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Phase-Change Heat Storage System Cuts Energy Input for Paper Drying by 14 Percent

In 2005, the Kruger pulp and paper mill in Bromptonville, Quebec, a producer of newsprint and recycled fibres, took part in a pilot project to improve the energy efficiency and humidity control of one of its paper machines. During the project, Groupe Énerstat Inc. integrated its Novanergy® thermal energy storage (TES) system with a paper machine to dehumidify and re-circulate a portion of the machine's ventilation air. The system stabilized the operation of the paper machine, improved the environment for workers in the mill, reduced greenhouse gas emissions and saved energy.

The Problem

Without dehumidification, the humid ventilation air exhausted from the paper drying process could not be recycled to the paper machine. Variations in the drying process would have made it difficult to efficiently dehumidify the exhaust air with a conventional dehumidification system. Furthermore, without dehumidification, humid ventilation air accumulated in the headspace of the paper machine room where the moisture in the air condensed and dripped on workers and equipment below.

The Solution

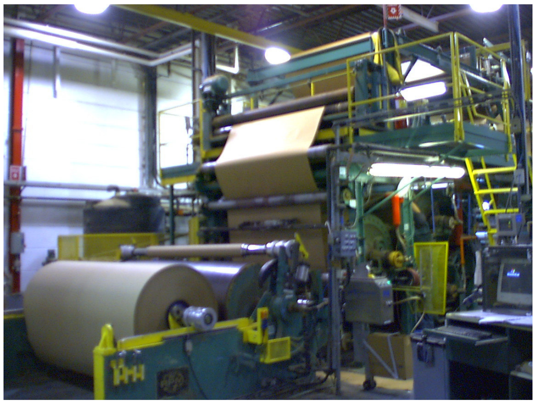
Coupling of a phase change thermal storage (PCTS) system to a mechanical dehumidification unit made it possible to efficiently dehumidify and re-circulate a portion of the ventilation air exhausted from the paper machine. The PCTS system stabilized the operation of the compressor in the dehumidification unit by storing heat from the dehumidification process when there was reduced demand for heat and by providing heat from storage when the dehumidification process could not meet heat demand. The PCTS acted as a buffer or "thermal battery" which enabled the compressor to run continuously at full capacity where it was most efficient.

In the PCTS system, thermal energy was stored in phase change materials (PCMs), which absorb and release large quantities of heat per unit volume at constant temperature when they change from the liquid to solid phase or vice versa. A PCTS system containing a synthetic PCM that changed phase at a temperature that was optimum for the dehumidification process was specially developed by Énerstat for the project.

The Components

The Novanergy system integrated with Kruger's paper machine, consisted of:

- a hermetically sealed reservoir containing Énerstat's synthetic PCM and a thermal fluid-to-PCM heat transfer coil;
- a packaged refrigeration screw compressor unit with a liquid heating evaporator and a liquid cooling condenser;
- a special non-corrosive coil to dehumidify recycled air and remove particulate matter;
- heat exchangers to preheat ventilation air and to preheat process water;
- process piping and pumps to circulate thermal



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fluids consisting of water in the heating (hot) loop, and a water and glycol mixture in the dehumidifying (cold) loop;
- ducts and dampers to re-circulate a portion of the exhaust ventilation air; and
- a programmable logic control system.

The Process

The paper machine's ventilation system was reworked to re-circulate up to 35% of the exhaust air to the ventilation air intake. A special dehumidification coil with a wide fin spacing, which could be washed down periodically to remove accumulated particulate matter, was installed in the return air duct. The dehumidification coil and the heat transfer coil in the PCTS reservoir were piped via a cold loop to the evaporator of the refrigeration unit. The condenser was piped via a hot loop to an air preheat coil located in the ventilation air intake and a coil in one of the plant's process water loops.

By manipulating valves in the process piping, a glycol/water thermal fluid could be circulated from the evaporator through the storage system, or through the dehumidification coil, or both. The TES system stabilized and maintained the thermal fluid temperature low enough to condense moisture from the recycled exhaust air when the fluid was pumped through the dehumidification coil. When the available energy in the re-circulated ventilation air fluctuated, the system was able to quickly switch between storage and recovery modes to maintain heat supply to the hot loop.

The programmable logic control panel was integrated with Kruger's existing control system and operated all system components and monitored operating parameters and environmental variables. To ensure maximum performance under severe conditions and to manage the TES, Énerstat developed control algorithms that responded to fluctuations in operating conditions and paper production patterns.

The Results

Energy consumption of the paper machine ventilation system before and after installation of the TES system was compared to estimate energy savings. Components of the energy balance were:

- latent heat energy recovered from the recycled pocket ventilation air and transferred as sensible heat to preheat the pocket ventilation air and the process water;
- sensible heat energy input avoided by not having to heat fresh air to the outside air temperature to match the recycled air temperature at the pocket ventilation system's inlet; and
- electrical energy input to operate the heat pump system.

The results of the pilot project confirmed that the TES technology can significantly reduce energy consumption and greenhouse gas emissions by a paper machine:

- The projected net annual energy recovery from ventilation air for Kruger's paper machine was 11,300 GJ, a net annual energy savings of approximately 14% for the paper-drying process.
- Assuming 75 percent efficiency of steam generation with natural gas, the system would save 19,022 GJ of natural gas per year. This savings, less electricity input, comes to a net energy savings of 16,055 GJ per year.
- The net reduction of greenhouse gas (CO_2) emissions based on natural gas and electricity consumption was projected to be 741 tonnes per year.
- With ventilation air and process water preheating, the system achieved a coefficient of performance (COP) (the ratio of useful energy recovered to the electrical energy input) of more than 6.5 on a seasonal basis.

Assuming a cost of $6/GJ for steam, an electricity cost of $0.027/kWh and an implementation cost of $150,000, the simple payback of the system was less than 2.5 years.

Project Funding

NRCan's, Emerging Technologies Program	$100,000
Groupe Énerstat	$136,725
Kruger	$63,225

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