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To: David P. Stinton – EERE Distributed Energy Program Manager

Subject: Distributed Energy Program FY2006 CPS/Control Milestones: Section 2 – Materials, Milestone 3 – Complete mechanical testing, aging and evaluation of exhaust valve alloys, in collaboration with TRW to determine temperature limitations, August 31, 2006 (Subtask 2.3.1)

A series of control specimens cut from fresh valves and aged at 700, 750 and 800°C for 100-3000h were utilized in microstructural and hardness evaluations to establish the maximum use temperatures for the Pyromet 31V superalloy. Previous microstructure and hardness studies conducted in Waukesha natural-gas reciprocating engines yielded unfailed superalloy exhaust valves (produced by TRW) at 20,000h of service as well as prematurely failed valves at only around 3,000h service.

In January 2006, both microstructural studies of Ni_3Al gamma-prime coarsening/dissolution and hardness measurements indicated that Pyromet 31V retained hardness (at or above initial hardness) after 3,000h of aging at 700 and 750°C; however, considerable microstructural instability and softening occurred at 800°C. In addition, solution-annealed (SA) Pyromet 31V samples demonstrated similar strength as those with standard SA + double-age heat treatment (HT) for precipitation-hardening (Figure 1). This result is very important to current work with TRW in the production of valves which have been coated prior to the SA treatment. In July 2006, similar specimens were aged to beyond 8,000 h, and they are now being evaluated.

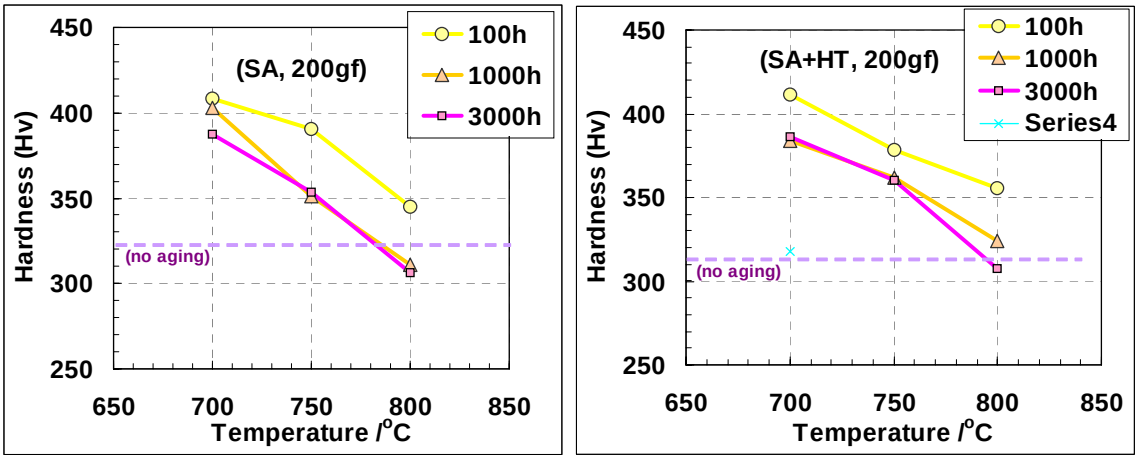
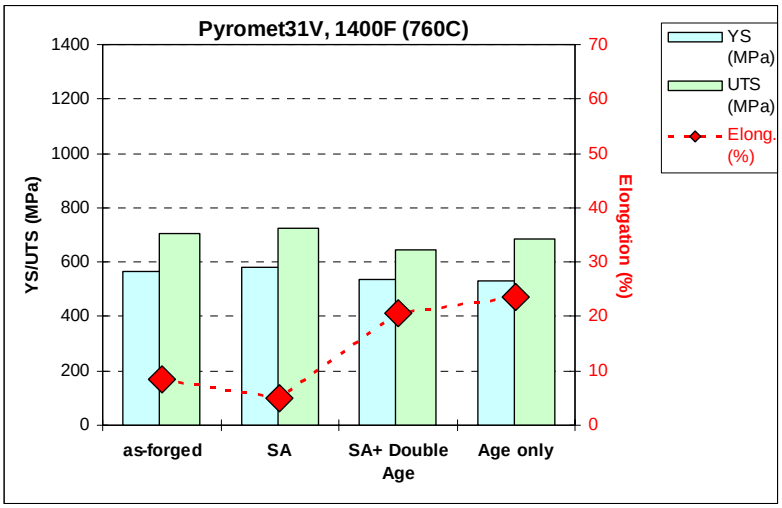


Figure 1 – Hardness measurements of SA and SA+HT Pyromet 31V specimens, aged at the conditions indicated.

To further support this evaluation of Pyromet 31V temperature capability in valves, mechanical property test specimens were made from both Pyromet 31V and IN751 at various stages of processing (including the standard final valve condition, SA+double aged HT). Both alloys are being used in new valves dsesigned by TRW for Waukesha, and both are candidates for coatings to improve resistance to moisture-

enhanced oxidation. Preliminary mechanical testing in different processing conditions at room temperature and at 760°C (1400°F) was completed at the end of August, 2006. Properties at elevated temperature are shown in Figure 2. Both Pyromet 31V and IN751 alloys show good yield and ultimate tensile strengths in the SA and aged only conditions at 760°C, relative to the standard SA+double aged condition, with reasonable ductility. These test results are consistent with the hardness data, which indicates that strength drops off only at higher temperatures.



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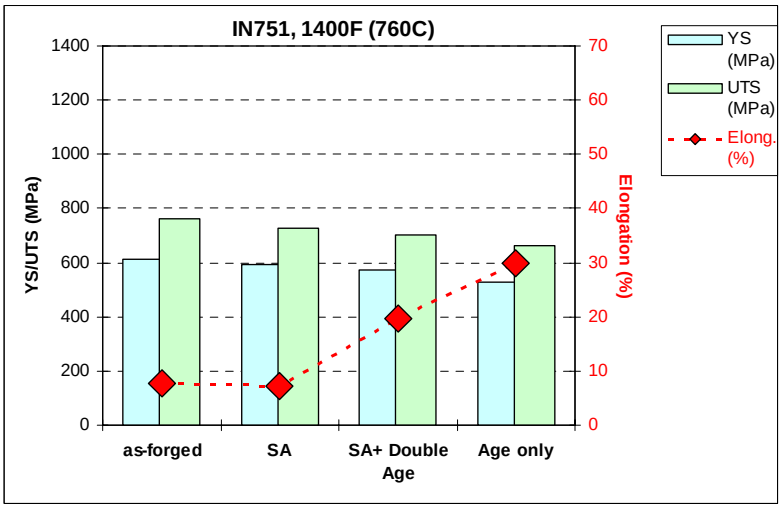

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Figure 2 – Mechanical properties of A) Pyromet 31V, and B) alloy 751, tested at 760°C in various processing conditions.

These efforts complete milestone 3 for subtask 2.3.1 on schedule, and support the overall ORNL/TRW/Waukesha effort to produce exhaust valves with upgraded temperature capability and reliability.

Sincerely,

Philip J. Maziasz

Dr. Philip J. Maziasz, Distinguished Research Scientist, ORNL