Rotating and stationary siphons in high-speed dryer sections

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The pressure differential required to clear a flooded dryer is greater with a rotating siphon than a stationary one, but the rotating siphon is better at evacuating the dryer when the condensate begins to cascade, while the stationary siphon is better for nonrimming condensate.

As the speeds of modern paper machines increase, the dryer system has to remove condensed steam faster. If the system does not evacuate condensate as quickly as the steam condenses, the dryer will begin to "flood," or fill up with water. Dryer flooding substantially increases the drive load and decreases the drying rate.

The capacity to remove condensate depends on the design of the dryer drainage system and its siphoning components. The two types of siphons in common use are the rotating siphon and the stationary siphon. With a rotating siphon system, a large enough pressure differential has to be maintained to overcome the centrifugal force (actually the inertia of motion) that would otherwise hold water against the inside of the dryer. In a stationary siphon system, the ability to evacuate condensate depends more on system stability and the ability to recover from system upsets.

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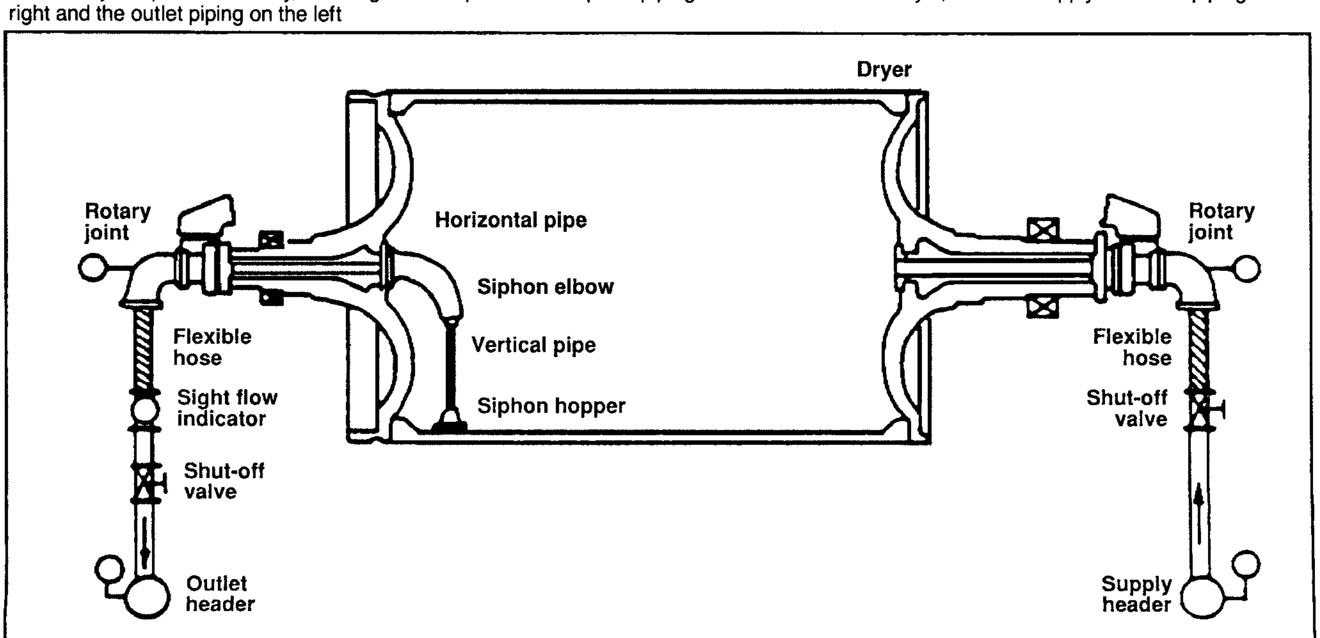
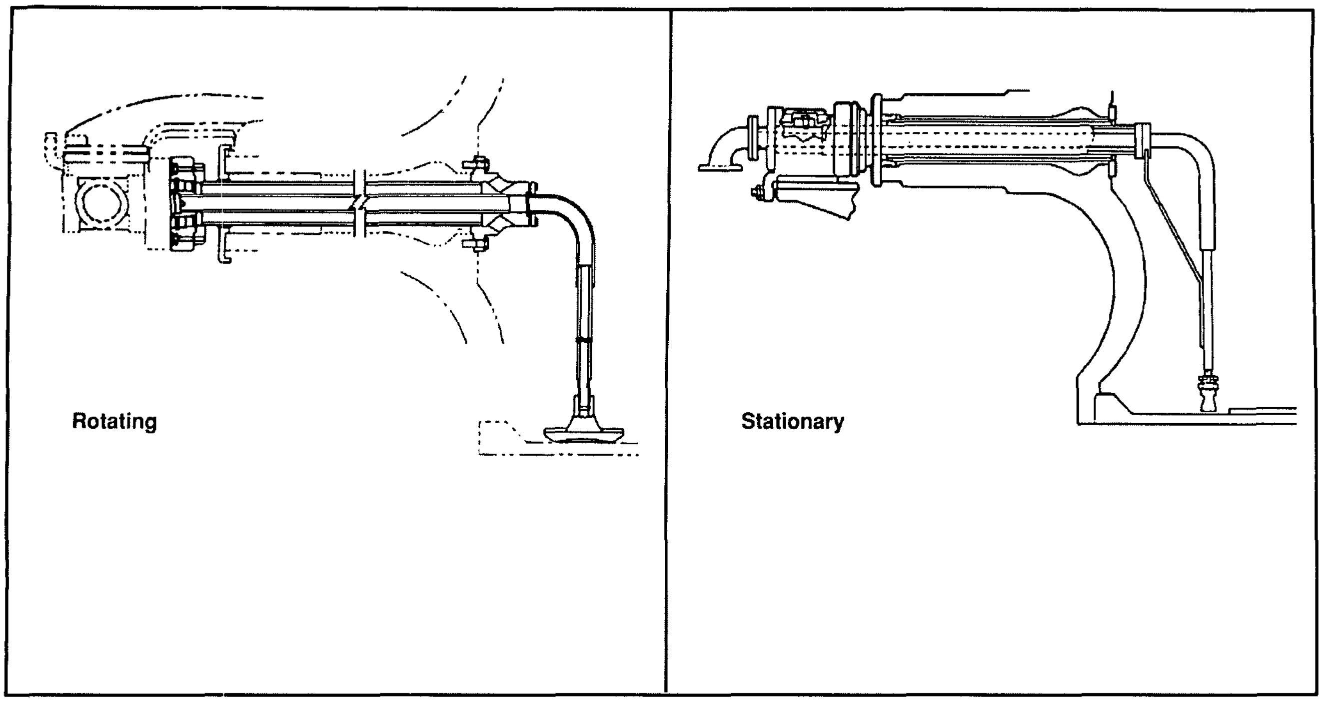
Differential pressure and blow-through

To ensure that the condensate is removed continuously, the operating differential pressures are increased above the minimum required. The higher pressure causes a

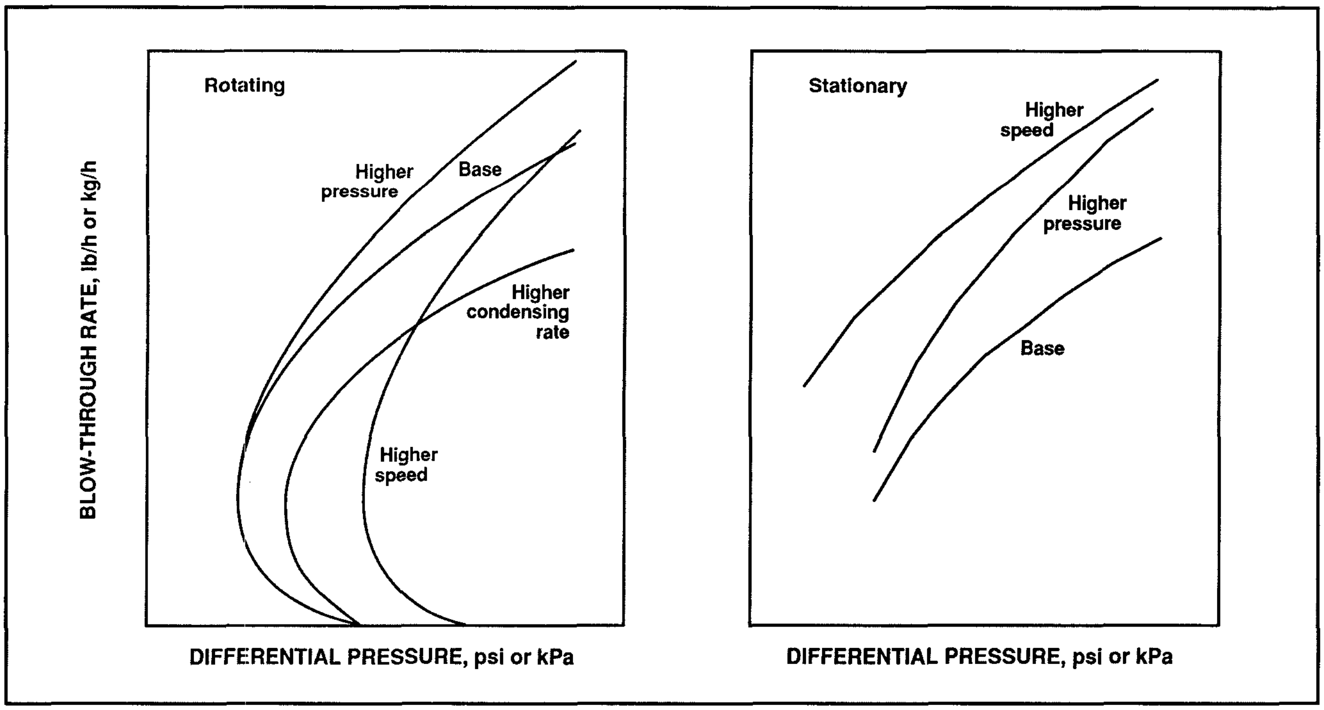
1. The dryer siphon assembly, showing the components of siphon piping on the inside of the dryer, with the supply and inlet piping on the right and the outlet piping on the left



2. Assemblies for both the rotating siphon and the stationary siphon



3. Typical curves for blow-through characteristics for a rotating siphon and a stationary siphon

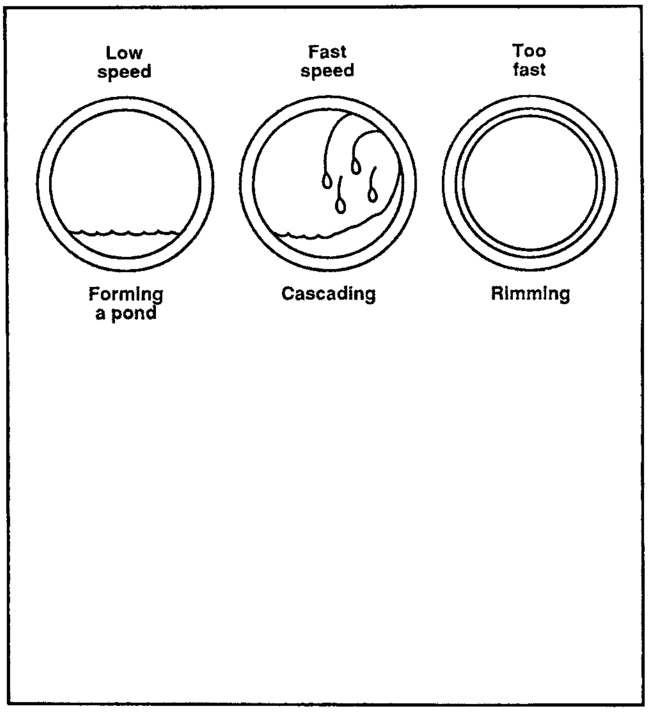


certain amount of steam to pass through the dryer. This steam is termed "blow-through" because it simply "blows through" the dryer without condensing.

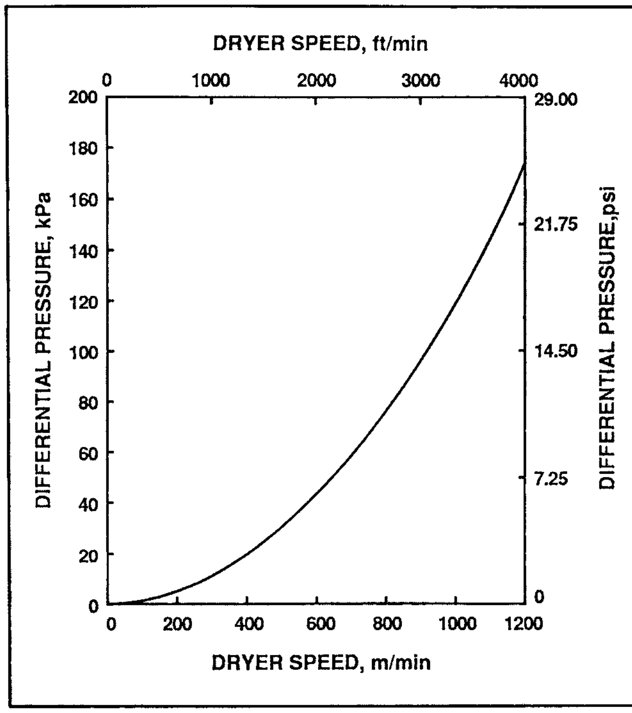
This blow-through steam serves several purposes. It reduces the density of the two-phase mixture, which lowers the differential pressure, it entrains and evacuates the noncondensable gases, and it helps to stabilize the evacuation of condensate. Rather than waste this steam, mills usually separate the blow-through from the condensate and reuse it. Generally, the blow-through steam is cascaded to a group of dryers that are operating at a lower pressure, or it is recirculated back through a thermocompressor.

A substantial quantity of blow-through steam could be tolerated, but the amount is generally limited to a mass fraction of about 15-20% of the condensation rate. The

4. As the speed increases, the behavior of condensate changes.



5. Differential pressures needed to clear a submerged rotating siphon



amount of blow-through steam is restrained because excessive flow rates will erode the piping components. High blow-through flow rates will also increase the pressure losses, decreasing dryer pressures in the cascaded sections. Too much blow-through will also increase the amount of steam eventually sent to vacuum condensers.

Consequently, a careful balance must be maintained between blow-through flow rates and high differential pressures.

Theory

The aspects of the relationship between the dryer differential pressure and the flow rate of blow-through steam are called the "blow-through characteristics." These characteristics and the differential pressure required are dependent on a number of factors. These factors can be divided into three basic categories: equipment design, machine conditions, and condensate behavior.

Equipment design

The blow-through characteristics are influenced by the design of the entire dryer siphon assembly. The various components that make up the dryer siphon assembly are illustrated in **Fig. 1**, which depicts the inside of the dryer. The supply piping, the inlet piping, the siphon piping, and the outlet piping combine to produce the flow restrictions that dictate the blow-through characteristics.

The restrictions on supply and outlet flow are affected by the lengths and sizes of the pipes, by the number of fittings and their locations, and by other restrictions pertaining to valves, flow indicators, and flexible hoses that may be in the lines. The restrictions on inlet flow are determined by the rotary joint, the pipe that runs through the dryer journal, and by any distribution manifold within the dryer. The siphon piping consists of a siphon hopper (or shoe), a vertical or radial pipe, an elbow, a horizontal pipe, and the outlet rotary joint.

As mentioned, there are two types of commonly used siphons—rotating and stationary. These siphons are depicted in **Fig. 2**. The rotating siphon is mechanically secured to the dryer, with the siphon hopper, radial pipe, and horizontal pipe all rotating with the dryer.

The stationary siphon is cantilevered from the rotary joint, which is fixed external to the dryer. In this design, the siphon hopper, the vertical pipe, and the horizontal pipe all remain fixed as the dryer rotates around the siphon assembly. The differential pressure required to evacuate the condensate from a dryer with a rotating siphon can be much greater than that required for a stationary siphon. With a stationary siphon, condensate must be lifted to the dryer axis against gravity only. With a rotating siphon, however, the condensate must be transported against a strong centrifugal force (31 g at 3000 ft/min, 60 inch dryer).

The supply restrictions serve no useful purpose—they simply lower the dryer pressure. For this reason, the supply line is normally oversized to avoid pressure losses. By contrast, the siphon and outlet piping are sized to produce the best balance between the blow-through flow rate and the operating differential pressures. The lowest possible differential pressure is maintained so the pressure in the cascade section can be maintained as high as possible. On the other hand, the blow-through flow rate is kept high enough to adequately evacuate the condensate under normal operating conditions.

The actual balance between differential pressure and blow-through rate for a particular machine must be based on the design of the steam system, the machine configuration, and the design parameters developed by the machine manufacturer.

Operating conditions

The blow-through characteristics are affected by the normal operating conditions in the dryer section. For a rotating siphon, the characteristics are determined by the machine speed, the steam condensing rate, and, to some extent, the dryer steam pressure. For a stationary siphon, the blow-through characteristics are determined largely by the machine speed, with some influence attributable to the dryer steam pressure and the steam condensing rate.

Figure 3 shows typical curves for blow-through characteristics for both rotary and stationary siphons. Such curves are based on experimental and analytical studies (*1-6*).

For a rotating siphon (on the left), there is a bow or "knee" in the blow-through curves. The upper half of the curve is dictated by the frictional flow resistance, and the lower half is determined by the centrifugal flow resistance. The curve reaches a minimum differential pressure on the left. Any differential pressure less than this value is not capable of evacuating the condensate at the rate shown.

For a stationary siphon (right), the curves also reach a minimum differential pressure, but it is much lower. This minimum occurs as the differential pressure or blow-through flow rate approaches zero.

The effects of the various operating parameters are also shown in Fig. 3. A change in one of these parameters—a higher pressure, for example, or a higher speed—will cause a shift in the blow-through curves. The system designer must take these variations into account.

Condensate behavior

The operating parameters are affected by the condensate behavior. Depending on the dryer speed, the steam pressure, the dryer diameter, and the volume of condensate, the condensate may form a pond, or it may cascade or even rim.

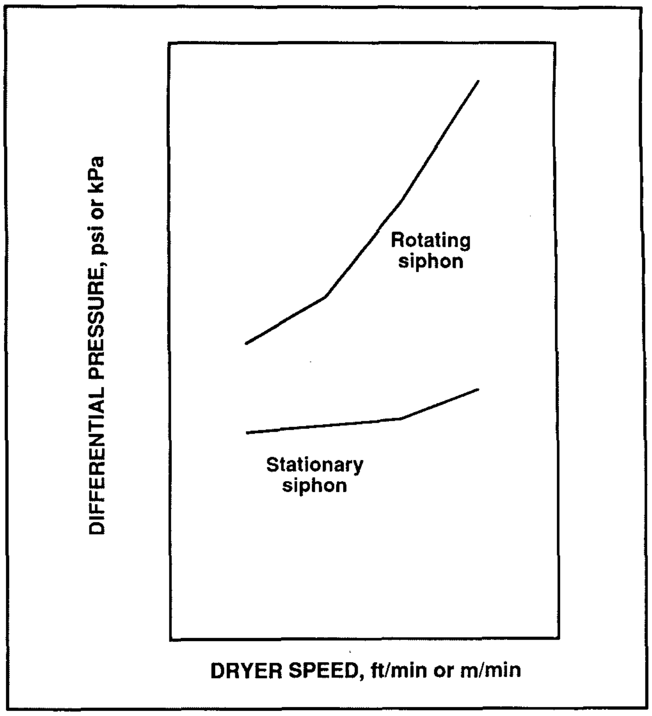
As illustrated in **Fig. 4**, if the dryer is rotating slowly, the condensate will run down the dryer shell and form a puddle at the bottom of the dryer. As the dryer speed is increased, the condensate rides further up the side of the rotating shell and cascades off, creating a greater drive load (*7*). At a higher speed, over 300-350 m/min, the condensate will rim the dryer. These conditions are discussed in detail elsewhere (*8*).

The dryer siphon may become submerged in rimming condensate after a temporary loss in differential pressure. The temporary pressure loss could be caused by an insufficient operating differential pressure, by a system upset such as a sheet break, or by the transition of the condensate in going from nonrimming to rimming behavior.

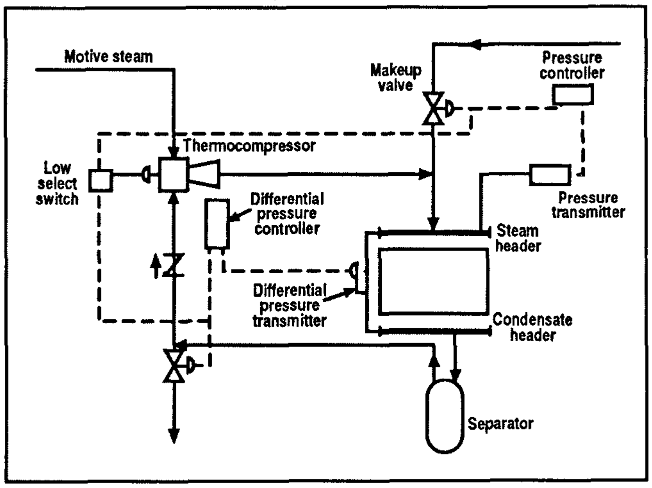
When a rotating siphon becomes submerged, the condensate will not be evacuated until the differential pressure is increased enough to move the solid column of condensate against the centrifugal force to the dryer axis. The differential pressure required to evacuate a dryer with a submerged rotating siphon is shown as a function of dryer speed in **Fig. 5**. This differential pressure is much greater than the normal operating differential pressure.

When the dryer has been evacuated, the differential pressure can be returned to a normal value. If the pressure is not reduced, the blow-through will be excessive, disrupting the operation of the steam and condensate system and possibly leading to premature failure. When a stationary siphon becomes submerged, the system will recover normally, unless the flooding was caused by a mechanical failure or a serious upset of the steam and condensate system.

6. Comparison of normal operating differential pressures



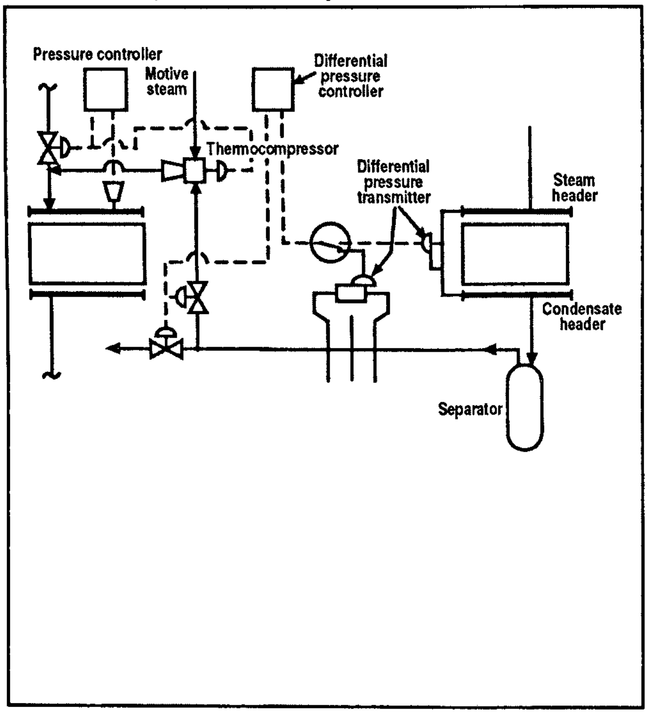
7. Thermocompressor loop system



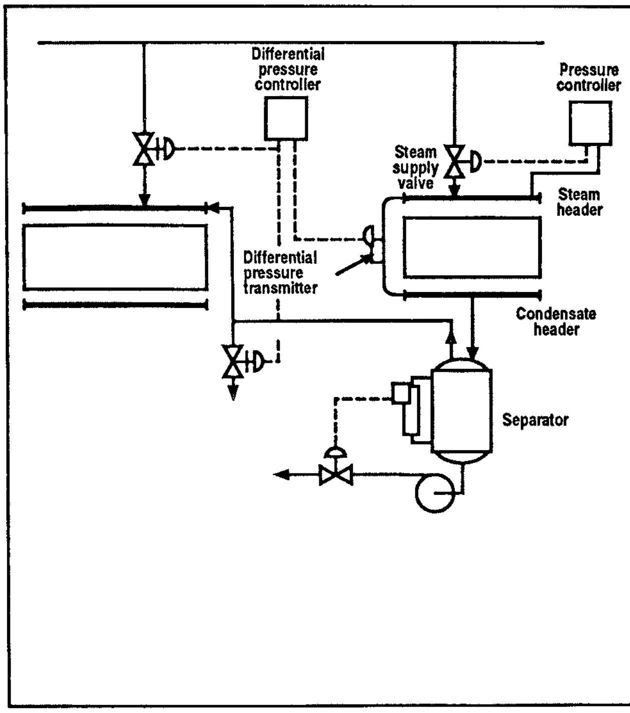
Comparative design parameters

In deciding which type of siphon system to use, we must consider the differential pressure required, the blow-through flow rates, and the condensate behavior. Operating parameters to consider include the type of steam system, the available steam pressure, the flood recovery characteristics, the drive characteristics, and the mechanical stability.

8. Thermocompressor cascade system



9. Straight cascade system



I. Pressures in the cascade sections

	Section			
	1st	*2nd*	*3rd*	*4th*
Inlet header, kPa				
Stationary	39	113	187	261
Rotating	80	195	310	425
Outlet header, kPa				
Stationary	0	74	148	222
Rotating	0	115	230	345
Differential pressure, kPa				
Stationary	39	39	39	39
Rotating	80	80	80	80

Machine speed = 1200 m/min (3937 ft/min).
Condensing load = 2000 kg/h (4410 lb/h).
psi = 0.145 kPa.

Required differential pressure

Figure 6 compares the differential pressures required for the two systems (*9*). A rotating siphon requires more differential pressure than a stationary siphon. The decision of which type of siphon to use must be based on the relationship between (a) the differential pressure required and (b) the type of steam system to be used and (c) the steam pressures available.

Flow rates of blow-through steam

The required flow rates for blow-through steam can be found by using curves such as those shown in Fig. 3. Again, the blow-through flow rates are higher for a rotating siphon than they are for a stationary siphon.

In deciding on the type of siphon, we must look at the type of steam system to determine whether all the blow-through steam can be used or if some must be dumped to the condenser. Higher blow-through flow rates usually result in more steam being dumped to the condenser and in an increased flow of cooling water when the dryers warm up and on a sheet break. Also, the higher blow-through flow rates will cause more erosion of the siphoning and steam handling equipment.

Condensate behavior

For the condensate conditions shown in Fig. 4, which siphon will do a better job of evacuating the condensate?

When the condensate is in a ponding or puddling condition, a stationary siphon, which stays in the pond, would do a better job than a rotating siphon, which must rotate through the pond only once per revolution. Once the condensate begins to cascade, a rotating siphon will evacuate better because of the turbulence in the condensate and because the thickest layer of condensate moves in the direction of rotation.

For a rimming condensate layer, either siphon type can evacuate the condensate successfully. However, as the speed increases, the differential pressures required and the resulting flow rates for blow-through steam must be considered.

Steam systems

The use of the blow-through steam and the effects of differential pressure must be taken into account when designing the steam system. The common steam systems are the thermocompressor loop, the thermocompressor cascade, and the straight cascade systems, as illustrated respectively in **Figs. 7-9** (*10*).

For a stationary siphon, the lower blow-through flow rate and lower differential pressure allow it to be used with any of these steam systems.

For a rotating siphon, the thermocompressor can compensate for the higher flow rates and higher differential pressures if a thermocompressor loop system or a thermocompressor cascade system is used. If a straight cascade system is used, a low enough pressure group may not be available to handle all the blow-through steam supplied at its related low pressure. In this case, the blow-through steam may need to be sent to the condenser.

Available steam pressure

The available steam pressure must be considered, especially with cascade systems. For the rotating and stationary siphons, **Table I** compares the required steam pressure in each of four steam groups. The higher steam pressures required with rotating siphons may not be available in some mills in which the pressure is limited at its source (in a TMP mill, for example). Also, a higher steam pressure may cause overdrying of the sheet.

Flood recovery characteristics

When the type of siphon is selected, the capability to recover from flooding must also be considered.

As Fig. 5 shows for a rotating siphon, the differential pressures required to evacuate the dryer are high at high speeds. Operators must be prepared to reduce the high pressure as soon as the dryer is evacuated. Otherwise, large quantities of steam may be wasted, and the extra load may be detrimental to the system.

With a stationary siphon, the low differential pressures required will result in more operational flexibility.

Drive considerations

Many machines are being converted to felt-driven machines, by removing the gears and driving either the felt rolls or dryers. The siphon performance must be optimized to reduce the amount of condensate being carried in the dryer under all conditions. Therefore, the siphon performance during system upsets must be considered.

When a dryer section with rotating siphons is stopped, the siphons must be pointed downward to remove the condensate. Otherwise, to remove this condensate, the section must be allowed to run at a slow speed for a period of time before accelerating. If this is not done, the felt-driven dryers, which are partially full of water, may slip as a result of the increased load. If this happens, the section may need to be stopped again with all siphons pointed down until the condensate is evacuated.

With a stationary siphon, the siphon is always pointed downward. Therefore, during an upset or shutdown, the siphons will be located in the proper position to evacuate the condensate and return the system to operating conditions.

Mechanical stability

In a rotating system, the siphon is bolted to the dryer shell. This rigid system is stable under all conditions. The close spacings required to maximize heat transfer can be maintained.

In the stationary system, the siphon assembly is centilevered off the steam joint. This structure requires that the components be designed for stability. To avoid the chance of the siphon hitting the shell's surface, the spacing is usually greater than it would be otherwise. To maintain the heat transfer requires some type of turbulence generator, such as dryer bars.

Advantages of both types of siphons

The advantages of the rotating system are:

- Better mechanical stability
- Fixed siphon clearance
- Better evacuation of cascading dryer
- A source of large quantities of low-pressure steam.

The advantages of the stationary siphon are:

- Lower differential pressures
- Reduced flow rates for blow-through steam
- Smaller thermocompressor required
- Lower pressures possible for motive steam
- Reduced condenser requirements
- Lower flow rates for cooling water
- Better flood recovery
- Siphon alignment not required.

The advantages of each type of system must be analyzed. The performance of each system under disadvantageous conditions should be weighed to determine if the system will operate successfully under all operating conditions. Only then should the decision on siphon type be made.□

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