Alaska SeaLife Center

windows to the sea

Proposal
to the

Alaska Energy Authority
Emerging Energy Technology
Grant Application AEA-2014-007

Trans-Critical CO_2 Heat Pump System
Alaska SeaLife Center

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Project Partner:
University of Alaska Fairbanks, School of Fisheries and Ocean Sciences

Budget:
Grant Funds Requested: $537,560
Match Committed: $66,440
Total Project Cost: $604,000

Previous Projects:
Denali Commission Grant. #01223-00 (through UAF)
Alaska Energy Authority Grant #7030017 (through City of Seward)

Abstract

1. **Project Summary**

   a. **Project Description:**

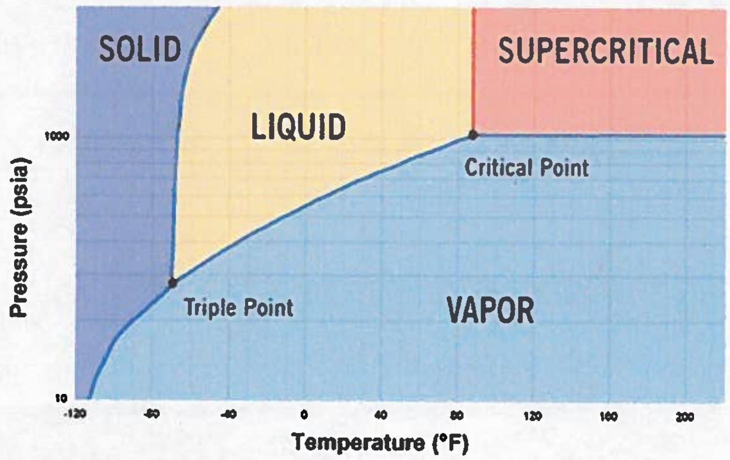
   Design, construction, and demonstration of an innovative Trans-Critical CO_2 Heat Pump System for the Alaska SeaLife Center (ASLC) that will displace an expensive electric boiler and provide heat to existing medium temperature (160°F to 180°F) hydronic baseboards, unit heaters and air handlers in the facility. This project will demonstrate an existing technology (heat pump with CO_2 refrigerant) not yet employed in Alaska. The heat pumps proposed are now used commercially in Europe and Japan, and accordingly this project has an anticipated Technology Readiness Level of TRL-7 & 8. Because the proposed CO_2 heat pump units have simulation software based on real operating conditions, the performance characteristics are well known and therefore the technical and financial feasibility is anticipated to be very strong. Once demonstrated at the Alaska SeaLife Center, the use of trans-critical CO_2 heat pumps to serve medium temperature loads (160°F to 180°F) can be considered by facilities across Alaska. CO_2 heat pumps can work where conventional heat pumps with low temperature output (100°F to 130°F) are unable to serve the medium temperature loads associated with existing hydronic fin tube baseboards, unit heaters and air handlers. CO2 heat pumps are also useful for heating domestic or process water.

   b. **Project Innovation:**

   This project will demonstrate the ability of CO2 refrigerant to increase the temperature range of heat pumps so they may serve existing medium-temperature heat load appliances in Alaska. Many buildings in Alaska have only medium-temperature baseboards, unit heaters, or air handlers that conventional refrigerant heat pumps such as (R-134a and R-410a) cannot serve due to a thermodynamic limit on the higher end of output temperature. The trans-critical CO_2 heat pump system proposed herein has proven to be a reliable and cost effective technology to eliminate or displace heating oil or electric boilers that serve medium-temperature hydronic heat loads from 160°F to 180°F. Considered one of five natural refrigerants on the planet, CO_2 is a refrigerant also known as R-744 that exhibits a unique trans-critical property when compressed at high pressure. Under these pressure and temperature conditions, the CO_2 exists as a mixture of liquid and gas above the critical point, and is thus described as being trans-critical in its entropy behavior. This unique characteristic allows the proposed CO_2 heat pumps to "lift" water temperatures on the load side up to 194F with a coefficient of performance (COP) that can exceed 4.0 (400% efficiency). The high compressor pressures presently limit manufacturers to smaller size units.

Refrigerant And Properties	R-134a	R-404A	CO_2
Natural substance	No	No	Yes
Ozone depletion potential (ODP)	0	0	0
Global warming potential (GWP)	1300	3260	1
Critical point	590 psia	541 psia	1,067 psia
	214°F	161°	88.0°
Triple point	0.058 psia	0.406 psia	75.1 psia
	-153.4°	-148°	-69.9°
Flammable or explosive	No	No	No
Toxic	No	No	No

   The major challenges in CO2 refrigeration involve the relatively high working pressures. The supercritical portion of the trans-critical cycle takes place above 1,067 psia. The phase diagram that follows illustrates the supercritical state in which CO_2 exists when pressure exceeds the critical point of 1,067 psia and 88F. Recent innovations in evaporator, compressor, and gas cooling technology have allowed manufactures to build CO2 heat pumps that take advantage of the tremendous range of lift afforded by exchanging heat on the load side with the refrigerant above the critical point. In simple terms, this innovation in high pressure CO2 vapor compression systems is what makes this technology a promising partner with medium temperature heat loads that are so common here in Alaska.



c. **Project Site and Demonstration Environment:**
The proposed project site is the existing mechanical room in the basement level of the Alaska SeaLife Center, where the existing electric boiler and sea water heat pumps are now located. The demonstration environment is the actual working full scale heating plant for the facility. This area of the heating plant is already open to visitors on a limited basis as a behind-the-scenes seawater heat pump tour. The ASLC operates the heating plant and will retain site control for the duration of the project.

d. **d. Priority:**
This project will be undertaken by Alaska SeaLife Center, a well-supported, established non-profit organization that has operated the 120,000 sq. ft. public aquarium and marine research and education facility in Seward, Alaska, since 1998. The Alaska SeaLife Center will provide staff labor to meet matching requirements. The proposed project will demonstrate an emerging energy technology that can be deployed in many other facilities in Alaska. The downtown, easily accessible, waterfront location of the ASLC makes it an ideal place for a demonstration project to educate tourists and residents about new and efficient heating systems.

Implementing this project will also strengthen the long-standing partnership with the University of Alaska Fairbanks (UAF) that ASLC has had since its formation. Installation of CO_2 heat pumps at the ASLC will demonstrate and prove the viability of this technology, paving the way for others such as UAF to follow. Additionally, UAF is involved in the construction of the R/V *Sikuliaq*, a 254-foot ice capable oceanographic research ship that will be homeported at the Seward Marine Center. We anticipate a number of researchers aboard the *Sikuliaq* will take advantage of research facilities at the Alaska SeaLife Center over the years to come. The heat pumps at the Alaska SeaLife Center have already proven to be a cost-effective heat source that has reduced overall facility costs at the Alaska SeaLife Center, which will reduce the cost of laboratory space for UAF researchers.

2. **2. Technology Validation and Research Methodology**

a. **Objectives:**
The key performance metrics that will be measured are system COP, individual heat pump COP, heat produced (MBH, MMBTU) and electrical energy used (KWH). The specific results that will constitute a successful project are production of the required flow and temperature to meet existing medium temperature hydronic loads under facility operating conditions; and an annual system COP that meets or exceed the minimum target of 3.0 (300% efficiency). The documentation and reporting will be achieved by the use of flow, temperature, and electrical energy metering; and web based data monitoring using new operator screens and control logic to be installed on the existing TRACER building automation system.

b. Data Collection:

Project data, including fluid temperatures, heat pump loop flows, hydronic loop flows, electricity usage, heat energy production, will be monitored with instrumentation (e.g., flow and temp sensors, power meter) mounted on the new equipment. These data will be reported in real time via new operator screens and control logic to be installed on ASLC's existing web-based building automation system (Trane TRACER). The Coefficient of Performance (COP) will also be calculated and logged in real time as the expression of heat produced divided by total electrical energy (KW) consumed by the loop pumps and heat pumps. An average COP of 3.0 or greater over the heating season is expected, meaning that for every unit of electrical heating energy consumed, three units of heat will be produced. The amount of heat produced by the CO_2 heat pumps will significantly reduce the need to operate the expensive electric boiler, resulting in cost savings and reduction in CO_2 emissions.

3. Project Schedule and Project Budget

Proposed Project Schedule - Design and Construction of CO_2 Heat Pump System

<u>Project Milestone Description</u>	<u>Target Date</u>
Pre-Deployment Phase	
Project scoping and agreements with design consultant finalized	Sept 30, 2014
Complete final mechanical and electrical design	Feb 1, 2015
Deployment Phase	
Advertise for equipment procurement and construction contractor bids	March 15, 2015
Award construction contract, begin construction activities	May 1, 2015
Complete construction of heat pump system	Aug 30, 2015
Complete start up and commissioning of CO2 heat pump system	Sept 30, 2015
Post-Deployment Phase	
Data monitoring for entire heating season (8 months)	Oct 2015 - May 2016
Complete final performance reports and analysis	May 31, 2016

Proposed Project Budget - Design And Construction Of Trans-Critical CO_2 Heat Pump System

Procure Transcritical CO_2 Heat Pump Units (four 20-ton units required)	160,000
Remove existing oil boiler, install heat pumps on housekeeping pad	10,000
Install new piping and valves to integrate heat pumps into heating system	70,000
Install new motor control center and electrical equipment for heat pump system	60,000
Install instrumentation devices (temperature probes, flow meters, etc)	40,000
<u>Prepare new operator screens and control logic for CO_2 heat pump system</u>	60,000
Total Construction cost	400,000
Construction contingency (15%)	60,000
Process, mechanical, electrical engineering design services (18%)	72,000
Construction inspection services, including submittal reviews, commissioning (8%)	32,000
Project administration by ASLC (10%)	40,000
Cost of Design, administration and permitting	204,000
Total Project Cost – Trans-Critical CO_2 Heat Pump System	**604,000**
ASLC in-kind labor for project administration & installation	66,440
Total Project Match Committed By ASLC (11%)	**66,440**
Total Grant Funds Requested	**537,560**

4. **Project Team Qualifications:**
ASLC: Alaska SeaLife Center (ASLC) operates the 120,000 sq. ft. public aquarium and marine research facility. The ASLC currently employs a staff of 100, including professionals with expertise in project and facilities management, aquaculture, aquarium science, fisheries biology and grant administration. The staff will provide in-kind labor project match for the administration & installation of the project. Project management will be led by ASLC Facilities Manager Darryl Schaefermeyer, who has considerable experience managing large, complex projects, including the funding and construction of the ASLC. ASLC life support staff will participate in the installation of the CO_2 heat pumps under the lead of John Underwood, Life Support & Facilities Manager. John and his staff have extensive experience in installing, operating and maintaining the complex life support systems at the Alaska SeaLife Center, including the seawater heat pump system currently in place.

YourCleanEnergy, LLC (YCE): - YCE completed the initial economic evaluation of seawater heat pumps for ASLC and designed the R-134a based heat pump system, including control logic and operator screens. YCE has gained knowledge of the trans-critical CO_2 heat pump cycle and will be instrumental in the integrated design of these heat pumps with the existing Trane RTWD heat pumps that have been operating successfully since 2011. YCE will partner with EDC Inc. of Anchorage to provide complete process, mechanical, and electrical design for the proposed heat pump system, and to provide submittal review and construction inspection services.

5. **Discussion of Commercialization of Funded Technology:**
The proposed project will be located at an aquarium and marine research facility with high visitation by the public, energy experts, politicians, traveling educators and scientists. Demonstration of the proposed trans-critical heat pump technology will greatly increase the probability for adoption by other facilities in Alaska within the next five years. The potential commercial market for trans-critical CO_2 heat pumps is very large in Alaska because of the large percentage of existing buildings with medium temperature hydronic heating appliances. In regions of the state where there is relatively low cost grid electricity, relatively high cost heating oil, and adequate resources for heat pump installation, the anticipated rate of commercialization is highest. This would include the cities of Seward, Juneau, Sitka, Kodiak, most of southeast Alaska, and other cities in coastal Alaska with low cost electricity and high heating oil prices.

6. **Signed Applicant Certification:**
By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered.

Seward Association for the Advancement of Marine Science, dba Alaska SeaLife Center

Tara Riemer Jones, Ph.D.
President and CEO