EVALUATION OF CATALYTIC MATERIALS FOR MILITARY AIR PURIFICATION APPLICATIONS

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1. INTRODUCTION

Fielded air purification systems designed for removal of chemical warfare agents from air streams are based solely on activated, impregnated carbon, namely ASZM-TEDA. The broad chemical biological and radiological (CBR) threat presents a challenge to the traditional fielded CBR air purification technology, impregnated carbon filters. While these filters function well against a wide range of chemical agents, they possess several shortcomings such as limited capacity for agents that are removed by chemical reaction and/or weakly adsorbed, and minimal protection against several of the toxic industrial chemicals (TICs). Further, prolonged environmental exposure has been shown to reduce the capacity of these filters for agents that are removed by chemical reaction. The result of these shortcomings are (1) to limit the usefulness/protection capability of current NBC filters and (2) to impose change-out requirements that present logistical as well as disposal burdens to the user.

Catalytic oxidation is an alternative air purification technology that is being investigated as a means of alleviating the above mentioned burdens. CATOX technology's target attributes include: (1) broad protection against chem-bio threat, (2) reduced logistics due to long operational life, (3) greatly increased capacity for CB agents and TICs compared to current NBC collective protection technologies and (4) lower energy costs relative to other regenerative filtration technologies.

2. TEST METHODOLOGY

Samples of monolithic catalytic materials were obtained from commercial vendors and tested in a fixed bed catalytic reactor (Figure 1). The system was designed to deliver either a dry or humid air stream containing the chemical of interest at the desired concentration to a fixed bed catalytic reactor. A water saturator or HPLC pump was used to deliver water to the process, allowing the process to be operated over a range of water concentrations. Chemicals were delivered to the process either as a gas (from a commercial cylinder) or a liquid (using a saturator cell located within a temperature controlled water bath). The reactor consisted of a glass tube (either 5.0 or 2.5 cm in diameter) housed within a dual zone tube furnace. Thermocouples were located within the channels of the monolith (monitoring the catalyst temperature) and. above the monolith (monitoring the temperature of the incoming process stream). A portion of the reactor effluent is delivered to the appropriate analytical device, such as a gas chromatograph or NO-NO_x analyzer. Catalyst tests consisted of the following: catalyst was heated to the desired operating temperature under flowing air (either dry or humid), then exposed to the desired concentration of chemical, with the initial catalyst temperature maintained at steady state and, subsequently, the catalyst temperature was be decreased at a steady rate. The effluent was sampled at discrete intervals for the concentration of reactant and reaction products and testing was terminated at the point in which the conversion of the desired compound decreases to below 10%. Data was plotted as conversion of parent chemical as a function of reaction temperature as well as additional plots of effluent concentration as a function of reaction temperatures.

3. RESULTS AND CONCLUSIONS

A number of commercially available catalytic materials were evaluated for their ability to decompose

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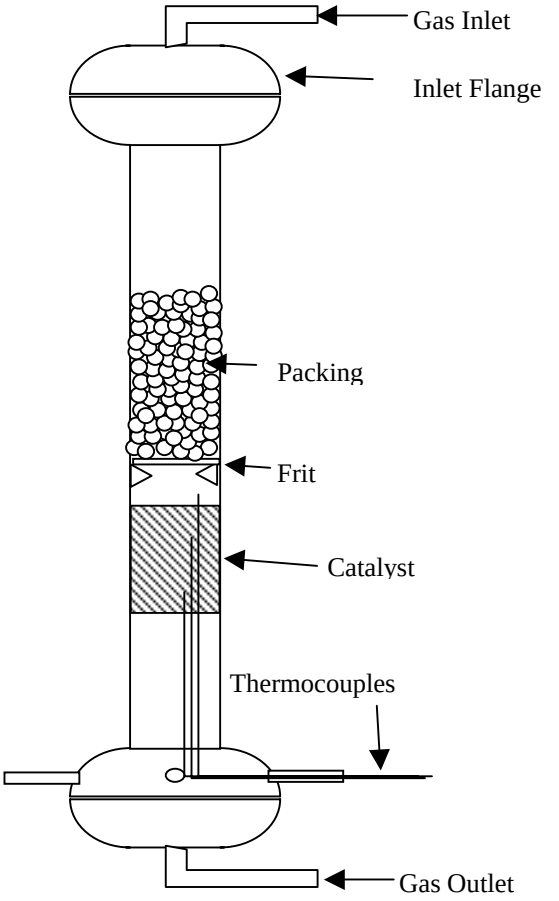

Figure 1. Schematic representation of catalytic reactor

chemical agent simulants and toxic industrial chemicals. Although many of these materials were highly reactive, none of the materials possessed the overall reactivity and selectivity necessary to meet performance guidelines. Many of the catalysts evaluated required excessive temperatures (greater than 450°C) in order to decompose halogen-containing compounds. Operation at the high temperature was not suitable for the destruction of nitrogen-containing compounds, due to the formation of NO_x.

In order to take advantage of specific catalyst features, a layered bed catalyst configuration was evaluated in a laboratory scale catalytic reactor test stand. The objective of this effort was to identify an operating "window" over which the catalyst technology could be successfully employed. The inlet layer employed a catalytic material designed to decompose nitrogen-containing compounds with minimal NO_x and N_2O formation. The outlet layer employed a highly reactive catalytic material designed for the destruction of halogen-containing compounds. The layered bed catalytic reactor configuration was evaluated for its ability to decompose ammonia, ethylene oxide, formaldehyde, hexafluoropropene, CEES and DMMP. Test results (Table 1) demonstrated that the layered bed configuration could be successfully operated at temperatures between 300 and 370°C over a range of ambient humidities. Over the stated temperature range, the layered bed was able to achieve greater than 99% ammonia destruction with less than 3% NO_x selectivity, achieve greater than 99% destruction of formaldehyde, ethylene oxide and hexafluoropropene, and achieve greater than 99.99% destruction of CEES and DMMP.

Table 1.
Catalyst performance summary information

Catalyst	DLC[1]	Temp.[2] (°C)	Ammonia $[NO_x]$[3] (ppm)	Ammonia $[N_2O]$[3] (ppm)
A	C_3F_6	T > 500	> 500	> 300
B	C_3F_6	350	15	160
C	C_3F_6	310	400	550
D	C_3F_6	440	> 1,000	~ 300
E	C_3F_6	T > 500	> 1,000	~ 300
F	C_3F_6	T > 500	> 1,000	~ 300
G	C_3F_6	450	> 1,000	~ 300
H	C_3F_6	450	> 1,000	~ 300
I	C_3F_6	T > 500	> 1,000	~ 300

Catalyst:
A: Guild No-NO_x
B: Guild No-NO_x Plus 3X
C: Guild 3X
D: Engelhard #164217005
E: UEC NB001-73-001
F: UEC NB001-73-002
G: SCP LS02-03145
H: SCP MISC-03144
I: JM CatalyK6 Sample

[1]Chemical requiring greatest temperature to achieve 99% destruction
[2]Temperature required to achieve 99% destruction of design limiting chemical
[3]NO_x or N_2O concentration formed during destruction of NH_3 at temperature