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Advanced Gas Turbine Systems Research

**Quarterly Report
January - March 1994**

April 1994

Work Performed Under Contract No.: DE-FC21-92MC29061

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
South Carolina Energy Research and Development Center
Clemson University
Clemson, South Carolina

WASH DC

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**For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880**

**By
South Carolina Energy Research and Development Center
Clemson University
386-2 College Avenue
Clemson, South Carolina 29634-5181**

April 1994

Technical Progress Report
Advanced Gas Turbine Systems Research
Cooperative Agreement DC-FC21-92MC29061

January 1 - March 31, 1994

SUMMARY

The second round of proposals for AGTSR has been evaluated and thirteen new subcontracts approved for additional university research. Forty-four proposals were submitted covering the five technology areas specified for this RFP. Including the ten subcontracts in place from the 1993 solicitation, AGTSR now has 23 projects with 22 universities.

A very successful Combustion Workshop was held in Nashville in February. Fifty-five university, industry, and METC experts participated in this technical exchange. Guidance for current research projects was provided, and issues for future discussion and research were identified.

The 1993 subcontractors have completed their first six months of work, and are beginning to make significant progress on their programs.

MEMBERSHIP

North Carolina State and Cincinnati are the two newest members of the program, bringing the total to 63. Thirty-three states are now represented. Attachment I contains a list of the Performing Members and the states represented in AGTSR.

Five visits were conducted in this reporting period, leaving sixteen to complete the objective of a personal meeting with each Performing Member.

ADMINISTRATION

During 1993, cost sharing membership fees were paid by General Electric, Westinghouse, Solar, TurboPower and Marine, Fluor Daniel and Allison Engine Company for IRB membership rights to AGTSR. For 1994, cost-sharing fees have been received from General Electric, Westinghouse, Solar, and TurboPower. Allison is again considering membership renewal while Fluor Daniel has declined.

EPRI and GRI continue to be non-voting, no fee members.

THIRTEEN NEW AWARDS JOIN THE RESEARCH PROGRAM

The second RFP cycle was completed in March with DOE approval received for thirteen awards recommended by the Industrial Review Board. Although less funding was available (\$4.9 million vs. \$6.5 million for the first round), more contracts were possible since several were one or two years in length. Forty-four proposals were received, with the technology breakdown shown below.

TECHNOLOGY	NO. SUBMITTED	NO. AWARDED
Heat Transfer	19	6
Aerodynamics	9	2
Materials	7	2
Combustion	6	3
Dynamics	3	0

The 1994 RFP was issued in late November 1993, with a proposal due date of February 4, 1994. The Industrial Review Board met at SCERDC February 9-11, and recommendations were submitted to METC March 2 (via video conference from Oak Ridge). The thirteen awards were approved as submitted, and subcontract negotiations are now in process. It is expected that signed contracts will be in place by early May, so that work may begin between June 1 and September 1. A tabulation of the award data is shown in Attachment II.

Presented alphabetically below are the winning universities, with a short summary of the planned research. The Principal Investigator has also been identified.

California/Irvine

Scott Samuelsen 714-856-7302

The effectiveness of mixing the fuel and air in lean premixed combustion is the key to obtaining low emissions. Understanding the premixing mechanisms and the role of turbulence is the thrust of this project, augmented by tests conducted at atmospheric and elevated pressures.

Carnegie Mellon

Mingking Chyu 412-268-3658

Obtaining higher turbine inlet temperatures while maintaining present metal temperatures requires better cooling techniques. A sensor that can provide heat flux data at the temperature levels of interest would be very beneficial in assessing these

techniques. CMU plans to pursue development of such a device, which is based on thermographic phosphor fluorescence.

Central Florida

Vimal Desai

407-823-5777

Substitution of steam for air extracted from the compressor for turbine cooling may be an attractive alternative for cycle efficiency enhancement. However, little is known about how steam may affect the materials used in the turbine hot section. This program will look at how steam, and some of its potential contaminants, might attack the nickel and cobalt based materials currently in use.

Clemson

James Leylek

803-656-5640

Film cooling of vanes and blades is expected to remain a critical heat transfer technology for the advanced turbines. Better design tools are key to minimizing the use of extracted compressor air, and also to reducing cycle time. Clemson's work will couple CFD analyses with wind tunnel testing to produce a useful "desktop" computation method.

Cornell

Stephen Pope

607-255-4314

The PDF (Probability Density Function) concept is one of the most widely accepted bases for combustion modeling. Its expansion into the use of methane as the fuel is relevant as natural gas is the fuel of choice for the ATS program. Objectives are to predict CO and NOx accurately, with a model that minimizes computation time.

Georgia Tech

Brent Carter

404-894-6762

Thermal Barrier Coatings (TBC's) are necessary to maintain the life of present superalloys at the elevated turbine inlet temperatures needed to meet the ATS efficiency goals. Developing appropriate coating compositions and applying them at reasonable cost are two of the challenges. Georgia Tech will pursue their concept of chemical vapor deposition through a combustion process to help in meeting these challenges.

Maryland

Ashwami Gupta 301-405-5276

The geometry of the fuel injector and the surrounding combustion system are important elements in achieving the level of premixing required to keep NO_x emissions down. Maryland, with help from Morgan State, will improve their modeling capabilities supported by pertinent experimental data. Specific effects to be examined are thermal stratification and shear layer strains.

MIT

Gerald Guennette 617-253-3764

Much work has been done in the area of heat transfer, but the effect of rotation on cooling air in blade passages has recently been identified as a significant issue. Testing this effect is not an easy task, but MIT has a facility which can simulate conditions in actual blade passages. This program will provide valuable experimental data for enhancing designs for more effective passage heat transfer.

Michigan State

Abraham Engeda 517-336-1834

The heat transfer characteristics of steam for blade cooling are not fully understood, along with the effects of steam on materials which Central Florida will examine. This one year program will provide some base line data comparing steam and air as the coolant, and will evaluate current codes for applicability to the use of steam as the cooling medium.

Minnesota

Richard Goldstein 612-625-5552

Design details of how film cooling holes are arranged on blade surfaces can have a significant effect on the heat transfer. In this project, computational schemes will be developed that take into account hole geometry, turbulence, pressure gradients, and blade curvature. Experimental data will be taken to support the modeling work.

Oklahoma

Ajay Agrawal 405-325-1754

An intercooler located between the low and high pressure compressor sections of advanced aeroderivative engines offers substantial gains in specific output and

thermal efficiency. Flow abnormalities and pressure losses need to be minimized in getting the air from the LP compressor, to the intercooler, and then into the HP compressor. CFD models will be prepared by Oklahoma and calibrated with scale model test results.

Purdue

Sanford Fleeter 317-494-1504

The unsteady flow conditions existing in actual turbine stages are complex, particularly when attempting to develop 3-D models. Purdue has a two stage research turbine which will be very useful in obtaining relevant data on some of these effects that are encountered in real machines. Applicable CFD models will be calibrated with the test results, which will provide flow field and heat transfer data for design use.

Wyoming

Paul Dellenback 307-766-2122

Turbulence may be the principal correlating factor for many gas turbine heat transfer cases, such as internal blade cooling and combustor jet mixing. This program will investigate whether such a correlation is accurate, and if the heat transfer is essentially independent of the geometry.

COMBUSTION WORKSHOP

AGTSR plans for improved industry/university communications were enhanced with the Combustion Workshop in Nashville, February 24-25. Mac Mellor of Vanderbilt was the official host and technical organizer, with SCERDC supplying administrative support. Total attendance was 55, with 14 universities represented. The universities in particular appreciated this early opportunity to review their research plans and obtain immediate feedback from industry.

A significant conclusion from the conference was the identification of combustion stability as a major industry problem and a fertile area for university research participation. AGTSR will translate this need into a top priority item for the 1995 RFP technology objectives.

A copy of the Workshop agenda is included as Attachment III. Participants' presentation material was duplicated by SCERDC and distributed at the Workshop, and has been made available to Performing Members that could not attend.

1993 SUBCONTRACT PROGRESS

The ten universities receiving 1993 research awards have completed their second quarter of work. Definite progress toward project goals can be seen in all cases, as indicated by the following summary of their activities:

Brigham Young (3D Combustion model): Modeling for their laboratory combustor tests has been modified to incorporate the Monte Carlo PDF approach, as their intended mixture fraction technique was inadequate for premixed flames. ACERC combustion codes are being incorporated into CFD codes. An industry survey was conducted to guide BYU with the latest technology and projected use for their combustion models.

California/Berkeley (Porous combustion components): The test rig has been run with sections of non-catalytic porous media. A top flight set of graduate students has been recruited to work on the project. NOTE: California/Berkeley has been late in technical and financial reporting. Efforts will be made to rectify this situation.

Clarkson (Iceformation design technique): Meetings were held with GE engineers to finalize the cascade design and assure that the final structure will be compatible with the GE test facility. Modifications to Clarkson's wind tunnel have been designed and are being fabricated. The iceformation heat exchanger has also been designed.

Lehigh (Functionally gradient materials): The initial work has focused on the review of two candidate fabrication techniques for FGM's: electrodeposition and reaction bonded aluminum oxide. The former is in use to produce metal and ceramic coatings, but has not been applied to FGM's. The RBAO concept is a long shot, but if successful would produce high quality ceramics.

Louisiana State (Vortex generators): The test section design was completed and machining is in progress. Data acquisition methods for the rotating rig are being assessed. Naphthalene sublimation will be used for the mass transfer data. An LSU computer code has been adapted to support the experimental work.

Penn State (Thermal mechanical fatigue): IN738 material samples were procured based on Westinghouse specifications. Sixty specimens will be used, some will be coated and the rest tested as received. Three graduate students have been assigned and are being trained on the equipment to be used.

Purdue (NO_x submodel): Measurements of NO in methane flames have been made to provide model input data. The flame modeling work has begun, based on Technical

modification of the Glarborg-Miller-Kee mechanism and Sandia's premixed flame code. Portions of the overall NOx submodel are being worked on, including the selection of FLUENT as the CFD solver. Selection of the burner type for the testing was completed.

Texas A&M (Blade heat transfer, TBC spallation and roughness effects): The principal effort for this period for the cooling passage heat transfer task was the design of the rotational heat transfer test section and its instrumentation. It will be a two pass duct with electrical heaters and thermocouples, mounted in A&M's existing test rig. For the task on TBC spallation, the experimental technique has been finalized. The third task, a series of cascade tests to determine surface roughness effects, is proceeding with facility mods and model fabrication. Preliminary facility checkouts showed no system problems.

Vanderbilt (NOx and CO submodels): Preliminary designs to be used for the tests to be run at METC have been completed. The Characteristic Time Model (CTM) will be used to design the tests, predict the test results, and then be modified as necessary based on the test results. Subcontractor University of Washington has started work on their role in applying chemical reactor modeling to the prediction of NOx and CO for lean premixed flames.

Virginia Tech (Combustor flow controllers): The two major tasks are proceeding in parallel. The first is the development of piezoelectric materials with high temperature capability and large enough displacements to be of value for a gas turbine application. Synthesizing these materials by the sol-gel process is under consideration. Secondly, for the actual flow tests, an experimental combustor has been designed and fabricated and is undergoing initial testing.

NOTE: The subcontract with Virginia Polytechnic Institute will be modified to include the University of Arkansas as a participant. One of the project PI's, Dr. Larry Roe, has accepted a position at Arkansas and requested that his portion of the work move with him. Since Arkansas is a Performing Member, and this is an opportunity to get them and another graduate student involved in the program, the IRB approved the work transfer and an additional \$52,000 to support the Arkansas graduate student.

MATERIALS PLAN

The Materials/Manufacturing portion of the ATS Technology Support Plan is completing its planning phase, and should be implemented by late summer as FY95 funds become available. The AGTSR has been a participant in the planning process

and is making sure that university materials research is coordinated. Technical thrusts are in line with AGTSR priorities: improved coatings and superalloy processing and characteristics. There are also plans for additional ceramic materials support, perhaps commencing in 1996.

SEMINARS

Another part of AGTSR's communication enhancement strategy is to invite outside speakers to conduct seminars on relevant gas turbine projects. The most recent attempt, however, was thwarted by the East Coast weather. Dr. G. Ol'Khovsky from the All-Russian Heat Engines Institute visited Morgantown, Orlando, and Washington, but could not make it to SCERDC on Friday, February 11, as planned due to a major snow storm in the northeast.

OTHER ACTIVITIES

An ASME paper has been written and approved for presentation at the IGTI Gas Turbine Congress and Exposition at The Hague in June. Co-authors are AGTSR Director, R. P. Allen, and METC Program Manager, P. L. Micheli. The paper is entitled, "The Advanced Gas Turbine Systems Research Program: A Model for Industry, University, and Government Cooperation."

R. P. Allen, manager of the AGTSR program, retired from South Carolina Energy Research and Development Center on March 31, 1994. Recruitment of his successor is proceeding, with applicant screening currently in progress. Program Principal Investigator, L. P. Golan, will be administering the program until Mr. Allen's replacement reports for work.

ATTACHMENT I

AGTSR
Performing Member List
March 31, 1994

<u>University</u>	<u>State</u>
University of Alabama, Huntsville	Alabama
University of Arkansas	Arkansas
Auburn University	Alabama
Brigham Young University	Utah
University of California, Berkeley	California
University of California, Davis	California
University of California, Irvine	California
Carnegie Mellon University	Pennsylvania
University of Central Florida	Orlando
University of Cincinnati	Ohio
Clarkson University	New York
Clemson University	South Carolina
Cleveland State University	Ohio
Cornell University	New York
University of Dayton	Ohio
University of Delaware	Delaware
University of Denver	Colorado
Drexel University	Pennsylvania
Duke University	North Carolina
Florida Atlantic University	Florida
Florida Institute of Technology	Florida
Georgia Institute of Technology	Georgia
University of Hawaii, Manoa	Hawaii
University of Houston	Texas
Iowa State University	Iowa
University of Iowa	Iowa

<u>University</u>	<u>State</u>
University of Kansas	Kansas
Lehigh University	Pennsylvania
Louisiana State University	Louisiana
University of Maryland, College Park	Maryland
Massachusetts Institute of Technology	Massachusetts
Mercer University	Georgia
Michigan State University	Michigan
Michigan Technological University	Michigan
University of Michigan	Michigan
University of Minnesota	Minnesota
University of Missouri-Rolla	Missouri
North Carolina State University	North Carolina
University of Notre Dame	Indiana
University of Oklahoma	Oklahoma
Pennsylvania State University	Pennsylvania
University of Pittsburgh	Pennsylvania
Princeton University	New Jersey
Purdue University	Indiana
University of South Carolina	South Carolina
Southern University	Louisiana
University of South Florida	Florida
Syracuse University	New York
University of Tennessee, Space Institute	Tennessee
Tennessee Technological University	Tennessee
Texas A&M	Texas
University of Texas, Arlington	Texas
University of Utah	Utah
Vanderbilt University	Tennessee
Virginia Polytechnic Institute	Virginia
Washington University	Missouri
University of Washington	Washington
West Virginia University	West Virginia
University of Wisconsin-Madison	Wisconsin
University of Wisconsin-Milwaukee	Wisconsin
Worcester Polytechnic Institute	Massachusetts
University of Wyoming	Wyoming
Yale University	Connecticut

ATTACHMENT II

ADVANCED GAS TURBINE SYSTEMS RESEARCH PROGRAM

RESULTS OF EVALUATION OF RFP 94-01 PROPOSALS

AND

RECOMMENDATIONS FOR AWARDS

R. P. ALLEN

MARCH 2, 1994

RFP 94-01 AWARD RECOMMENDATION SUMMARY

No. of Awards	13
Total \$ value	\$5.37 million
Cost sharing offered	\$0.45
EE Funding of HBCU	\$0.11
Net cost to AGTSR	<u>\$4.81</u>
Average length of project	2.2 years
No. of states represented	13
No. of proposals received	44
% of proposals awarded	30%
Faculty/student involvement (For awards)	31 faculty 30 grad students 9 undergrads 2 Post Docs
Total	<u>72</u>

Technology areas	Submitted	Awarded	% Award	\$
Heat transfer	19	6	45	
Aero/performance	9	2	20	
Materials	7	2	10	
Combustion	6	3	25	
Dynamics	3	0	0	
No. of scope changes requested	4			
Total cost reduction		\$0.43 million		
Total funding requested-44 props		\$20 million		

RP Allen 2-28-94

SUMMARY OF RECOMMENDED AWARDS FOR RFP 94-01
Advanced Gas Turbine Systems Research Program

University	Research Area	PI	Term Yrs	<u>Costs (\$000)</u>			Fac	<u>Personnel Involvement</u>			Notes
				AGTSR	Shared	Total		Grads	Ugd	P. Doc	
MIT	Rotational HT	Guenette	1	156		156	2	1			
Cornell	PDF for Methane Combustion	Pope	2	166		166	1			1	
Purdue	Multistage turbine aerodynamics	Fleeter	3	690		630	2	2			Allison Sub
Cal/Irvine	Premix Combustion	Samuelsen	3	501	93	594	3	2			
Minnesota	Optimum Film Cooling	Goldstein	3	661	206	867	5	4		1	
Central FL	Compatibility of steam	Desai	1	70			1	2			
Carnegie	Optical Flux Sensor	Chyu	3	527		527	2	2			
Clemson	Film cooling design aids	Leylek	3	601		601	2	6	2		
Wyoming	Turbulence effects on HT	Dellenback	1	69		69	2	1	2		
Michigan St.	Steam cooled blade	Engeda	1	182	67	249	2	2			
GA Tech	Combustion CVD of TBC's	Carter	3	432	33	465	2	3			GE Sub
Maryland	Premixing enhancement	Gupta	3	573		573	5	3	3		HBCU Sub (Morgan St)
Oklahoma	Intercooler flows	Agrawal	2	292	50	342	2	2	2		
Totals				4920	449	5369	31	30	9	2	

TECHNICAL SUMMARY - AWARD RECOMMENDATIONS FOR RFP94-01
(Presented in alphabetical order)

California/Irvine

"The Role of Mixedness and Length Scale on Performance and Emissions in GTE Can Combustor"

The effectiveness of mixing the fuel and air in lean premixed combustion is the key to obtaining low emissions. Understanding the premixing mechanisms and the role of turbulence is the thrust of this project, augmented by tests conducted at atmospheric and elevated pressures.

Carnegie Mellon

"Development and Application of Novel Optical Temperature and Heat Flux Sensor for Advanced Blade Cooling and Engine Thermal Diagnostics"

Obtaining higher turbine inlet temperatures while maintaining present metal temperatures requires better cooling techniques. A sensor that can provide heat flux data at the temperature levels of interest would be very beneficial in assessing these techniques. CMU plans to pursue development of such a device, which is based on thermographic phosphor fluorescence.

Central Florida

"Compatibility of Superalloys with Steam Cooling"

Substitution of steam for air extracted from the compressor for turbine cooling may be an attractive alternative for cycle efficiency enhancement. However, little is known about how steam may affect the materials used in the turbine hot section. This program will look at how steam, and some of its potential contaminants, might attack the nickel and cobalt based materials currently in use.

Clemson

"Advanced Design Methodology Using Combined Computational and Experimental Techniques for Gas Turbine Film Cooling"

Film cooling of vanes and blades is expected to remain a critical heat transfer technology for the advanced turbines. Better design tools are key to minimizing the use of extracted compressor air, and also to reducing the design cycle time. Clemson's work will couple CFD analyses with wind tunnel testing to produce a useful "desktop" computation method.

Cornell

"Manifold Methods for Methane Combustion"

The PDF (Probability Density Function) concept is one of the most widely accepted bases for combustion modeling. Its expansion into the use of methane as the fuel is relevant as natural gas is the fuel of choice for the ATS program. Objectives are to predict CO and NOx accurately, with a model that minimizes computation time.

Georgia Tech

"Combustion Chemical Vapor Deposition of Thermal Barrier Coatings"

Thermal Barrier Coatings (TBC's) are necessary to maintain the life of present superalloys at the elevated turbine inlet temperatures needed to meet the ATS efficiency goals. Developing appropriate coating compositions and applying them at reasonable cost are two of the challenges. Georgia Tech will pursue their concept of chemical vapor deposition through a combustion process to help in meeting these challenges.

Maryland

"Advanced Concepts for High Efficiency and Low NOx Gas Turbine Combustor Development"

The geometry of the fuel injector and the surrounding combustion system are important elements in achieving the level of premixing required to keep NOx emissions down. Maryland, with help from Morgan State, will improve their modeling capabilities supported by pertinent experimental data. Specific effects to be examined are thermal stratification and shear layer strains.

MIT

"Effects of Rotation on Internal Heat Transfer in Turbine Blades"

Much work has been done in the area of heat transfer, but the effect of rotation on cooling air in blade passages has recently been identified as a significant issue. Testing this effect is not an easy task, but MIT has a facility which can simulate conditions in actual blade passages. This program will provide valuable experimental data for enhancing designs for more effective passage heat transfer.

Michigan State

"Steam Cooled Gas Turbine Blade"

The heat transfer characteristics of steam for blade cooling

are not fully understood, along with the effects of steam on materials which Central Florida will examine. This one year program will provide some base line data comparing steam and air as the coolant, and will evaluate current codes for applicability to the use of steam as the cooling medium.

Minnesota

"Experimental and Computational Studies of Film Cooling with Compound Angle Injection"

Design details of how film cooling holes are arranged on blade surfaces can have a significant effect on the heat transfer. In this project computational schemes will be developed that take into account hole geometry, turbulence, pressure gradients, and blade curvature. Experimental data will be taken to support the modeling work.

Oklahoma

"Improving Aerodynamics of the Intercooler Flow Path for Development of High Efficiency Gas Turbines"

An intercooler located between the low and high pressure compressor sections of advanced aeroderivative engines offers substantial gains in specific output and thermal efficiency. Flow abnormalities and pressure losses need to be minimized in getting the air from the LP compressor, to the intercooler, and then into the HP compressor. CFD models will be prepared by Oklahoma and calibrated with scale model test results.

Purdue

"Advanced Multistage Turbine Blade Aerodynamic, Performance, Cooling and Heat Transfer"

The unsteady flow conditions existing in actual turbine stages are complex, particularly when attempting to develop 3-D models. Purdue has a two stage research turbine which will be very useful in obtaining relevant data on some of these effects that are encountered in real machines. Applicable CFD models will be calibrated with the test results, which will provide flow field and heat transfer data for design use.

Wyoming

"Impact of Turbulence on Heat Transfer in Internal Flows"

Turbulence may be the principal correlating factor for many gas turbine heat transfer cases, such as internal blade cooling and combustor jet mixing. This program will investigate whether such a correlation is accurate, and if the heat transfer is essentially independent of the geometry.

AGTSR RFP 94-01 SYNOPSIS

Technical Area - Heat Transfer
and Cooling

<u>PROP. NO.</u>	<u>Proposal Submitted By</u>	<u>RFP Priority</u>	<u>Specific Objective</u>	<u>No. Years</u>	<u>\$K Total Requested</u>	<u>\$K First Year</u>
H-1	Michigan	1	Liquid cooled blades	3	761.8	261.8
H-2	Duke		Fin optimization in cooling passages	3	395.2	132.8
H-3	Florida Tech		Film cooling of stationary parts	3	622.0	211.7
H-4	MIT		Rotational effect on heat transfer	1	156.5	156.5
H-5	Arkansas		Enhanced convective cooling	3	450.5	164.5
H-6	Utah		Allison turbine blade tests	3	340.9	146.9
H-7	Minnesota		Optimum film cooling schemes	3	661.1	219.2
H-8	Michigan State		Steam cooled blade	1	181.9	181.9
H-9	Wyoming		Turbulence effects on internal flows	1	69.3	69.3
H-10	Carnegie Mellon		3-D Heat transfer model for blades	3	414.4	132.0
H-11	UTSI		Periodic fluidic controllers	1.5	235.9	157.0
H-12	California/Davis		Transpiration cooled blade	3	560.8	170.0
H-13	Carnegie Mellon		Optical Temperature/Heat Flux Sensor	3	527.2	175.4
H-14	Wisconsin/Milwaukee		Rotating disk cooling	3	330.8	109.4
H-15	Cleveland State		Blade/Tip Seal heat transfer	2	337.0	170.3
H-16	Oklahoma		Fluorcarbon coolants	1.5	84.3	56.0
H-17	Texas A&M		Turbine blade cooling	3	610.5	196.2
H-18	Clemson		Alternate cooling media	3	720.9	229.3
H-19	Clemson		Design methods for film cooling	3	703.8	232.4

Technical Area - Aero and Performance

81

Technical Area - Materials

19

AGTSR RFP 94-01 SYNOPSIS

[illegible]

AGTSR RFP 94-01 SYNOPSIS

[illegible]

ATTACHMENT III

AGENDA

AGTSR Industry/University Combustion Technology Workshop February 23-25, 1994, Nashville, TN

Wednesday, February 23

6:00-8:00 p.m. Registration and Welcome Reception

Thursday, February 24

7:30 a.m. Late registration

8:10 a.m. Welcome
George E. Cook, Director of Industrial Liaison and Technology
Development, Vanderbilt University School of Engineering

8:20 a.m. Introduction
Roy Allen, Director of Advanced Gas Turbine Systems Research, South
Carolina Energy Research and Development Center, Clemson University

Morning Session Chairmen and Discussion Leaders, R. J. Antos, Westinghouse Electric Corporation, and K. O. Smith, Solar Turbines, Incorporated

8:30 a.m. "Liquid Fuel/Air Mixing and Combustor NO_x Emissions," T. S. Snyder,
United Technologies Research Center

9:00 a.m. "Development of a Fuel/Air Premixer for Aeroderivative Dry, Low
Emissions Combustors," N. D. Joshi, General Electric Aircraft Engines

9:30 a.m. Coffee Break

9:45 a.m. "Monte Carlo Models for Turbulent Combustion," S. J. Correa, General
Electric Corporate Research and Development

10:15 a.m. "Application of Hybrid Analytical/Semianalytical Combustor Performance
Model to Gas Turbine Combustors," N. K. Rizk, Allison Engine Company

10:45 a.m. "Application of CFD to Current, Low Emissions Gas Turbine Combustor
Designs," D. L. Burrus, General Electric Aircraft Engines

11:15 a.m. Discussion

11:45 a.m. Luncheon

Afternoon Session Chairmen and Discussion Leaders, S. J. Correa, General Electric Corporate Research and Development, and N. K. Rizk, Allison Engine Company

- 1:15 p.m.** "Design and Analysis of Advanced Gas Turbine Combustors Using CFD," M. Sharifi, Westinghouse Electric Corporation
- 1:45 p.m.** "Overview of Gas Turbine Combustor Modeling: Status and Needs," B. S. Brewster, Brigham Young University
- 2:15 p.m.** "Discrete Probability Function (DPF) Method for the Treatment of Turbulence and NO Chemistry Interactions," J. P. Gore, Purdue University
- 2:45 p.m.** Coffee Break
- 3:00 p.m.** "Advanced Model for Gas Turbine Combustors," B. S. Brewster, Brigham Young University
- 3:30 p.m.** "Combustor Design and Modeling Efforts for NO_x Reduction in Advanced Gas Turbines," P. E. Sojka, Purdue University
- 4:00 p.m.** "Temperature Measurements in a Turbulent, Swirling Premixed Flame," P. O. Hedman, Brigham Young University
- 4:30 p.m.** "NO_x/CO Trade-Off at Low Equivalence Ratio," R. W. Dibble, University of California, Berkeley
- 5:00 p.m.** Discussion
- 5:30 p.m.** Adjourn

Friday, February 25

Session Chairmen and Discussion Leaders, W. J. Dodds, General Electric Aircraft Engines, and T. J. Rosfjord, United Technologies Research Center

- 8:00 a.m.** "Measurements of Turbulent Premixed Methane Flames by Raman Scattering and Fluorescence: Plans and Progress," R. W. Pitz, Vanderbilt University
- 8:30 a.m.** "Flow Fluid Structure Control and Materials Development for Combustion Control," U. Vandsburger, Virginia Polytechnic Institute and State University
- 9:00 a.m.** "METC Syngas Generator," M. J. Monahan, Morgantown Energy Technology Center
- 9:30 a.m.** Coffee Break

- 9:45 a.m.** "NO_x Kinetics and Mechanism for Lean Premixed Combustion: Part I - One Atmosphere Experimental Results," R. C. Steele, University of Washington
- 10:15 a.m.** "LIF Measurements of NO in High-Pressure Flames," M. Klassen, Purdue University
- 10:45 a.m.** "NO_x Kinetics and Mechanism for Lean Premixed Combustion: Part II - Engineering Modeling Considerations," D. G. Nicol, University of Washington
- 11:15 a.m.** "METC Combustion Facility," D. J. Maloney, Morgantown Energy Technology Center
- 11:45 a.m.** Luncheon
- 1:15 p.m.** "Gas Sampling and Analysis Capabilities at METC," T. S. Norton, Morgantown Energy Technology Center
- 1:45 p.m.** "LP NO_x Tests Using METC Combustor Rig Facility," R. J. Roby, Hughes Associates, Inc.
- 2:15 p.m.** "LP NO_x Characteristic Time Model Validation Tests at METC," J. P. McDonald, Vanderbilt University
- 2:45 p.m.** Discussion
- 3:30 p.m.** Adjourn

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