Respiratory Protection From CO Inhalation

Girish Srinivas

Steven Gebhard
Rita Dubovik
Drew Galloway

TDA Research, Inc.

ISRP, Prague

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PPE Projects

- CO oxidation catalysts for CBRN – CO escape respirator
- CO oxidation catalysts for wild land firefighter respirators (NFPA 1984 standard)
- Compact heat exchanger for cooling wild land firefighter breathing air
- Heat exchanger for Level A Hazmat Suit Cooling
- Colorimetric End of Service Life Indicator (ESLI)

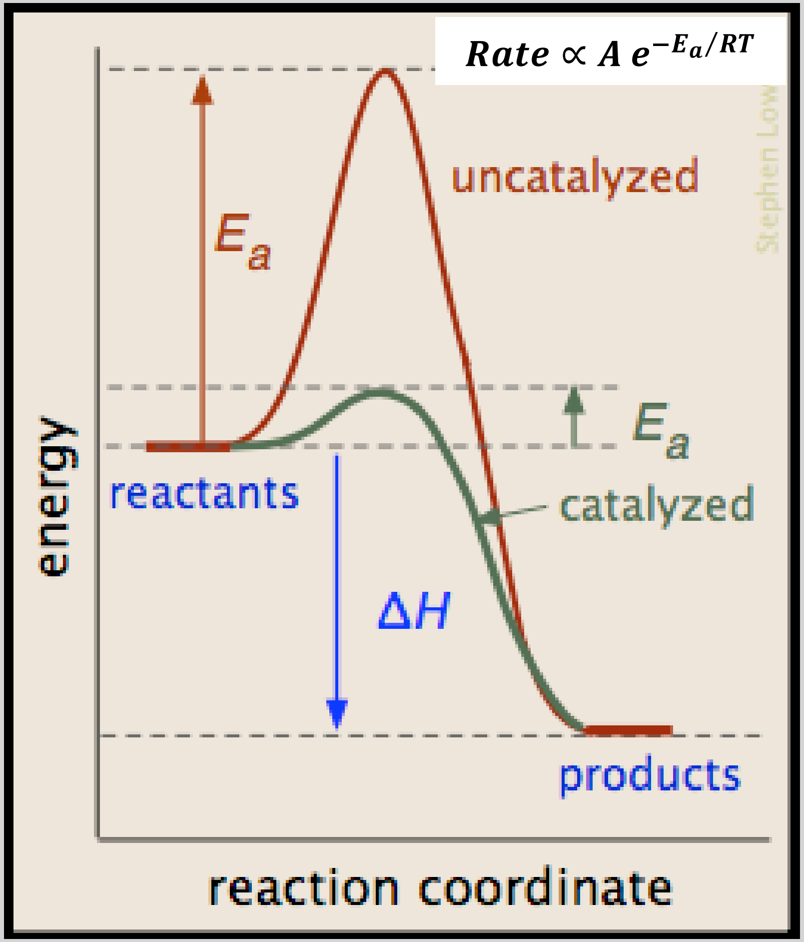
Need for CO Protection

- Most CBRN/fire contaminants are removed by specially treated activated carbon (acid gases, organics, chemical agents, etc.)
- CO can be fatal in a few minutes at 2000+ ppm
- About two thirds of fire deaths are due to CO poisoning.
- CO cannot be removed by adsorption on activated carbon

NIOSH Certification for CBRN

- NIOSH has an expedited program to test and certify escape respirators for emergency preparedness in the workplace.
- Escape respirators (escape hoods) protect users from breathing harmful gases, vapors, fumes, and dusts for the limited amount of time needed to reach fresh air.
- Escape respirators that pass the full set of tests will be approved by NIOSH
- NIOSH has added CO protection to their most recent standard for CBRN respirators
- Catalysts for oxidizing CO are the best option to protect from CO exposure

Catalysts Lower Activation Energies



http://chemwiki.ucdavis.edu/Physical_Chemistry/Kinetics/Complex_Reactions/Catalysis/Catalysts

- Catalysts only affect kinetics (reaction rates)
  - Thermodynamics NOT changed
- Catalysts lower the activation energy (E_a) of a chemical reaction, which increases the reaction rate
- Lowering E_a means can operate at lower temperature
- For multiple reactions, can lower E_a for a desired reaction, making the catalyst selective
- Both activity and selectivity are important for good catalyst performance

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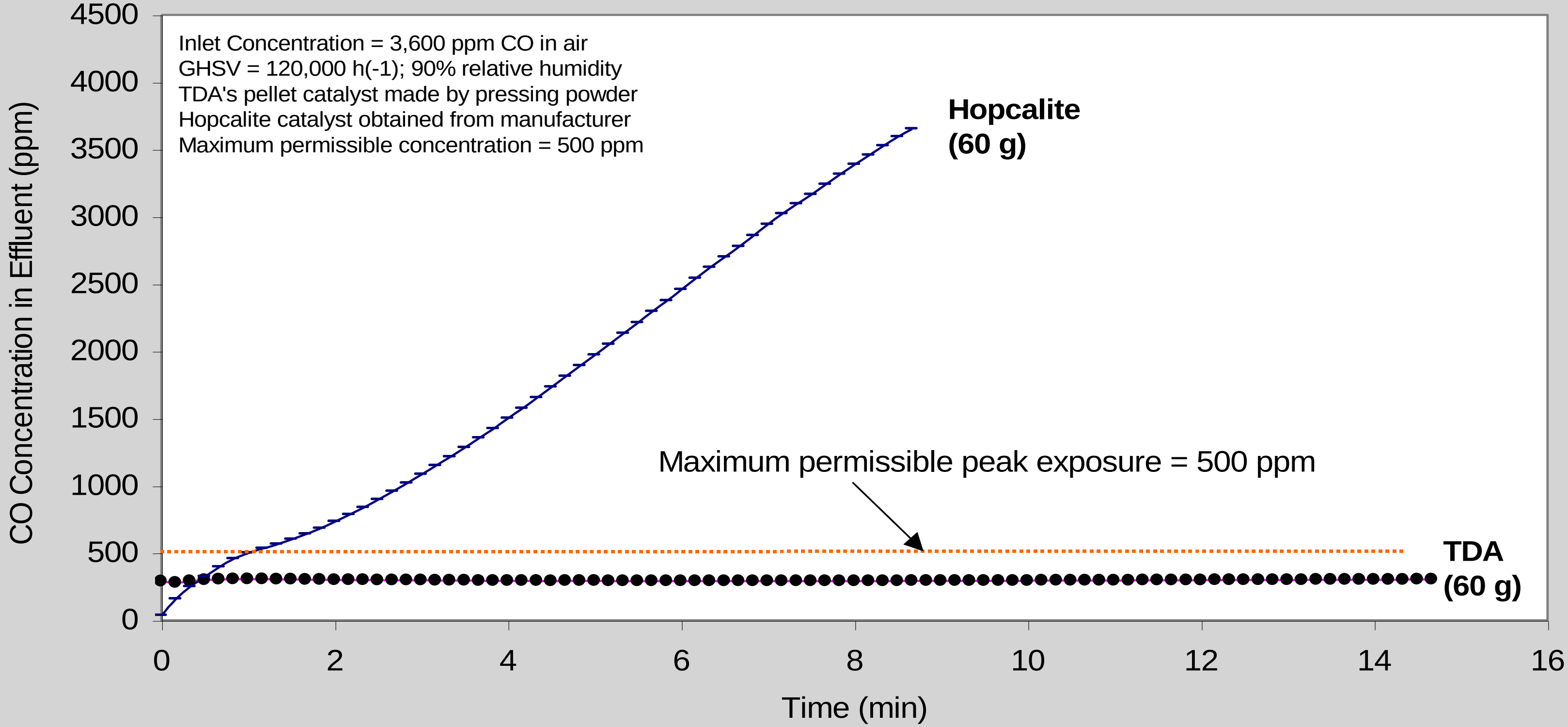
Hopcalite: "Standard" CO Oxidation Catalyst

Deactivated by Water



- Hopcalite is copper-manganate that has been used for CO oxidation since around WW I.
- Hopcalite is very sensitive to moisture and requires a large desiccant bed upstream to remove water vapor

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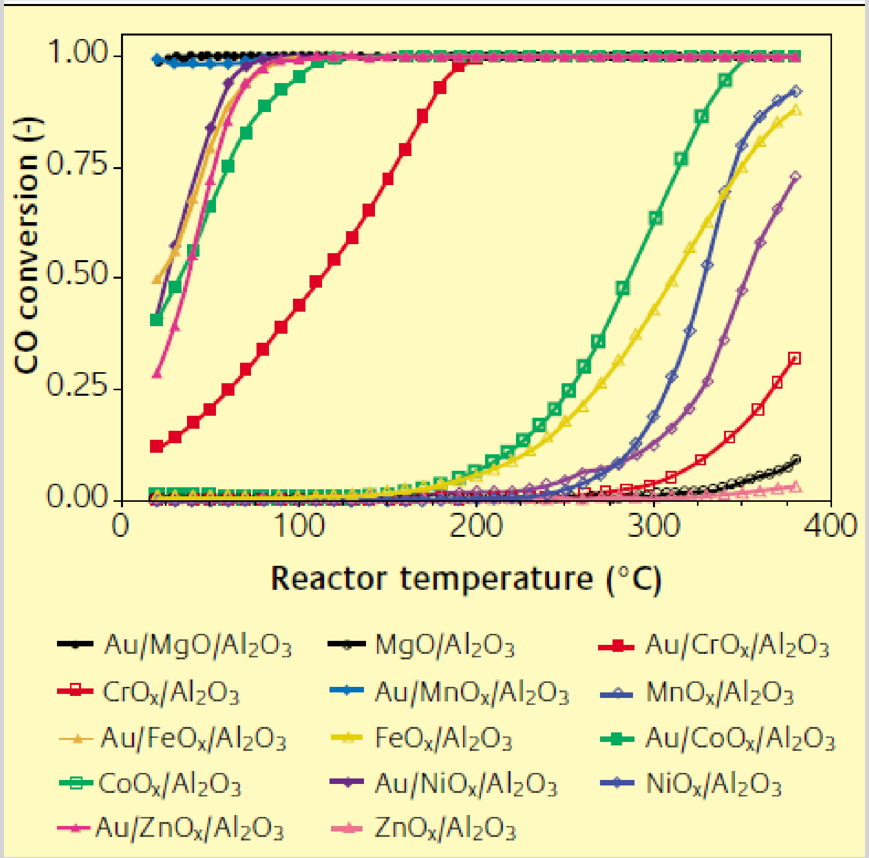
CO Oxidation Catalysts

- Conventional CO oxidation catalysts such as chromium and iron oxides require temperatures of ~400°C for complete conversion
- Even Pt/Al_2O_3 requires ~200°C
- Nano-Au supported on transition metal oxides function at much lower temperatures
  - Room temperature & lower

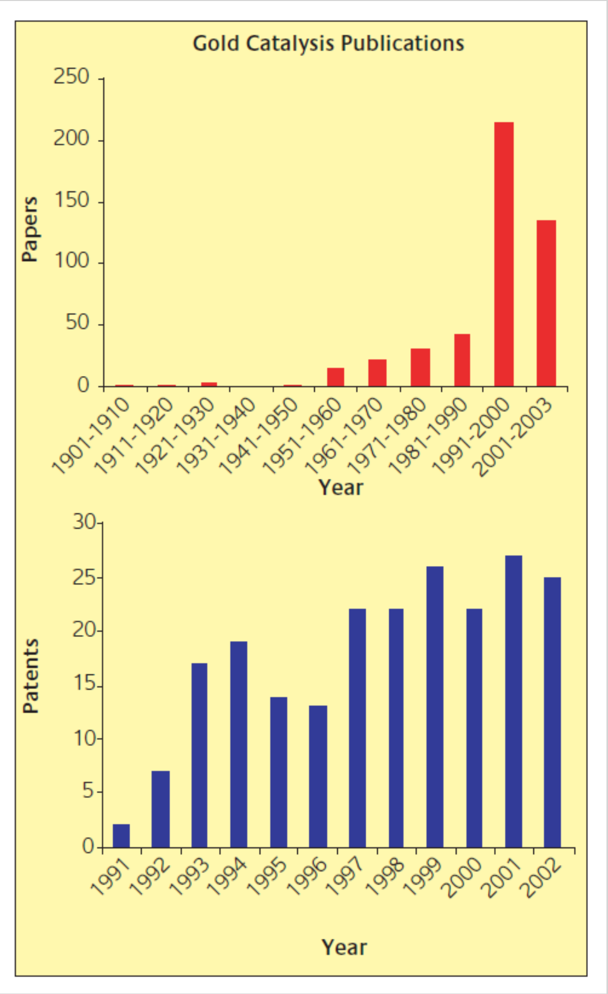


"Catalysis by Gold Nanoparticles," Ruud Grisel, Kees-Jan Weststrate, Andrea Gluhoi and Bernard E Nieuwenhuys* Gold Bulletin 2002 • 35/2 39-45

Catalysis by Gold

Bulk Au is a Noble Metal

- Discovery by Haruta and coworkers in the late 1970s
  - Au supported on transition metal oxides had activity for CO oxidation
  - Reducible oxide with cations that have multiple oxidation states gave more active catalysts (e.g. Au/SiO_2 catalysts had low activity)
  - Au crystallites had to be about 5 nm to be active
  - Activity for CO oxidation was observed at T = –70°C
- This discovery created great interest in Au catalysis



Ref: **"New Directions in Gold Catalysis,"** Graham J. Hutchings *Gold Bulletin* 2004 • 37/1–2 3-11

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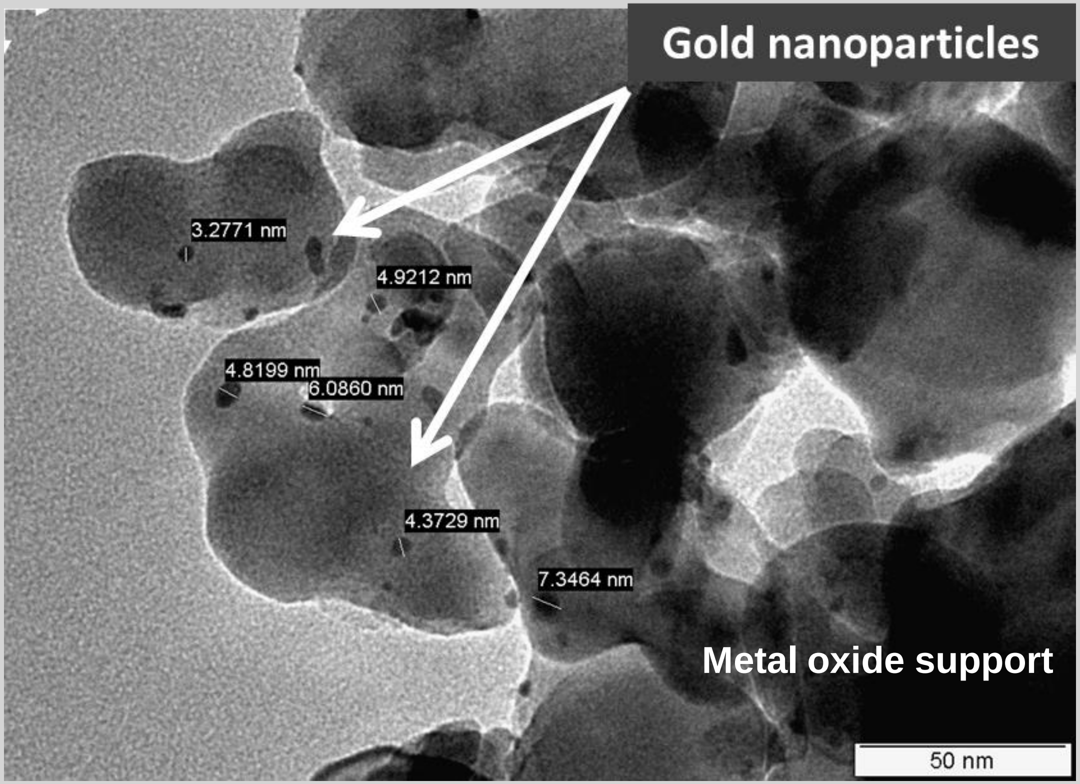
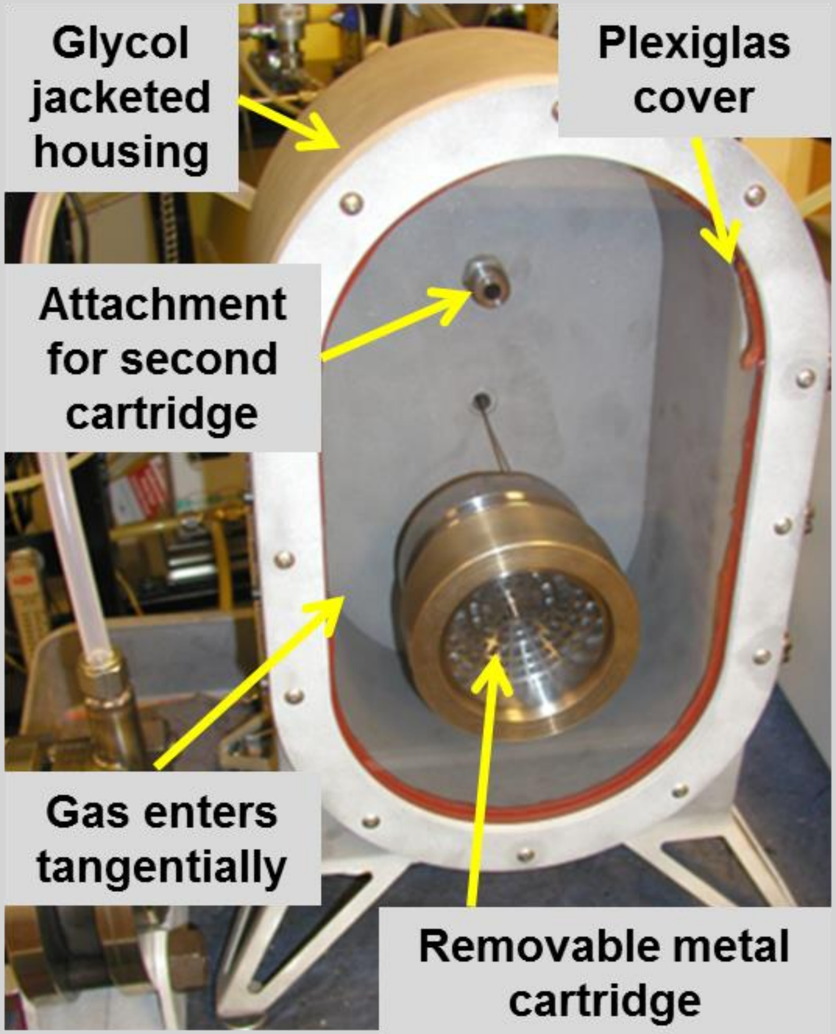
Example of TDA Nano-Au Catalyst



- High resolution TEM image of TDA's low temperature oxidation catalyst showing Au nanoparticles

CO Oxidation Catalyst Test Apparatus



- Environmental chamber for respirator cartridge testing
- Apparatus is fully computer controlled (flows, temperatures, data-logging, etc.)
- Respirator cartridge machined from brass and stainless steel
- Permits rapid loading and unloading of carbon, catalysts etc.
- More than one cartridge can be tested at a time

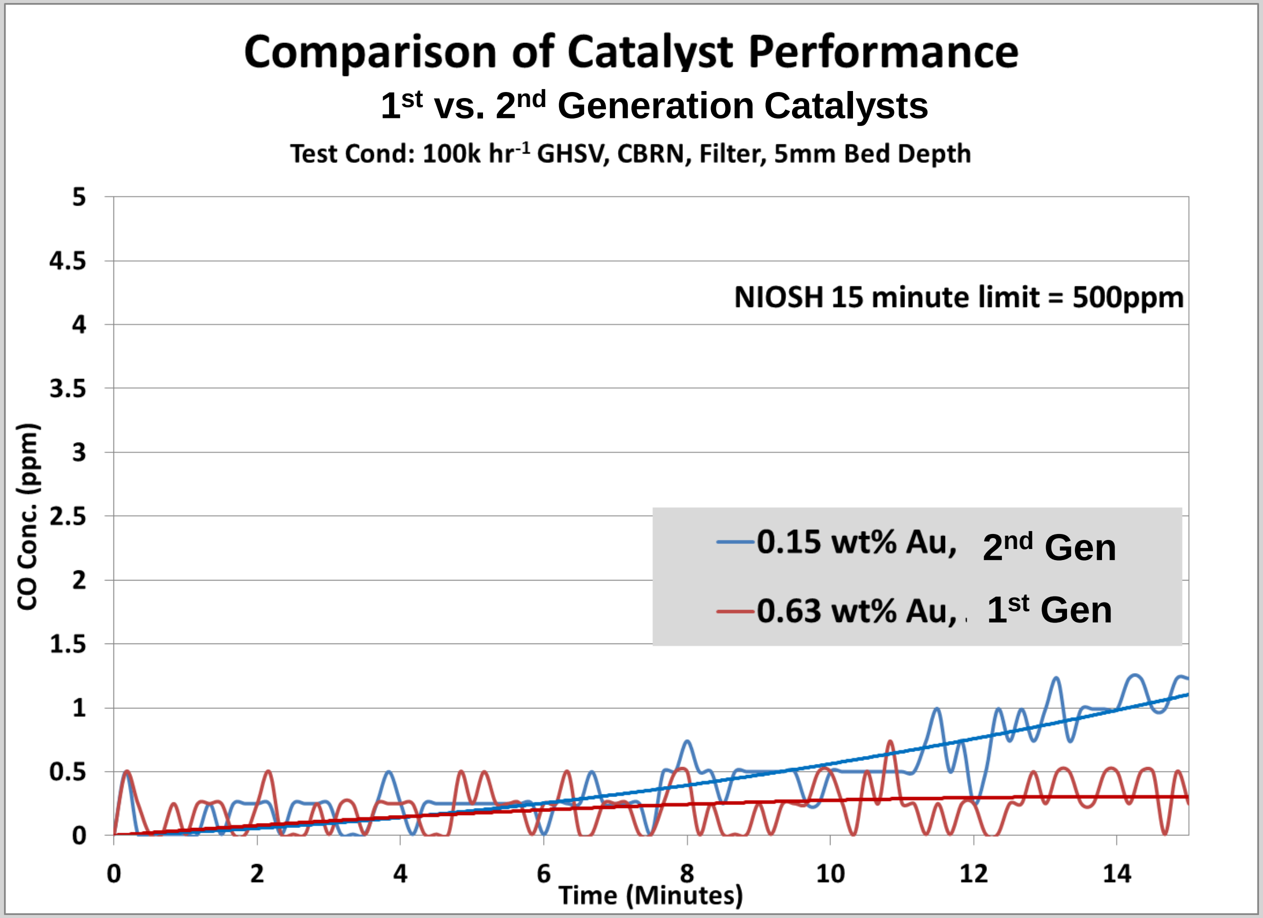
CO Removal for CBRN Respirators

CBRN Challenge Conditions

- CO oxidation catalyst for escape hood (CBRN application)
  - Project funded by NIOSH
    - Challenge = 3,600 ppm CO
    - Air flow = 64 liter/min, T = 0°C
    - Less than 500 ppm CO slip
    - Needs to operate for 30 minutes
    - No spike above 500 ppm at any time

CBRN Catalyst Performance

Reducing the Au Content = production cost savings



- Reduced Au content without compromising catalyst performance

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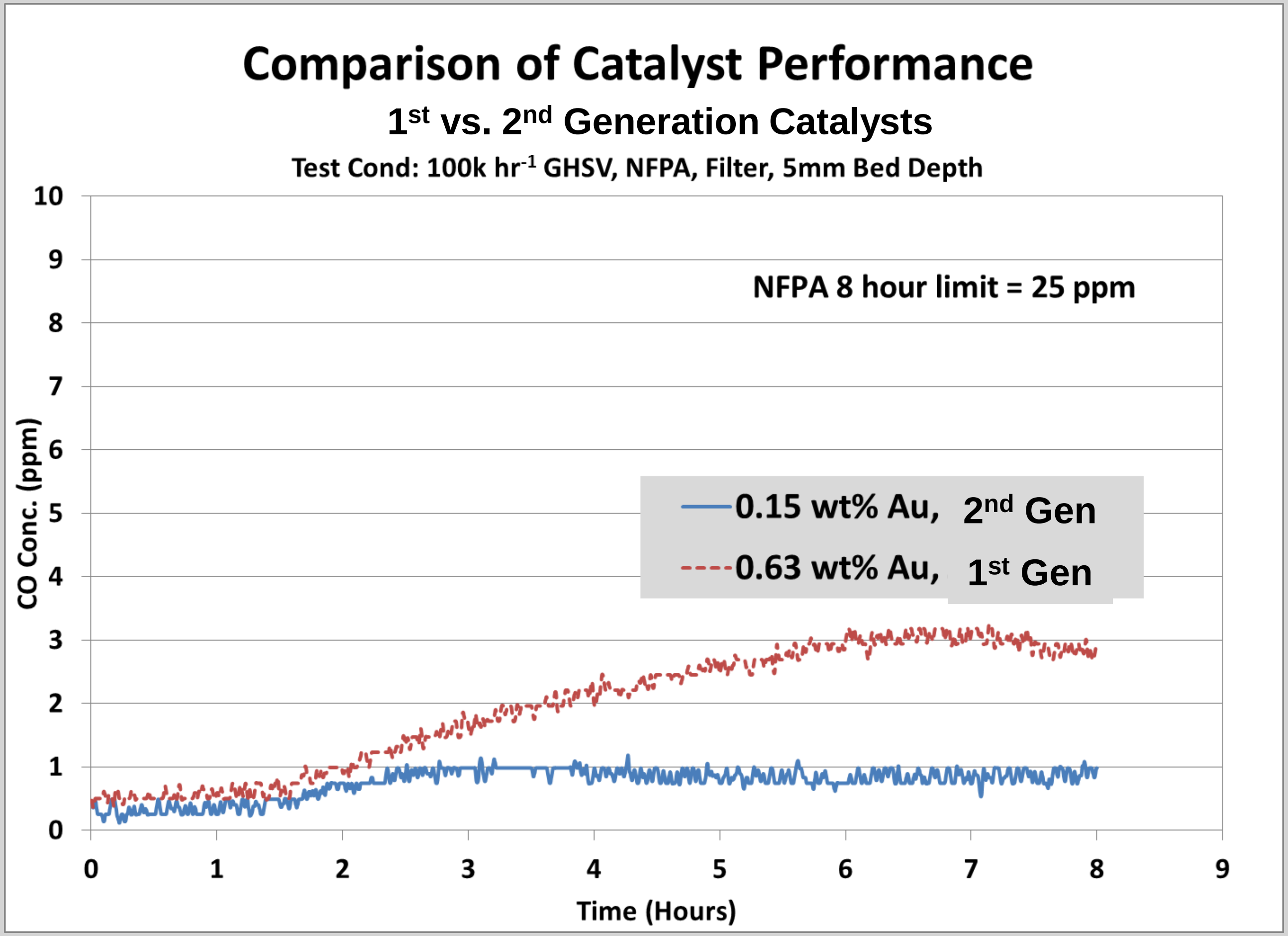
CO Removal for Wildland Firefighters

U.S. National Fire Protection Association (NFPA) Standard #1984

NFPA 1984 Challenge Conditions

- CO oxidation catalyst for wildland firefighters
  - Challenge = 200 ppm CO
  - Air flow = 64 liter/min, RH = 92%, T = 25°C
  - 90% removal (no more than 20 ppm average breakthrough over 5 minutes)
  - Needs to operate for 8 hours

NFPA 1984 Catalyst Performance



- Again, reduced Au content without compromising catalyst performance

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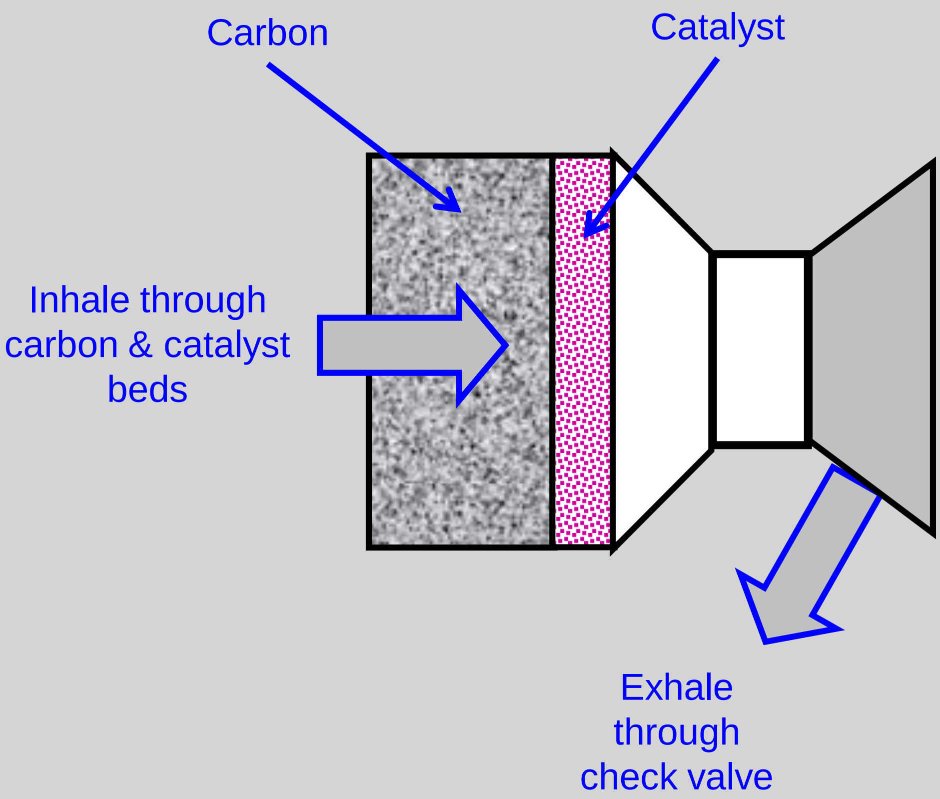
Activated Carbon Protects User and Catalyst

- In both CBRN and NFPA 1984 applications
  - Catalyst is located downstream of the activated carbon in the canister
  - Activated carbon removes contaminants by adsorption, thus…
  - Activated carbon protects the user from harmful substances and protects the catalyst from contaminants that could cause deactivation
  - Activated carbon also
    - Helps establish uniform flow and velocity profile upstream of the catalyst bed
    - Minimizes channeling
    - More efficient catalyst use



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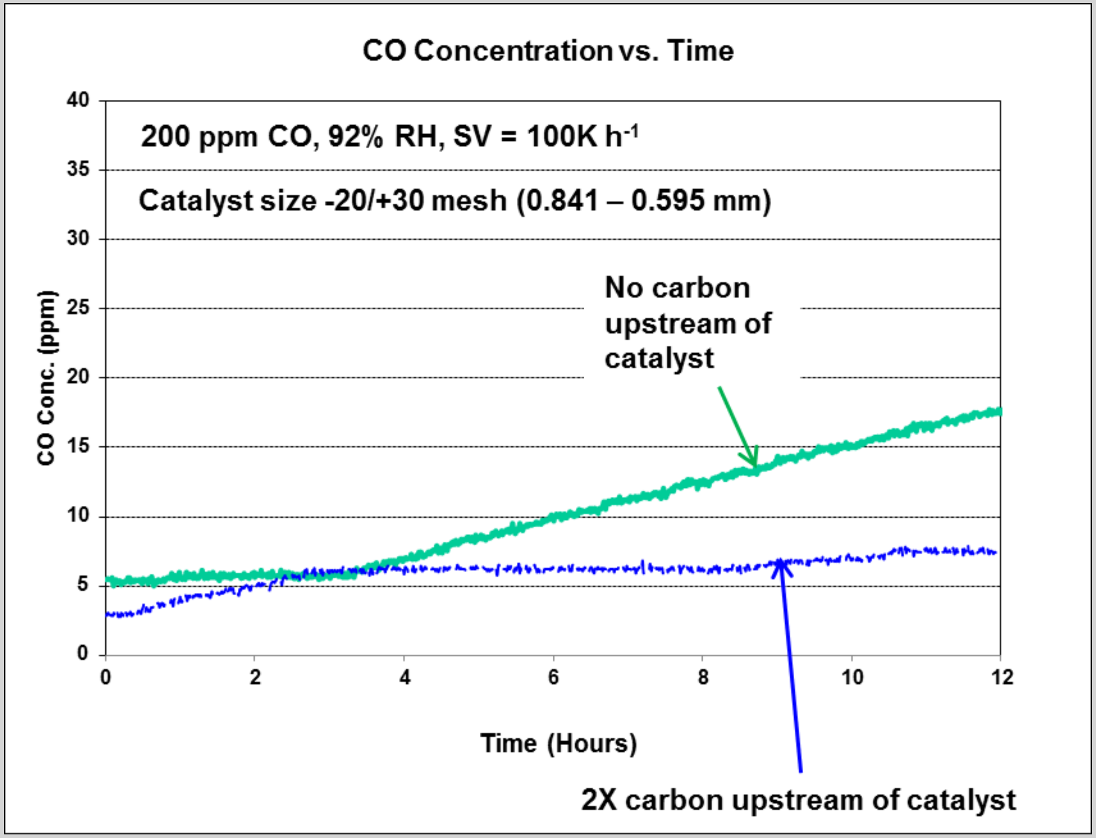
Catalyst Performance
With and Without Activated Carbon Upstream

- Catalyst tested under NFPA 1984 conditions
- With and without a carbon bed upstream of the catalyst bed
- Without carbon, slow deactivation is observed (still passes however with < 20 ppm CO over 8 hours)
- With carbon upstream, performance is greatly improved
  - Carbon bed improves flow distribution through the catalyst bed
  - Carbon removes trace amounts of contaminants that could deactivate the catalyst



Conclusions

- TDA Research Inc. has successfully developed a series of Au based, low temperature CO oxidation catalysts whose performance exceeds the NIOSH CBRN-CO and wildland firefighter NFPA 1984 standards

- TDA's catalysts can remove 99.7+% of 3600 ppm of CO at 0°C at flow rates that exceed the NIOSH requirement by up to a factor of

- We estimate that each mask cartridge will require about 20 grams of TDA catalyst. This is in contract to more than 150 grams of Hopcalite + desiccant that need to be typically used

Acknowledgments

- NIOSH for funding the research effort

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