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# THIN FILM THERMOCOUPLES FOR HIGH TEMPERATURE TURBINE APPLICATION

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The objective of this in-house program is to develop thin film thermocouples (TFTC) for space shuttle main engine (SSME) components such as high-pressure fuel turbopump (HPFTP) blades and to test TFTC survivability and durability in the SSME environment. The purpose for developing TFTC's for SSME components is to obtain blade temperatures for computational models developed for fluid mechanics and structures. The TFTC must be able to withstand the presence of high-temperature, high-pressure hydrogen as well as a severe thermal transient due to a cryogenic-to-combustion temperature change. TFTC's will eventually be installed and tested on SSME propulsion system components in the SSME test bed engine.

TFTC's were successfully fabricated on flat coupons of MAR-M 246 (+Hf), which is the superalloy material used for HPFTP turbine blades. The multilayer sensor, as adapted from technology developed for aircraft gas turbine engines, is shown in figure 1 (refs. 1 to 4). The platinum and platinum-13% rhodium thermocouple legs are sputter deposited on an electrically insulating aluminum oxide layer. Aluminum oxide is initially thermally grown on a NiCoCrAlY coating and then an additional aluminum oxide layer is sputter deposited to insure an electrically insulating coating. The NiCoCrAlY coating is a thermal barrier coating with a composition of 23% Co, 18% Cr, 12% Al, 0.3% Y, and the balance Ni. TFTC's fabricated on flat coupons (fig. 2) survived thermal shock cycling as well as testing in a heat flux measurement facility which provided a rapid thermal transient (ref. 5).

The same fabrication procedure was used to deposit TFTC's on HPFTP first-stage rotor blades (fig. 3). Three blades, each with three TFTC's, were mounted in a wired blade holder (fig. 4) and subsequently tested in the Turbine Blade Tester (TBT) facility located at the NASA Marshall Space Flight Center (fig. 5). The TBT simulates the SSME HPFTP turbine environment with the combustion of oxygen and hydrogen at approximately 930 °C (1700 °F) and 16 MPa (2400 psi). The test cycled between cryogenic temperatures and 930 °C for two and one-half cycles. As shown in figure 6, the TFTC's were unable to withstand the SSME simulated environment and consequently were completely removed from the blade surfaces during testing.

Analysis by energy dispersive spectroscopy (EDS) revealed trace amounts of silicon originating from the masking technique that was used in fabricating the platinum and platinum-13% rhodium films on the turbine blades. The masking technique consisted of a thin strip of mylar tape that was used to delineate the thermocouple leg. A thin coating of adhesive was sprayed over the remaining surface area, the tape was removed, platinum was sputtered onto the exposed surface, and the adhesive was removed. The mylar tape is the source of silicon and may have contributed to poor film adherence. However, additional study has demonstrated that the combination of treatments used to fabricate the insulating aluminum oxide film as well as the platinum films is also critical in producing a high degree of adherence between the two layers in both the as-deposited and thermally cycled conditions (ref. 6). These [redacted] treatments include variables such as substrate temperature, oxygen content, and power levels used during sputter deposition of aluminum oxide, platinum and platinum-13% rhodium. It is critical to the platinum adherence that a pure, defect-free, insulating oxide be formed. Because of the temperature limits of the adhesive used in the masking procedure, changes in some of these variables from that used previously have dictated that a different masking procedure be used in fabricating the TFTC's. Alternate masking procedures are also being investigated.

TFTC's are being fabricated on coupons in preparation for testing in a hydrogen-oxygen rocket engine facility located at the NASA Lewis Research Center (figs. 7 and 8). Hydrogen-oxygen combustion gases ranging in temperature from about 1000 °C (1800 °F) to about 2700 °C (5000 °F) are obtainable at combustion chamber pressures up to 4 MPa (600 psi) and are discharged to the atmosphere. The sample can be mounted in the combustion chamber or downstream of the exhaust nozzle (ref. 7). This facility will be used to test samples prepared with different fabrication procedures to determine which procedure provides the greatest degree of film adherence when the film is subjected to a hot gas flow environment. TFTC's will then be fabricated on SSME turbine blades and tested in the TBT.

## REFERENCES


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6. Prakash, S.: Thin-Film Temperature Sensors for Gas Turbines. Ph.D. Thesis, UCLA, 1987.

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## Basic Thin-Film Thermocouple Technology

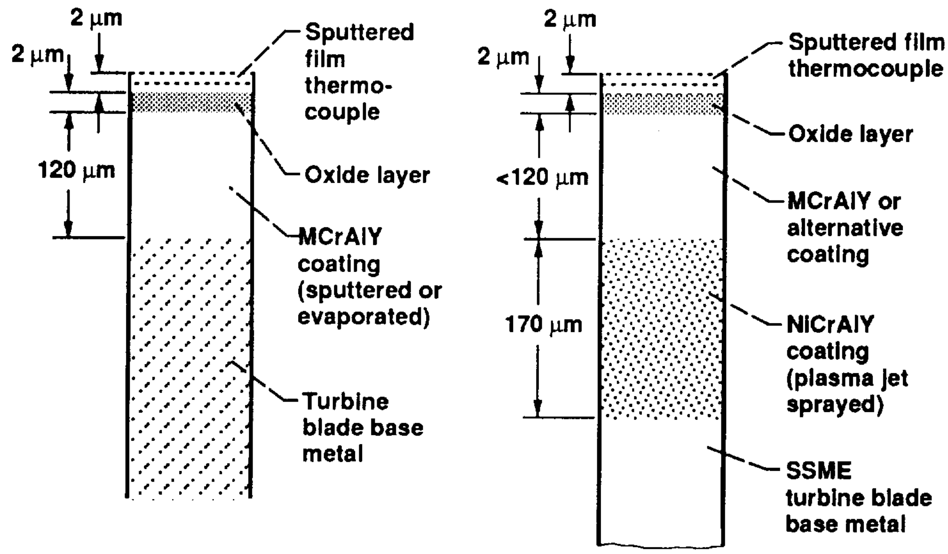


Figure 1 CD-91-52057

## TFTC on SC PWA 1480 Coupon

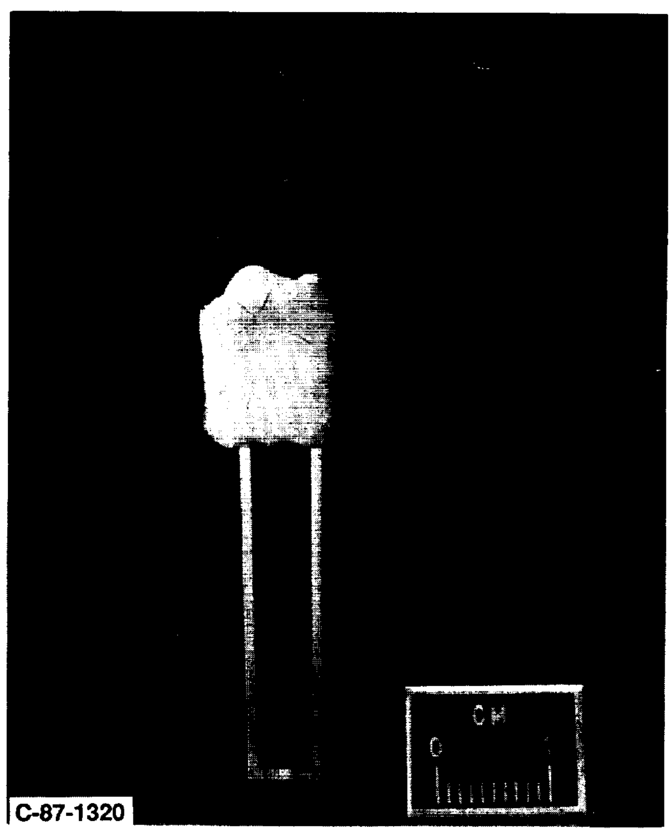


Figure 2 CD-91-52058



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## TFTC's on SSME Blade

### Chromel/Alumel Wire Thermocouple on Shank

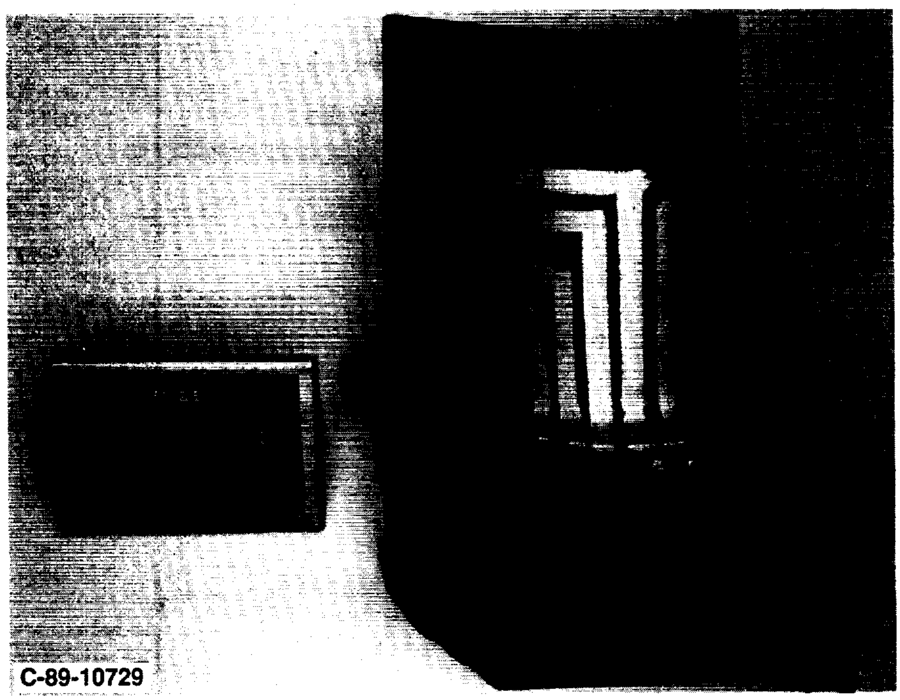


Figure 3 CD-91-52059

## Blade Holder Assembly

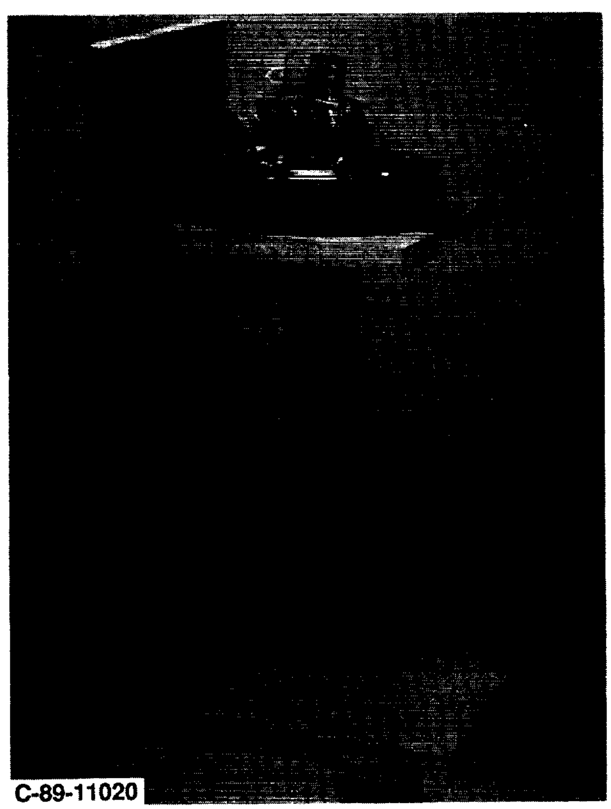


Figure 4 CD-91-52060

## Schematic of MSFC Turbine Blade Tester

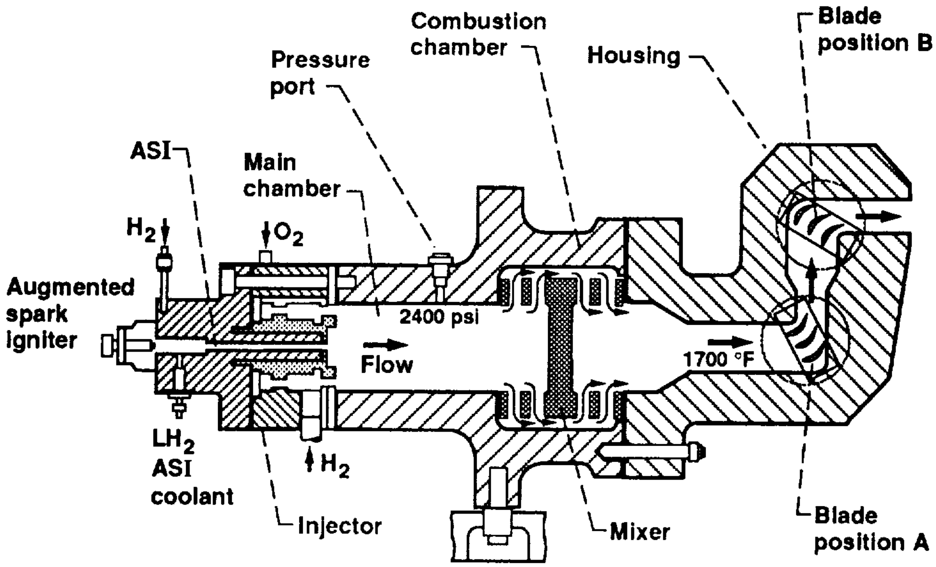


Figure 5 CD-91-52061

## SSME Blade Tested in TBT


Figure 6 CD-91-52062



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## Hydrogen-Oxygen Rocket Engine Facility During Operation

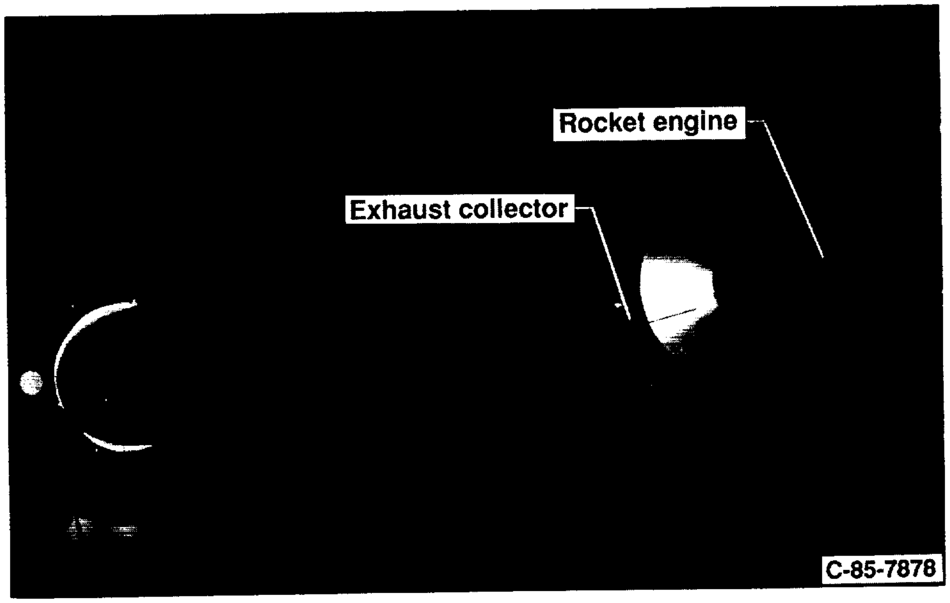


Figure 7

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## Test Specimen Mounted in Exhaust Flow During Operation

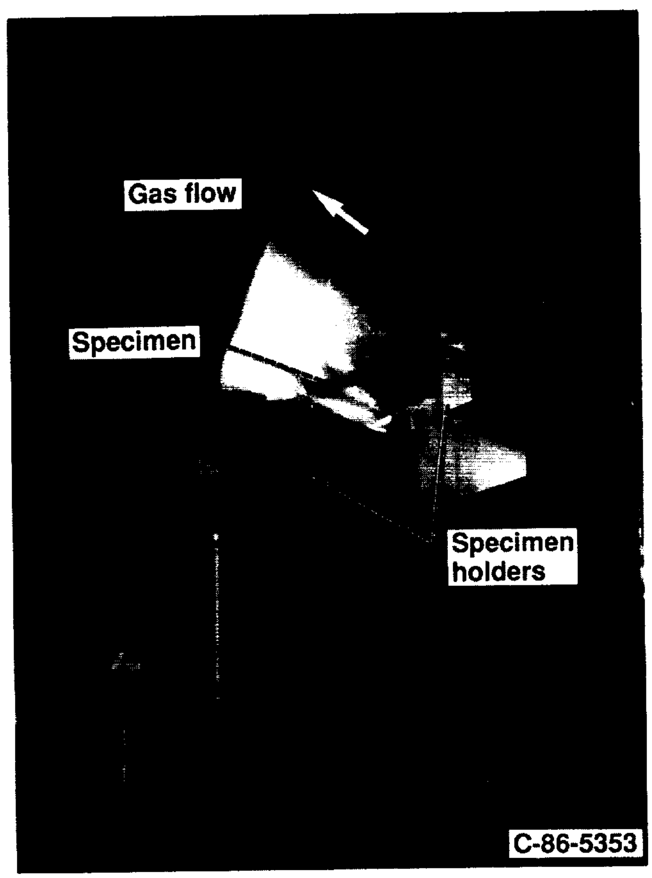


Figure 8

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