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**CONCURRENT RESEARCH ON HIGH
GRAVITY (g) COMBUSTION AND
ENABLING MATERIALS**

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Turbine Engine Division
Propulsion Directorate
Air Force Research Laboratory, Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7251**



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/s/

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13. SUPPLEMENTARY NOTES						
14. ABSTRACT A gas turbine engine has been proposed that uses a near constant temperature (NCT) cycle and Inter-Turbine Burner (ITB) to provide large amounts of power extraction from the low-pressure turbine. This level of energy is achieved with a modest temperature rise across the ITB. The additional energy can be used to power a large fan for an ultra-high bypass ratio transport aircraft, or to drive an alternator for large amounts of electrical power extraction. Conventional gas turbine engines cannot drive ultra-large diameter fans without the use of excessive turbine temperatures, and cannot meet high power extraction demands without a loss of engine thrust. Reducing the size of the main combustor and ITB is essential to reducing or maintaining overall engine weight and size for the NCT cycle. Concepts for an ultra-compact combustor (UCC) are being explored experimentally. The basic combustor design involves flame-holding in a cavity within which the flow is strongly swirled. Experimental results at atmospheric pressure indicate that the combustion system flame holding zone operated at 95 – 99 percent combustion efficiency over a wide range of operating conditions. Flame lengths were extremely short, at about 50 percent those of conventional systems.						
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LABORATORY ANNUAL TASK REPORT

LRIR: 99PR12ENT

Title: Concurrent Research on High Gravity (g) Combustion and Enabling Materials

Lab Task Managers:	Dr. Joseph Zelina (AFRL/PRTS)	Dr. R. J. Kerans (AFRL/MLLN)
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AFOSR Program Manager: Drs. Julian Tishkoff, Joan Fuller, and Thomas Hahn

Research Objectives: 1) Establish science needed for an ultra-compact, high-energy-density Inter-Turbine Burner (ITB) that will enable a constant temperature (CT) cycle engine. 2) Establish science-based methodology for concurrent development of new component strategies and enabling materials via interactive studies needed for development of ITB.

Background: This is a joint program between MLLN and PRTS. A key technology essential for the development of a propulsion system that operates on a CT cycle is an ITB that will efficiently add heat between the turbine stages and is constructed of advanced, lightweight ceramic-matrix composites (CMC) materials.

Summary of Progress and Forecast for Next Year FY: Progress: Concepts for an ultra-compact combustor (UCC) which uses high g loading are being explored experimentally. The rig, which simulates the flameholding zone in a circumferential cavity, uses a centerbody to simulate the actual engine configurations. The fuel is introduced in the cavity at 6 discreet injection sites equally spaced around the circumference. Part of the total combustion air is admitted into the cavity to mix with the fuel and provide a stability zone for the flame. The cavity mixture burns and transports to the axial main air zone, where the mixture is quenched and reactions continue to completion. A parametric study was conducted to investigate the effect of airflow rates into the swirling cavity. Results of the best design were very encouraging, indicating that the combustion system flame holding zone operated at 99+% combustion efficiency over a wide range of cavity fuel-air ratios and combustor pressure drop conditions burning JP-8 +100 fuel. Flame lengths were extremely short, at about 50% that of conventional systems. High heat release rates on the order of 2 times conventional primary zone heat release rates were seen while maintaining high combustion efficiencies. It is believed that combustor cavity g-loading, on the order of 1000 g's compared to conventional combustion systems near 100 g's, enhanced reaction rates and provided a longer residence time for un-reacted mixture via centrifugal forces, thereby increasing the combustion efficiency. CFD tools were used successfully to determine test matrix designs and to understand physical processes in the high g-loaded combustor. **Forecast:** Investigation into the effects of fuel injection method into highly swirling flow, and the impact of atomization, fuel velocity, and fuel-air mixing on combustion performance will continue. Additionally, the study of mixture transport from the cavity to the main air stream will continue by investigation of strut and vane configurations. The combustion system will be investigated at modest pressure ratio to study pressure effects on system performance.

The materials portion status of this program is included in a separate AFOSR report provided by Dr. Ronald Kerans, AFRL/MLLN.

Use of Funds: (FY00, \$370K)	<u>In House</u>	<u>Capital Equip.</u>	<u>On Site Contractor</u>	<u>Contracts/Grant</u>
PR	\$60K	\$10K	\$120K	0
ML	\$55K	0	\$135K	0

Funding Profile (\$K):	<u>FY01</u>	<u>FY02</u>	<u>FY03</u>
Core	\$350	\$370	\$380
Fallout	\$ 90	\$100	
Total	\$440	\$470	\$380

APPENDIX A: IN-HOUSE ACTIVITIES

Name	Degree	Discipline	Involvement
W. M. Roquemore	PhD	Physics	10%
R. D. Hancock	PhD	Mechanical Engineering	10
J. Zelina	PhD	Mechanical Engineering	60
R.J. Kerans	PhD	Metallurgical Engineering	10
N. J. Pagano	PhD	Engineering Mechanics	10
R.S.Hay	PhD	Geological and Geophysical Sciences	10
R. John	PhD	Civil Engineering	10
L.P. Zawada	M.S.	Materials Science and Engineering	10
M.K. Cinibulk	PhD	Materials Science and Engineering	10

On-Site Contractors

V. R. Katta	PhD	Aerospace Engineering	5%
G. J. Sturgess	PhD	Aerospace Engineering	20
T. A. Parthasarathy	PhD	Metallurgical Engineering	20
R. Brockman	PhD	Mechanical Engineering	10
D. Buchanan	MS	Materials Science and Engineering	20
G. P. Tandon	PhD	Mechanics and Materials Science	20
M.K. Cinibulk	PhD	Materials Science and Engineering	10
T. Mah	PhD	Ceramic Engineering	10
K. Keller	MS	Materials Science and Engineering	20

Publications, Patents and Invention Disclosures

Zelina, J., Ehret, J., Hancock, R., Shouse, D., Roquemore, W., and Sturgess, G., "Ultra-Compact Combustion Technology Using High Swirl for Enhanced Burning Rate," AIAA 2002-3725.

Zelina, J., Ehret, J., Hancock, R., Shouse, D., Roquemore, W., and Sturgess, G., "Ultra-Compact Gas Turbine Combustor Designs and Enabling Materials Technology," 26th Annual Conference on Composites, Materials, and Structures, 29-31 January 2002, Cocoa Beach, FL.

Katta, V., Meyer, T., Parthasarathy, T., Kopp, J., Gord, J., Roquemore, W. and Kerans, R., "Numerical and Experimental Study of Heat Transfer Through Ceramic Disk Under Combusting Flow Environment," 26th Annual Conference on Composites, Materials, and Structures, 29-31 January 2002, Cocoa Beach, FL.

Zawada, L., and Cinibulk, M., "Performance of Oxide/Oxide CMC's Exposed to Jet Fuel and Thermal Treatments," 26th Annual Conference on Composites, Materials, and Structures, 29-31 January 2002, Cocoa Beach, FL.

John, R., Buchanan, D., Kramb, V., Zawada, L., and Brockman, R., "Creep Rupture Behavior of Nextel 720/AS Composites With Effusion Holes," 26th Annual Conference on Composites, Materials, and Structures, 29-31 January 2002, Cocoa Beach, FL.

Zawada, L., Zelina, J., and Anthenien, R., "Oxide/Oxide CMC's for Combustor Liners," 26th Annual Conference on Composites, Materials, and Structures, 29-31 January 2002, Cocoa Beach, FL.

Seminars and Workshops

Program Planning Meeting for Future Joint Reheat Programs – NASA, NAVAIR, NAVSEA, DOE, May 8-9, 2002 at AFRL.

Professional Affiliations

Dr. R.J. Kerans, American Ceramic Society (Fellow), Materials Research Society, TMS-AIME
Dr. R.S. Hay, American Ceramic Society, Materials Research Society, American Geophysical Union
Dr. R. John, ASTM, American Ceramic Society, Society for Experimental Mechanics
Mr. L. P. Zawada, American Ceramic Society, ASTM
Dr. R. A. Brockman, American Society for Mechanical Engineers
Dr. M. K. Cinibulk, Member American Ceramic Society, Materials Research Society
Dr. W. M. Roquemore, AIAA (Fellow), APS, ASME and The Combustion Institute
Dr. Joseph Zelina, Senior Member AIAA, Member ASME, Member Combustion and Fuels Committee IGTI,
Member ILASS.