Status of CATOX Technology for Collective Protection

Peter Michalakos, Michel Jonqueres, Bob Tom,
Anil Trivedi, David Loeffelholz, Russell W. Johnson
Honeywell International

Alex Balboa, Michael Parham, Cheri Borruso and Christopher Karwacki,
Research and Technology Directorate, Edgewood Chemical Biological Center
US Army, Research Development and Engineering Command

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Changing Threat Scenarios Impose Protection Against Increasing Number of Chemicals

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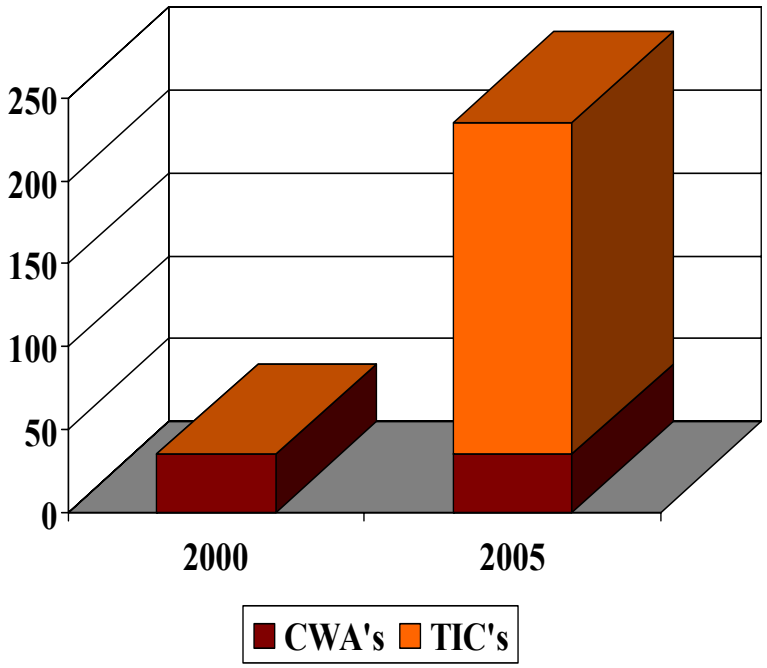
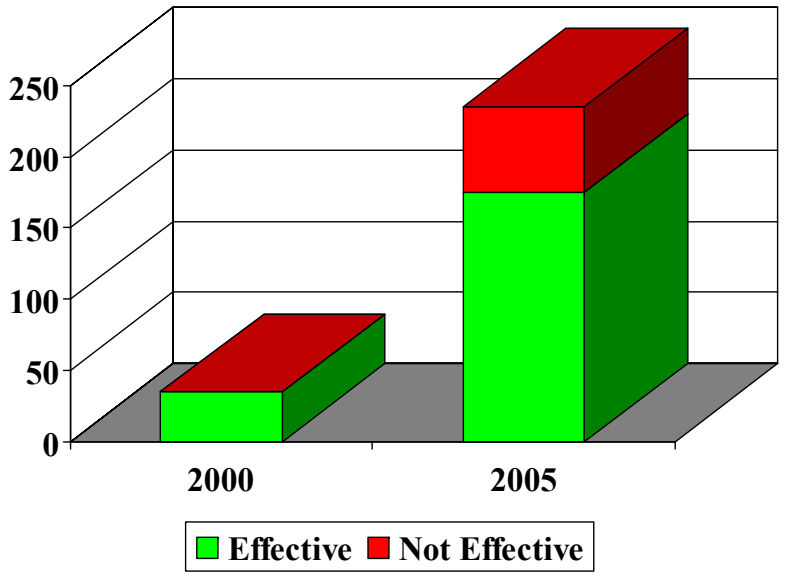
Number of chemicals is increasing…leading to a gap in single-pass protection



Chemical Threats



Single-Pass (Carbon-Based) Effectiveness

Changing landscape demands new collective protection approaches

Requirements for Chemical Threat Protection Changing

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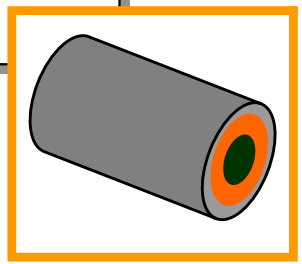
Established Battlefield Threats

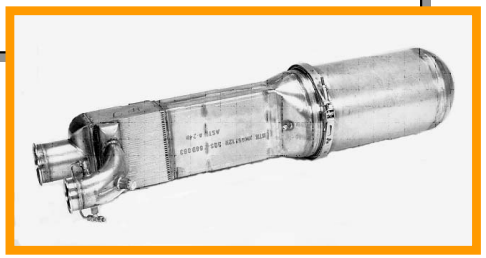
Established CWA's removable with ASZM-TEDA



Transforming to...

Asymmetric Threats

Broad spectrum challenges CWA's & TIC/TIM's

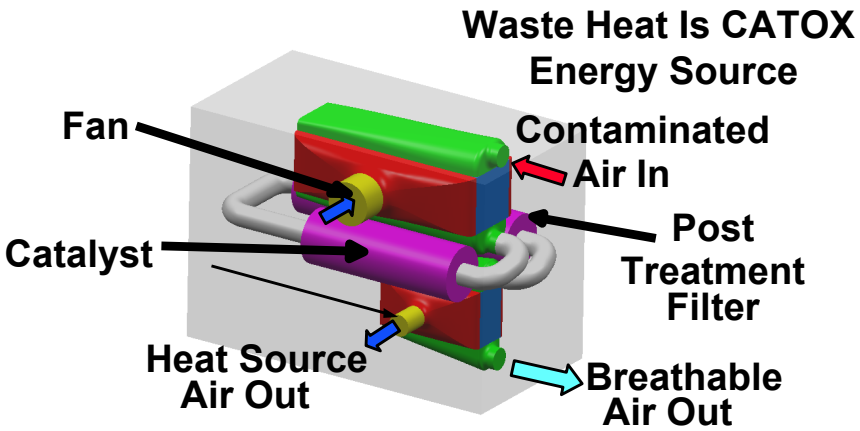


CATOX Benefits:

- Broad-spectrum threat coverage
- Based on mature industry technology
- Scalability issues are understood
- Acute toxicants destroyed rather than Just separated
- Self decontaminating & cleaning
- Very low maintenance
- No moving parts
- Can be applied to platforms in near future

CATOX Challenges:

- Integration to use waste or recuperated heat key requirement to make practical



CATOX: Protection against Broad-Spectrum of Challenges

High-Level Challenges or TIC/TIM Threats Require Additional Protection

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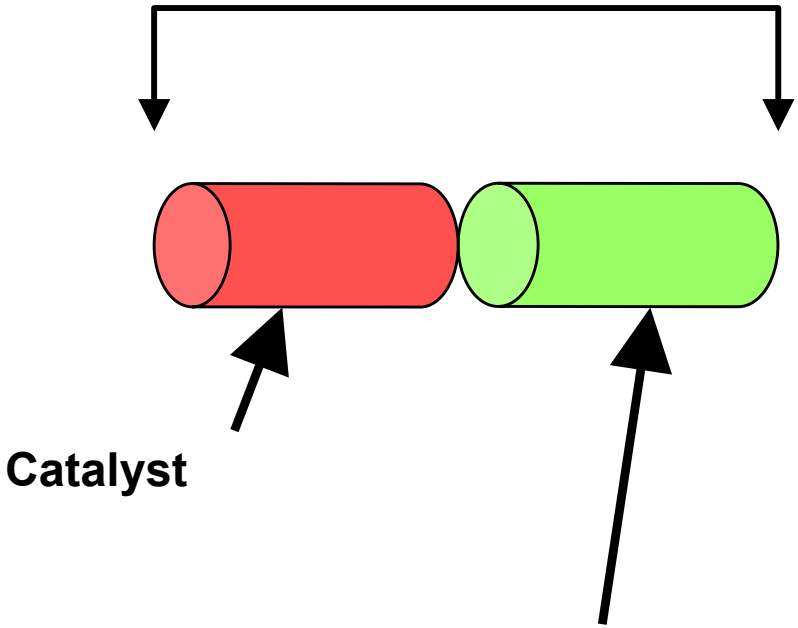
- Catalyst destroys chemical agents,; eliminates acutely toxic inventory
- Less toxic secondary products can be reacted with adsorbent
- Catalyst and post treatment filter (PTF) will not have inventory of acutely toxic materials
- Similar to Automotive and Indust CATOX…But Has Higher Tolerance For Poisons e.g. Cl & P

CATOX System Can Include Catalyst and PTF



PTF – If used, Adsorbent Designed to Remove Heteroatom Compounds Such as HCl, HF, NO_x, SO_x

Until recently, PTF Did Not Provide Sufficient Protection Against Acid Gases, Especially NOx

Catalysts Are Widely Used

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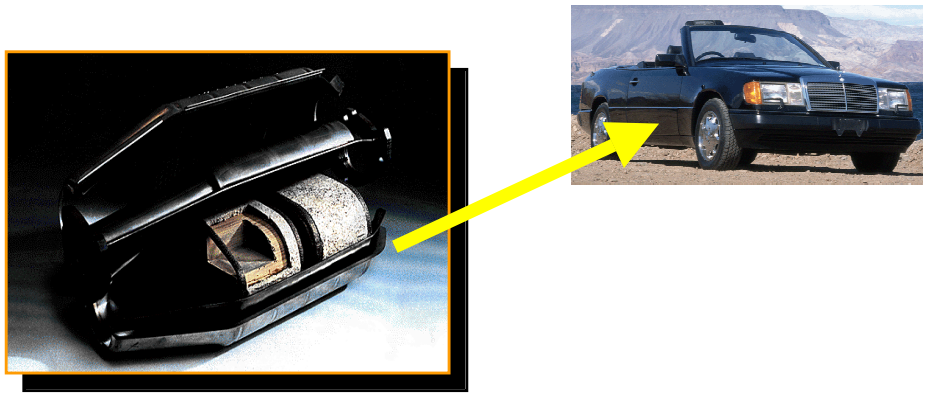
Catalysts in 90% of processes to make $1.3 Trillion/year chemicals

Petroleum Refining

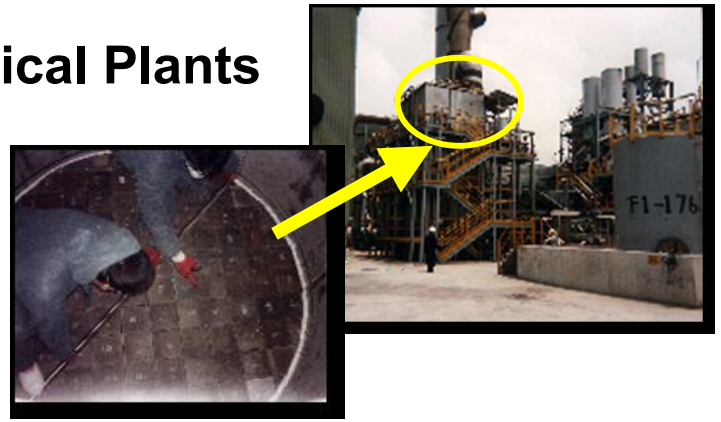
- Several catalyst compatible with "dirty" residual petroleum fractions (*e.g.* reduced crude desulf.)
- Extensive work on poison tolerance
- Used to "tailor" product properties (*e.g.* octane number)

Automobile Catalytic Converter



- Introduced 30 yrs ago
- Sensitive to P, Pb, Cl…
- Required new fuel to operate
- ~35,000 pounds of fuel
- Required new gasoline to remove P, Pb, halogen

Chemical Plants



- Widely used to obtain the desired chemical products
- Used for emission controls – often for streams containing high halogen concentration

Proven Methodology Will Be Used For Collective Protection Catalysts

Key CATOX Data

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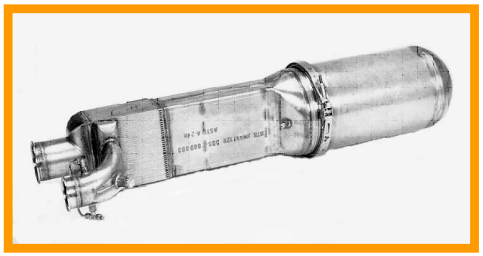
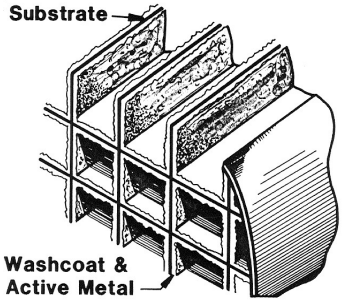
- **Extensive catalyst data from lab to full-scale**

1987-1991



Chemical and Biological Agent Protection System (CABAPS)



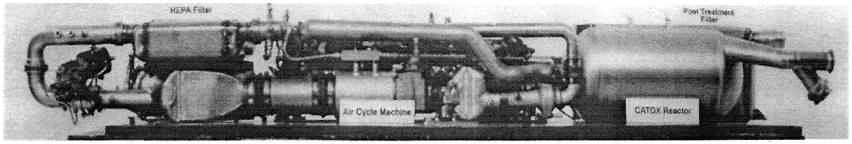
Data available for:
CG CK AC HD L GB GD VX others (Including earlier programs)

1999 – ACWA Validates Catalyst

Agent	Injection Conc.	Conversion
GB	880 mg/m^3	>99.999992%
VX	268 mg/m^3	>99.999999%
HD	390 mg/m^3	99.9995%

- **NRC Review**: ***Evaluation of Demonstration Test Results of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: A Supplemental Review*, National Research Council, National Academy Press, p. 22-23.**

1993-1994



- CATOX/ECU Integrated Collective Protection System (successfully tested at Dugway against agents, shock and vibration loads)

Current – Broad Screening of catalyst & PTF at ECBC (In Progress)

Carbon Monoxide	Chloroform
Ethylene Oxide	CK
Formalin	CEES
Acetonitrile	DMMP

CATOX Chemical Performance Has Been Extensively Evaluated

PTF Capacity Now Suitable For CW & TIC/TIM Threats

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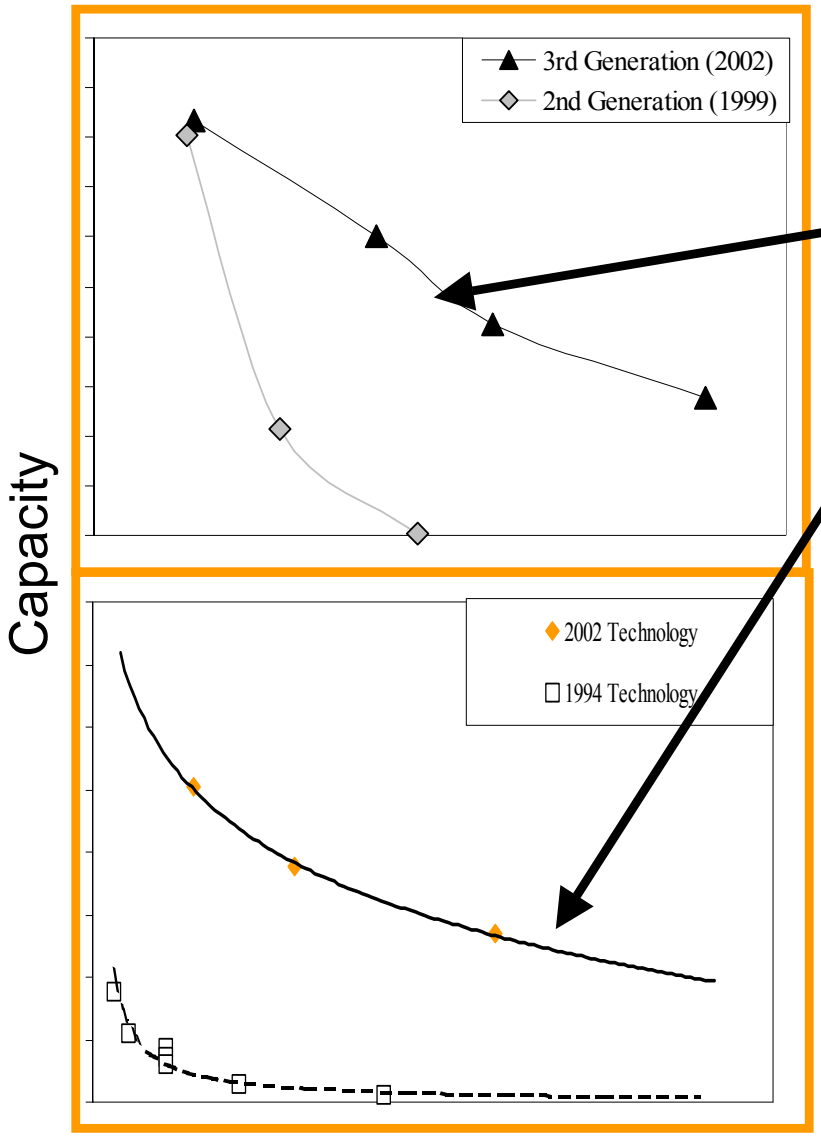

- New Honeywell PTF developed
- Removes acid gases much better than in earlier testing
- New PTF capacity for weak acids such as NOx improved 900% relative to 1994
- New PTF capacity for strong acids such as HCl improved 1500% relative to 1994
- PTF now has suitable size for platforms
- Demonstrated in laboratory
- Demonstrated at Honeywell at 50 CFM
- Broad Screening at ECBC underway

Carbon Monoxide	CEES
Ethylene Oxide	Acetonitrile
Formalin	Chloroform
DMMP	CK

(Grayed list doesn't produce acid products other than CO_2)

PTF Now Effective To Support CATOX For Credible Exposures

We are working through TIC/TIM's

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Toxic Chemicals Under Evaluation		
Acrolein	Dimethylamine	Methyl hydrazine
Acrylonitrile	Ethylene oxide	Nitric acid
Allyl alcohol	Fluorine	Nitrogen dioxide
Ammonia	Formaldehyde	Paration
Arsine	Hydrazine	Phosgene
Boron trifluoride	Hydrogen chloride	Phosphorous trichloride
Bromomethane	Hydrogen cyanide	Phosphoryl trichloride
Carbon monoxide	Hydrogen fluoride	Propylene oxide
Chlorine	Hydrogen selenide	Sulfuric acid
Cyanogen chloride	Methylamine	Sulfur dioxide
Diborane	Methyl isocyanate	Sulfur trioxide

Demonstrated Effective

Very likely to be effective based on reactions of similar chemicals

Likely to be effective but higher risk

Ineffective or probably ineffective

CATOX Protects Against Broad-Spectrum of TIC/TIM's

System Power & Size Requirements

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- CATOX requires operating temperature of 507 F for effective destruction of threat agents. Processed air then needs to be cooled down to acceptable near ambient temperature for comfort.

- Heating power required:
  - 13.8 kW per 100 CFM of treated air
  - 4.1 kW with use of recuperator heat exchanger
  - Free if waste heat is available from vehicle (engine exhaust) or building

- Cooling power required:
  - 2.9 kW per 100 CFM after ambient air heat exchanger only
  - 0.5 kW per 100 CFM using recuperator and ambient air heat exchanger
  - Includes both cooling fan power and remaining heat load above ambient temperature

- CATOX Can Be Optimized To Minimize Operating Power Requirements

CATOX offers superior protection while maintaining Comparable power & size relative to M98

CATOX: Performance and Maturity

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Chemical Performance

- ✓Catalyst and PTF combination eliminates a very broad-spectrum of chemical threats
- ✓Conversions greater than 6-log are achievable
- ✓Reduction of toxicant levels to MEG levels are achievable, indicating that breathable air quality is achieved

Engineering Maturity

- ✓Catalyst
  - modification of commercial catalyst; manufacture is very low risk
  - Scalability: up to >100,000CFM
- ✓PTF
  - New product – similarity to catalyst manufacture reduces risk
  - Scalability: proven at 50CFM… and scalable to at least 3000 CFM
  - Process model under development and will be complete by summer

Other Components

- No System engineering technology issues. All auxiliary system components (heat exchangers, valves, fans, sensors, heaters, controls) use well established COTS technologies

CATOX Technology Benefits and Maturity Make It A Candidate for Platform Development

CATOX Ready For Broad-Spectrum Protection

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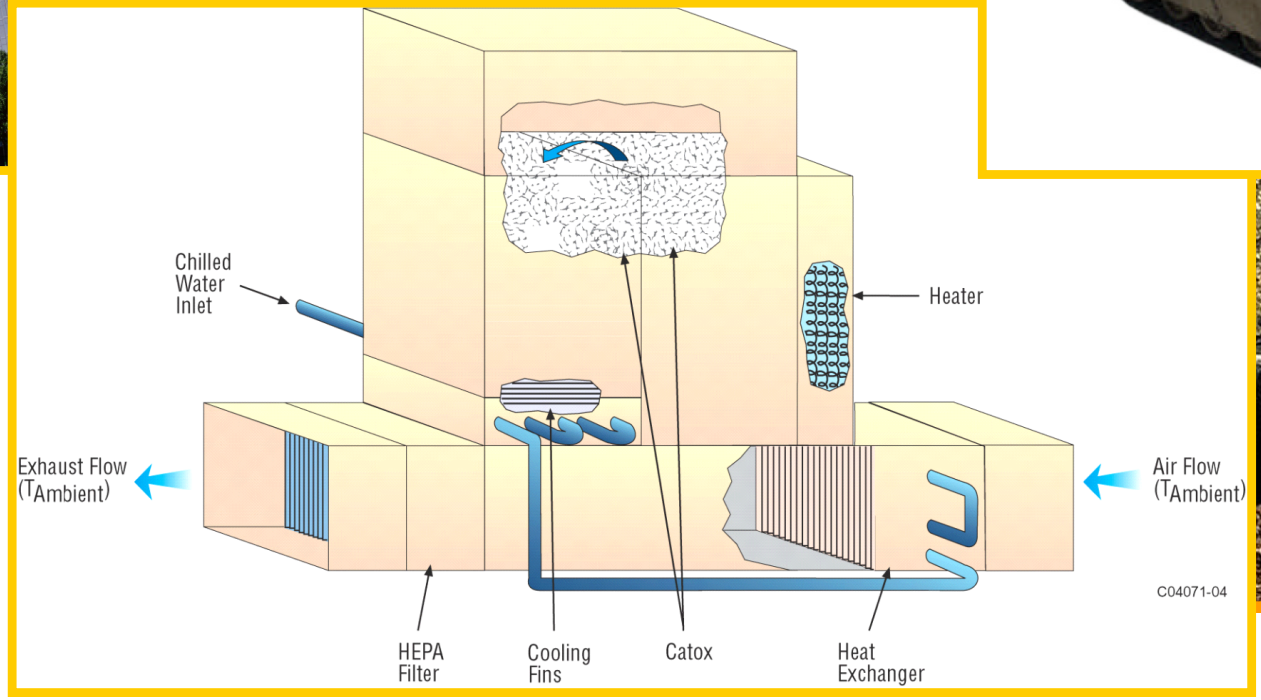

CATOX Technology Can Provide Solutions for Military and Homeland Security Collective Protection