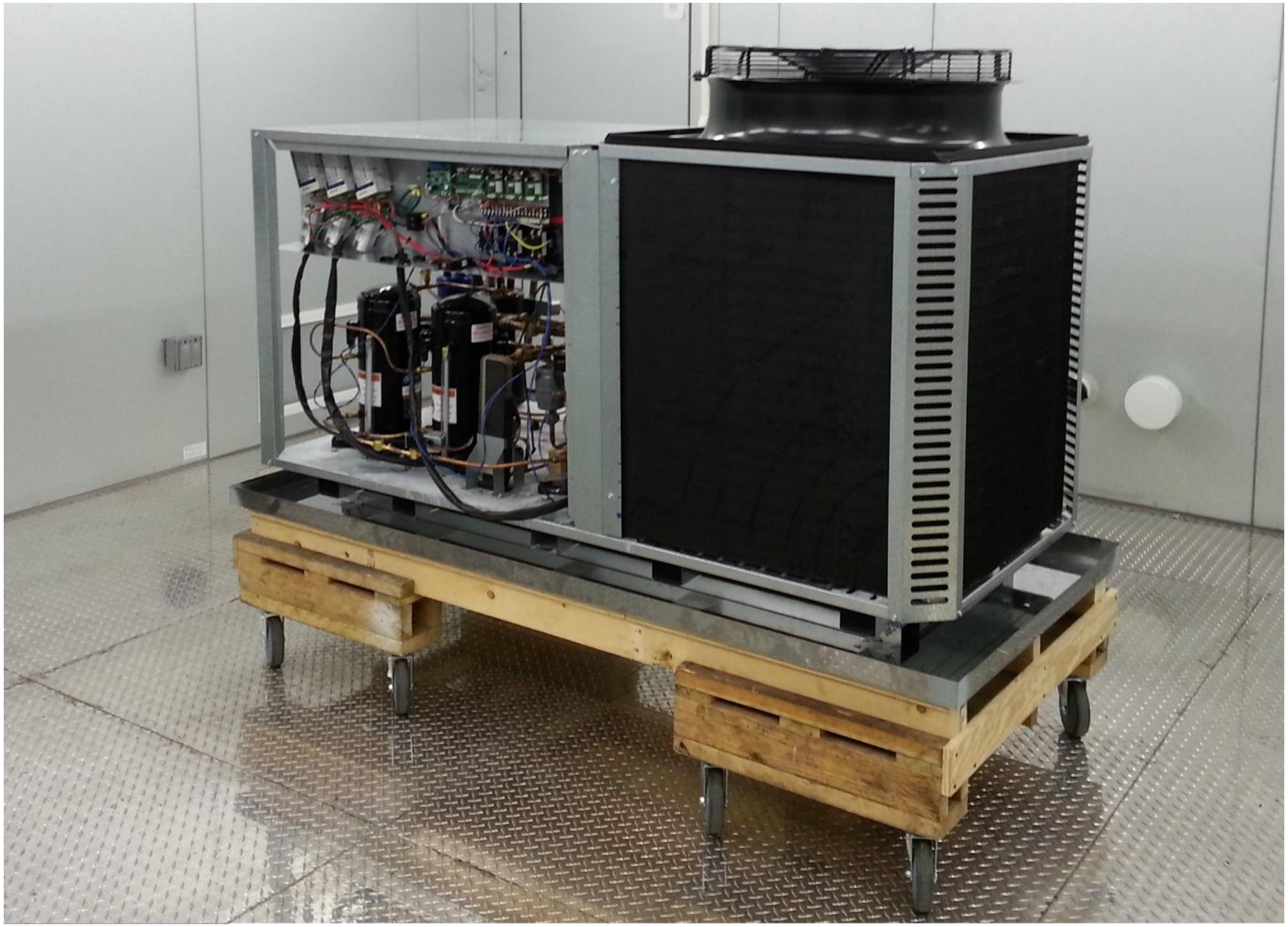
Residential Cold Climate Heat Pump (CCHP)

2015 Building Technologies Office Peer Review



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Unico, Inc.

The Unico Story

- **FAMILY OWNED U.S. MANUFACTURING BUSINESS** in St. Louis, Missouri.
- Largest SDHV manufacturer in the world with over **200,000 SQUARE FEET OF MANUFACTURING** space.
- Partnering with the U.S. Department of Energy to develop the next generation of **HIGHLY EFFICIENT AND COST-EFFECTIVE** HVAC systems.

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The Unico Cold Climate Heat Pump (CCHP)

- In partnership with the **U.S. DEPARTMENT OF ENERGY**, Unico is developing the next generation of highly efficient and cost-effective HVAC system specifically geared towards colder U.S. climates.
- The new technology will generate comfortable heat while **MAINTAINING EFFICIENCY AND RELIABILITY** at very low temperatures.
- The new technology provides efficient and effective heat conversion **AT THE BEST VALUE FOR THE CONSUMER**.
- Dramatically **REDUCES HEATING COSTS** and **INCREASES U.S. ENERGY INDEPENDENCE**
  - *The **electric-based** system works to keep costs down during cold winter months through its efficient use of energy and reliance on electricity, resulting in lower costs to consumers and increasing our nation's energy independence.*

The Unico Cold Climate Heat Pump (CCHP)

- The **U.S. DESIGNED & MANUFACTURED** product positions America as the world's leading innovator in modernizing heating and cooling systems and creates significant global export potential.

- This new system will **DRIVE SIGNIFICANT, GLOBAL EXPORTS**, helping to strengthen the American economy.

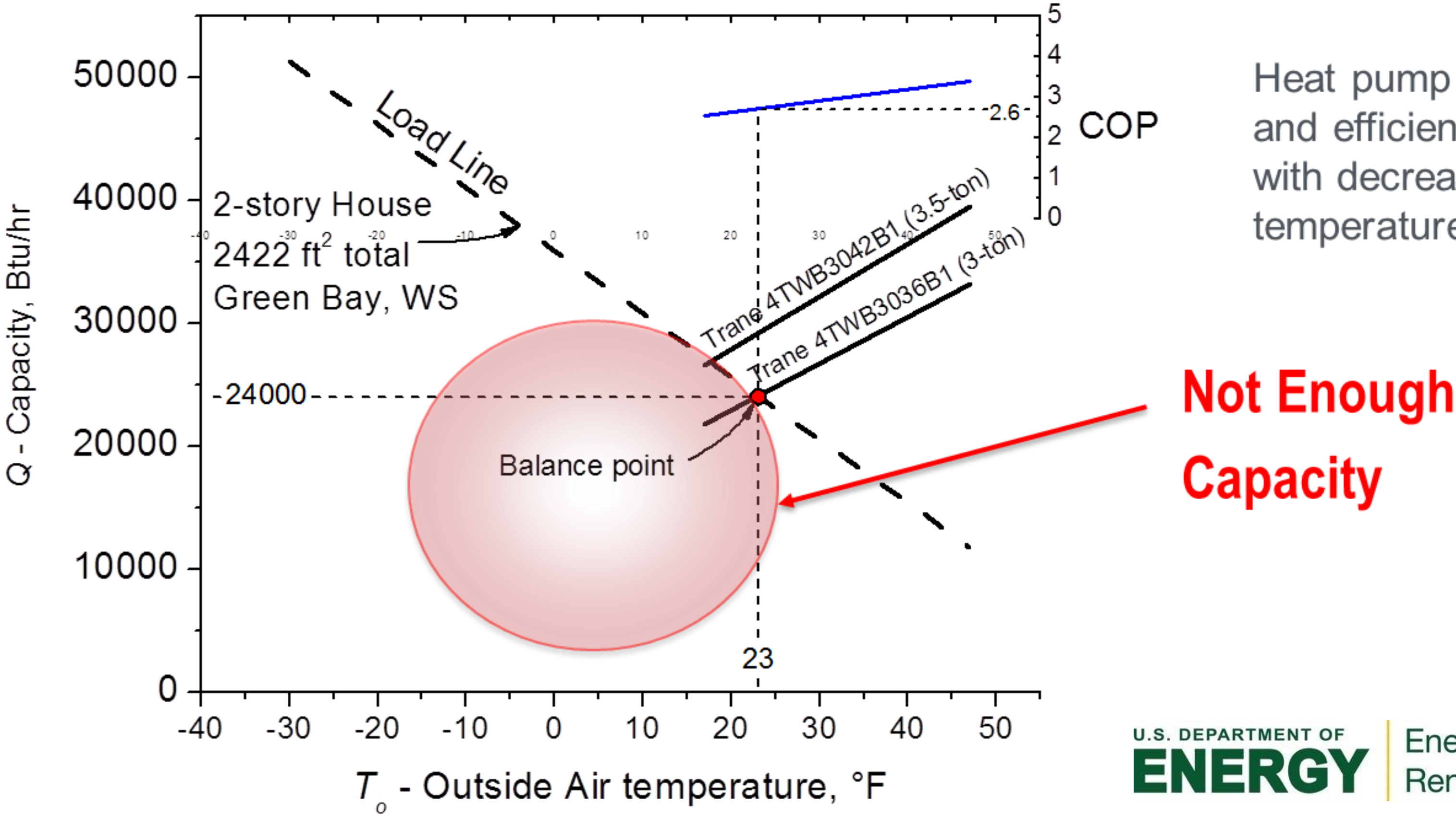
- Unico's CCHP technology has the potential to **CREATE U.S. MANUFACTURING** JOBS.

- The efficiency of the system **REDUCES STRESS ON THE GRID** caused by traditional systems, preventing shortages and blackouts across communities.
  - *Traditional heating units are inefficient when it comes to converting very hot or very cold air to desired temperatures. Unico's technology allows for steady temperatures, even when outdoor temperatures reach -13° Fahrenheit.*

Heat Pumps

Reduce Fossil Fuel

- Use electricity to heat (allows renewal power sources)
- Electric furnace: 1 kW INPUT = 1 kW OUTPUT
- Coefficient of Performance (COP) = 1.0 is not enough
- Heat pumps: 1 kW INPUT = more than 1 kW OUTPUT



Heat pump capacity and efficiency decrease with decreasing temperatures

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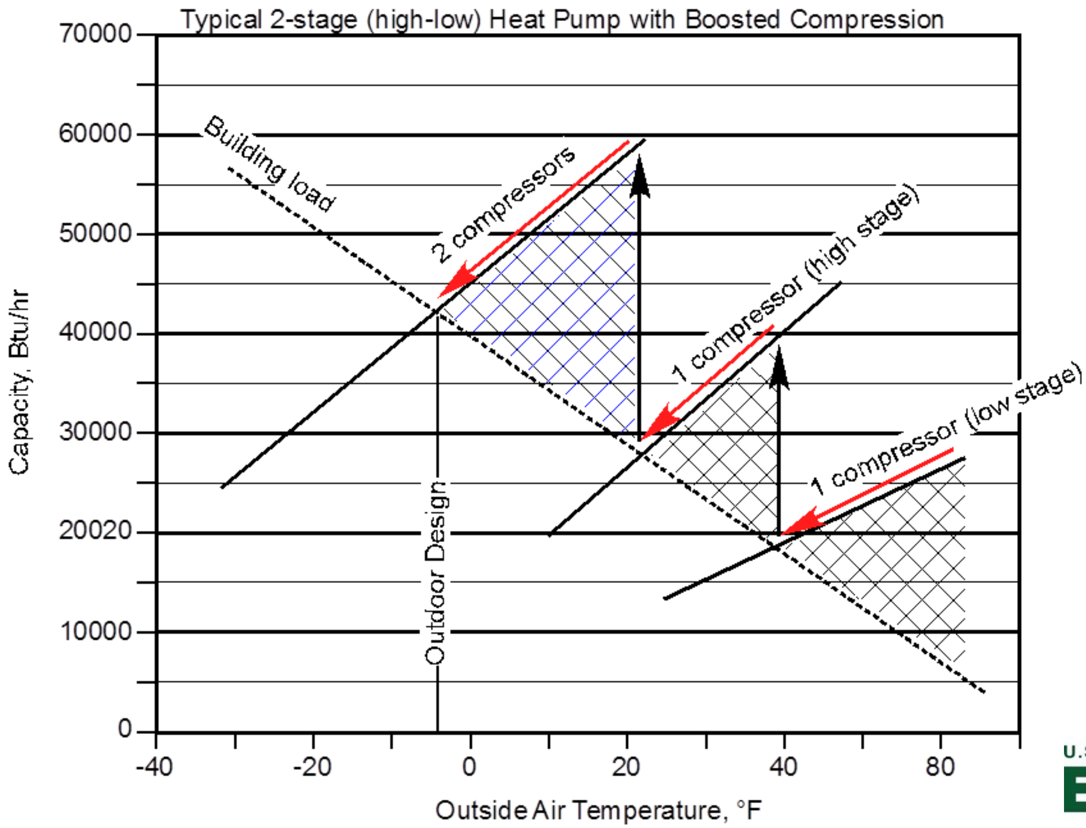
Cold Climate Heat Pumps

Need better COP and capacity, need a “Boost”. How?

- Oversize the compressors
- Use multiple compressors in series

This creates a problem in cooling – need capacity control

- allows sizing for HEATING, not COOLING



Project Scope

Develop and commercialize a heat pump that achieves a higher than normal COP for residential buildings as an alternate to systems that heat with fossil fuels (e.g. gas furnaces). The heat pump has the following goals:

Compared to state-of-the-art systems using the same fuel, these systems will achieve, in the long term:

1. Acceptable reliabilities, maintenance intervals, and life expectancies
2. Similar levels of product safety
3. Simple payback of 5.0 years
4. Performance of

Outdoor Temperature, °F (°C)	Capacity, Btu/hr (kW)	COP (W/W)
+47 (+8.3)	+36000 (10.5)	4.0
+17 (-8.3)	90%	3.5
-13(-25)	75%	3.0

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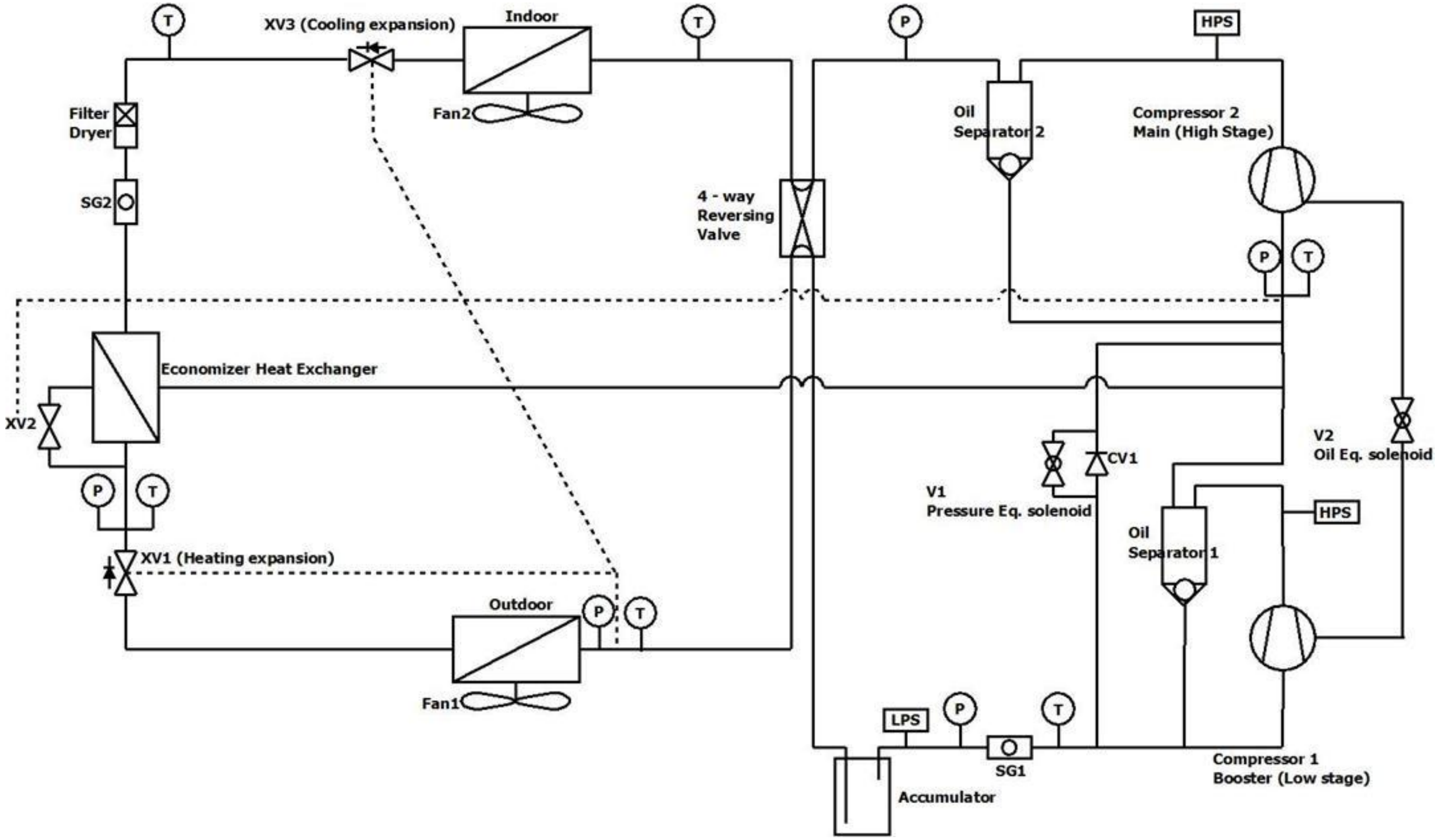
The Technology (Initial)



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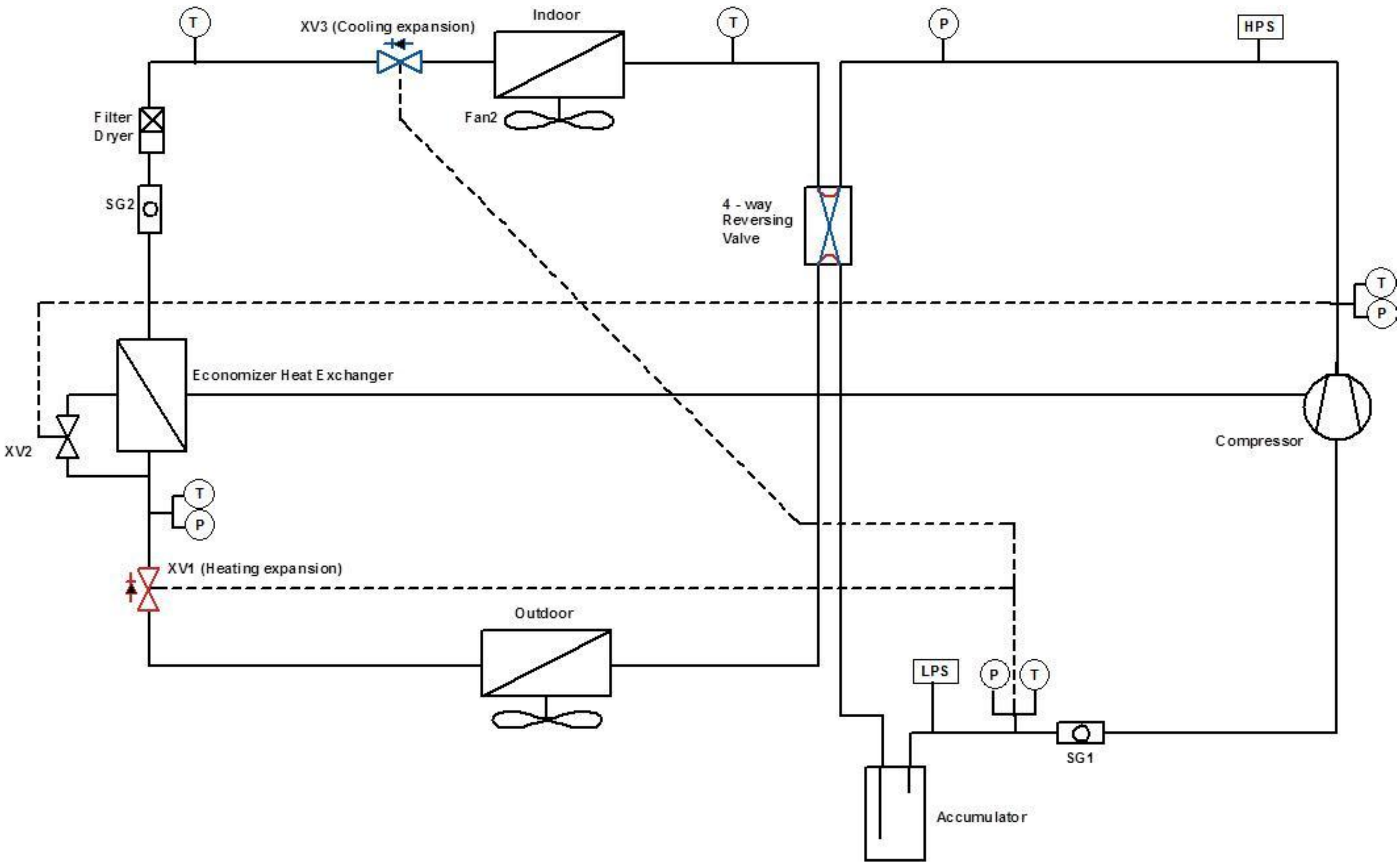
The Technology (Next Generation)



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Unico CCHP Test Chamber

Chamber Specifications:

- Unit Under Test Capacity: 6-ton heat pump
- Outdoor: -30F/10%RH to 120F/95%RH
- Indoor: +30 to 120F/95% RH

Process equipment:

- (x4) 4.5-ton Chillers – bank of 4, 18 ton capacity
- 200 gallon Chilled water storage tank
- 95 GPM variable speed pump
- (x3) 10 kW Electric Heaters
- Med temp 1.5 ton refrigeration System (+10 to +30 F)
- Low temp 2.5-ton refrigeration system (-30 to +10F)
- 120 lb/hr steam humidifier
- (x6) Unico SDHV with variable speed blowers

<u>IOTech DAQ System</u>

(112) T/C Channels
(14) Isolated T/C Channels
(32) 4-20mA inputs
(48) DIO Channels
(8) 4-wire RTD inputs
(8) Relay outputs
(4) 4-20mA output
LabVIEW software for control

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Project Summary

Timeline:

Start date: March 1, 2013

Planned end date: February 28, 2016

Key Milestones

1. System Design;
2. Lab Prototype;
3. Market and risk analysis;
4. Field Trials

Key Partners:

ORNL	
Purdue	
Emerson Electric	
Invention House	

Budget:

Total DOE $ to date: 991,028

Total future DOE $: 1,008,972

Project Goal:

To develop and commercialize an energy efficient residential heat pump optimized for extremely cold climates.

Target Market/Audience:

Electric utilities supplying to homes and business that would benefit from a heating system that can compete with fossil fuels in terms of efficiency and comfort.

Purpose and Objectives

Problem Statement: Heat pump technology is an efficient method to heat but the capacity and efficiency of existing heat pumps degrades significantly at cold temperatures. This project seeks to develop and commercialize a heat pump that maintains at least 75% of its rated capacity down to -13F with a COP of 3.0.

Target Market and Audience: The product will be designed for both new and existing residential homes in the northern USA and Canada currently heated with fossil fuels. This is a large number of homes. For example, there are 4.4 million homes in the Northeast region heated with fuel oil and 500,000 heated with bottled LP gas.

Impact of Project: This project will bring a new 4-ton heat pump to the market that is compatible with a traditional indoor air handler (fan-coil unit).

Monitored metrics

1. Modeling, development, manufacturing, marketing, product release
2. Identify markets and establish incentives and sales growth
3. Grow market share, continue and refine and augment the product line.

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Approach

Approach: Model, build, test a unit that meets the project objectives. Establish and implement marketing and manufacturing plan to commercialize the product.

Key Issues: Refrigerant oil management, software, and components. Refrigerant oil management affects the reliability of the compressors; Software algorithms for defrost and compressor are critical to performance; Component selections are critical to performance and manufacturability.

Distinctive Characteristics: Use a unique oil management system utilizing oil separators, equalization valves, and software; design software to independently control the outdoor unit (compressor speed/capacity, expansion valve position, and fan speeds) to optimize performance based on temperatures for any compatible indoor unit; leverage existing vendor relationships to optimize components for performance.

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Progress and Accomplishments

Lessons Learned: The time required to build a viable cold climate chamber is significantly longer than we anticipated. Two compressors in series represent a significant risk.

Accomplishments: The first prototype using two variable speed compressors achieved the capacity requirement in the SOPA. The next two prototypes with two-stage compressors increased capacity and slightly improved efficiency.

Market Impact: We are actively searching for a single compressor solution to decrease cost and market liability risk.

Awards/Recognition: The DOE recognized that the second year resulted in a positive response to move forward to budget period three with a modified SOPO.

Project Integration and Collaboration

Project Integration: As an established HVAC manufacturer allows us to seamlessly coordinate with key vendors to design and build a heat pump.

Partners, Subcontractors, and Collaborators: Our partners include

- **ORNL** performing the system and component modeling under a separate CRADA
- **Purdue University** patent on oil management for cold climate heat pumps, and contracted them for technical advice; Unico purchased the rights
- **Emerson Electric** providing customized compressors and technical advice specific to our cold climate heat pump technology;
- **Invention House** developing the electronics and software, well established experience with variable speed technology and strong track record delivering results for Unico

Communications: Presentations to building professionals, architects and engineers, preparing the market for a future product launch

Next Steps and Future Plans

Next Steps and Future Plans:

1. Technical
   1. Find market-ready single-compressor solution (most likely vapor injection)
   2. Revise development (lab) and validation (field trials) plan accordingly; expand field trials to minimize risk
2. Business Development
   1. Create initial marketing and website for interested stakeholders to review.
   2. Meet with interested stakeholders and potential partners including utilities and governmental agencies
   3. Form partnerships with the above for further development, future sales, and future development of sales and distribution at the commercialization stage of the project

Project Budget

Project Budget: The original total budget was $2.0M from DOE and $0.825M from Unico.
Variances: Funding was reallocated accordingly to support complex controller development and field trial test unit manufacture
Cost to Date: To date DOE expended $991,028 and Unico expended $402,512

Additional Funding: None

Budget History					
March 1– FY2013 (past)		FY2014 (past)		FY2015 – Feb 28, 2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
507,537	149,419	483,491	233,679	1,008,972	441,902

Project Plan and Schedule

System modeling showed that 2-stage compressors have nearly same performance as variable speed with lower cost but still higher cost than market would accept. Oil management and two compressor complexity presents a high market risk. Decision was made to search for a more reliable technology to reduce product risk. Vapor injection single-compressor appears promising and is being explored.