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An Overview of NASA Testing Requirements for Alternate Cleaning Solvents Used in Liquid and Gaseous Oxygen Environments

By

John W. Strickland
BAMSI, Inc.
MEDB
P.O. Box 9154
Huntsville, Al. 35812
Phone: (205) 544-7375, Fax: (205) 544-7372

S. Eddie Davis
NASA Marshall Space Flight Center
EH44
Huntsville, Al. 35812
Phone: (205) 544-2490, Fax: (205) 544-7372

Abstract

The elimination of CFC-containing cleaning solvents for oxygen systems has prompted the development of a number of alternative cleaning solvents that must now be evaluated not only for cleanability, but compatibility as well. NASA Handbook 8060.1 (NHB 8060.1) establishes the requirements for evaluation, testing, and selection of materials for use in oxygen rich environments. Materials intended for use in space vehicles, specified test facilities, and ground support equipment must meet the requirements of this document. In addition to the requirements of NHB 8060.1 for oxygen service, alternative cleaning solvents must also be evaluated in other areas (such as corrosivity, non-metals compatibility, non-volatile residue contamination, etc...). This paper will discuss the testing requirements of NHB 8060.1 and present preliminary results from early screening tests performed at Marshall Space Flight Center's Materials Combustion Research Facility.

The NASA Handbook 8060.1C (NHB 8060.1C) establishes the requirements for evaluation, testing, and selection of materials that are intended for use in space vehicles, associated ground support equipment and facilities used during assembly, test, and flight operations. A portion of this specification deals specifically with all materials that are exposed to liquid oxygen (LOX), gaseous oxygen (GOX), and other reactive fluids. Materials for use in LOX/GOX must be evaluated for compatibility with the fluid in their use application (pressure and/or impact energy potential). In the case of alternative cleaning solvents the evaluation is made in LOX and/or GOX. Test 13A and Test 13B of NHB 8060.1C outlines the test procedures and criteria for evaluation of materials compatibility in these environments.

Test 13A of NHB 8060.1C defines the test procedure for the evaluation of the mechanical impact sensitivity of materials in ambient pressure LOX environments. Test 13B of NHB 8060.1C is the test procedure for the evaluation of mechanical impact sensitivity of materials in variable elevated pressure LOX or GOX environments. Both of these procedures have ASTM equivalents -- ASTM D2512-82 for Test 13A, ASTM G86-84 for Test 13B. The basic criteria of these tests are to impact samples with 72 ft-lb. (98 J) of impact energy to determine if a material reacts in various oxygen environments when mechanically impacted. The data presented in this paper, along with the initial screening test matrix, concentrates on the results produced from NHB 8060.1C, Test 13A, for initial evaluation.

The test unit utilized for these initial evaluations is the ambient pressure LOX impact test unit. This unit uses a 20 lb. plummet on nylon roller bushings, guided by 6 legs, to deliver impact energy to the sample being tested. This plummet can be dropped from various heights in order to obtain varying amounts of impact energy to the sample being tested. All testing performed for this evaluation utilizes a drop height of 43.3 inches to obtain the required 72 ft-lb. (98J) of impact energy. An electromagnet holds the plummet at the desired drop height until the test technician is ready to impact the sample. When the technician is ready, all lights in the testcell are turned off, and the technician releases the plummet and observes the impact for a flash or audible report (both are indications of a reaction taking place during testing).

The NHB 8060.1C, Test 13A, was chosen as the initial screening method for alternative cleaning solvents' compatibility with oxygen environments. This testing method is an aerospace industry standard and was chosen to establish a baseline of data comparable to historical data available from other sources. It should be emphasized that the results presented from this study are *only preliminary* and the overall goal of this program is to provide *a relative rating of each material as they compare to other candidate materials* that have been tested. **The data presented is not intended in any way as a recommendation or endorsement for the use of one product over any other**.

After the establishment of a standard testing method, sample preparation for testing and evaluation were then examined. Two different methods of sample preparation were chosen to reflect the wide range of possible use conditions that might be encountered by the various cleaning solvents. Sample preparation techniques follow those outlined in ASTM D2512-82, in paragraph 10.1 and paragraph 10.3. Paragraph 10.1 details the preparation of liquid samples in cups that are approximately 0.625 inch inside diameter and 0.050 inch deep. Sample material is placed in each cup in sufficient volume to fill each cup; then the cups are chilled in a container of liquid nitrogen to freeze the sample prior to impact testing in LOX. Paragraph 10.3 details the preparation of liquid samples on sulfuric acid anodized 6061-T6 Aluminum disks. Test disks are allowed to soak in the sample solution for approximately 15 minutes, then removed and allowed to drain at a 90 degree angle for approximately 15 minutes. The purpose of each of the above described preparation methods is to test a material for compatibility in bulk form and in residue form.

The test plan matrix (shown in Figure 1) was then developed. This matrix is designed so that all candidate materials are prepared and tested in a similar manner. Included in this test matrix is an option that allows for materials to be tested in the manufacturer's suggested solution strength, if it is different from the non-diluted full strength concentration. This allowance is made to cover the broadest possible range of end-use concentrations for each material. The matrix has been devised so that each material is tested at least twice, once as a full strength bulk solution and once as a residue. For each concentration of solution tested that is not "full strength", both test methods (0.050 inch bulk solution and residue) are utilized to test the various manufacturers suggested solution concentrations. The rationale for this test matrix is to test a material in the two most likely end-use conditions. Testing the sample in a bulk form (0.050 inch deep sample cups) examines the possible reactivity of a material in situations where a pocket of the fluid in question has been trapped somewhere in an oxygen system. Residue testing of a material examines the possible reactivity of the remnants of the fluid in question in an oxygen system.

Table 1 describes some of the historical data available for the various tested materials. A complete listing of all data presented in this report is available for review and analysis on the Materials And Processes Technical Information System (MAPTIS) resident at Marshall Space Flight Center (MSFC). The format of the data presented in Table 1 is altered from the standard MAPTIS output format for ease in comparison and presentation in this paper. The data in Table 1 shows historical data by product trade name, a unique NASA Material Code (a five digit number assigned to a specific material for tracking and identification purposes on MAPTIS), the test conditions (test fluid, test temperature, and sample form), and the number of reactions per tests. The standard acceptance criteria utilizing the methods described for a given energy level in NHB 8060.1C is less than 2 reactions per 20 samples tested. If only 1 reaction is noted during the initial 20 sample drops, then an additional 40 samples must be tested with no further reactions noted in order for the material to be considered passing this test (i.e. 0/20 or 1/60 is passing, 2 or more reactions failing, 1/20 is considered inconclusive).

Table 2 describes a partial list of the alternative solvent results produced to date in this testing program. The results are reported in the same format as Table 1, described earlier. It should be emphasized again that these preliminary results are meant only as a relative rating of the liquid and gaseous oxygen compatibility of the tested materials and are not meant to imply any endorsement of any material. The preliminary results indicate that, under certain conditions, some replacement materials should be considered for further oxygen compatibility study. Again, this paper only deals with the area of oxygen compatibility. There are a number of other areas (such as corrosion, metals and non-metals compatibility, etc...) for which each of these materials must be evaluated prior to implementation as a cleaning solvent.

Table 1. Historical Data

Product Name	MAPTIS Material Code	Test Pressure (psia)	Test Fluid	Test Temp. (°F) 68	Sample XC5dem	Reactions/ Tests	Concentration
Blue Gold	87992	14.7	LOX	-297	Bulk	0/20	Full Strength
Amway SA8	88157	14.7	LOX	-297	Residue	1/20	Full Strength
CCS-4000	00961	14.7	LOX	-297	Bulk	0/20	Full Strength
					Residue	0/20	Full Strength
Neugenic 4175	89936	1050	LOX	-297	Residue	0/20	Full Strength
		1050	GOX	75	Residue	0/20	Full Strength
Turco Spray-eze LT	01352	10,000	LOX	-297	Bulk	0/20	Full Strength
		10,000	LOX	-297	Bulk	0/20	5 oz./gallon deionized water

Table 2. Program Data

Product Name	MAPTIS Material Code	Test Pressure (psia)	Test Fluid	Test Temp. (°F)	Sample Form	Reactions/ Tests	Concentration
Isopropyl Alcohol	01524	14.7	LOX	-297	Bulk	9/20	Full Strength
					Residue	0/20	Full Strength
Amberclean L12	01241	14.7	LOX	-297	Bulk	0/20	Full Strength
					Bulk	0/20	75% deionized water/ 25% sample fluid
					Residue	7/20	Full Strength
Amberclean L21	01249	14.7	LOX	-297	Bulk	0/20	Full Strength
					Bulk	0/20	90% deionized water/ 10% sample fluid
					Residue	19/20	Full Strength
TCE (Hi-Purity Grade)	01257	14.7	LOX	-297	Residue	0/20	Full Strength
DOT 111/113	01252	14.7	LOX	-297	Bulk	0/20	Full Strength
					Bulk	0/20	90% deionized water/ 10% sample fluid
					Residue	6/20	Full Strength
					Residue	0/20	90% deionized water/ 10% sample fluid

Figure 1. Test Plan Matrix

<u>PHASE 1</u> - Prepare and test in accordance with NHB 8060.1C, Test 13A per instructions for liquid samples as described in ASTM D2512, Para. 10.1 (0.050 inch deep Aluminum grease cups, samples to be tested full strength). Start testing at 72 ft-lb. impact energy, theshhold for energy as required.

<u>PHASE 2</u> - Prepare and test in accordace with NHB 8060.1C, Test 13A per instructions for emulsifiers as described in ASTM D-2512, Para. 10.3 (unsealed sulfuric acid anodized Aluminum disks, soaked in full strength solution 15 minutes then drain at 90 degrees for 15 minutes). Start testing at 72 ft-lb. impact energy, thershhold for energy as required.

<u>PHASE 3</u> - Prepare and test in accordance with NHB 8060.1C, Test 13A per instructions for liquid samples as described in ASTM D2512, Para. 10.1 (0.050 inch deep Aluminum grease cups, samples to be tested in solution prepared according to manufacturer's recommendations). Start testing at 72 ft-lb., threshhold for energy as required.

<u>PHASE 4</u> - Prepare and test in accordace with NHB 8060.1C, Test 13A per instructions for emulsifiers as described in ASTM D-2512, Para. 10.3 (unsealed sulfuric acid anodized Aluminum disks, soaked in solution prepared per manufacturer's recommendations for 15 minutes then drain at 90 degrees for 15 minutes). Start testing at 72 ft-lb. impact energy, thershhold for energy as required.

<u>PHASE 5</u> - Prepare a container of full strength solution and evaporate to dryness for analytical testing. Perpare a second container of solution prepared according to manufacturer's recommendations and evaporate to dryness for analytical testing.