Isothermal Microcalorimetric Evaluation of Compatibility of Proposed Injector Materials with High-Test Hydrogen Peroxide Propellant

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Introduction

High-test hydrogen peroxide (HTP) is receiving renewed interest as a monopropellant and as the oxidizer for bipropellant systems. HTP is hydrogen peroxide in concentrations ranging from 70 to 98%. All surfaces wetted by HTP must be evaluated for compatibility with the fluid. In the case of tanks, lines and valves compatibility is required to preserve the HTP oxygen and energy content and to avoid overpressurization due to decomposition. With injectors and regenerative cooling passages shorter exposure time reduces these concerns. However, phase changes from fluid to gas impact heat transfer and become the dominant compatibility concern.

Isothermal microcalorimetry (IMC) provides a convenient and reproducible means to observe the decomposition of HTP when exposed to structural materials and therefore the compatibility of those materials[1]. The instrument provides heat flow values in terms of watts that may be converted to a reaction rate given the heat of reaction for the decomposition of hydrogen peroxide. These values are then converted to percent active oxygen loss per week (%AOL/wk) to preserve an earlier convention for quantifying HTP compatibility. Additionally, qualitative designations of compatibility[2] have been assigned to these values. This scheme consists of four classes with Class 1 being the most compatible. While historical compatibility data is available[2] its current applicability is in question due to subtle changes in the compositions of both HTP and structural materials. Trace levels of molecules can have significant influence on compatibility. Therefore representative samples of materials must be evaluated with current HTP formulations.

In this work seven materials were selected for their strength characteristics at high temperature as expected in a HTP injector. The materials were then evaluated by IMC for HTP compatibility.

Experimental Approach

IMC instrumentation and method described in an earlier work[1] was also used in this investigation. Rocketdyne Propulsion & Power supplied samples of Inconel 625, Nickel 200, A-286 and CRES 347. A manufacturer of specialized alloys, Foster-Miller, Inc., furnished three proprietary metals (Batch 1, 2 and 3) for evaluation. All samples were prepared to have surface roughness between 0.8 and 1.6 R_q (μm). Propulsion grade high-test hydrogen peroxide (98%, FMC, Inc.) and the metal samples were used as provided.

Results and Discussion

As shown in Table 1, two of the generally available materials (Inconel 625 and Nickel 200) and one of the proprietary formulations (Foster Miller Batch 2) had very poor compatibility with HTP and would be immediately excluded from this application. The alloy A-286 has marginal compatibility and would likely also have poor heat transfer characteristics, as much of the propellant would be decomposing into gas phase products.

The stainless steel CRES 347 has acceptable compatibility considering the short residence time it would be wetted. Two Foster-Miller specimens (Batch 1 and 3) displayed exceptional compatibility. If other requirements are meet, such as high temperature strength, these materials are a clear choice for construction of a HTP injector.

Table 1. Percent active oxygen loss per week[a,b]

Material	%AOL/wk	Class
Inconel 625	over[c]	4
Nickel 200	over[c]	4
Foster-Miller Batch 2	over[c]	4
A-286	82.4 ± 1.6	3
CRES 347	12.7 ± 1.5	2
Foster-Miller Batch 1	2.8 ± 0.2	1
Foster-Miller Batch 3	2.2 ± 0.3	1

[a] Average of three coupons.

[b] 90% confidence level.

[c] Over maximum instrument measurable value 680000 μwatts (72.7 %AOL/day).

Most of the Class 3 and 4 materials showed visible signs of incompatibility where Foster-Miller Batch 2 was the most dramatic (Fig 1 and 2). In this case the entire coupon is discolored following HTP exposure. However visual inspection is not a reliable evaluation of compatibility as Nickel 200 showed no perceivable signs of reaction yet was clearly observed to decompose HTP in the IMC experiment.

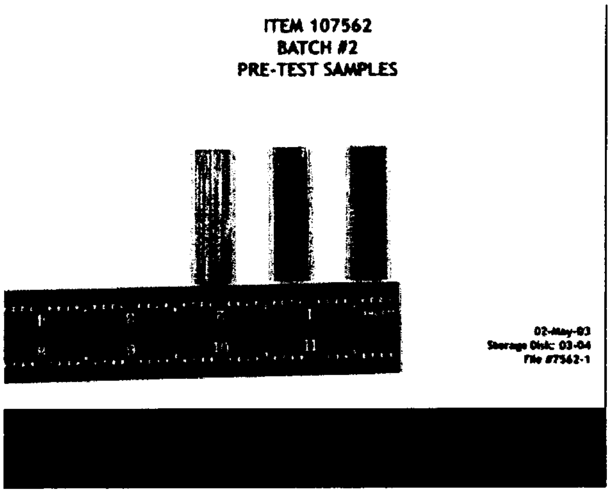

Figure 1. Foster Miller Batch 2 Material Pre-Test.

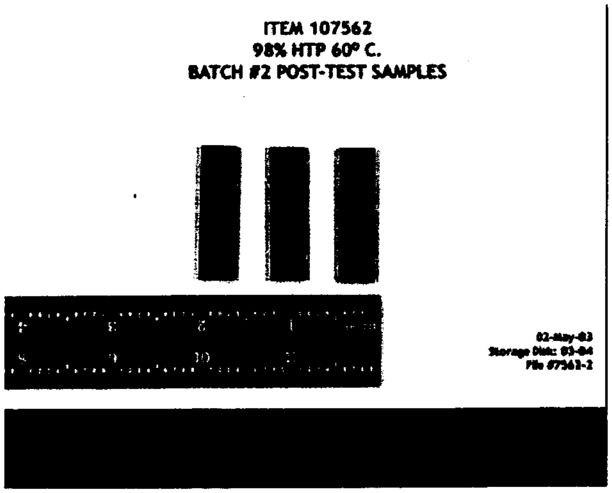

Figure 2. Foster Miller Batch 2 Material Post-Test.

Conclusions

The isothermal microcalorimeter provides a simple and reproducible means to quantitatively assess compatibility of propulsion system materials with high-test hydrogen peroxide propellant.

Acknowledgements

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References

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[1] R. Gostowski, Thermochim. Acta 404 (2003) 279.

[2] Bulletin #104, Materials of Construction for Equipment in Use with Hydrogen Peroxide, FMC, 1966, p.48.