Energy Audit Uncovers Major Energy Savings for Paper Mill

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ABSTRACT

Energy and financial savings are presented through the results of a recent Stora Enso North America – Stevens Point Paper Machine No. 34 (PM34) dryer section feasibility study and rebuild. The project, funded partially by the Wisconsin Focus on Energy program, increased the effectiveness of the paper machine's dryer section through an improved dryer drainage system, the reduction of uncondensed steam and the addition of differential pressure controls. Improvements in energy efficiency were carefully documented to demonstrate significant reduction of energy use and increases in production achieved during each phase of the rebuild. This paper tracks the results from the dryer section feasibility study through the installation of the Dryer Management System™ control software. The four-step approach is discussed as follows:

- Dryer Section Feasibility Study. This audit quantified the potential energy savings and outlined a plan to upgrade the dryer section.
- Phase 1 – After Section Rebuild. Steam system modifications and equipment upgrades were made to the after section.
- Phase 2 – Pre-dryer Section Rebuild. Modifications similar to those made to the after section were continued in the pre-dryer section.
- Phase 3 - Dryer Section Rebuild. The final stages of the project included the installation of new valves, transmitters and a complete supervisory control system.

The paper describes the upgrade and details the benefits of each phase. The energy use and paper production in March of 2005 are compared to the same information from March of 2004. Observed benefits include energy savings of 4,500 pounds per hour of steam and improvements in machine production, runnability and paper quality. The expected financial benefits of the rebuild are estimated to be $300,000 annually. Production increases of up to 20 percent are also possible.

Introduction

Wisconsin is the No. 1 papermaking state in the nation and has held that status for 50 years. More than 5.3 million tons of paper and 1.1 million tons of paperboard are produced in Wisconsin annually. The value of the shipments from Wisconsin paper companies tops $12.4 billion annually. Of the 72 counties in Wisconsin the paper and forest products industry is the largest employer in 28 of them. Fourteen other counties rank paper and forest products as one of their top three employers. In 1980 there were 35 paper companies in Wisconsin. Today, there are 28, including Stora Enso North America (formerly Consolidated Papers, Inc.). [WPC] Since the late 1990s, paper supply has been brought in line with demand by shutting down old, inefficient operations. According to Fisher International, 21 machines in Wisconsin have been shut down since 1999.

Breaking down wood into small particles called fibers is the first step in the papermaking process. These fibers are reformed to make a sheet of paper, which then has a variety of chemicals and materials added to it in order to reach desirable properties for processing. Large amounts of water are used in the transportation of fibers from the pulp mill to the paper machine. This allows for easy mixing of the added chemicals and other raw materials. The mixture is then dried from a concentration of 98 percent water to about five percent. At this point the paper is converted for a variety of uses, such as coating for food packaging or postage stamps.

A paper machine measures about 250 feet long and is made up of two major areas. The first section, called the wet end, consists of the wire and press sections and is about one-third of the total machine length. The solution of fibers, chemicals and other raw materials is poured onto a fine, moving mesh in the wire section to form a "sheet" of paper that is 14 feet wide. The solution allows water to freely flow through the wire mesh and water continues to be removed as the sheet travels through the mechanical squeezing process in the press section. This part of the machine removes 50 percent of the water and uses a relatively small amount of energy. The sheet of paper spends less than 10 seconds in the wet end.

The rest of the moisture is removed in the dryer section by evaporation, which can require 10 to 15 times the energy that it took to remove water in the wet end. Because the paper wraps partially around the 22 dryer cans stacked one above the other, this section occupies over 60 percent of the space of the entire paper machine. The sheet of paper is in the dryer section for about 18 seconds. The energy spent here is the focus of the modifications being addressed in this paper.

In steam-heated dryer cylinders, energy from the steam is transferred to the sheet of paper. In giving up its energy, the steam forms a layer of condensate, which must be kept to a minimum in order to maximize heat transfer. Syphon equipment removes condensate from the cylinder, as uncondensed steam pushes condensate out of the dryer through the syphon pipe. This uncondensed, or "blow-through," steam is a significant source of energy waste in the process of papermaking. To make it more difficult, as the paper machine increases production, the speed of the sheet increases and the rotational speed of the dryer cans also increase. This makes it harder to remove the condensate from the outer dryer shell when using rotating syphons, due to centrifugal force causing the condensate to push away from the axis.

While the function of steam-heated dryers and their role in the papermaking process is at the heart of this paper, it is also necessary to look at the technology push and funding behind this project. In 2001 all Wisconsin public utilities turned over control of their demand-side management dollars to the state, which began administering the Focus on Energy program. Focus on Energy is a public-private partnership offering energy information and services to gas and electric customers throughout Wisconsin. The goals of this program are to encourage energy efficiency and the use of renewable energy, enhance the environment and ensure the future supply of energy for Wisconsin.

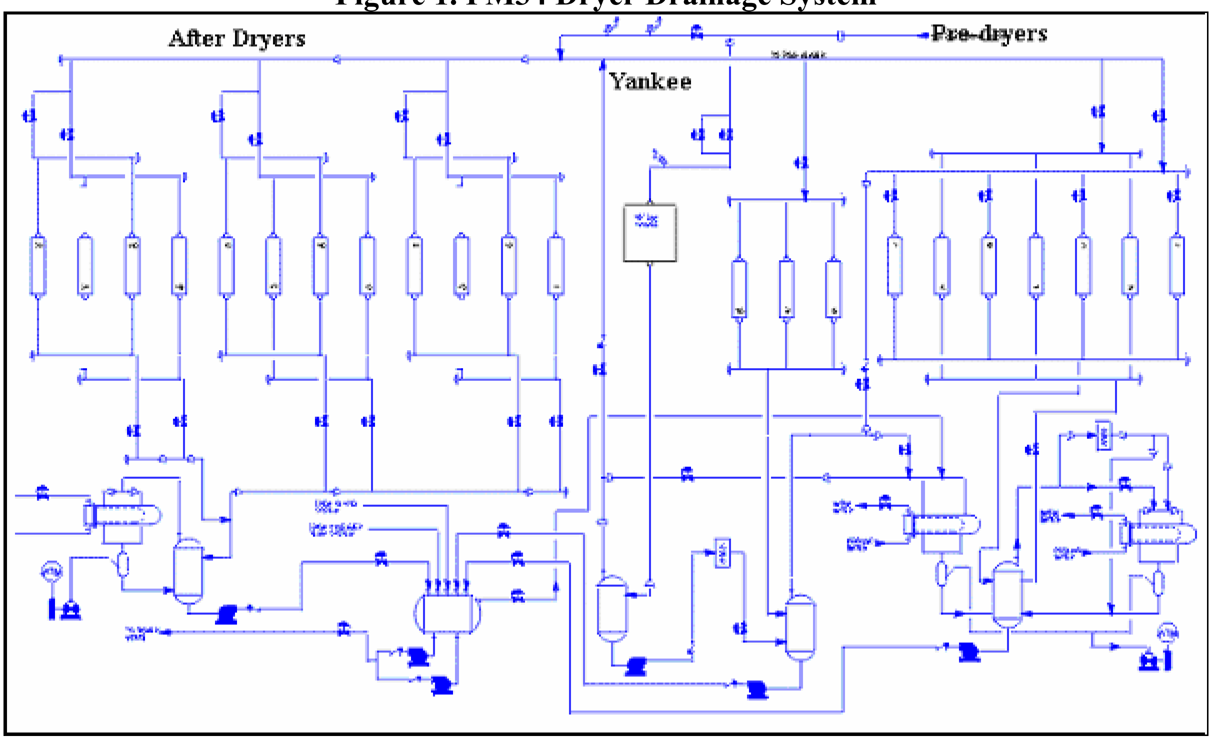
Focus on Energy's Best Practice provides specialized support for the pulp and paper, metal casting, plastics, food/dairy and water/wastewater industries. These services improve the energy efficiency of manufacturing processes. Services include walk-through audits, project evaluation assistance, measurement and evaluation of savings, financial assistance for stalled projects, training opportunities, tools to manage energy and third-party reviews.

The Project

In May 2002 Stora Enso North America – Stevens Point requested that Focus on Energy assist in the funding of a dryer section feasibility study of Paper Machine No. 31 (PM31). This energy audit identified substantial savings. As the projects on PM31 were being implemented, the paper machine superintendent requested an audit for PM34.

Stora Enso North America – SP PM34 was built in 1989. Its specifications include a Yankee dryer and three on-machine coaters. The reel trim is 165” and runs at 1,150 to 2,500 feet per minute. The machine produces coated specialty papers with a machine glaze. Figure 1 shows the distribution of PM34’s 22 dryer cans. The pre-dryer section contains 10 dryer cans leading into the Yankee dryer, an oversized dryer that adds a shiny surface to one side of the paper. Following the Yankee dryer, the 12 remaining cans are evenly divided between three coaters in an area called the after section.

Figure 1. PM34 Dryer Drainage System



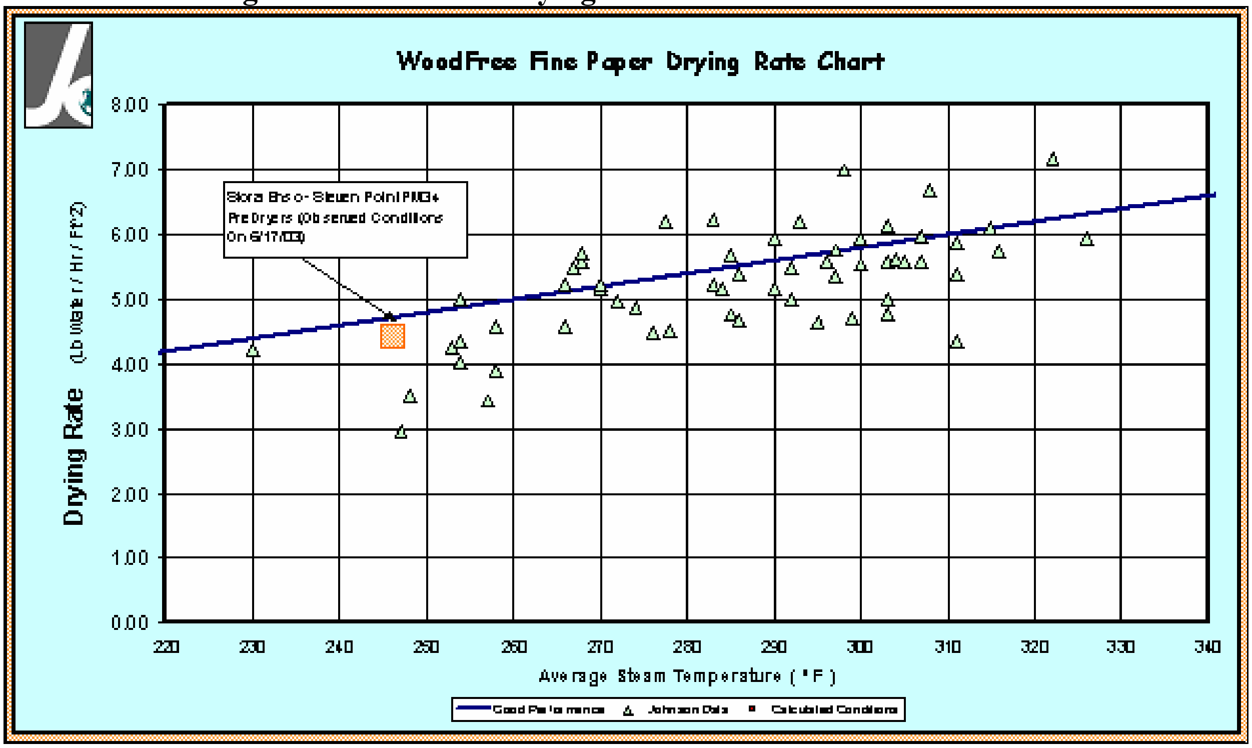
Source: Johnson System Study, 2004

The feasibility study identified changes necessary to reduce energy waste by utilizing uncondensed steam in both the pre-dryers and after dryers. As part of the rebuild that resulted from this study, 17 dryer cans were refitted with stationary syphons and new steam joints. The remaining five cans have their steam valves shut off and are wasting no energy. Control valves were added to regulate the amount of blow-through steam and piping changes were made to re-use the steam at a lower pressure. Prior to this rebuilding project the steam was piped to a condenser with little or no control over its flow through the dryer cans.

Dryer Section Feasibility Study

In May 2003 Focus on Energy responded to the request from Stora Enso North America for assistance in funding a thorough evaluation of PM34's dryer section. This week-long study, conducted by the Johnson Corporation, provided measurements to evaluate the present drying efficiency of the machine and identified specific improvements.

Figure 2. Calculated Drying Rate for PM34 Prior to Rebuild

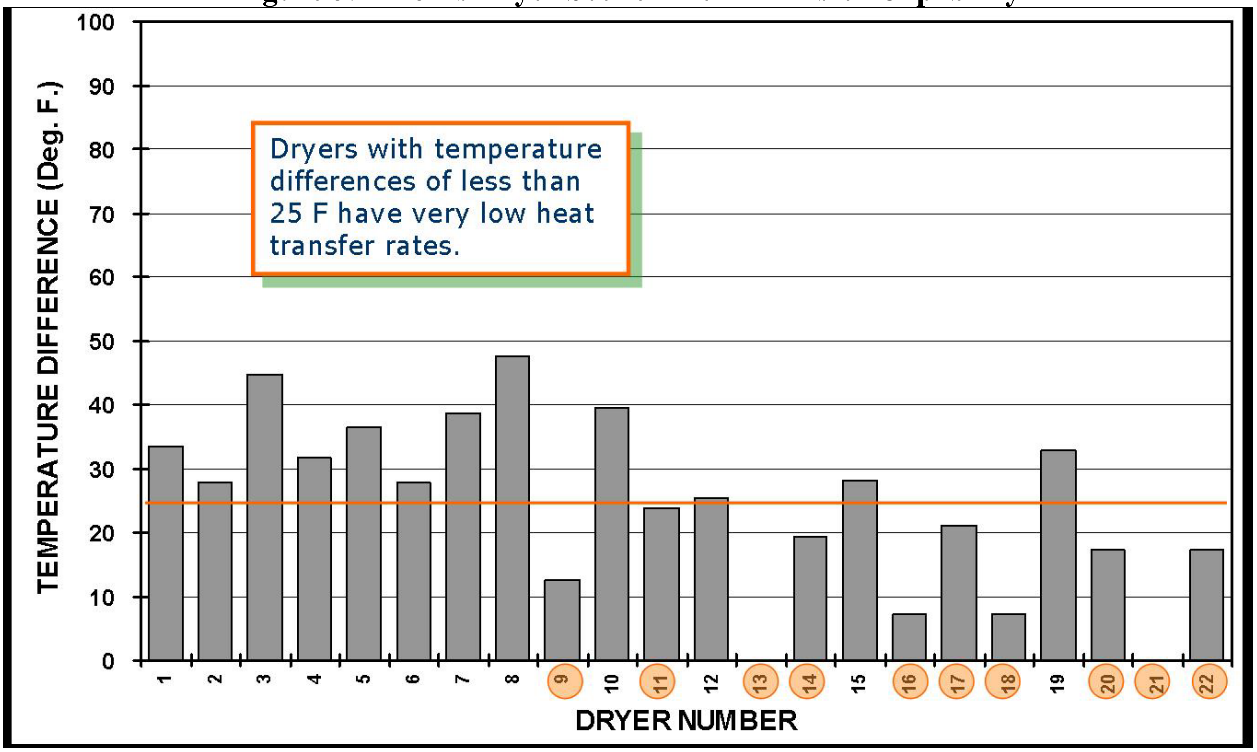


Source: Johnson System Study, 2004

Figure 2 illustrates the drying rates of various wood-free fine paper grades as well as the drying rate for PM34, calculated with on-machine measurements. Labeled in pounds of water evaporated per hour per square foot of surface, the drying rate shows the effectiveness of the dryer in removing moisture from the sheet of paper. [JS]

Each triangle represents the results of one machine studied, with machines performing above the solid line having better performance than the others. By identifying the relationship between the steam temperature and the drying rate, the graph shows PM34's potential for improvement. The dryer section feasibility study also defined a roadmap for realizing this potential.

Figure 3. PM34's Dryer Section Heat Transfer Capability



Source: Johnson System Study, 2004

Figure 3 shows the difference between the steam temperature and the dryer surface temperature; this is the measure of each dryer's heat transfer capability. As the condensate thickness increases it is harder to move the energy from the steam to a dryer can, because the condensate layer acts as an insulator. The lower the value in Figure 3, the less contribution the dryer makes in drying the sheet. Projected steam savings were estimated to exceed 4,500 pounds per hour.

The Johnson Corporation study discovered that some dryer cylinders experience a high blow-through steam flow sending a large amount of steam to the condensers. Inconsistent pressure differentials and dryer flooding were also evident. The system lacked "turn-down" capability, the ability to reduce the steam pressure, which resulted in the sheet being over-dried. This ultimately resulted in overall poor energy performance by the paper machine.

The study's proposed solution included installing cantilevered stationary syphons to eliminate dryer flooding and minimize blow-through steam requirements. These syphons would also allow the system to operate at a lower pressure, minimize differential pressure and provide better control of the dryer drainage system. The installation of Turbulator® bars was also recommended to provide a uniform moisture profile across the shell of the dryer cylinder. Additional modifications to the dryer system would include disconnecting the bottom uni-run dryers and cascading the steam in the dryer section to gain control of the condensers. The final recommendation was to install the Dryer Management System™ (DMS) control software. The Johnson Corporation offered the following benefits on this turnkey project:

- **Steam savings of 4,500 pounds per hour**. These savings were realized by reducing differential pressures and blow-through with stationary siphons and the installation of DMS and its ability to manage differential pressures during sheet-on and sheet-off conditions. [JC]
- **Increased turn-down dryer pressure capability**. This was a result of Turbulator® bar installation and stationary siphons to prevent over drying the paper.
- **No dryer flooding**. DMS provided anti-flooding logic.
- **Piping and equipment will be leak free**. Turnkey installation allowed the Johnson Corporation to guarantee any rework to be done at no added cost to the customer.
- **Trained operators**. Machine crews have passed hands-on testing prior to system startup.

Phase 1 – After Section Rebuild

The after section rebuild included the installation of new steam joints and stationary syphons as well as changes in the steam piping. Stationary syphons replaced the rotary syphons on the dryer cylinders. The re-piping consisted of adding tanks to collect condensate, allowing it to separate from the steam, which was then re-used at a lower pressure. These changes resulted in better drainage from the dryer cylinders and more efficient use of the steam. This change also reduced the condensing load and improved efficiency.

The steam joints and syphons were replaced during normal machine maintenance outages. This allowed for minimal interruption in the production schedule. While the machine was running, installers made the necessary preparations to accomplish the upgrades during the short down time.

Phase 2 – Pre-Dryer Section Rebuild

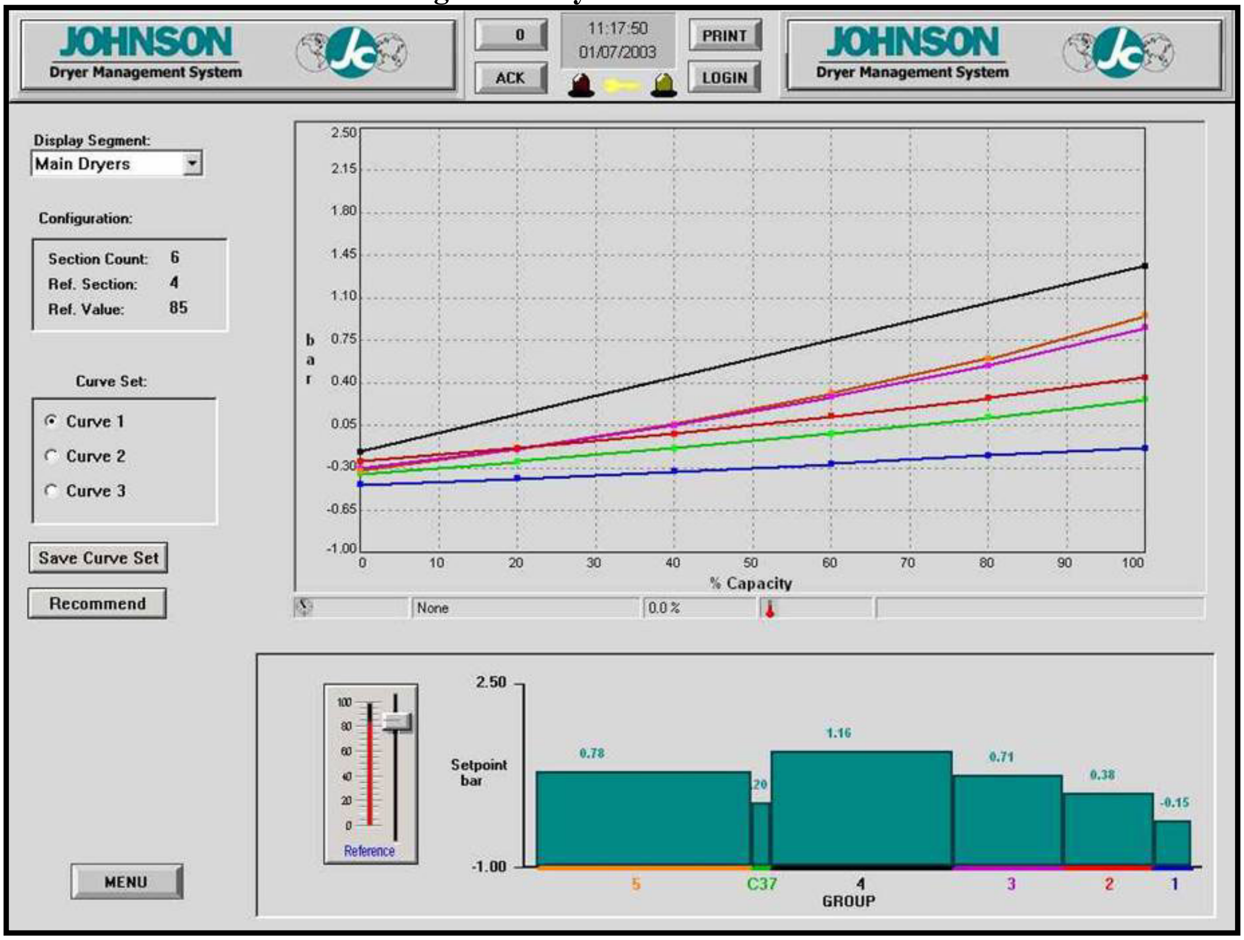
The pre-dryer section rebuild was similar to the rebuilding of the after section. Much of the work was done prior to the regular maintenance outages. The lead-in dryers were designed to accept lower pressure steam and minimize sheet picking, a defect on the paper surface caused by a wet sheet of paper contacting a dryer can that is too hot. This design change gave the operators control over the steam pressure and resulting surface temperatures.

Phase 3 – Dryer Section Rebuild

The final phase took place over a five-day outage. The final joints, syphons and piping changes were completed and new valves, transmitters and the supervisory control portion of the DMS control software were installed.

DMS continually optimizes dryer system set points to improve machine efficiency and steam effectiveness. This control system provides for shorter sheet breaks, faster grade changes and ease of use for the operator. The program control of the dryer system derives from pressure curves that generate the pressure set points for all dryer cans. A curve is customized for each grade of paper produced. The dryer curves are constantly being adjusted according to the moisture remaining in the sheet as it leaves the dryer section.

Figure 4. Dryer Pressure Curves



Source: Johnson System, 2004

The development of pressure curves (see Figure 4) is a key component of the dryer section supervisory control system. The pressure curves determine the relationship between the pressures used in the various steam groups of the dryer section. The pressure curves are developed using drying formulas, which keep the dryer temperature response linear with regard to drying capacity. Linear temperature response, not pressure response, is the key in sheet moisture control. The linear temperature response provides the same sheet moisture control response whether the dryers are operating at high or low pressures.

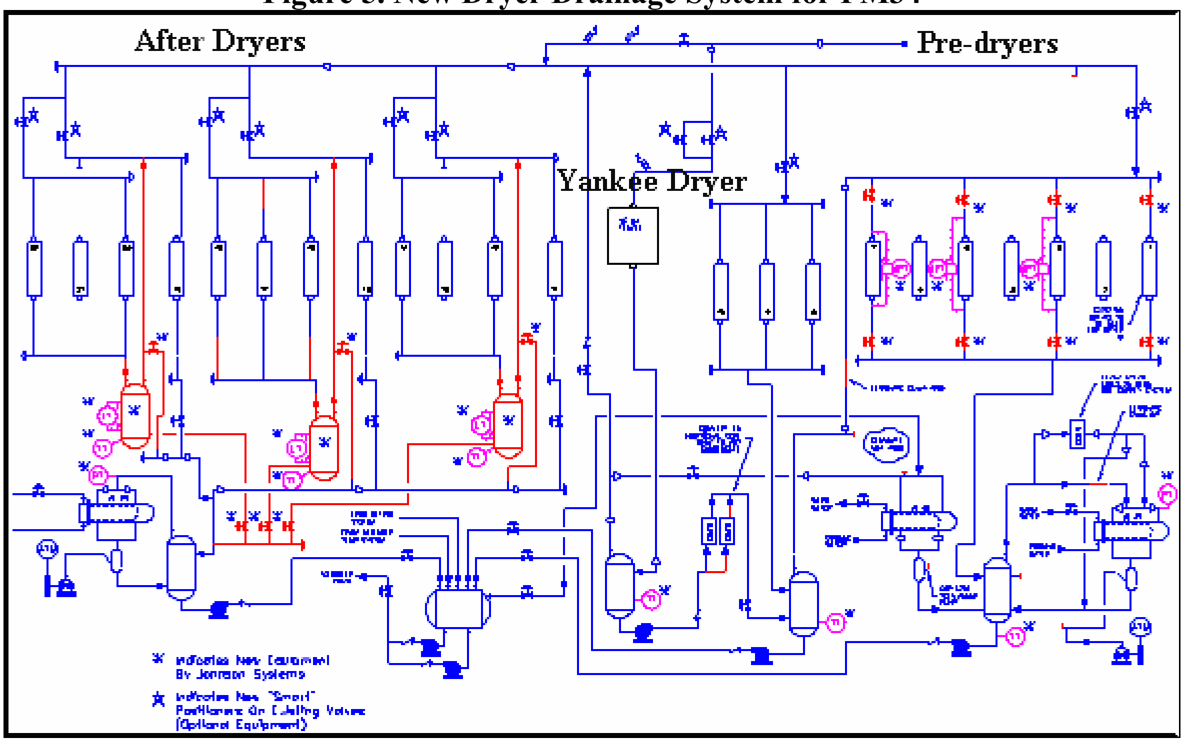
The pressure curves are controlled from the moisture measurements in the dryer section. As the moisture control group pressure changes in response to a change in machine operating conditions, the steam pressures in all control groups change according to a set of pressure curves. The moisture control section is either driven by the machine's moisture gauge or can be manually set by the operators. If the operators choose to manually adjust pressures, they are only required to change the pressure in the moisture control group. All other pressures will be set accordingly by the supervisory control using the pressure curves. With DMS, operators are provided with two buttons: one for increasing drying and one for decreasing drying.

Improved consistency and runnability are the benefits of using pressure curves. Previously, as machine operating conditions changed, each operator chose new set points. The advantage of using pressure curves is that dryer pressure adjustments do not vary when operating crews change. As a machine operator said, “The settings are repeatable and I don’t have to worry about the steam system during an upset.” [CR] The pressure curves are developed to keep the machine-direction moisture constant at each dryer section split. This regulates where the sheet shrinkage occurs, a frequent cause of sheet breaks, and helps to keep the draws consistent as the speed of the machine changes.

The pressure curves are also used to keep the system at the most energy efficient operating point. The system can be kept stable, without venting, over the entire operating range by closely regulating the dryer pressure relationships. The operators can select the appropriate set of pressure curves from those built into the supervisory control system. Because an aggressive drying strategy would be used for heavier weight grades and a more passive drying strategy would be used for lightweight grades, a variety of set points is necessary.

It is important that the pressure curves be adjustable by mill supervisory personnel, who then will have fine-tuning capabilities to create optimal dryer use.

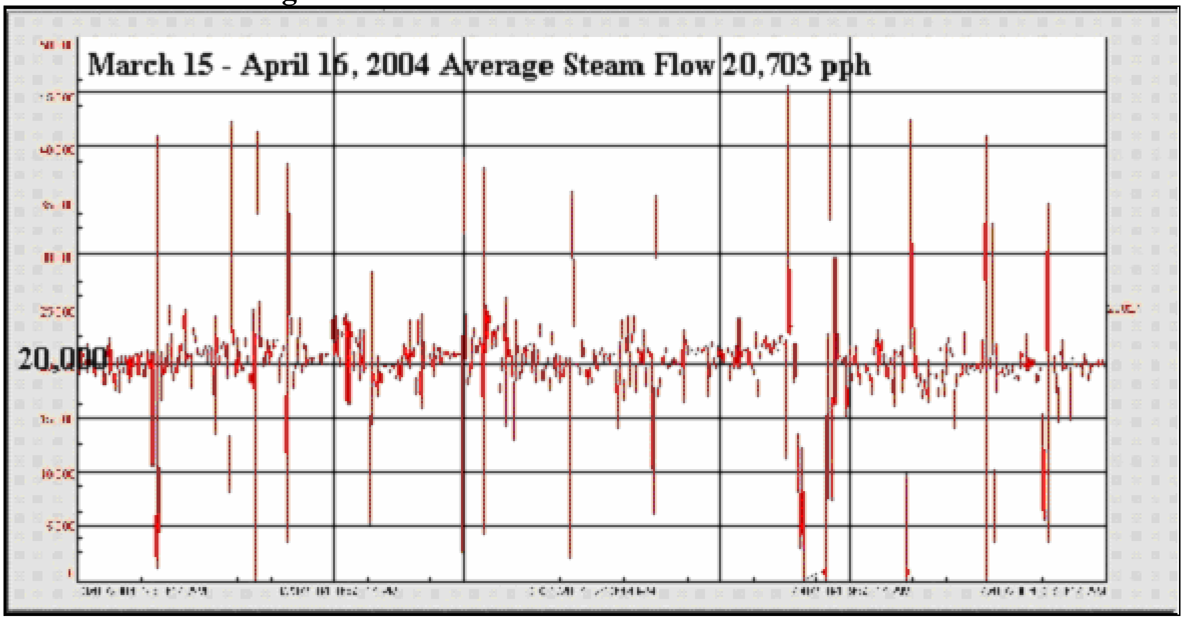
Figure 5. New Dryer Drainage System for PM34



Source: Johnson System Study, 2004

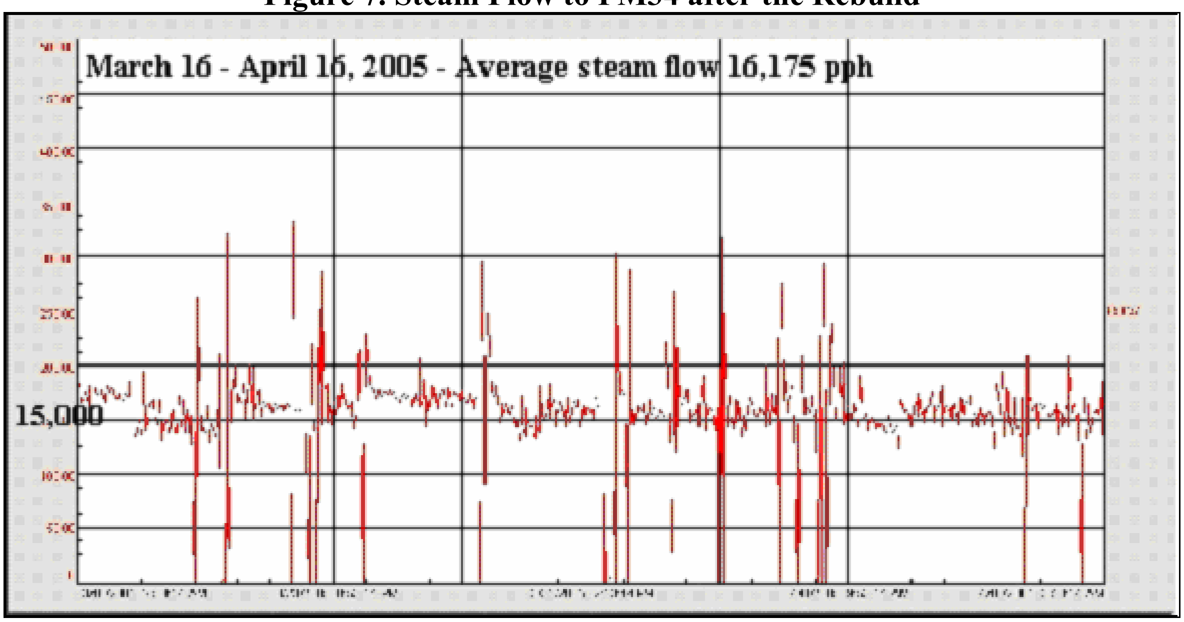
Figure 5 shows the schematics of PM34 after the rebuild. Formerly all of the condensate and entrained steam flowed directly into the condensers. With the piping changes, a by-product called “flash” steam is separated from the condensate in the new tanks, and then fed into lower pressure dryers. This allows for the recycling of steam before it reaches the condenser.

Figure 6. Steam Flow to PM34 before the Rebuild



Source: Stora Enso North America, 2005

Figure 7. Steam Flow to PM34 after the Rebuild



Source: Stora Enso North America, 2005

Figures 6 and 7 show the steam flow to PM34 before and after the rebuild, respectively. The paper machine rebuild resulted in higher production rates (up 4 percent) due to increased speeds and has reduced the amount of steam used in the dryer section by 4,500 pounds per hour. Assuming a cost of $8 per 1,000 pounds of steam, the savings could exceed $300,000 annually. Higher profit from increased production, reduced maintenance costs, dryers not flooding and improved sheet quality in addition to the steam savings make an enticing payback.

Summary

The results of the feasibility study and upgrades made to PM34 have provided considerable energy savings, as well as significant financial savings, to the paper mill. Steam consumption was reduced by 4,500 pounds per hour, which equates to an estimated $300,000 annually, while providing intangible benefits of improved operations due to elimination of dryer flooding and increased turn-down capability.

A leak-free system with a no-hassle turnkey installation was an important benefit to machine supervisors. Operator training and a hands-on approach made for a smooth startup.

The concept of an improved dryer control system is to utilize computer capabilities to provide supervisory management over the steam and dryer drainage systems. Consistent dryer operation is produced over the entire machine operating range and for every machine operating crew. Drying conditions are controlled in a manner that produces consistent machine direction, sheet moisture, constant draws and improved runnability. Upsets, such as sheet breaks, grade changes and wash-ups, are handled efficiently by the dryer control system. The improved machine efficiency has met and exceeded expectation.

Acknowledgement

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