PROJECT DATA

AIL Research - 03GO13170

High Efficiency Liquid-Desiccant Regenerator

Recipient:	AIL Research	Instrument Number:	DE-FG36-03GO13170
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Subcontractor(s):		B&R Number(s):	ED1906020
		PES Number(s):	03-10157
EERE Program:	Building Technologies	State Congressional District:	NJ - 12

PROJECT SCOPE: This project will demonstrate the feasibility of a liquid-desiccant regenerator that can reach thermodynamic performance Coefficient of Performance (COP) of 1.25. It is referred to as a 1½-effect regenerator, which is a two-stage device in which water is first removed from the desiccant in an atmospheric boiler. The steam from the first stage has a saturation temperature of 212 deg F. The steam can then heat a second heat transfer loop that provides 190 deg F (or higher) hot water to a scavenging-air regenerator. Based on computer models of liquid-desiccant systems, the overall COP for this two-stage regenerator will be 1.25 when restoring a dilute 37% solution of lithium chloride to 43%.

FINANCIAL ASSISTANCE

Approved DOE Budget:	$248,500	Approved DOE Share:	$248,500
Obligated DOE Funds:	$124,250	Cost Share:	$50,000
Remaining Obligation:	$124,250		
Unpaid Balance:	$39,266	**TOTAL PROJECT:**	**$298,500**

Project Period: 9/30/03-9/30/05

TECHNICAL PERFORMANCE
DE-FG36-03GO13170
AIL Research
High Efficiency Liquid-Desiccant Regenerator

PROJECT SYNOPSIS

This project will demonstrate the feasibility of a liquid-desiccant regenerator that can reach thermodynamic performance (COP) of 1.25. It is referred to as a 1½-effect regenerator, which is a two-stage device in which water is first removed from the desiccant in an atmospheric boiler. The steam from the first stage has a saturation temperature of 212°F. It can then heat a second heat transfer loop that provides 190°F (or higher) hot water to a scavenging-air regenerator. Based on computer models of liquid-desiccant systems, the overall COP for this two-stage regenerator will be 1.25 when restoring a dilute 37% solution of lithium chloride to 43%.

SUMMARY OF TECHNICAL PROGRESS

AIL has found that the leading candidate for the high-temperature stage of the 1½-effect liquid desiccant regenerator is a spiral liquid-tube boiler made from a single coiled tube that is finned on the outside. Desiccant is pumped through the inside of the tube and hot combustion products are drawn over the outside of the tube. The spiral tube boiler has given AIL sufficient confidence in this system to place an order for a unit with a hastelloy coil. This modification will allow them to run continuously without corroding the coil. This system will have the required capacity to meet the regeneration needs of the 6,000-cfm rooftop liquid-desiccant air conditioner.

Two models of higher temperature scavenging-air regenerators were built and installed. One is made of Noryl, and engineering plastic made by GE that can operate at 260°F. The other is made of Ultem, and engineering plastic made by GE that can operate at 325°F. The Noryl regenerator has since developed significant leaks; however, the Ultem regenerator has shown no signs of degradation. AIL has designed a high-temperature interchange heat exchanger made from thin films of polysulfone that will be able to operate at the required 290°F.

SUMMARY OF PLANNED WORK

AIL expects to receive the hastelloy boiler and separator from the vendors in the near future. The units will be set up in the lab and testing will begin to prove their performance. AIL will build and test a small model of a third design for the scavenging-air regenerator that uses metal tubes and non-metal fins. This design may be a lower cost alternative to the Ultem regenerator that is now being thermally tested. After these tests, AIL will select a design for the scavenging-air regenerator and begin to make a full scale model that can work with the high temperature boiler. AIL also plans on completing the welding fixtures that are required to assemble the polysulfone interchange heat exchanger. A small-scale model will be built and tested first, followed by a full-scale model.

PROJECT ANALYSIS

This project is doing well and is within budget. No major obstacles are seen that would prevent AIL from successful completion of their award.

ACTION REQUIRED BY DOE HEADQUARTERS

No action is required from DOE Headquarters at this time.

STATEMENT OF WORK
DE-FG36-03GO13170
AIL Research
High Efficiency Liquid-Desiccant Regenerator

Detailed Task List

Task 1 – Determination of Heat Flux Limits

AIL Research shall determine the operating limits for a falling-film regenerator that permits quiescent evaporation from the films without nucleate boiling. They shall use a two-plate test rig similar to the one shown in Figure 4 of their proposal. These limits shall be determined as a function of desiccant concentration, desiccant flow rate and degree of superheat at the wall of the plates. They shall recommend a control strategy for the falling-film regenerator that avoids nucleate boiling as the operating conditions change. They shall identify all instrumentation that will be needed to implement this control strategy. AIL Research shall prepare a task report that describes the test rig, the test procedures and the test results.

Task 2 – Design, Fabrication and Testing of Multi-Plate Models

AIL Research shall develop both a plastic-plate and an aluminum-plate model of the falling-film regenerator. The models shall have between four and ten plates, with each plate being full size (i.e., the same size as the plate that would be used in a full-scale regenerator with between 100 and 200 plates). For the plastic-plate design, AIL Research shall first produce extrusions of a high-temperature, chemically inert plastic such as polyphenylsulfone. In short-term exposure tests, they shall identify an adhesive for this plastic that will provide strong, leak-tight joints at temperatures of 300°F to 320°F. They shall then proceed to fabricate the multi-plate model. Before building the aluminum-plate model, AIL Research shall conduct short-term exposure tests of coated plates in lithium chloride at between 300°F to 320°F. Coatings that they shall study include phenolics, epoxies, polyurethane, polyphenylsulfone and polyamides. Once an acceptable coating has been identified, AIL Research shall fabricate a multi-plate model.
AIL Research shall set up a flow facility for testing the plastic-plate and aluminum-plate regenerators. The facility shall include a circulating system for 300°F to 320°F heat transfer fluid, a pumped desiccant distribution and collection system, and a water-cooled coil for condensing the steam that the regenerator produces. Instrumentation for this facility shall include:

- temperature measurements of the heat transfer fluid into and out of the model
- desiccant temperature delivered to and collected from the regenerator plates
- heat transfer fluid and desiccant flow rates
- pH of the desiccant
- desiccant concentration delivered to and collected from the regenerator plates

In addition to determining thermodynamic performance (i.e., COP), AIL Research shall study the ability of the wicks to rewet after the regenerator has been off for an extended period, the formation of scale on the wick as a function of the pH of the desiccant solution, and operating conditions that produce nucleate boiling. They shall also determine the heat transfer coefficient for the condensation that occurs on the water coil. These test results shall be summarized in a task report.

Task 3 – Accelerated Testing of Component Materials

AIL Research shall set up bench-top test rigs for measuring: (1) the resistance of coatings to attack by hot lithium chloride, (2) the degradation in the strength of adhesive bonds after exposure to hot lithium chloride, and (3) the dimensional creep in the plastic that is used in Task 2 when a constant wall stress is applied. The test of the coatings shall proceed by first preparing films of a uniform thickness (e.g., 4 mils). These films shall be cut into strips of constant width. One set of strips shall be immersed in a bath of 43% lithium chloride at 290^{o}F; one set shall be immersed in a bath at 250^{o}F; and one set shall be kept in a dry, sealed container away from heat and light. The tensile strength of two strips from each set shall be measured on AIL Research's tensometer at 2, 4, 8, 16, 32, 48 and 64 weeks from the start of the test. AIL Research shall identify coatings that will resist attack by the lithium chloride solution for the lifetime of the regenerator (e.g., 10 to 15 years).

AIL Research shall test the adhesive used in the plastic-plate model of Task 2 using a procedure very similar to that described above for coatings. They shall also test a second adhesive as a possible replacement for the first. Approximately 50 identical samples shall be prepared for each adhesive, each sample consisting of a lap joint of two thin films of plastic. These samples shall undergo the same measurement of tensile strength following exposure to lithium chloride solution at two temperatures after seven time intervals. AIL Research shall determine whether the either of the two adhesives will maintain its strength over the lifetime of the regenerator. If both adhesives degrade too quickly to be useful, AIL Research shall immediately start the test of additional adhesives that appear promising based on product literature and recommendations of manufacturers.

In the last set of tests, AIL Research shall determine the rate of dimensional creep in the plates used in the plastic model in Task 2. They shall design and build a test rig that can keep a constant internal pressure on samples of the plastic extrusion, while exposing groups of samples to at least two different temperatures. The test rig shall permit the measurement of the change in dimension (either the volume within the extrusion or the thickness of the extrusion) without interrupting the test. AIL Research shall develop curves of creep versus time for different temperatures. From these curves they shall determine the limit in internal pressure at which the plastic-plate regenerator will have a useful life of at least 12 years. AIL Research shall prepare a report that summarizes the results of the materials tests in this task.

Task 4 – Lab-Testing of One-Fifth Scale Model

Based on the tests in Tasks 2 and 3, AIL Research shall select either the plastic-plate or aluminum-plate regenerator for further testing. They shall build a model of the complete regenerator (both the high-temperature and the scavenging-air stages) at a scale that is one-fifth the size required by a 6,000-cfm conditioner. They shall install this regenerator in their existing 1,200-cfm flow loop. They shall design and implement a controller for the regenerator that will permit the regenerator to follow varying water-removal rates by the conditioner without departing from stable (i.e., no nucleate boiling) operation. They shall operate the regenerator and conditioner in the test loop to prove its stable operation under varying loads and to measure its COP. AIL Research shall prepare a report that summarizes the results of the performance tests in this task.

Task 5 – Estimate of Manufacturing Costs and Retail Price for the Advanced Liquid-Desiccant Air Conditioner

For a sales level that is likely to be achieved within five years (e.g., 500 to 1,000 units per year), AIL Research shall define the manufacturing steps needed to produce a 6,000-cfm packaged roof-top air conditioner that uses the 1½-effect regenerator. They shall determine which components should be purchased from outside vendors and which should be produced in-house. They shall describe all tooling, fixtures, machine tools, etc. needed in each manufacturing step, and they shall estimate the cost to buy or develop this hardware. They shall also determine the labor needed to operate each station in the manufacturing process. They shall prepare a layout within the plant of the manufacturing stations and estimate the total plant area that will be needed. Finally, using generally accepted values for labor rates, amortization rates for tooling, rent, insurance, etc. they shall estimate the cost to manufacturer the advanced liquid-desiccant air conditioner.

Task 6 – Seasonal Simulations of High-Efficiency Cooling/Dehumidification System

AIL Research shall recalibrate their computer models of the 1½-effect regenerator so that they reproduce the performance that was measured in Task 4. They shall then simulate the performance of a liquid-desiccant air conditioner that uses this regenerator in an application that is likely to be an early market for this technology (i.e., the cooling and drying of ventilation air for a commercial building in a hot, humid climate). They shall also simulate the performance of a competing all-electric conventional air conditioner (e.g., Trane, FAU-066). They shall quantify both electric and gas use for the two competing systems. Finally, they shall identify gas and electric utility rates that will produce "breakeven" competition between the two systems, accounting for the first-cost for each system, assuming customer planning horizons of 3, 5 and 10 years. In a task report, AIL Research shall discuss the geographic markets where the liquid-desiccant air conditioner is likely to compete well against the conventional system.

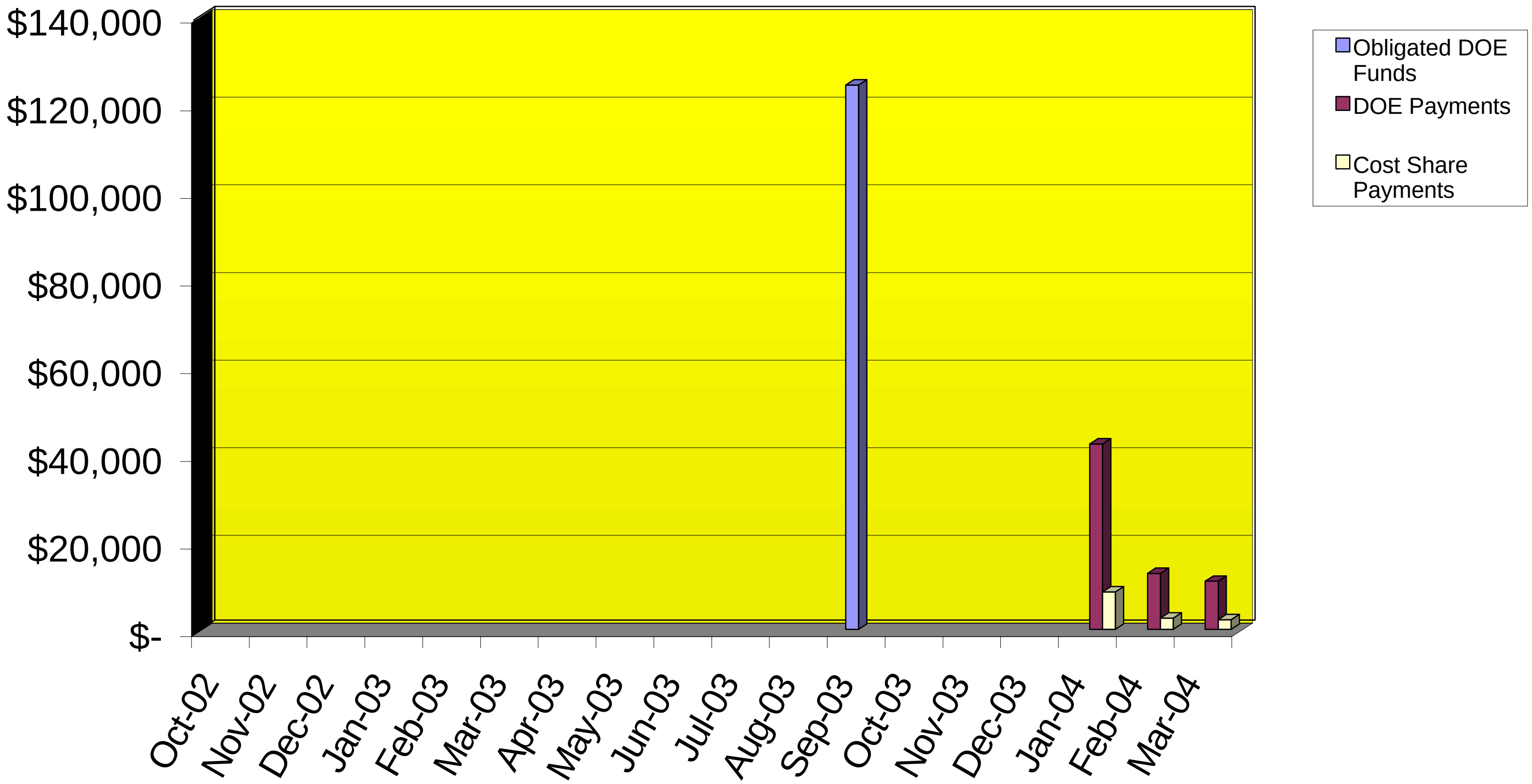
Task 7 – Assessment of Feasibility of a Liquid-Desiccant Dehumidifier for Lumber Drying

Working with Nyle Corporation, AIL Research shall define typical drying cycles for hardwood and softwood lumber. They shall then calculate the energy consumption for a liquid-desiccant dehumidifier that uses a 1½-effect regenerator and compare it to that for the electric vapor-compression dehumidifier that Nyle now manufacturers. AIL Research shall study possible operational problems associated with lumber drying such as the presence of high levels of wood dust and acid gases in the process air and determine whether the liquid-desiccant dehumidifier either is tolerant of them, or can be protected from them. If the liquid-desiccant dehumidifier can operate in the lumber-drying environment and if its energy savings are significant, AIL Research shall prepare a conceptual design of a liquid-desiccant dehumidifier for this application.

Project Cost Performance in DOE Dollars for Fiscal Year 2003

DE-FG36-03GO13170 AIL Research

High Efficiency Liquid-Desiccant Regenerator



	Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03
Obligated DOE Funds	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$124,250
DOE Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cost Share Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	PFY*	Cumulative
Obligated DOE Funds	$0	$0	$0	$0	$0	$0	$0	$124,250
DOE Payment	$0	$0	$0	$42,339	$12,760	$11,001	$0	$66,100
Cost Share Payment	$0	$0	$0	$8,519	$2,567	$2,214	$0	$13,300

Approved DOE Budget:	$124,250
Approved Cost Share Budget:	$50,000
Total Project Budget:	$174,250

* Prior Fiscal Years

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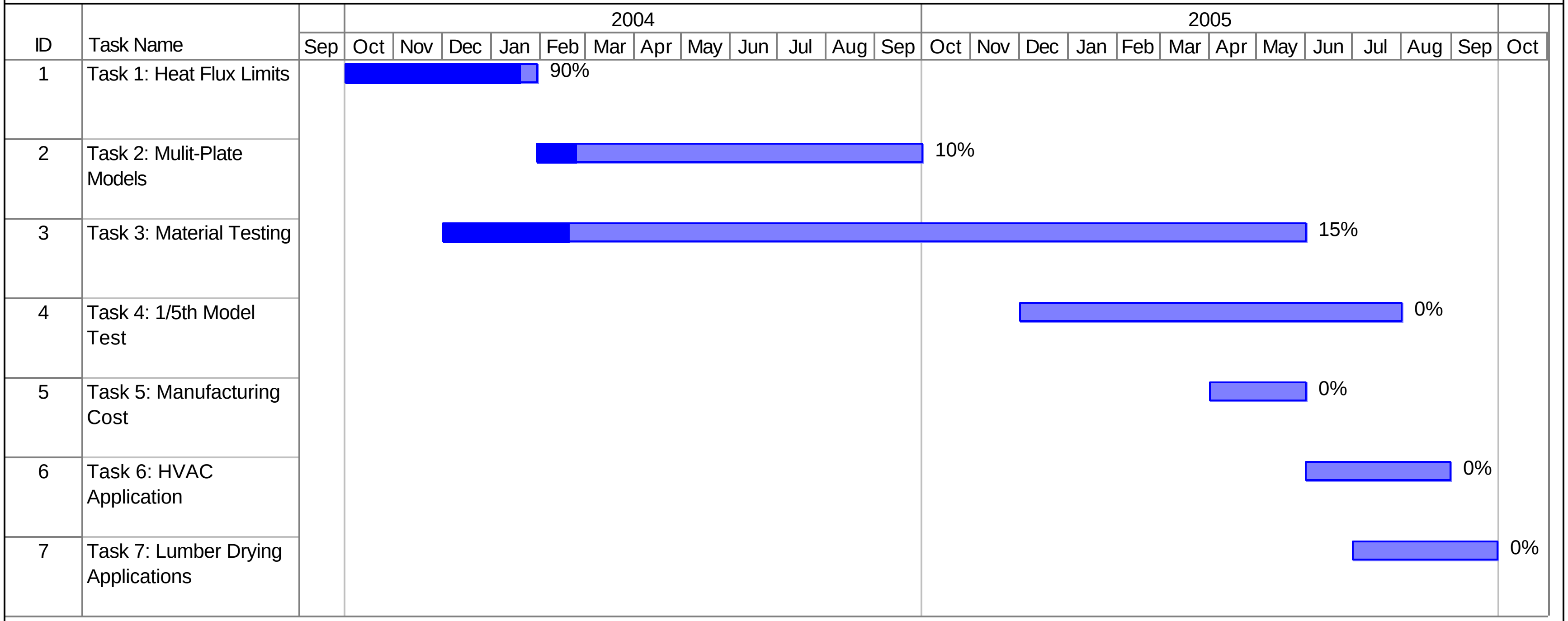

ID	Task Name
1	Task 1: Heat Flux Limits
2	Task 2: Mulit-Plate Models
3	Task 3: Material Testing
4	Task 4: 1/5th Model Test
5	Task 5: Manufacturing Cost
6	Task 6: HVAC Application
7	Task 7: Lumber Drying Applications