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STRAIN ISOLATED CERAMIC COATINGS

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Plasma sprayed ceramic coatings are used in gas turbine engines to improve component temperature capability and cooling air efficiency. A compliant metal fiber strain isolator between a plasma sprayed ceramic coating and a metal substrate improves ceramic durability while allowing thicker coatings for better insulation. The low modulus strain isolator moves elastically to accommodate differential expansion of ceramic and metal to reduce the stress transmitted to the ceramic. A typical ceramic-strain isolator-backing system consists of .060-.100" of plasma sprayed zirconia (YSZ) applied to .060" fiber metal strain isolator. The strain isolator improves coating performance by: partially decoupling coating and backing, providing insulation to protect the metal backing from heat deformation, allowing thicker ceramic coatings for improved insulation, widening the operating boundaries of the coating system, and improving cooling and substrate protection by flowing air through the strain isolator. Strain isolated coating applications include ceramic seals, combustors, scrolls, vanes and internal combustion engines.

Development of strain isolated coatings has been concentrated on design and fabrication of coatings and coating evaluation via thermal shock testing. Coating design requires interactive matching of coating, strain isolator and backing for effective performance. Coating design is determined by material properties, component geometry and engine operating conditions. In thermal shock testing, five types of failure are possible: buckling failure in compression on heat up, bimetal type failure (see below), isothermal expansion mismatch failure, mudflat cracking during cool down, and long term fatigue. Preventing heat up and cool down failure require conflicting design approaches. Strain isolation allows a middle ground approach than can tolerate both types of cycles. Isothermal failure is atypical with proper cooling and data on long term fatigue is very limited at present.

A primary failure mode for thermally cycled coatings is what we have designated bimetal type failure. Bimetal type failure is tensile failure in the ceramic near the ceramic-metal interface (it occurs in both ceramic-metal and strain isolated coatings). A ceramic-metal coating can be viewed as a composite beam with a centroid or null point at which zero stress occurs. The centroid is the transition between compression and tension. Typically a plasma sprayed coating is a buildup of multiple thin layers on a cool backing. This produces a coating in compression with centroid location in the metal. Heat work on the metal substrate in plasma spraying or operation can reduce the metal modulus and allow plastic deformation of the metal substrate. As metal deformation occurs, the centroid moves into the ceramic creating a zone where the ceramic is in tension between the ceramic-metal interface and the centroid. Bimetal type tensile failure in the ceramic occurs due to thermal cycling after the centroid has moved into the ceramic. One of the significant benefits of the strain isolator is as an insulating layer protecting the metal substrate from heat deformation and thereby preventing bimetal type failure.

Substantial thermal shock testing has demonstrated the value of strain isolation as shown in the figures. Temperature, thermal loads, heating and cooling rates and steady-state holds in thermal shock testing should approximate engine operating conditions. Sample and test design have been found to be very important. Coating performance in thermal shock testing can be compromised by sample cutting, welding, cold work, attachment method, cooling method and inappropriate backing alloy or thickness.

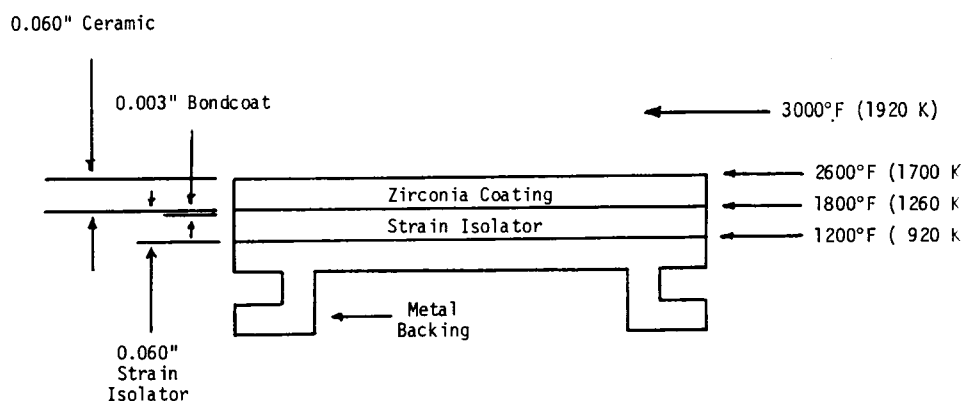


FIGURE 1
CROSS-SECTION VIEW OF A TYPICAL
STRAIN ISOLATED CERAMIC COATING.
 THE STRAIN ISOLATOR IS BRAZED TO
 THE METAL BACKING. THE STRAIN
 ISOLATOR SURFACE IS GRIT BLASTED
 AND LIGHTLY BOND COATED (.001-.003"
 THICK BY WEIGHT) BEFORE PLASMA SPRAY
 APPLICATION OF THE ZIRCONIA COATING.

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OF POOR QUALITY

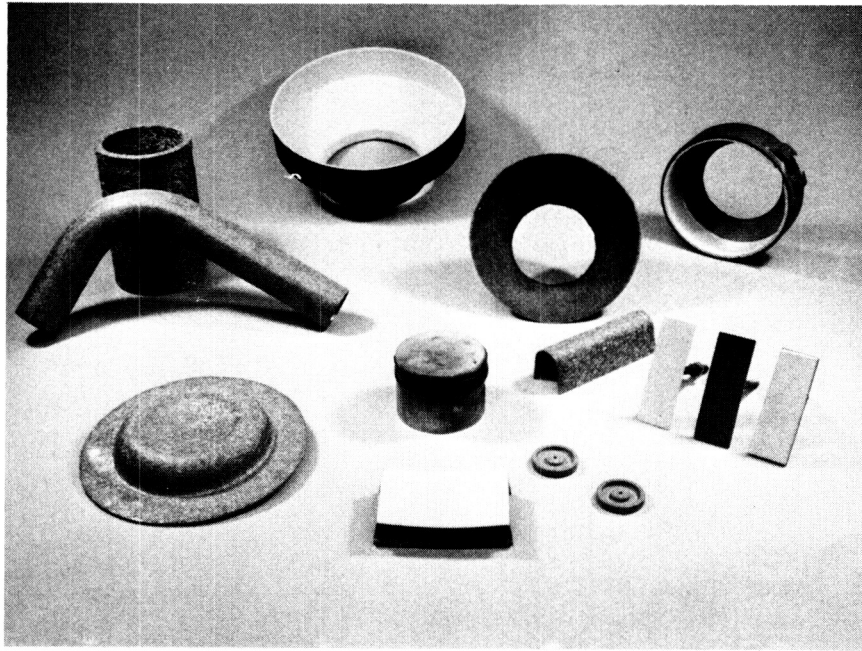


FIGURE 2
STRAIN ISOLATOR COMPONENTS WITH
AND WITHOUT CERAMIC COATINGS

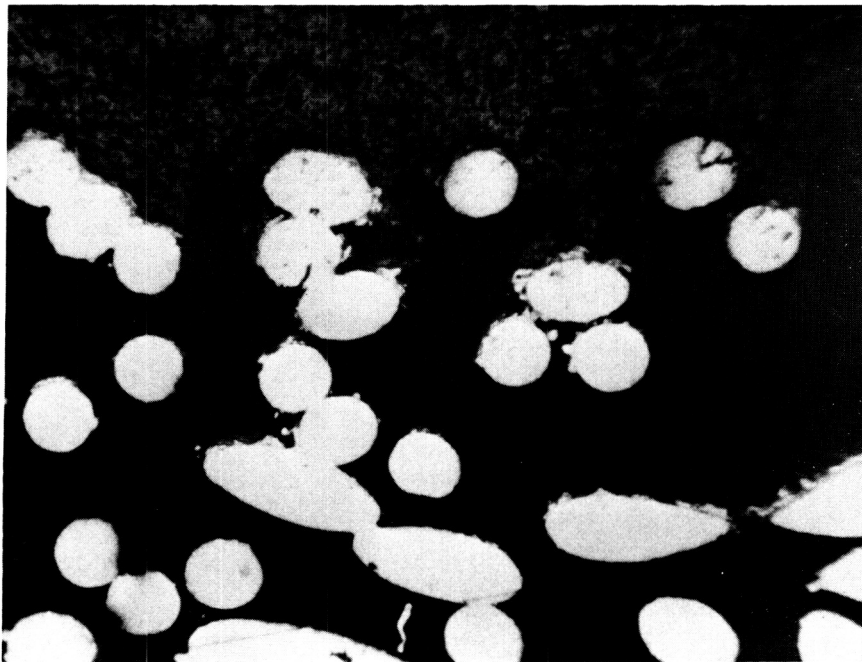


FIGURE 3
CROSS SECTION VIEW OF THE
CERAMIC-STRAIN ISOLATOR INTERFACE.
PENETRATION AND INTERLOCKING OF THE CERAMIC
COATING WITH THE POROUS STRAIN ISOLATOR IS ILLUSTRATED.

FIGURE 4
TYPICAL STRAIN ISOLATOR PROPERTIES

- . HOSKINS 875 (FeCrAl) FIBER .0056" DIAMETER
- . 35% DENSITY (65% POROSITY)
- . .060" THICK
- . UTS - IN PLANE: 4800 PSI
TRAVERSE: 1000 PSI
- . ELASTIC MODULUS: 1.1×10^6 PSI
- . THERMAL CONDUCTIVITY: .010 W/CM-K
- . OXIDATION RESISTANCE: 1800°F CAPABILITY - 10,000 HOUR LIFE

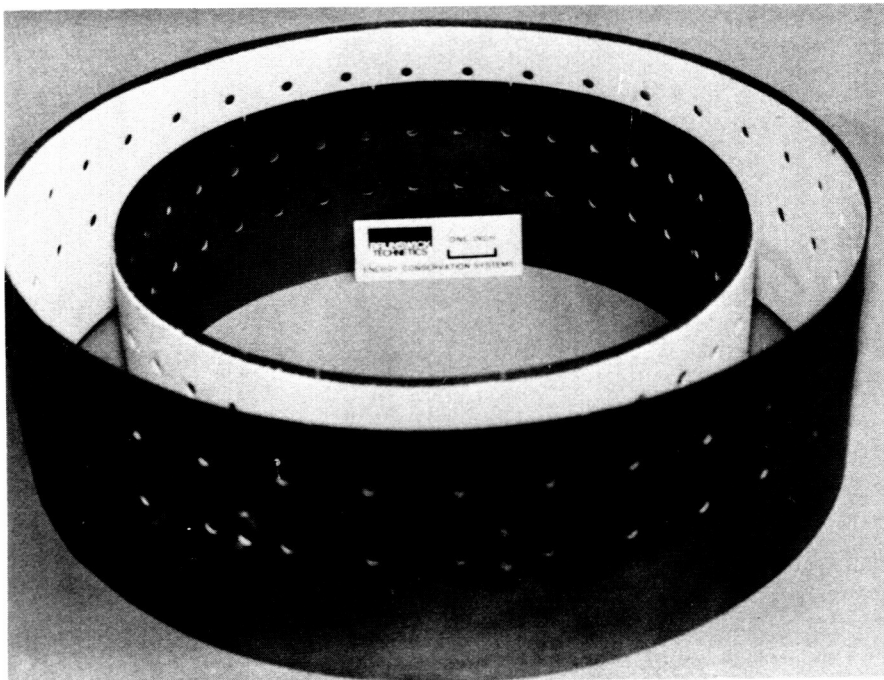


FIGURE 5
STRAIN ISOLATED ZIRCONIA
COATED COMBUSTOR SECTIONS

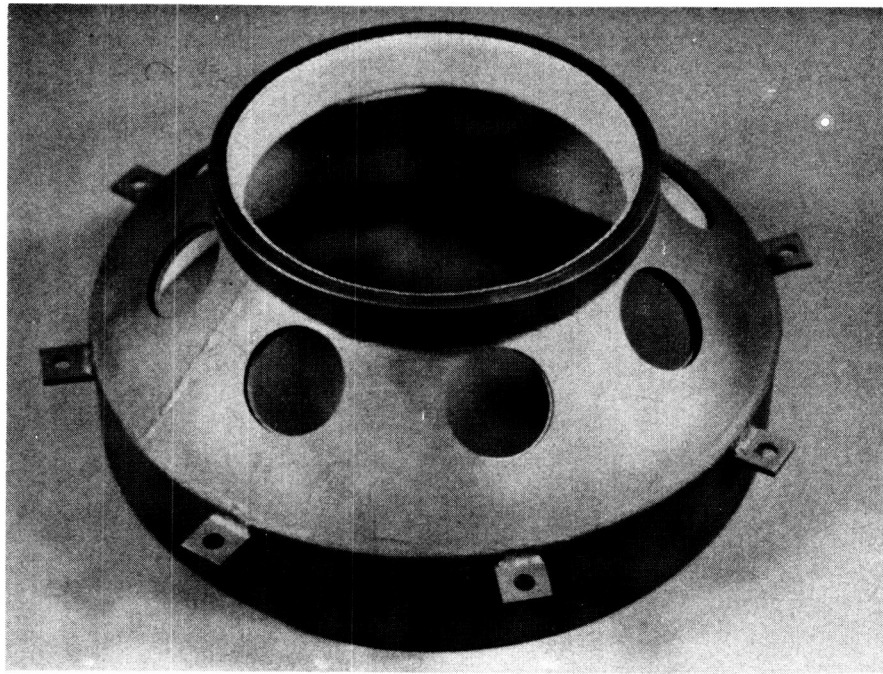


FIGURE 6
STRAIN ISOLATED ZIRCONIA
COATED COMBUSTOR SECTIONS

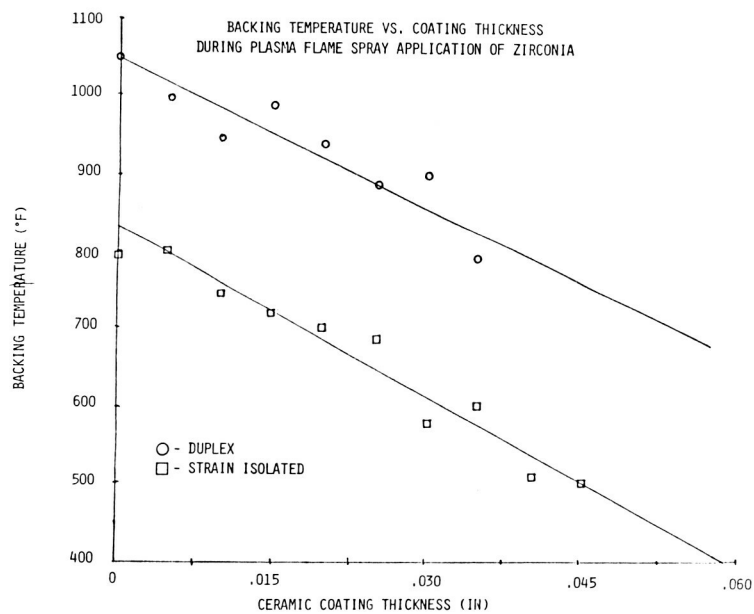


FIGURE 7
EFFECT OF STRAIN ISOLATION AND COATING
THICKNESS ON METAL BACKING TEMPERATURE

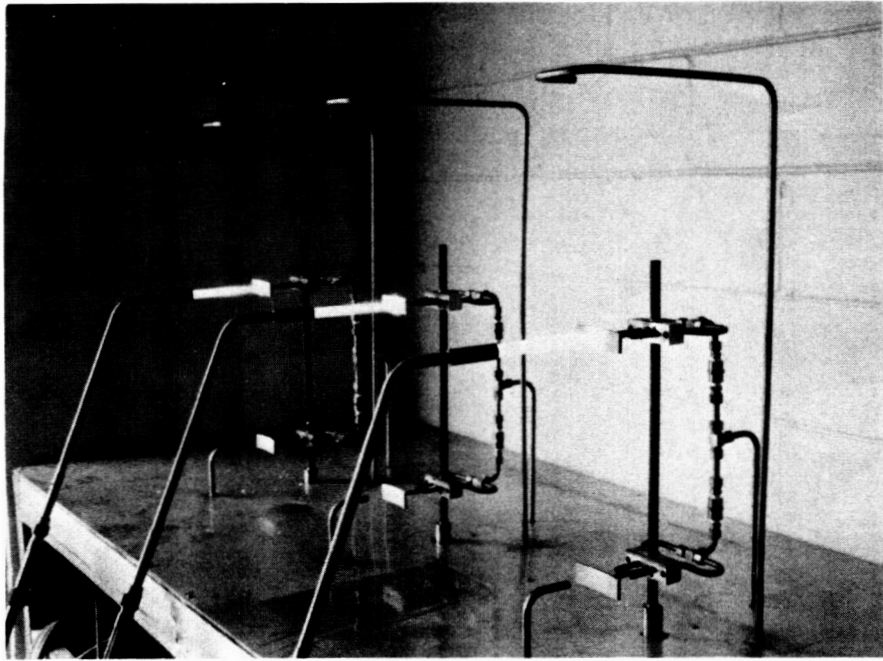


FIGURE 8
THERMAL SHOCK RIG

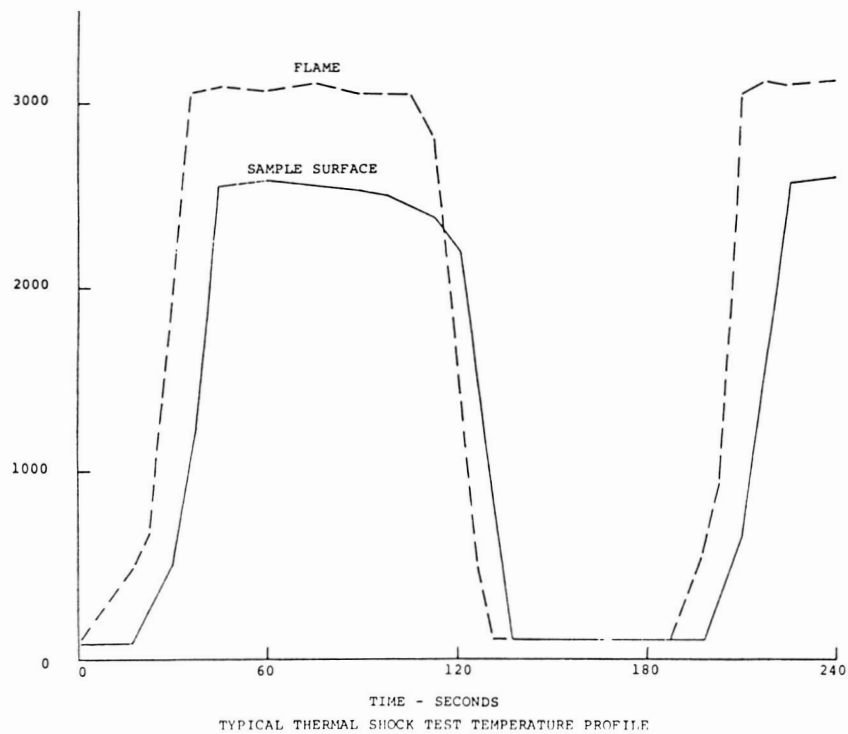


FIGURE 9
TYPICAL THERMAL SHOCK
RIG TEMPERATURE CYCLE

FIGURE 10
THERMAL SHOCK TEST RESULTS
.060" THICK ZIRCONIA COATING

	<u>AVG. CYCLES TO¹</u> <u>LAMINAR CRACKING</u>	<u>AVG. CYCLES</u> <u>TO FAILURE</u>
ZIRCONIA COATING ² NO STRAIN ISOLATOR	125	1100
ZIRCONIA COATING STRAIN ISOLATED	1700	>5000 ³
IMPROVED ZIRCONIA COATING STRAIN ISOLATED	5300	>6600 ³

1. AVERAGE OF 3 SAMPLES
2. ZIRCONIA USED IS $\text{ZrO}_2 - 20\% \text{Y}_2\text{O}_3$
3. SAMPLES DIDN'T FAIL; TEST WAS DISCONTINUED