AC 2007-1528: A COLLABORATIVE UNIVERSITY-COLLEGE-INDUSTRY-GOVERNMENT TECHNOLOGY TRANSFER PROJECT

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Engineering Education Thorough a Collaborative Technology Transfer Project

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Abstract

Western Carolina University, Asheville-Buncombe Technical Community College (ABTCC), and Sci-Cool, Incorporated contributed resources and support for the design, fabrication, and testing of a new Water Heating and Dehumidifying (WHD) appliance. The project goal was to develop a viable energy saving product by carrying out a collaborative technology transfer initiative through Oak Ridge National Laboratory (ORNL). This creative and applied engineering project provided each institution with the opportunity to integrate applications of theoretical concepts into course and laboratory exercises and direct engineering applications. Additionally, the purchase of new equipment, tooling and software allowed for the enhancement of engineering and technology laboratories at each educational institution. Faculty and graduate students gained technical knowledge of current products and processes in subjects that may have otherwise remained uncultivated. In turn, this new knowledge and experience provd to be valuable in the development of engineering technology curriculum and future engagement projects.

The project helped to build stronger ties with industry, better community relations, and stronger relationships with government agencies. Both educational institutions look forward to future engagement projects so that they may continue to serve the local community, students and industry. Partnerships among government agencies (ORNL), regional industry and regional educational institutions offer an excellent opportunity for advancing professional development, enhancing student learning and promoting economic development. The foundation for potential economic development in western North Carolina has been demonstrated through collaboration with Sci-Cool, Incorporated and coordinated by ORNL.

This paper provides a general description of the project relative to technology transfer and further explains the mutual benefits of collaborative efforts. Emphasi iss placed on educational merit and opportunities for advancing graduate education through applied engineering experiences.

Introduction and Background

Western Carolina University is committed to supporting economic development through engagement and partnerships within its region. The university established a campus-wide mandate for engagement with regional business and industry and has provided support to schools and departments active in the commitment to foster the implementation of new and emerging technology. Engagement activities focus on sustaining economic development and boosting entrepreneurial startups through innovative and creative projects that develop both intellectual capital and technology transfer.[1,2]

The Kimmel School of Construction Management, Engineering and Technology has demonstrated leadership in applied research within the university community and has taken an active role in economic development opportunities. The school was approached on December 1, 2003 by the Education and Research Consortium to discuss the opportunity of working with a manufacturing company in western North Carolina. The collaboration was to assist in prototyping and field testing of water-heating dehumidifier (HWD) combination units. The opportunity for faculty members to collaborate with a regional manufacturing company to enhance economic development was of interest to the university. Teaming with Asheville-Buncombe Technical Community College and a manufacturing company selected by Oak Ridge National Laboratory, provided a unique opportunity for all three organizations. A collaborative effort to develop energy efficient technologies for reducing electrical consumption is important and the potential to create manufacturing jobs in western North Carolina was of even greater importance for all parties involved.

The Department of Energy's Office of Energy Efficiency and Renewable Energy states that its mission is "To strengthen America's energy security, environmental quality, and economic vitality in public-private partnerships that:

- Enhance energy efficiency and productivity;
- Bring clean, reliable and affordable energy technologies to the marketplace;
- Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life." [3]

The Office of Energy Efficiency and Renewable Energy's Building Technologies Program assumes the responsibility for developing and researching new technologies directed at increasing the energy efficiency of buildings, appliances and equipment. The Building Technologies Division also disseminates information to key decision makers who are able to influence construction, manufacturing and purchasing decisions.[4]

Phase I of the proposed project included the development of two viable prototypes and demonstrated energy conservation through improved use of efficient technology. The project met the mission and goals of the Building Technologies Division. Phase II included the design refinement and field testing for a marketable product. Demonstrating significant potential for reducing energy costs, and increasing employment in western North Carolina is of particular concern in light of the significant number of displaced workers in the region.[5,6]

Based on previous work of engineers, scientists, and technologists at Oak Ridge National Laboratory, 18 percent of residential energy utilization is consumed by water heating.[7] Laboratory results have shown the efficiency ratings of test units to be approximately 90 percent of the maximum achievable operating efficiency.[8] Research conducted throughout the WHD project suggests that substantial improvement can be made by implementing a heat pump type unit with dehumidification for supplementing a standard electric water heater. The WHD field tests have demonstrated that the overall energy costs of heating water can be reduced by 30 to 50 percent.[7] This project addressed the monitoring, development, and testing needed to prototype a marketable product with the added feature of dehumidification. Thus, the project focused on developing a hybrid electric and Water Heater and Dehumidifier (WHD) product. Two viable prototypes demonstrating proof of concept were delivered in Phase I, and field testing of 8 units in households was carried out during Phase II.

Project Partners: Responsibilities and Strengths

Partnerships are only as effective as the strengths of participating organizations, and it is imperative that goals and responsibilities are understood and clearly defined for a project to be successful. The overall goals of the project defined, identified and a concerted effort was made to identify required contributions from each organization. The following section outlines the responsibilities and strengths of each of the project teams.

Oak Ridge National Laboratory

Strengths provided by Oak Ridge National Laboratory for this project included prior heat pump water heater research, engineering support, and product testing capabilities. Through previously funded projects and collaborative work between Oak Ridge National Laboratory, California Energy Commission, and Enviromaster International Corporation, a marketable heat pump water heater was developed.[8] However, sustained growth in sales for this product was not recognized due to high cost for the consumer. Resources in the form of engineering support, federal testing procedures, prior testing results and a laboratory heat pump water heater prototype were provided by Oak Ridge National Laboratory. A marketing analysis was also concurrently conducted through a separate partnership between the national laboratory and Clemson University, and results were made available. Oak Ridge National Laboratory maintains an extensive testing facility for appliance characterization and performance and provided engineering support throughout the duration of the WHD project.

Western Carolina University

Western Carolina University served as the primary contractor and coordinated the project. Additionally, engineering support, component prototyping, and sub-assembly fabrication was provided. Western Carolina University has exceptional facilities to support a new product development project, and also houses the Center for Applied Technologies (CAT building) and the Center for Rapid Product Realization. The $8 million dollar, 28,000 square feet Center for Applied Technologies was completed in 2003, and incorporates rapid prototyping, laser machining, reverse engineering and metrology, telecommunications, and other emerging technologies for technical assistance programs (TAP). Equipment was procured through grants and ear marks from state and federal sources as well as corporate and private benefactors. A list of equipment housed in the CAT building that was available for supporting this project is shown on the following page.

- Zeiss Contura ® Coordinate Measuring Machine
- OGP Flash ® Optical Surface Profiler
- Stratasys Titan ® Fused Deposition Modeling System
- Z-Corp 3-D Printer ® Concept Modeling Unit;
- Dell ® Engineering Workstations
- PRO/ENGINEER Wildfire ® and modules
- HAAS Z4-500 ® 2D laser cutting center
- HAAS VF Series ® CNC milling machines
- HAAS SL Series ® CNC lathes
- Oxford Laser

The automation, polymer, and materials laboratories were also sufficient in providing support for the WHD project. Faculty, staff, and students were involved in engineering, design, prototyping, fabrication, control, and testing throughout the project.

Asheville-Buncombe Technical Community College

The primary responsibilities of the community college faculty, staff, and students were control and testing of the prototype models. Control for the product required the development of an embedded micro-controller. Fundamentals of micro-controllers and related electronic topics are covered by the Electronics and Computer Engineering Technology Department. Instructors and students from this department are experienced in hardware design, software development, printed circuit board layout, and fabrication of the electronic modules used in communications, robotics and medical applications.

Testing of the water heating dehumidifier unit required one system to simulate the environment and an instrumentation system to evaluate the unit. Testing consisted of a variety of focused procedures to evaluate components and a full performance test on the developed prototypes and field test units. The Instrumentation and Control Systems courses have long been offered at Asheville-Buncombe Technical Community College. Many of the students taking these courses have extensive industrial experience and are seeking advancement with their current employers. These students provide benefits in their abilities to translate concepts into working systems. Finally, the modest size and cooperative spirit of the college provided broad based support for building and modifying components on-site. Faculty and staff from the Electrical, Heating and Air Conditioning, Welding, Machining, and Information Technology departments all contributed to the project.

Sci-Cool, Incorporated

Sci-Cool, Inc., served as a sub-contractor for engineering design modifications, fabrication and assembly for field test units. Strengths of this firm were in mechanical design and HVAC fabrication. Flexibility to take on the project while maintaining current levels of demand for other committed products proved to be an asset in carrying out the WHD project. The long term goal of the project is regional economic development and the creation of additional jobs to the region. Sci-Cool had a vested interest in both the Intellectual Property (IP) and long term production leading to potential profitable gain for the firm. In addition to their engineering expertise and manufacturing capability, the firm produced scaled up production costs and marketing projections.

Milestones and Responsibilities

Milestones and responsibilities of team members were identified during the initial planning of the project as well as the second phase. Due to the compressed time schedule requirements and critical completion dates were also established as shown in Table 1.

Table1: Project Milestones and Target Completion Dates for Phase II (Field Testing)

Milestone	***Scheduled Completion Dates***
Project initial meeting	June, 2005
Order and procure selected equipment	July, 2005
Fabrication of laboratory test unit	August, 2005
Review laboratory test results, engineering changes, and launch production of field test unit	September, 2005
Initial testing of field test units	October, 2005
Field test controller development	October, 2005
Establish field test sites and test plan	November, 2005
Develop remote data acquisition plan	December, 2005
Laboratory testing and evaluation of field test prototypes	January, 2006
Fabrication of field test controller and data acquisition units	February, 2006
Laboratory testing and design refinement	March, 2006
Installation and initiation of WHD field tests	June, 2006
Data Analysis and final report	August, 2006
WHD project completion	September, 2006

Responsibilities of each organization were identified and coordinated by Dr. Aaron Ball, PI, Western Carolina University. A list of responsibilities by organization is provided in the following section.

Western Carolina University (Aaron Ball, Chip Fergueson, Monty Graham, James Zhang, (Duane---I'm not sure about listing everyone's name maybe project leaders of each group?) It gets someone tricky is we do not include everyone involved so I would sugguest not listing names)

- Project coordination and management
- Instrumentation support
- Field test controller prototyping support
- WHD engineering documentation support
- WHD prototyping support
- Coordination of WHD laboratory and field testing
- Data analysis
- Reporting results
- Project final report

Asheville-Buncombe Technical Community College

- Instrumentation and environmental chamber testing
- Identify and implement testing standards
- Identify test standards and develop laboratory and field test procedures
- WHD control system development
- Testing WHD field test units
- Develop data acquisition design and implementation

Sci-Cool, Incorporated

- WHD engineering and redesign of field test units
- Engineering specifications
- Component selection
- Fabrication of field test WHD units
- Delivery of units to laboratory for testing
- Cost and scale-up plan
- Final report

Educational Goals

Rarely do faculty and students have the opportunity to design, fabricate, instrument, and test a new product in preparation for field testing and launching into the market place. The WHD project presented a challenging opportunity for integrating new product development into the engineering technology curriculum at Western Carolina University. Specifically, the educational goals were professional and technical development of faculty, engineering project work for students, and building closer ties with industry and government sponsoring agencies.

Faculty Involvement

Faculty members from Western Carolina University and Asheville-Buncombe Technical Community College were involved in numerous activities throughout the project. This close partnership was strengthened through total team participation between the two institutions and established a solid foundation for future collaborations. Although the principal investigator served as project coordinator and community college faculty were initially charged with the responsibility for control development and testing, all faculty were committed to making the project a success. Both institutions freely exchanged support in the form of research reviews, prototype designs, test site development, instrumentation, testing, and support to the manufacturer. As a result of this cooperative team effort, eight prototype designs were developed, installed and field tested. Design changes were implemented based on laboratory testing and results from experimental screening tests used to analyze heat exchange rates, power consumption, dehumidification capability, and system control requirements resulting in the following outcomes.

- Test platform and site developed
- Field prototypes fabricated and tested
- Field test data analyses conducted
- Performance characterized
- Test guidelines established
- Control system developed
- Federal test programs written and executed
- Vendors and components specified
- Cost and scale up estimates developed
- Field test data acquisition and analysis completed
- Final report of findings submitted to ORNL

Student Involvement
Students from both institutions made important contributions and support to the project. Western Carolina University students were primarily involved with engineering documentation and modeling, rapid prototyping, component machining, and fabrication. Graduate students conducted design of experiments and data analysis. Two-year college student involvement included site development work, instrumentation, controls, and testing. The follow section provides more specifics on student activities throughout the project.

While there were many isolated contributions by students, the greatest support was provided by two project classes (Instrumentation and Applications Project). These classes provided much of the work related to site preparation, instrumentation and testing. Student participation proved beneficial to the students themselves, the project team, and to the educational process at each institution. As members of the project team, students had to contend with technical problems and proposed solutions. They were confronted by issues such as cost and scheduling that are often not paramount in the classroom. Student contributions also provided relief to the primary researchers for much of the routine tasks such as reconfiguring equipment and calibrating or installing multiple sensors. Of all the outcomes, the most significant was an actual engineering project which revealed the greatest weakness in the college curricula. The students have developed the prescribed technical skills but have not gained the ability to integrate and apply their skills in engineering and development.

Snellenberger and his colleagues have emphasized the need for higher technical skills and practical engineering experience to reinforce a stronger U.S. engineering workforce.[9] Technical skills, practical engineering experience and progressive professional skills from industry advisors often urge that graduates must be made aware of skills such as planning, communications and safety. The comments from industrial advisory board members have had a major influence on accredited engineering technology programs. Under their guidance, the curricula for each of the engineering technology programs were designed to provide flexibility and accommodate two general categories of students. For students seeking to transfer for a bachelor's degree, electives in math and science are made available. However, for those students seeking immediate employment with an associate's degree, project classes are recommended to establish workplace experience. Project classes are the college's vehicles for allowing the student to integrate the technical and non-technical skills. The WHD project, with challenges in many disciplines, was well suited for this very type of student experience. This project was in essence the experience that the industrial advisory board desired.

The initial phase of the project ran smoothly with assignments established for two person teams. Teams were assigned to prepare the laboratory and test up to four units. After a mass effort to clear a suitable work area, a team constructed a platform and added water supply and drain manifolds. A second team, with industrial wiring experience installed a 480V/240 service transformer with the needed distribution equipment. A third team prepared a control cabinet with power supplies, programmable logic controllers and computers.

Once all the mechanical elements where in place, the student projects focused on control instrumentation. One team wired the control loop needed to automate the demand of water placed on a residential water heater. A staff member teaching in the electronics division at AB-Tech and currently a graduate student at WCU designed the programmable logic control program that automates the standardized tests. Two-year students carried out system wiring, trouble shooting, debugging, and verification of system operation including - control and the flow measurement The second team wired all of the sensors and brought the data into the instrumentation computer. Students operated LabVIEW and verified correct sensor operation. A third team installed current transformers and wired voltage and current signals into the instrumentation computer for calculation of true and apparent power. Using bench meters and a resistive dummy load, the team calibrated the measuring instruments, incorporated the constants in the LabVIEW program and verified the instrumentation using reactive loads. To the greatest extent possible, students were able to initiate a test and comprehend all of the information on the LabVIEW instrumentation console.

As the testing activity increased and true performance data was revealed, many design changes were considered to improve manufacturing cost, water heating and dehumidification performance. During the test phase, students had to become flexible and adapt to new and varied responsibilities. Seldom was there any hesitation in accepting responsibilities as students tackled varied tasks. Students were also responsible for some data collection and analysis. Graduate students conducted controlled laboratory tests on heat exchangers and dehumidification. Statistical experimental designs and analysis were carried out for the purpose of system improvement and provided input for design changes. The following illustrations show student involvement at various stages of the project ranging from laboratory test layout by undergraduates to field test data analysis by graduate students.

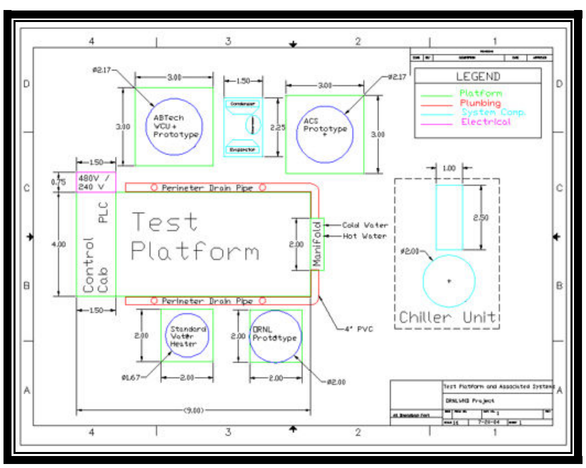


Figure 1: Test Site Layout

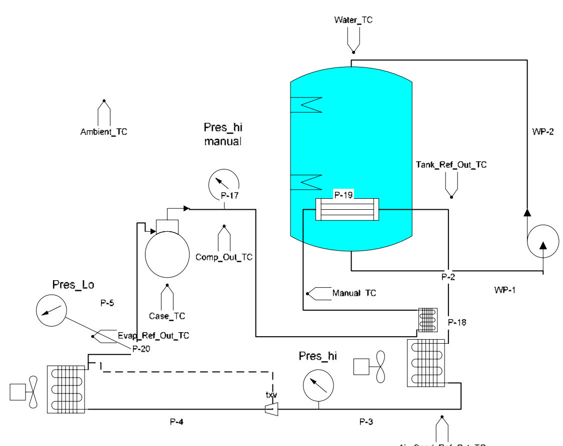


Figure 2: Refrigeration Test Circuit

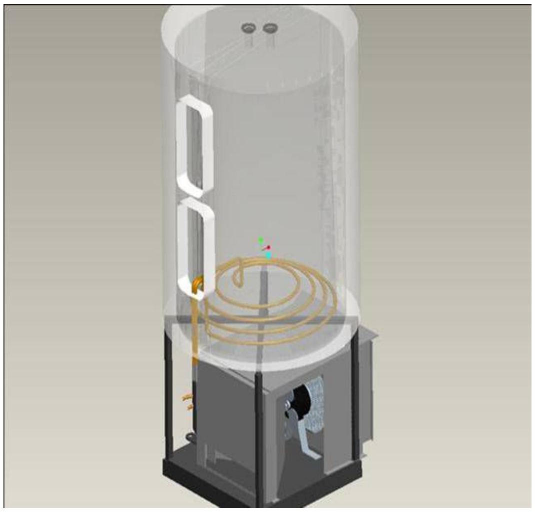
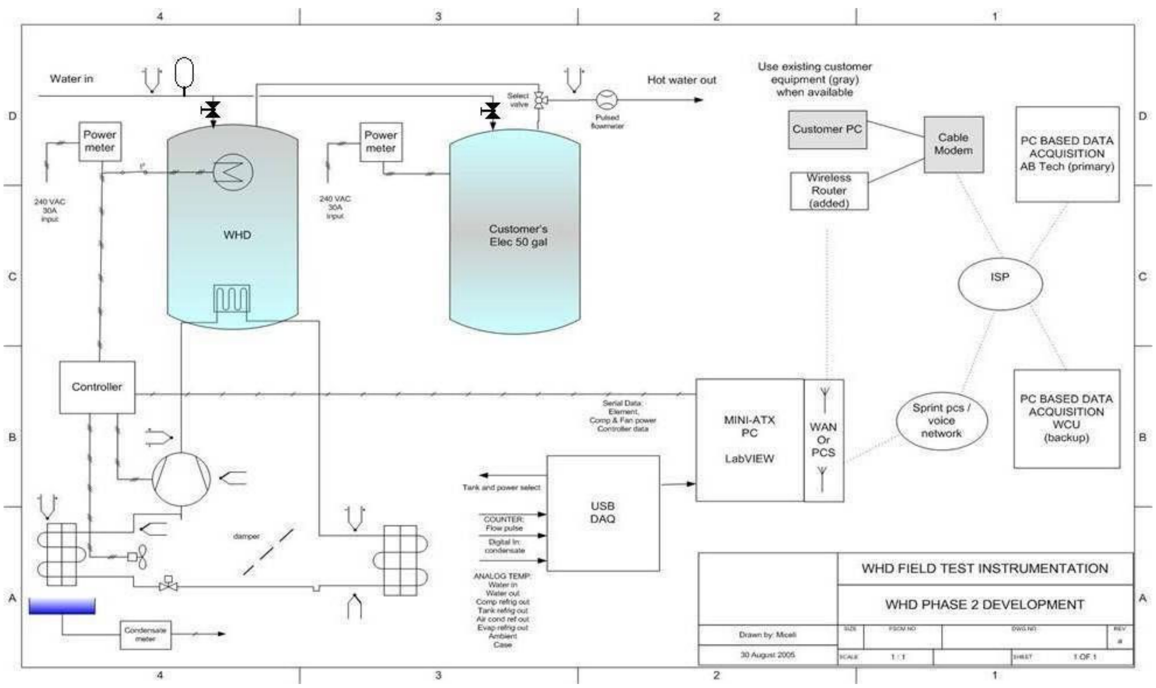


Figure 3: Engineering Model

Figure 4: Field Test Unit



Figures 5: Field Test Plan and Layout

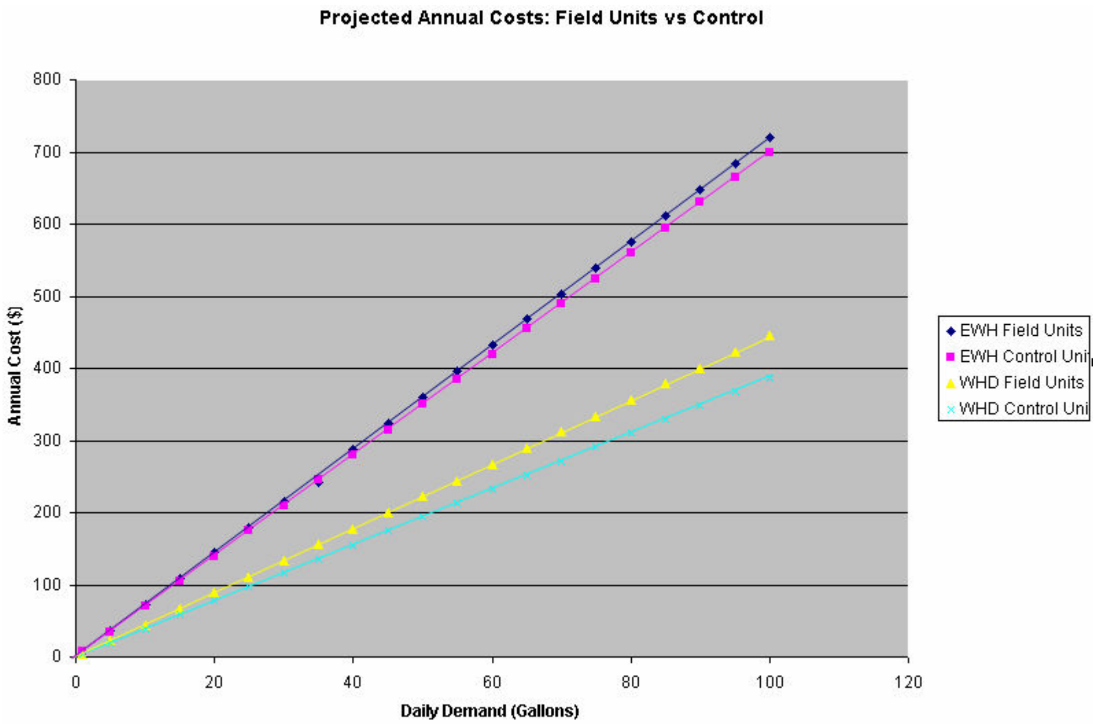


Figure 6: Field Test Data Analysis

Projected Annual Costs Based on Performace of Field Test Units and Control Unit									
Field Units: EWH		**Control Unit: EWH**		**Field Units: WHD**		Savings	**Control Unit: WHD**		Savings
Daily Use (gal)	Annual Cost	Daily Use (gal)	Annual Cost	Daily Use (gal)	Annual Cost	WHD vs EWH	Daily Use (gal)	Annual Cost	WHD vs EWH
1	7.2	1	6.99	1	4.45	$2.75	1	3.87	$3.12
5	35.98	5	34.98	5	22.25	$13.73	5	19.37	$15.61
10	72.96	10	69.96	10	44.5	$28.46	10	38.73	$31.23
15	107.94	15	104.95	15	66.75	$41.19	15	58.1	$46.85
20	143.92	20	139.93	20	88.99	$54.93	20	77.46	$62.47
25	179.9	25	174.91	25	111.24	$68.66	25	96.82	$78.09
30	215.89	30	209.89	30	133.49	$82.40	30	116.19	$93.70
35	241.87	35	244.87	35	155.74	$86.13	35	135.56	$109.31
40	287.85	40	279.85	40	177.99	$109.86	40	154.92	$124.93
45	323.83	45	314.84	45	200.24	$123.59	45	174.29	$140.55
50	359.81	50	349.82	50	222.49	$137.32	50	193.65	$156.17
55	395.79	55	384.81	55	244.74	$151.05	55	213.02	$171.79
60	431.77	60	419.78	60	266.98	$164.79	60	232.38	$187.40
65	467.75	65	454.76	65	289.23	$178.52	65	251.75	$203.01
70	503.73	70	489.74	70	311.48	$192.25	70	271.12	$218.62
75	539.71	75	524.73	75	333.73	$205.98	75	290.48	$234.25
80	575.69	80	559.71	80	355.98	$219.71	80	309.85	$249.86
85	611.68	85	594.69	85	378.23	$233.45	85	329.21	$265.48
90	647.66	90	629.67	90	400.48	$247.18	90	348.58	$281.09
95	683.64	95	664.65	95	422.72	$260.92	95	367.94	$296.71
100	719.62	100	699.64	100	444.97	$274.65	100	387.31	$312.33

Figure 7: Field Test Data Analysis and Projected Savings

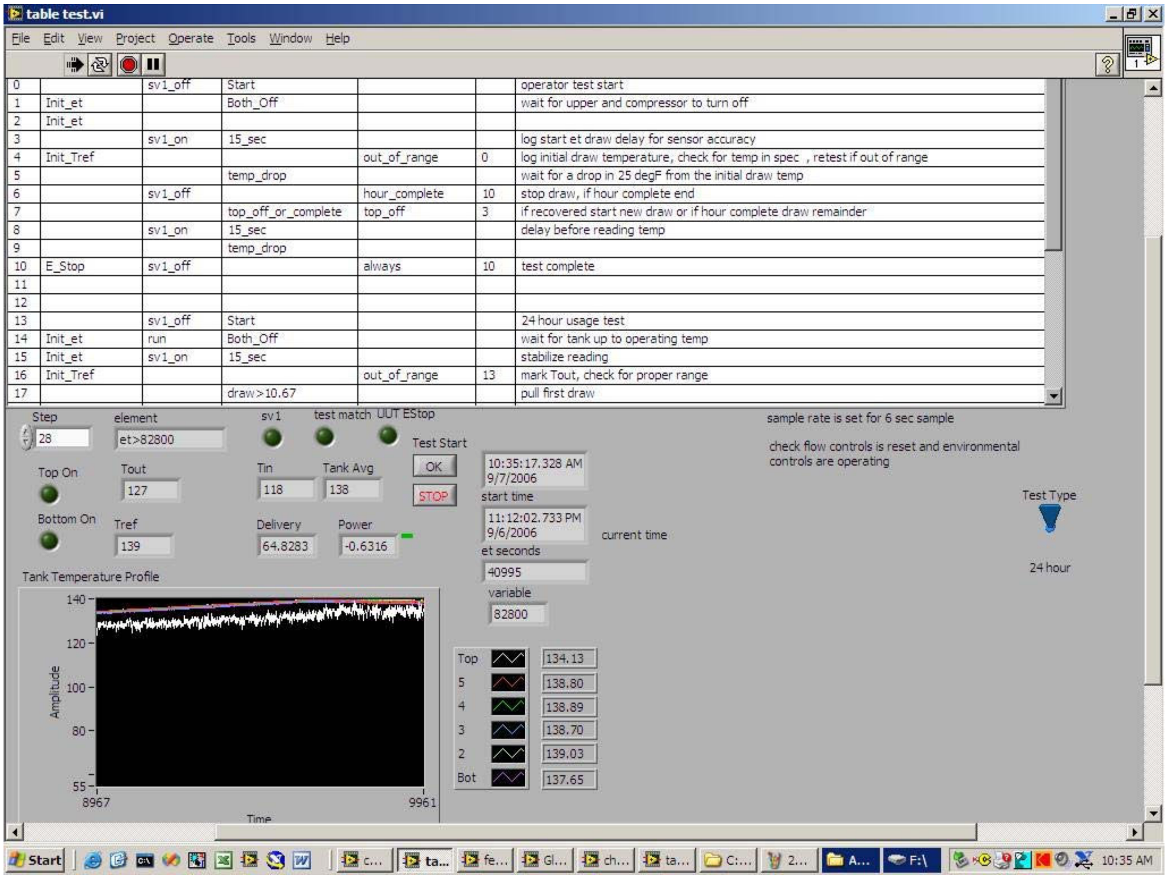


Figure 8: Federal tests: LabVIEW Instrumentation and Data Collection

Benefits of the WHD Project

The benefits gained from this project have been broad in scope and contributed to the overall goal of the WHD project. A win-win situation was developed and fostered through the non-competitive and collaborative efforts of each contributing team member. The literature notes that technology transfer has the potential to enhance the competitiveness of small businesses, which in turn spurs regional economic development and job growth. Small companies (less than 25 employees) such as Sci-Cool, Inc. typically struggle with allocating resources for the development of new products and processes. Additionally, the lack of time, experience and high-tech equipment necessary for the comprehensive creation of viable prototypes and the risks incurred by refocusing resources are usually not worth the gamble when time spent on improving existing products or processes can immediately affect critical revenues. The authors believe Sci-Cool, Inc. will benefit from the relatively low cost product development through technology transfer. The central missions of Western Carolina University and Asheville-Buncombe Technical Community College have been complimented through efforts in providing new technology and modern engineering support. Oak Ridge National Laboratory gained the potential to expand the body of knowledge and demonstrate concepts of viable alternative energy products.

Conclusion

Western Carolina University and Asheville-Buncombe Technical Community College contributed resources and support for the design, fabrication, and testing of the WHD prototype. A significant milestone was achieved through this project since no other similar product has been developed in the United States. Patents are pending, and Sci-Cool, Inc. is in process of securing manufacturing licenses as the firm evaluates strategies for launching the WHD into the market. This creative and applied engineering environment provided each educational institution with the opportunity to integrate applications of theoretical concepts into course and laboratory exercises. Additionally, the purchase of new equipment, tooling and software allowed for the enhancement of engineering technology laboratories at each institution. Equipment purchased will be used in future laboratory courses and industrial engagement projects. Faculty have gained and strengthened their technical knowledge of current products and processes in subjects that may have otherwise remained uncultivated. In turn, this newly gained knowledge and experience will prove to be valuable in the development of engineering technology curriculum and in future engagement projects. The project has helped to build stronger ties with industry, better community relations, and stronger relationships with government agencies. Both educational institutions look forward to future engagement projects so that they may continue to serve the local community, students, and industry. Partnerships among government agencies, regional industry, and regional educational institutions offer an excellent opportunity for advancing professional development, enhancing student learning, and promoting economic development.

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