

# Characterization of Sorbents for Controlling Ammonia in Spacecraft Cabin Air

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The trace contaminant control system (TCCS) utilizes packed beds of Barnebey-Sutcliffe (B-S) Type 3032 to remove ammonia from ISS cabin air. BS Type 3032, an acid-impregnated activated carbon, is no longer produced and must be replaced. The adsorptive capacities of Calgon Carbon Ammonasorb II and Molecular Products Chemsorb<sup>®</sup> 1425 for ammonia were measured using moist (40% RH) spacecraft simulated gas streams. These candidate replacement sorbents had 66% greater ammonia removal capacities at low (5 ppm) ammonia concentrations than B-S Type 3032.

## Nomenclature

<i>ECLS</i>	=	environmental control and life support
<i>GAC</i>	=	granular activated carbon
<i>ISS</i>	=	International Space Station
<i>SMAC</i>	=	spacecraft maximum allowable concentration
<i>TCCS</i>	=	trace contaminant control system
<i>g</i>	=	gram

## I. Introduction

AMMONIA in portable life support systems, spacecraft, and surface habitats is produced by crew metabolism and by offgassing from hardware and payloads<sup>1</sup>. Ammonia is given off in sweat (40 g NH<sub>3</sub>-N person<sup>-1</sup> year<sup>-1</sup>) and in human breath (3 g NH<sub>3</sub>-N person<sup>-1</sup> year<sup>-1</sup>)<sup>5</sup>. Ammonia was observed during the 60-day and 90-day tests of the Closed Environment Living Study conducted by NASA.<sup>6</sup> During the 60-day test ammonia rose to 0.14 mg/m<sup>3</sup> by day 5 and remained constant until day 60. During the 90 day test, ammonia was low during the first 20 days, but it rose to 0.35 mg/m<sup>3</sup> by day 30 and to 0.8 mg/m<sup>3</sup> by the end of the test. The offgassing and production rates of ammonia for calculating the expected trace contaminant design loads in man-rated spacecraft are given in Table 1<sup>7</sup>. These sources of ammonia must be controlled below a 180-day SMAC level of 2 mg/m<sup>3</sup>, to avoid symptoms from exposure such as eye discomfort, solvent smell, and headache<sup>8</sup>.

**Table 1. Trace Contaminant Design Load - 2008**

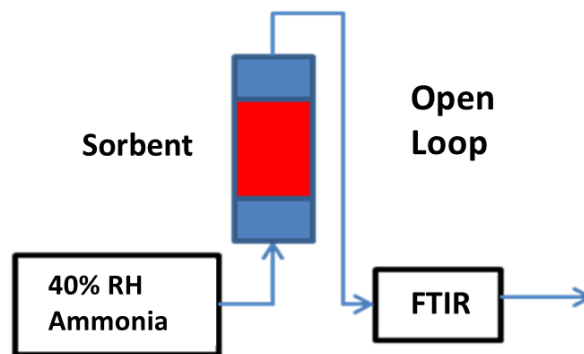
Contaminant	180-day SMAC mg/m <sup>3</sup> (ppm)	Equipment Offgas- sing (mg/d-kg)	Metabolic Produc- tion (mg/d-person)
Ammonia	3.5 (5)	$8.5 \times 10^{-5}$	50

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Aboard the ISS, ammonia is removed by the granular activated carbon bed (GAC) of the TCCS and through incidental removal via absorption by humidity condensate collected by the condensing heat exchangers. The size and flow rate of the GAC bed is determined by the required rate of ammonia removal. Currently, the GAC utilizes the commercially obsolete Barnabey-Sutcliffe (B-S) Type 3032 impregnated carbon. The purpose of this study was to compare the efficacy of two candidate commercial replacements for B-S Type 3032: Calgon Carbon Ammonasorb II and Molecular Products Chemsorb 1425. This comparison was made at low ammonia concentrations in the presence of water vapor similar to those found aboard ISS because adsorptive capacities measured at higher concentrations would overestimate the performance of the sorbents. The need for identifying sorbents with similar performance characteristics using conditions found aboard the ISS helps mitigate commercial obsolescence risks associated with commercial products over their market life cycle.



**Figure 1. Open loop system for measuring adsorptive capacity of treated activated carbons for ammonia.**

## II. Materials and Methods

### A. Sorbents

Two candidate ammonia adsorbents were evaluated. Chemsorb 1425 is a granular coconut-shell, impregnated activated carbon sorbents produced by Molecular Products, Inc. used for the adsorption of airborne ammonia and amines. Calgon Carbon Ammonasorb II is marketed as the replacement coconut-shell, treated activated carbon for B-S type 3032.

Treated activated carbons such as Ammonasorb II and Chemsorb 1425 are impregnated with a chemical agent such as phosphoric acid that reacts with  $\text{NH}_3$ , converting it to a salt within the carbon thus removing it from the air stream via chemisorption<sup>9</sup>. Adsorption capacity is exhausted when the available impregnated chemicals are consumed. Moisture affects removal performance since adsorption sites within the pores are filled with water. The co-adsorption of water vapor and 50 ppm  $\text{NH}_3$  increased the adsorptive capacities of Ammonasorb II and Chemsorb 1425 increased by 25% and 74%, respectively<sup>4</sup>.

### B. Apparatus

An open loop system was used to measure the adsorptive capacity of the candidate sorbents (Fig. 1). A gas stream composed of nitrogen was humidified to 30-40% RH and mixed with ammonia. The system delivered between 2-50 ppm of moist ammonia gas to a sorbent tube filled with 40-60 mg of treated carbon at 0.6 to 1 liter/min flow. The temperature of the laboratory was set at 23 °C. The gas stream passed through the sorbent and the  $\text{NH}_3$  concentration was measured using a Gaset 4030 FTIR.

### C. Ammonia Capacity Measurements

#### 1. Sorbent Preparation

The sorbent granules were crushed into 2-3 mm pieces in a mortar with a pestle and loaded into 4-mm internal diameter desorption tubes. Powder formed during crushing was not used. The desorption tubes were loaded with enough activated carbon to ensure that the aspect ratio (length/diameter) was near 5. The adsorbent sample tubes were dried prior to use because they adsorb water vapor during storage. A weighed sample (40-60 mg) as received was loaded into the desorption tube and held in place using two glass wool plugs. The loaded tube was weighed and heated to 100 °C with a flow rate of 100 ml/min of  $\text{N}_2$  in a desorption tube conditioning oven (Scientific Instrument Services, Inc). This process dried the adsorbent and removed moisture adsorbed during storage and transport to the Kennedy Space Center (KSC). The loaded tube was weighed after 1 h and after 2 h, until its mass was constant. The mass difference was ascribed to water and subtracted from the initial sample mass.

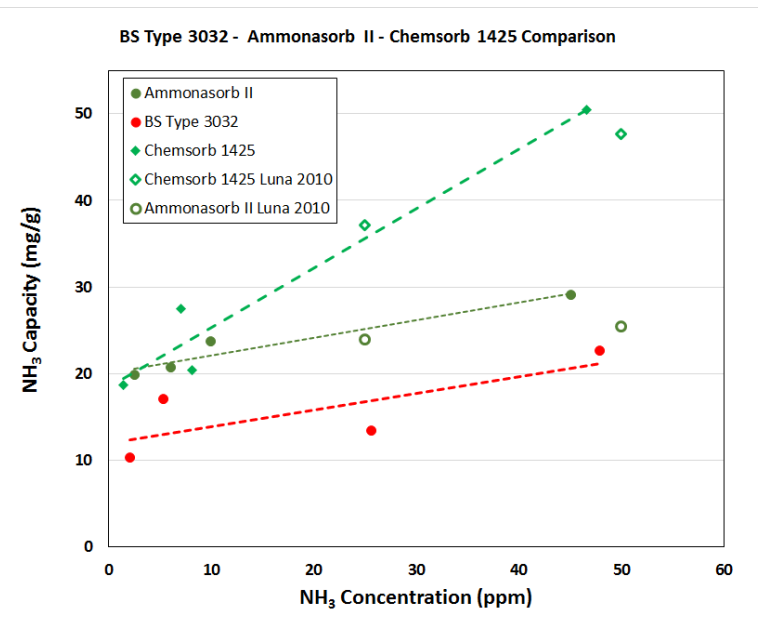
## 2. Breakthrough Measurements

Breakthrough experiments were performed by flowing a constant stream of nitrogen containing 2-50 ppm ammonia and 30-40% inlet relative humidity through the packed desorption tubes. The amount of  $\text{NH}_3$  adsorbed by the bed can be calculated from the difference between inlet and outlet  $\text{NH}_3$  concentrations and the flow rate. The approach is similar to that reported in previous studies by Monje using other carbons and evaluating the capacities for volatile organic carbons VOCs.<sup>3,4</sup>

## III. Results

The adsorptive capacities of Ammonasorb II, Chemsorb 1425, and B-S Type 3032 for moist ammonia gas streams (closed symbols) are compared (Fig. 2). The data of Luna et al., 2010 at 25 and 50 ppm are also shown for comparison (open symbols). Post-flight analysis of the ISS TCCS carbon beds measured that B-S Type 3032 has a capacity of 11.9 mg/g (not shown) at an ammonia concentration of 0.2 ppm (the ISS cabin average indicated by humidity condensate loading).

Chemsorb 1425 has a much higher adsorptive capacity than Ammonasorb II and B-S Type 3032. However, Ammonasorb II has a similar adsorptive capacity to that of Chemsorb 1425 at low ammonia concentrations, typically found in spacecraft (2-10 ppm). At 5 ppm of moist ammonia, the adsorptive capacities of Chemsorb 1425 (21.8 mg/g) and Ammonasorb II (21.1 mg/g) were ~66% greater than that of B-S Type 3032 (12.9 mg/g).



**Figure 2. Adsorptive capacities of Ammonasorb II, Chemsorb 1425, and B-S Type 3032 for moist ammonia gas streams (closed symbols). The data of Luna et al., 2010 is also shown for comparison (open symbols).**

## IV. Conclusion

The adsorptive capacities for moist ammonia of two commercially-available sorbents, Chemsorb® 1425 and Ammonasorb II were compared to that of Barnebey Sutcliffe Type 3032, an acid-impregnated activated carbon utilized in the TCCS. These comparisons are for adsorbent bed design but also for comparing candidate replacements for the commercially-obsolete adsorbent media used in the ISS TCCS. This comparison suggests that Chemsorb® 1425 and Ammonasorb II have a similar performance at low ammonia concentrations typically experienced aboard crewed spacecraft. Ammonasorb II and Chemsorb® 1425 have 66% higher capacity than B-S type 3032 which can result in reduced mass or a longer service life for future ammonia adsorbent bed designs.

## Acknowledgments

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