Advanced Gas Turbine Systems Research

**Quarterly Report
October - December 1995**

January 1996

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
Clemson University
Clemson, South Carolina

MASTER

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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

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January 1996

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

October 1, 1995 - December 31, 1995

SUMMARY

Major Accomplishments and Reports issued by AGTSR during this reporting period:

- Prepared and presented the AGTSR program review paper at the ATS Annual Review meeting, October 18, 1995
- Conducted poster session for 31 research projects and chaired and organized university-industry panel for ATS Annual Review
- Compiled poster research viewgraphs to be distributed to ATS participants
- Prepared AGTSR's fourth RFP for release and coordinated research issues with DOE-METC, DOE Oak-Ridge Labs, and the IRB
- 1996 AGTSR Contract Renewal for \$4.3M prepared and submitted to METC
- Received and distributed final reports from Wyoming and Central Florida
- Co-organized and participated in AGTSR's first technical retreat on combustion instability at Penn State University, September 12, 1995
- Co-organized ATS Materials Workshop with DOE-HQ and DOE Oak-Ridge, and Energetics
- Began coordination of AGTSR's third combustion workshop to be hosted with UC-Irvine
- Began coordination of an ATS Sensors & Controls specialty meeting at Clemson University, to be hosted with DOE-HQ and DOE Oak-Ridge
- 1993 second annual progress reports distributed to IRB and METC
- Completed interest survey for 31 AGTSR research projects and distributed results to METC's ATS product team
- Generated research subarea "points-of-contact" within IRB and distributed results to METC and AGTSR PI's
- Conducted high-risk property survey for 31 AGTSR research projects
- Distributed progress report "guidelines" information to 1993, 1994, and 1995 AGTSR PI's

- Reviewed several IGTI technical papers for METC and IRB
- Prepared paper and presentation on AGTSR's Internship Program for the FIE'95 conference, November 1995
- Facilitated new publications review policy with DOE-METC and Clemson University (CURF)
- Hosted seminar visitor at SCERDC from Iowa State University to discuss potential international gas turbine R&D activities
- Coordinated AGTSR internship start-up with EPRI via the CAGT program
- Updated METC's ATS Technology Matrix for 9 new AGTSR projects
- Three new universities expressed interest in joining the AGTSR consortium
- Received constructive feedback from IRB on AGTSR combustion instability research and distributed results to AGTSR PI's for consideration
- Initiated AGTSR research survey on interactions with IRB R&D experts
- Received two additional AGTSR endorsement letters from Penn State and Lehigh University, distributed to local congressmen in Pennsylvania
- Coordinated 5 AGTSR research pictures for METC's ATS brochure

The ATS Annual Review was held at DOE-METC, October 17-19, 1995. AGTSR had a substantial role during the review: An AGTSR Program Update paper was presented and an AGTSR industry-university panel was assembled to discuss the effectiveness of the consortium. The panel consisted of two members from industry (Ihor Diakunchak from Westinghouse and Sy Ali of Allison), and two members from universities (Maurice Gell from the University of Connecticut and Vimal Desai of Central Florida). All panelists had positive comments on AGTSR's mission: to support industry-driven collaborative R&D, nurture industrial internships, and organize ATS technology-specific workshops. To improve AGTSR, they recommended closer relations with industry R&D staff as opposed to just interacting with the main focal point from each company -- this should improve the relevance and value of the AGTSR research and instill more of a "sense of ownership" for industry in the AGTSR research projects. As a result of this recommendation, AGTSR has identified subarea R&D points-of-contact within the various discipline areas and is now coordinating progress reports and research issues with them directly as well as the IRB main focal points. The poster session at the ATS Review meeting was well received. This year 30 posters were displayed and reviewed openly by the IRB, DOE, and other universities. One poster was not displayed this year because of potential patent rights protection. The poster session generated a lot of interest and several people from industry and universities requested hardcopies of the poster viewgraphs. A compilation of these

viewgraphs has now been assembled and will be released by the end of January, 1996.

AGTSR has finished the coordination of research topics for the fourth AGTSR RFP solicitation. Research issues were coordinated with the IRB, DOE-METC, and DOE Oak-Ridge. Subthrust topics in CFD-Aerodynamics, Materials, and Combustion were highlighted. This year the RFP topics will not be prioritized. The number of proposals recommended for support will depend on the quality of proposals submitted in a certain area and the availability of funds for new starts in fiscal year 1996. It is anticipated that six new awards may be made. The RFP should be released on January 22, 1996 with proposals due March 27, 1996.

AGTSR's FY96 renewal extension for \$4.3M was submitted to Mr. Thomas Martin on October 30, 1995. The extension included the requested budget on the Standard Form 424, Financial Status of 31 AGTSR Subcontracts, IRB Membership Fees, list of AGTSR Performing Members, Accomplishments in FY95, and an outline of the Goals for FY96. The COR, Norm Holcombe, informed us that the package is complete and is awaiting funding as soon as budget appropriations are approved by Congress.

AGTSR has been actively engaged in the planning and organization of several workshops and specialty meetings. The final announcement has been released for the first ATS Materials Workshop, February 13-14, 1996, in Charleston, SC. This Workshop will highlight three main research areas in materials: casting and alloy development, ceramics and ceramic matrix composites, and thermal barrier coatings. AGTSR has started organizing the third Combustion Workshop, hosted with UC-Irvine, March 19-21, 1996, Lake Arrowhead, CA. The first announcement for this Workshop was released in December, 1995. AGTSR also held their first specialty meeting on combustion instability at Penn State University, September 11-12, 1996. This meeting was productive in improving interactions between the AGTSR PI's doing combustion research and the industry experts. Experimental data and computational exchanges have been initiated because of this meeting. AGTSR has just begun planning another specialty meeting in the sensors and controls area. This meeting will be at Clemson University on April 17, 1996 and will be hosted with DOE Oak-Ridge through coordination from DOE-HQ.

In 1993, 1994, and 1995, AGTSR received cost-sharing contributions of \$25,000 from each of the IRB members. The IRB consists of six U.S. turbine engine manufacturers, with EPRI and GRI continuing to act as utility and industrial gas turbine advisors for AGTSR. Invoices for 1996 were mailed out in early January, 1996 to the six IRB companies. Payment is due on March 31, 1996.

Ohio State University and the University of California - San Diego joined the AGTSR program during this reporting period. Currently, 81 universities are members of AGTSR. Northwestern and Wright State University recently expressed interest in joining the program.

Membership

During this reporting period, Ohio State University and the University of California - San Diego were added as AGTSR Performing Members. AGTSR membership is now at 81 schools, representing 36 states. Northwestern and Wright State University have recently expressed interest in joining the program.

Parker Hannifin attended our recent combustion instability meeting at Penn State, September 11-12, 1996 and have expressed continued interest in joining AGTSR, possibly in FY96. I will follow up with them after the RFP is released in January, 1996 since it includes a topic on dual-fuel issues which they are quite interested in. Parker has also expressed interest in teaming with UC-Irvine to piggyback their AGTSR research and conduct some experiments related to lean premixed fuel nozzles.

Last quarter, IRB invitations were sent to Howmet and PCC (two material coating companies). PCC has now declined and Howmet has not yet responded. I will follow-up with Howmet at the Materials Workshop in February, 1996.

I will also follow up with Dresser Rand, POC is Miles Bintz. Miles has not yet declined membership and told me last year that FY96 may be a better year -- perhaps they could participate in the AGTSR Internship Program as an affiliate or associate member. BFGoodrich, POC is Gary Worth, have not yet responded for FY96 -- they are interested in leveraging additional research in low emission combustion.

1993-1994-1995 Subcontract Progress

AGTSR has now completed all the follow-on year amendment packages for the 1993 and 1994 subcontracts. The nine new projects approved in FY95 have all been started, with start-dates of either August 1 or September 1, 1995. The second annual progress reports for the 1993 subcontracts have been received and were distributed to METC and the IRB points-of-contact in December, 1995. The 1994 semi-annual progress reports are due on January 31, 1996, and the first semi-annual reports for the 1995 projects are due on March 31, 1996. Final reports were received from Central Florida, Michigan State, and Wyoming. MIT's final report was due last month and is expected to be submitted shortly. Recall that Central Florida, MIT, and Michigan State will continue under new subcontracts, as recommended by the IRB. For all the AGTSR PI's, progress report "guidelines" were distributed to better standardize the format of full reports and executive summaries. A new AGTSR

publications review policy was worked between Clemson and DOE/METC. This new policy will go into effect as soon as the AGTSR FY96 budget gets approved. At that time, all 31 AGTSR research subcontracts will be amended to reflect this new policy change.

The AGTSR Research Interest Survey with the IRB has now been completed and with the exception of Allison, the results have been consolidated and reported to METC. AGTSR also generated a list of IRB R&D experts, over 40 individuals, to improve the relations and collaboration with AGTSR university research. This list was also distributed to METC to improve communication between the METC ATS Product Team and the IRB.

AGTSR's Third Combustion Workshop

The third AGTSR Combustion Workshop will be hosted by UC-Irvine and will take place in Lake Arrowhead, CA, March 19-22, 1996. A Gordon-style format will be used, which consists of morning topical sessions, and afternoon poster-interactions period, and an evening industry-government-university feedback session. There will be four morning sessions: Engineering Models for Lean Premixed Combustion, Premixer-Swirl Experiments and Advanced Diagnostics, Catalytic Combustion, and Combustion Instability. Both industry and university posters will be presented. NASA-Lewis will also present their Wave Rotor RD&D program so that AGTSR and METC can evaluate the potential of this concept for land-based application. David White of Solar Turbines will give the keynote dinner address and plans to discuss Solar's Phase 3 ATS program and other future programs such as catalytic combustion and the gas turbine/fuel cells coupled program. This Workshop represents a turning point in the program as several combustion projects will be ending next summer and critical industry reviews are being sought to determine which combustion programs may be recommended for continuation. Registration material for the third AGTSR Combustion Workshop will be distributed by the end of January, 1996.

AGTSR's First Combustion Specialty Meeting

AGTSR hosted their first specialty technical retreat on combustion instability with Penn State University, September 11-12, 1995. This first such retreat was motivated by the need to bring university and industry researchers closer together in certain subthrust topics of a technical discipline -- in this case, combustion instabilities in lean, premixed systems. As an action item, the IRB combustion R&D experts agreed to review in detail the AGTSR combustion instability proposals and report back their comments on the university's technical scope and direction. These

comments were received last month and have been distributed to the respective PI's for rebuttal and comment. In addition, Dr. Mongia and Dr. Pandalai of GE-Aircraft have agreed to run their first-order wave equation numerical model for each of the geometries associated with the AGTSR-supported combustion projects. Their model will estimate the longitudinal instability mode for the AGTSR experiments being conducted. Furthermore, Geo Richards of METC will be sending GE their combustion instability data and geometry specifications so that calculations may be done for METC's in-house combustion research. Jeff Lovett of GE-CRD has also received his management's permission to distribute realistic combustion instability data to Vigor Yang of Penn State to test his numerical models. Vigor's combustion project is supported by AGTSR and got started in September, 1995.

ATS Materials Workshop

The first ATS Materials Workshop is scheduled for February 12-14, 1996 in Charleston, SC. This workshop will be co-hosted with DOE Headquarters, DOE-Oak Ridge and Energetics. Registration material and the final announcement for this Workshop was released last month by Energetics. The Workshop will cover ATS industry and university research in Casting and Alloy Development, Ceramics and Ceramic Matrix Composites, and Coatings. The Workshop will also include a programmatic overview of the ATS Materials/Manufacturing Element and the AGTSR program. A Plenary Session will be held consisting of key talks from Pete Schilke of GE, Bill Brentnall of Solar Turbines, and John Stringer from EPRI. Pete will present a "utility" perspective on materials research, Bill will discuss industrial size engines with an emphasis on ceramics, and John will provide a gas turbine users perspective. SCERDC provided the plenary presenters with suggested guidelines for their talks focusing on three main points: 1.) How do advanced materials and coatings contribute to your company's goals for ATS, 2.) Describe your company's development and applications experience with directionally solidified and single crystal turbine blades and vanes, structural ceramics and thermal barrier coatings, and cost benefits associated with these advanced technologies, and 3.) Provide suggestions as to how ATS goals can be satisfied or surpassed with further industry/university research collaboration. The Workshop will close with a Panel Session to discuss future ATS materials issues for industry and universities.

AGTSR Completes Industrial Internship Report

A brief summary report pertaining to AGTSR's Industrial Internship Program was written and distributed to METC and the IRB. Based on positive responses from industry, professors, and students, AGTSR plans to double the program for the Summer of 1996. AGTSR will place two, top-rate graduate students at each of the IRB sponsoring companies and will extend the internship program from 8-weeks to 10-weeks. Intern salary will remain at \$450 per week and a one-time relocation expense amount for \$1000 will be provided to each intern. AGTSR is in the process of developing a more professional internship application packet that is expected to be released by the end of January 1996. EPRI has also indicated to us that they are interested in the internship program and on a trial-basis would like to have one intern for next summer. The points-of-contact at EPRI are George Hay and Clark Dohner. Clark is currently the CAGT project manager. A few AGTSR PI's have recommended that a similar industrial program be set-up for faculty members, but for a longer duration such as a half-to-full year sabbatical. The AGTSR Internship Program was presented and discussed in Atlanta, Georgia at the Frontiers In Education (FIE 1995) Conference, November, 1995. As both Dan Fant and Larry Golan had conflicts that day, the Associate Dean for Research at Clemson, Dr. Christian Przirembel, gave the presentation in Atlanta since he had planned to attend the meeting as part of another session.

Three Research Topics Highlighted for AGTSR's FY96 RFP

As coordinated with the IRB, DOE-METC, and DOE Oak-Ridge, the following three research topics will be included in AGTSR's FY96 RFP: *CFD for 3-D Turbomachinery Design and Aero-Optimization, Advanced Thermal Barrier Coatings and Single Crystal Alloys, and Combustion Issues*. The combustion subthrusters include the effects of fuel composition and contaminants on lean premixed low NOx combustion, new sensors to reliably measure the temperature in the primary combustion zone, and dual-fuel, low emissions issues. The RFP is expected to be released by the end of January, 1996 with proposals due near the end of March, 1996. DOE-METC has recommended that the FY96 RFP process continue under current budget uncertainty with the notice that SCERDC "reserves the right to cancel the RFP at any time and not fund any proposals submitted under this request." The majority of the IRB (5 of 6) have agreed to continue with the RFP under these conditions.

SCERDC-METC Prepare Compilation of Research Posters

AGTSR is preparing a Poster Booklet which represents a volume of AGTSR university research poster charts that were displayed as part of the ATS Annual Review at METC on October 18, 1995. These charts will provide ATS participants with an up-to-date summary of the results achieved and key issues being pursued for the various research projects underway in the AGTSR program. For potential patent reasons, two projects were omitted from the volume. The AGTSR projects cover some of the major technical R&D concerns in combustion, heat transfer, aerodynamics, and materials. AGTSR has and will continue to be active in these areas, in direct support of the advanced development of land-based gas turbine engines. This Poster Booklet should also serve as a vehicle to encourage further collaboration between the ATS Industrial Members and the AGTSR University Participants. The POC at METC is Ms. Donna Kullman.

Invited Seminar on International Research and Educational Activities

Dr. James Vary of Iowa State University gave a seminar at SCERDC on December 14, 1995. The topic of the seminar was Iowa State's International Institute on Theoretical and Applied Physics. AGTSR has interest in expanding internationally and felt it would be of value to hear Dr. Vary's views on their newly started Institute: its mission, goals, and research and education activities. The meeting was attended by several of Clemson's heads who seemed quite interested and receptive to Dr. Vary's talk and collaborative ideas. AGTSR is interested in following up with Dr. Vary on Iowa State's industry partnership with United Technologies-P&W in the international gas turbine R&D area. Supposedly, they will be discussing a renewal program with P&W near the end of January, 1996. AGTSR sees a potential three-way partnership in the making, with Iowa State, Clemson-AGTSR, and the Gas Turbine Industry.

Overall, by striving to promote collaborative R&D and working more closely with the IRB R&D staff, the AGTSR industry-university relations have grown stronger, which in turn will enhance the value and relevance of the AGTSR research activities.

Considering AGTSR's plans for continued research, educational internship and fellowship programs, and workshops, we have a lot to be excited about and look forward to in 1996. Here's to a great year and I thank you for all the support during 1995!