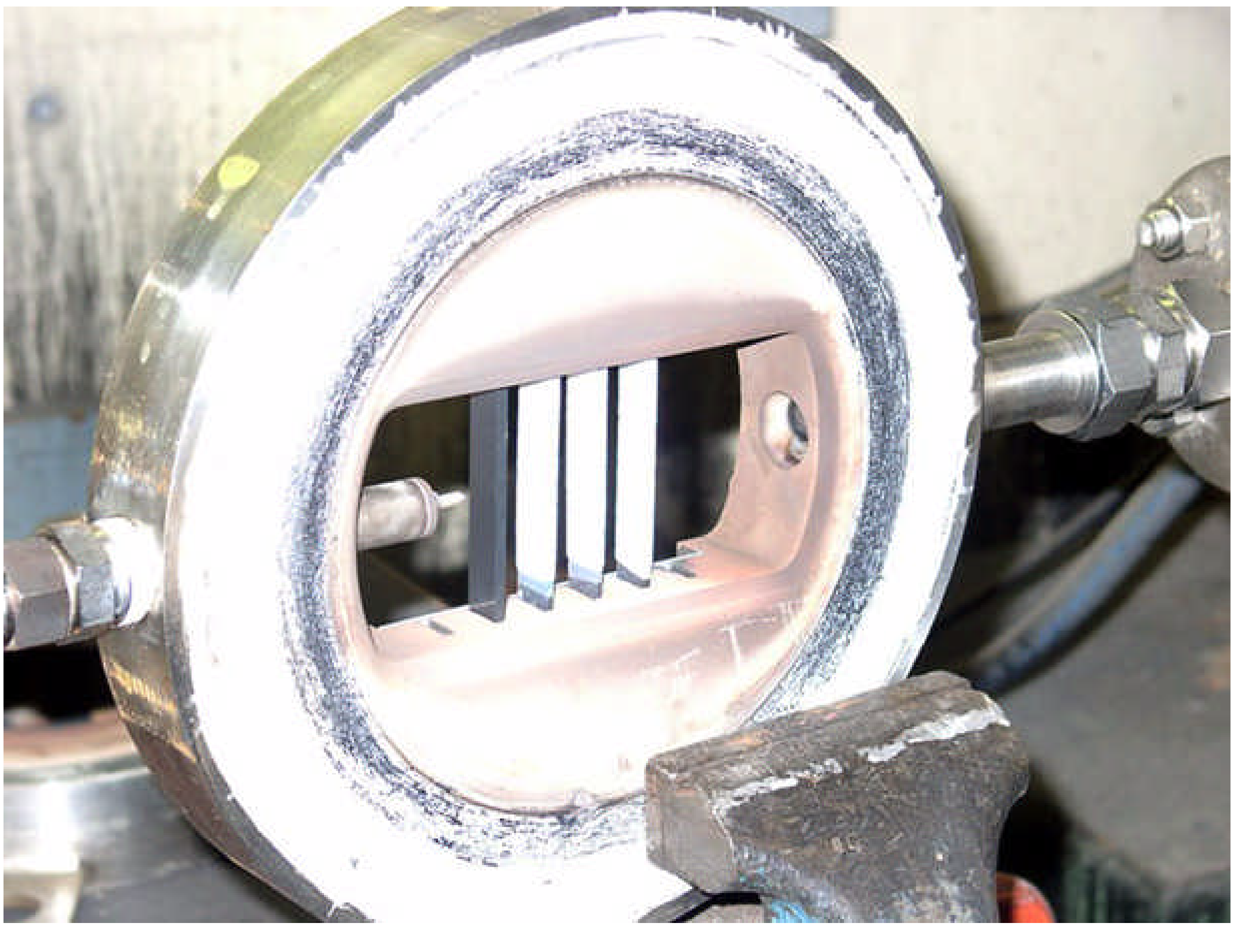
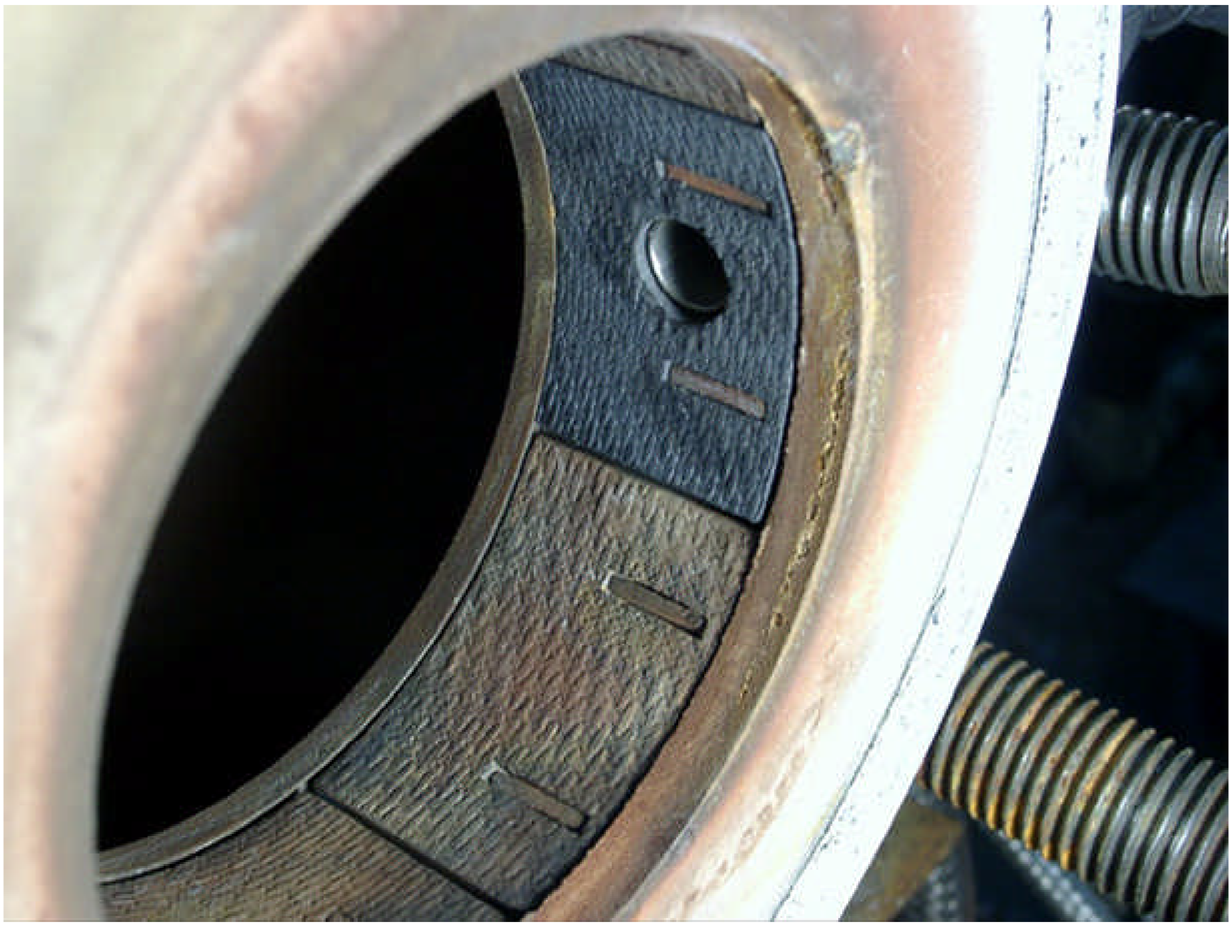
Combustor and Vane Features and Components Tested in a Gas Turbine Environment

The use of ceramic matrix composites (CMCs) as combustor liners and turbine vanes provides the potential of improving next-generation turbine engine performance, through lower emissions and higher cycle efficiency, relative to today's use of superalloy hot-section components. For example, the introduction of film-cooling air in metal combustor liners has led to higher levels of nitrogen oxide (NO_x) emissions from the combustion process. An environmental barrier coated (EBC) silicon-carbide-fiber-reinforced silicon carbide matrix (SiC/SiC) composite is a new material system that can operate at higher temperatures, significantly reducing the film-cooling requirements and enabling lower NO_x production.



EBC coupon test module with four specimens.

Evaluating components and subcomponents fabricated from these advanced CMCs under gas turbine conditions is paramount to demonstrating that the material system can perform as required in the complex thermal stress and environmentally aggressive engine environment. To date, only limited testing has been conducted on CMC combustor and turbine concepts and subelements of this type throughout the industry. As part of the Ultra-Efficient Engine Technology (UEET) Program, the High Pressure Burner Rig (HPBR) at the NASA Glenn Research Center was selected to demonstrate coupon, subcomponent feature, and component testing because it can economically provide the temperatures, pressures, velocities, and combustion gas compositions that closely simulate the engine environments. The results have proven the HPBR to be a highly versatile test rig amenable to multiple test specimen configurations essential to coupon and component testing. Typical conditions include 6 to 8 atm of pressure (10 vol% water vapor), 50 to 100 ft/sec gas velocities, and 2400 to 2550 °F material temperatures.



CMC lean transition liners mounted in the HPBR.

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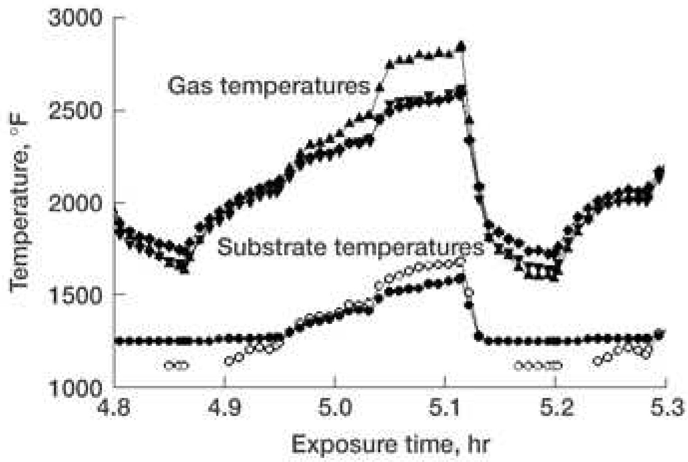
Testing of subcomponent features for combustor liners began on lean transition liners that had been developed for testing in a fuel-rich quick-quench fuel-lean combustor sector rig at Glenn. Only limited exposure time was available because of operational and cost issues. In the current effort, the geometry of these liners, their CMC attachments, and the HPBR configuration were adapted to accommodate continued testing. A water-cooled test module that slipped into existing flanges allowed for separate gas and backside cooling paths and provided access ports for obtaining both surface and substrate temperatures using both optical and fiber-optic measurement techniques. The baseline cycle adopted was a 30-min transient with 15 min of dwell time at a gas temperature of approximately 2700 °F and surface temperatures between 1800 and 2400 °F, depending on cooling flows. To date, the original set of six lean transition liners and numerous attachments have been exposed to over 180 hr (280 cycles). Tests such as these are successfully demonstrating the feasibility of using CMCs integrated with metallic parts in a combustor application.



Cycle and material temperature for lean transition liners tested in the HPBR.

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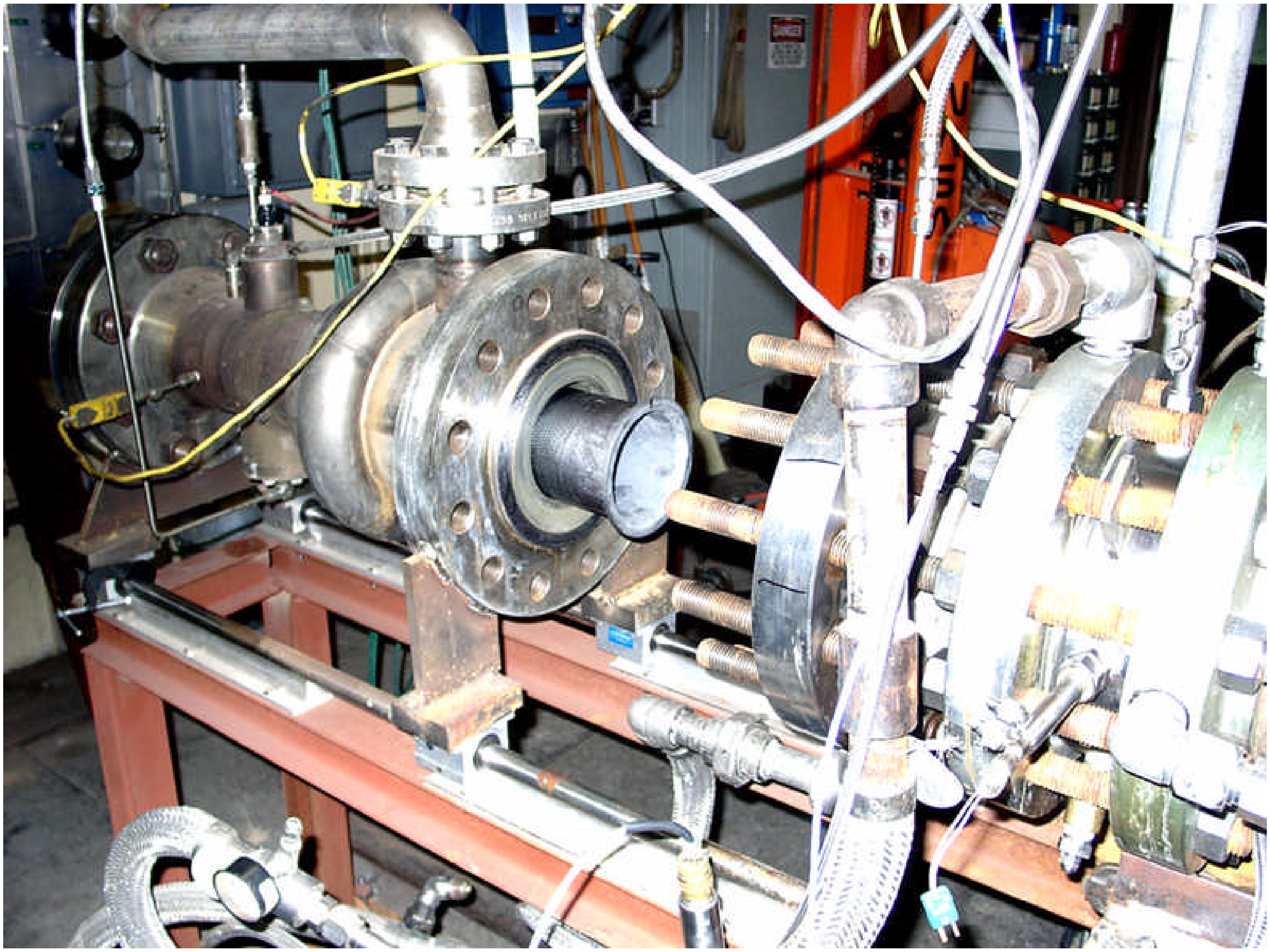
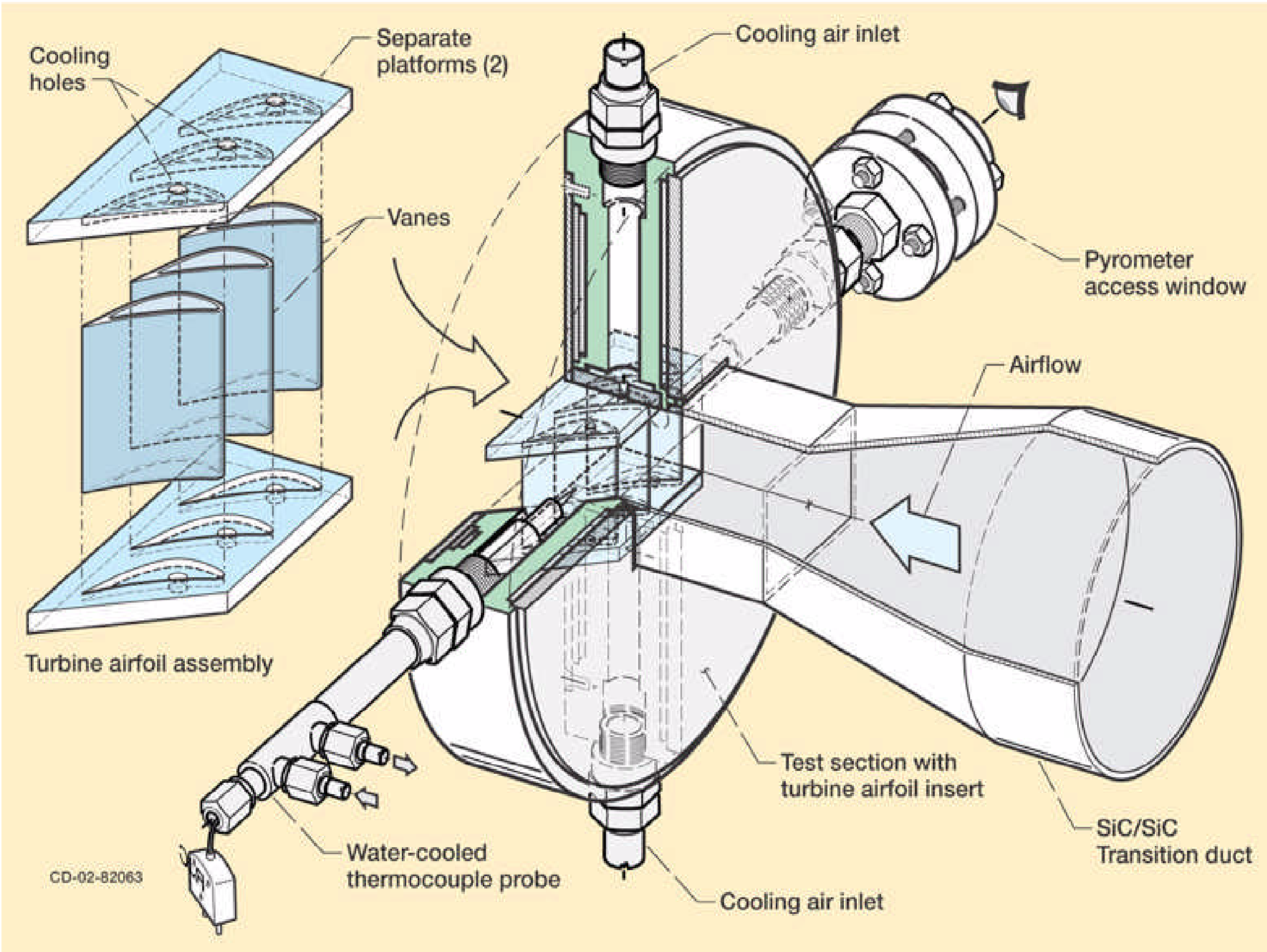
A second feature test for the combustor application incorporates a unique SiC/SiC combustor liner, designed and fabricated to replace the original metal component in the HPBR. This EBC-coated CMC liner, equipped with an integral attachment flange, will be installed in the test rig and run parallel to other ongoing testing for over 1000 hr of exposure. This test will provide valuable long-term durability data on recession and microstructural damage for a stressed, actively cooled CMC component in a high-water-vapor combustion gas environment.



SiC/SiC CMC combustor liners installed in the HPBR.

A test to expose SiC/SiC CMC airfoils in a configuration similar to a stationary inlet guide vane will be used to demonstrate the technology readiness of fabricating a generic EBC-coated, melt-infiltrated, SiC/SiC airfoil as well as meeting the mechanical capability and environmental durability requirements imposed by the combustion gas environment. The test module requires three vanes (with separate metal platforms) to provide the proper boundary conditions for both the "pressure" and "suction" side of the center airfoil. The configuration employs a SiC/SiC transition duct to accelerate the incoming flows, provides internal cooling to the airfoils, and has designs to monitor the resulting temperatures and pressures. Typical gas conditions in the test section will include 6 to 8 atm, 300 ft/sec, and 2650 °F.



HPBR turbine test configuration.
Long description **Long description of figure 5**

Illustration shows enlarged turbine airfoil assembly with cooling holes, two separate platforms, and vanes It also shows the entire configuration labeling the cooling air inlet, pyrometer access window, airflow, SiC/SiC transition duct, test section with turbine airfoil insert, water-cooled thermocouple probe, cooling air inlet, and the position of the turbine airfoil assembly.

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Testing and evaluation of advanced materials for turbine engines require studies to address the scaleup issues inherent in coupon-level studies in the application engine or at least in testing situations as close to simulating the actual application environment as is possible. The combustion environment provided by the HPBR as well as the versatility in test fixturing and design make it a valuable test rig for evaluating new materials for gas turbine engines.

Find out more about the research of Glenn's Environmental Durability Branch http://www.grc.nasa.gov/WWW/EDB/.

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