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Effect of Oxygen Concentration on Autogenous Ignition Temperature and Pneumatic Impact Ignitability of Nonmetallic Materials

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Abstract: Extensive test data exist on the ignitability of nonmetallic materials in pure oxygen, but these characteristics are not as well understood for lesser oxygen concentrations. In this study, autogenous ignition temperature testing and pneumatic impact testing were used to better understand the effects of oxygen concentration on ignition of nonmetallic materials. Tests were performed using oxygen concentrations of 21, 34, 45, and 100 %. The following materials were tested: PTFE Teflon®, Buna-N, Silicone, Zytel® 42, Viton® A, and Vespel® SP-21.

KEYWORDS: Autogenous ignition temperature; pneumatic impact; oxygen concentration; nonmetallic materials

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Introduction

Increased fire hazards are inherent in oxygen-enriched environments. Extensive data have been generated to study the flammability and ignitability of materials in pure oxygen. However, there are limited data for environments using less than 100 % oxygen but greater than 21 % oxygen (as is found in air). The purpose of this study was to determine the effects of oxygen concentration on the ignitability of nonmetallic materials. Specifically, autogenous ignition temperature (AIT) and pneumatic impact tests were performed in several different oxygen concentrations.

Test Materials

Tests were performed on several elastomers and plastic materials, as described in Table 1. According to ASTM G63, *Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service* [1], materials preferred for oxygen service are those that have AITs of 400 °C or greater, heats of combustion of 10,500 J/g or less, and oxygen indices greater than 55. The materials selected for this study exhibit varying degrees of oxygen compatibility, as shown in Table 1.

Test Environments

Tests were performed in four different oxygen concentrations (21, 34, 45, and 100 %), with the balance being nitrogen. The intermediate oxygen concentrations of 34 and 45 % were chosen because they are environments currently being used within NASA. The upper limit for the cabin atmosphere for NASA's Constellation Program is 34 % oxygen, and the environment used by the scuba divers at NASA's Neutral Buoyancy Laboratory is 45 % oxygen.

Test Methods

The AIT test measures the minimum temperature where a material will spontaneously ignite when heated in an oxygen or oxygen-enriched atmosphere. The test apparatus is depicted in Figure 1, and the procedure used was ASTM G72, *Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment* [2]. The test pressure was 10.3 MPa (1500 psi). The heating rate was 5 ± 1 °C per minute from 60 to 260 °C, and > 3 °C for temperatures greater than 260 °C.

The pneumatic impact test measures the relative ignitability of materials by heat of compression. The test apparatus is depicted in Figure 2, and the procedure used was ASTM G74, *Standard Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact* [3]. These tests were performed to determine the threshold for ignition by pneumatic impact. Each sample was impacted five times.

Test Results

The AIT data are shown in Table 2. These data indicate that oxygen concentration has an effect on the AIT. The overall trend is that AITs decrease with increasing oxygen concentration. For some materials, such as Zytel® 42, [2] the oxygen concentration has a significant effect on the AIT; for other materials, such as Teflon®,[2] the effect of oxygen concentration is smaller.

The pneumatic impact data are shown in Table 3. The overall trend is that materials ignite at lower pressures as oxygen concentration increases. The effect of oxygen concentration on the passing impact pressure is substantial for all of the materials tested.

Discussion and Conclusions

As would be expected, materials are easier to ignite as oxygen concentration increases. There can be dramatic effects on AITs and ignitability by pneumatic impact, but the effects vary greatly from material to material. For instance, Teflon exhibited the greatest differences in pneumatic impact ignition thresholds. In 21 % oxygen, Teflon did not ignite even at 9500 psi; but as the oxygen concentration increased there was a dramatic change in the ignition threshold, culminating in ignition of Teflon in

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[2] Zytel® and Teflon® are registered trademarks of E. I. Du Pont de Nemours and Company, Wilmington, Delaware.

100 % oxygen at 1500 psi. However, Teflon's AIT was not greatly affected by oxygen concentration, with a change of less than 10 °C from 21 to 100 % oxygen. In comparison, Zytel 42 exhibited a change of nearly 70 °C in its AIT from 21 to 100 % oxygen. No obvious trend was found in terms of which materials are more greatly affected by oxygen concentration. The data from this study will be helpful in assessing the ignition hazards in oxygen-enriched systems.

References

[1] ASTM G63, "Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service," ASTM International, West Conshohocken, Pennsylvania.

[2] ASTM G72, "Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment," ASTM International, West Conshohocken, Pennsylvania.

[3] ASTM G74, "Standard Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact," ASTM International, West Conshohocken, Pennsylvania.

TABLE 1—*Test Materials and Oxygen Compatibility Data*

Material	Batch Number	Limiting Oxygen Index, %[a]	Autoignition Temperature, °C [a]	Heat of Combustion, J/g [b]
Buna-N Nitrile Rubber	RB 711	22	142	41,460
PTFE Teflon®	ACCA241064	95	>425	7,118
Silicone Rubber, Class 2, Grade 70	R5789	21	262	12,895
Vespel® SP-21 polyimide	B/N 050722519	53	321	31,810
Viton® A	44893	32	155	16,714
Zytel® 42 Polyamide	PC44G64 L/N 603930	30	183	36,960

[a] Data shown are lowest values listed in ASTM Manual 36, 2nd Edition, Table 3-12.
[b] Data shown are highest values listed in ASTM Manual 36, 2nd Edition, Table 3-12.

TABLE 2—*AIT Test Results.*

Material	Average AIT, °C [a]			
	21% O_2	34% O_2	45% O_2	100% O_2
Buna-N	394	392	391	385
Teflon®	446	442	440	439
Silicone Rubber	306	301	301	302
Vespel® SP-21	420	376	368	342
Viton® A	312	305	299	293
Zytel® 42	272	255	247	203

[a] Data shown are the average value from a total of five tests.

TABLE 3—*Pneumatic Impact Test Results*

Oxygen Concentration	Passing Impact Pressure [a]	Failing Impact Pressure	Number of Reactions/ Number of Samples Impacted
	Buna-N		
21%	2500	3000	1/20
34%	2000	2500	1/13
45%	1000	1500	1/17
100%	1000	1500	1/1
	Teflon®		
21%	9500	N/A [b]	N/A [b]
34%	4500	5000	1/13
45%	1500	2000	1/1
100%	1000	1500	1/10
	Silicone Rubber		
21%	4500	5000	1/10
34%	2500	3000	1/4
45%	1500	2000	1/4
100%	1000	1500	1/16
	Vespel® SP-21		
21%	9500	N/A [b]	N/A [b]
34%	9500	N/A [b]	N/A [b]
45%	-- [c]	-- [c]	-- [c]
100%	5000	5500	1/2
	Viton® A		
21%	3000	3500	1/1
34%	2000	2500	1/10
45%	1500	2000	1/1
100%	1000	1500	1/6
	Zytel® 42		
21%	2000	2500	1/1
34%	1000	1500	1/1
45%	500	1000	1/2
100%	500	1000	1/8

[a] Materials pass pneumatic impact testing when there are zero reactions in 20 tests.
[b] The material passed testing at the highest possible impact pressure.
[c] Pneumatic impact tests were not performed on Vespel SP-21 in 45 % oxygen.

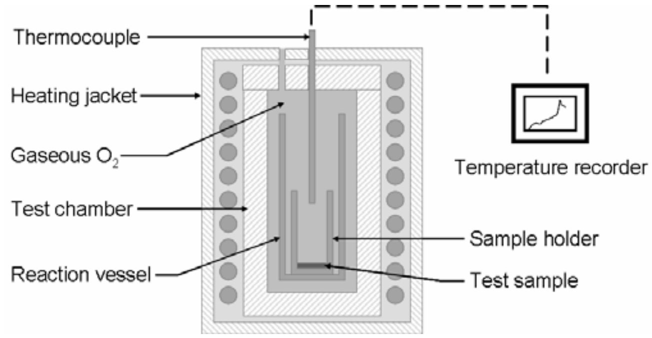

FIG. 1—*AIT test apparatus.*

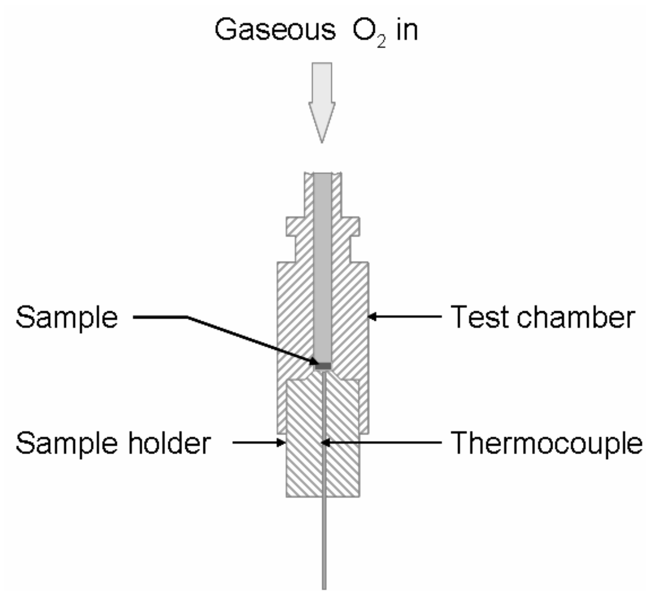

FIG.2—*Pneumatic impact test apparatus.*