GARDNER SYSTEMS CORP.

ADVANCED DRYER DRAINAGE SYSTEMS:

A RESOURCE FOR CAPITAL RECOVERY

ADVANCED DRYER DRAINAGE SYSTEMS: A RESOURCE FOR CAPITAL RECOVERY

Thomas A. Gardner
President, Gardner Systems Corp
Neenah, WI 54957

ABSTRACT

Installations of advanced steam and condensate systems have greatly augmented the recovery of capital for paper manufacturing for most or all types of paper machines. These new age systems have completely outperformed the old processes. According to recent reports, encapsulated here, the combination of increased drying capacity and machine efficiency obtained by the systems has routinely enabled huge production rate increases of eight to ten percent. At the same time, return on investment for the installations has been secured almost exclusively by steam and condensate savings, quite frequently in less than a year. Furthermore, much of the operational uncertainty related to steam systems has been eliminated. For example, one machine crew reportedly did not see a break for three weeks following a startup. Commonly viewed with concern or outright skepticism, steam systems have been treated like orphans when plans are drawn to update paper machines, but the overall performance record of advanced systems has established their role as basic necessities for high capital return on paper machines.

INTRODUCTION

Production increases on paper machines, regardless of the source, can have a huge effect on net earnings. The effect of production rates on profit and the concept of break-even analysis were presented by MacKinnon (1) who demonstrated that profit is proportional to production rate change, positively or negatively, from a break-even production rate. At current rates of capital utilization in the industry an average paper machine must produce very roughly 75% of its theoretical potential to pay the fixed costs of the entire facility. Mardon et al (2) define absolute efficiency as the tonnes shipped as a percentage of theoretical production in all the hours a mill is open, including maintenance time. The level of absolute efficiency is critical in view of the high fixed costs. An absolute efficiency of 75% is admittedly a rough characterization of the break-even point in view of the great variety of products and their prices but it does convey the gist of the financial problem faced by papermakers. Operation of an average machine at less than about 80 percent does not make much profit for the owner, but raising efficiency from 80 to 90 percent, for example, might well have the effect of tripling profit, regardless of variable cost. Characterized by major investment, complex machinery and processes, and a history of operational difficulties, the dryer part of a paper machine has a major impact on earnings. And of the drying processes, steam controls and dryer drainage are undoubtedly the most critical.

CHAOS IN THE WORLD OF STEAM

Maximum utilization of the dryer part is achieved when the maximum allowable working pressures of the dryers limit production and the dryer drainage systems perform impeccably well. In the real world not much of this happens. Dryer pressures are infrequently limited by the available turbine back-pressure or by boiler limitations but antiquated dryer drainage systems commonly fail to secure potential drying rates and are responsible for countless hours of lost production time. The bad design and disorganized state of these old systems place a heavy tax on the return on investment in paper machines. It is extraordinary that after more than a hundred years of use, steam is still so badly utilized that it imposes major losses in the production and cost of paper.

Losses in drying capacity due to steam system deficiencies occur in several ways: reduction in workable steam pressures, poor internal heat transfer, chronically flooded individual dryers, and overdrying related to non uniform drying and poor control. In some cases, raising steam pressure above some intermediate level causes the dump valve to open and waste steam to the condenser. But the reverse is even more common, that is, lowering pressure causes the dump valve to open. The inability to operate at low pressures in machines producing a wide range of grades not only wastes steam but also increases maintenance because of the need to shut off dryers. Not uncommonly, raising pressure causes separators to fill with water and flood whole sections of dryers. For example, a large corrugated board machine in the Midwest operated for the first dozen years at about 85% of capacity because dryer pressures could not be raised to what are now normal levels without flooding separators and dryers. Poor system configuration, such as the cascade or queer arrangements like the thermocompressor cascade, and cheap relief valves also limit pressure and drying capacity unnecessarily.

Recirculation of condensate in varying degrees is characteristic of old dryer drainage systems with their simple or badly designed separators. Since recirculated water is added to the condensed water, the rate of water flow to the syphon is larger, often perhaps as much as twice the condensing rate. As developed by Appel and Hong (3), the depth of residual condensate varies as the exponent two-thirds of the rate of condensate flow toward a single circular syphon. They also measured the rate of heat transfer as a function of speed and condensate depth in a plain-shell dryer and showed large heat losses with increasing depth in spite of increasing Reynolds number. Thicker layers of rimming condensate have also been shown to dry the edges of the web faster, necessitating overdrying of the web to get more uniform moisture. The effects being cumulative, a deficiency such as a small amount of condensate recirculation can substantially lower drying capacity.

Many operating hours are lost from flooding on breaks. In a typical scenario for a web break, the main section pressure is set down and all the dump valves open to the condenser. The condenser becomes pressurized and backs up drainage from the wet end dryers and they fill with water. Meantime, with no drying load, excess residual condensate is drained from the rest of the dryers, causing them to get hot, too hot to thread up the dryers. When the web is threaded up, steam pressure in the main sections is raised suddenly causing a great gush of condensate, loading the dryers up with water. At high speeds with rotary syphons, individual dryers often do not recover from the flooded condition and fill right up with water. Whatever else, the establishment of on-grade production normally takes a long time.

Control problems like wide dead bands and cycling of pressure that coincides with cycling of residual condensate also take their toll. Both are responsible for overdrying the product that costs dearly in drying capacity and energy. Excess residual condensate compounds overdrying in consequence of its effect on both CD and MD moisture profiles.

Steam and condensate systems are extremely complex and it is not surprising that production people often do not relate the loss of capacity and machine efficiency to the design of the steam system. The corrugated board machine mentioned above is a good example of serious problems that were accepted as the norm by the mill. Many systems designers still base their work on dubious assumptions: that the process is steady state, that condensing rates are uniform, that process equipment functions as envisioned, that condensate does not produce flash steam, and on and on. One chief engineer when informed about advanced systems refused to believe that the claimed performance was possible. The science of steam system design for paper machines has seen truly remarkable advances over the last 30 years, beginning with fundamental understanding of two phase transport and culminating with sophisticated computer programs that simulate operation of systems and equipment.

ADVANCED DRYER DRAINAGE SYSTEM DEFINED

Advanced dryer drainage systems incorporate blow-thru controls (4), certain specially developed proprietary equipment, and design by process simulation. Any design lacking these primary elements cannot turn in the faultless performance that characterizes advanced systems and that makes truly reliable operation of the dryer part possible. In fact it is performance that ultimately defines advanced systems. The following are the key performance features:

1. All sections of dryers must be controllable from lowest to maximum pressures without dumping steam on run or break.
2. Each section of dryers must be independently controllable over its full range.
3. Control of dryer drainage must be totally automatic and never require operator attention.
4. Controls must never operate in dead bands and must never produce significant cycling even when large sections are used for moisture control.
5. Blow-through steam flow must exceed 15% of max condensing load in all dryers to accommodate surges.
6. Syphons must be correctly selected and sized (blow-thru control is especially required for stationary syphons with their flat performance curves, DP vs Blow-through flow).

7. Wet end dryers must be operable at low enough pressures to assure pick free drying without flooding.
8. With few exceptions steam consumption must not exceed 1.2 pounds of steam per pound of water evaporated.
9. Maintenance for erosion losses must be virtually eliminated.

Figure 1 shows the basic building block of an advanced system, a totally independent section of dryers with recycling of blow-through steam by a thermocompressor. In the diagram the use of blow-thru control is obvious (note that differential pressure is measured as well). The special equipment includes correctly selected syphons sized by process simulation to fit the process. A high efficiency radial type separator is absolutely essential for accurate operation of the blow-thru control and for elimination of recirculation of condensate. The thermocompressor is designed by special program to fit all ranges and conditions of operation (incorrect sizing of thermocompressors is a major source of trouble in old systems). Not designated in the diagram, the sizing of pipelines for all conditions by simulation is an important piece of the puzzle. The synergism of all of these special parts underlies the exceptional, clean operation of advanced dryer drainage systems in accordance with the above performance criteria.

RECENT REBUILD HISTORIES

The encapsulated reports about system installations in the following list are not selective, but encompass all of the reasonably complete advanced dryer drainage systems commissioned in a two year period from mid 1996 to mid 1998. A number of piecemeal system changes such as vacuum stations, individual dryers, or corrections to syphons were omitted from the study because they were directed at special local problems and not able to affect production.

Machine A:

- Midwest mill, wide range of on-machine clay coated papers, under 200" trim, less than 2500 fpm, steam system rebuilt in 1997.
- Advanced system rebuild included installation of blow-thru controls, revised control configuration, replacement of thermocompressors, all new radial separator stations, and new syphons and controls on wet end dryers. Wet end dryers operate at 0.0 psi, main sections are operable from 5 to 120 psi, after-dryer sections from subatmospheric pressure to 50 psi. Performance is in accordance with system design specifications.
- Results include 8% to 10% production increase and savings of 15,000 pph of steam with improved condensate recovery. First quarter earnings reportedly exceeded previous year quarter by five times the cost of the rebuild.

Machine B:

- Eastern mill, wide range of sized fine papers, under 150" trim, 1500 fpm, main dryer section steam system rebuilt 1998.
- Advanced system included addition of blow-thru controls, revised configuration, one new thermocompressor, new radial separators, and new vacuum condenser. Wet end dryers operate at -2.0 to 0.0 psi and main section from 5 to 120 psi. Performance is in accordance with design specifications.
- Primary result is a production increase of 10% on heavier grade weights, about three times greater than expectations. Steam savings were not monitored. Return on investment was estimated to be in about four months.

Machine C:

- Midwest mill, on-machine coated offset, etc., under 200" trim, 1600 fpm, main dryer section steam system rebuilt in 1996.
- Advanced system included blow-thru controls, addition of four thermocompressors, three for blow-thru control and one for pressure booster, new radial separator stations, new syphons and controls for wet end dryers, and exceptional amount of piping replacement. The booster thermocompressor is a special feature that raises back pressure steam from 50 psi directly into the last section of dryers at their working pressure of 75 psi. Performance is in accordance with design specifications.
- Production increased about 8% and 8,000 pph of steam savings were obtained.

Machine D:

- Midwest mill, on-machine coated offset, etc., under 200" trim, 2500 fpm, main dryer section steam system rebuilt in 1996.
- Advanced system included blow-thru controls, addition of four thermocompressors, two for blow-thru control and two for boosting pressure, and new radial separator stations. The booster thermocompressors raise back-pressure steam from 50 psi line directly into the two main dryer sections at their working pressure of 75 psi. Performance is in accordance with design specifications.
- Production increased 8-10% with some steam savings. The return on investment in this case was estimated to be in two months of full operation.

Machine E:

- South central mill, sized and coated on-machine board, over 200" trim, 1200 fpm, over 800 tpd, complete steam system rebuilt in 1998 (system had been rebuilt in 1992 with poor results).
- Advanced system included seven blow-thru controls, revised control configuration, replacement of three thermocompressors, eight new radial separators, new condenser and vacuum condensate station, and replacement of all 68 syphons with syphons fabricated especially for the machine. Performance is in accordance with design specifications.
- Production has increased about 4.3% and some steam savings are in place. The steam plant appreciates the return of much greater percentage of condensate. The return on investment was achieved in about four months.

Machine F:

- Shanghai, China mill, coated multiply fourdrinier boxboard with Yankee, 3300 mm trim, 210 m/min, 150 mtpd, steam system completely rebuilt in 1997.
- Advanced system included seven blow-thru controls, seven thermocompressors, eight radial separators, and replacement of 55 syphon shoes. Performance is in accordance with design specifications.
- The rate of production increased about 15% and steam savings were about 0.8 pound per pound of paper. Steam savings have paid for the installation in about six months but difficult market conditions of this date have limited total production. Much improved surface properties due to fine control of Yankee glazing have increased salability of the product.

Machine G:

- Southern mill, sized fine paper, 350" trim, 3450 fpm, 1000 tpd, all main steam and flash systems rebuilt in 1998 as part of an upgrade that included a metering size press and transfer of four dryers into the main section.
- Advanced system included blow-thru controls, four thermocompressors, six radial separators, and new stationary syphons. Two-stage flash steam recovery was an important feature. Performance is in accordance with design specifications.
- Production drying capacity increased substantially, roughly 10% of which was the result of better condensate drainage. Steam consumption dropped by approximately one pound per pound of paper to about 1.2 pounds per pound of water evaporated. One crew saw no breaks for three weeks.

Machine H:

- Midwest mill, new Yankee for high quality tissues including deep tone coloreds, 140" trim, 5000 fpm max, 120 tpd, all new machine 1998.
- Advanced system included blow-thru control with thermocompressor, two radial separators, and condenser. Operation is in accordance with design.
- Production rate exceeds design by about 12% on medium to heavy weight grades and there is virtually no steam waste.

OBSERVATIONS

Production rate increases of the machines in this two-year sample typically fall in the range of eight to ten percent, one exception being the large board machine for which the steam system had been rebuilt only six years earlier. Even in this case the increase is over four percent. On two machines the increase applies to the heavier of a wide range of grade weights because of other machine speed limitations. With production rate to break-even ratios in mind, it would be very interesting to see the internal financial results for the machines listed here.

The consistency of the substantial drying speed increases in all cases appears to be evidence of an entrenched deficiency in the old systems. The common thread is that drying speed always exceeded expectations. In most cases the impetus for rebuilding was a combination of control difficulties, local flooding, time lost on breaks and the like. Of course the primary justification was usually the saving of steam. What was not initially clear, however was the extent of existing drainage deficiencies. For example, dryer surface temperatures obtained in prior evaluations revealed some individual dryer problems, and frequently the temperature differences between steam and shell surface were variable and suspiciously high. But lacking specific standards of temperature performance, the evaluations tended to be conservative about potential gains in drying. The rebuilt systems provided optimum drainage of all dryers, but the old DP controls had at least the appearance of maintaining drainage. The only plausible explanation is that the new systems reduced the amount of residual condensate by eliminating recirculation of condensate. This supports the theory that few existing separators are acceptably efficient in separating condensate from blow-through steam. Further support is found in the fact that blow-thru controls do not function well on the blow-through steam from other than radial separators.

Not well documented but a major contribution to the production gains, reduction in maintenance has substantially improved machine efficiency. Under blow-thru control, main dryer sections can be operated in normal mode at very low steam pressures, below atmospheric if necessary. Thus the need to turn off dryers and to burn up steam joint seals in the process is eliminated in machines with wide ranges of grades. The risk of wrinkling on cold dryers is also eliminated. Blow-thru controls also prevent massive blasts of wet and erosive blow-through steam from the dryers, normally occurring on breaks under DP control, and they act quickly to purge surges of condensate after threading up the web. In the worst situations, surges of condensate load the dryers and cause frequent breakage in dryer section drives. Thus the controls reduce erosion and quickly establish normal operation by clearing out excess water after a break. In addition, the process of simulation has repeatedly uncovered undersized pipelines subject to frequent repair due to erosion. It is rare to find even one dryer in poor steaming condition with advanced systems.

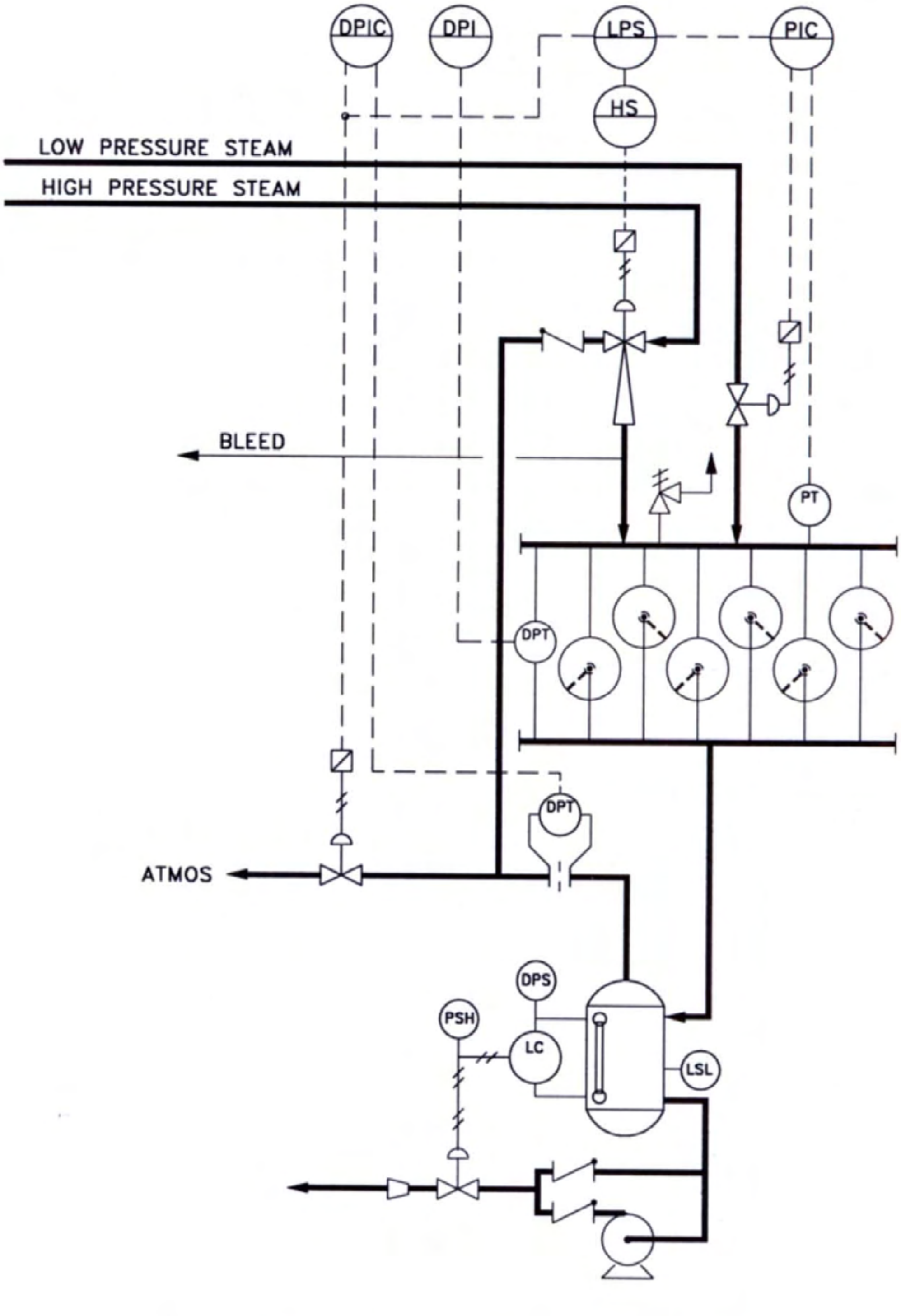
The size of the gains is more than ample relative to the size and age of older machines to achieve major profit improvement in these machines. Sometimes paper mills employ staff engineering to rebuild old systems but such work seldom has a payback. In the typical rebuild the cost of process equipment, even the special equipment required for advanced systems, is rarely over 30 percent of the project cost. Spending a lot of money without professional guidance like that is not good management. Engineering of advanced systems involves special training and special computer programs. At least three of the capsules were for quite old machines and the results for all three were outstanding. In one of these cases the machine had been under review for possible retirement, but the new steam system changed the picture completely.

Noteworthy in several of the histories, quite workable programs for automatic start-up of the dryer section were installed in the DCS. The new steam systems enabled the programs to work with a high degree of reliability because drainage under blow-thru control is independent and totally automatic. Thus the programs did not have to deal with variable or unstable drainage and simply scheduled the operation of equipment and control valves.

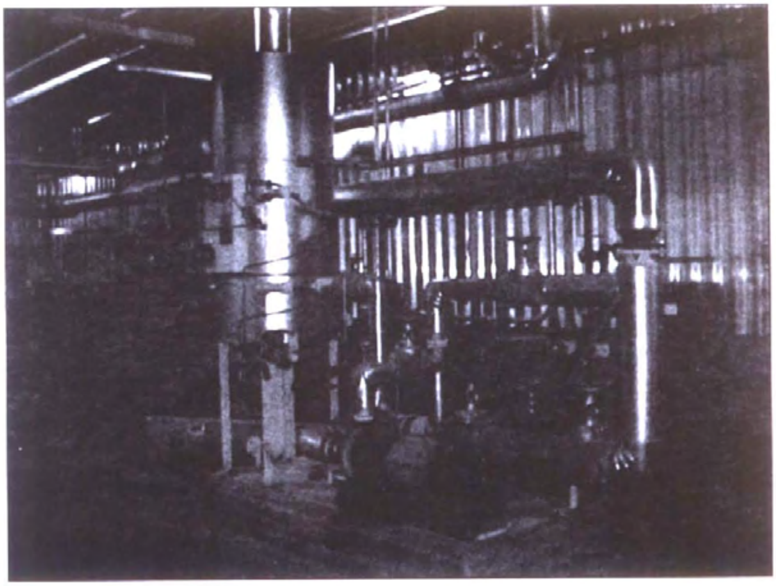
No steam system is a stand-alone producer of production or profit any more than any other part of the complex facility that comprises a paper machine. In spite of their excellent performance advanced dryer drainage systems produce nothing unless the machine has the capability to produce more paper, given increased drying capacity and efficiency. However, the histories presented here do show that they are indispensable for top performance and reliable operation of paper machines. In the longer view, they are contributing to further shrinkage in the size of dryer sections. The new systems have earned a place as an essential part of the equipment required to guarantee the return on capital invested in a paper machine.

REFERENCES

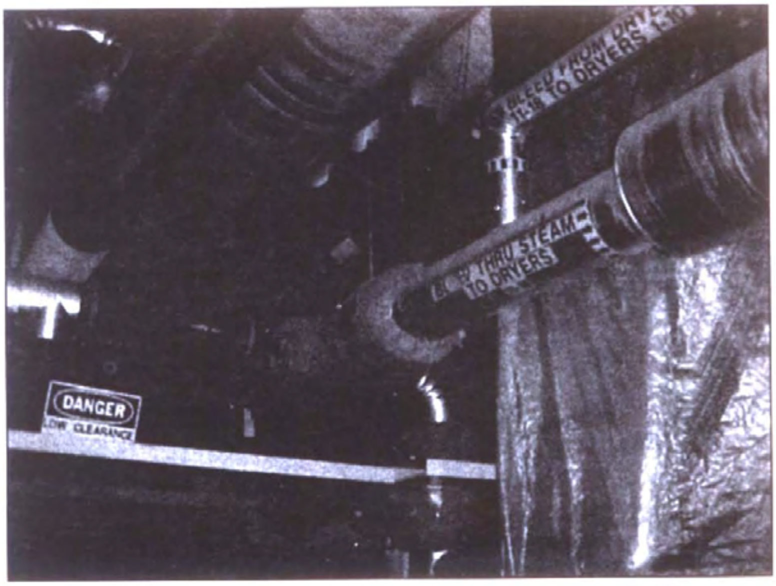
1. MacKinnon, D. A., "Incremental Investments Offer Big Rewards, Also Some Complexity", Pulp & Paper, pp 140-143 (July 1976).
2. Mardon, J., Vyse, R., and Ely, D., "Paper machine Efficiency: The most Important Parameter; How to Get It and How to Keep It", Pulp Paper Can. 92, No. 12: T285-T293 (December 1991).
3. Appel, D. W. and Hong, S. H., "Condensate Distribution and Its Effects on Heat Transfer in Steam-Heated Dryers", Pulp Paper Can. 70, No. 2: T51-T62 (February 1969).
4. Gardner, T. A., "Fundamentals of Blow-Through Control: the Optimum in Steam Control", Pulp Paper Can. 87, No 5: T167-T172 (May 1986).



1. Standard control block with recycling of blow-through steam by thermocompressor with Blow-Thru control.



2. Skid mounted radial separator station with pump by-pass.



3. Thermocompressor recirculating blow-through steam.