Carbon Monoxide (CO) Protection for Escape Respirators

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TDA Research

Abstract

First responders (policemen, firemen, etc.) are the men and women who are first on the scene of a disaster. There are 11 million state and local first responders in 87,000 jurisdictions throughout the United States. Escape hoods that are effective against chemical, biological, radiological and nuclear (CBRN) agents need to be developed and approved by NIOSH so that first responders may use them effectively.

TDA Research, Inc. (TDA) has collaborated with a major PPE (Personal Protective Equipment) manufacturer to develop a CBRN escape hood that will meet the recently announced standards by the NIOSH. In addition to CBRN protection, the escape hood will be designed to be effective against carbon monoxide (CO). In the Phase I SBIR project, TDA has designed, fabricated, and tested catalytic materials that were effective in removing CO at 0 C. TDA has tested the product successfully using NIOSH specified criteria. In the Phase II project, TDA will scale up the catalyst, optimize the composition and amounts, and test it in a canister at its collaborator's facilities.

Introduction

When responding to hazardous situations such as fires or chemical spills, one of the primary concerns for first responders and civilians trying to escape is respiratory protection. While firefighters have access to SCBA, civilians and other potential first responders (police, paramedics, etc.) are typically not equipped with this type of long-term respiratory protection. As a result, short-term protection, such as gas masks or bottled air escape respirators, are used by those without access to SCBA.

One form of short-term respiratory protection is the air purifying escape respirator (Figure 1), which has been approved for chemical, biological, radiological, and nuclear (CBRN) hazard protection. The escape hood, made of a laminate material, is easy to put on and completely covers the head and neck. The contaminated air is breathed-in through a canister containing impregnated carbon, where it is purified, and exhaled air flows out of the hood through a separate valve to make breathing easier for the user. The escape hood is designed to provide ~15 minutes of escape time for first responders or civilians.

Figure 1. Escape hood.

The most common incidents resulting in the need for respiratory protection are fire related. In 2000, 1.7 million fires in the U.S. resulted in 4,200 deaths. A common cause of death in these instances is exposure to the hazardous compounds produced by a fire (Table 1), including carbon monoxide (CO). Though the escape hood described above provides effective protection against CBRN, it does not provide any protection against CO exposure. Furthermore, new NIOSH certification requires CO protection. As a result, technologies that will protect users against CO when using respiratory protection, such as the escape hood, are highly desirable.

Table 1. Typical contaminant levels in fire smoke.

Contaminants	Typical Conc. (ppm)	Max. Conc. (ppm)	IDLH (ppm)
Acrolein	1.9	98	5
Benzene	4.7 – 56	250	3000
CO	246 – 1450	27000	1200
HCl	0.8 – 1.3	280	100
HCN	0.14 – 5.0	75	50
NO_2	0.04 – 0.7	9.5	50
SO_2	2.3	42	100
Particulates (mg/m^3)	232	15000	n. a.

Methods

TDA Research, Inc. (TDA), in collaboration with a major PPE manufacturer, is developing catalysts for the low temperature oxidation of CO to CO_2. The inclusion of these catalysts in the carbon cartridge used in the escape hood will provide the wearer protection against dangerous levels of CO. Several of TDA's CO-oxidation catalyst formulations have been shown to successfully oxidize CO at low temperatures (Figure 2).

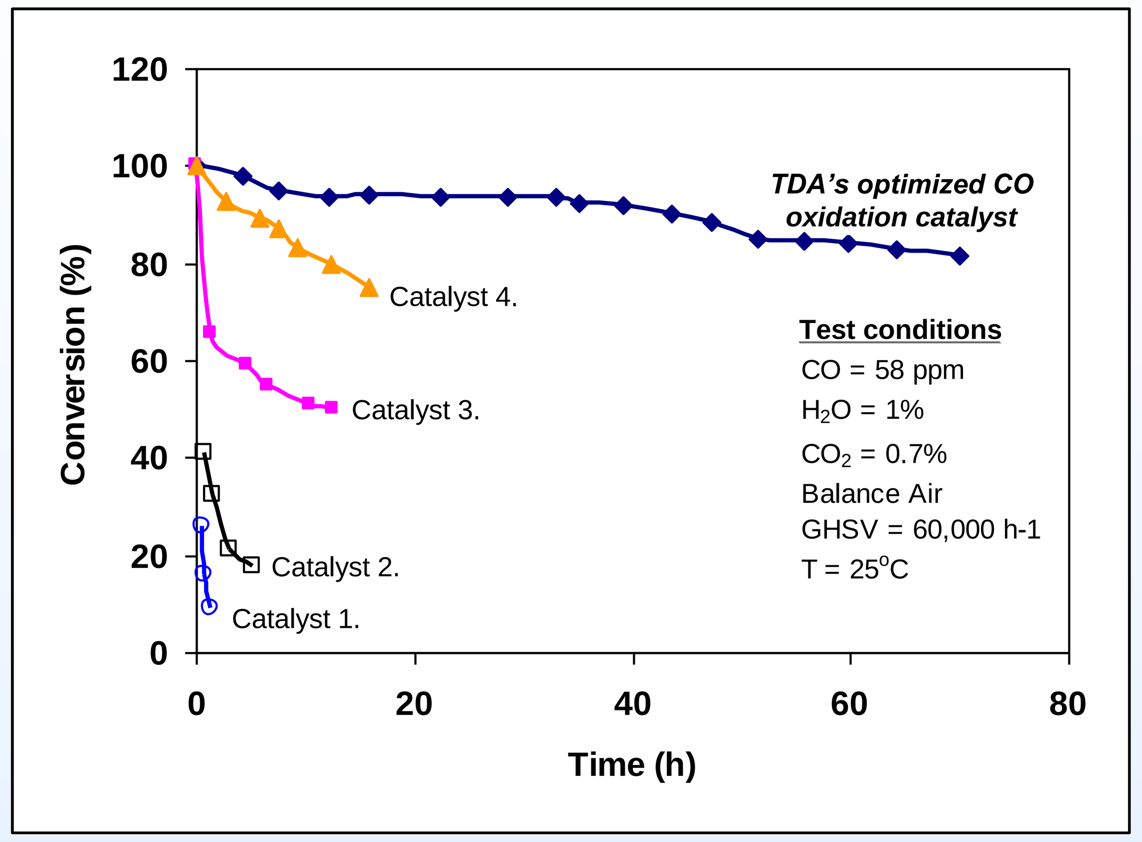

Figure 2. CO oxidation results for various transition metal oxide catalysts developed at TDA.

Based on these novel catalysts developed previously at TDA, catalyst compositions were further optimized for low temperature (0 C) oxidation of CO and screened under NIOSH specified conditions:

- 15 minutes of protection from 3,600 ppm of CO
- peak CO slip during 15 minutes should be no higher than 500 ppm
- testing to be done at 0 C with 64 slpm of air

Catalyst screening experiments were performed at TDA using a down-flow, fixed bed CO oxidation test reactor apparatus (Figure 3). The optimized CO oxidation catalysts were tested at GHSV of 30,000 to 120,000 hr^{-1} under the specified NIOSH testing protocol.

Following catalyst screening experiments, TDA tested its best catalyst in a canister in accordance with NIOSH test protocols. In these tests, a canister was filled with carbon and TDA's CO oxidation catalyst. The canister was then hooked-up to a test apparatus and evaluated under the NIOSH conditions of 64 slpm of 0 C air containing 3,600 ppm of CO. The canister outlet was then monitored for CO using an infrared CO analyzer. Initial tests with the canister failed to meet the NIOSH prescribed CO slip in the first 2 minutes of the test. The composition of the canister was then modified, resulting in a successful test.

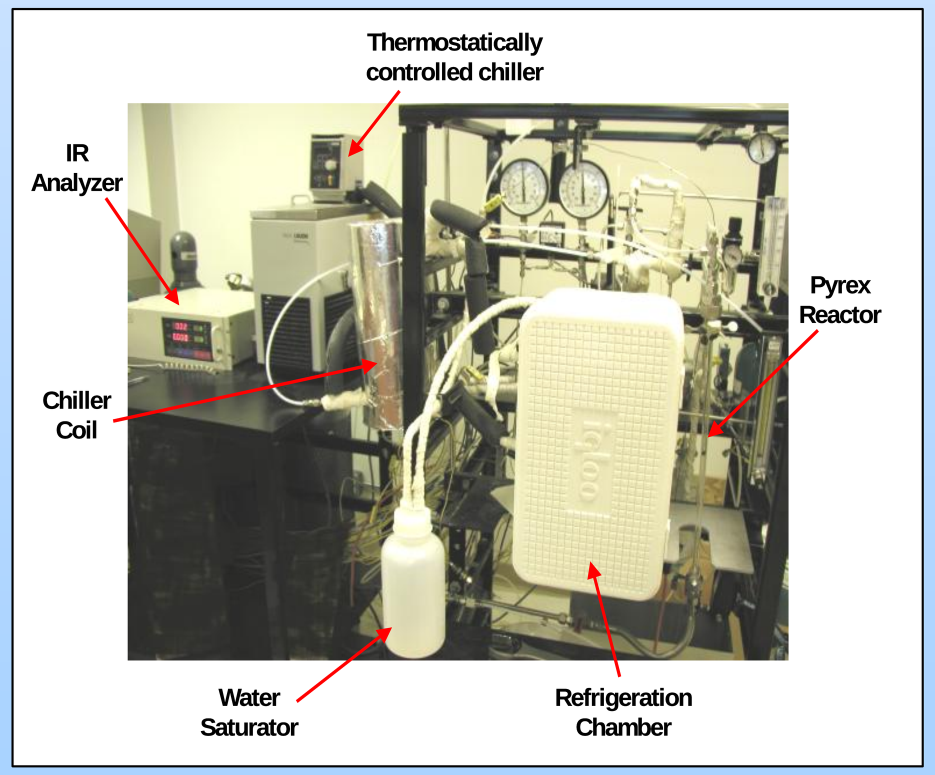

Figure 3. TDA's CO oxidation test apparatus.

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Results

TDA screened CO oxidation catalysts in order to optimize its catalyst for operation at 0 C. Catalyst screening results using NIOSH testing protocols for TDA's best catalyst can be seen in Figure 4. In all cases, >80% of the CO was oxidized and 100% conversion of CO was observed for our best catalyst.

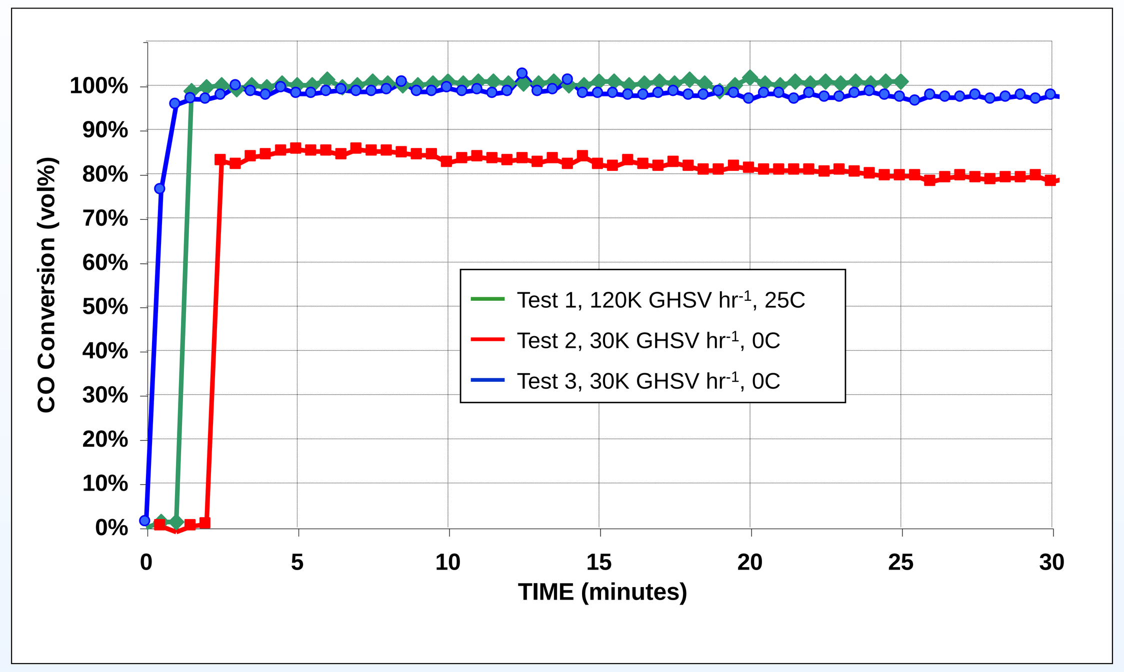

Figure 4. Catalyst screening results using NIOSH test protocols for TDA's best CO oxidation catalyst.

Prototype testing was performed with a canister using a NIOSH prescribed test apparatus. Results for initial testing under NIOSH test conditions are shown in Figure 5. As can be seen, the canisters containing TDA's CO oxidation catalyst failed the test due to CO spikes >500 ppm (NIOSH protocol #2) that occurred in the first two minutes of the run. In order to eliminate these CO concentration spikes, TDA further modified the canister content formulation in order to pass the NIOSH protocols. Figure 6 shows the results of repeated NIOSH protocol testing using the modified canister formulation. With the new canister, which included TDA's CO oxidation catalyst, TDA was able to eliminate the >500 ppm CO spikes, thus passing all NIOSH protocol for respiratory CO protection.

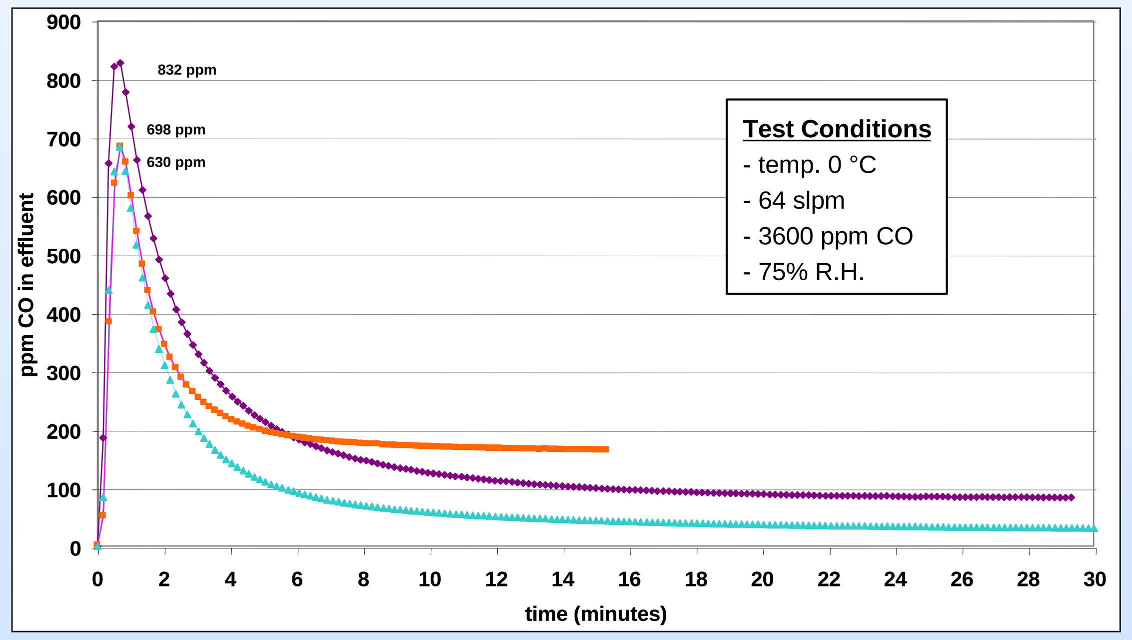

Figure 5. Initial testing results performed with a prototype respirator canister.

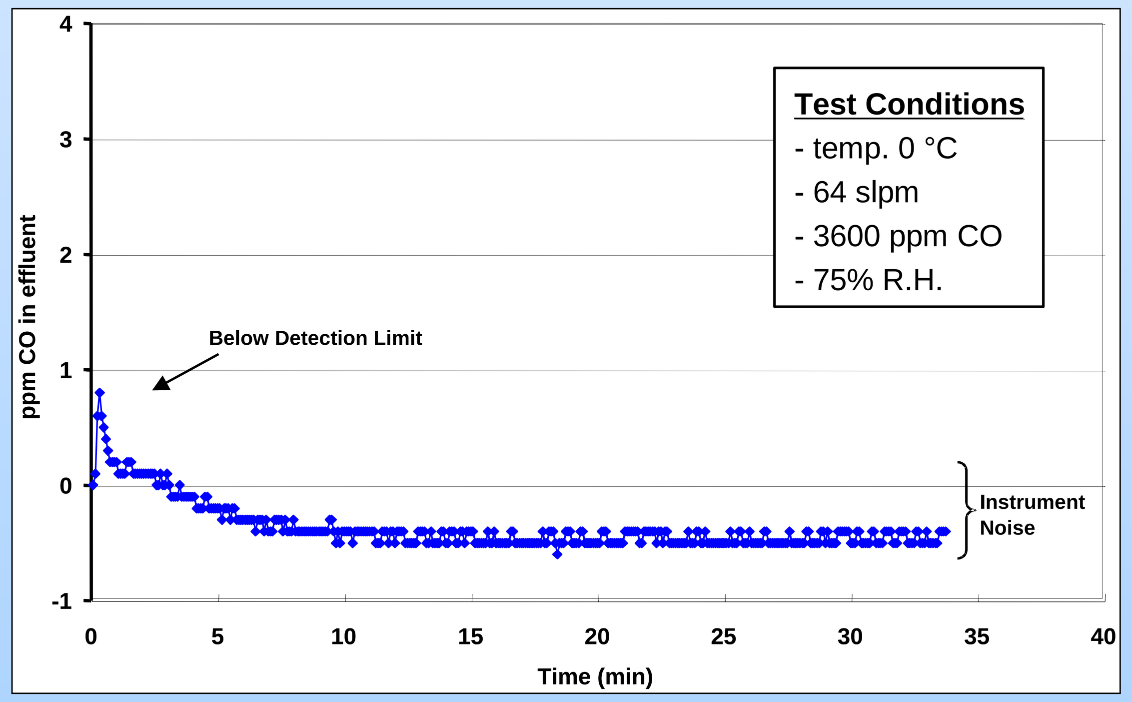

Figure 6. Prototype canister test results with TDA's modified composition, which passed NIOSH protocols.

Conclusions

TDA, in collaboration with a major PPE manufacturer, has developed a CO oxidation catalyst that can be used in respirator cartridges to protect the user from dangerous atmospheric levels of CO. Results indicate that this approach will allow escape respirators to pass the NIOSH certification tests.

Disclaimer

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