N89-13661

519-27
181387
6P.

THERMAL BARRIER COATINGS FOR THE SPACE SHUTTLE MAIN ENGINE TURBINE BLADES

B. N. Bhat, H. L. Gilmore and R. R. Holmes
Materials and Processes Laboratory
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

The Space Shuttle Main Engine (SSME) turbopump turbine blades experience extremely severe thermal shocks during start-up and shut-down. For instance, the high pressure fuel turbopump turbine which burns liquid hydrogen operates at approximately 1500°F, but is shut down fuel rich with turbine blades quenched in liquid hydrogen (-423°F). This thermal shock is a major contributor to blade cracking. The same thermal shock causes the protective ZrO_2 thermal barrier coatings to spall or flake off, leaving only the NiCrAly bond coating which provides only a minimum thermal protection. The turbine blades are therefore life limited to about 3000 sec. for want of a good thermal barrier coating.

NASA-MSFC is active in developing a suitable thermal barrier coating (TBC) for the SSME turbine blades. Various TBCs developed for the gas turbine engines were tested in a specially built turbine blade tester (also called thermal cycling tester or burner rig, Figure 1). This tester subjects the coated blades to thermal and pressure cycles similar to those during actual operation of the turbine (Figures 2, 3). The coatings were applied using a plasma spraying technique, both under atmospheric conditions and in vacuum. Results are given in Table 1. In general vacuum plasma sprayed coatings performed much better than those sprayed under atmospheric conditions A 50-50 blend of Cr_2O_3 and NiCrAly, vacuum plasma sprayed on SSME turbopump turbine blades appear to provide significant improvements in coating durability and thermal protection.

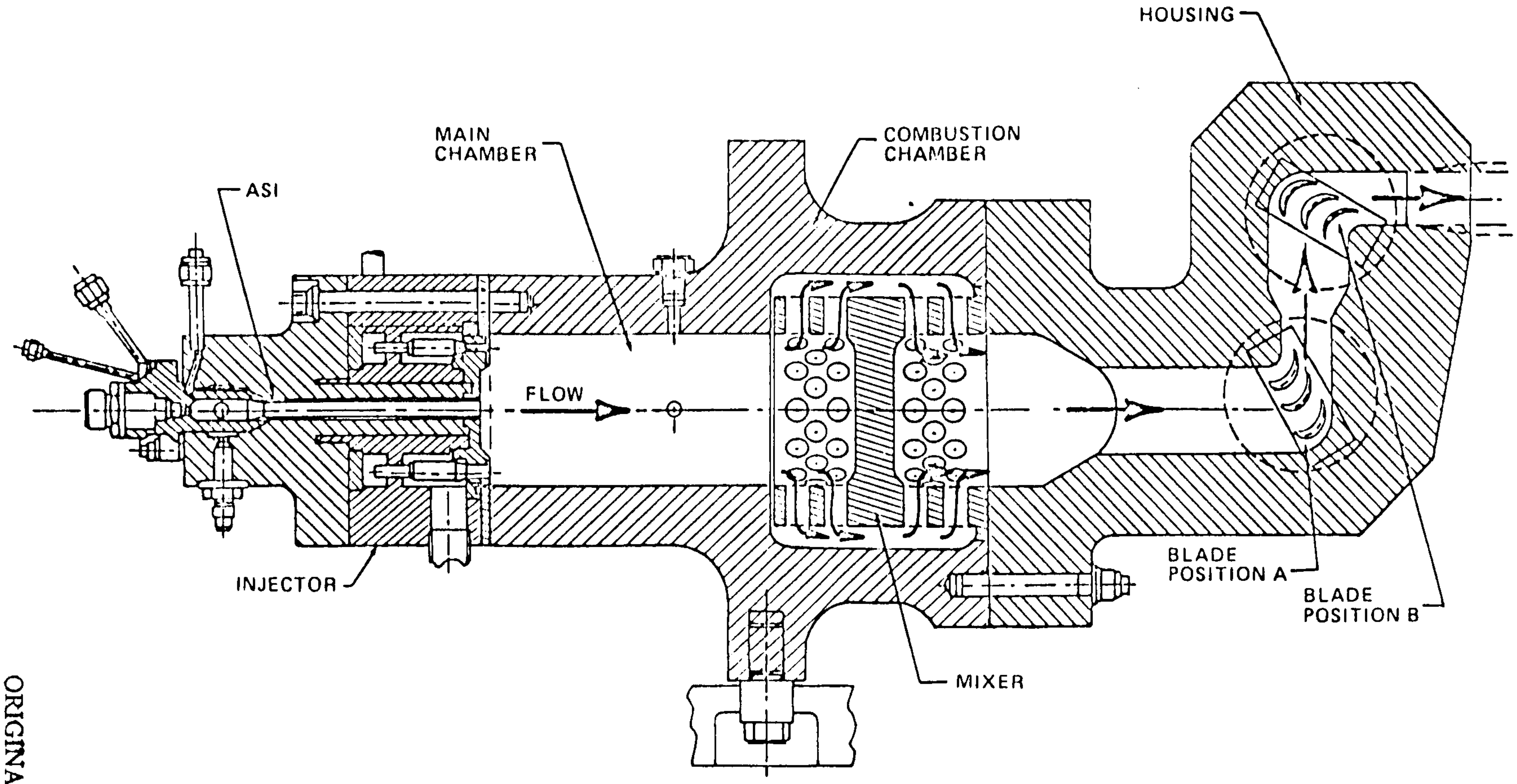

FIGURE 1. THERMAL CYCLING TESTER

R-TEST 338

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 2

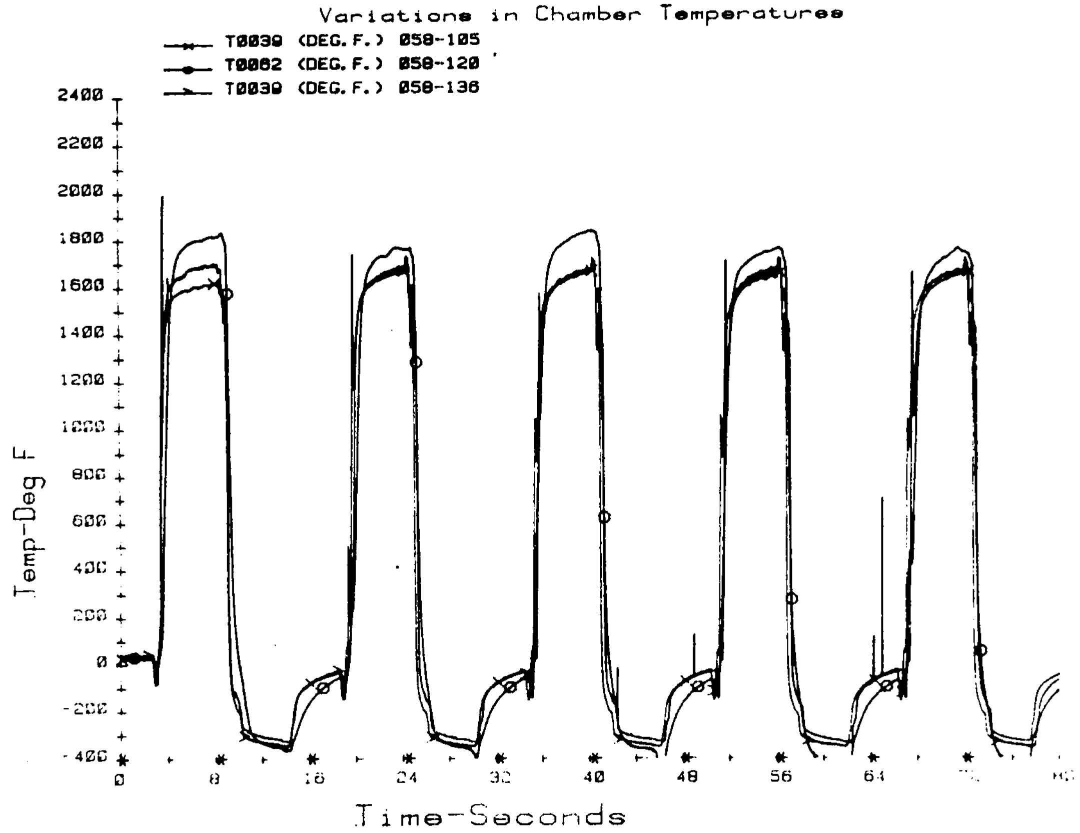

FIGURE 2

FIGURE 3

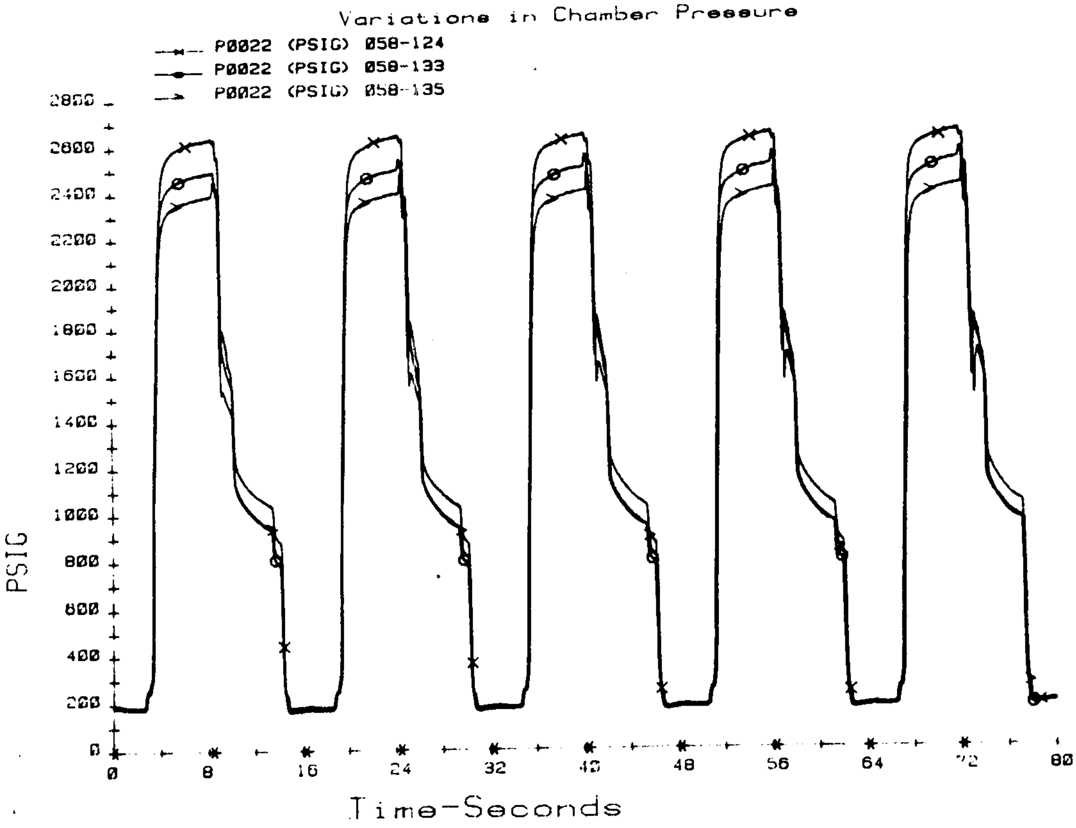

FIGURE 3

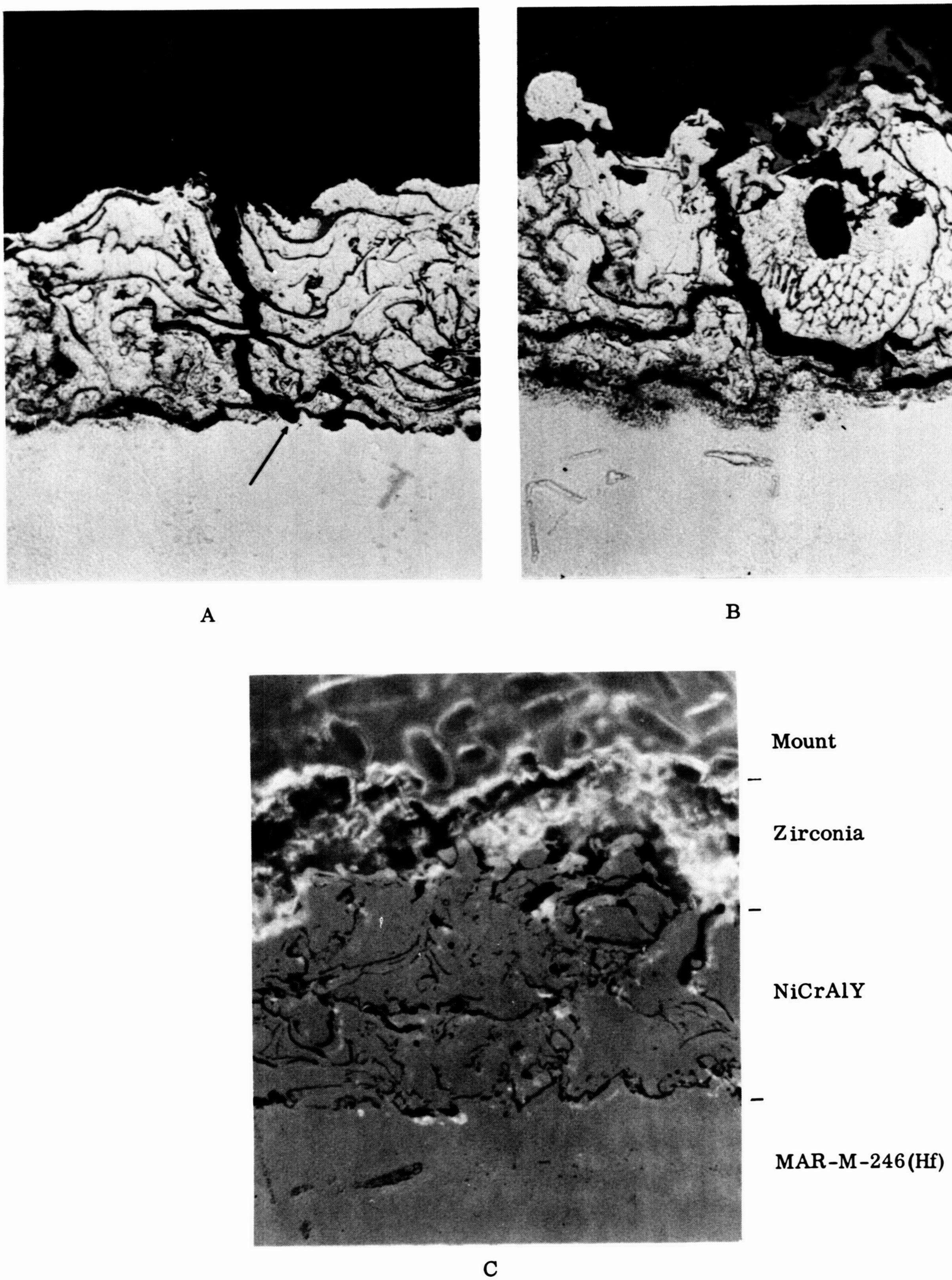

Figure 4 - NiCrAlY Airfoil Leading Edge Cracking on Blade 9Z13 From HPFTP 9005 (A&B) and Thin Layer of Zirconia on NiCrAlY (C). Mag. 400X

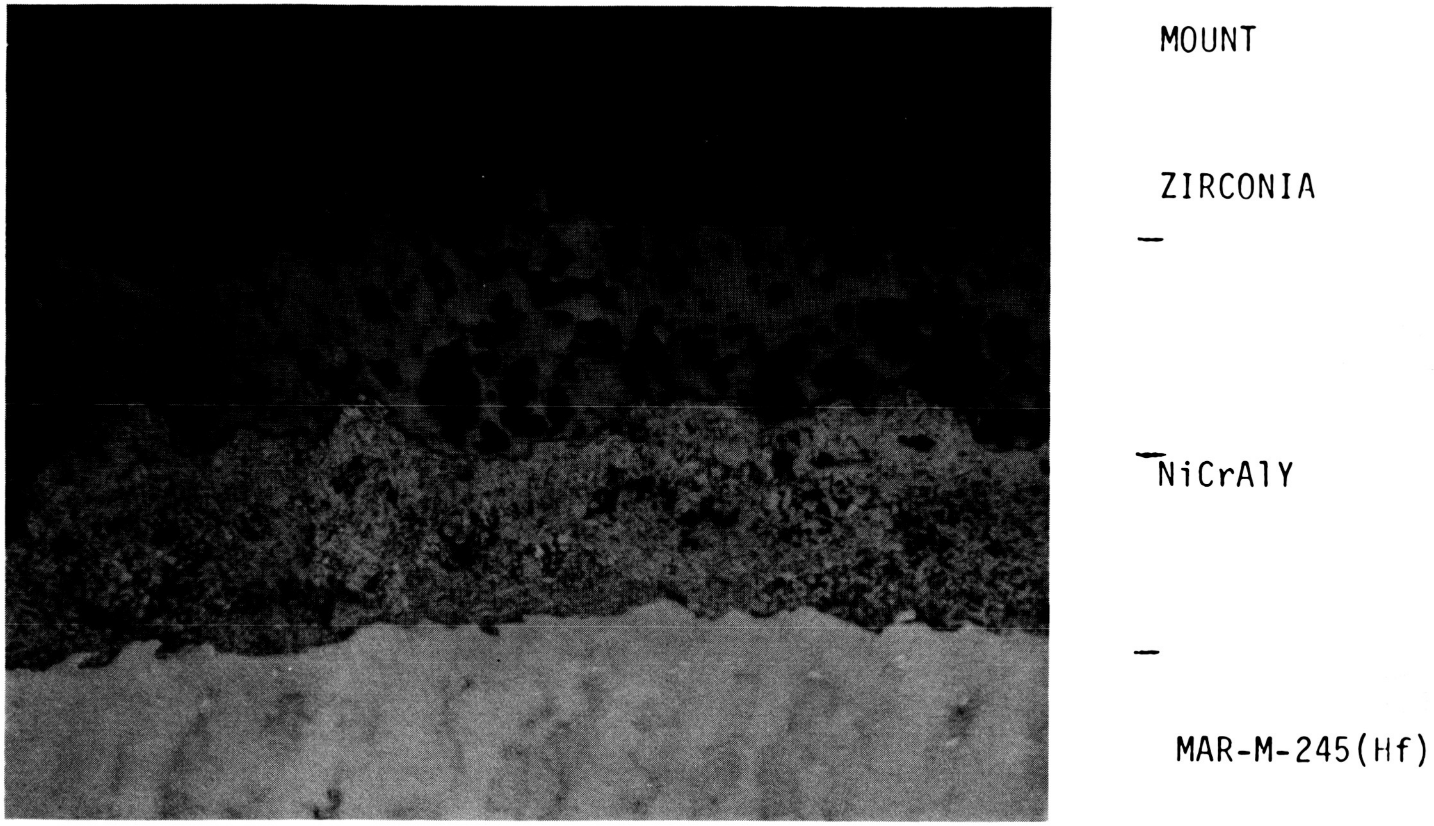

Figure 5 - NiCrAly Airfoil Leading Edge Applied by low Pressure Plasma Flame Spray Showing Improvements: (1) No cracks in NiCrAly bond coating. (2) No oxide layers in NiCrAly bond coating

Mag. 200X

TABLE 1
PLASMA COATED TURBINE BLADES
BURNER RIG CYCLIC THERMAL TESTING
25 CYCLES (1700°F TO - 350°F

VACUUM SPRAY POWER MESH	BOND COATING*	THERMAL BARRIER COATING (4 MIL)	RATING** 100=PERFECT	COMMENTS
-200/+325	NiCrAlY	_	95	NO SPALLING
-400	CoCrAlY	_	94	NO SPALLING
-400	NiCrAlY	_	93	NO SPALLING
-200/+325	NiCrAlY	Cr_2O_3.50 NiCrAlY	94	NO SPALLING
-400	CoCrAlY	Cr_2O_3.50 CoCrAlY	94	NO SPALLING
-400	NiCrAlY	Cr_2O_3.50 NiCrAlY	93	NO SPALLING
-200/+325	NiCoCrAlY	_	25	SPALLING
ATMOSPHERIC SPRAY SSME BASELINE				
-200/+325	NiCrAlY	_	35	SPALLING

* BOND COATING ONLY : 6 MIL THICKNESS
BOND COATING BEFORE ADDING THERMAL BARRIER COATING: 3 MIL THICKNESS

** 3 BLADES EACH SAMPLE