Higher National Certificate

In

Technology and Management of Paper and Board making.

The module on “The drying of Paper and Board and On-machine Surface Modification, will increase the individuals knowledge and understanding of the drying of paper and board and the equipment and coating materials for coating them.

AIMS.

1. To increase technical knowledge with regard to water removal by evaporation in the dryer section.
2. To enhance the knowledge of the dryer section and dryer fabrics
3. To explain dryer section runability
4. To explain dryer section developments.
5. To explain the alkaline sizing theory
6. To explain what influence the base sheet has on coating
7. To explain the coating formulas and equipment used in coating

LEARNING OUTCOMES.

On completion of this part of the module the students should be able to: -

1. Understand the theory of water removal by evaporation in the dryer section.
2. Explain condensate removal from the drying cylinders and efficient condensate recovery.
3. Explain dryer section design criteria.
4. Understand developments in dryer section design
5. Understand dryer fabric design criteria.
6. Understand the alkaline sizing theory
7. Understand the properties of the base sheet relative to coating
8. Understand why there are different formulas and coating methods

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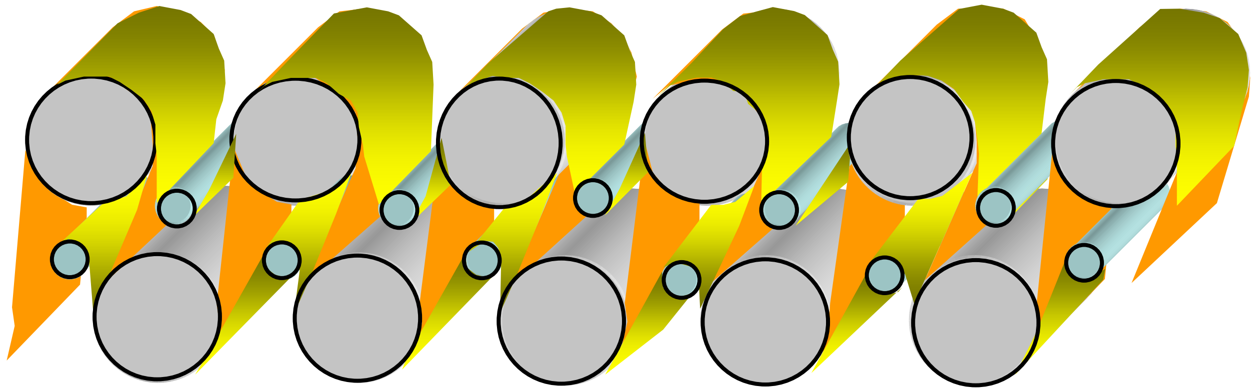
DRYING OF PAPER AND BOARD

Introduction.

The drying of paper and board is a very critical and important part of its manufacture. It is therefore essential that the student has an understanding of the principles that govern the correct drying of paper and board and the parameters that make for efficiency and economy.

A SECTION OF TYPICAL MACHINE DRYERS.



The dryer section consists of hollow cast cylinders (cans) of approximately 1.5 meters in diameter, accurately machined both externally and internally.

These cylinders are heated with steam, which passes in through a journal, condenses and the condensate formed is removed by a syphon via the same journal.

The surface of the cylinders is polished and kept clean by doctors that press against the cylinder face.

The cylinders are usually arranged in double tiers so that the paper is dried from each side in turn.

The number of cylinders for any machine will vary according to the grade of paper being produced, but the average number will be 50. These will be split up into sections so that the shrinkage can be compensated for as the paper dries, this is accomplished by driving the sections at slightly different speeds. This difference in speed is called the “draw”

The paper is initially fed round the cylinder by a Sheeham Carrier, which consists of an “endless rope” which passes round the cylinder in a groove on the extreme edge and is kept tight at some point on its return run by a system of hydraulic or pneumatic pistons and pulleys.

The drying of a sheet of paper is a complex process, and all grades should be dried at the lowest temperature commensurate with machine speed and sheet formation. The too rapid application of heat to the sheet creates fibre stress and surface hardening which results in low production and excessive machine down time.

Definitions.

Sensible heat.

This is the heat which reveals its presence by changing the temperature of the substance to which it is applied.

Latent heat.

This changes the state of the substance e.g. melting a solid or vaporizing a solid and this heat energy remains in the vapor. When the state is reversed the same amount of heat energy is given up without a loss in temperature.

This is exactly what happens in the drying cylinder, the steam enters the drying cylinder and comes into contact with the condensate and the cylinder wall, which is at a lower temperature, the steam immediately condenses and gives up its latent heat which is transferred to the paper via the cylinder wall.

Heat Transfer.

This is the transfer of thermal energy resulting from a temperature difference.
The heat transfer of this thermal energy in the drying of paper can involve three mechanisms.

1. ***Conduction***. This refers to the flow of heat within a medium by the transfer of energy between adjacent molecules without mixing.

2. ***Convection.*** This is the way that heat energy is transferred in liquids and gasses. The fluid molecules carry the heat from a hot zone to a cooler part of the system, give up the energy and move back into the hot zone to absorb more heat.

3. ***Radiation.*** This mode of heat transfer is different to the other two, they relied on molecules, and this is accomplished by heat rays, very similar to light and radio waves. The other major difference between this mode and the other two is that the other two depend on a temperature difference radiation does not.

When steam condenses and gives up its latent heat, it passes via the cylinder wall to the paper or board. However there are several restrictions that slow down this heat transfer because of differences of conductivity. So some of the latent heat liberated is lost and the temperature reduced.

The restrictions are: -

1. The steam side layer. This comprises a layer of condensate and scale, rust and other material that has been deposited on the inside of the drying cylinder

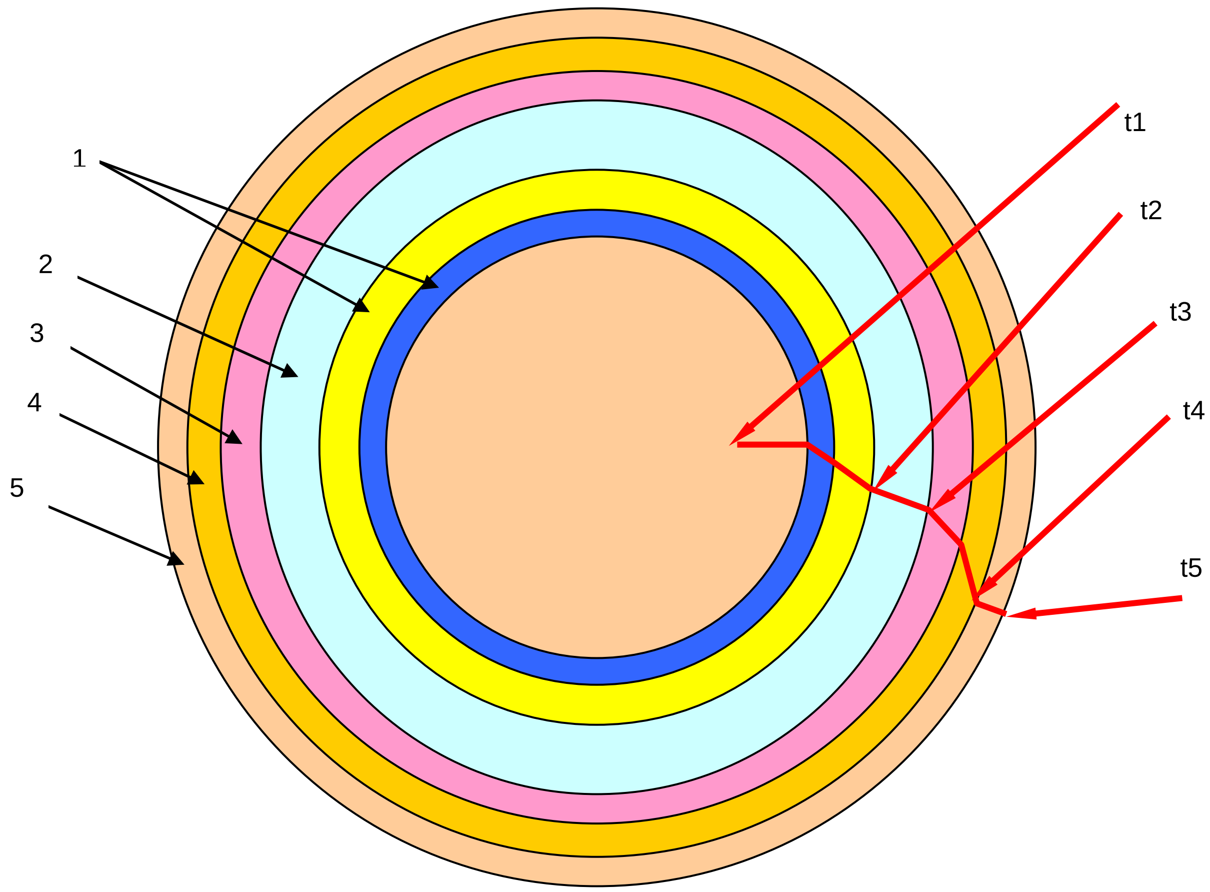
2. The dryer shell itself

3. Dirt on the face of the dryer

4. The air gap between the face of the dryer and the paper or board itself

5. The paper or board itself

The sketch below shows the temperature drop between these various layers.



t1 Steam temperature

t2 Temperature at inner face of dryer

t3 Temperature at outer face of dryer

t4 Temperature at inner side of paper

t5 Temperature at outer side of paper

Mass Transfer.

This is the tendancy of one componant of a mixture to redistribute from a region of high concentration to a lower concentration.

Heat is transferred from the cylinder face to the web of paper to increase the temperature so that the water vapour will evaporate. This results in a trasnsfer of the internal moisture and the evaporation of moisture.

Just as there are restrictions in heat transfer so are there are obstacles to mass transfer. Thses will be in the form of:-

1. Air velocity
2. Air temperature
3. Humidity
4. Dryer temperature.

These are all an intrigal part of the pocket ventilation system which will be discussed later on in the module, but it necessary to know and understand the definitions of Relative Humidity and Dew Point.

Relative Humidity.

This is the amount of water vapour actually present in the atmosphere expressed as a percentage of the amount present when the atmosphere is saturated at the same temperature

Dew point.

This is the temperature at which the atmosphere becomes saturated with water and starts to condense.

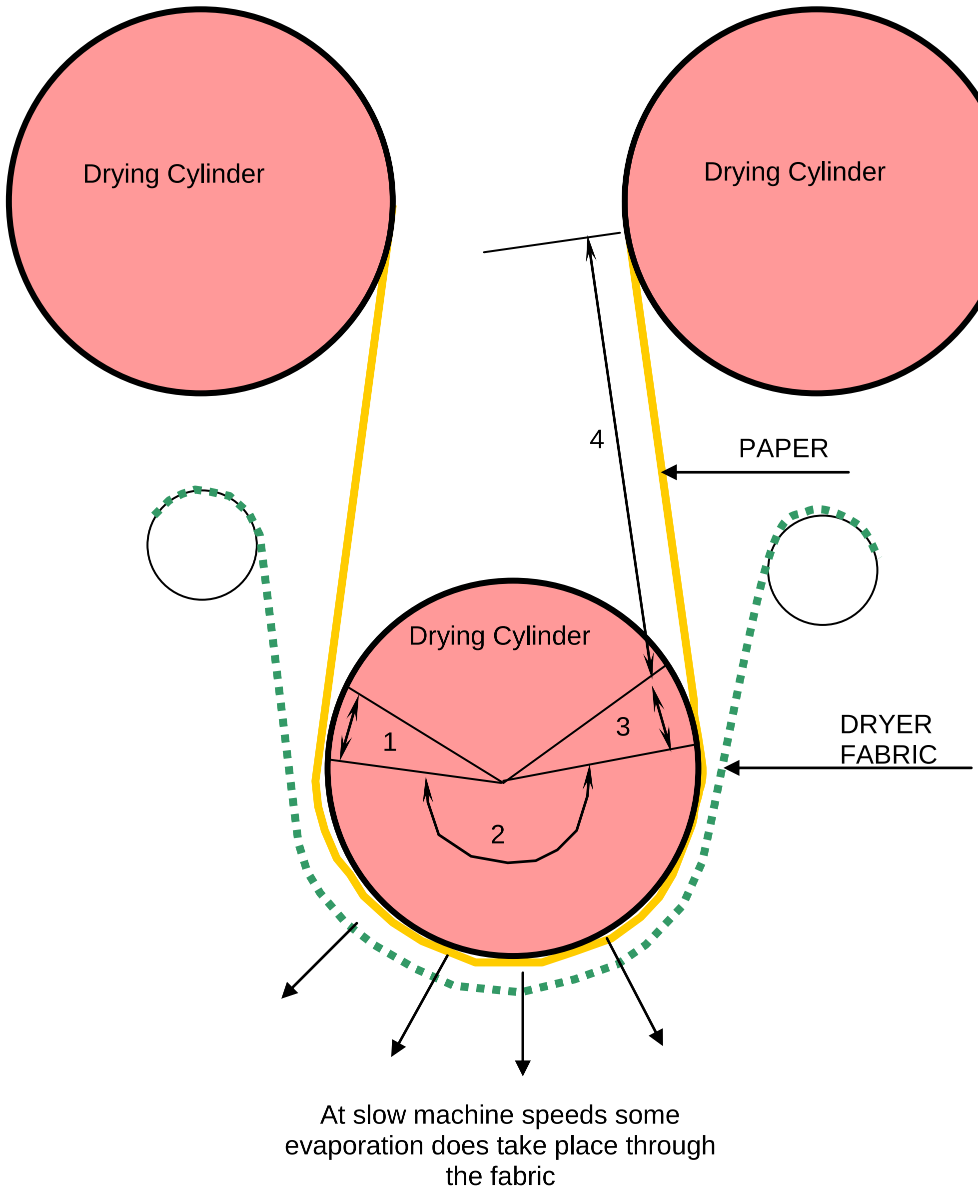
It can be seen that both these criteria are very important in the drying of paper and board.

In mass transfer the water moves from a high concentration to a lower one, therefore if the relative humidity is approaching 100% in the vicinity of the paper then it will be very near to saturation point and there will be little or no evaporation from the surface of the paper and drying will be reduced.

The same will apply if the air in the dyer pockets is near to the dew point temperature, it will have a high percentage of water vapour present and little or no mass transfer will take place and drying will again be retarded.

THE FOUR PHASES OF DRYING.

On conventionally felted dryers the phases of drying can be divided into FOUR.



Phase 1.

Relatively cool paper contacts the hot drying cylinder on one side. There is a relatively small loss of moisture at this point because a thick vapor air film prevents the paper coming into contact with the drying cylinder surface and the air between the paper and the fabric becomes saturated. Heat input is used for heating up the paper.

Phase 2.

The sheet now covered by the fabric is in contact with the cylinder. The fabric restricts the evaporation to some extent, but there is a substantial temperature increases because the paper is in close contact with the dryer.

Phase 3.

This is similar to phase 1 but the paper is at a relatively higher temperature so more evaporation takes place from the exposed surface. Heat input from the cylinder does not equal heat loss by evaporation so temperature falls.

Phase 4.

The sheet is now hotter than the surrounding air so evaporation occurs, and since there is no heat in put the sheet cools.

The whole cycle is repeated as the paper enters phase 1 of the next drying cylinder.

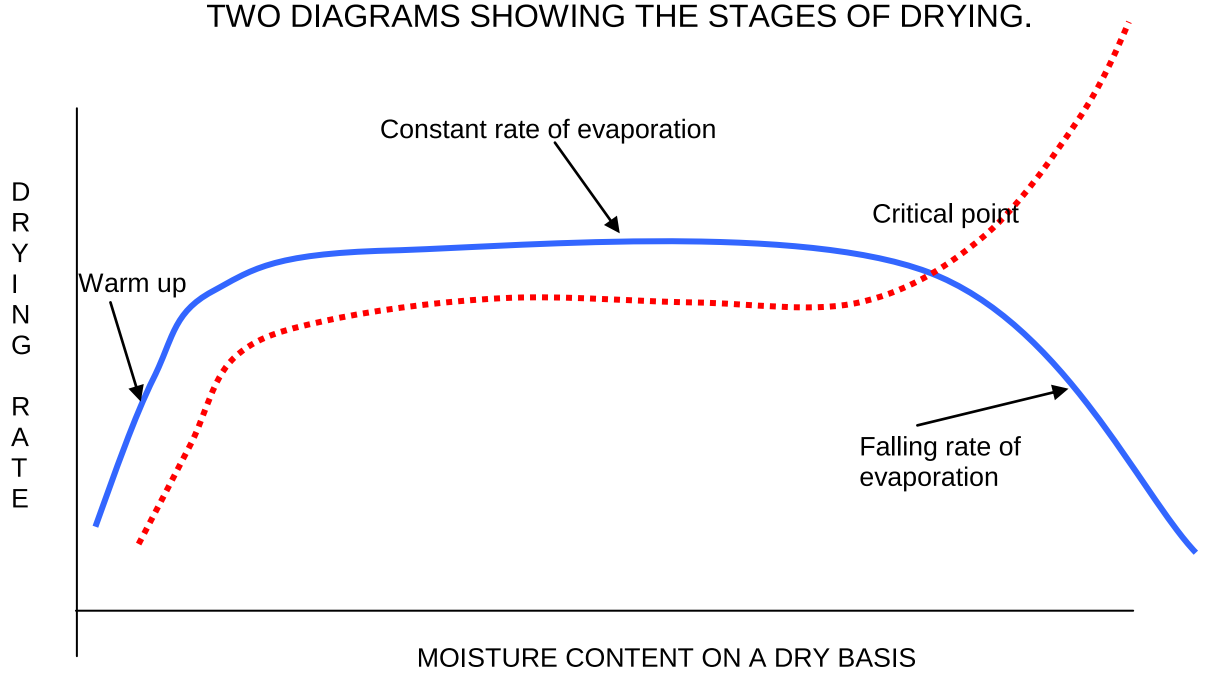
THE THREE STAGES OF DRYING.

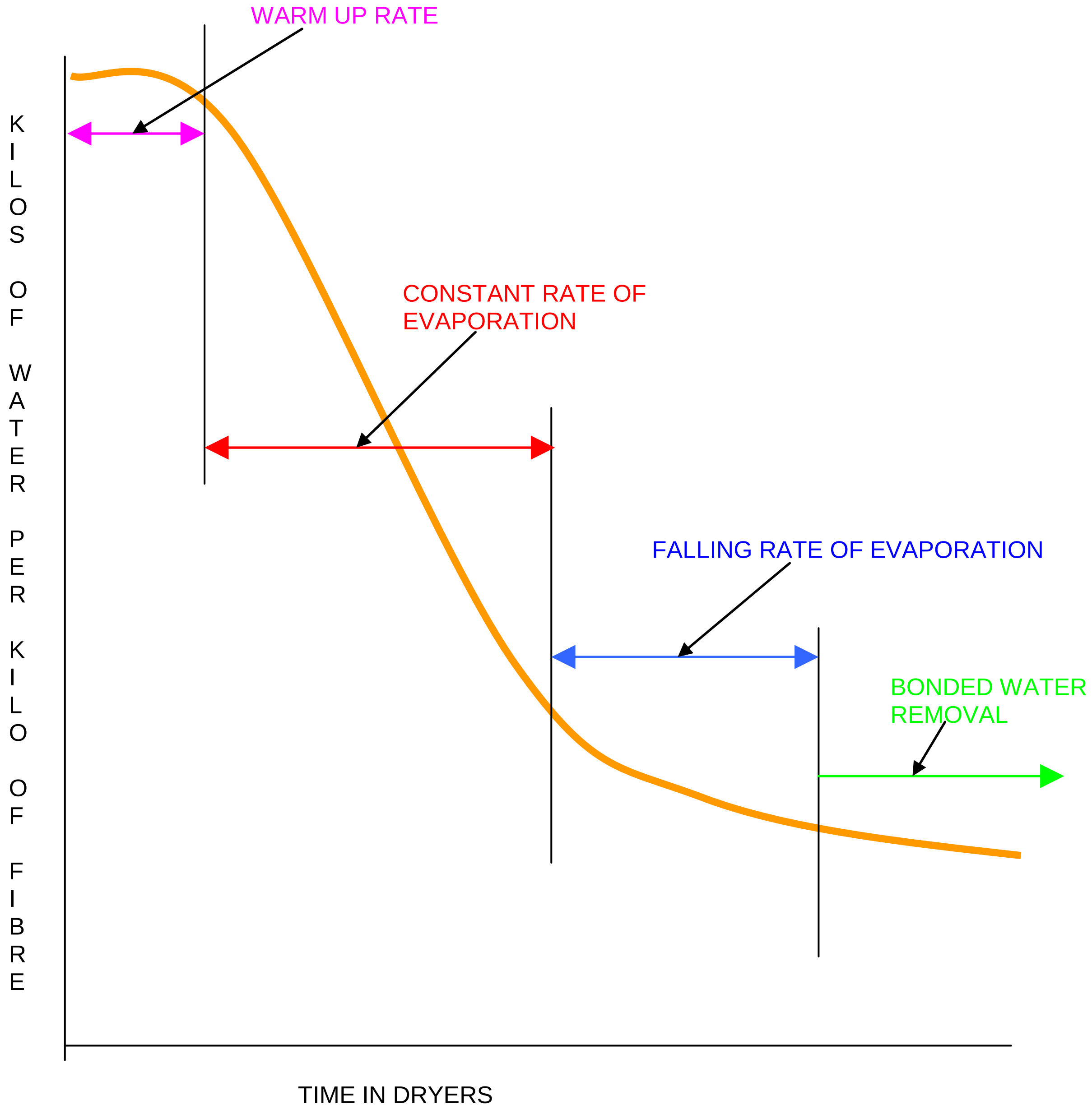
The phases of drying refers to the cycle of drying the paper round each of the individual cylinders.

The drying of paper throughout the length of the drying section is divided up into **Three stages**

1. The warm up stage
2. The constant rate of water removal stage (Evaporation)
3. The falling rate of water removal stage (Evaporation)

TWO DIAGRAMS SHOWING THE STAGES OF DRYING.




WARM UP RATE
CONSTANT RATE OF EVAPORATION
FALLING RATE OF EVAPORATION
BONDED WATER REMOVAL
KILOS OF WATER PER KILO OF FIBRE
TIME IN DRYERS

THE PROPERTIES OF STEAM.

The properties of steam are obtained from “The Steam Tables”.

The steam tables is a set of information which gives:-

1. The pressure of the steam absolute and above atmospheric.
2. The saturation temperature º Fahrenheit and º Rankine (ºF + 459.7)
3. The sensible heat contained in 1 pound of water at its boiling point at a given pressure
4. The latent heat of vaporisation under the conditions of pressure and temperature
5. The total heat in 1 pound of steam which is dry saturated at the given pressure (it is the sum of the sensible heat and the latent heat) and is sometimes called the ***enthalpy.***
6. The ***entropy*** (not to be confused with ***enthalpy***) of water and steam which is the heat content of 1 pound of the substance divided by the absolute temperature of the substance.
7. The specific volume of dry saturated steam in ft^3 / lb.

CALCULATION OF EVAPORATION RATES

$$\frac{Basis weight\ of\ sheet\ x\ speed\ 60\ x \left\{ \frac{Dryness\ out\ of\ dryers}{Dryness\ into\ dryers} \right\} - 1}{1000} = E$$

Evaporation rate in Kilos of Water / Hour / Meter width of sheet width

If circumference = A

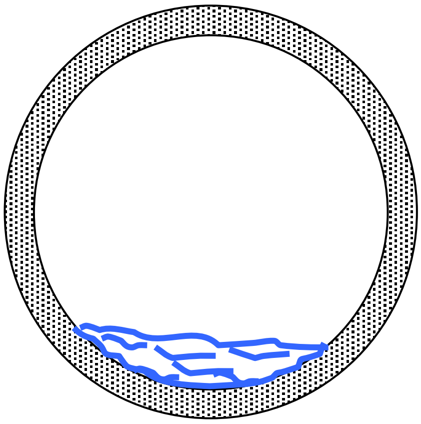
Then $\frac{A}{Number\ of\ dryers}\ x\ \ E = Ev =$ Kilos of water removed per hour per mtr^2 of drying cylinder face

If the evaporation of the contact area is to be found then the wrap and contact angle need to be known.

CONDENSATE

When the steam condenses in the drying cylinder it is imperative that it removed as rapidly as possible. This is to minimize the layer of condensate formed inside the dryer and therefore maximize the heat transfer.

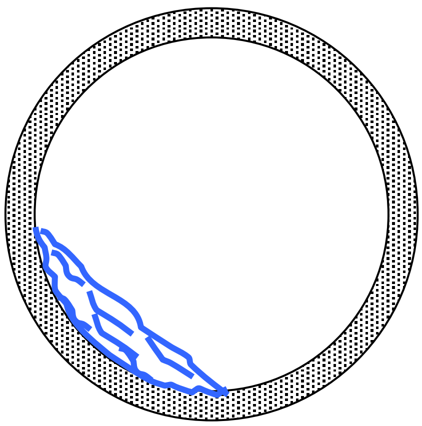
On slow machines or where a considerable amount of condensate has accumulated it collects a as a “puddle” at the bottom of the cylinder.



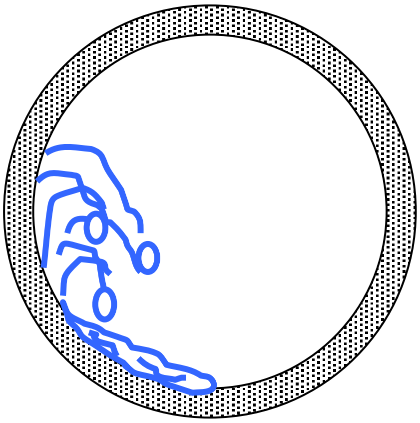
PUDDLING

The condensate is removed by a syphon assembly. In the case of a slow speed puddle it could be a stationary syphon, which is set to a predetermined distance from the bottom of the cylinder.

As the speed increases or as the amount of condensate is reduced the puddle starts to “climb” and will eventually “cascade”



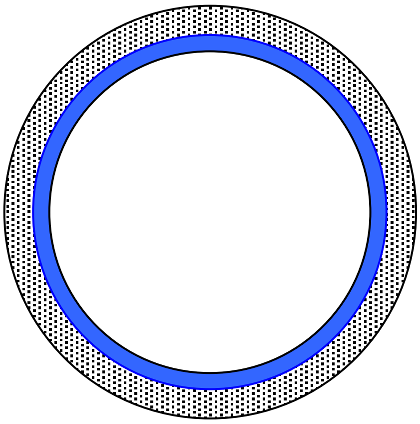
CLIMBING PUDDLE



CASCADING

In these situations the fixed syphons would not be immersed in the condensate all of the time, so would only remove condensate intermittently and when the tip of the syphon was not immersed it would pass large amounts of steam which would make for excessive wear on the tip and a great reduction in efficiency. It these situations rotary syphons are used.

As the speed increases still more or as the quantity of condensate is reduced “rimming starts to occur and the condensate forms a uniform thickness round the inside of the cylinder due to centrifugal action.



RIMMING

In theory then the two situations that must be avoided at all costs are the “climbing puddle” and “cascading” because in these situations large amounts of steam will be lost out of the dryer. So it therefore essential that the rimming stage is gained as soon as possible and that it is maintained.

The speed at which the condensate will rim in a dryer is a function of: -

1. Volume of condensate.
2. The inside diameter of the dying cylinder
3. The condition (smoothness) of the inside of the drying cylinder
4. The acceleration of the drying cylinder.

But the shape and thickness of the condensate layer once it has started to rim is a function of: -

1. The speed of the cylinder
2. The condensate hopper design
3. The differential pressure between the inside of the dryer and the condensate system
4. The volume of condensate.

SYPHONS FOR PAPER MACHINE DRYERS.

Condensate behavior in a revolving cylinder has been observed and photographed, and depending on the quantity of condensate, diameter of the cylinder and the speed of rotation the following has been noted.

1. A film of condensate adheres to the dryer at all speeds
2. Increasing the rotational speed of the dryer will cause a fixed quantity of condensate to progress through the following stages:-
    - Most of the condensate collects as a puddle at the bottom of the dryer.
    - The puddle progresses up the wall of the dryer in the direction of rotation
    - The condensate drops or showers from the wall of the dryer this is called cascading
    - As a result of centrifugal action condensate forms into a layer, this condition is known as rimming.
3. The rotational speed at which one stage ceases and the next begins depends upon the quantity of condensate and the diameter of the cylinder.
4. A condition of partial rimming and cascading has been observed at the same time in one dryer.

There is continuing research on the effect of condensate in the dryer and it has been established that syphon design and sizing is a contributing factor to the condensate behavior and uniform dryer surface temperature.

The syphon is a device with connecting piping through which condensate and blow-through steam, air and non condensable gases pass from the inside of the dryer to the condensate outlet connection of the rotary joint mounted on the dryer journal.

The ideal syphon should be designed and sized so as to keep the thickness and variation of condensate film to a minimum. It is possible with proper design to produce and maintain a thin rimming film at low machine speeds.

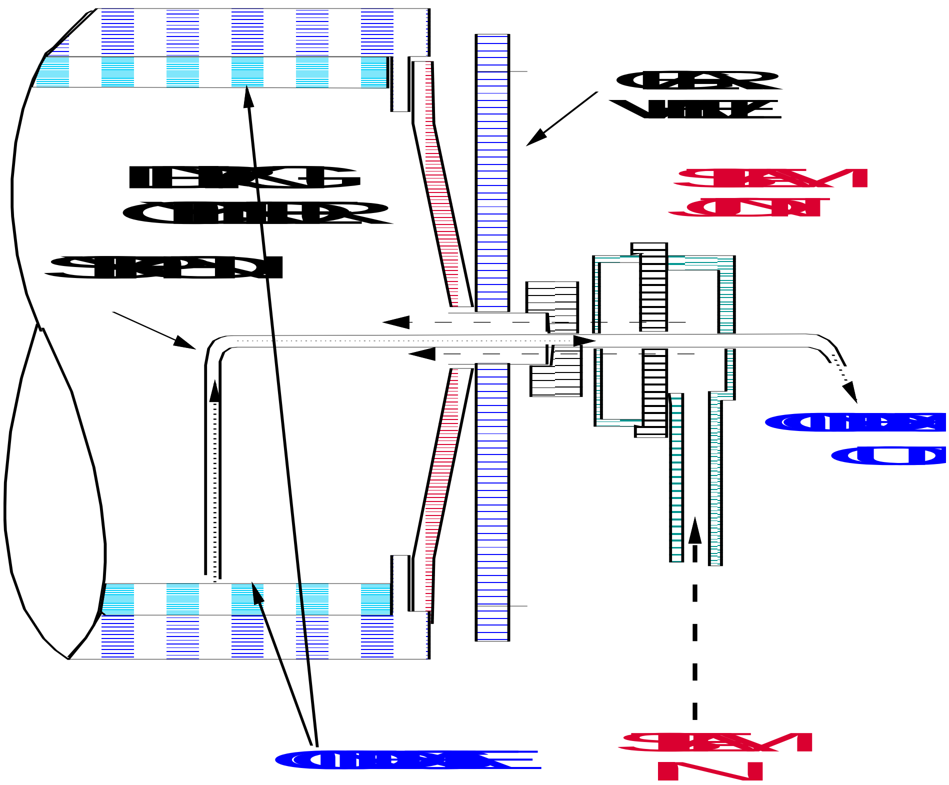
Cascading within the dryer increases horsepower requirements and may contribute to dryer bearing problems. It also increases heat transfer from steam to dryer in comparison to a dryer with rimming condensate.

There are two general types of syphons; rotating and stationary. The rotating syphon revolves with the dryer and the stationary siphon remains fixed relative to a point outside the dryer.

Generally rotating syphons require less maintenance insomuch as the opening is fixed in relationship to the inside of the dryer shell and is securely fastened in position.

Differential pressure requirements necessary to have the condensate flow from the dryer is a function of proper syphon sizing in relation to condensate load and speed. Stationary syphons require less differential pressure under similar operating conditions since centrifugal action is not involved.

Blow through steam mixed with condensate; results in a two-phase system with an average density much lower density than liquid water. Therefore, the differential pressure required to drain the dryer will be much lower than that compared to the theoretical differential pressure in the case of cold water.



AXIAL BARS or SPOILER BARS.

The spoiler bar is based on the premise that the thermal resistance of the dryers condensate layer can be reduced by fitting axial bars on the inside of the dryer shell. These bars generate a turbulence in the condensate layer, and enhance heat transfer during high-speed operation.

Dryer performance and the ability to transfer heat is dependant on the movement or behavior of water within the dryer. At low speeds condensate rests in a puddle at the bottom of the dryer causing steam to condensate on the inside wall. As the speed increases cascading occurs this is usually accompanied by large-scale turbulence, which provides good heat transfer.

When speeds reach about 350 meters a minute a relatively uniform thickness of water forms around the entire circumference with a turbulent sloshing motion present. However as speeds increase the turbulence stops and heat is forced to conduct through an essentially stagnant layer of water.

Spoiler bars placed longitudinally around the circumference of the cylinder will tend to generate turbulence thus enhancing heat transfer.

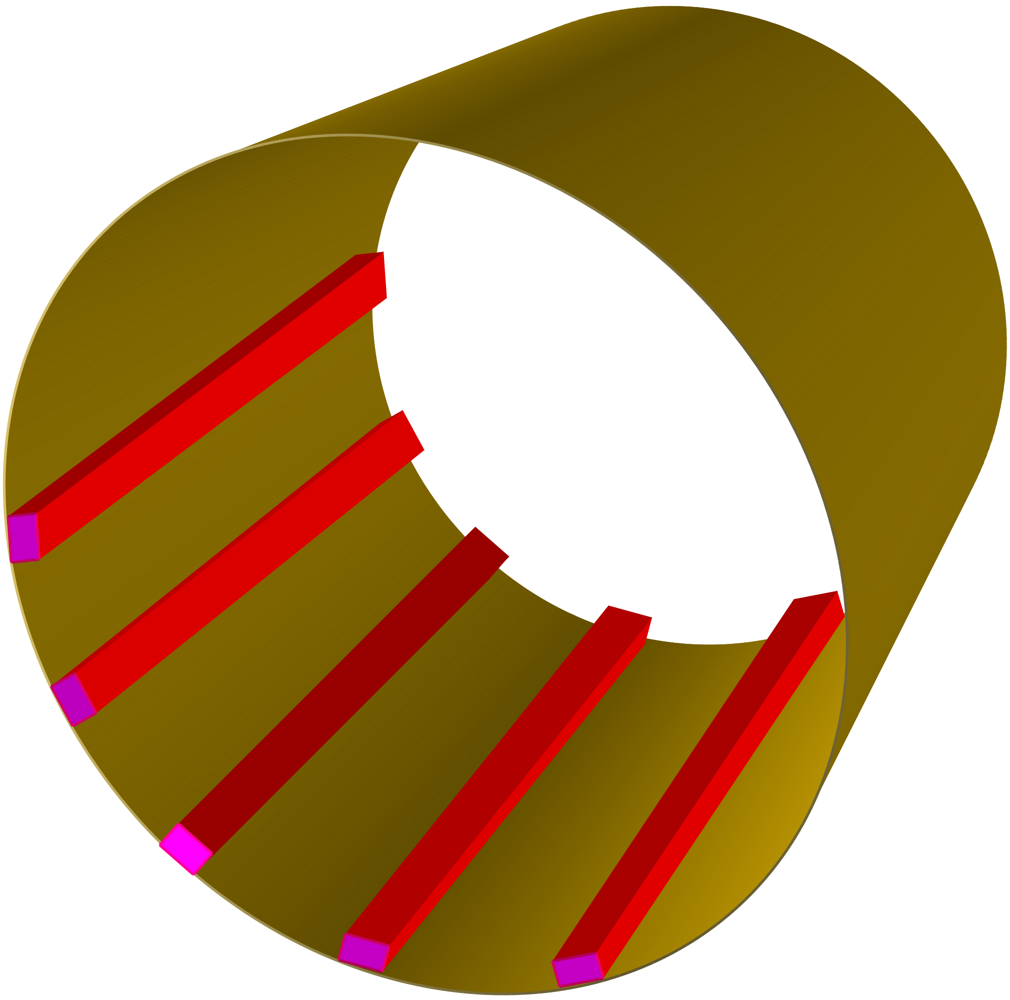
Limitations.

Spoiler bars added to existing machines can produce remarkable results. However despite their benefits spoiler bars do have limitations. For example, to increase speed, spoiler bars should only be applied to dryers that are steam pressure limited due to steam header limits or steam design limitations. Also spoiler bars should not be used on dryers of machines that restrict steam pressure due to the sheet's low tolerance to higher temperatures. Spoiler bars are also not applied to the bottom dryers of a serpentine (salom) felted section since the bottom dryers do not contribute to drying.

Profiling.

Spoiler bars can also improve sheet moisture profile. One proven method is to apply partial length bars to cover only the "wettest" portion of the sheet. This method improves drying only where required, and allows the wetter portions of the sheet to catch up with the dyer portions thus producing a leveling effect.

The preferred location of profiling dryers is in the maximum drying rate area of the machine (usually mid machine in the steam group that is running the highest pressure). Felted dryers are preferred with the highest possible wrap and adequate pocket ventilation for maximum effectiveness.

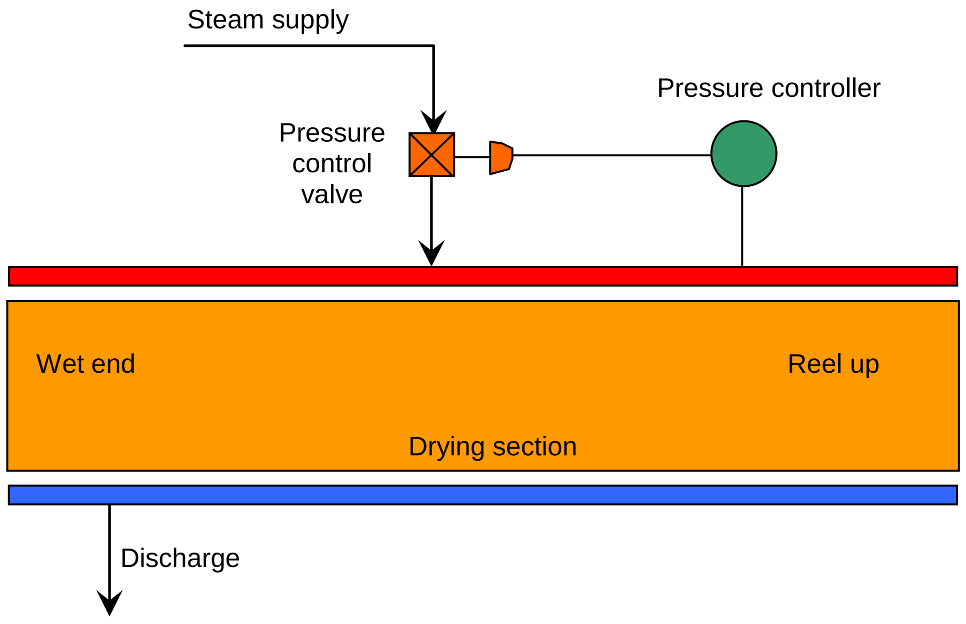


Schematic view of spoiler bars

STEAM AND CONDENSATE SYSTEMS.

The function of a dryer drainage system is to assure through the control of steam and condensate pressure systems throughout the dryer section, the machine, economic optimal evacuation of condensate, air and other non-condensable gasses under all operating conditions.

A "basic" system shown below, could be considered adequate for some applications, however, the limitations to such an application are numerous.

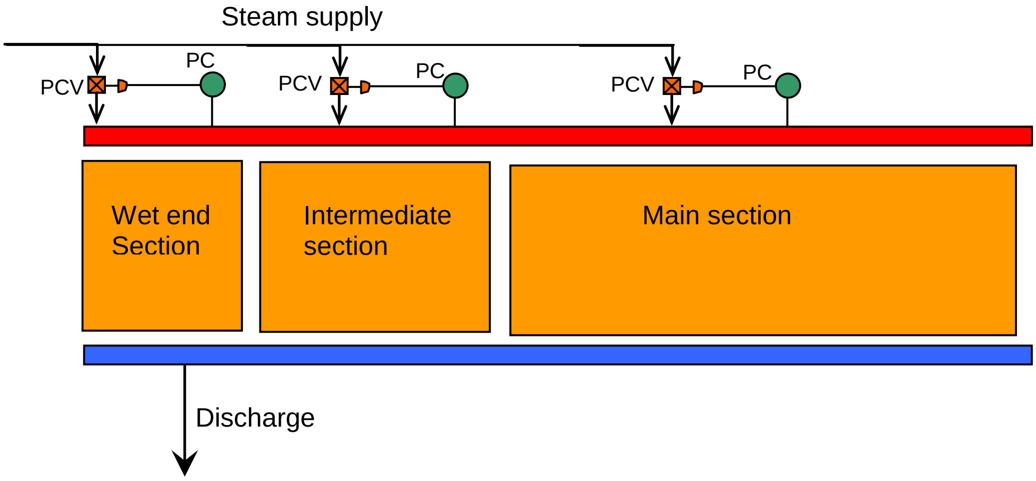


A pressure control loop throttles in steam to the dryers. Blow-through steam, condensate and flash steam are discharged. A fixed restriction is installed in each condensate outlet pipe from the dryers in an attempt to limit blow-though steam flow.

In the system shown all the dryers operate at the same pressure, and unless the operating pressure and resultant surface temperature are low, picking, sticking and other related problems will result on the wet end dryers.

Production is directly related to dryer operating pressure, therefore, it is obvious that if pressures are reduced to eliminate the above mentioned wet end conditions, the capacity of the machine will be limited.

A partial solution to this problem is to isolate several of the wet end dryers in a separate dryer section with its own steam supply and control loop. The pressure and resultant surface temperature of these wetend dryers may then be reduced without significantly reducing the drying capacity of the machine. Should the required drying pressure be high, it could be necessary to add a third dryer section, which would operate at some intermediate pressure between the wet end and the main dryer sections. (See next page)



Control of Condensate Pressure.

In this system the dryer outlet pressure will always be slightly greater than 0 psi/g inasmuch as the dryers continually discharge through the fixed restrictions in the condensate outlet lines from the dryers. As dryer operating pressures are raised, blowthrough steam quantity and velocity will increase. In addition to the waste of steam due to exsessive blowthrough, the increased in velocity will accelerate the rate of erosion of dryer syphons and piping, and in extreme cases, cause breakage of the syphons.

An automatic evacuation of controlling condensate pressure could consist of a transmitter which relates the pressure in the condensate header to the pressure in the steam header and sends a proportional signal to a control instrument which throttles a control valve to maintain the condensate pressure at a value lower, by a fixed amount, than that being carried by the steam header. This differential in presser between the dryer inlet and outlet is commonly referred to as “The Differential Pressure”.

The continuous evacuation of condensate, air and other non-condensable gasses from the dryer assures even drying of the sheet. Heat transfer to the sheet improves, therefore lower steam pressure will be required to evaporate the water from the paper and this may reduce total steam consumption, this will result in significant savings.

However other savings come from the reuse of the condensate, blow-through and flash steam.

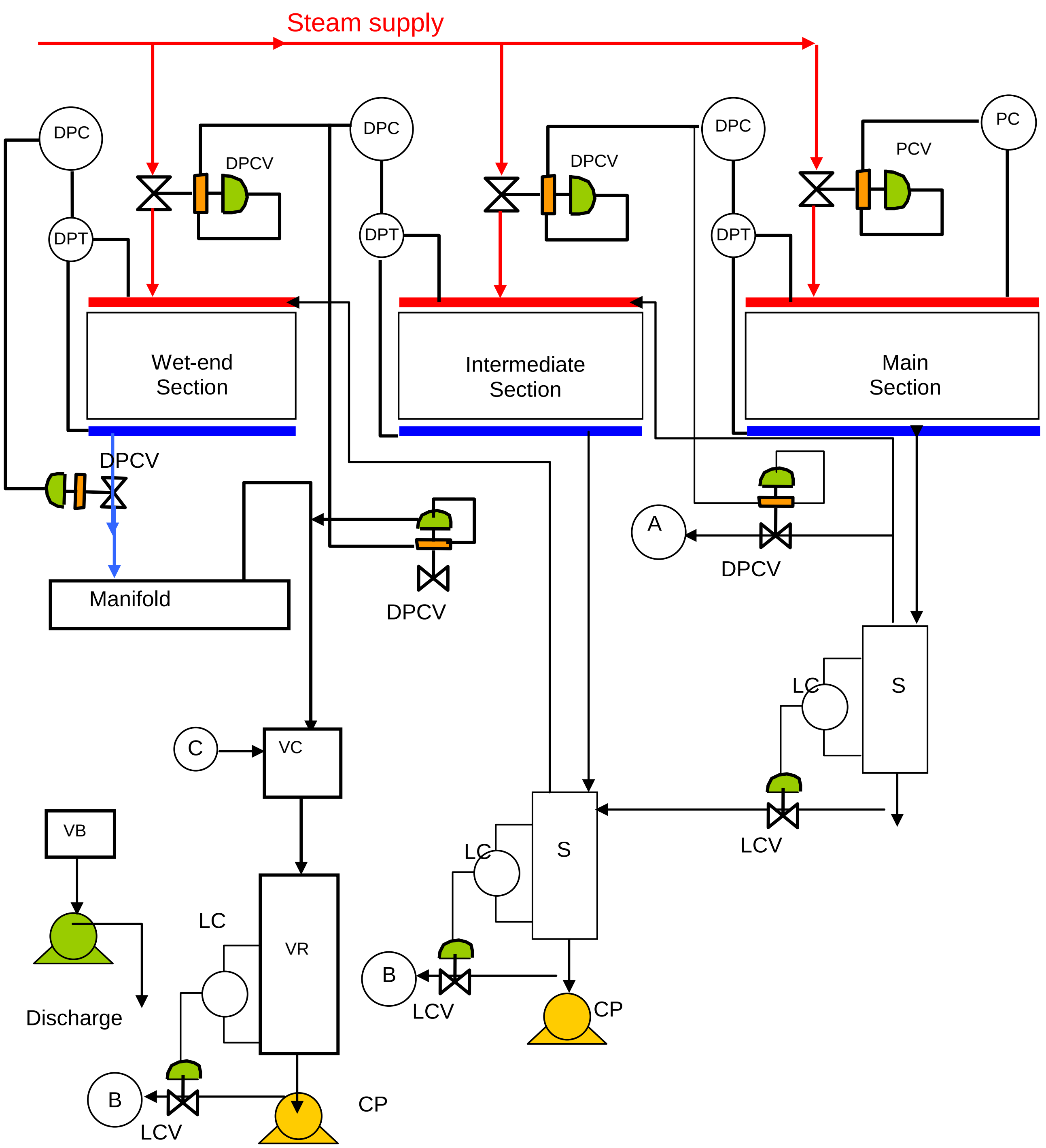
Treated water is needed for the generation of steam; therefore reuse of condensate will result not only in BTU savings but also savings in chemical treatment.

THE CASCADE SYSTEM.

There are several types of system which provide a method of reusing blow through steam within the dryer section, and the most prevalent in use today is commonly referred to as the “cascade system”

This System cascades the blow-through steam through succeeding dryer sections to a small group of dryers at the wet end. This last group discharges to a condenser and depending on the minimum pressures required, it might discharge to some other moll process.

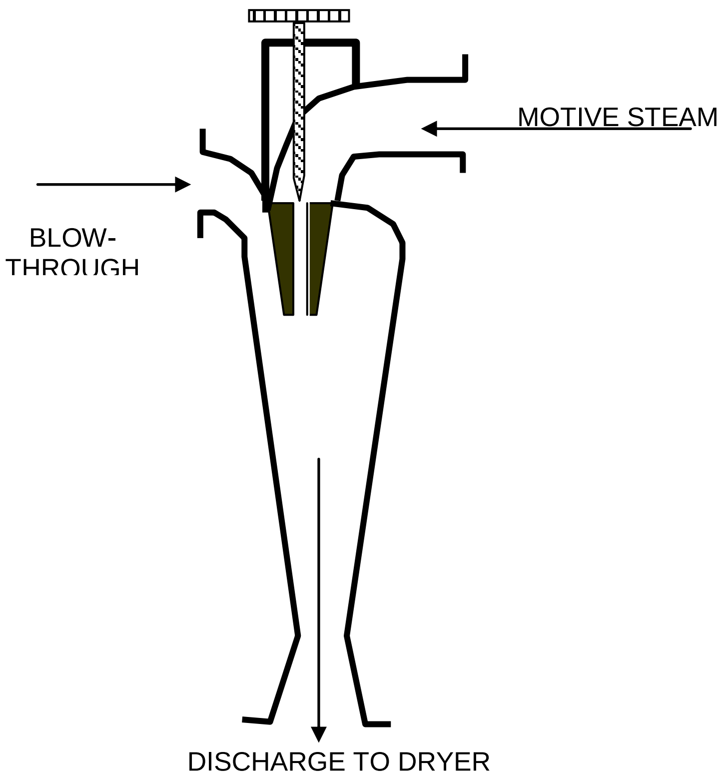
The Diagram shows a simple cascade system.



A pressure control loop throttles the steam to the main dryer section. Differential across the syphons of the main section are controlled by a loop consisting of a differential pressure transmitter, receiver controller and the steam blowdown and make up valves.
The differential valves are sequentially operated and the blowdown valve closes on an increasing signal from the controller. The make up valve opens on an increasing signal. Each valve will be fully open on one half of the instrument output signal. The control instrument is direct acting; i.e. an increase in differential will cause the controller to increase its output.
Upon an increase in differential, the instrument output will increase and close the blow down valve. If it is not sufficient to restore the differential, the output will continue to increase and open the steam makeup valve.

JET COMPRESSORS

A jet compressor is a device that uses a fluid at high pressure to entrain a fluid at low pressure and discharge a mixture at some intermediate pressure. It can be used to re-circulate either a compressible or non-compressible fluid.
In their application in the papermachine the medium is steam. When both motive and suction gasses are steam the compressor is referred to as a “theremocompressor.” They have been available since the early 1900’s and in recent years have enjoyed a rapid growth in popularity. They are simple, versatile, can be designed to operate atmospheric or sub atmospheric pressures, consist of a few parts and when used on the papermachine enjoy a reasonable rangeability.



Construction and operation.

The basic compressor consists of a body, diffuser, nozzle, spindle and a cylinder or diaphragm actuator to operate the spindle.

Motive steams expanded from the inlet pressure to that in the suction chamber where the pressure energy is converted to velocity energy. The steam leaves the nozzle at velocities in the order of 500 - 700 mts./sec.

As it passes through the suction chamber, the lower pressure steam is mixed and entrained.

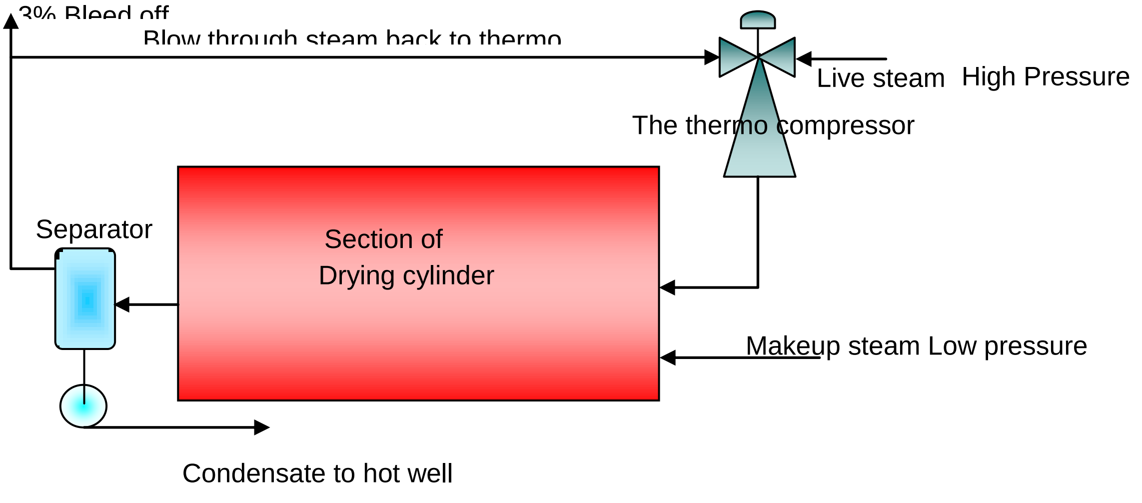
The steam now at an intermediate velocity, enters a convergent / divergent diffuser, after expansion, mixture velocity decreases and mass velocity is converted to pressure energy.

Performance.

Thermo-compressor performance is of two types based on compression ratio. Compression ratio is discharge pressure divided by the suction pressure in absolute terms. Ratio = P_2 / P_S (absolute units)

In general terms when the compression ratio is two or more, performance is critical. This type of performance produces sonic velocity in the throat of thew diffuser. While this dose not often occur in thermo-compressors on papermachines, it can, if wide ranges of operation are required.
An example would be a dryer section operation at 15p.s.i.a. with a 15 p.s.i. differential.

The other type of performance is non-critical and does not require sonic velocity in the diffuser to achieve the desired compression. Most dryer drainage systems utilise non-critical compressors and suction capacity varies directly with motive flow at a given discharge pressure. If motive flow increases and additional suction flow is not available, differential pressure will increase until equilibrium is established.
One of the simplest systems for controling a section of paper dryers using a thermo-compressor is shown.



The pressure control of the section is achieved by a pressure control instrument throttling in the themocompressor and the makeup steam. They operate on a split range. Differential across the drying section is maintained by throttling of the split range valve and differntial pressure control valve.

Advantages of thermocompressors.

Thermocompressors when used on papermachine dryer sections, offer the advantages of machine flexibility and maximum production capabilities.
Each seperatly controlled dryer section can be looked upon as a single papermachine that will operate within the design limits of the thermocompressor.
Depending on the paper grades, all sections could be run at maximum pressures for optimum p-roduction, or the dryers can be arranged into steaming sections so that better control can be obtained over picking at the wet end and curl at the dry end.

A thermocompressor can be a useful tool if the correct information is provided for its designe. An incorrect designed unit can be very wasteful of high pressure motive steam and also suction steam if it can not be recirculated.

YANKEE DRYERS

The use of a YANKEE dryer introduces some special control problems, particularly during start up when gradual warm- up of the cylinder is necessary and when the machine is running under no load, so called “Sunday drive “ conditions.
Too rapid an inflow of steam can cause serious damage to the cold dryer because of unequal distribution of heat through the shell. Therefore it is desirable that some provision be made to gaurd against the accidental or intentional shortening of the warm up period.

Operating pressures may range from 75 p.s.i.g. to as high as 175 p.s.i.g. with machines being balanced for speeds in exsess of 2000 mts / min. These high speeds, combined with large dryer diameters, require large differentials to be carried across the steam joints. These differentials are in the order of 12 to 18 p.s.i.

Syphon sizing becomes very inportant when operating at these high differential pressures. If a jet compressor is used, all under condensed steam blowing through the syphons must be recirculated. If the quantity of blow through steam is too great, the motive steam requirements could exceed that being condensed in the dryer thereby choking the compressor and causing loss of differential which would result in a flooded cylinder.

THE VACUUM SYSTEM

A most important part of the paper machine drainage system is the vacuum system. Design of this system is dependent on the type of paper to be manufactured as well as the machine speed and differential pressure, high vacuums areusually required to maitain reduced surface temperatures. On the majority of machines, vacuums of the order of 15 to 20 inches of mercury are sustained, although vacuums as high as 24 inches of mercury are not unusual on some speciality macines.
This latter figure is not easy to obtain unless all pipe fittings, flanges, steam joints etc. Are free from leaks. Atmospheric condensers may be used if low machine operating pressures are not required.

On machines running at high pressure, air leakage into the system will be at a minimum and many mills will forgo the use of a vacuum pump. A vent condenser is utilised and air and non-condensable gasses are vented to atmosphere.

Machines manufacturing the finer grades of paper require a tighter control of the graded temperature in the dryers and because of this the machine could be operating below atmospheric pressure, particularly in the situation where light weight sheets and slow machine speeds are encountered. In this situation air leakage could high.

POCKET VENTILATION

It was pointed out at the beginning of this module that drying was an integrated process of heat transfer and mass transfer.

Mass transfer will takes place in the drying section naturally, albeit very slowly, by convection currents, but to make it more efficient mass tenser must be induced.

This is done by injecting hot dry air into the dryer pockets in order to replace the hot humid air, which is at near saturation point brought about by the moisture evaporating from the sheet.

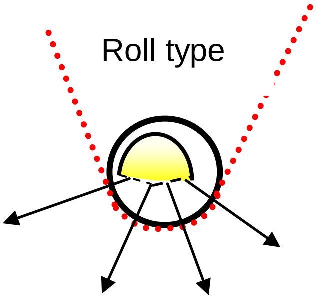
Early attempts to do this involved locating the ventilating system inside the pocket which was very restrictive and in some cases made for a long “draw” between the top and bottom tier of the dyer.

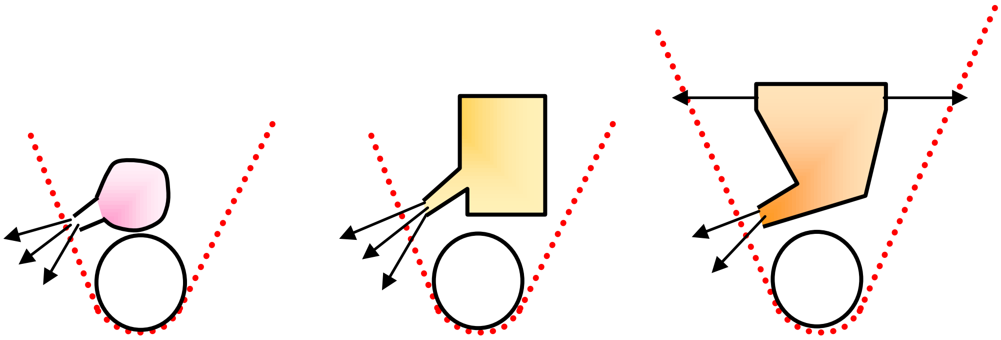
Open fabrics allow the location of these ventilating systems outside the pockets, and in many cases a ventilating roll replaces the felt roll and supplies air into the pocket via the roll and fabric. Other designs use ducts to direct the air through the fabric into the pocket

Sometimes the air directed through the jets impinges upon the sheet replacing the humid boundary layer air with dry air and on selective impingement systems this air can be concentrated in specific areas across the sheet to help correct profile in the sheet.

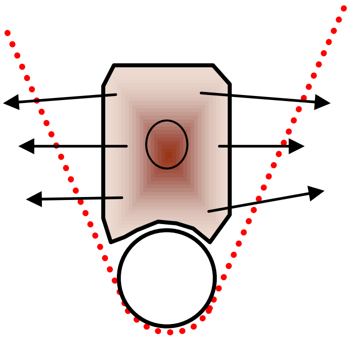
Some of the designs of the various systems are shown below

Roll type





Nozzle types



Box type

The open dryer fabric itself represents a pocket ventilating system due to the air movement and pumping action resulting from its permeable nature.

Frictional drag on the air surrounding a moving fabric causes the air to move with the fabric. As the fabric contacts the dryer or carrier roll air is forced through the fabric with air movement away from the roll or dryer at the converging nip, (compression wedge). The result of these forces is a net inflow of air into the dryer pocket resulting in an outflow of air from the front and backside of the machine. But this can be disruptive on high-speed machines if the permeability of the fabric is not carefully considered and will cause "*sheet flutter*"

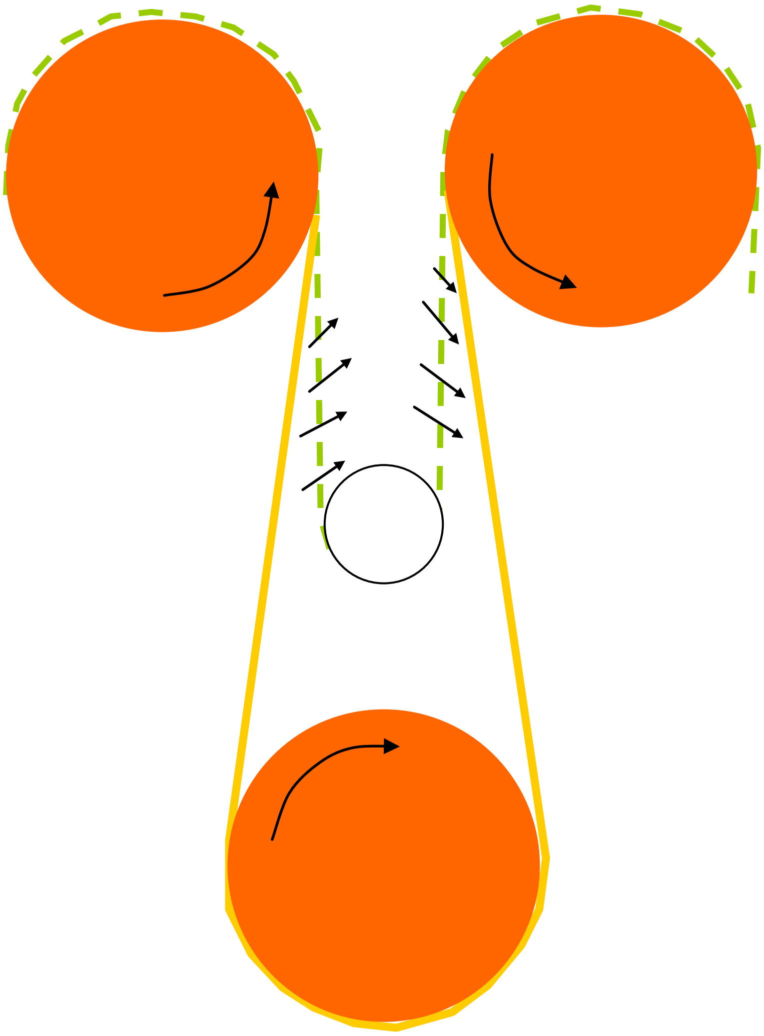


ILLUSTRATION OF HOW A PERMEABLE FABRIC PROVIDES DISPLACEMENT OF AIR IN A DRYER POCKET

HOODS AND CANOPIES

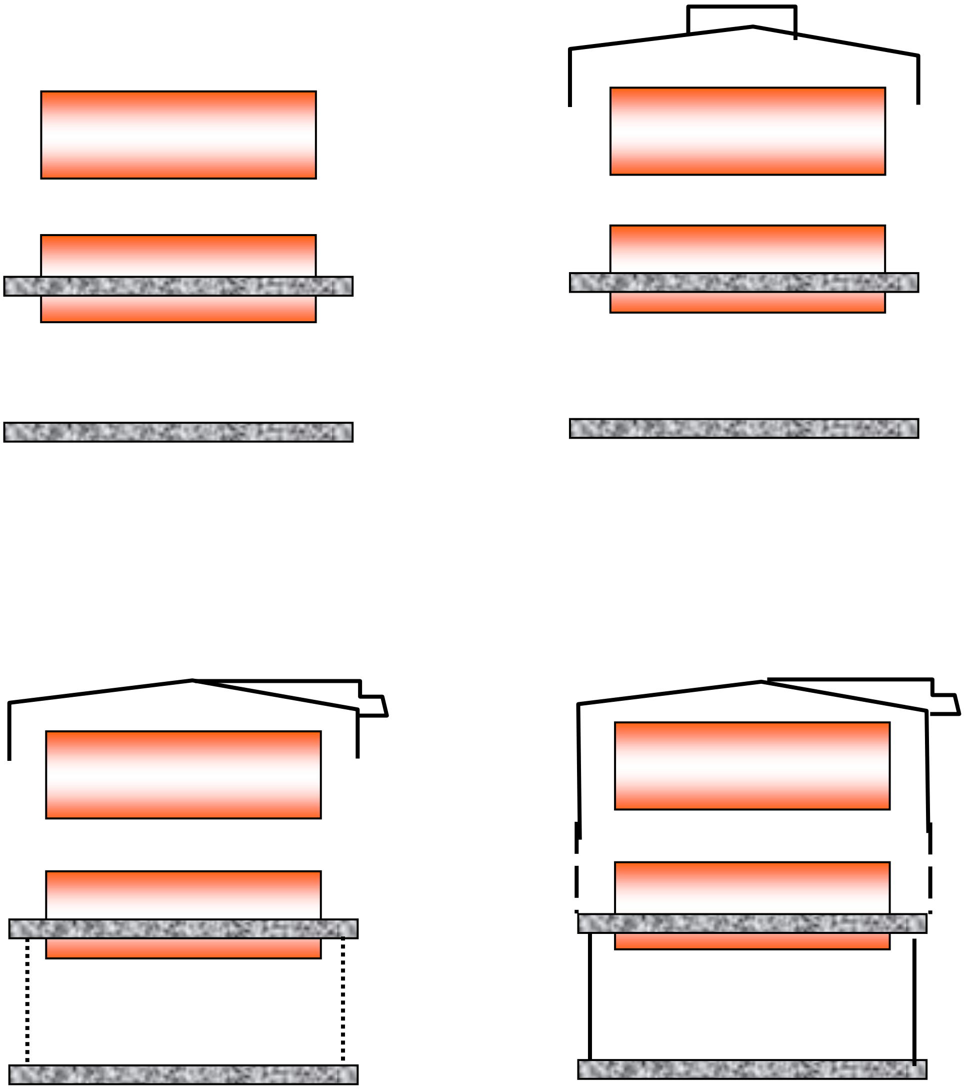
Air is an important part of the paper drying process and to utilise it to it full potential hoods and canopies are fitted to the machines.

Depending on what type of hood arrangement is used on the machine from 3 to 8 kilos of air is utilised for each kilo of water evaporated.

Enough air must be used to absolutely avoid condensation anywhere in the hood to prevent drips. The air should be strategically supplied for economic operation.

As a general rule this can be determined by taking the relative humidity of the outgoing air, 80% RH being the optimum. If the air is less than 80% then it is considered too much air is being used and energy is being wasted, and if it is higher than 80% then efficient removal of moisture is not taking place.

The first dryer hoods consisted of little more than “false ceilings” with exhaust fans, all the supply air was sucked from the machine room and was not efficiently utilised. Partially enclosed hoods were an improvement, but totally enclosed hoods provide much better control of supply and exhaust air flows and minimize random air currents that cause drying non-uniformity.



The modern generation of hood (high dew point hood) are well sealed and insulated. Diffusion of air is totally eliminated, and the amount is sharply reduced by operating at high temperature with a partial recycle.

All modern hoods are equipped with an economizer heat recovery systems. The primary element is the air to air heat exchanger for transferring heat from the hot humid exhaust air to the fresh ambient supply air. Steam economy can be optimised in case of high dew point hoods because less air is used and a high level of heat recovery is possible.

DEVELOPMENT OF THE DRYER SECTION.

One of the developments in drying is the introduction of the single tier drying sections.

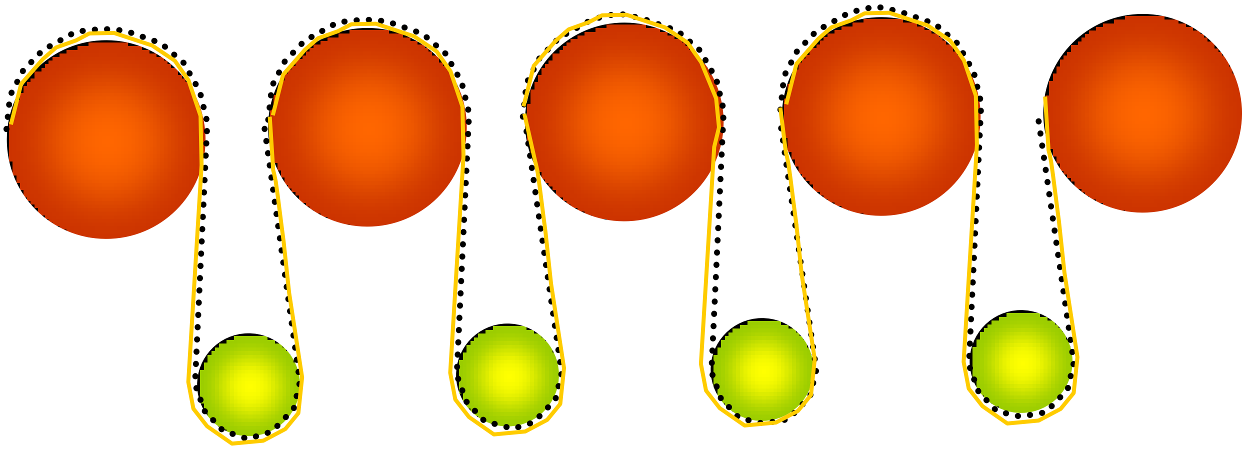
Published data has shown that it is beneficial to dry paper under restraint to prevent shrinkage, it ha been found that the lack of restraint found in conventional two tier drying sections is a source of cross machine non-uniformity in cross direction properties. The extensive number of open draws in a two-tier system also contributes to poor high-speed runability.

Single tier geometry addresses these issues by providing restraint and full web support, and it has been shown that cross machine shrinkage in a single tier dryer configuration is only 40% that found in a two tier system. This decrease in shrinkage can result in a flatter cross machine property profile.

Other befits claimed are: -

- Automatic threading capabilities
- Improved drying rates
- Improved dryer section runability.

Single tier dryer geometry is a significant improvement over the conventional two-tier configuration. Unlike the two tier, where the sheet runs through open draws between the dryers, the single tier provides full web support with no open draws. After passing over a drying cylinder, the web follows the fabric round a felt roll and onto the next dryer. To maintain web / fabric contact, the felt rolls are vacuum assisted. The combination of no open draws and vacuum assisted rolls not only gives the web full support in the dryer, it also provides the opportunity to restrain it against shrinkage in the cross machine direction.



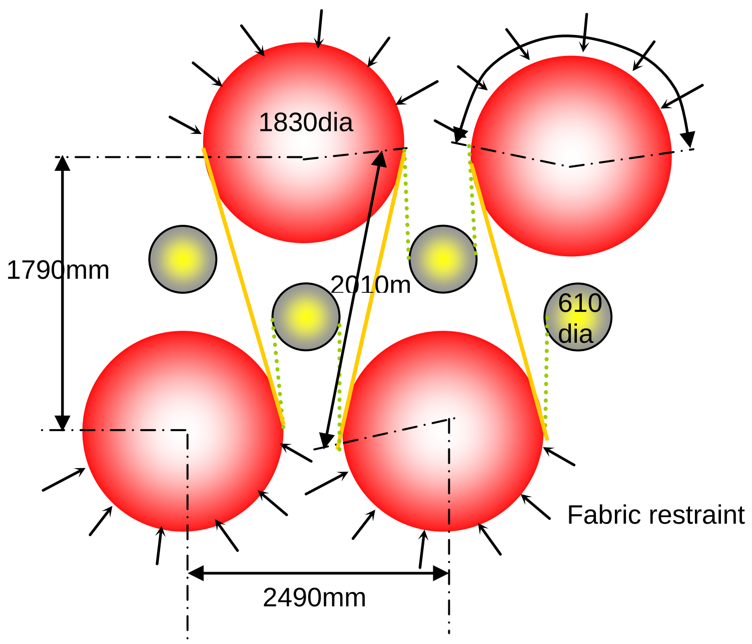
Drying both sides of the paper uniformly is addressed by alternating between dryer groups where the fabric passes around the top of the cylinders and groups where the fabric passes round the bottom. In the top felted groups the bottom side of the sheet contacts the cylinders and in the bottom felted groups the topside of the sheet contacts the cylinders. Passing the web between the groups is accomplished using the closed draw transfer.

Two tier drying geometry shows that it does not offer much in the way of dryer restraint, as is shown the two tier configuration provides only 58% of active restraint in the dryers and this restraint is in the form of fabric tension holding the paper when it is on the dryer cylinder.

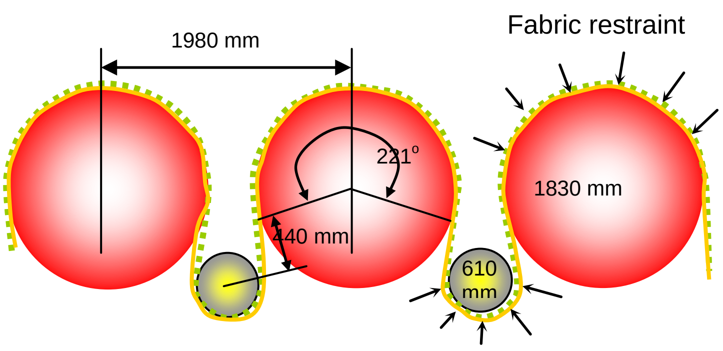
Effective restraint or the amount of water evaporated from the web while under restraint, is much; lower as most of the evaporation occurs in the open draw where the web is totally unrestrained.

Contrast this to the single tier geometry, which provides active restraint foe 84% of the time the web is in the dryer section.

This restraint is provided by a combination of web tension holding the web while on the cylinders and vacuum retention when the web is passing between cylinders.
The addition of vacuum rolls between the cylinders is an important point as they are in an area where restraint is most needed.



58% Active Restraint



Machine threading. Because of the full support in the drying section no ropes are needed to thread the tail through the dryer.
Threading is initiated by actuating a press to dryer, which flips the tail into the dryer section, once in the dryer section the special design of the vacuum felt rolls hold the tail onto the fabric as it passes down the machine. To enhance the threading, air nozzles are strategically placed on the dryer doctors to direct the tail to follow the fabric on the outgoing side of the dryer.

High speed runability. Again because of full support in the dryer section and lack of open draws, the number of dryer breaks is dramatically reduced.

Increased drying rates. There are several factors contributing to this, one is the increased wrap with the single tier geometry, This is from the closer spacing of the cylinders.
Another advantage is the increased felt wrap, lack of contact pressure in regions where paper is on the dryer but the fabric is not resulting in a loss of heat transfer to the web.
A third factor is ventilation; the absence of closed pockets and the use of vacuum rolls achieve this.

In discussions involving single tier geometry the question of over all dryer section length is often raised. This is usually based on the thinking that the single tier is the top and bottom of a two tier dryer design laid end to end. If this were true then the resulting dryer section would be twice as long.
But this is not the case, the higher drying rate means that fewer dryer are required and this combined with the closer spacing of the dryers means the single tier designs are usually in the region of some 10 meters longer that the two tier designs.

SILENT DRIVE.

The term “silent drive” usually refers to an installation where the dryers are driven by the dryer fabrics through the felt rolls which are directly coupled to DC motors.
It was called silent drive because all the gears were eliminated and therefore the common gear noise was eliminated.

However the silent drive designation is also being used to refer to other dryer section drive arrangements in which one or more of the dryers are driven by the felt even when gears are used to synchronise the tiers.

The drive-input points may be either felt rolls or dryers, or a combination of rolls and dryers.

Silent drive has several technical advantages over the common gear sections both for new machines and rebuilds.

Technical advantages

1. The dryer pockets are ventilated more uniformly because the backside framing is more open.
2. Dryer “wrap-ups” and diameter differences will not cause gear failure.
3. Dryer drive noise is subsequently reduced
4. The machine speed is no longer limited by gear limitations, and rebuilds are less costly.
5. Gear cases are eliminated so there are no oil leaks.
6. The spare drive motors are lower horsepower and therefore lower cost.
7. The size of the lubrication system and the amount of associated piping is reduced.
8. Front and back framing can be simplified and can be made identical
9. Inter dyer draws are more uniform.
10. Elimination of gear “back lash” allows tighter tuning of the drive.
11. Front and back plate loads are the same
12. Better access for broke removal.
13. Access to backside felt rolls is improved.
14. Excess horsepower is not required because the gears no longer force dissimilar surface speeds.

Here are also some limitations.

1. There may be difficulty speed matching an electrically driven section with a line shaft driven section during transient loading
2. Because of low permeability of coated sheets, when placed in the after coated dryer section, the air which is entrained under the sheet as it goes into the dryers cannot bleed out and the sheet floats on the dryer. This also applies to other low permeable papers particularly at high speed.
3. Dryers with low felt wraps may have to be separately driven or geared into another driven dryer.
4. The current design of some pocket ventilation rolls does not allow them to be driven.

DRYER FABRICS.

Polyester monofilament is the most common material of construction of dryer fabrics. It has ideal properties; it is non-absorbent, strong and readily available.
Various sizes and shapes of these monofilaments are being used to produce a multitude of structures. These structures are clean running, dimentionaly stable and reasonably priced. Polyester monofilaments cloth over 65% of all dryer positions.

In very hot, moist conditions of the machine adequate fabric life cannot always be achieved with polyester. The combination of high humidity and temperature accelerates hydrolysis, (degradation and embrittlement of the material). This severe loss in strength and flexibility renders the fabric unusable and forces premature removal.

Steam pressures have always been higher for heavy-weight producers (liner board etc.) so these dryer sections have very few positions where polyester monofilaments fabrics can be used.

Multi filament fabrics made from a combination of acrylic, nylon, nomex and fibreglass Tend to dominate because of their resistance to hydrolysis. Unfortuneatly these fabrics have less desirable properties than monofilaments.

White paper machines are running hotter than in the past. Many top positions following un-iruns and other tops can no longer achieve adequate life with polyester fabrics as steam pressures increase. Very expensive monofilaments such as Ryton, which has excellent hydrolysis resistance, are used on a limited basis. However, the cost of these fabrics has restricted the exposure of Ryton in the dryer section.

The challenge for hydrolysis prone positions has been spelled out the dryer fabric producers to develop a monofilament fabric with significantly more hydrolysis resistance than polyester at a cost-effective price.

Monofilament over Multifilament

Dryer fabrics are expected to deliver excellent runability and enhance the drying process while on the machine. Monofilament fabrics perform these functions better than multifilament fabrics do because: -

1. A monofilament fabric retains manufactured permeability better. The fibrous multifilament fabric acts like a filter to retain fines and debris. A monofilament fabric not only runs cleaner but it can be cleaned easier, and in furnishes which contain short fibre high filler loads this is critical.

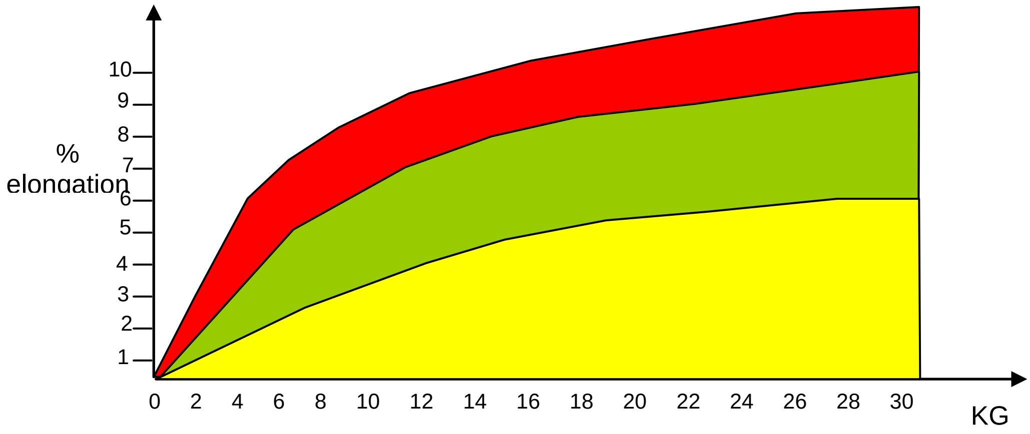
2. All monofilament fabrics run dry. Multifilament fabrics absorb moisture. Anything that contributes to the increase of humidity of the pocket air impedes drying. A non-absorbent monofilament fabric is ideal; a fibrous multifilament is not.

3. Superior fabric surfaces and seams are available with monofilament fabrics. The pin spiral seam which has the non-marking in-line properties of a pin seam and the durability of a spiral seam can be installed on a monofilament fabric. \The seam is

damage resistant and stitching free. If the seam is stiffer tan the fabric this flex point can cause premature failure. In-line seams, like pin spiral, eliminate this concern.

4. Monofilament fabrics deliver a more uniform cross machine tension profile. Of all the fabric's properties that influence drying, the most important is running tension. Some machines are now running in excess of 15 pli to improve drying. If the dryer fabric cannot evenly distribute this load, wet streaks at the low-tension areas will occur. Because a monofilament can be crimped or permanently deformed it can be heat set into a stable structure. Multifilament fabrics rely on resin treatments to impart stability. These stiff treatments limit the ability of a multifilament fabric to adjust to minor misalignments on a machine. If a fabric is too stiff, poor guiding, slack edges roll failures and poor profiles result. A woven monofilament absent of resin treatments can make adjustments.

A diagonal stress-strain test separates these fabrics



Diagonal
Stress-strain
10.16cm X 10.16cm sample

Too rigid fabrics are found on the lower portion of the curve, most multifilaments are here.
Fabrics prone to narrowing are on the upper portion of the curve and are not desireable
Properly designed and heat set monofilament fabricsoccupy the middle of the graph.
For clean, dry running fabrics, which are easy to guide, distribute tension uniformly and maintain stability it is generally considered that monofilaments are superior to multifilaments.

HYDROLYSIS

Hydrolysis is a function of both temperature and moisture. The long-term exposure of fabrics to hot, humid air leads to degradation. Polyester is particularly susceptible.

Polyester at high temperature, in the presence of water and under pressure experiences hydraulic chain cleavage with the formation of carboxyl groups. Hydrolysis can break the polymer down to basic raw materials such as, terephthatic acid and monoethylene glycol. Under high temperature and humid conditions it undergoes simultaneous thermo-oxidative and hydrolytic degradation.

Based on hundreds of pocket humidity surveys done over a wide range of conditions inadequate polyester life occurs when the wet bulb temperature of the pocket air exceeds 160 ^{0}F

Operating above 160^0 F wet bulb temperature requires materials more resistant to hydrolysis.

Steam pressure can also be a guide. Sections using steam pressure above 75 psi are often on the limit for polyester, pressures above 120psi almost always require fabrics made with high temperature materials.

THROUGH AIR DRYING

Through air dried tissues require a very uniform sheet in both the machine direction and the cross machine direction, otherwise any difference in paper weight would cause irregular drying owing to variation in permeability.
Special attention therefore must be given to formation and de-watering.

On conventional tissue machines the sheet is about 88% moisture as it is transferred to the press section or presser roll.
For soft tissue production the sheet must not be pressed in order to preserve bulk, so that drying with hot air would need to begin at a dry consistency of 12%. This is not practically possible because the air permeability is too low and also through air drying is highly uneconomical below certain dry consistencies because fan energy expended to develop vacuum inside the drum would be too high.

For through air drying the moisture content of the sheet should be 75% or 25% dry consistency, so the de-watering of the sheet needs to be increased on the former. This is achieved by vacuum extraction and steam boxes over the suction boxes to reduce the water viscosity.
This increased vacuum also effects the design of the forming fabric.

The sheet is transferred from the forming fabric to the TAD fabric by a suction type pickup arrangement usually with out any problems.

Because of the course structure of the TAD fabric the sheet is provided with a “3D” effect (embossing) which increases its bulk.
The synthetic TAD fabric needs to protected against damage, normally the temperature of the sheet when leaving the through air dryer with a moisture content of 30% or dry consistency of 70% will not be higher than the wet bulb temperature.

However in the case of a sheet break the TAD fabric can quickly reach 270 ^{0}C

Having a dry consistency 70% the tissue is transferred directly from the TAD fabric to the Yankee dryer by slightly pressing the tissue onto it using and adhesive which is sprayed onto the surface of the Yankee.

As a result of the embossing effect from the TAD fabric the sheet contact with the Yankee is reduced, this intern reduces the efficiency of the Yankee and also the adhesive needs to be evaporated.

Since the bulk of tissue, which has been dried by through air, is considerably higher than with conventional drying the crepe can be lowered which has a favorable effect on productivity.

The TAD drum has an open area of about 95%, in this way large quantities of air and consequently energy can be imparted to the sheet very quickly.

The TAD wraps the drum by about 270^0; hot air is blown into the hood, which is arranged round the drum. Perforated screens inside the hood create a dynamic pressure that ensures uniform distribution across the width of the machine.

Once the hot air has passed the sheet and the fabric it is sucked out from one side or both sides of the drum. The major part of this air is re-circulated through the heating system but a small part is exhausted to atmosphere.

It is possible to combine the heating system of the through air dryer with the impingement hood of the Yankee dryer. It is essential the air returned to the through air dryer hood is always at constant temperature so that a uniform moisture profile can be guaranteed.

Critical loads caused by centrifugal force, vacuum, the fabric and thermal stresses caused by temperature gradients need to be understood.

The modern through air dryers are now operating at speeds of 2200 mts / min.