Solid-Fuel Absorption Refrigeration

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Partners:
University of Alaska, Fairbanks

Total Project Cost: $1,547,500
Grant Funds Requested: $547,500
Match Committed: $1 million

Emerging Energy Technology Grant
AEA-12-047
March 2012
Project Description

The objective of this grant is to fund the demonstration phase of a biomass/solid-fuel Absorption Refrigeration system for a fish processing plant in Alaska. The pilot project is in its third month of realization at The Auction Block Co. in Homer, Alaska.

Established in 1997, The Auction Block is an Alaskan-owned fish processing plant with an annual cash flow of over $16 million. Commercial seafood processing requires refrigeration in three forms: blast freezing, ice making, and cold storage. The Auction Block is implementing a $2 million project that will provide us with the refrigeration volume we require using low-cost energy. The Auction Block will be the first commercial seafood processor in Alaska to achieve “off the grid” fish processing – no need for municipal energy sources. Our novel use of biomass energy (in the form of waste heat, coal heat, and biomass heat) to power Absorption Refrigeration using eco-friendly refrigerants (CO₂, ammonia, and water) is an innovative, economical, and ecologically superior approach to traditional industry norms.

Innovation and Scientific Concept

Absorption Refrigeration uses environmentally-friendly refrigerants and is an emerging energy technology already widely in use in the European Union. The Montreal Protocol of 1989 essentially ended the use of chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) because of these common refrigerants’ high levels of pollution. The United States has joined efforts to decrease greenhouse gas pollution; a ban is set on all HCFCs production and consumption by year 2030. Absorption Refrigeration is a new source of green refrigeration, in which the Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) of the refrigerants used is 0 or 1.

In Absorption Refrigeration, two non-toxic refrigerants are used: water (H₂O) and ammonia (NH₃). As opposed to CFCs and HCFCs, refrigerants in Absorption Refrigeration have no impact on the environment. The process is efficient, using less energy and low-to-moderate temperatures to create refrigeration. At The Auction Block, ammonia and water are used in the ice-making process. Our two flake-ice drums produce ten tons of high-quality, commercial-grade ice each day. The demonstration phase of this part of the project is already underway. The next phase for The Auction Block is the development and implementation of our 4840 ft³ blast freezer (capable of -40°F refrigeration temperature) using ammonia and carbon dioxide.

Heat energy is produced from the combustion of a fuel source or waste heat from other industrial processes. The Auction Block employs a biomass boiler which currently runs on coal from Usibelli Coal Mine in Healy, Alaska.¹ We plan to further refine the ratio of coal to biomass to produce the lowest cost of refrigeration. Using this combination of locally acquired biomass material and coal supports Alaskan jobs, saves money, and is beneficial for the environment.

A biomass boiler, working in conjunction with Absorption Refrigeration will power the ice makers and freezers. The Auction Block will thus be equipped to provide commercial fishing boats with fresh ice year-round, and to blast freeze product on-site in our processing plant. The ultimate goal is to make the energy demands of fish processing independent from high-priced electricity sources.

Technology Readiness

Absorption Refrigeration technology has been in use for years in Europe since the signing of the Montreal Protocol in 1989. Biomass boilers have been successfully installed in lieu of traditional heating systems in the US and Canada. Our concept combines these two technologies for use in commercial fish processing for the first time. This project presents an enormous opportunity for Alaska’s economy which is heavily dependent on the fishing industry. The Auction Block uses designs developed and tested by Energy Concepts and M&M Refrigeration Inc., Saskatoon Boiler, and engineering plans by Energy SEA, LLC.

¹ Alaska exports nearly 750 million tons of coal to Asia and Chile. Chile is a major source of farmed salmon which is directly in competition with wild Alaskan salmon in seafood markets.
Technology Validation and Research Methodology

The refrigeration system is composed of three components: the boiler, the absorber, and the plant refrigeration system.

1. Biomass Boiler

The Canada-based Saskatoon Boiler’s C-VH-400-W is a coal-fired boiler capable of running on wood pellets. The boiler is configured with a vertical combustion chamber, rotary grate, and forced combustion air specifically designed to burn solid fuels. The vertical combustion chamber allows combustible gases to burn above the fuel source to facilitate complete combustion. Currently, the boilers are fired with Alaskan coal. A proven alternative energy strategy is to fire solid fuel boilers with a combination of biomass (wood pellets, chips, residue, or processed municipal waste) and coal. There will be experimentation with three different types of biomasses and two types of coal to discover the best biomass-coal ratio for maximum performance. We will explore the types of biomasses available in different regions of the state, and apply any adaptations to the boiler in regards to different materials burned.

2. Absorber

The ThermoChiller absorber utilizes an ammonia-water working pair to produce refrigeration. Ammonia gas is absorbed by water to produce an ammonia-water solution. This solution is then pumped to high pressure with a small multistage pump requiring much less mechanical energy than a conventional refrigeration compressor. The compressed ammonia solution is heated with high-temperature hot water from the boiler which distills the ammonia from the solution producing a two-phase stream. The two-phase mixture travels to the rectifier and using mass exchange and internal heat exchange, the vapors are further purified to 98% ammonia. The high pressure vapor flows to the condenser where it is cooled and condensed into high pressure liquid. The liquid passes through a refrigerant heat exchanger (RHX), to the Electronic Expansion Valve, where the high pressure liquid expands to low pressure. The expanded liquid splits into the evaporator and ice-maker. The ammonia vapor returns back through the RHX into the absorber, absorbing the ammonia vapor. The ammonia is cooled down before it enters into the generator to start the processes again.

3. Plant Refrigeration System

The ammonia produced by the ThermoChiller absorption unit is used by the processing plant in two different applications. The plant icemakers use ammonia refrigerant directly from the absorber. The blast freezer located in the main processing plant utilizes CO₂ refrigerant that is condensed by the ammonia from the absorber. CO₂ was selected for use in the processing plant to address flammability issues associated with ammonia, as well as the possibility of product contamination should a refrigerant leak occur. A heating loop/defrost circulates propylene glycol-water solution heated via heat exchangers by the boilers. The propylene glycol heating loop is heated with process heat from the boilers and is intended to heat the building when the demand from the refrigeration system is less than the capacity of the boiler plant. The process heat is attractive because the fuel cost (coal and biomass) for the process boilers is much less than the fuel cost for the propane boiler that presently heats the building. This heat loop also provides heat to defrost the blast freezer coils as an alternative to electric defrost.

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<tr>
<th>TRL</th>
<th>REALISTIC SCHEDULE</th>
<th>Status</th>
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<tbody>
<tr>
<td>6</td>
<td>Boiler is in operation using 100% coal. Ice makers in operation producing 10 tons of ice in a 24 hour period. Modifications need to be made to plant refrigeration system to achieve low temperatures desired. System revisions are in progress. Plans to install heat recovery system.</td>
<td>In Progress</td>
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<td>7</td>
<td>Projected for summer 2012: full system in operation with plant refrigeration system, ice makers, and blast freezer running 100%. Experimentation to find optimal coal-biomass ratio will be conducted using biomasses native to Alaska’s different regions. UAF under Chuck Crapo to perform energy audit.</td>
<td>Summer 2012</td>
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<td>8</td>
<td>Once system is running at 100% and appropriate modifications have been made to boiler, blast freezer, and heat recovery system, The Auction Block will begin marketing the model to other fish processors in the state, using The Auction Block site as the prototype for UAF energy audit kits.</td>
<td>Fall 2012</td>
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### Site Suitability

The Auction Block’s 6,000 ft² building houses the administrative office, processing plant, retail shop, and blast freezer. The feasibility study for the solid-fuel Absorption Refrigeration project began before construction of the new building which was built in 2008. The current site of the project is adjacent to the public dock in Homer, Alaska. At present, the Auction Block is on a 30-year lease of .8 of an acre from the city, signed Fall 2008. The boiler is housed in a refurbished Alaska Railroad car on the property which has been remodeled to create a code-complaint engine room and boiler module. The 4840 ft³ blast freezer is located on the premises.

### Financing Plan & Project Match

The Auction Block has invested $1.6 million dollars in this project since June 2010. In-kind funds at $1 million as cost-share to cover facility and equipment use during the demonstration phase. The demonstration project which will comprise the initial 18 months of operation, budgeted at $1,000 per day, equates to $547,500 overall.

<table>
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<th>FINANCING PLAN</th>
<th>BUDGET</th>
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<tr>
<td>Coal Purchase Delivered</td>
<td>$65,800</td>
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<tr>
<td>Biomass Purchase Delivered</td>
<td>$40,100</td>
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<tr>
<td>Blast Freezer Low Temperature Modification</td>
<td>$38,000</td>
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<tr>
<td>Biomass Feed Modification</td>
<td>$18,000</td>
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<tr>
<td>Ash Removal Modification</td>
<td>$12,000</td>
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<tr>
<td>Test Operations</td>
<td>$186,000</td>
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<tr>
<td>Data Recording &amp; Analysis in conjunction with UAF</td>
<td>$37,000</td>
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<tr>
<td>Project Reporting in conjunction with UAF</td>
<td>$19,600</td>
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<tr>
<td>Marketing to Other Seafood Processors</td>
<td>$10,000</td>
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<tr>
<td>Administrative Overhead</td>
<td>$108,000</td>
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<tr>
<td>Contract Remittance to Energy Concept Co.</td>
<td>$13,000</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$547,500</strong></td>
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### Project Team Qualifications

**Kevin Hogan, President of The Auction Block, Co.** – Kevin Hogan started The Auction Block Co. in 1997 as an independent fish buyer, handling all dock operations involved in commercial offloads. In 2003, Kevin Hogan met with Walt Kallenberg, current Project Manager, to discuss the feasibility of Absorption Refrigeration for The Auction Block. Kevin Hogan is committed to building a business that emphasizes innovative technology and reduced dependence on municipal energy sources.

**Walt Kallenberg, P.E. & Project Manager, Energy SEA LLC** – Walt Kallenberg is the mechanical engineer for The Auction Block’s refrigeration project. He received a B.S. in Astronautics and Aeronautics from the University of Washington in 1972. Since then, he has gained extensive experience with energy systems in institutional and industrial facilities in Alaska, Europe, and Asia. He was retained by the Alaska Energy Authority in the early 1990s to consider feasibility for the application of Absorption Refrigeration technology in the Alaska fish processing industry. He was invited by The University of Alaska to present a paper discussing this technology at the Public Seafood Processing Cold Storage Workshop in 2003, attended by Kevin Hogan, president of the Auction Block, and organized by Chuck Crapo of the University of Alaska, Fairbanks.

**Don Erickson, President, Energy Concepts Co.** – Based in Annapolis, Maryland, ECC has developed and commercialized advanced heat activated ammonia-water absorption cycle technology for 30 years. In conjunction with the advanced cycle work, ECC develops new components which best exploit the potential of and reduce the cost of ammonia absorption cycles. Don Erickson has been working with us on this project from the start.

**Clark Andrews, Project Engineer, M&M Refrigeration** – Based in Federalsburg, Maryland, M&M sells, designs, and installs industrial refrigeration equipment and control systems. M&M designed a control system for the plant, and the CO₂ component of the CO₂-ammonia cascade refrigeration system for The Auction Block. M&M has been in operation since 1969 manufacturing industrial refrigeration equipment and controls. They have been the US leader in marketing CO₂ systems since 2004.
Chuck Crapo, Professor of Seafood Technology at University of Alaska, Fairbanks – Chuck Crapo’s extensive education and experience in Alaska’s seafood processing industry is the basis for his current project with UAF and Alaska Sea Grant Marine Advisory Program which performs affordable energy audits in small and medium seafood processing plants in Alaska. The project Improving the Energy Efficiency of Alaska Food Processing Plants received an AEA grant funding the administration of these energy audit kits to help determine power leakages in the systems of seafood processing plants. This summer, Chuck Crapo and his project team will help The Auction Block find optimal energy efficient practices in relation to our solid-fuel Absorption Refrigeration system. There will be continued partnership with Chuck Crapo and his program through the final phase.

Potential Market Defined & Alaska Public Benefit

This system is tailored to commercial fisheries enterprise as part of a for-profit business model. It was developed for the Auction Block Co. to save costs and reduce our dependency on external energy. The dollar amount saved will eventually cover the cost of our current investment as well as drastically reduce our operating expenses overall.

The seafood industry accounts for $3.6 billion dollars in annual revenue for the state of Alaska. After labor, utility costs are the largest expenses for seafood processors. If high-efficiency refrigeration technology is adopted by the seafood processing industry, an enormous amount of money will be saved in utility costs. Beyond the seafood industry, any place where refrigerated storage spaces are in use - supermarkets, cold storage warehouses, or refrigerated container trucks - will benefit from this technology.

Application of this technology is not limited to the commercial sector. This model would be appropriate in any environment where central heating and cooling systems are needed. The system would be of particular benefit to remote Alaskan communities that depend on barged transport of fuel sources at extremely high cost. For example, in Nome, Alaska, diesel delivered by barge is $600 for 100 gallons, while coal delivered is $144/ton. A savings of $456 is achieved using coal versus diesel. These shipments are equal in terms of energy output - one ton of coal has a BTU equivalent to 100 gallons of diesel.

The specific use of a coal-biomass mixture will also help the Alaskan mining and timber economies. There are numerous coal seams and biomass sources in Alaska. Using locally-sourced raw materials to power refrigeration helps ensure jobs remain in the state for the Alaskan benefit.

The economic benefits of implementing Absorption Refrigeration are massive, but equally impressive is the potential for industrial refrigeration processes to drastically reduce their carbon footprint in the state of Alaska. The experimentation with biomass fuel sources will reduce dependency on fossil-fuel and municipality-based energy sources, making green energy available on a large scale. Coal and biomass fuel sources are also easier and safer to transport than petroleum products, eliminating the chance of oil spills and contamination.

Market Size & Commercialization of Funded Technology

Remote access and extreme conditions provide energy acquisition challenges for many communities in Alaska. Most communities in Western and Northern Alaska are entirely dependent on diesel fuel that is barged in at a high cost. Biomass boilers provide an alternative heat source that is cheaper and cleaner. Current methods of permafrost control to ensure infrastructure integrity are also costly. The application we describe in our proposal can be used wherever air conditioning and freezing operations are required.

Many seafood processing plants are located in remote parts of the state. Commercial fishing grounds are nearest ports that are not connected to the road system. Implementing Absorption Refrigeration systems at these large facilities would facilitate their independence from traditional fuel sources and free them from the limitations of fuel shipping schedules.

A major advantage of our model is the modular design and portability. This feature was considered in the design phase of the project as a necessity. The system could be readily available for barge shipment and quick installation. This allows this technology to be quickly transported and installed in several barge-accessible communities state-wide.

A non-industry endorsement from the University of Alaska Fairbanks gives further credibility to the merits and potential application of this technology. The system model developed and in use by The Auction Block will provide important data to the UAF team. Our experimentation will determine maximum-yield bio-mass fuel ratios and overall energy efficiency and savings information. This information will be provided to UAF for use in their seafood processing energy audit program.