

Calmac Manufacturing Corporation

New Refrigeration Cycle To Improve 100-Year-Old Technology

Refrigeration is one of the leading uses of electric power in the United States. The term "refrigeration" refers to air-conditioning for homes, businesses, and industry and the operation of refrigerators, freezers, and heat pumps. The technology most often used in refrigeration, the vapor compression cycle, is 100 years old, inefficient, and environmentally unsound. Since the 1980s, the refrigeration industry has faced pressure to improve efficiency and reduce emissions of the chlorofluorocarbon (CFC) compounds used in vapor compression cooling. Attempts to decrease CFC emissions by using alternate compounds have typically made refrigeration devices less efficient.

Calmac Manufacturing, Inc., proposed a new, efficiency-enhancing twist on the old paradigm. It proposed an ejector expansion refrigeration cycle (EERC) to increase the efficiency of the cycle by recovering some of the unused energy in the compressed fluid. Calmac targeted a 10-percent reduction in energy used for air-conditioning and up to a 20-percent improvement for other, lower temperature applications over standard vapor compression refrigeration systems. Because Calmac lacked the internal funding resources to support such an ambitious, but risky, project, it turned to the Advanced Technology Program (ATP). In March 1993, ATP awarded \$729,000 to Calmac to pursue the development of EERC technology. Unfortunately, scientific and technical failures prevented Calmac from successfully developing the EERC technology and, by the project's end in February 1996, the company had abandoned its efforts. Calmac did, however, advance the refrigeration industry's body of knowledge for modernizing the vapor compression process, and future industry efforts may potentially expand on the inroads made by Calmac.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

No Stars

Research and data for Status Report 92-01-0007 were collected during October-December 2001.

100-Year-Old Refrigeration Techniques Are Obsolete

Vapor compression refrigeration systems use 23 percent of all electric energy in the United States. Add the millions of gallons of gasoline burned to power automobile air conditioners, and it is clear that any increase in efficiency could lead to tremendous societal benefits. Unfortunately, decades of attempts to improve the vapor compression refrigeration system by reducing chlorofluorocarbon (CFC) emissions have not resulted in increased efficiency or reduced the environmental impact of the system. Typically, reductions in CFC

emissions lead to decreased efficiency, requiring the use of more electric power as well as the emission of more environmental toxins from the electric-power-generation process.

Efficient, Cleaner Refrigeration Through EERC

Calmac developed an ejector expansion refrigeration cycle (EERC) process to improve the efficiency of vapor compression refrigeration by recovering energy typically lost during the process. Specifically, the EERC process uses the energy normally lost in the expansion process to help compress the gas entering the compressor. The

EERC expands the liquid refrigerant in two steps. The first step is through a specifically designed nozzle where the liquid is used to increase the pressure of the gas returning to the compressor. After this stage, the liquid refrigerant is collected in a receiver where it is metered into the evaporator by conventional methods.

Prior Success Indicates Goals Are Possible

Before applying for ATP funding, Calmac had expended significant internal resources to overcome prior EERC failures in the industry. For example, industry efforts to achieve EERC had not generated sufficient pressure within the ejector nozzle to enhance refrigeration efficiency. Calmac, however, had developed techniques to achieve a six-percent improvement in energy expended for refrigeration through the use of the EERC. That level of improvement was not high enough to make the technology cost effective, but, with further research and refinement, Calmac expected a 10-percent improvement for air-conditioning and up to a 20-percent improvement for other, lower temperature applications. Moreover, more efficient refrigeration would reduce both the size of the equipment needed in the process and the potential release of CFCs into the environment. When improvements reached the 10-percent threshold, cost savings would then be high enough to encourage original equipment manufacturers (OEMs) to use the EERC process. At that point, economic and environmental spillover could be achieved.

Limited internal funds had hindered efforts, however, to reach the commercially viable 10-percent improvement stage. Furthermore, given the previous failures to develop EERC technology within the industry, external funds through the private market were not available to Calmac.

Improved Refrigeration Efficiency Has Potential Spillover Benefits

Because refrigeration is used in almost every residential and commercial structure, and because it accounts for such a high percentage of the nation's consumption of electric power, improvements in refrigeration efficiency could result in lower overhead costs across many industries. In the commercial setting, cost savings could then be invested back into

product development. In the residential setting, the decrease in money spent each month on electricity could free up spending for a host of consumer items or for personal savings. The potential spillover benefits supported Calmac's proposal to receive cost-shared funds from ATP. Therefore, in 1993, ATP awarded the company \$729,000 to pursue further development of the EERC technology.

Unforeseen Obstacles Block Increased Efficiency and Commercialization

In the first 18 months of the project, Calmac engineers researched materials and engineering advances that had the potential to push the EERC above the 10-percent efficiency improvement threshold. The following six months were spent integrating these innovations into the EERC technology. At the start of the third year of the project, however, Calmac encountered unforeseen instability in the ejector's operation. Three sources of the instability were examined, but Calmac was unable to completely pinpoint and solve the problem. The specific operating parameters needed in the ejector for the EERC operation introduced inherent instabilities to the system outside this design window.

Calmac conducted research into the cause of the instability and generated extensive documentation of its findings. However, the company could not make the EERC operate efficiently for the equipment's complete range of operation.

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Consequently, Calmac could not commercialize a component package for retrofitting older machines or for installation by OEMs because the costs were still prohibitive. When the ATP project concluded in 1996, Calmac decided not to continue its work on EERC.

Conclusion

ATP funded Calmac's effort to develop more efficient, more environmentally friendly refrigeration technology based on recovering the energy lost during the process.

However, scientific and technical failures prevented the company from achieving the performance goal needed to make the EERC technology financially viable.

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Nevertheless, Calmac's research did add to the body of knowledge of engineering processes related to refrigeration. In the future, that knowledge may save engineers time and money as they continue to search for more efficient refrigeration methods.

PROJECT HIGHLIGHTS

Calmac Manufacturing Corporation

Project Title: New Refrigeration Cycle To Improve 100-Year-Old Technology (Ejector Expansion Refrigeration Cycle (EERC))

Project: To improve the efficiency of refrigeration through an ejector expansion refrigeration cycle (EERC) that recycles energy normally lost during the process. If successful, this technology would benefit every consumer of electric power by making refrigerators, air conditioners, and freezers substantially more efficient and cost effective.

Duration: 3/1/1993-2/29/1996

ATP Number: 92-01-0007

Funding (in thousands):

ATP Final Cost	\$ 729	62%
Participant Final Cost	<u>448</u>	38%
Total	\$1,177	

Accomplishments: Although Calmac made some progress in developing more efficient, more environmentally friendly refrigeration technology based on recovering the energy lost during the process,

technical problems prevented the company from achieving the performance goal needed to make it cost effective. Despite this failure, however, Calmac advanced the refrigeration industry's body of knowledge for modernizing the vapor compression process by identifying for the industry those EERC methods that would not work.

Commercialization Status: Calmac was unable to commercialize the EERC technology it worked to develop in this ATP-funded project due to scientific and technical failures.

Outlook: Calmac has abandoned further work on the EERC project, and there are no plans for commercialization at this time. In 2003, the outlook for this particular project is poor.

Composite Performance Score: No Stars

Number of Employees: 16 at project start, 65 as of December 2001

Company:

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