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Advanced Air Purification Technology Capabilities Assessment

Michael Parham

Research and Technology Directorate
Edgewood Chemical Biological Center



Report Documentation Page

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Abstract

Several programs under development, such as Comanche and Future Combat Systems have selected or are considering the use of advanced air purification technologies. In addition to these vehicle specific programs, the collective protective community will require an advanced air purification solution for shelters and fixed sites. To best handle the broad chemical and biological threat while reducing the logistical burden of current Joint Collective Protection Equipment a flexible hybrid approach is needed. This hybrid approach entails being able to select the best technology or combination of technologies for a given application's requirements. While comparisons have been made of advanced air purification technologies before, they have either only examined gross systematic strengths and weaknesses provided by subject matter experts, or they have compared demonstration systems designed for different applications. In order to develop the hybrid technology matrix of system metrics, a design study was conducted for a common chemical threat scenario over a wide range of potential application constraint conditions. Valuable comparison between two mature advanced air purification technologies, regenerative filtration and catalytic oxidation, are made from this common design case.





Objective

- Evaluate near term capabilities of single pass filtration, regenerative filtration and catalytic oxidation technologies.
- Provide a common comparative basis for all three technologies over an application relevant range of conditions.
- Quantify key system metrics: weight, size, and power requirement in a matrix incorporating flow rate and chemical threat.





Approach

- Common design problem posed for three technologies: single pass filtration, regenerative filtration, and catalytic oxidation.
- Only one application constraint variable was chosen: clean product air flow rate. This was done to reduce the scope of the study.
- Designs optimized to meet chemical threat requirement while minimizing weight, space claim and power requirements.
- Designs are non-application specific. Some applications may be more or less forgiving in terms of the size, weight, and power requirements.



Application Constraints

- Product air: breathable air at 25 C and 30 to 60% relative humidity.
- Application flow rates:
 - 200 SCFM vehicles (FCS, AAV, Comanche, etc.)
 - 1000 SCFM shelters/safe rooms
 - 10000 SCFM fixed sites
- Environmental inlet condition extremes
 - Hot-dry 49 C (-7 C dew point)
 - Hot-humid 41 C (31 C dew point)
 - Constant high humidity 24 C (24 C dew point)
 - Basic hot 43 C (10 C dew point)





Chemical Threat Profile

- Six 20,000 ct ($\text{mg}\cdot\text{min}/\text{m}^3$) single component attacks over a 30 day period – 120,000 ct total – $2,000 \text{ mg}/\text{m}^3$ peak challenge concentration
- Threat profile 1: chemical warfare agents
 - Mustard (HD)
 - Sarin (GB)
 - Cyanogen chloride (CK)
- Threat profile 2: chemical warfare agents and toxic industrial compounds
 - Threat profile 1 chemicals
 - Carbon monoxide
 - Ammonia
 - Ethylene oxide
 - Carbon disulfide
 - Formaldehyde
 - Nitric acid





Chemical Removal Capability

Chemical	Single Pass Filtration	Catalytic Oxidation	Regenerative Filtration
Mustard (HD)	X	X	X
Sarin (GB)	X	X	X
Cyanogen chloride (CK)	X	X	X
Carbon monoxide	O	X	O
Ammonia	X	X	X
Ethylene oxide	X	X	X
Carbon disulfide	X	X	X
Formaldehyde	X	X	X
Nitric acid, fuming	X	O	No data avail.

X – Removed X – Design limiting, O- Not removed





Nominal System Metrics

- Single pass filtration
 - CWA threat profile results estimated from modular collective protection equipment system.
 - CWA/TIC threat profile results estimated with data gathered from the advanced adsorbents DTO and TIC filtration programs.
 - Environmental control unit provides application required conditioned air but is not required for chemical vapor removal.
- Regenerative filtration
 - Temperature swing adsorption (TSA) chosen as the representative regenerative filtration technology.
 - Environmental control unit cools the air and removes water prior to the TSA unit.
- Catalytic oxidation
 - 200 – 1000 SCFM designs utilize a venturi scrubber supplied with water from the environmental control unit for post treatment of the catalytic reactor effluent.
 - 10000 SCFM design utilizes a packed bed water scrubber as both the post treatment of the catalytic reactor effluent and the environmental control unit.
 - Design is threat profile non-specific; CWA and CWA/TIC threat profile results are identical for this technology.
 - Estimates of total system weight are unavailable for the CatOx technology.

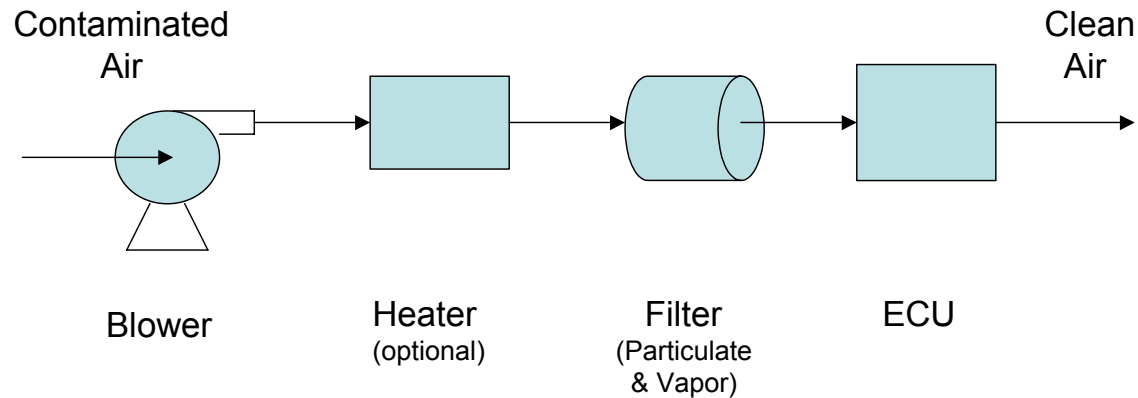




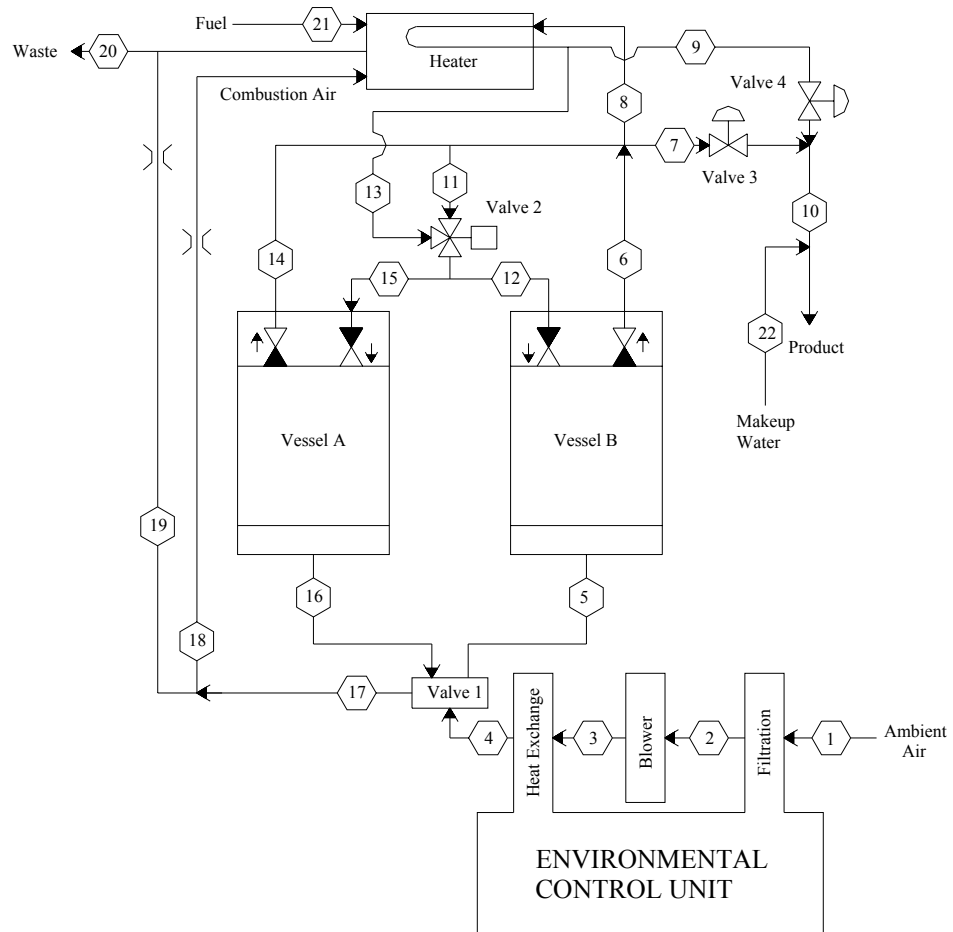
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Single pass filter

Schematic of Single Pass Filtration System

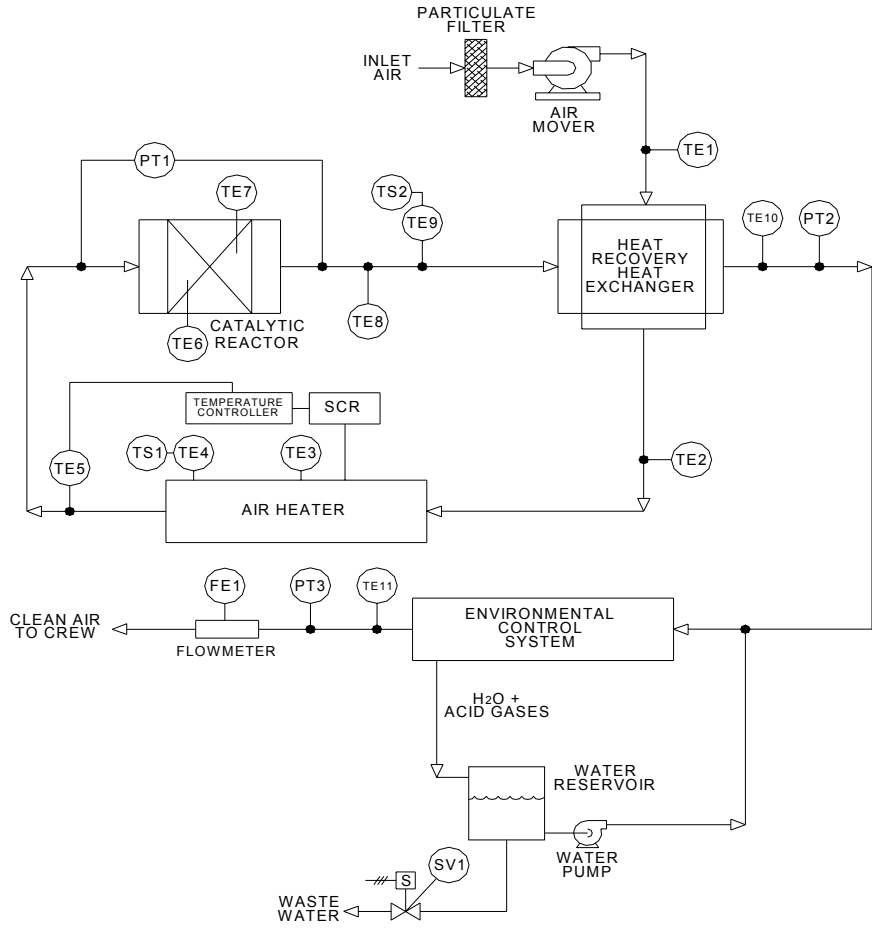


Temperature Swing Adsorption Unit



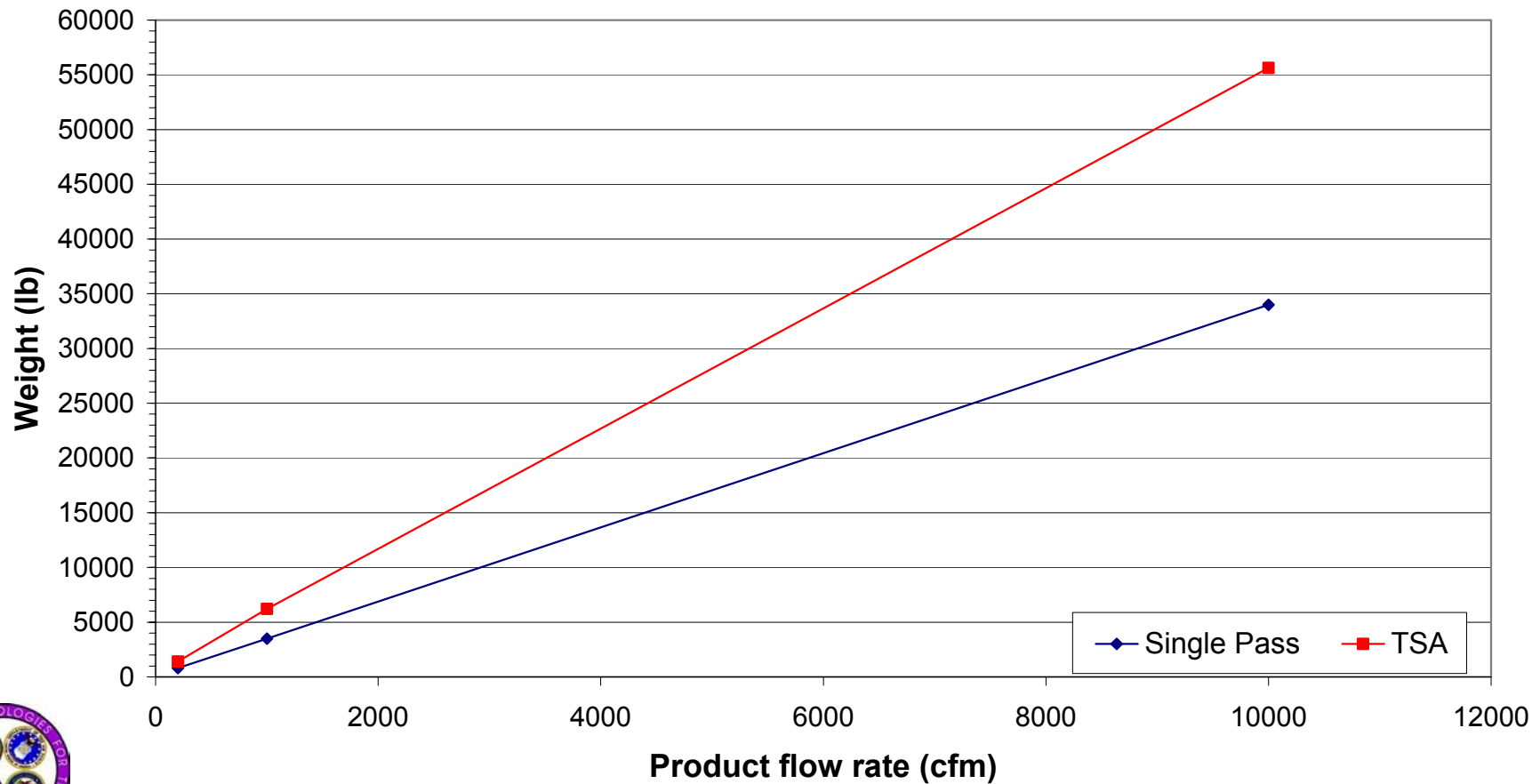


Catalytic Oxidation Unit



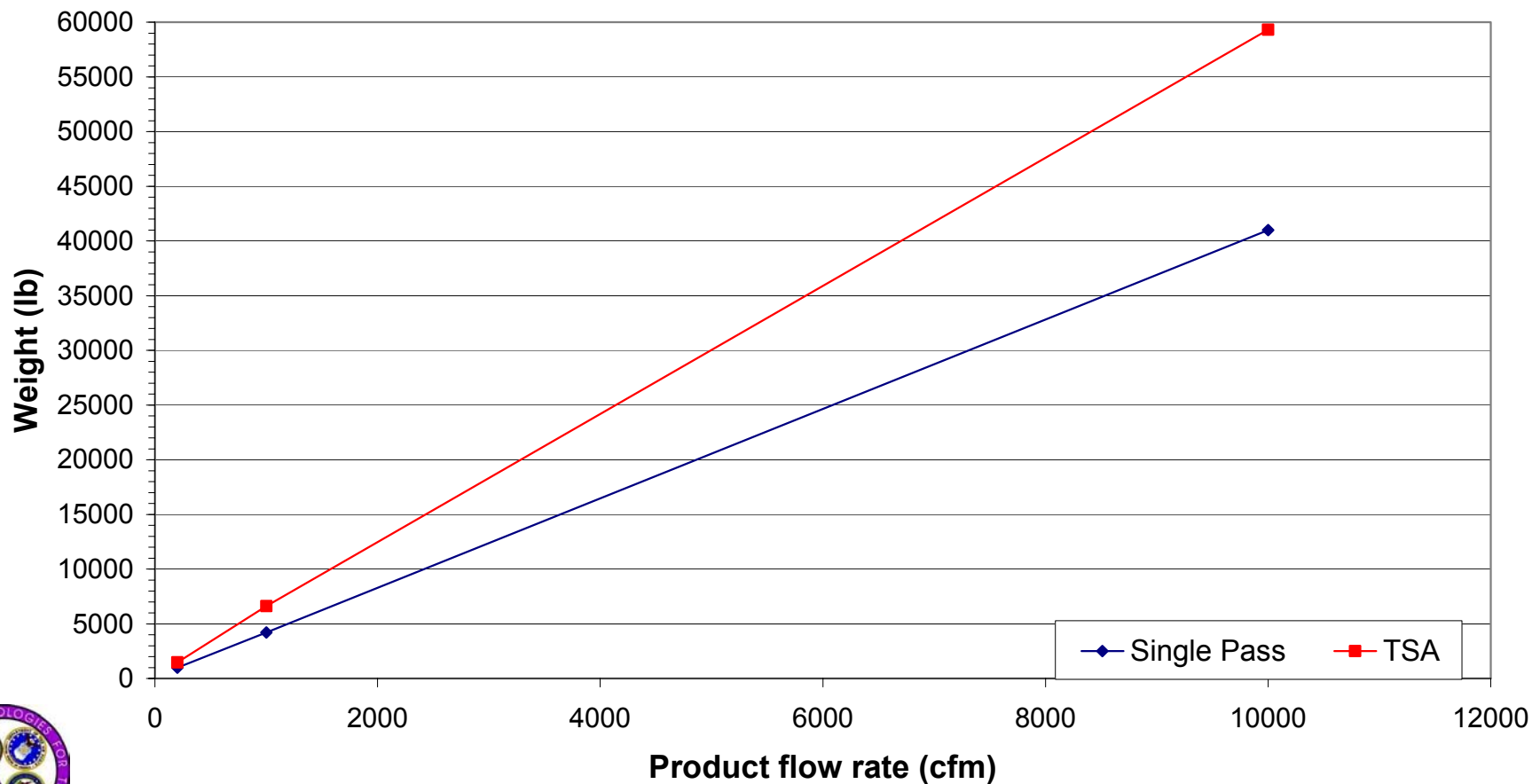
Nominal System Metrics

System weight of single pass and regen filtration technologies sized for the CWA chemical threat scenario



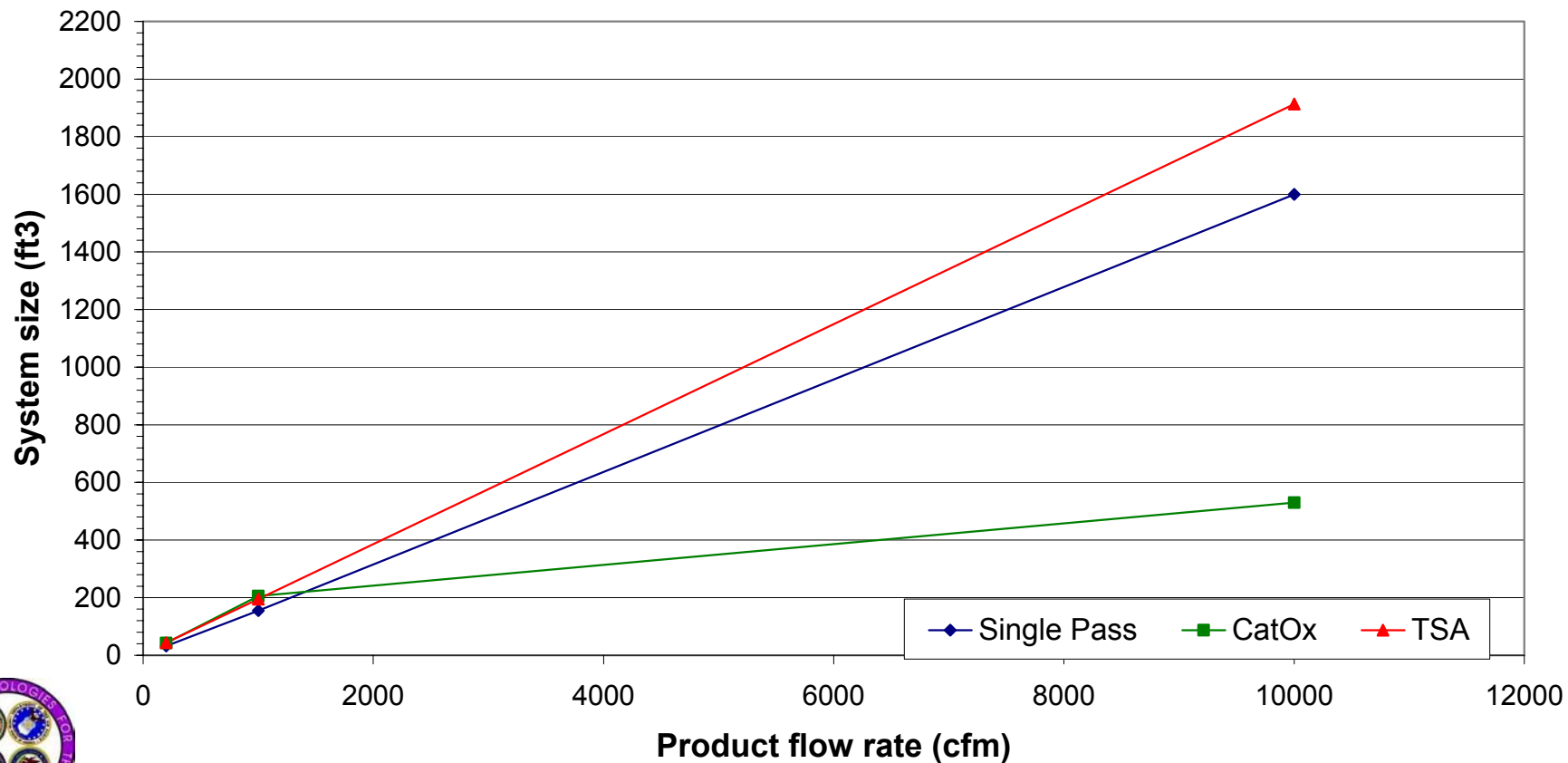
Nominal System Metrics

System weight of single pass and regen filtration technologies sized for the CWATIC chemical threat scenario



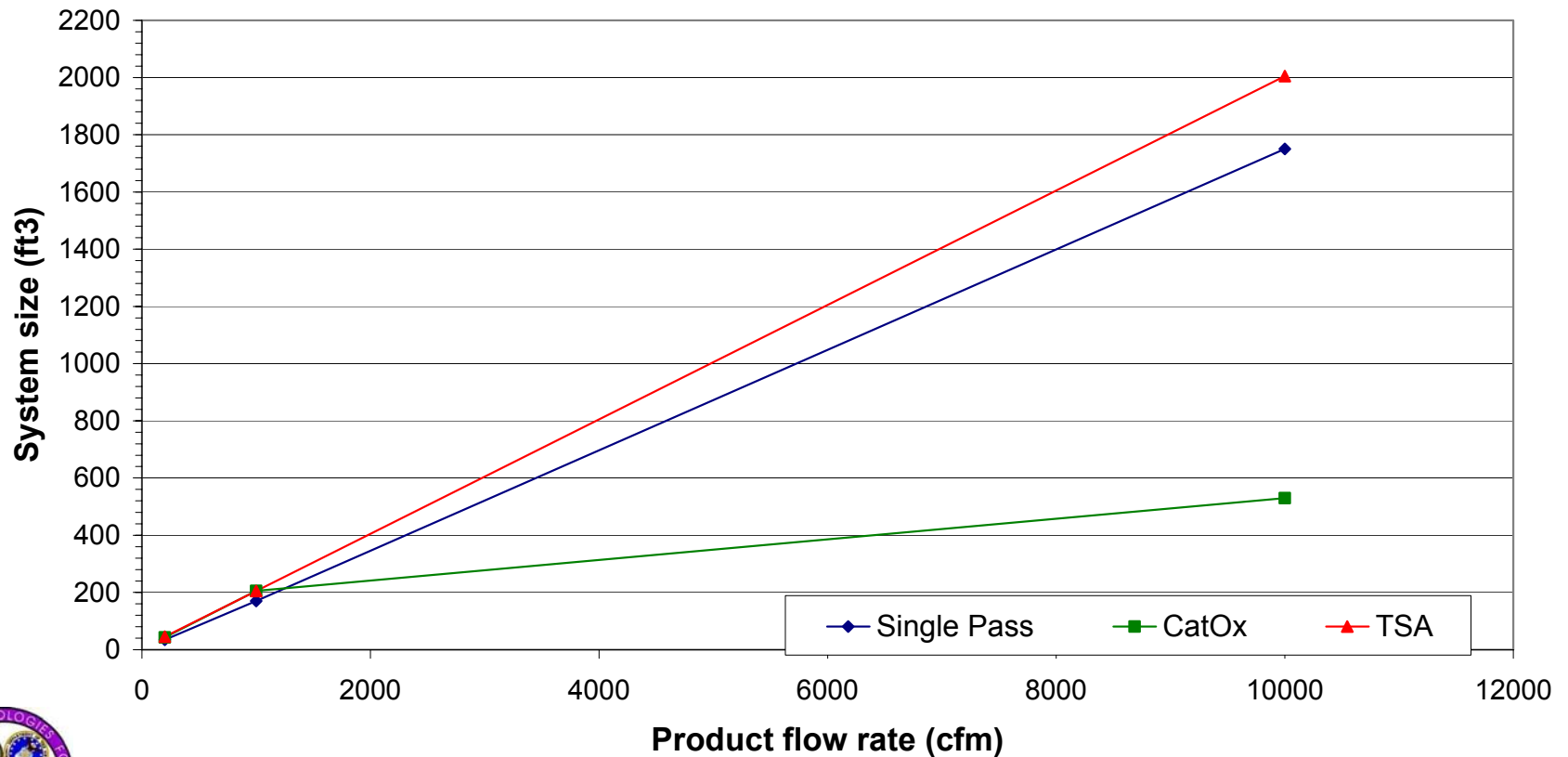
Nominal System Metrics

System size for single pass, regen and catox technologies for the CWA chemical threat



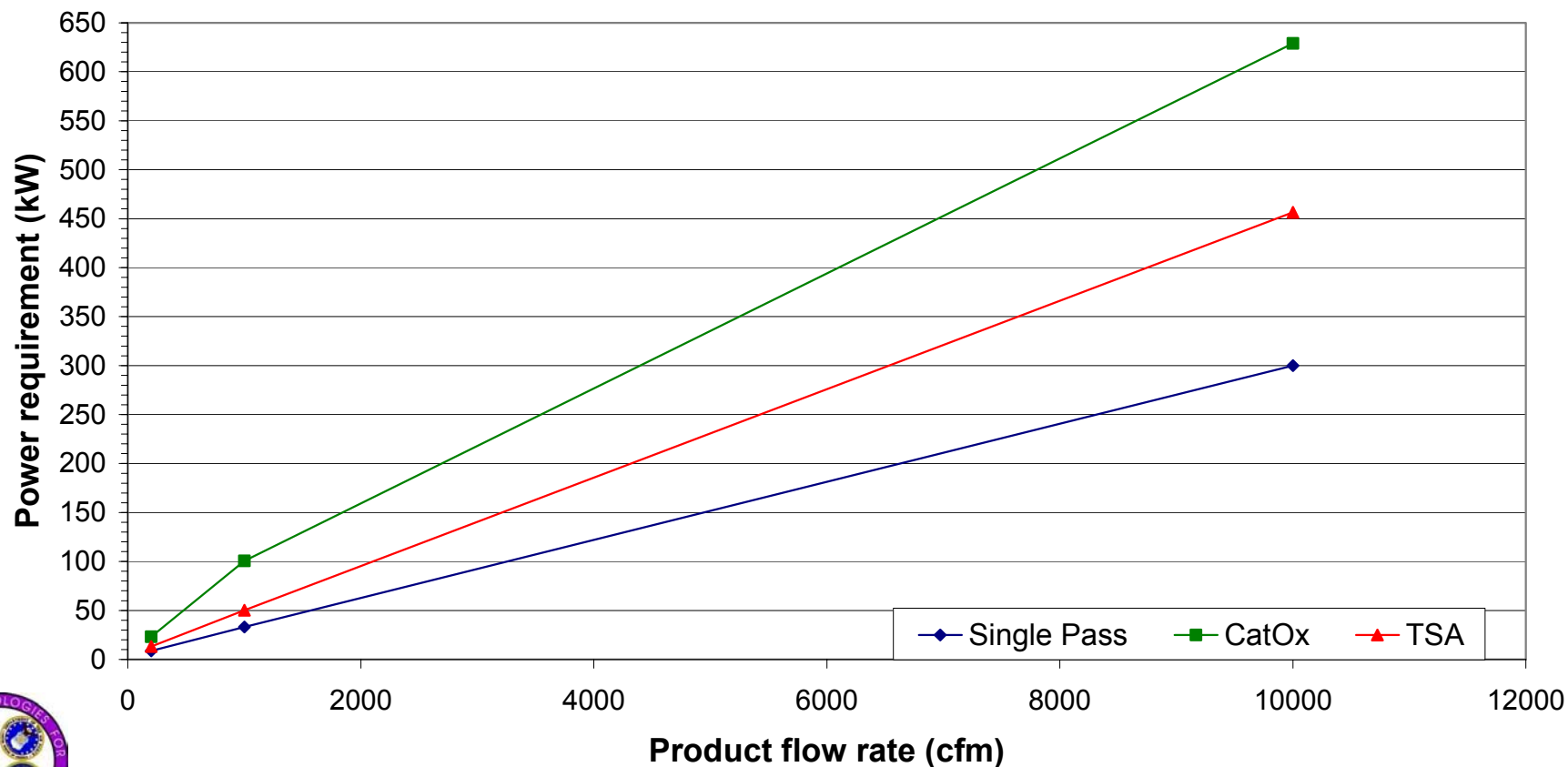
Nominal System Metrics

System size for single pass, regen and catox technologies for the CWAT/IC chemical threat



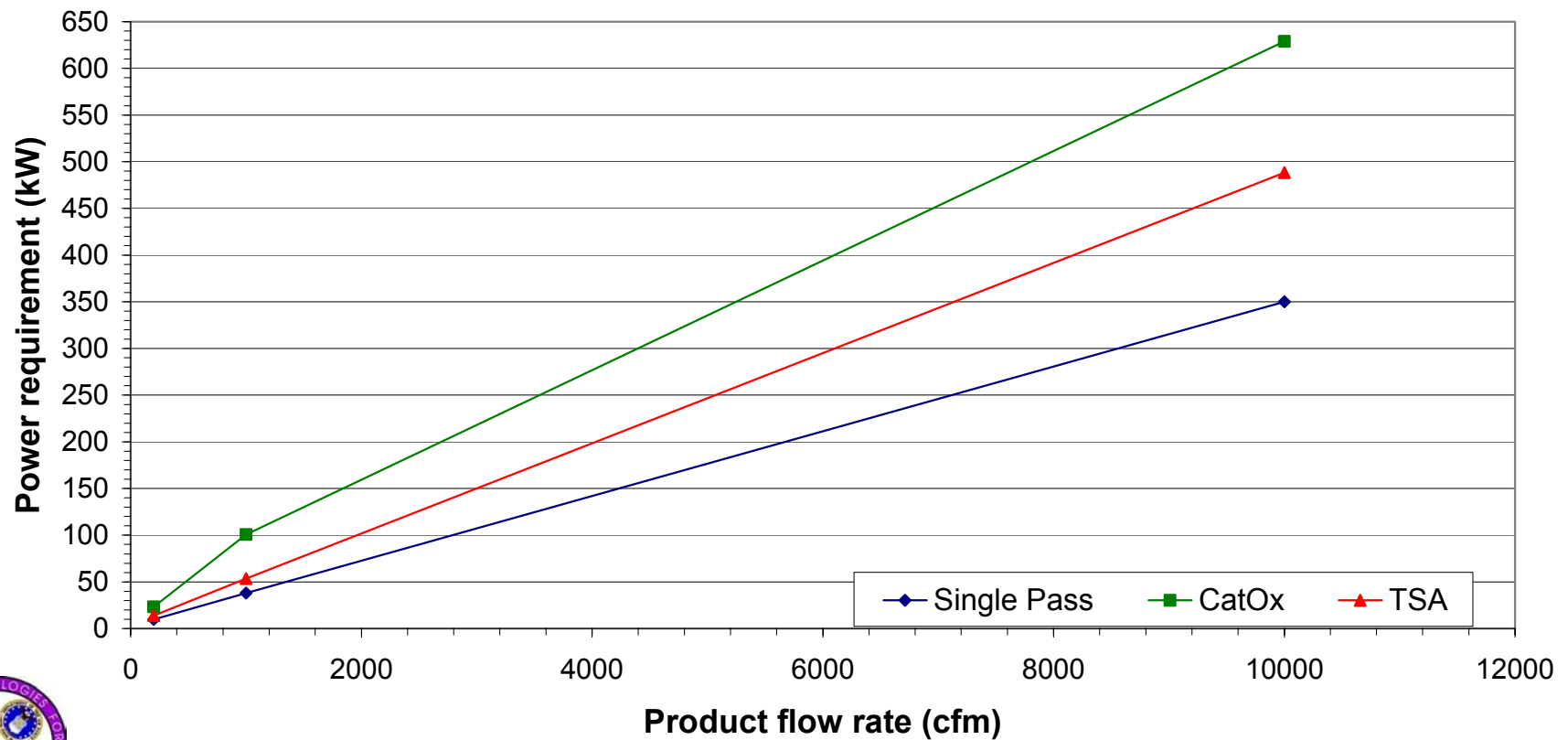
Nominal System Metrics

System power requirement for single pass, regen, and catox technologies for the CWA chemical threat scenario



Nominal System Metrics

Power requirement for Single pass, Regen, and CatOx technologies for CWA/TIC chemical threat scenario





Scaled System Metrics

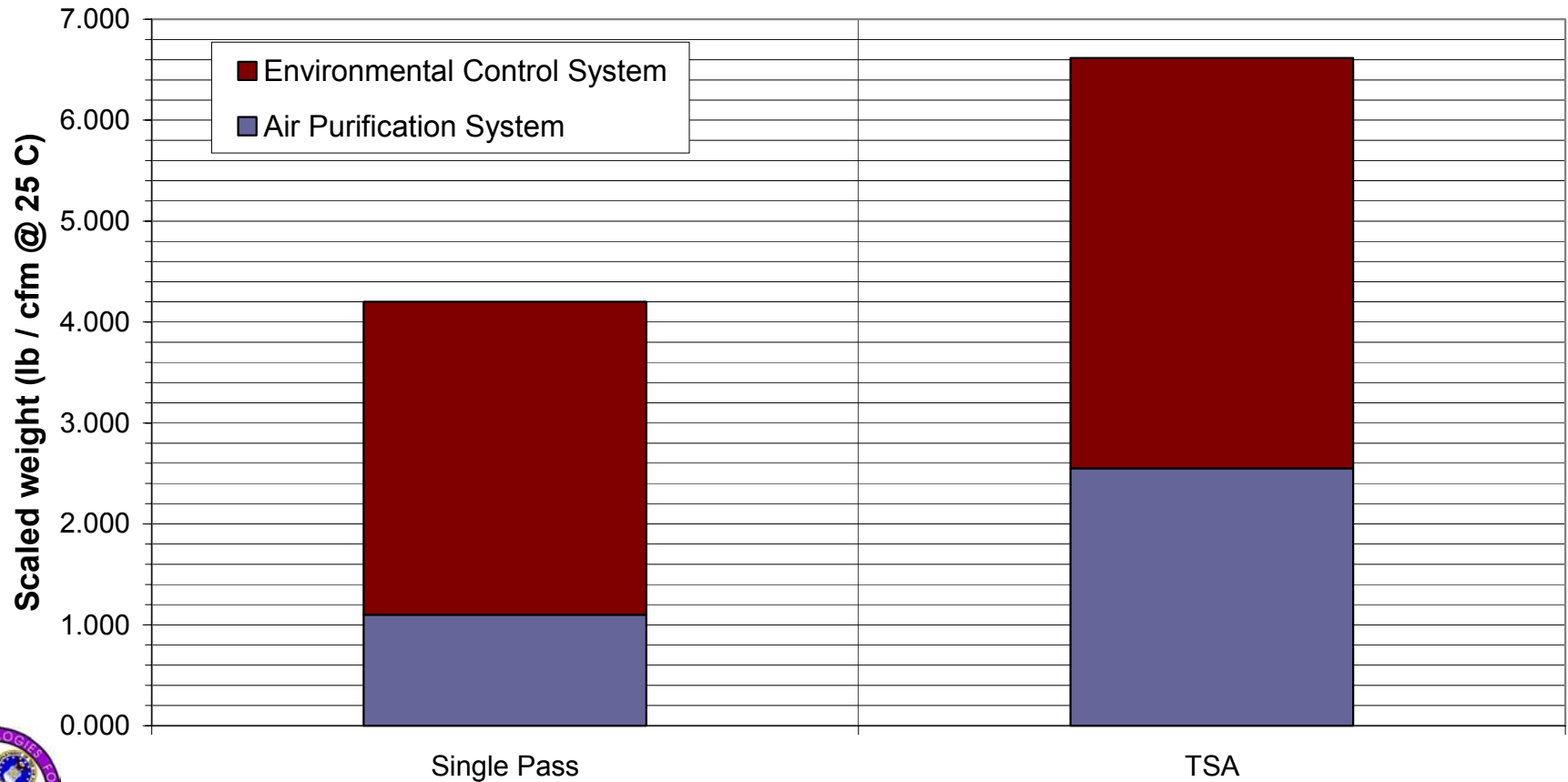
- Application requirements are a key consideration when comparing system capabilities.
- Environmental control system requirements are responsible for a significant fraction of total system requirements.
- As configured an environmental control system is not required in conjunction with single pass filtration to meet chemical vapor removal requirements.
- Without the environmental control system cooling the inlet air and removing water the temperature swing adsorption unit would fail to meet chemical vapor removal requirements.
- Catalytic oxidation system power requirements are comparable to the ECS due to its electric heater.





Scaled System Metrics

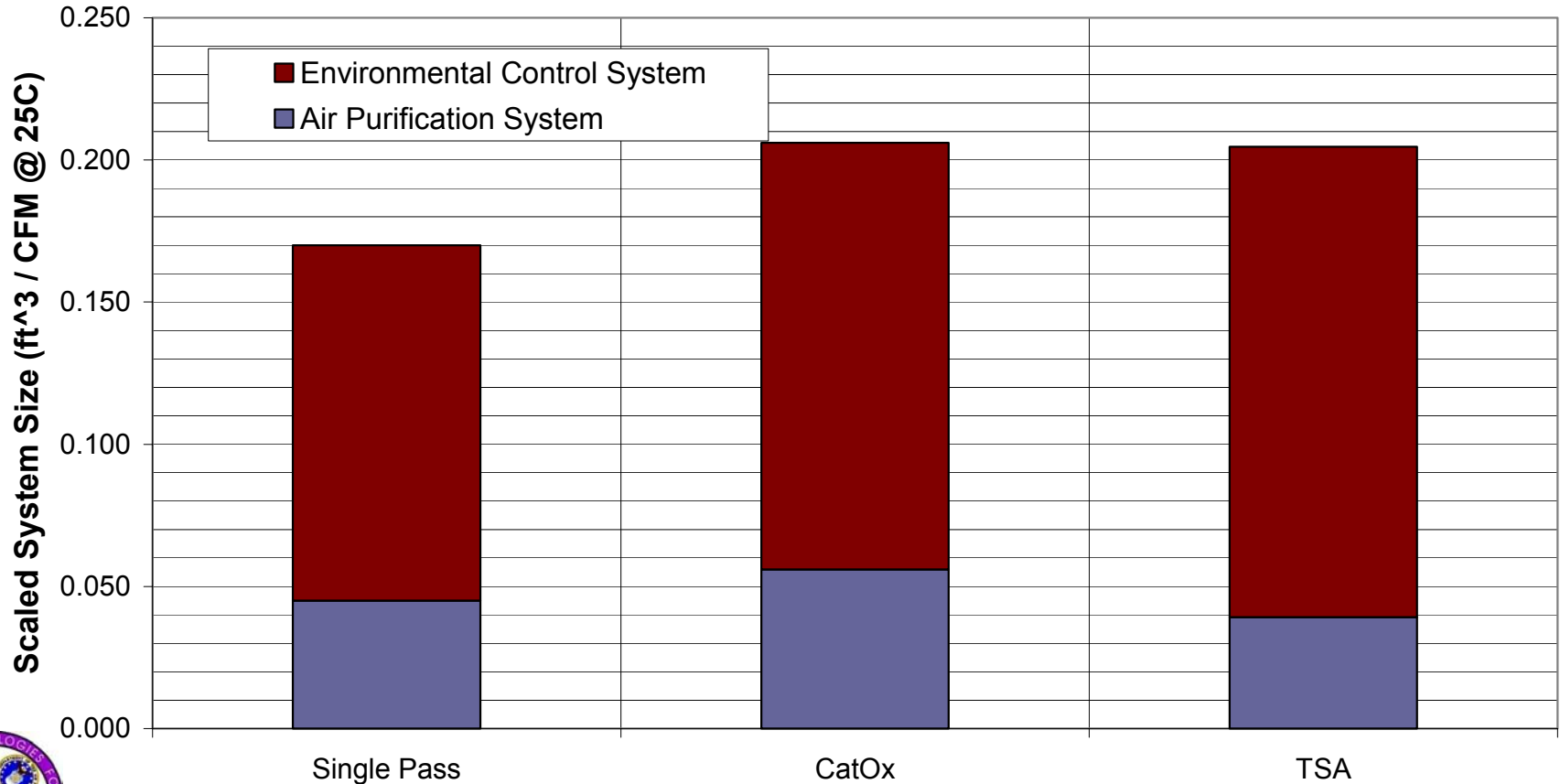
**Integrated Air Purification System Weight
CWA/TIC chemical threat, 1000 CFM System**





Scaled System Metrics

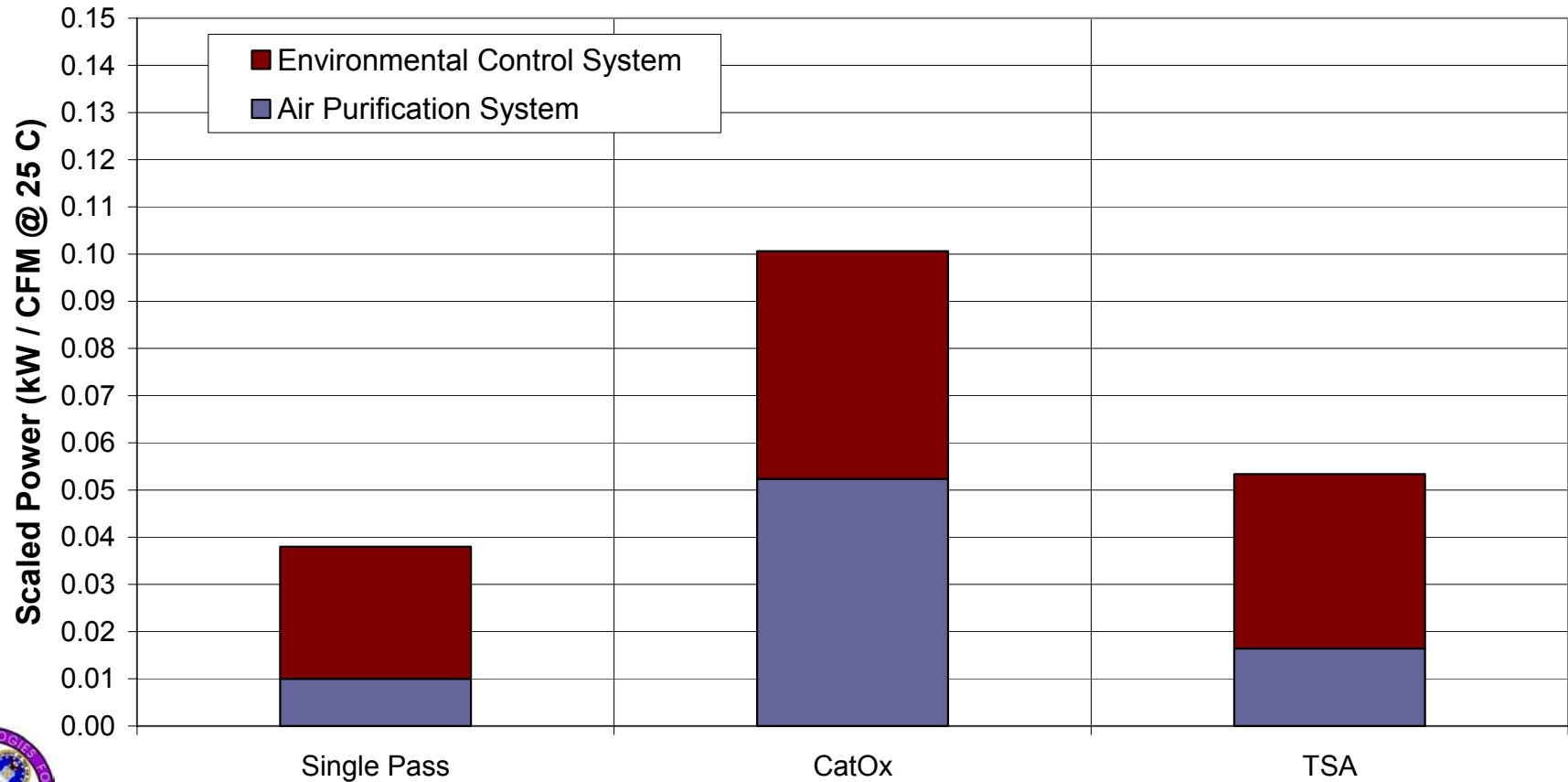
**Integrated Air Purification System Space Claim
CWATIC chemical threat, 1000 CFM System**





Scaled System Metrics

**Integrated Air Purification System Power Requirement
CWA/TIC chemical threat, 1000 CFM System**



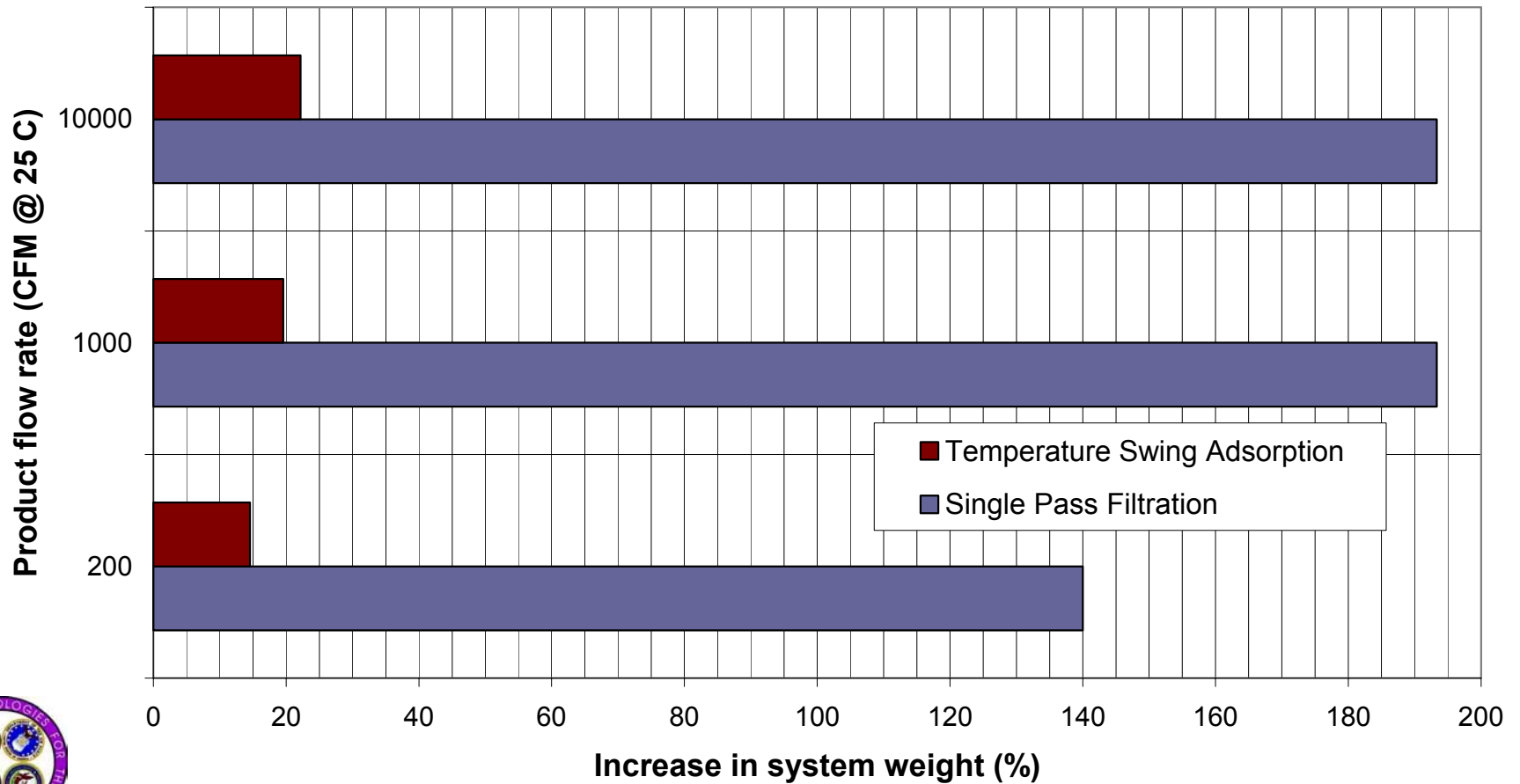
Toxic Industrial Chemical Sensitivity

- Technologies need to be flexible to meet new chemical threats such as toxic industrial chemicals.
- The catalytic oxidation system design presented is insensitive to chemical threat.
- The temperature swing adsorption system design presented can handle the CWA/TIC threat profile with minor modifications.
- The single pass filtration system design presented requires significant alterations to handle the CWA/TIC threat profile.



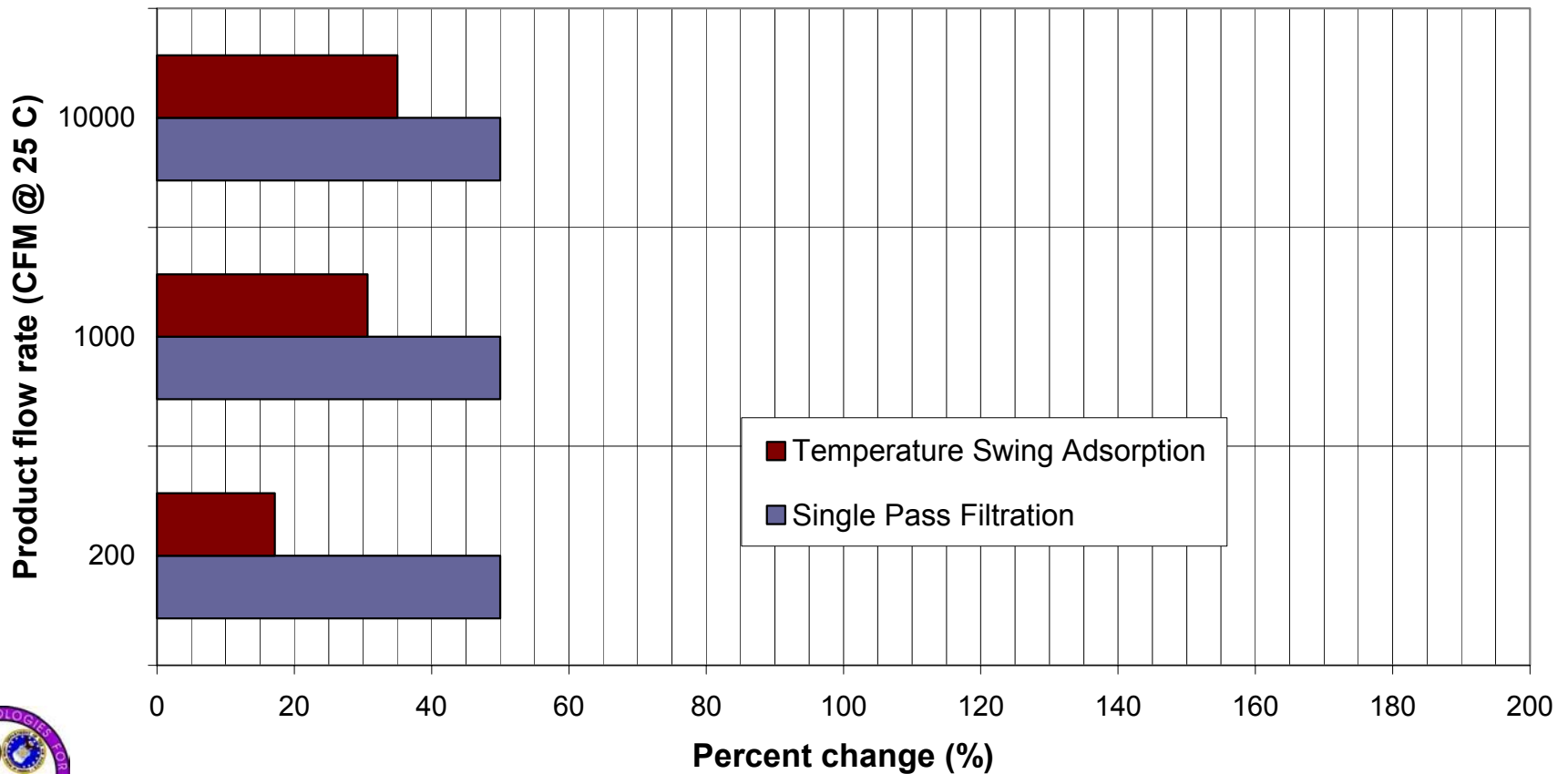
Toxic Industrial Chemical Sensitivity

Sensitivity of air purification system weight to the introduction of toxic industrial chemical threat



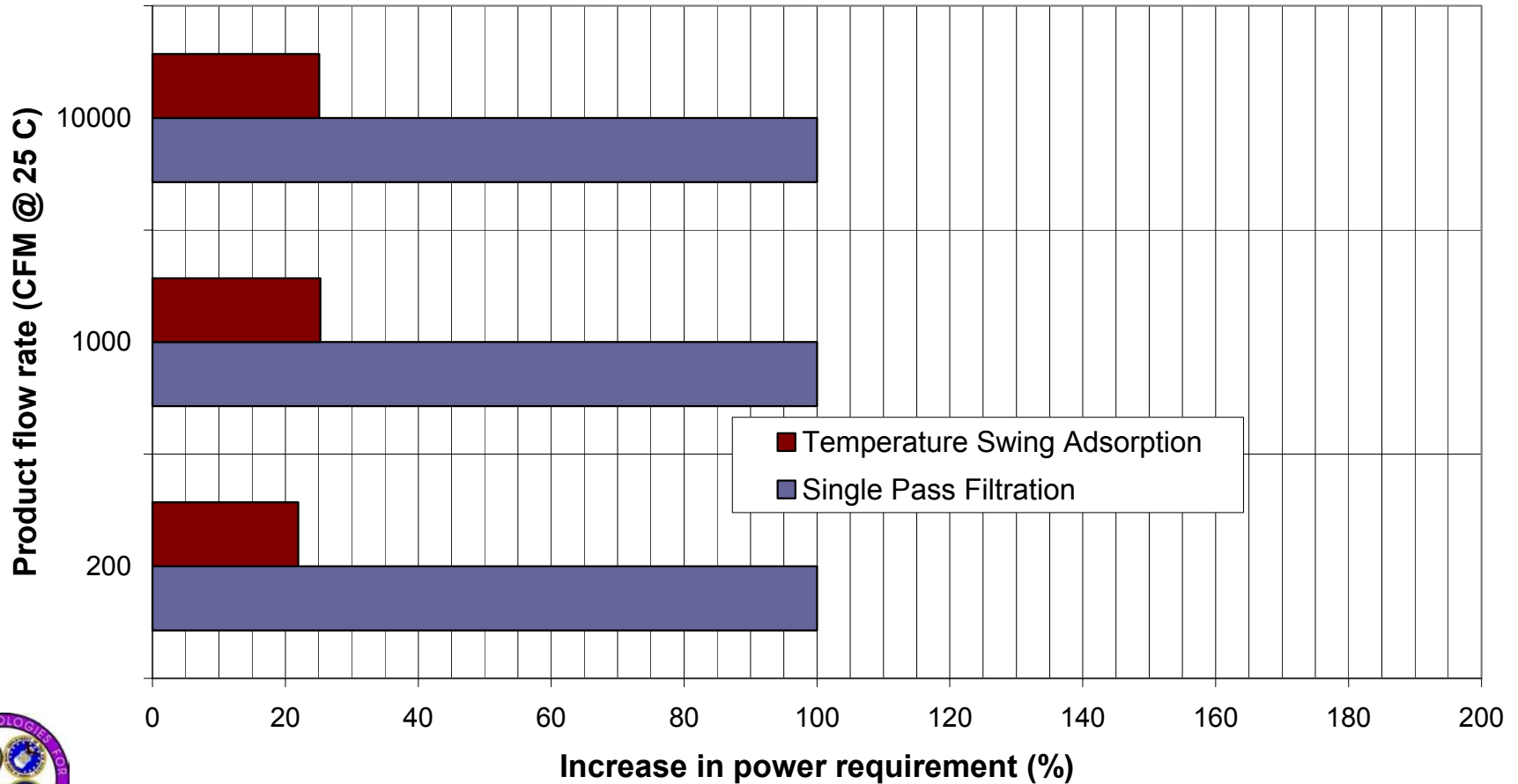
Toxic Industrial Chemical Sensitivity

Sensitivity of air purification system size to the introduction of toxic industrial chemical threat



Toxic Industrial Chemical Sensitivity

Sensitivity of air purification system power requirement to the introduction of toxic industrial chemical threat





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Single Pass Filtration

- Advantages
 - Protection against standard chemical/biological agents and many toxic industrial compounds.
 - Low system and material cost.
 - Low complexity.
 - Optimized mature technology.
- Disadvantages
 - Limited protection against expanding number of threats.
 - High logistical burden.
 - Susceptible to environmental aging.





Regenerative Filtration

- Advantages
 - Broad protection against chemical/biological agents and toxic industrial compounds.
 - Very large capacity.
 - Reduced logistical requirements compared to single pass filtration.
 - Not dependent upon impregnated adsorbents sensitive to environmental conditions.
- Disadvantages
 - Increased complexity, weight, size, and power requirement.
 - Potential for toxic purge gas.
 - Adsorbent-adsorbate database not well developed.
 - Issues impacting regeneration need to be addressed.
 - Co-adsorbed water is an issue.





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Catalytic Oxidation

- Advantages
 - Broad protection against chemical/biological agents and toxic industrial compounds.
 - Decomposes hazardous chemical and biological agents rather than retaining them.
 - Very large capacity.
 - Reduced logistical requirements compared to single pass filtration.
- Disadvantages
 - Increased complexity and power requirement.
 - Not immediately operational from cold-start.
 - Potential catalysis deactivation methods must be identified and quantified before sizing the system for an application.
 - A post treatment method must be devised, tested and integrated with any final system.





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Conclusions

- Single pass filtration is a superior option for the current CWA threat due to its many decades of optimization.
- Catalytic oxidation and regenerative filtration are feasible and necessary options depending upon the chemical threat profile and mission duration.
- A well defined threat profile is required to best optimize the advanced air purification technologies.
- Significant effort must be made before catalytic oxidation and regenerative filtration are acceptable for fixed site (~10,000 SCFM) applications.





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