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**ADVANCED THERMAL BARRIER
COATING SYSTEM DEVELOPMENT**

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TECHNICAL PROGRESS REPORT

to the

U.S. DEPARTMENT OF ENERGY

Oak Ridge Operations Office

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Submitted By

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Advanced Thermal Barrier Coating System Development

Program Objectives

The objectives of the program are to provide an improved TBC system with increased temperature capability and improved reliability relative to current state of the art TBC systems. The development of such a coating system is essential to the ATS engine meeting its objectives.

The base program consists of three phases:

Phase I: Program Planning - Complete

Phase II: Development

Phase III: Selected Specimen - Bench Test

Phase IV: Rainbow Test

Work is currently being performed in Phase II and III of the program. In phase II, process improvements will be married with new bond coat and ceramic materials systems to provide improvements over currently available TBC systems. Coating reliability will be further improved with the development of an improved lifing model and NDE techniques. This will be accomplished by conducting the following program tasks:

- II.1 Process Modeling (deleted)
- II.2 Bond Coat Development
- II.3 Analytical Lifing Model
- II.4 Process Development
- II.5 NDE, Maintenance and Repair
- II.6 New TBC Concepts

In phase III of the program, proof testing of the coatings is being performed on the best of the newly developed TBC systems under ATS thermal conditions at the Westinghouse Science and Technology Center.

Technical Progress Report

Task II.2 Bond Coat Development

- Coating deposition trials were completed on four variations of bond coats designed for improved resistance to substrate-bond coat interdiffusion. Samples are being sectioned and furnace testing will be performed during the next quarter.
- Testing of the new bond coat chemistries is nearly complete. Bond coats were deposited by LPPS and evaluated with an APS ceramic topcoat. While several of the chemistries performed similar to the baseline, three of the chemistries displayed marked improvement over the baseline. The improvement was strongly tied to the substrate material. Continued effort on new bond coats will therefore be restricted to these three. Additional work will include: 1) replication of performance with APS TBC's, 2) Evaluation of performance for EB-PVD TBC's, and 3) deposition using HVOF.

Task II.3 Analytical Lifting Model

In the last reporting period the APS TBC lifing model developed by SwRI, entitled "TBCLPM" was exercised to provide a better understanding of the program under a greater range of input variables, and the results were compared to test data from the Waltz Mill High Heat Flux Test Rig (HHFTR). A work session was held in January with SwRI at Westinghouse. At this meeting the program, which runs on a PC, was run several times to investigate the effect of various parameters on TBC life. A decrease in TBC life with increasing hold time was predicted, and a reduced TBC life with increasing thermally grown oxide thickness was also predicted, with the general behavior similar to that found in the literature.

The first results from the Waltz Mill HHFTR for APS TBC specimens became available during the last reporting period. The program TBCLPM was exercised and compared to the test results. The model appears to work well for the furnace data, however, it significantly over predicted the high gradient HHFTR data. During the next reporting period additional HHFTR data will become available, after which SwRI will refit the model constants, this time using HHFTR data in the data set.

Task II.4 Manufacturing Process Development

Task Complete - No work during the current period.

Task II.5 NDE, Repair and Maintenance

Repair and Maintenance

- Cyclic furnace testing of TBC patch repairs under nominal conditions continued throughout the quarter. All repaired and unrepaired (control) samples remain in test.
- Based on favorable results from accelerated furnace testing of TBC patch repairs, further deposition and testing of TBC patch repairs is being pursued. Testing will focus on repair of corner and edges (the most likely place for TBC damage due to handling), PVD topcoats, and service exposed bond coats (simulated by pre-oxidizing). Sample fabrication will be initiated during the next quarter.
- Due to the temperatures involved in the coating refurbishment process, recrystallization of single crystal components is a concern. In an effort to examine the effect of coating refurbishment processes on single crystal substrates, creep bars were subjected to coating, creep testing, stripping, recoating, and aging simulating the steps in the thermal and mechanical history of a component. Creep testing and aging parameters were chosen in accordance with anticipated ATS conditions. Examination after aging revealed no sign of recrystallization to date. Final aging and metallography will be completed during the next quarter.

Task II.6 New TBC Concepts

- Three new chemistries were evaporated using the EB-PVD equipment at Chromalloy. Of these, one chemistry exhibited excessive "spitting" such that coatings could not be deposited. Coatings were obtained from the other two chemistries, however, both of these failed prior to furnace testing. Examination of the failure suggests significant residual stresses in the films. In addition, both of these coatings had very dense microstructures as opposed to the discrete, separate columns found in 7%YSZ.
- One new ceramic chemistry was resprayed by APS in an effort to reproduce earlier microstructures and furnace test results. Furnace testing of the resprayed samples under accelerated and nominal conditions is in progress.
- Based on the selection criteria given in the prior quarterly report, approximately 80 new chemistries were identified. Forty of these have been selected for screening via laboratory testing. Laboratory fabrication and evaluation was initiated in December, 1997. To date, 30 chemistries have been fabricated and are undergoing laboratory testing. Five chemistries have been eliminated to date due to insufficient high temperature phase stability and/or reaction with MCrAlY. Down selection from the initial set of 30 chemistries for small batch coating trials is expected by the end of March.

Phase III Bench Test

- No rig testing was performed under this program during the current reporting period. Testing has, however, continued under other programs to define the baseline material response to the high heat flux and thermal gradient. Under the conditions examined to date, coatings have shown either extremely short cyclic life (<50 cycles) or very long life (>1000 cycles). The intent is to define conditions where intermediate life is produced. It is within this range that difference in coating systems will be distinguished. Testing of the baseline system will continue through the next quarter for both EB-PVD and APS TBC systems.

III.6 Blade and Vane TBC Monitor - Feasibility Study

The adherence of the TBC to the row 1 blade and vanes is absolutely critical to the ATS engine. With the life of the component dependent on the coating, early detection of failure is necessary to ensure safe operation and enable component refurbishment.

- In the feasibility study of a TBC monitor for the row 1 vane, it was found that the system would lack the sensitivity and response time required to be effective. Evaluation of this concept for monitoring the vane TBC has been discontinued.
- IR imaging of the blades to detect TBC failure appears feasible. Equipment recommendations have been made. Westinghouse is evaluating options for demonstrating the technology. A host engine has been identified. Details of the demonstration within the current budget need to be examined.