Alternatives to CHLORO-FLUROCARBON FLUIDS *in the* Cleaning *of* Oxygen *and* Aerospace Systems *and* Components

BRYAN / GEBERT-THOMPSON

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Coleman J. Bryan and Karen Gebert-Thompson, editors

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Foreword

The Symposium on the Replacement of Chlorofluorocarbon (CFC) Fluids in the Cleaning of Oxygen and Aerospace Systems and Components was held 19-20 Nov. 1992 in Miami, FL. The symposium was sponsored by ASTM Committee G-4 on the Compatibility and Sensitivity of Materials in Oxygen-Enriched Atmospheres. Coleman J. Bryan and Karen Gebert-Thompson, NASA John F. Kennedy Space Center, served as chairmen of the symposium and as editors of the resulting publication.

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Overview

With the signing of the Montreal Protocol in 1987, it became apparent that cleaning and verification procedures for aerospace systems and components in general and oxygen systems and components in particular were soon to become obsolete. For years, industry and government have heavily relied on the use of chlorofluorocarbons (CFCs) and other halogenated fluids because of their low cost, efficiency, and inertness in cleaning and verification procedures. Subsequent amendments to the Montreal Protocol have moved the elimination dates for these materials forward as data indicating that the loss of ozone in the upper atmosphere was accelerating became available. As a result, many manufacturers of these fluids have also moved forward the closing of the manufacturing facilities producing these fluids. This has resulted in higher prices for the fluids, that are also being taxed at increasingly higher rates each year in order to encourage their replacement.

As a result, many aerospace companies, oxygen producers, government agencies, and manufacturers began programs to develop alternative cleaning and verification procedures. Each of these groups tended to focus on processes that were most critical to their own unique operations or missions. The purpose of this symposium on alternatives to the use of CFCs in the cleaning of oxygen and aerospace systems and components was to:

- allow researchers a forum to present alternative cleaning and verification procedures,
- exchange information of mutual benefit to the producers, customers, and manufacturers,
- provide a data base for the revision of cleaning and verification of systems and components, and
- serve as a guide for future efforts in the problems of cleaning and verification of systems and components used by the aerospace and oxygen communities.

The first ten papers of this Special Technical Publication (STP) address the use of water-based cleaning and verification procedures. Included in these ten papers are descriptions of laboratory studies, successfully implemented piece processes, and a custom designed commercial flow cleaning line. The remaining three papers address the use of "witness coupons" in the validation of cleaning procedures, a plasma cleaning technique, an evaluation of isopropyl alcohol as a verification fluid, and a selection and evaluation protocol for the testing of candidate cleaning agents for oxygen systems and components.

In the first paper, Hunt and Milholen describe a process developed by the U.S. Air Force's Aerospace Guidance and Metrology Center for the precision cleaning of inertial guidance and navigation systems and components. This process uses ultrasonic cleaners filled with biodegradable detergents and deionized water at temperatures between 65 and 75°C. Deionized water rinse water is supplied at 65°C for spray applications.

Next, Pedley, Janoff, and Johnson discuss a comparison of CFC and Non-CFC methods for the removal of organic and particulate contaminants at NASA's Johnson Space Center. This comparison used stainless steel coupons and fittings contaminated with oils and particulates. The major finding in this study was that CFCs are poor solvents for the contaminants used and that deionized water with detergents could clean all contaminated parts to at least the level recommended by the Compressed Gas Association.

Then, Bassett and Welch evaluate isopropyl alcohol as an alternative solvent for chlorofluorocarbons in the cleanliness verification of aerospace hardware and ground support equipment.

Welch, at NASA's Kennedy Space Center, presented the results of a study to evaluate particulate analyses using water instead of CFCs. This study agreed with Pedley et al. in that particle counts using deionized water were often higher than those obtained using CFCs.

Allen, Hoppesch, Johnson, and Buckley evaluated the effectiveness of using water in ultrasonic cleaners at NASA's Kennedy Space Center. Ultrasonic cleaners, varying in frequency from 25 to 80 KHz and in power from 19 to 59 W/m^2, were evaluated at various temperatures using deionized water. Various methods of analysis were: TOC, surface tension, infrared liquid attenuated total reflectance, turbidity, and ultraviolet scattering (UVS). The contaminant consisted of a mix of silicone, hydraulic fluids, hydrocarbon greases and oils, fluorosilicones, and fluorocarbon. TOC and UVS were the only analytical methods capable of detecting the mix of contaminants evaluated at the required level of 10 mg/m^2.

Next, Koch and Kmetko from the Nupro Co. described a commercial process developed to replace CFCs for cleaning industrial valves and fittings. The processes and methods are described, and data on hydrocarbon residues, particulate contamination ionic residues, and adsorbed moisture are presented. One important finding was that water-based systems may require more technical support than existing CFC systems, but are cost-effective and can save money.

In the seventh paper, Dearing, Bales, Bassett, Caimi, Lafferty, Melton, Sorrell, and Thaxton, from NASA's Kennedy Space Center, discuss the use of water impingement in lieu of CFCs for the determination of non-volatile residue (NVR) levels on precision cleaned hardware. Contaminant removal tests were conducted on stainless steel plates using liquid, steam, and gas/liquid impingement methods and TOC analysis to determine the NVR cleanliness levels. A supersonic gas/liquid mixing nozzle was designed and fabricated that entrains a small amount of water into a high velocity gas stream. This supersonic impingement nozzle was found to provide a highly efficient removal of contaminant with a minimal volume of water to provide a high sensitivity for subsequent analytical analysis.

Becker and Shoemaker described an aqueous fine clean process developed by the Rocketdyne Division of Rockwell International for complex rocket engine hardware. The hardware must be cleaned to the 10 mg/m^2 NVR level and be compatible with liquid oxygen at 61 MPa and gaseous oxygen at 704°C and 31.5 MPa. A two step operation was developed using a non-ionic detergent in deionized water followed by a deionized water rinse. A final NVR determination was made using 1,1,1- trichloroethane.

Then, Werling and Knutson discussed a detergent cleaning technique developed by the Aerojet Propulsion Division that eliminated CFCs in the cleaning of rocket engine test systems and components. This engine used chlorine pentafluoride and hydrazine as the propellants, and developed thrust levels up to 4448 N. The cleaning requirement was no particles greater than 100 μm and a maximum NVR of 43 mg/m^2. All parts used in the cleaning facility were fabricated from commercially available components.

In the final paper on water-based cleaning techniques, Meyers discusses the cleaning of aluminum heat pipe casings by the Lockheed Missiles and Space Company. A new process was developed and tested using an alkaline cleaner and deionized water with a nitrogen gas aeration. Since normal NVR and particulate analysis techniques do not necessarily guarantee successful performance, life cycle testing is normally performed to validate the cleaning procedures. After cleaning, all heat pipe casings were found to have acceptable noncondensable gas levels.

In the eleventh paper, Williams and Jones evaluated "witness coupons" as a possible method for validating cleaning procedures at NASA's Kennedy Space Center. In this process, a precontaminated coupon is processed through the cleaning operation with the parts to be cleaned. Subsequently, the "witness coupon" is evaluated by analytical techniques. Infrared specular reflectance was used for the analysis of the "witness coupons" after processing. It was found that the infrared specular reflectance did not appear to be sensitive enough to detect NVR levels at the 10 mg/m^2 level.

Paciej, Jansen, and Krommenhoek from the BOC Group Limited discussed the effectiveness of plasma cleaning as a substitute for CFCs. This technique was compared to CO_2 snow and detergent cleaning for the removal of two different oils from aluminum, brass, and carbon steel test coupons. It was reported that the plasma process resulted in the reduction of the oil contaminants to an extremely low level.

Finally, Million, McIlroy, and Zawierucha from the Linde Division of Praxair presented a selection and evaluation protocol for alternatives to halogenated hydrocarbon solvents for oxygen cleaning applications. The desirable characteristics for alternatives are identified, types of contamination frequently found in industrial oxygen systems are discussed, and geometric constraints are identified. A screening protocol is presented that identifies what are considered to be mandatory evaluations, and supplementary tests are suggested.

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