Testing and Evaluation of Full-scale Collective Protection Filter Systems Against CWA Using Validated Advanced Air Purification Test Fixture (AAPTF)

*Sun McMasters * and Kent Redwine*
Chemical Test Division, West Desert Test Center, Dugway Proving Ground, Dugway, UT 84022
**Corresponding Author – sun.h.mcmasters.civ@mail.mil*

Background

•Chemical and biological (CB) air purification filters have been used by military collective protection (ColPro) systems more than a decade for removal of chemical warfare agents (CWAs) and toxic industrial chemicals (TICs).

•Test and evaluation (T&E) of CB filters has not been conducted in full-scale configuration against nerve and blister agents. T&E has been limited to full-scale testing against CWA simulants and extensive small-scale testing using adsorbent filtration media.

•Assessment of ColPro filtration performance has been to rely on small-scale testing, historical tests, theoretical calculations, and full-filter breakthrough tests against dimethylmethylphosphonate (DMMP) and carbon tube tests with challenges of DMMP, hydrogen cyanide, cyanogen chloride, and phosgene.

•Joint Program Manager (JPM) ColPro identified the need to test full-scale ColPro filters to correlate with historical small-scale testing results, and ensure war fighters' protection in operational environments that may be contaminated by CWAs, TICs, and potential battlefield interferents. The lack of full-scale filter test data on advanced filtration systems, and limited full scale test data on fielded/used filters, were identified as concerns.

•A validated test fixture was needed within the Chemical and Biological Warfare test community to evaluate performance of full-scale collective protection systems.

Figure 1: CB air purification filters and its applications for mobile, individual, and shipboard CBRN protection

AAPTF Testing Capabilities and Attributes

•A validated test fixture was needed within the Chemical and Biological Defense test community to evaluate performance of full-scale collective protection systems.
•AAPTF has been verified and validated to meet the environmental control requirements for testing large ColPro filter devices.
•Test operating procedures have been standardized, demonstrating that the fixture is operationally safe and reliable.
•Capabilities and limitations of the AAPTF for T&E have been established based on completion of its verification and validation trials.
•Results from the representative validation trials are summarized in Tables 1&2 and the data plots are shown in Figure 3.
•Air flows within the AAPTF can be controlled and maintained at all levels between 20 to 500 CFM.
•Temperatures within the AAPTF are controllable and stable with less than 5% variations at levels from 0 to 49 °C.
•Relative humidity within the AAPTF was achievable from 6 to 94 % depending on the temperature.
•Full-scale CB filters were tested against sarin, soman, and mustard as representative CWAs.

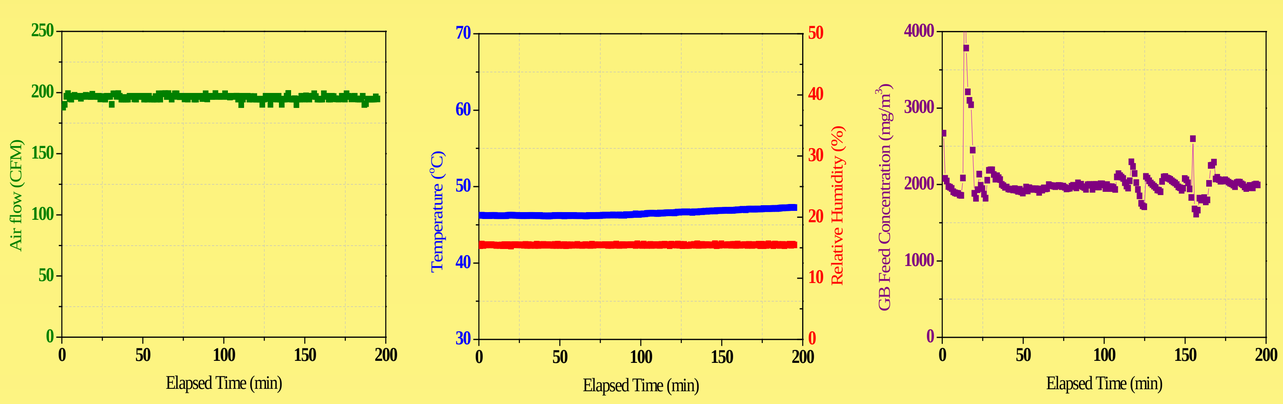

Figure 3: Representative plots of Airflow Upstream of the Filter Box targeted at 200 CFM (Left). Relative Humidity at 15% and temperature at 49°C (Center). Targeted Sarin at 2,000 mg/m³ refereed concentration (Right).

Evaluations

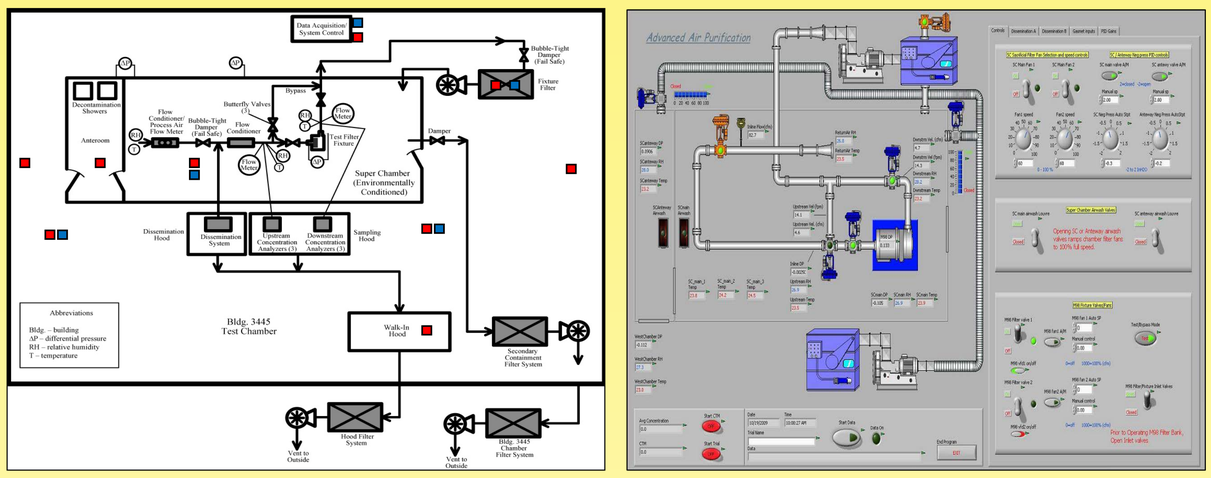

Figure 4: Safety air monitoring locations indicated as red and blue boxes for CWAs and TICs, respectively (Left). Graphical representation (LabVIEW®) TM of AAPTF remote operation (Right)

Trial Number	Challenge Agent/Toxic Industrial Chemical (TIC) Vapors	Target Relative Humidity (%)	Target Temperature (°C)	Number of Replicate Trials		Target Challenge Concentration (mg/m³)
				M98	M48Al	
1	Sarin (GB)	15	25	2	1	2,000
2		15	45	2	1	2,000
3		50	5	2	1	500
4		50	25	2	1	2,000
5		50	45	2	1	2,000
6	Soman (GD)	15	5	2	0	300
7		15	25	2	1	400
8		15	45	2	0	1,500
9		50	25	2	1	400
10		50	45	2	0	1,500
11	Distilled Mustard (HD)	15	25	2	1	200
12		15	45	2	0	400
13	Cyanogen chloride (CK)	15	25	2	0	1,000
14		65	25	2	0	1,000
15	Hydrogen cyanide (AC)	15	5	2	0	1,000
16		15	25	2	0	1,000
17		15	45	2	0	1,000
18		50	45	2	0	1,000
19		65	25	2	0	1,000

Table 3 : Full-scale filter testing test matrix indicating challenge concentrations and environment control requirements.

Introduction

•The AAPTF was constructed in a secondary engineering controlled containment and its capability to test large ColPro filtration systems has been verified and validated.

•Testing procedures were standardized and implemented for testing CB ColPro filters against CWA.

•Engineering control and safety practices for handling large quantities of hazardous materials were developed.

•Operation of the AAPTF was verified and validated under the ColPro Upgrades Program by the Product Director-Test Equipment, Strategy, and Support (PDTESS) and Capability Area Process Action Team (CAPAT). Full-scale filter test results would established a dataset of filter capacities under controlled operating conditions per test requirements.

Figure 2: Chemical Agent Super Chamber, which is the primary containment for the AAPTF, (Left) and the test filter fixture, AAPTF (Right).

Verification & Validation

System Verification:
•Airflow Rates-Results from the airflow excursion trials verified the consistency and accuracy of the airflow rate. Confirmed controllability of targeted rates were 20, 100, 200, and 500 cubic feet per minute (CFM).

•Temperature and Relative Humidity-All targeted temperatures were achieved within ±2°C as shown in Table 1. Temperature was controllable and maintainable in the fixture at the required temperatures from 0° to 49°C. The targeted RH was achievable and controllable with temperature restrictions.

•CWA and Simulant Dissemination-A sparger-type disseminator was used to achieve the targeted vapor challenge concentration of CWA and methyl salicylate (MeS).

System Validation:
•The AAPTF was validated for challenging full-scale filters with CWA until breakthrough. Summary of results are shown in Table 2.

Temp. (°C)		WVC (mg/m³)		RH (%)	Airflow (CFM)	
Target	Measured	Target	Measured	Measured	Target	Measured
Amb.	28.00	Amb.	2512	13.60	500	489.53
Amb.	30.89	Amb.	2105	11.02	200	195.71
Amb.	32.12	Amb.	1541	8.74	20	19.46
0	0.27	Amb.	1306	31.83	200	195.11
0	0.26	Amb.	1194	29.56	500	488.82
25	23.99	Amb.	4767	22.91	200	195.58
49	48.64	Amb.	3109	6.72	200	195.59
49	48.44	Amb.	2621	5.94	500	489.72
49	48.46	3921	4648	6.08	200	193.10
49	48.38	3921	4243	5.57	500	488.45
49	48.42	31366	26969	35.34	200	195.41
5	4.94	2699	2770	41.21	200	195.60
5	5.43	6411	6473	93.22	200	195.11
5	6.55	6411	6093	81.51	500	488.64

Table 1 : Representative summary of Environmental Results including water vapor content (WVC) from V&V of the AAPTF for trial duration of 120 minutes.

Chem	Vapor Concentration (mg/m³)		Temperature(°C)		RH(%)		Trial Duration (minutes)
	Target	Measured	Target	Measured	Target	Measured	
MeS	1000	824	25	24.41	25	24.95	120
MeS	1000	1005	49	48.26	85	38.56	120
MeS	1000	1024	49	49.06	10	9.81	120
GB	5000	2391	47	45.66	25	24.69	30
GB	2000	660	49	48.96	15	18.94	540
MeS	400	408	49	49.09	15	15.58	420
GB	2000	2032	49	46.52	15	15.45	195

Table 2 : Summary of Chemical Dissemination Results from V&V performed under controlled airflow rate set at 200 CFM

Standardized Test and Evaluation Procedures

•Proper seating of the test filter in the test fixture filter housing is ensured using a halide detector, and measuring a minimum 3-log reduction of the halide concentration measured down stream of the filter housing.

•Mass balance was performed by measuring actual mass of chemical challenge in the disseminator reservoir and difference in weights of the test filter pre- and post-challenge.

•Full-scale filter was exposed to environmentally conditioned air at least 16 hours prior to chemical vapor challenge.

•System configuration management and data management processes were developed and standardized.

•Standard operating procedure (SOP) was established for AAPTF operation and addresses safety procedures and composite risk assessments.

•Engineering controls of the fixture were verified to be maintainable and sustainable. A series of filtration/blower systems provides a negative air flow through the walk-in hood, referee systems hood, dissemination hoods, and the airlock relative to the surroundings.

•Safety air-monitoring systems are integrated throughout the chamber and filter banks as shown in Figure 4. These fixed alarm systems are set to warn all test participants when the monitored vapor exceeds the worker population limit or permissible exposure limit.

Conclusion

•The AAPTF T&E capabilities enable challenging full-scale CBRN filtration components against CWA. Testing using AAPTF has been extended to TICs and test trials IAW the test matrix under specified test requirements shown in Table 3 are currently being executed.

•Achievable environmental control parameters include airflow, relative humidity, and temperature; CWA vapor challenges could be targeted and maintained during the V&V investigation.

•Validated standardized testing using AAPTF can be extended to perform T&E of advanced air-purification devices such as catalytic oxidation (CatOx) systems, passive filtration panels, expired/used filters, and regenerative (REGEN) filters for their filter performance.

Acknowledgements

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•Construction and fabrication of the AAPTF was supported by Chemical Test Division, West Desert Test Center, Dugway Proving Ground (WDTC/DPG).

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