A Partnership for Reviving Manufacturing Through Technology Transfer

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Abstract

With continued job losses to overseas markets and increased awareness of energy costs, opportunities to revive American manufacturing may lie in producing improved energy efficient products. Prior research sponsored by the Department of Energy (DOE) has resulted in a demonstrated proof of concept for a new hybrid energy saving product. A call for proposals addressing the transfer of energy conservation and efficiency technologies into a workable prototype was issued by the Department of Energy. The ultimate goal is to stimulate regional economical development and promote job growth. Resulting from an awarded contract, a unique partnership was formed among Oak Ridge National Laboratory, Western Carolina University, Asheville-Buncombe Technical Community College, and American Carolina Stamping Company to develop a marketable energy efficient hybrid water heating and dehumidifying product. This partnership was made possible by securing funding from the Department of Energy's Office of Energy Efficiency and Renewable Energy through a competitive request for proposals. Benefits through technology transfer from Oak Ridge National Laboratory to engineering technology faculty, students, and industry are highlighted. Product development, prototyping, fabrication, instrumentation, controls, and testing procedures were integrated into relevant engineering technology courses.

Background

Western Carolina University is committed to supporting economic development through engagement and partnerships. The university established a campus-wide mandate for engagement with regional business and industry and has provided support to departments active in this endeavor. Engagement activities focus on sustaining economic development and boosting entrepreneurial startups through innovative and creative projects that develop intellectual capital and technology transfer.[1,2]

The Engineering and Technology Department was approached December 1, 2003 by the Education and Research Consortium of the Western Carolinas to discuss the opportunity of working with a manufacturing company in western North Carolina to assist in managing the prototyping and field testing of a water-heating dehumidifier combination unit. 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 is of 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; and
- 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 was to develop a working prototype that demonstrates energy conservation through improved use of efficient technology. The project met the mission and goals of the Building Technologies Division. Phase II would include 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] Further research conducted by the national laboratory suggests that substantial improvement can be made by implementing a heat pump type unit for supplementing a standard electric water heater. The heat pump water heater field tests have demonstrated that the overall energy costs of heating water can be reduced by 50 percent.[7] This project addressed the monitoring, development, and testing needed to prototype a similar product with added dehumidification capability. Thus, the project focused on developing a hybrid Water Heater and Dehumidifier (WHD) product. Two viable prototypes demonstrating proof of concept were targeted as deliverables.

Project Partners: Responsibilities and Strengths

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

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. Results from the marketing analysis were made available. Oak Ridge National Laboratory maintains an extensive testing facility for appliance characterization and performance. This facility will be made available for conducting chamber testing of the developed product, and testing is scheduled at the conclusion of this 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. The university secured federal funding for the construction of a new facility to house the Center for Applied Technologies and the Center for Rapid Prototyping. The $8 million dollar, 28,000 square feet Center for Applied Technologies was completed in 2003, and incorporates rapid prototyping, reverse engineering, telecommunications, and other emerging technologies into the engineering technology curriculum. Equipment was procured through grants and donations from state and federal sources, as well as corporate and private benefactors. Equipment housed in the university and available for supporting this project is shown below.

- 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

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 tests to evaluate components and a full performance test on the final prototypes. The Instrumentation and Control Systems courses have long been offered at Asheville-Buncombe Technical Community Colleges. 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.

American Carolina Stamping

American Carolina Stamping served as a sub-contractor for prototype fabrication and assembly on selected designs. Strengths were in mechanical and HVAC fabrication. Flexibility to take on the project while maintaining current levels of demand for other committed products was provided. The long term goal of the project is regional economic development and the creation of additional jobs. Upon selection of the most viable prototype designs, scale up and cost projections, and establishing vendor contacts became the responsibility of American Carolina Stamping.

Milestones and Responsibilities

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

Table1: Project Milestones and Target Completion Dates

Milestone	*Scheduled Completion Dates*
Project initial meeting	May 1, 2004
Order and Install Selected Equipment	June 1, 2004
Instrumentation of purchased test units	July 15, 2004
Develop Prototype Design, CAD, Engineering Documentation	July 31, 2004
Prototype Control Design	June 1 , 2004
Begin Control Simulation	June 15, 2004
1st WHD Prototype Evaluation	July 31, 2004
Midway Progress Review	August 1, 2004
Testing and Evaluation of Prototypes	January 15, 2005
Data Analysis	February 28, 2005
Final Report and Documentation	March 27, 2005
Phase I Completion	March 31, 2005

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

Western Carolina University

- Project coordination and management
- Instrumentation support
- Control prototyping support
- WHD engineering documentation support
- WHD prototyping support
- Coordination of WHD testing
- Data analysis
- Reporting results
- Project final report

Asheville-Buncombe Technical Community College

- Develop pilot instrumentation site
- Install and validate testing instrumentation
- Identify and implement testing standards
- Develop test procedures
- WHD control system prototype
- Testing WHD prototypes
- Archive test data

American Carolina Stamping

- WHD engineering and product design
- Engineering specifications
- Component selection
- Fabrication of 2 WHD prototype units
- Delivery of units to test site
- 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 engineering technology courses. Specifically, the educational goals were professional 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. 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, six prototype designs have been developed and tested, well beyond the stated project goal of two viable options.

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. To date, the following accomplishments have been achieved.

- Test platform and site developed
- Six prototypes fabricated and tested
- Test data analyses conducted
- Performance characterized
- Test guidelines established
- Control system developed
- Federal test programs written
- Vendors and components specified
- Cost and scale up estimates developed
- Phase II plans submitted

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 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 the 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.

With the mechanical elements 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 designed the programmable logic control program that automates the standardized tests but the students used debug tools to control valves and read the resulting flow. 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.

The applications proved valuable in that the students seemed well versed with the equipment they were dealing with. In their instrumentation training, many types of physical sensors were covered in chronological order. Each was examined for its theory, application, characteristics, troubleshooting and calibration procedure. LabVIEW was used in the classroom to visualize the sensors output and implement a calibration method. This comprehensive coverage gave the students the capability to understand the LabVIEW control screen and trouble shoot sensor problems.

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.

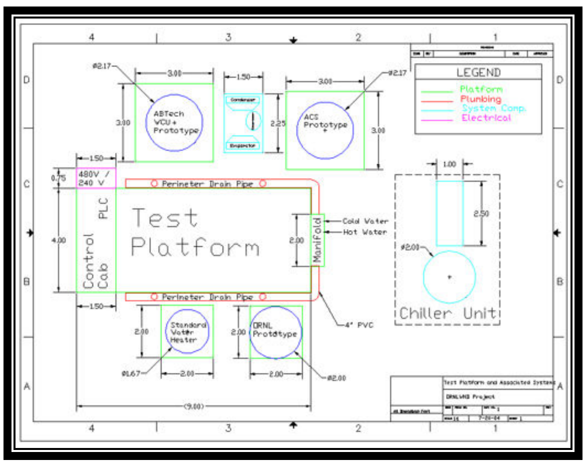


Figure 1: Test Site Layout

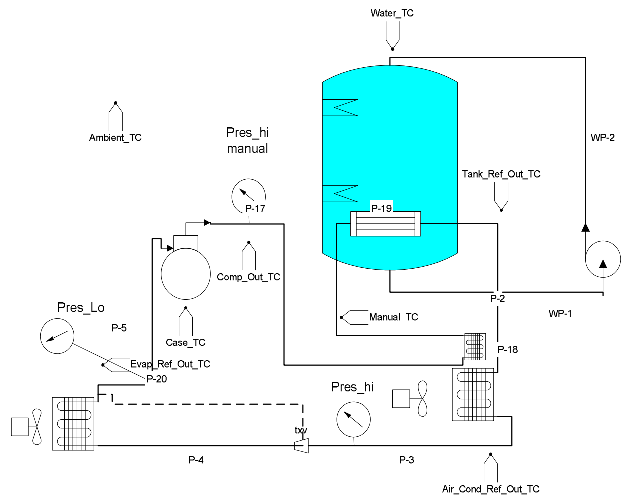
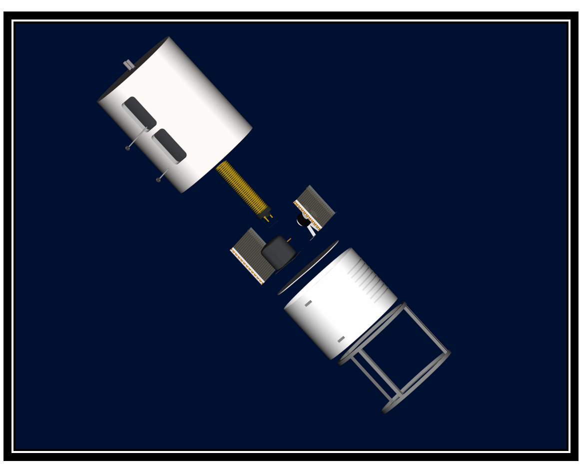
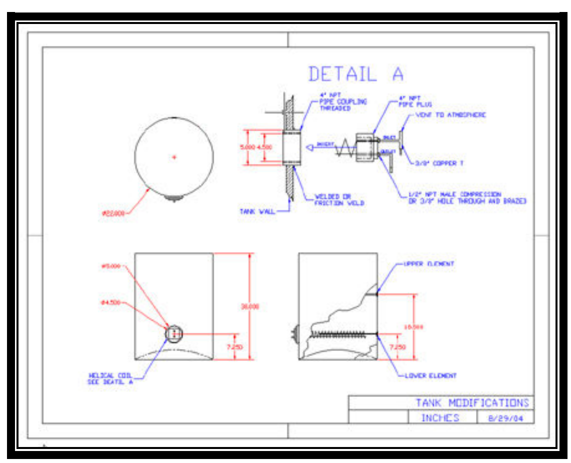


Figure 2: Refrigeration Test Circuit





Figures 3-4: Sample Parametric Models and Engineering Drawings

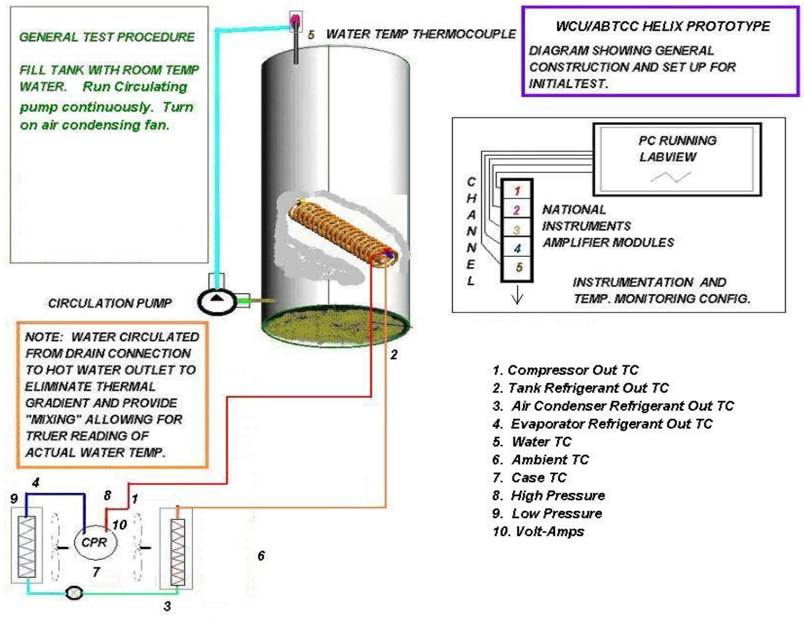


Figure 5: Typical Test Configuration

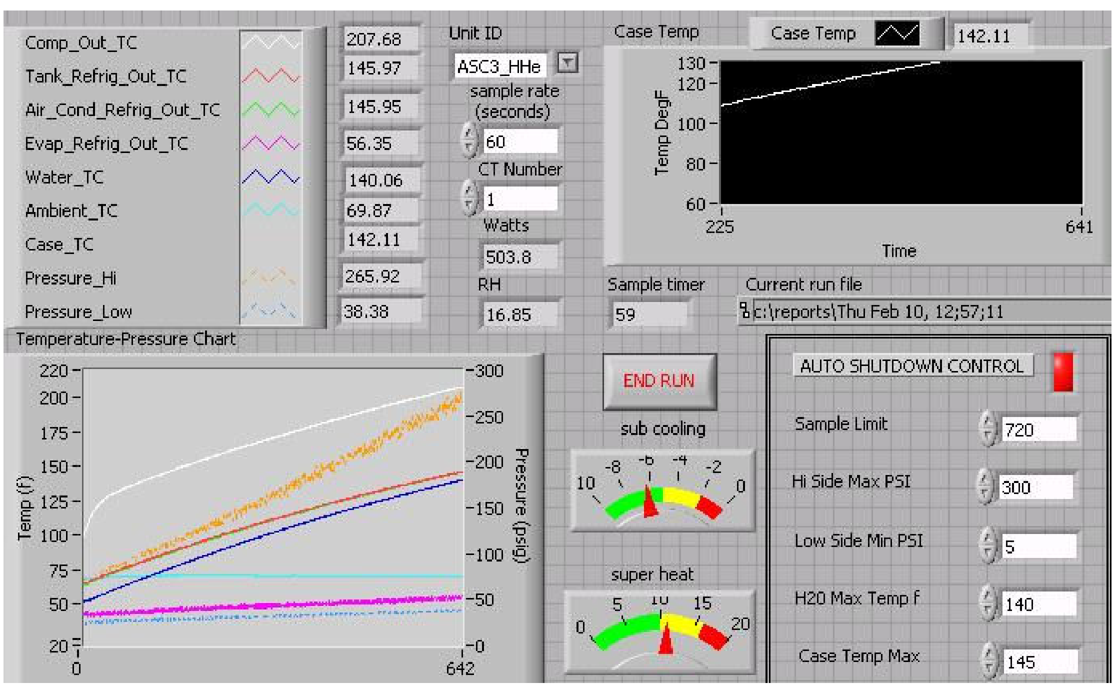


Figure 6: Typical LabVIEW Instrumentation and Data Collection

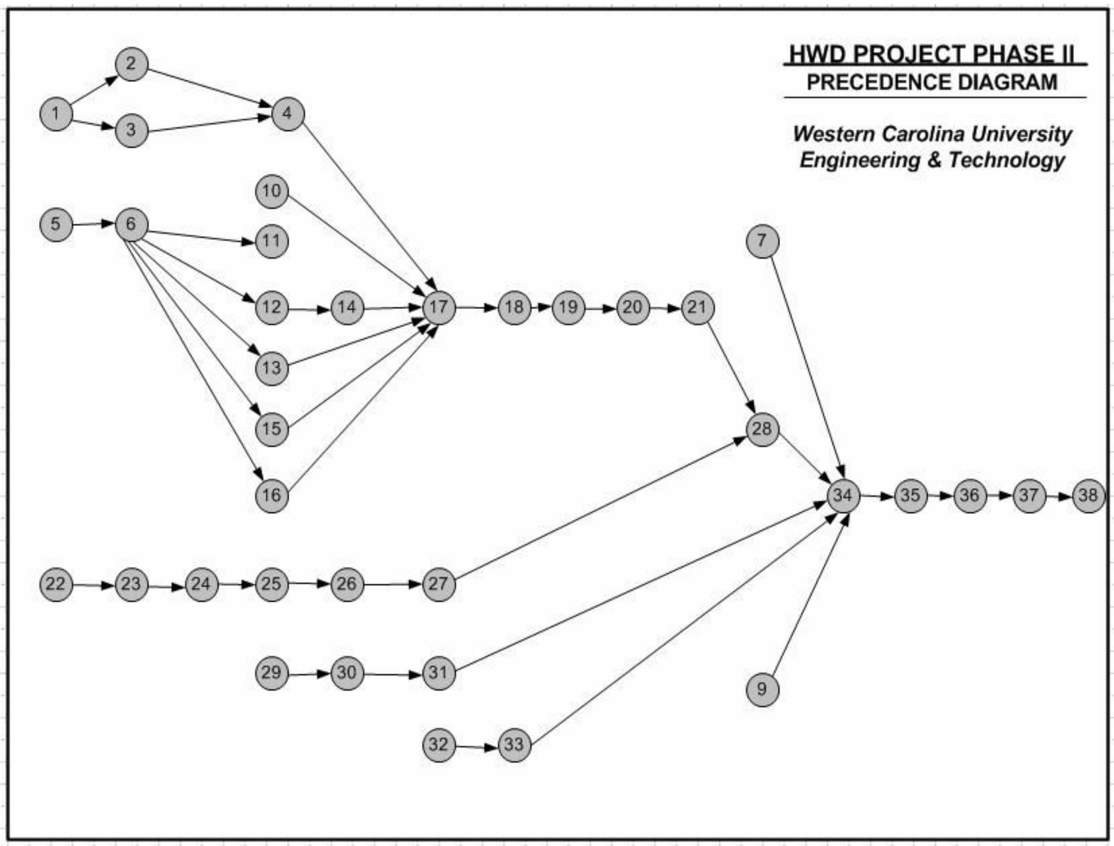


Figure 7: Phase II Project Management and Planning Activities

Benefits of the WHD Project

The benefits gained have been broad in scope and contributory to the overall goal of the WHD project. A win-win situation has been developed and fostered through the non-competitive and collaborative efforts of each contributing team member. It is widely recognized 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 such as American Carolina Stamping 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 American Carolina Stamping 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 saving appliances.

Conclusion

Western Carolina University and Asheville-Buncombe Technical Community College contributed resources and support for the design, fabrication, and testing of the WHD prototype. This creative and applied engineering environment provided each 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 can 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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Biographies

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