speed was well-controlled near the target value. Flow control was less effective when the exterior wind blew at an angle to the JABT. Typical precision and accuracy was 5%.



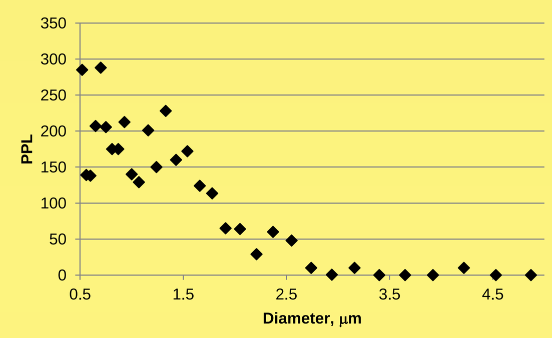
Real-time measurements of air flow at a location outside the SUT



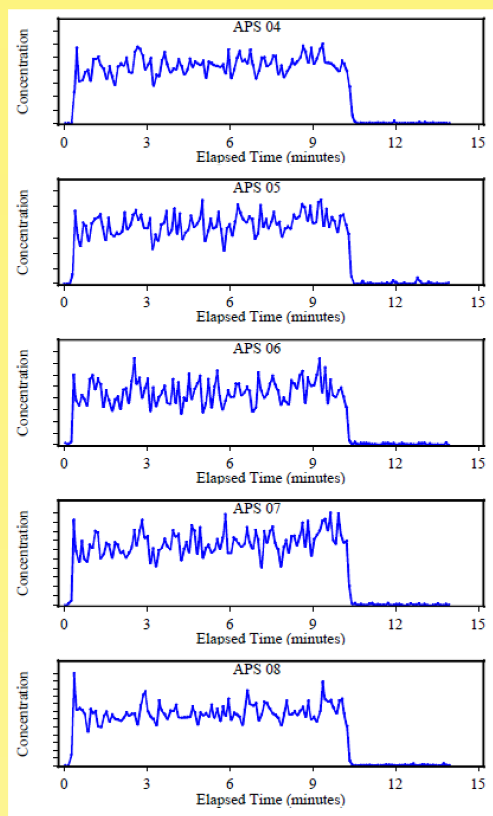
Representative, simulated horizontal air velocities for one trial with a target air speed of 5 m/s

Bio

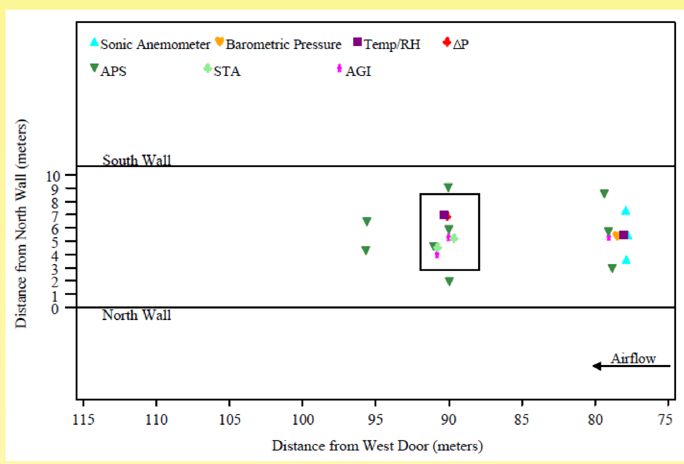
APS™ aerosol histograms outside the SUT peaked near 1 μm, the approximate diameter of a viable BG spore.



The challenge aerosol outside the SUT was somewhat uniform across time and space. Simulated aerosol data:



Particles below 1 μm diameter were removed from all APS™ data. Pre-trial background was then subtracted from APS™ data taken outside the SUT:



Instrument locations for a trial

Outside the SUT, the viable BG Ct measured by AGI was comparable to the total aerosol Ct measured by APS™. Selected challenge data:

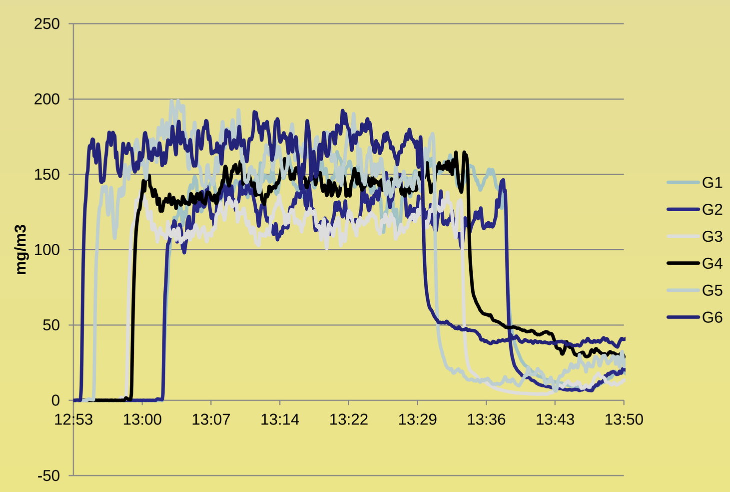
Challenge Position 7 - Upwind of Tent, Center				Temp. Mean (°C)	RH Mean (%)
Background APS Mean (particles/m³)	Net APS Mean (particles/m³)	Net APS CT (min*particles/m³)	AGI CT (min*spores/m³)	JABT	JABT
3.10E+05	4.09E+06	5.72E+07	2.96E+08	17.71	18
4.48E+05	4.06E+06	5.67E+07	1.20E+08	17.85	18
7.04E+05	4.48E+06	6.26E+07	7.28E+07	11.24	11
4.56E+06	1.02E+07	1.42E+08	2.61E+08	15.79	16
3.11E+06	1.05E+07	1.47E+08	1.41E+08	17.79	18
3.18E+06	1.09E+07	1.53E+08	9.97E+07	18.76	19
6.18E+05	6.39E+06	8.90E+07	6.29E+07	19.29	19
8.80E+05	6.37E+06	8.91E+07	9.23E+07	20.10	20
1.49E+06	6.65E+06	9.28E+07	9.67E+07	20.69	21
9.32E+05	4.29E+06	7.13E+07	2.84E+08	25.94	26
7.39E+05	3.85E+06	5.39E+07	2.39E+08	27.13	27
6.05E+05	4.16E+06	5.84E+07	1.05E+08	28.38	28

APS and STA data were also collected inside the SUT, but are not presented in this poster.

Analysis (cont'd), Summary

Chemical

Gasmet™ data taken outside each SUT revealed a challenge concentration that was somewhat consistent with time and uniform from one location to another.



Spiked SST data showed greater than 90% recovery; i.e. simulant did not evaporate from the SST during trial. It is also likely that the sample SSTs effectively captured vapor from the inside of the SUT. Because SST data are averaged over the whole trial, and the MINICAMS® data are measured every few minutes, the SST data serve to confirm the MINICAMS® data.

Future Work

122 well-characterized airflow and simulant challenge trials have been performed on candidate CP tent systems. Each data stream will be further reviewed. Statistics will be determined, trends quantified, and conclusions presented.

SST data will be compared to MINICAMS® data. The concentration measured by the MINICAMS® will be mathematically corrected for the background concentration of vapor remaining from the previous trial. The background-corrected data will be assessed against the MEG concentration for the corresponding agent [1]. Agent-Simulant Relationships have been established.

Field and laboratory test results will be combined. Operationally sound, science-based tactics, techniques, and procedures will be derived for the optimal use of CP tent systems by the first responder and warfighter.

JABT Facility

The JABT has been verified and validated. It is a capable and versatile facility in which chemical and biological protective materials and equipment can be tested using simulants. Standoff optical detection tests have also been performed. To date, the JABT has logged approximately three years of testing. It has met most community and test-specific needs.

Several DoD programs have used the JABT and have accepted the majority of test data. Test reports for completed tests are available from the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD).

Acknowledgements

Employees of the West Desert Test Center, Jacobs Dugway Team, IP Network Solutions, and Dugway Data Services Team coordinated and performed the test, processed trial data, and prepared test documents.

Reference

[1] U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), U.S. Army Aberdeen Proving Ground, Maryland, Health-Based Chemical Vapor Concentration Levels for Future Systems Acquisition and Development, USACHPPM 64-FF-07Z2-07, February 2008 (July 2008 Update).

First Responders and Warfighters

Thank you for protecting the population.
Testers test equipment that protects you!