Industrial Heat Pumps

U.S.A. Perspective

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EPRI’s Vision
To be a world leader in advancing science and technology solutions for a clean energy future

EPRI’s Mission
Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Together…Shaping the Future of Energy®
Three Key Aspects of EPRI

**Collaborative**
Bring together scientists, engineers, academic researchers, and industry experts

**Independent**
Objective, scientifically based results address reliability, efficiency, affordability, health, safety, and the environment

**Nonprofit**
Chartered to serve the public benefit
EPRI’s History in Industrial Heat Pumps

Started in the 1980s!
EPRI’s History in Industrial Heat Pumps (Continued)

The Challenge: Simplifying Operations in Petroleum Refining

In the 1990s, EPRI documented significant opportunities to improve efficiency in the refining industry by replacing steam with heat pumps. Steam is a traditional energy source in refineries, but it is inefficient and can be costly. Heat pumps, on the other hand, can operate more efficiently and provide a cost-effective solution. EPRI's work focused on demonstrating the feasibility of using heat pumps in refining processes, which could lead to significant energy savings and reduced emissions.

The Conventional Way

In the early 1990s, refineries used steam to heat various processes and equipment. Steam is generated from water that is heated, converted to steam, and then used in various applications. This process is energy-intensive and can be costly. Steam is typically used for steam-driven turbines, steam turbines, and steam generators, which are essential for generating power and driving machinery.

The New Way

Heat pumps, on the other hand, use a different approach. They use a refrigeration cycle to transfer heat from one location to another. This process is more efficient than using steam, as it requires less energy to transfer the same amount of heat. Heat pumps can be used for various applications, including heating, cooling, and industrial processes.

The Benefits

Heat pumps offer several benefits over steam. They are more energy-efficient, require less maintenance, and are more flexible in terms of application. Heat pumps can be used in a variety of industrial processes, including distillation, evaporation, and heat recovery. They can also be used for chilling, freezing, and dehumidification.

The Results: More Work for Less Energy

Heat pumps are more energy-efficient than steam, which means they can do more work with less energy. This can lead to significant cost savings for refineries. By replacing steam with heat pumps, refineries can reduce their energy costs by up to 70%.

The Importance of EPRI's Work

EPRI's work in the 1990s was important because it demonstrated the feasibility of using heat pumps in refining processes. This work helped to pave the way for further research and development in this area. Heat pumps have since become a more common solution in the refining industry, and their use is expected to continue to grow in the future.
Pinch Analysis – Appropriate Placement of Heat Pumps

- Minimize heat loss by thermal energy optimization technique
- Matching hot streams with cold streams via optimum heat recovery
- Minimize reliance on external energy inputs
- Pinch temperature (where heating and cooling curves come close together) defines an industrial site’s unique heat distribution
- Pinch Analysis also provides amount of waste heat that can be recovered by IHPs

EPRI and US DOE Championed “Pinch Technology” in 1990s

Source: EPRI Report CU-6775
Some IHP Successes in the US

High End Cabernet Estate Winery Facility located in Alexander Valley California
First New Commercial Winery in the World to Achieve LEED Platinum Certification!
Water Source CO₂ Heat Pumps provide Hot Water for Winery DHW/Tank/Barrel Cleaning
and Chilled Glycol for Barrel Room and Tank Cooling

(2) UNIMO ww units installed in Mechanical Room

Courtesy of Mayekawa MYCOM
Other Installations in the US

Kraft Foods relies on industrial heat pump for sustainable operations

**Result**
- Annual operating savings of $382,467
- 16,000,000 gallons of water saved annually
- Waste heat recovery of 7.8 MMBtu (6.1 MW)
- 6.1 COP (coefficient of performance) for ammonia
- 4.22 COP for performance (water)
- Ammonia refrigerant used
- 1% higher efficiency than comparable technologies
- Design for >20 years service without costly maintenance

**Application**
Heating and cooling industrial heat pump plant using heat extracted from refrigeration for energy saving heating and cooling systems.

**Customer**
Kraft Foods plant in Davenport, Iowa.

**Challenge**
The Kraft Foods plant in Davenport, Iowa, made significant investments in energy savings through refrigeration. With a focus on energy savings, the plant installed high-efficiency boilers and improved the operation to recover the boiler stack heat. Yet, the many food processing plants, Kraft Foods was paying for electricity to recovering heat from their refrigerated spaces with an ammonia refrigeration system and rejecting that heat into the atmosphere. Also, they were paying for natural gas to add heat to hot water used for the hygienic cleaning of the plant.

“...The heat pump automatically responds to varying operating conditions for the ammonia and hot water. There is very little input needed from the operators. Maintenance requirements are really no different than what is already required for existing compressors, vessels and heat exchangers. Between the boiler stack gas heat recovery and the heat pump, we no longer use the conventional hot water heaters on a daily basis.”

Don Stroud, Infrastructure Program Manager, Kraft Foods

Ref – Emerson Website

Ref – AMI Foundation Conference 2012
Next Frontier – Steam Generating Heat Pumps

Photo – EDF Lab, France
EPRI Project: High temperature heat pump that can produce steam at low pressure

- Key characteristics of the heat pumps:
  - 30 kW prototype system
  - Low ODP, GWP refrigerant
  - Develop prototype system produce steam at 120°C from waste heat (80°C) @ COP of 3.4
  - Test in a lab in California; make it ready for field deployment
  - Offer solutions for industrial decarbonization in California and Nation

Project funded by California Energy Commission – Ongoing
Photos of the 30kW prototype system

HP Prototype System

Prototype Showing Monitoring Instrumentation

Prototype Showing Controllers and ASDs
Prototype Testing Results

Key findings from the tests:

- Coefficient of Performance (COP) has an inverse relation with system speed, a direct indicator of system load.
- Higher load (capacity) or compressor speed results in lower COP values.
- Two refrigerants performed the best:
  - R1233zd[E]: Higher COP, but has ODP
  - R1336mzz[Z]: Lower COP, no ODP
- System should be optimized to obtain the target COP>3.4 or greater.

Next Steps – EPRI Lab Tests + Field Tests
Utility Incentive Programs – California Example of TSB

CPUC has initiated the application of a Total System Benefits (TSB) approach to address the following:

- **Comprehensively capture fuel switching benefits and environmental benefits**
- Include other high value but non-monetized benefits
- Other system benefits

Starts in 2024 – Other States May Follow Soon
Heat Pumps and the Grid – A Consideration

Top barriers to Heat Pumps at scale that must be addressed:

- Power availability
- Power reliability
- Grid interconnections
- Grid readiness

Some Enabling Actions

- Ensure utilities (and regulators) are in lock-step with technology developers, OEMs, and consumers
- Optimize systems and processes that support the pace of activity/investment required
- Develop needed tools and technologies that enable HP scale and (perhaps) capture the grid benefits of HPs

Customers and Utilities Need to Work Together!
Industrial Heat Pumps – Needs

- Document Status of Current Applications
- Focus on Technology Development
- Apply Technology to Several Applications
- Conduct Case Studies and Technology Transfer
- Utility and Government Incentives
- Collaboration between all Stakeholders
Thank You!

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