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Differential Pressure and Blowthrough Steam Flow for Managing Dryer Drainage

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Abstract

Paper machine dryer drainage is commonly controlled by one of two strategies; differential pressure control or blowthrough steam flow control. With differential pressure control, a differential pressure is maintained between the steam supply header and the condensate header to control condensate and blowthrough steam evacuation. With blowthrough flow control, the flow of blowthrough steam is controlled to control dryer evacuation.

In the design of a dryer drainage system syphon selection greatly influences the required differential pressure and the quantity of blowthrough steam for a paper machine section. The relationships between operating conditions, syphon selection, and the control strategy must be understood to properly design a paper machine steam and condensate system.

Drainage of paper machine dryer cylinders is accomplished by controlling the condensate header at a pressure sufficiently less than the steam supply pressure. Differential pressure provides the mechanism for condensate drainage for the dryers. Given sufficient differential pressure, condensate and steam will flow from the dryer cylinders to the low pressure condensate collection header.

Blowthrough steam is non-condensed steam that enters the dryer and is removed with the condensate. It is an inevitable result and necessary component of the process of condensate removal. Blowthrough steam assists the process on condensate evacuation by reducing the density of the condensate. It also removes non-condensable (air) from the dryers.

The quantity of blowthrough steam must be accurately predicted in

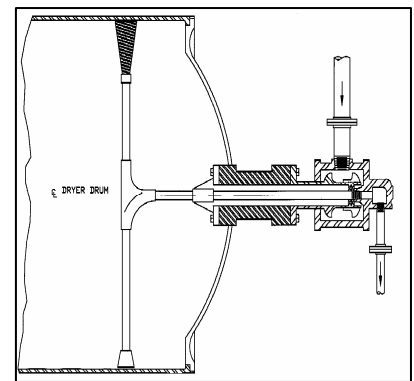
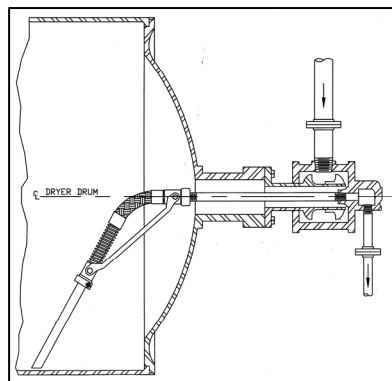
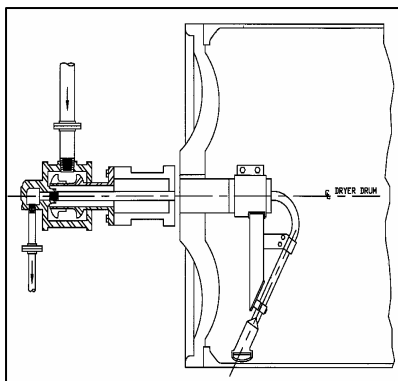
the design of the dryer drainage system as it has a direct impact on component sizing and selection. Many factors however, influence the blowthrough steam flow rate, such as syphon size, steam pressure, and differential pressure. The amount of blowthrough steam increases with increases in syphon size, steam pressure, or differential pressure.

Condensate and blowthrough steam are removed from dryer cylinders using syphons. Syphons can be generally categorized into three types (see Fig. 1).

- Low speed stationary syphons
- High speed stationary syphons
- Rotary syphons

Low Speed Stationary Syphons are relatively lightweight devices, supported from a pipe connected to the steam joint. They can be installed through the dryer journal and are oriented vertically downward in the six o'clock position.

High Speed Stationary Syphons are heavy duty, rigidly supported devices that require access into the dryer cylinder for installation. They are also oriented down in the six o'clock position. Both high speed and low speed stationary syphons remain in a fixed position relative to a rotating dryer.



Rotary Syphons are fixed to the dryer shell and head and rotate with the dryer. Rotary syphons typically are internally braced for support. They also require access to the inside of the dryer for installation and maintenance.

Syphon application is primarily a function of machine speed as condensate behavior in dryers varies as a function of speed. At low machine speeds, 350 feet per minute and less, the condensate collects in a puddle in the bottom of the dryers. As speed increases, the condensate will start to be carried up the inside surface of the dryers and will cascade back down to the bottom. This cascading action occurs between 350 and 850 fpm nominally. Cascading is the least desirable operating condition as it is characterized by turbulent and unpredictable condensate action making drainage, and therefore drying, difficult. At speeds greater than a nominal 850 fpm, rimming occurs and the condensate is held to the inside of the dryer. The speed at which rimming occurs is a function of the dryer cylinder diameter and of the film thickness of the condensate in the dryer.

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Rotary syphons are used for speeds between 500 and 300 fpm. They are not well suited for speeds less than 500 fpm as the syphon is constantly rotating through a relatively stationary puddle of condensate. The syphon is only in the condensate puddle for a short time during every revolution of the dryer cylinder, resulting in high levels of blowthrough steam flow. As speeds increase past 2000 fpm, the every increasing centrifugal forces need to be overcome by increasing levels of

differential pressure. Due to centrifugal forces encountered at high speeds, the practical speed limit for rotary syphons is 3000 fpm.

High speed stationary syphons are used for speeds from 2000 fpm to speeds in excess of 5000 fpm. Cost typically precludes the use of high speed stationary syphons at speeds below 2000 fpm.

Syphon selection is of critical importance because it impacts both the differential pressure required to evacuate a dryer and the quantity of blowthrough steam that the dryer drainage system must be capable of handling. The design of a paper machine steam and condensate system must take into consideration the full range of differential pressures and blowthrough steam flows.

The differential pressure across a dryer is predominantly affected by the pressure loss in the dryer syphon tube. The total pressure loss in a syphon tube can be analyzed as the cumulative effect of:

- Accelerational pressure loss.
- Gravitational pressure loss.
- Centrifugal pressure loss.

Accelerational and gravitational pressure loss components are negligible when compared with the frictional and centrifugal pressure loss components.

Frictional pressure loss is due to the energy required to overcome the frictional forces acting on the condensate and blowthrough steam as they travel through the syphon. At a constant pressure, the friction loss increases as the amount of blowthrough increases.

Centrifugal pressure loss is due to the energy required to overcome the centrifugal forces acting on the condensate in a rotating dryer syphon. For stationary syphons, the centrifugal pressure drop is zero as the syphon is not rotating. As the amount of blowthrough steam increases in a rotary syphon, the density of the 2-phase mixture of steam and condensate decreases and causes the centrifugal pressure loss to decrease.

The total pressure loss in a rotary syphon can be seen in **Figure 2**. It's important to note that the plot of pressure drop versus blowthrough steam will be different for each syphon size, condensing load, dryer speed, and operating pressure.

Figure 3 shows a comparison of pressure drops for rotary syphons, low speed stationary, and high speed stationary syphons as a function of blowthrough steam flow. Note that the stationary syphons have no centrifugal influence and the total pressure drop can be simplified to be seen as a function of friction alone.

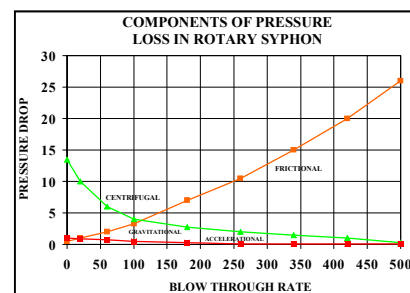


Figure 2

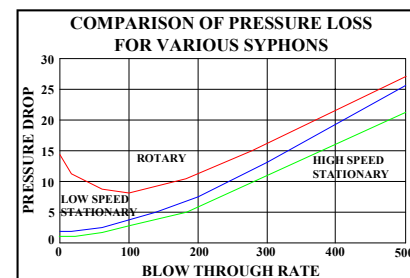


Figure 3

The effect of changing syphon size is that a larger diameter syphon will allow more blowthrough at a given differential pressure to escape with the condensate than a smaller diameter syphon.

The effect of increase condensate flow is that a higher differential pressure is required to maintain a constant blowthrough rate.

Increasing the dryer speed causes the centrifugal component of the total pressure drop to increase for rotary syphons. At low blowthrough rates this results in an increase in pressure drop. The effect is less

pronounced at increased blowthrough flow rates as the density of the mixture of condensate blowthrough steam is reduced.

Increasing the operating pressure causes the amount of blowthrough steam flow to increase for a constant differential pressure and condensate flow. A decrease in pressure has the reverse effect.

The relationship between pressure drop in a syphon and the amount of blowthrough steam is not simply defined, but rather a function of many correlated and sometimes opposing factors. These factors include syphon type, syphon size, condensing load, dryer speed and operating pressure. The combination of these factors on the relationship between pressure drop and blowthrough steam flow results in an infinite number of operating points. The range of operating conditions can be viewed as a “playing field”: a specific combination of operating conditions specifies a single operating point in the playing field. (See Figure 4:) Conversely, a single set point is appropriate only for a specific condensing load, dryer speed and operating pressure.

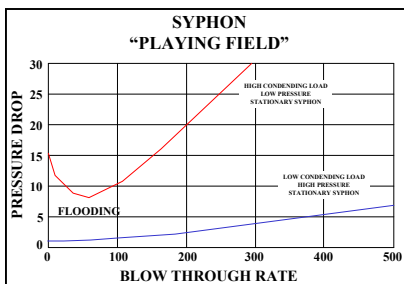


Figure 4

Note that operational changes have a compound effect on the operating point in the playing field. For example, an increase in production may be accomplished by speeding up the paper machine and by increasing the operating pressure of the dryer section. This effectively increases the condensing load on the dryers.

The increase in condensing load results in a decrease in blowthrough for a constant differential pressure.

The increase in dryer speed may result in an increase in blowthrough (this is particularly true at low blowthrough rates). The increase in operating pressure also leads to an increase in blowthrough flow. The net result is the cumulative effect of increases and decreases in blowthrough. Similarly, the effect of the speed and pressure increase can be analyzed in terms of changes in differential pressure while holding blowthrough constant.

Our intuition is to look for the simplest means of controlling drying and drainage. However, regardless of the control strategy selected, fixed settings cannot adjust to changing condensing loads, speeds or steam supply pressures. As illustrated in Figure 4, different areas of the playing field lend themselves to different control strategies. In the middle of the playing field, either control strategy works equally well, be it differential pressure control or blowthrough flow control.

The upper, steep extreme of the playing field is characterized by high speed, high condensing load and low pressure. In this area of the playing field, controlling differential pressure is advantageous as large changes to differential pressure result in only small changes to blowthrough steam flow. Should blowthrough flow control be used in these conditions, a small change in flow results in a large change in pressure drop. Differential pressure control results in more stable control.

The lower, flat extreme of the playing field is characterized by low speed, low condensing load and high pressure. In this area of the operational spectrum, the advantage lies with blowthrough flow control. Large changes in blowthrough flow result in small changes in differential pressure; the control strategy is stable.

The operating point in the playing field is affected by many factors, some of which vary by design such as operating speed and daily production or grade requirements. Some factors may vary over time. As press felts fill and compact, their permeability decreases resulting in an increase in

the incoming sheet moisture and a corresponding increase in condensing loads. Still other factors are dictated by the initial machine design, such as syphon size and available steam pressure.

For each dryer steaming section, it is desirable to define the playing field. This will assist in syphon selection and sizing and will assist in determination of the best suited drainage control strategy.

Control Strategies

Figure 5 shows a typical control diagram for a paper machine section. For either strategy, the control of the steam supply header, the Thermocompressor, and the vent valve is identical.

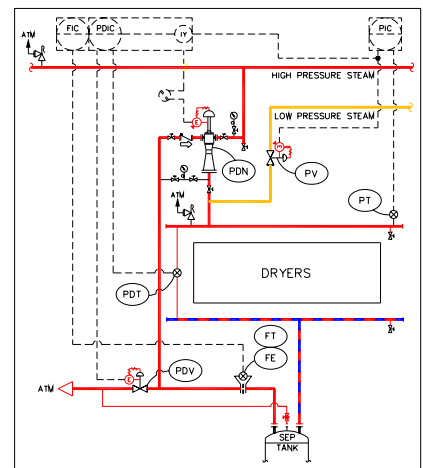


Figure 5

In spite of the difference in terminology, both strategies are based on the measurement of a differential pressure. Differential pressure control measures the pressure differential between the steam supply header and the condensate header (DPT). Blowthrough flow control measures the pressure differential across an orifice plate (FT). Both strategies use this measurement to control the vent valve and the thermocompressor via the low select relay. As mentioned earlier, the location on the “playing field” will indicate which strategy is recommended.

Another factor in selecting a strategy is how each responds to sheet

breaks. At sheet break, the condensing load drops and the steam header pressure increases. Both strategies respond by closing the pressure valve.

With differential pressure strategy, the controller wants to maintain a set pressure differential, causing the thermocompressor to open. This leads to steam venting.

A blowthrough flow strategy will want to maintain a set flow at break, closing the thermocompressor. Venting is minimized.

The last consideration is syphon breakage. In essence, a broken syphon is a short circuit which maximizes the flow of supply steam that will exit as blowthrough. Differential pressure control will continue to maintain its set point and to drain other dryers in the same section. Blowthrough flow control, seeing and increase in flow, will reduce the differential pressure and may cause flooding.

Conclusion

In normal operation, the control of differential pressure or of blowthrough steam flow are interdependent. An increase in differential pressure will result in an increase in blowthrough and vice versa. As control strategies, both differential pressure control and blowthrough flow control work well under most normal operating conditions. The common exception occurs in lead-in dryer sections which see high condensing loads and typically operate at low pressures. These conditions favor differential control and blowthrough flow control is not recommended as a control strategy for lead in dryer sections. Additionally differential pressure has been easier for most operators to understand.

The only difference in the equipment required for the two control schemes is that the differential pressure transmitter is placed with a blowthrough steam flow orifice plate and transmitter. All other control elements are the same.

Monitoring of both the differential

pressure and the blowthrough steam flow for each steaming section of a paper machine dryer section is readily accomplished with a minimal amount of additional equipment.

Selective control allows operators to monitor one parameter (eg. differential pressure) while controlling the other (eg. blowthrough flow). The control scheme is selective and readily changed.

The advantages of dual monitoring with selective controls are:

- Additional operating information for improved troubleshooting and maintenance.
- Additional comparative data for various grades and speeds.
- Maximum flexibility to suit operational speeds.
- Operational back-up control system for increased reliability.

For more information on this subject, contact Fulton Systems at (770) 447-1400 (Tel) or (770) 447-4277 (Fax).



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- 1927 Midwest Fulton
- 1954 Ross Midwest Fulton Division of Midland Ross
- 1957 Ross Pulp & Paper
- 1984 Hercules Steam Systems
- 1991 Fulton Systems
- 2002 Fulton Systems Acquires TSG Steam Group