Steam and condensate for paper machines

Depending on the thickness of the paper, of the production speed and of the weight of the paper, more than 100 tons of steam per hour are necessary.

One ton of steam is about 20 – 25 Euro. When producing 8200 hours/year the steam requirement of about 100 tons/hour will cost ca.16.400.000 Euro to 20.500.000 Euro.

Saving one ton of steam per hour leads to a reduction of 164.000 to 205.000 Euro per year. At the need of ca. 100 t/h it is always possible to save one ton of steam! However, you have to know how!

The aim of every steam and condensate plant should be to create a closed system. That means the steam which is fed into the pm for drying the paper should be completely used for heating the dryer and after may be for the other consumer of heat energy. There must be a problem with plants which blow off the steam into the atmosphere or heat up the cooling water from the auxiliary condenser in such way it would be able to heat up whole cities.

Often the reasons are:

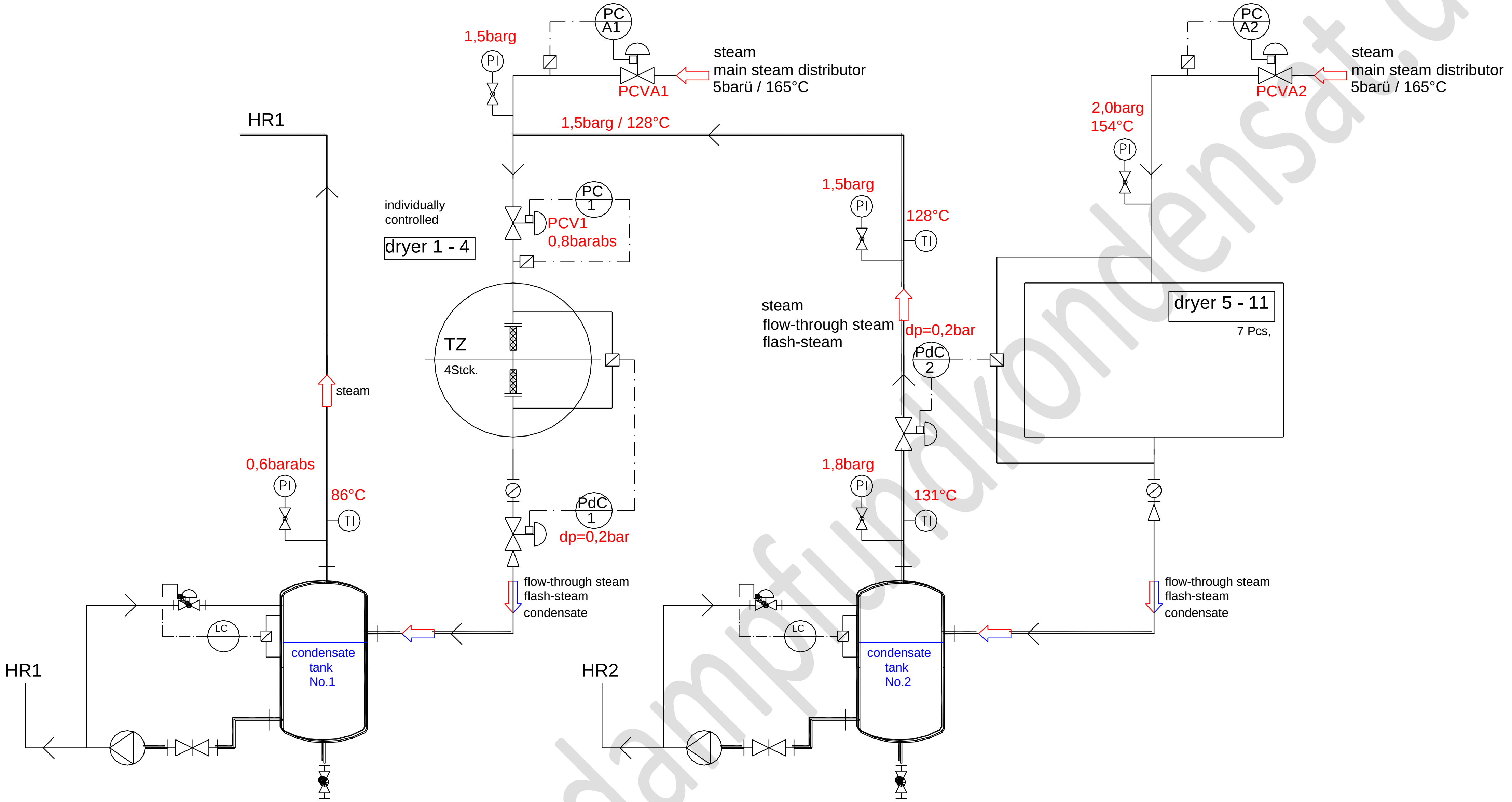
- Wrong operation because of missing training
- Modified operation conditions in contrast to the original layout design
- Wrong layout by the planning engineer
- No ideas or no knowledge of the planning engineer

The question is, whether the operator of the pm really wants a re-build for energy optimization, and is he able to do this. Mostly everybody knows the problems, but the costs for a re-build seem to be too high.

If after the re-build one ton of steam is saved, the re-build will pay for itself after one or two years.

Design of a cascade system with the help of differential pressure control

The cascade system is probably installed at every pm. Actually it's a kind of heat recovery, because the flow-through and flash steam which arise at the heating of the dryer or of one drying group is used again for heating the dryers. (to use a cascade system is not necessary in order to dry paper…)



In the example above the first drying group consists of 4 individually controlled dryers. The second drying group consists of 7 dryers which have been united to one group. Depending on the drainage system in the dryer (stationary or rotating syphon, scoop) a special differential pressure is necessary for an optimal drainage. That means at steam side the pressure must be higher than behind the dryer at condensate side. This differential pressure is fixed in the process control system as nominal value and should be constant during the paper drying. In the example above stationary syphons are assembled as drainage system. At stationary syphons a differential pressure of 0,1 bar to 0,2 bar is necessary for an efficient drainage. That means the pressure in the condensate vessel 2 is always 0,1 bar to 0,2 bar less than behind the steam pressure control valve PCVA2. With the help of the cascade system you can use the flow-through steam of the syphons from the second drying group for heating the dryer in the first drying group. If the steam amount is not sufficient, the steam pressure drops below the nominal value of PCA1. Now automatically steam will be fed in via control valve PCVA1.

What to do if the pressure difference between the dryer groups is not possible?

There are three situations at which it is very difficult to keep the pressure difference between the dryer groups.

Paper break

The condensation in the dryers drops immediately, because the dryers are no longer cooled by the paper. Where nothing condenses, nothing flows in, that means the steam consumption drops immediately after the paper break. Note: Basically the heating pressures of the drying groups should be reduced to a break-nominal value (as far as possible automated in the process control system).

Dryers are flooded.

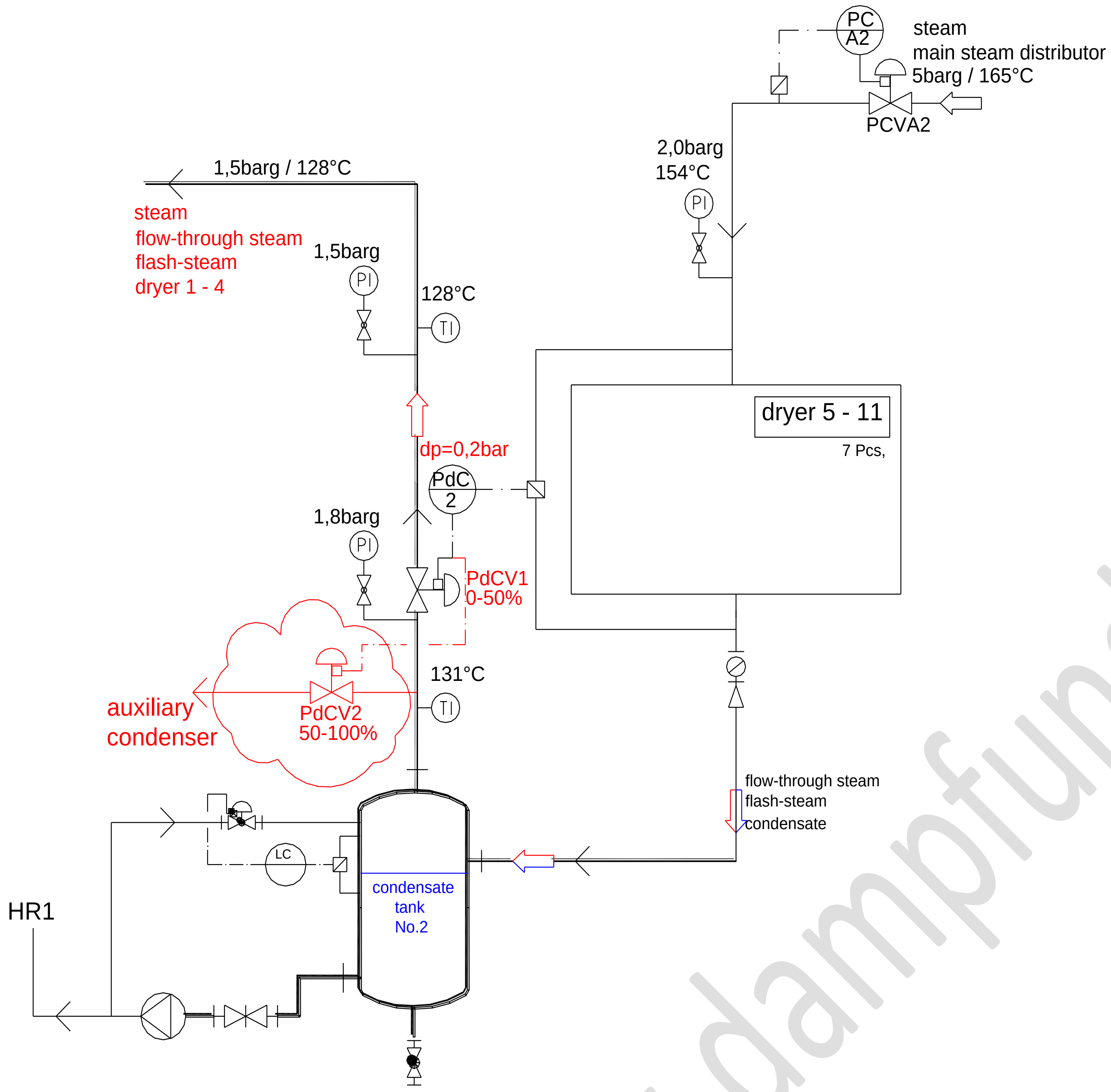
Because of wrong adjustment at the process control system by the operating staff, or a mistake of the measuring and control technology, or as a consequence of damages at the drainage elements or the steam joints the differential pressure drops. Then the condensatering in the dryer rises and floods the syphon shoe. This may also happen if the drainage systems are not designed in the right way or the dimensioning does not correspond to the actual steam request. If the dimension of the siphon pipe or the siphon shoe is too small then amount of condensate cannot be completely discharged. At a production speed below water ring speed often scoops are used as drainage system. These scoops cannot flood. Mainly for rotating syphons the flooding of the shoe is a problem.

Heating up the pm

For heating up the pm only a small amount of steam is necessary and there are the same conditions like in the case of a paper break.

And then?

The differential pressures are necessary for the drainage of the dryers even in the case if the dryers are flooded. In order to keep the differential pressure at any operating situation, an additional control valve is installed for every dryer group.



The control valve PdCV1 is attached to a further control valve PdCV2.

Control valve PdCV1:

If the nominal value of 0,2 bar is in danger, control valve PdCV1 closes or opens.

At the outlet of 50% the control valve PdCV1 is opened 100%.

Control valve PdCV1: outlet 0% - valve opens 0%

outlet 50% - valve opens 100%

If this opening is not enough, control valve PdCV2 opens.

Control valve PdCV1: outlet 50% - valve opens 0%
outlet 100% - valve opens 100%

The piping behind the control valve PdCV2 leads to the place of the lowest pressure at the steam and condensate system.

This is the auxiliary condenser which is an “steam eliminating heat exchanger”.

If nothing works, however the steam to the auxiliary condenser flows.

In this heat exchanger the steam is condensed by cooling water.

If the heat exchanger is dimensioned sufficiently, this condensation leads to a volume reduction and thus to a low vacuum formation.

Therefore in the auxiliary condenser you can measure the lowest pressure.

With the help of the Valve PdCV2 and with the installation of an auxiliary condenser it is possible to reach the differential pressure in any situation, which is necessary for the drainage of the dryer.

In case of normal production these control valves should always be closed.

(normal production: without paper break and so on)

Note: If you want to know whether the steam and condensate system has been designed in the right way and whether the amount of flow-through and flash steam can be used again, you only have to look at the consumption of cooling water in the auxiliary condenser. The amount of cooling water for the condensation of the steam should always be as low as possible. A big amount of cooling water means that also a big amount of steam is eliminated.

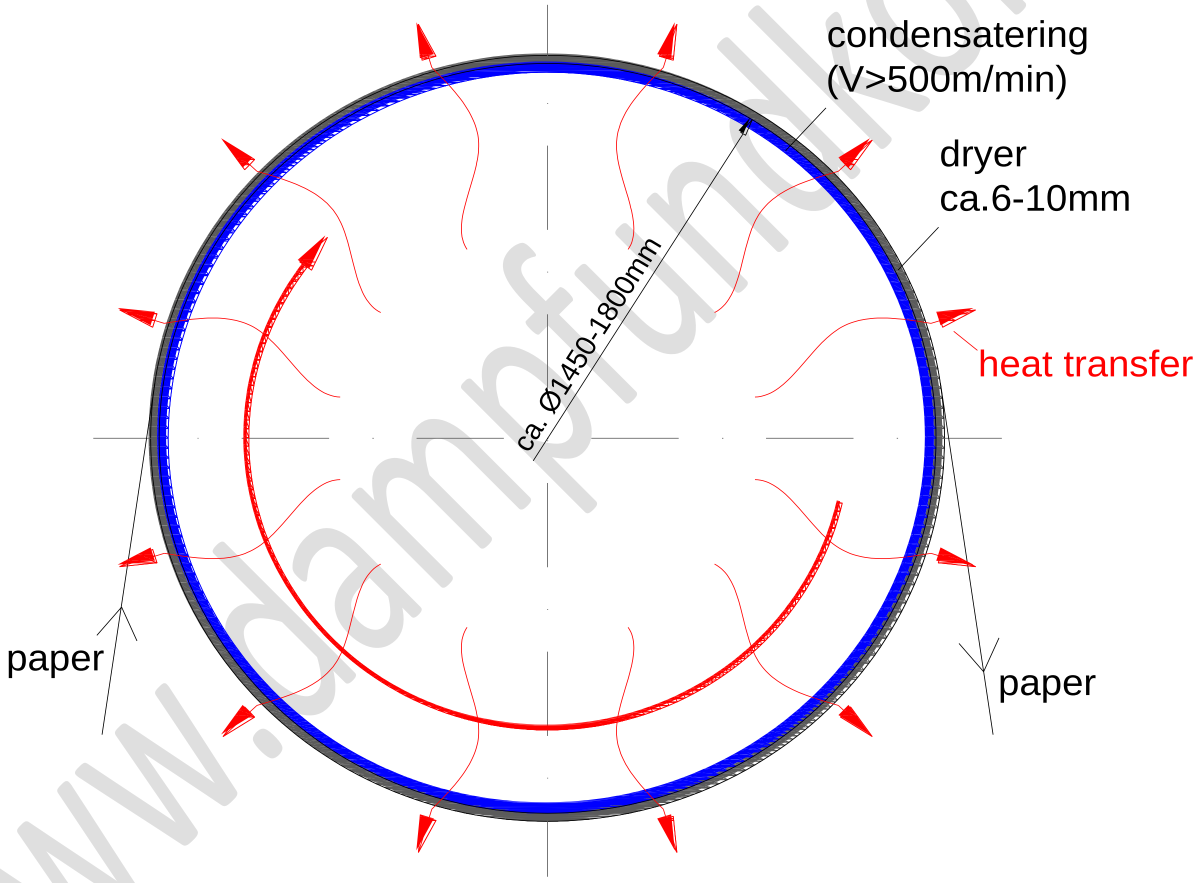
Saturated steam or overheated steam – that's the question

"We only use saturated steam… Everybody knows that overheated steam is not the best for using in heat exchanger and so for drying..::" That's right. Saturated steam is better for heat exchanger. However, about 90% of all paper machines use overheated steam, because there is no alternative as a result of the construction of the steam and condensate system.

Why? First a short description of the function of the dryer as a rotating heat exchanger for paper drying.

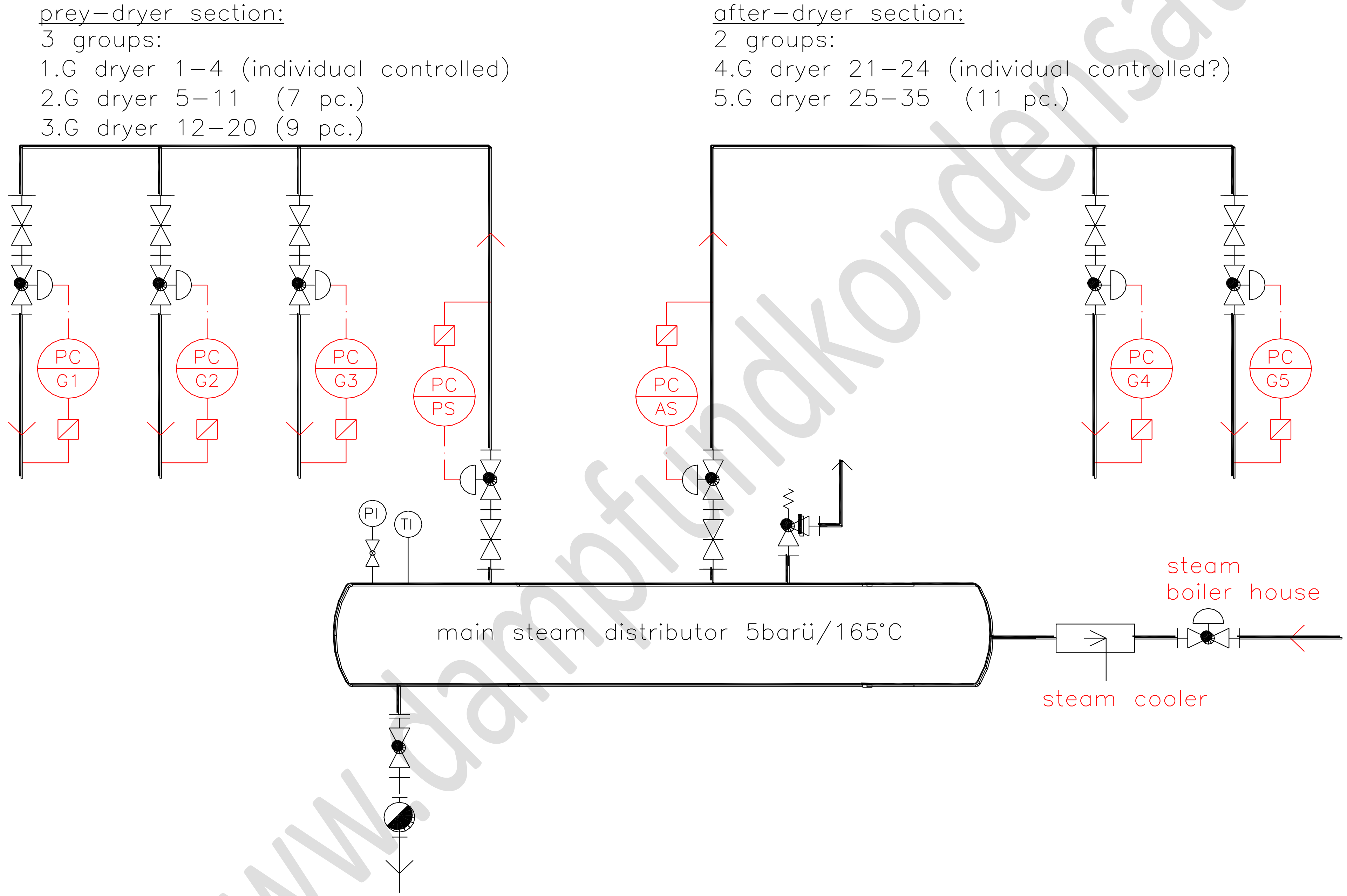
The dryer as heat exchanger

Dryers of paper machines are only tube heat exchangers. Simply said, steam flows into the dryer, the dryer is cooled by the paper and steam became condensate. The condensate is collected at the bottom of the dryer. Is the speed more than 350 m/min the condensate moves with the dryer. The reason is the friction between the condensate and the inner surface of the dryer. Is the speed more than 500 m/min, the centrifugal forces press the condensate into the inner surface of the dryer.



The steam distribution at the pm

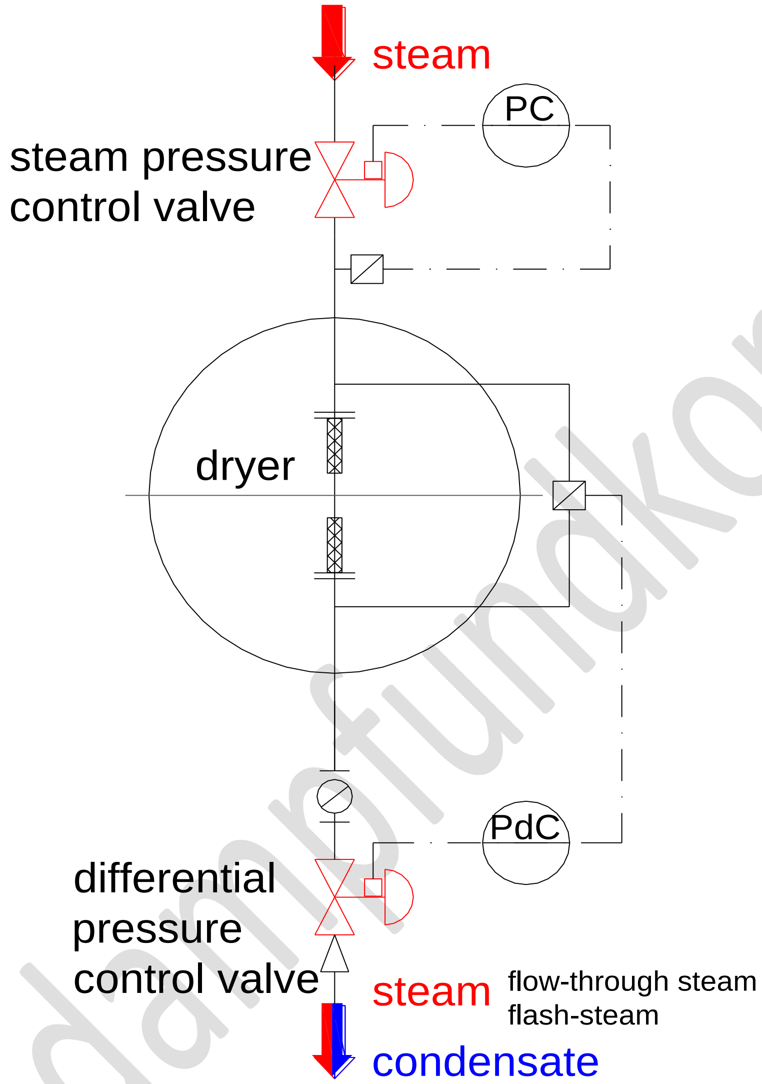
Mostly the steam for the pm is generated in a boiler house. From there the steam flows via a main steam pipe to the steam distributor directly at the pm. As the steam is not generated in a quality which is needed for a pm, often a pressure reduction with steam cooling is installed between power house and pm. A steam temperature of ca. 10°C over saturated steam at the main steam distributor is usual. The pipes for the supply of the pre-drying section, the after-drying section and the auxiliary consumers are connected at the main steam distributor. Auxiliary consumers are e.g. the heating for the diluting water, the heating of the fresh water for cleaning systems and the hall heating.



In this steam distribution / tubing which may be found at about 95% of all paper machines, you can see the reason for the use of overheated steam.

Explanation why overheated steam is used at the pm

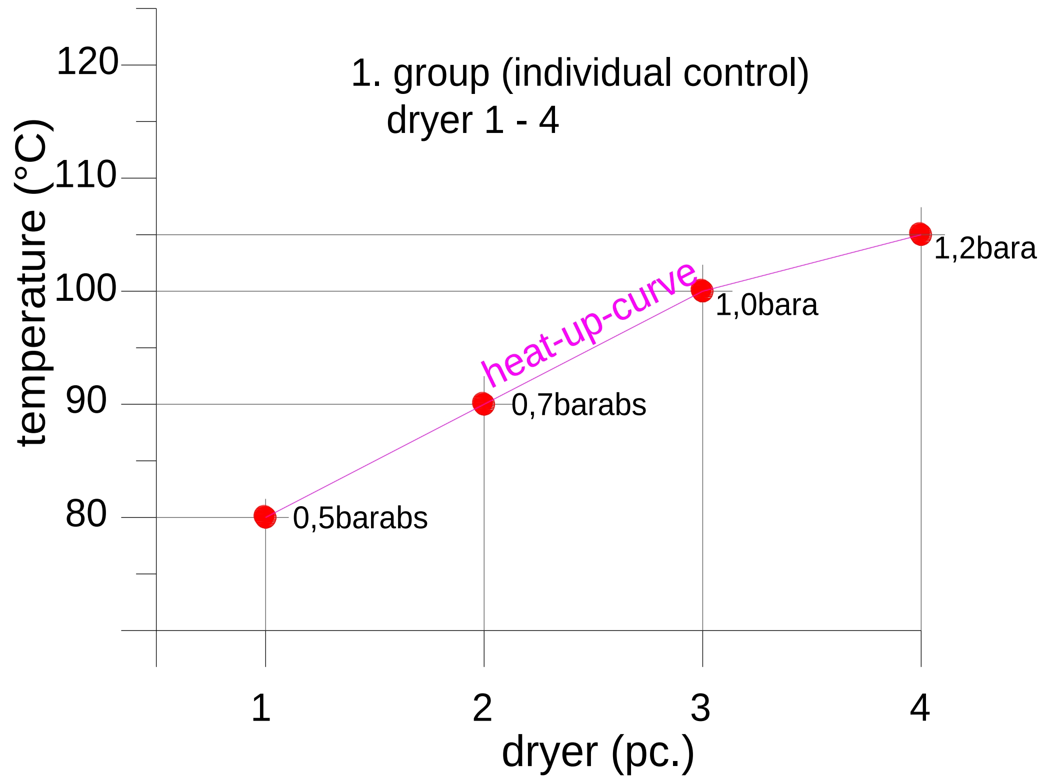
When the pre-drying section of the pm is divided into 3 drying groups, the first drying group is much lower heated than the third. (it depend on the paper weight). In the first drying group the paper is prepared for the drying in the second and third drying group. The moisture with a temperature of ca. 45°C to 50°C in the paper is heated up and the evaporate start in the second and mainly in the third drying group. The dryers in the first drying group are often equipped with a so-called individual control in order for heat up the paper careful.

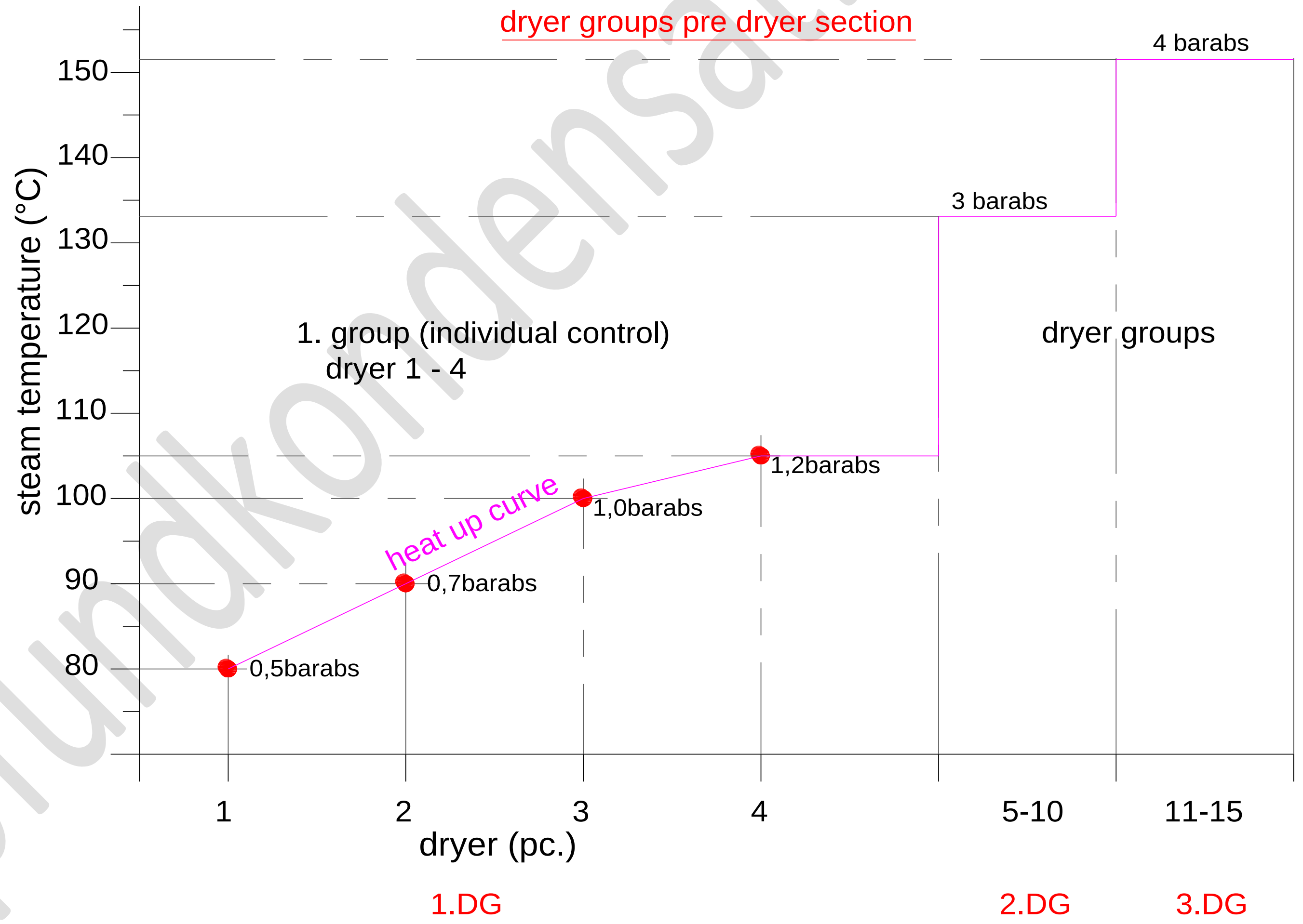


That means, each dryer is equipped with a steam pressure control valve and with a differential pressure control valve on the condensate side. With these control valves you can set a so-called heat-up-curve.

What`s a heat-up-curve by individual control?

With the individual control it is possible to adjust a different temperature beginning with the first dryer. That means the nominal value at the first dryer is the lowest. At the second dryer the nominal value is about 0,2 – 0,3 bar higher and so on. papermachine witch produce paper with lower weight, temperatures are 50°C to 65°C is needed at the first dryer (newspaper). Because of the setting of these nominal values the below shown heat-up-curve would arise, measured at the surface of the dryer.





However, the heat-up-curve as a consequence of the different nominal values of the individual controls is not realistic!

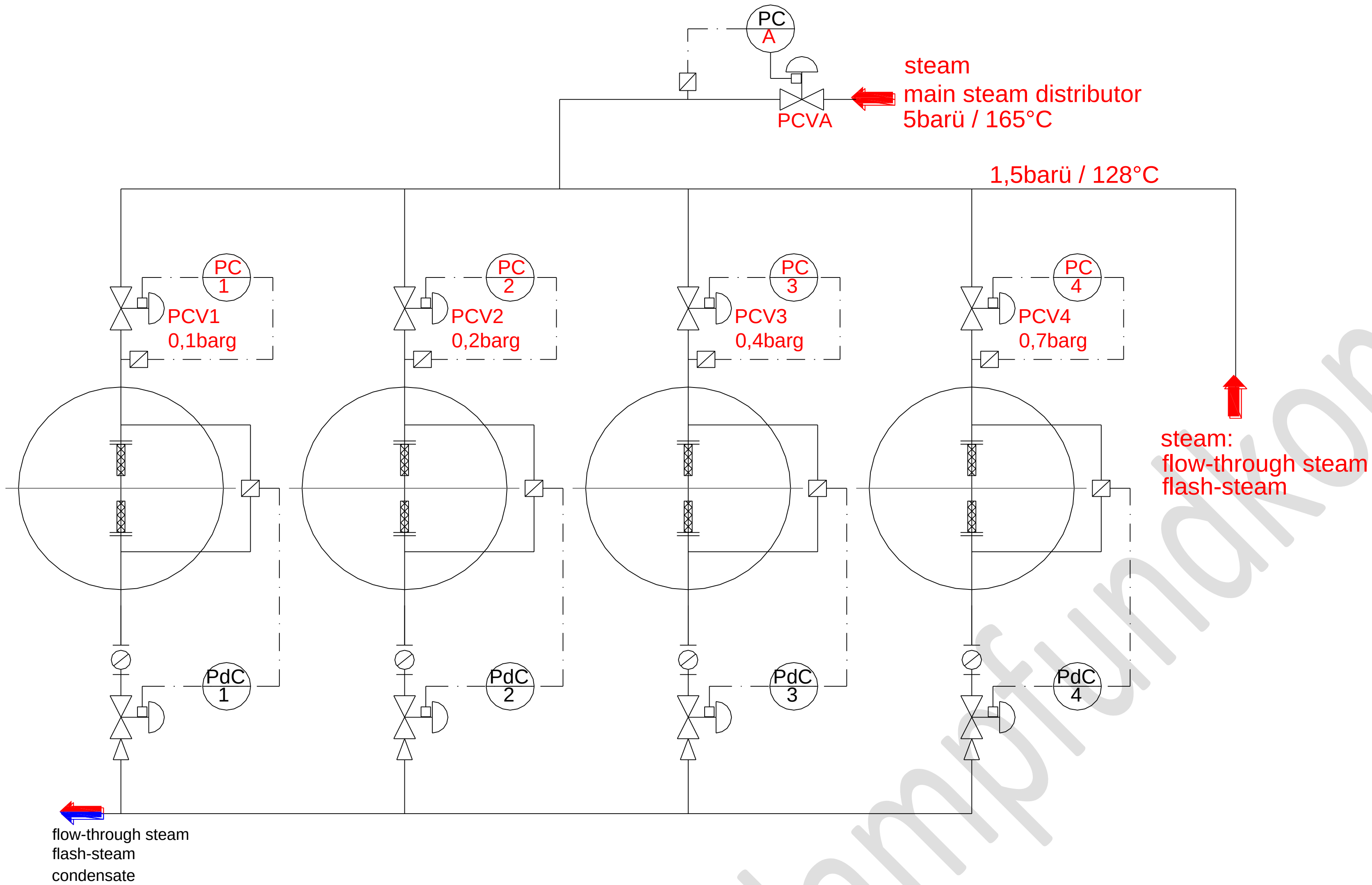
Why not? And why do most paper machines operate the first dryers with highly overheated steam?

From thermodynamical aspect it is not possible to reduce the steam temperature by means of two or three pressure reductions from 165°C at the main steam distributor to 100°C or even 90°C at the dryer. This is only possible by using steam cooling.

A heat-up-curve does even exist if you check the surface temperatures of the first dryer. This is however caused by the decreasing cooling effects of the paper from one dryer to the next one, it's not caused by the low temperatures in the dryer generated by the steam pressure (because the paper becomes more and more dry from one dryer to the next one).

What are pressure reductions?

Pressure reductions are the number of steam pressure control valves which the steam flows through on its way from the main steam distributor to the dryer. Of course, a pressure reduction also means a reduction of the temperature. However the reduction of the temperature is less.



before	steam pressure P1	5barü	5barü	5barü	5barü
	steam temperature T1	165°C	165°C	165°C	165°C
	pressure reduction	**PC1**	**PC2**	**PC3**	**PC4**
after	steam pressure P2 (nominal value)	0,1barü	0,2barü	0,4barü	0,7barü
	steam temperature (satturated)	102°C	105°C	109°C	115°C
	steam temperature actually	147°C	147°C	148°C	149°C
	overheating	45°C	42°C	39°C	34°C

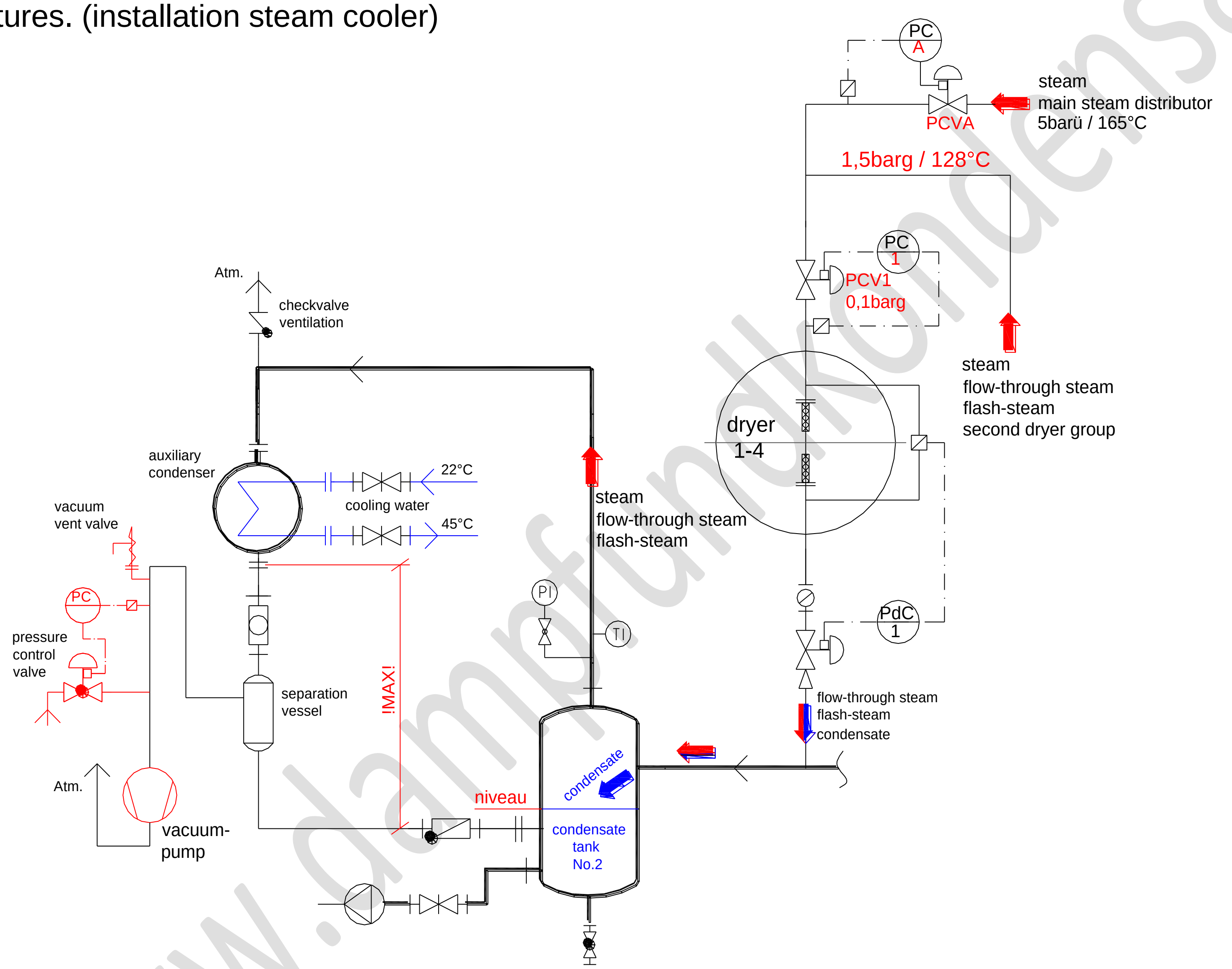
The low steam pressure is not equivalent to the accordingly low desired temperature of saturated steam. As shown above, in spite of different nominal values the temperature of the steam is equally high. At above conditions there is no such a low steam temperature at the first dryer. The low steam pressure is not equivalent to the accordingly low desired temperature of saturated steam. The data for steam temperatures behind pressure reductions which are given in the list are mathematically calculated. Waste of temperature, e.g. by heat transfer, have not been considered. Even if these wastes are considered by most complicated calculations, the temperatures change only slightly. It is obvious: you can't reduce the steam pressure so far that you reach the desired low temperature for the first dryer (even not in a vacuum plant)

Although different nominal values are adjusted, the temperature of the steam is equally high. You can't reduce the steam pressure so far that you reach the desired low temperature for the first dryer. From thermodynamical aspect it is not possible.

The use of a vacuum plant for producing low pressures

Why do you need a vacuum system at a steam and condensate plant? The heating of dryers in a vacuum zone will be necessary, if at small paper weights steam temperatures of below 100°C are necessary. Mostly the first dryers or the dryers after the size press are heated with steam pressures of below 1,0 bar abs.

Vacuum plants for the steam and condensate system are installed at many paper machines. Not in every case are these plants necessary. The reduction of the steam pressures with vaccum plant is unnecessary at several paper machines. As explained above it is not possible to reduce the steam temperature from 165°C at the main steam distributor by two or three pressure reductions so that the steam temperature corresponds to the low steam pressure. It would be better to supply the dryers with steam with a low steam temperatures. (installation steam cooler)



Summary: To reach a low temperature with a low pressure is not possible. The reason is the structure of the steam and condensate plant.

The use of a vacuum plant is sometimes necessary, if dryers shall be heated with steam below 100°C, i.e. with a steam pressure below 0,1 bar abs. The low steam pressure is not equivalent to the necessary low temperature of saturated steam. At most applications the steam temperature is much higher than the temperature of saturated steam. Therefore it would be better to reduce the temperature with the help of steam cooling.

Vacuum plant and ventilation

After the paper machine has been stopped, the steam condenses in the piping, vessels and dryers which leads to a reduction of the volume. After standstill the sucking process is starting. Through flanges or open dewatering valves on tanks air flows into the steam and condensate system. After a short time the pipes and the dryers are filled complete with air.

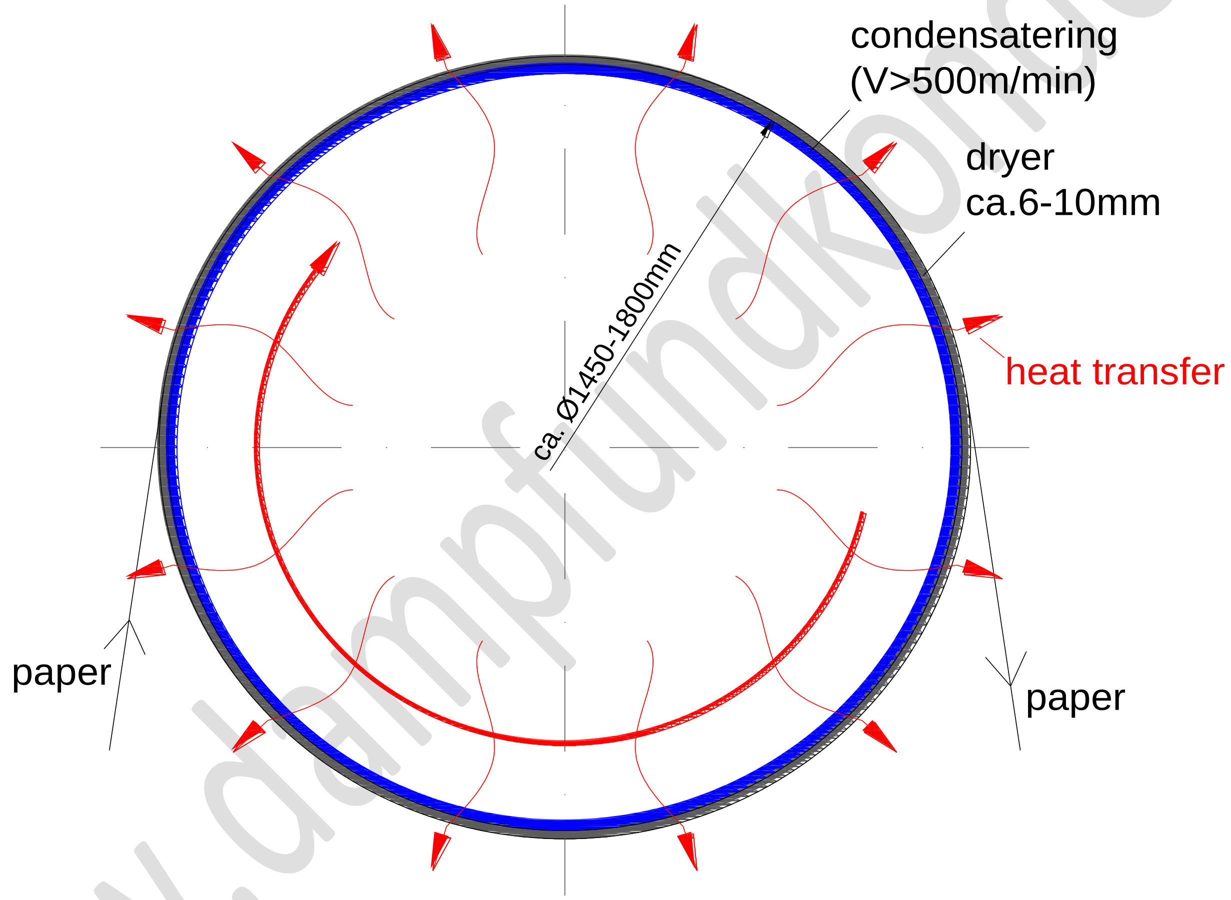
Before heating up, the paper machine has to be ventilated. With a vacuum pump the process of ventilation is quick. But basically a vacuum plant is not necessary for the ventilation. The paper machine can do this by itself. The ventilation of a paper machine also works without a vacuum plant. There are one or several sufficiently pipes which air can flow out of the system. The air is pressed out of the plant by the inflowing steam. This may take half an hour at a paper machine with 35 dryers. Of course, it would take less time with a vacuum plant, because the air is sucked out by the vacuum pump. But mostly the dryers are made of cast steel which has to be heated slowly in order to prevent damages of the material. Slowly means, that after cooling down the dryers it should take 1 – 2 hours for heating them up again. After short standstills the time for ventilation would be enough. That means there is no necessity for quick ventilation by a vacuum plant.

The centrifugal force as a reason for problems with dewatering of dryers

Steam flows into the dryer of a paper machine. The heat energy of the steam go`s to the internal surface and the steam becomes condensate. Basically the steam does not “want” into the small dryer, it would prefer to flow into the atmosphere or to the vacuum.

In opposite to the condensate steam does not need a pump to flow through the pipes and even overcome level differences. The reason is the low density. Steam only reacts on pressure differences. Even a few 0,.. bar overpressure may animate big amounts of steam to flow.

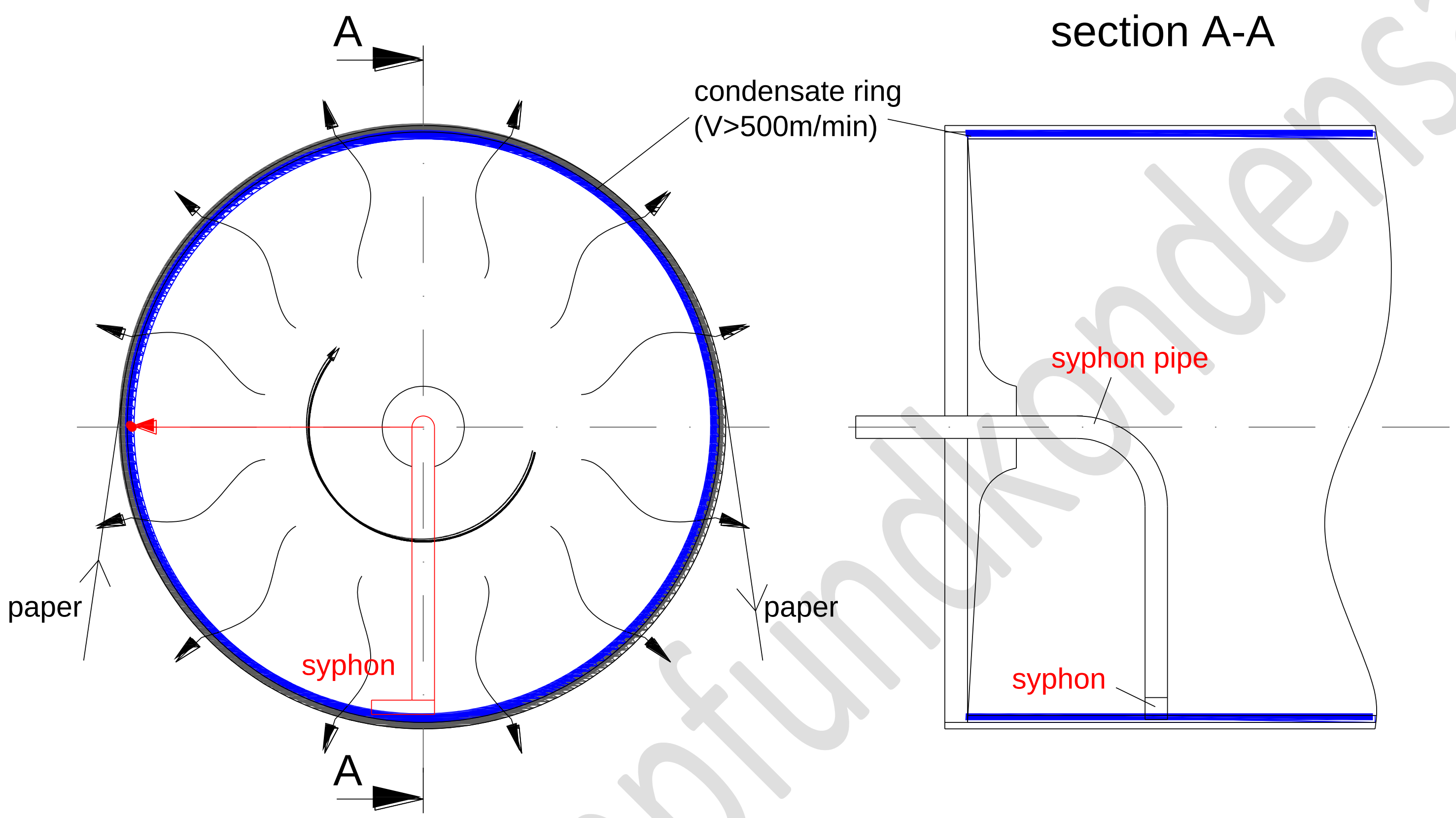
Why does steam flow into the dryers? As a consequence of the condensation of the steam in the dryer the volume is reduced. For example 2 t/h steam with a pressure of 0,1´bar overpressure and a specific volume of 3000 m3 become 3 t condensate with a volume of 3 m3. Because of this volume reduction a pressure arises in the dryer which is lower than in the piping. This pressure difference animates the steam to flow in the dryer. After touching the cool internal surface of the dryer it immediately condensates and reduces volume and the process starts again.



The moist and cool paper is very essential for the condensation. If the paper is gone, immediately the condensation and thus the steam consumption reduce. Every papermaker has experienced this at a paperbreak. The dryer is a rotating tube heat exchanger. The dryer only rotates because the cool and moist paper is transported with the help of this rotating movement through the drying section of the paper machine. The dryers rotate very slowly (e.g. 40 m/min) or even very quickly (e.g. 1300 m/min). As a consequence of this rotation centrifugal forces arise which press the condensate to the internal surface of the dryer depending on the speed. The higher the speed, the bigger is the centrifugal force. At a speed of > 500 m/min a watering is formed. The condensate is pressed by the centrifugal force very uniformly to the internal surface of the dryer.

Rotations against dewatering

Without the rotation you could install a ball valve at the bottom of the dryer and then the condensate could flow out automatically. Because of the rotation and the arising centrifugal forces special drainage devices are necessary. The so-called steam joints with syphon system (or scoops) make it possible that the steam may flow without leakage into the rotating dryer and the condensate may flow equally without leakage out of the rotating dryer.



However, there must be a possibility to move the condensate out of the dryer. Otherwise the layer thickness, resp. condensate film would be bigger. Condensate is a very bad heat conductor. Therefore the drying of the paper in the drying section would become worse if the condensate film increased. If available, the quality control system would notice the missing dryness and would try to raise the steam pressure of all dryers. If this did not satisfy, the speed of the paper machine would have to be reduced, so that the time of the paper on the dryers which are filled with condensate would be longer. In short, the operation manager will not reach the daily production!

Popular question in the test for a papermaker master: How far is the condensate able to rise?

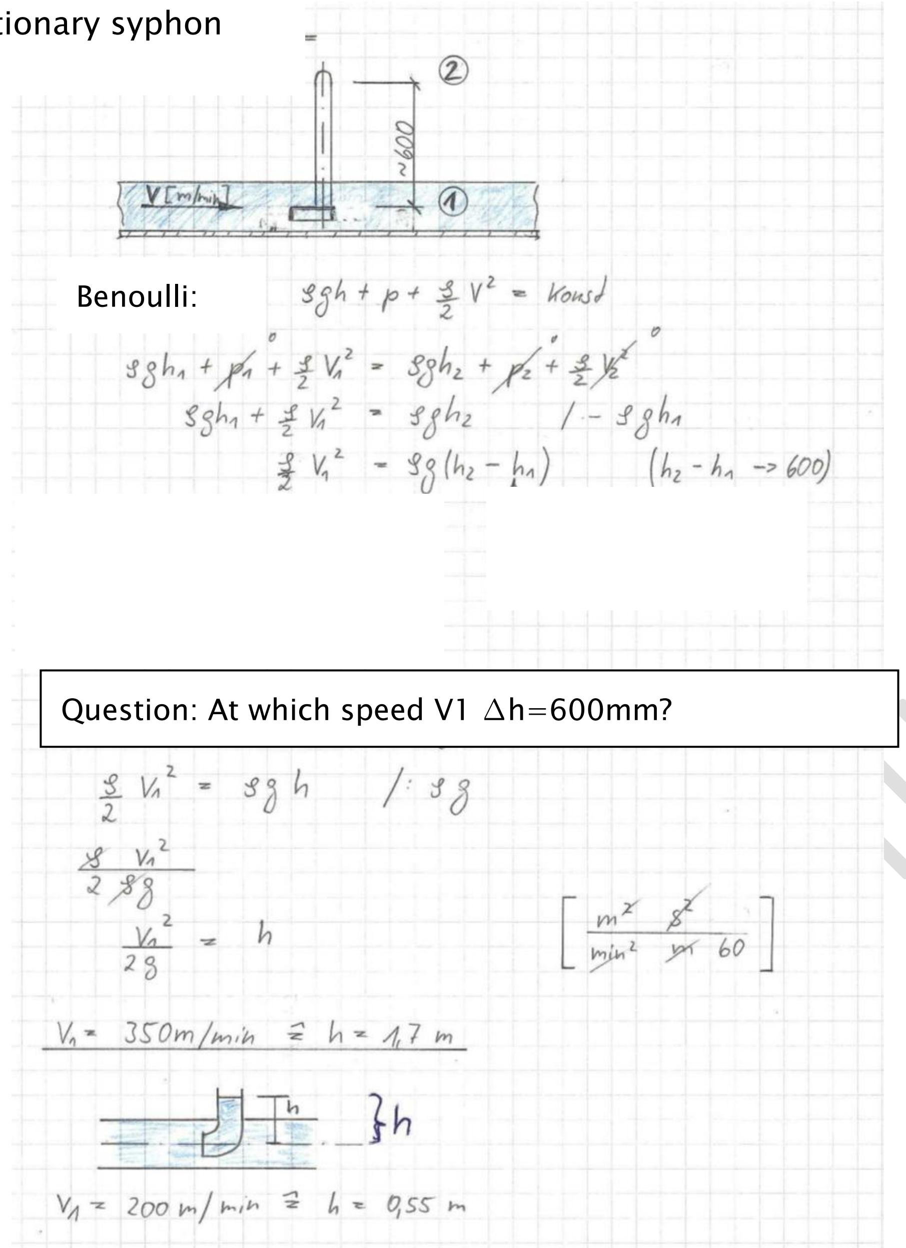
That's very simple: at flooded drying groups the condensate may only rise up to the half of the dryer. After that the condensate flows through the nozzle either via the steam joint into the condensate pipe or into the steam pipe. The condensate does not cause any steam hammer. Therefore the condensate is able to flow out in spite of the rotations, because the thicker the condensate film is, the lower is the centrifugal force. Directly at the nozzle the radius is very small and thus the centrifugal force is very small or even zero. (Flooded means the state of the dryer when the condensate has flooded the siphon shoe)

It is not difficult to find a flooded dryer. Because of the condensate, which has been collected in the dryer, the surface temperature of the dryer is lower than in those which are heated by the same steam pressure. Furthermore, a dryer filled with condensate is heavier and may cause problems with the drives. This may be realized in the bearing pressure of the process control system.

Rotations per drainage at a stationary syphon

As described above the rotation has a positive character and also a negative character which has not yet been discussed. The negative one is the arising centrifugal force depending on the speed of the pm, which presses the condensate to the inside of the dryer. The positive character only refers to dryers which are equipped with stationary syphons. To the same degree as the centrifugal force rises with the speed of the pm, a second force arises which helps the condensate to flow out of the dryer.

Stationary syphon

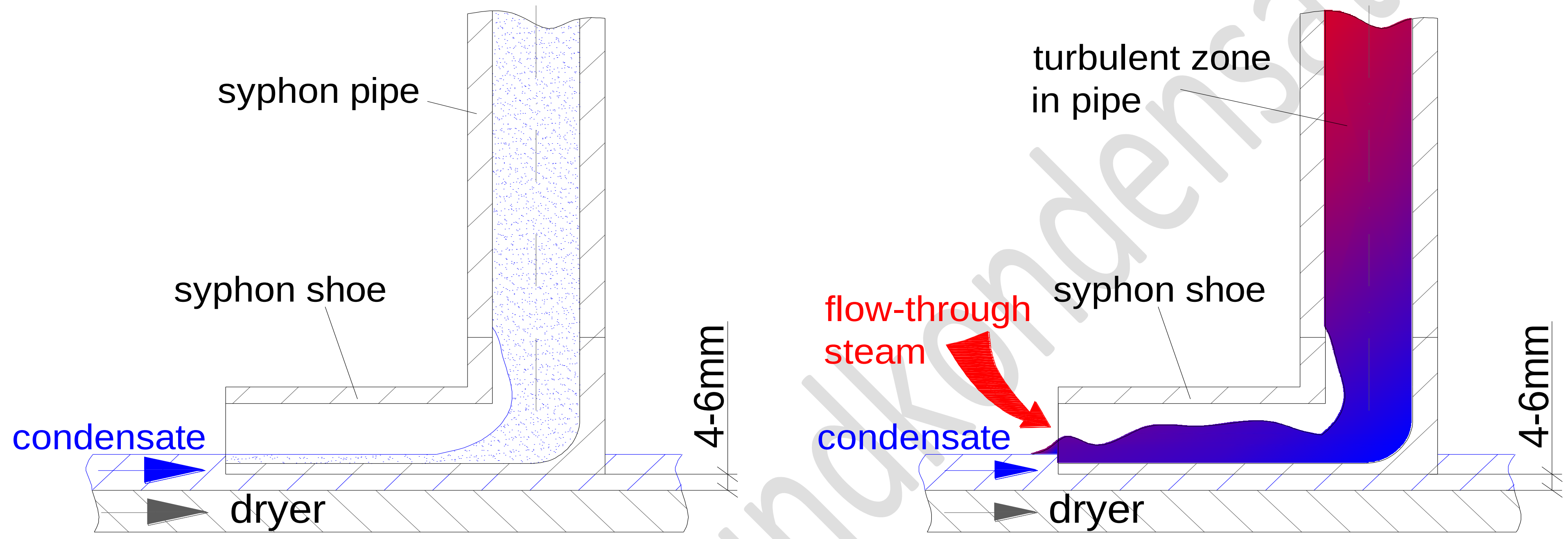


Let’s call this force flow-against-force, even if it’s not physically correct. That means the condensate which flows together with the dryer and against the stationary syphon presses itself into the syphon tube at a special speed and overcomes the height difference to the middle of the dryer – this happens without pressure difference.

The stationary syphon

The stationary syphon does not rotate with the dryer like the rotating syphon. It is stationary and the dryer rotates around the syphon. The flow-against-force, which arises and depend of the dryer rotations, can be used. There are three well-known manufacturers of stationary syphons. The physics of the flowing characteristics is identical, therefore the syphons of all manufacturers look the same.

Simple illustration of a stationary syphon



the best: dewatering without flow-through-steam dewatering with flow-through-steam

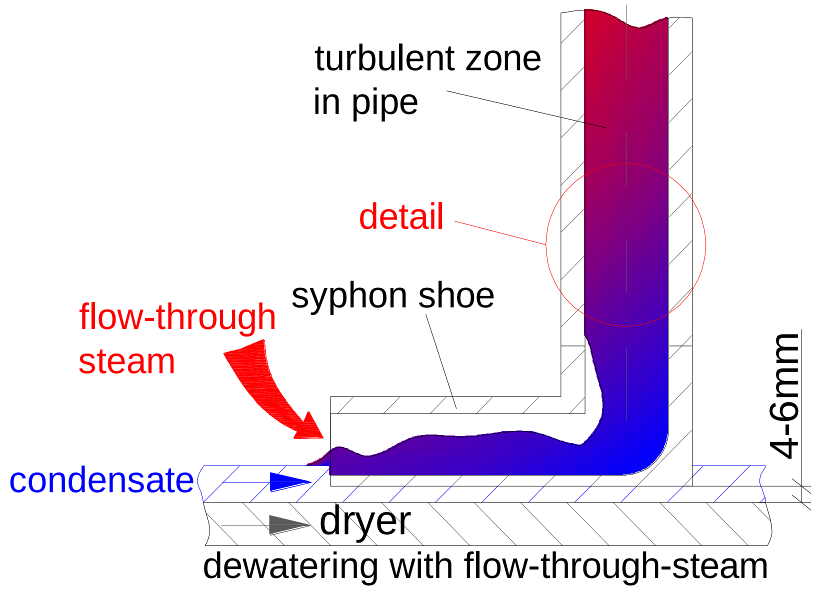
The condensate is not sucked off by the syphon shoe. For this a much bigger pressure loss would be necessary than 0,1 bar to 0,2 bar which is requested by the manufacturer. The syphon shoe of a stationary syphon works somehow as a snow shovel. If the condensate film rises, the syphon shoe is rubbing the condensate from the inside of the cylinder. If the dryer is equipped with turbulator bases, the distance between the bottom side of the syphon shoe and the inside is 4 – 6 mm.

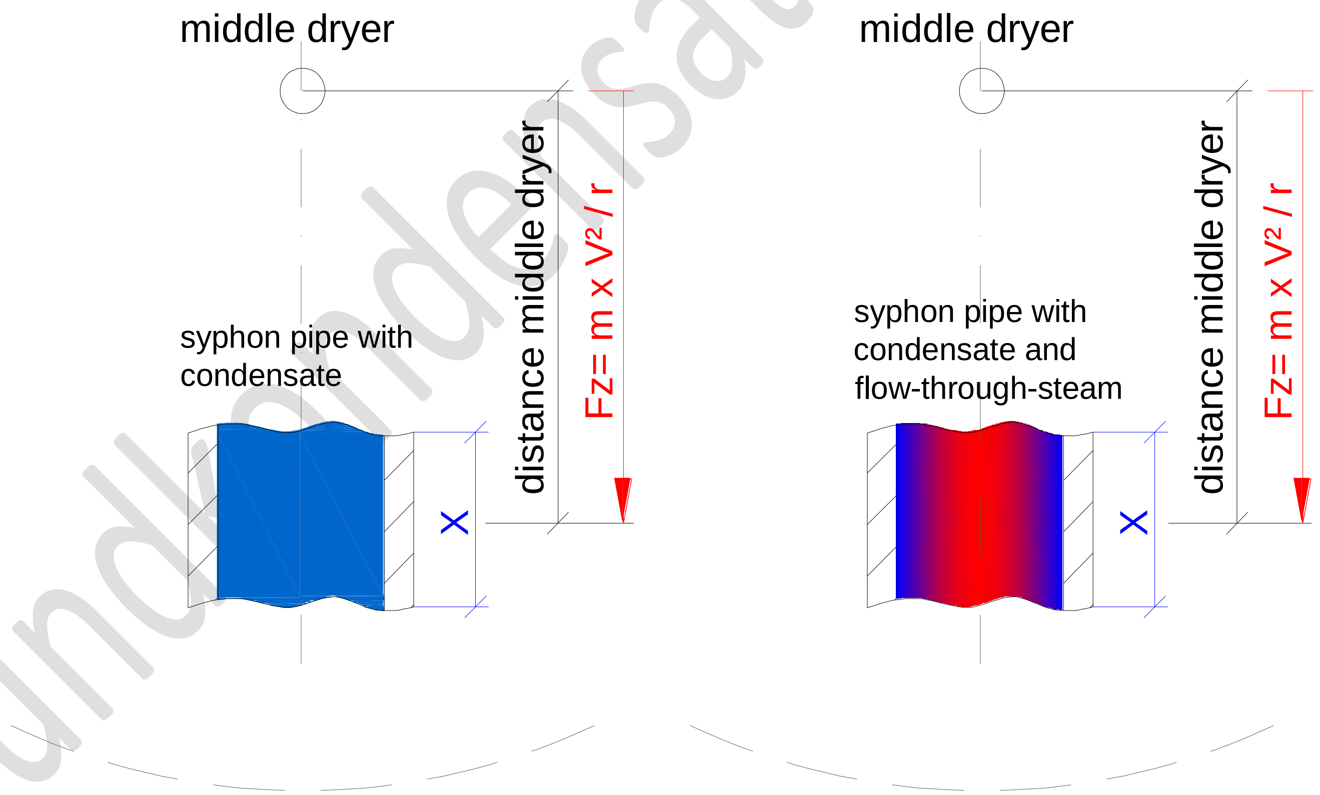
In the manufacturers instruction explained to have a differential pressure of at least 0,1 bar at the dryer for a good drainage, it would also be possible at a pm speed of ca 1000 m/min to achieve an efficient drainage for a longer period without differential pressure – provided a correct design of the syphon tube. Correct design means that the amount of condensate, which arises during minimal and maximal production in the dryer, may flow out of the syphon and the syphon tube.

A second effect which is positive for the drainage arises in the syphon shoe and in the syphon tube. Because of the geometry always a small amount of the steam flows through the syphon shoe and after that through the syphon tube. You can assume a steam amount of 10%, which will not be used for the heating and flows through the steam joint into the dryer and then through the syphon shoe and syphon tube out of the dryer. This flow-through steam whirls the condensate in the syphon tube. Because of the mixing of steam and condensate the specific weight of the condensate becomes less.

Why is the specific weight of the condensate reduced in the syphon tube and why is this helpful at the drainage? In order to be able to explain this, you will find in the following a cross-section of a syphon tube

mixing condensate and steam





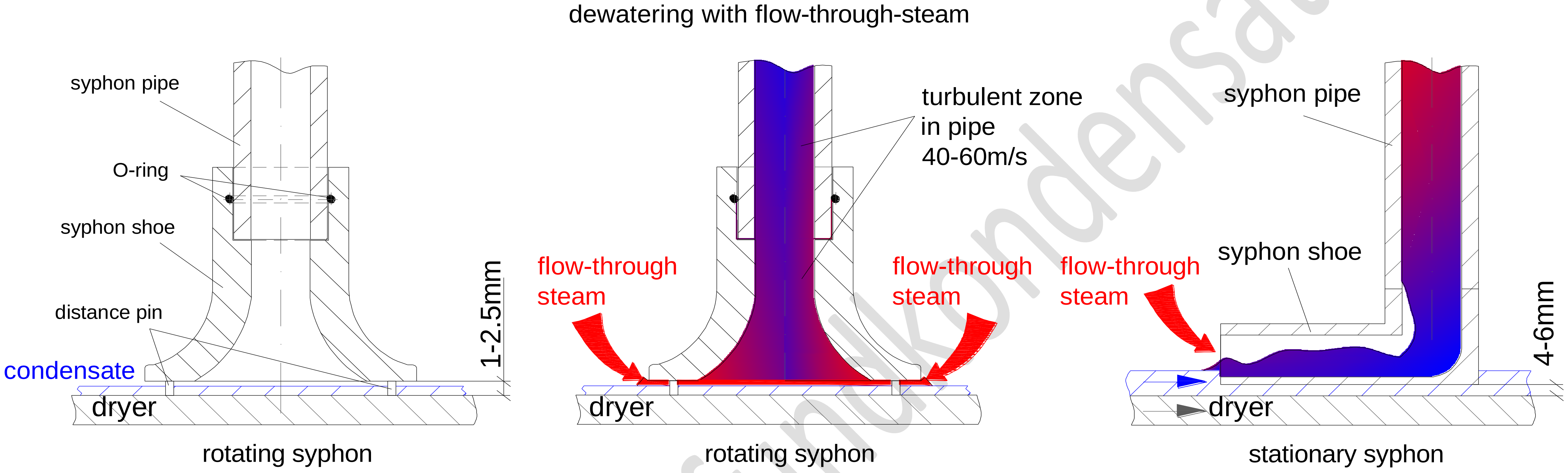
When you compare both tube sections, you can realize in the one pipe only condensate, in the other pipe a mixture of condensate and steam. The steam has a bigger volume and a much lower mass density than the condensate. The steam which is powered by the differential pressure between steam in-flow and condensate out-flow flows out of the dryer in the steam joint and from there into the condensate pipe of the dryer. When you compare the weight of the flow in section X, the mixture of condensate and steam is lighter, that means the specific weight of the condensate is clearly reduced by the whirling with the steam. Of course, this also influences the centrifugal force.

If the mass (m) reduces in the equation for evaluating the centrifugal force, the centrifugal force reduces to the same extent. Because of the reduced specific weight of the condensate it can flow more easily from the syphon shoe to the syphon tube. The force which wants to prevent the condensate from doing so is smaller. At stationary syphons this effect is necessary for the drainage, but not regulatory. However at rotating syphons the reduction of the centrifugal force by weight reduction is absolutely necessary.

The rotating syphon

The rotating syphon is fixed in place. Most types of rotating syphons are fixed by strong springs to the dryer. However, the detailed structure of a rotating syphon including the horizontal tube system is not subject of this chapter.

Simplified illustration of rotating and stationary syphon



Similar to the stationary syphons, there are also three well-known manufacturers in Germany for rotating syphons. Also the physics is the same at all und so the syphon shoes have also a similar form. Similar to the stationary syphons, the centrifugal force as consequence of the dryer rotation has to be overcome when the condensate is transported. As the rotating syphon moves together with the condensate film, no flow-against-force arises. Let's keep in mind that this flow-against force helps the condensate to overcome the height difference to the steam joint without differential pressure at the stationary syphon. However, this does not work at the rotating syphon. Only the effect of the centrifugal force reduction by weight reduction can be used for the drainage of the condensate out of the dryer. Correspondingly the form of the rotating syphon is illustrated.

In general you realize that the rotating syphon shoe has the shape of a cone. This cone has a distance of ca. 1 – 2,5 mm to the dryer. In contrast to the stationary syphon the flow through steam is absolutely necessary. Without this steam there will be no whirling under the syphon shoe. Without whirling there will be no mixing and without mixing there will be no reduction of the specific weight of the condensate. In short:

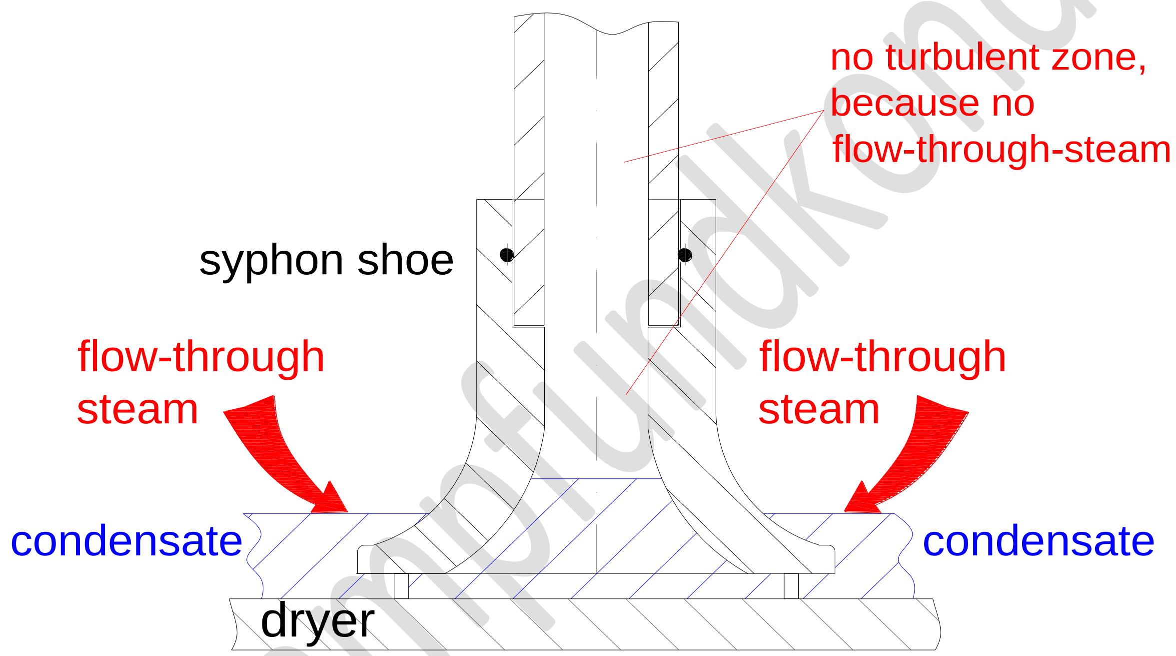
without flow-through steam – no drainage

At rotating syphons about 15% to 25% of the steam amount, which flows into the dryer, is used as flow-through steam amount. That means if 1000 kg/h steam are necessary for paper drying, a steam amount of ca. 1250 kg/h has to flow into the dryer. This fact must be considered at the design of steam supply as well as of condensate pipes.

Because of the much bigger steam volume the flow-through speed is very high in the syphon tube. Powered by the differential pressure between in-flow of steam and out-flow of condensate at the steam joint, the steam and the condensate squeezes through the narrow pipe. As described above, that’s a desired fact. Flow speed of up to 40 m/s of the steam-condensate mixture in the syphon tube is quite usual.

When the differential pressure is reduced as a result of problems with the measuring and control technology, of misadjustment by the operator or as a consequence of damages at the syphons, the dryer is flooded. The syphon shoe is flooded and the flow-through steam is no longer able to flow through the condensate film under the syphon shoe in order to create the whirling which is necessary for drainage.

Problems of drainage



The so-called drowning, that means the flooding of the syphon shoe because of bad drainage of the dryer, may happen with stationary as well as with rotating syphons. However, it happens more often with rotating syphons. At paper machines with dryers that rotate below waterring speed of ca. 450 m/min the dryers are often equipped with scoops. These scoops are not flooded and do not need any flow-though steam for drainage. Scoops will be discussed in a later chapter.

A person without experience does not notice the flooding of single dryers. Some dryers within a bigger drying group are dragged with. If the steam joint is tight and no condensate is leaking, this single flooded dryer will not be noticed.

If several dryers do no longer drain, a first indication for flooded dryers could be an increased number of paperbreaks. The flooded dryers begin to vibrate and thus the paper breaks always at the same spot in the drying group. Of course, the drying reduces, because the drying surface decreases as a consequence of the thick condensate film in the dryer. The quality control system notices the increasing moisture content of the paper and would react by raising the steam pressures automatically. The observant operator might realize that. It always has a reason why – at same surface weight and same production speed – the steam pressure suddenly has to be adjusted higher.

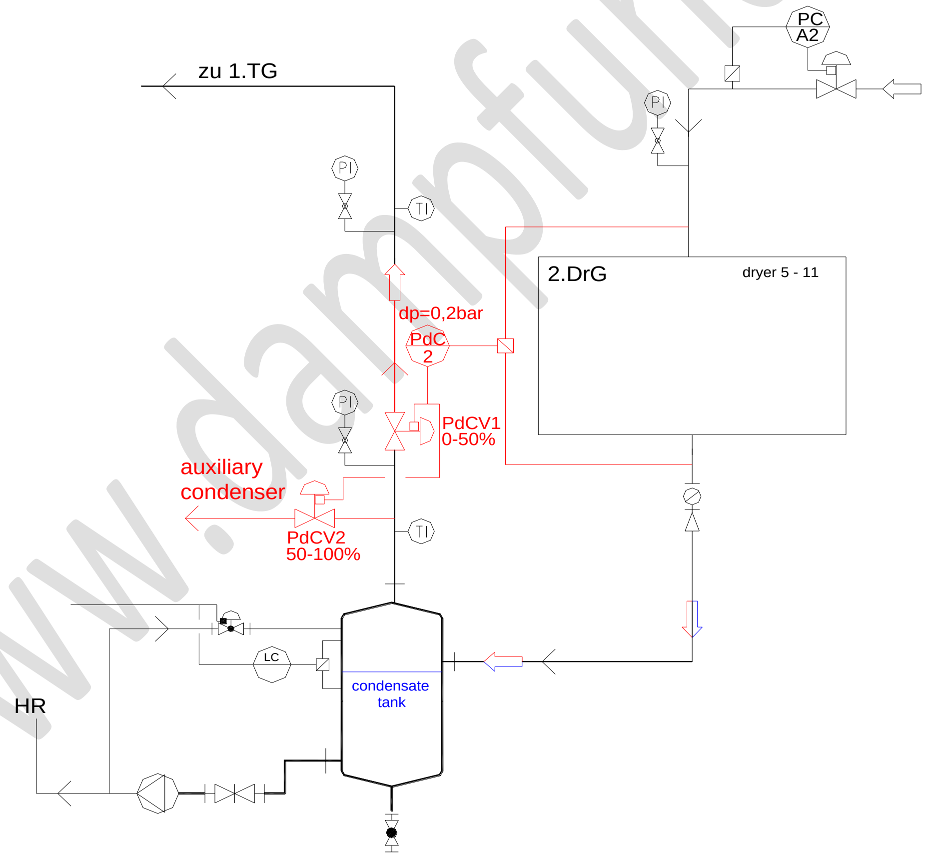
Reasons for a bad drainage:

- Fault by the operating staff

The differential pressure has to be adjusted at rotating syphons at every modification of the pm speed. Dependent on the inflowing steam amount for example at 500 m/min a differential pressure of ca. 0,5 bar is necessary, at 1000 m/min even ca. 1 bar! Of course, also at reduction in speed, the differential pressure has to be reduced in order to reduce the flow-through steam. The same is valid for changing surface weights. At low surface weights a lower differential pressure is necessary than at higher surface weights. The operator's experiences are important at the adjustment of the pressures. If the differential pressure is set too high or too low, this may cause problems at the drainage. As you can only watch the drainage through a sight glass on the condensate pipe, the operator has to develop a special feeling for the quality of drainage. Therefore at once a day the draining should be observed through the sight glass. At stationary syphons an adjustment of the differential pressures to the production is basically not necessary.

- Fault by measuring and control technology

Are the differential pressures adjusted correctly and do even exist?



As described above, the differential pressures have to be adjusted to the pm speed at rotating syphons. At stationary and rotating syphons the differential pressure, which is set in the process control system, should indeed exist at every production and at every operating condition. However, temporary variation may happen. At problems and causal research a staff member of the measurement and control department should check the measurement, i.e. the pressure transmitter and the pressure reductions as well as the valve position of the differential pressure control valves. Often the measuring is correct, however the valve positioner has a problem because of overheating and moisture or because of oil and dirt in the control air. At bad maintenance even the pipes between pressure reduction and pressure transmitter may be blocked by rust particles. Does the valve position correspond to the indication in the process control system?

- problems caused by bad maintenance

Bad maintenance of the steam joints, syphon shoes and the horizontal pipe system are very often the reasons for problems at the drainage, though the steam joints for stationary syphons as well as the stationary syphons with horizontal pipe system require less maintenance.

Maintenance of stationary and rotating syphons

Stationary syphons:

The steam joints of stationary syphons are basically indestructible. If you don’t crash against them with a fork truck, you can’t destroy these steam joints. According to the editor’s experience, it is sufficient to check the wear-out of new steam joints first after 5 years. In contrast to rotating syphons, the steam joint doesn’t have to be disassembled. The wear-out of the seal coal can be realized from outside. You may take the information from the operating instructions, which parts have to be checked.

Every two years the syphon shoes should be visually checked, you may connect this check with the inspection of the dryers inside. It is necessary to check, is the syphon shoe damaged at the bottom side, because it touches the dryer as a consequence of vibration. Open the manhole, look in it, check the syphon shoe, ready!

Syphon shoe made of metal or teflon?

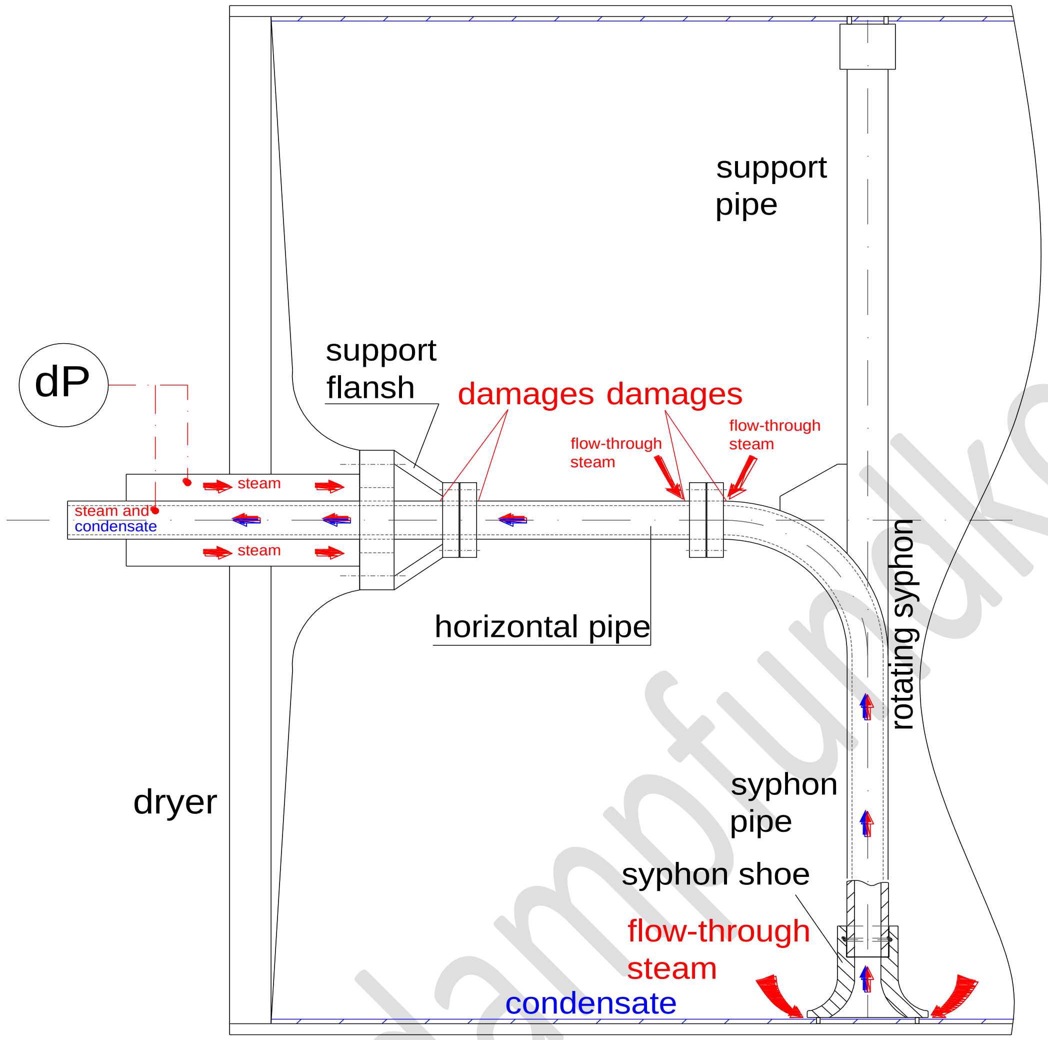
The drainage of the dryer is performed very well by a syphon shoe made of metal as well as one made of teflon. The only problem is the touching of the syphon shoe with the dryer inside as a consequence of vibrations. Although the syphon shoe basically cannot touch the dryer because of the adjusted distance and the whole structure seams strong, this may happen. Therefore to the editor’s opinion syphon shoes made of teflon are generally better. They may be copied by every CNC-supplier according to the original.

Sales people, who say their syphon shoe cannot touch the dryer, do not know that in advance. How could they? The vibrations cannot be felt nor measured. Only after longer operation this can be realized.

At teflon shoes only small abrasive signs arise in the dryer. Screws which have been lost from the assembled turbulator bases cause much higher damage at the syphon shoe.

Rotating syphons:

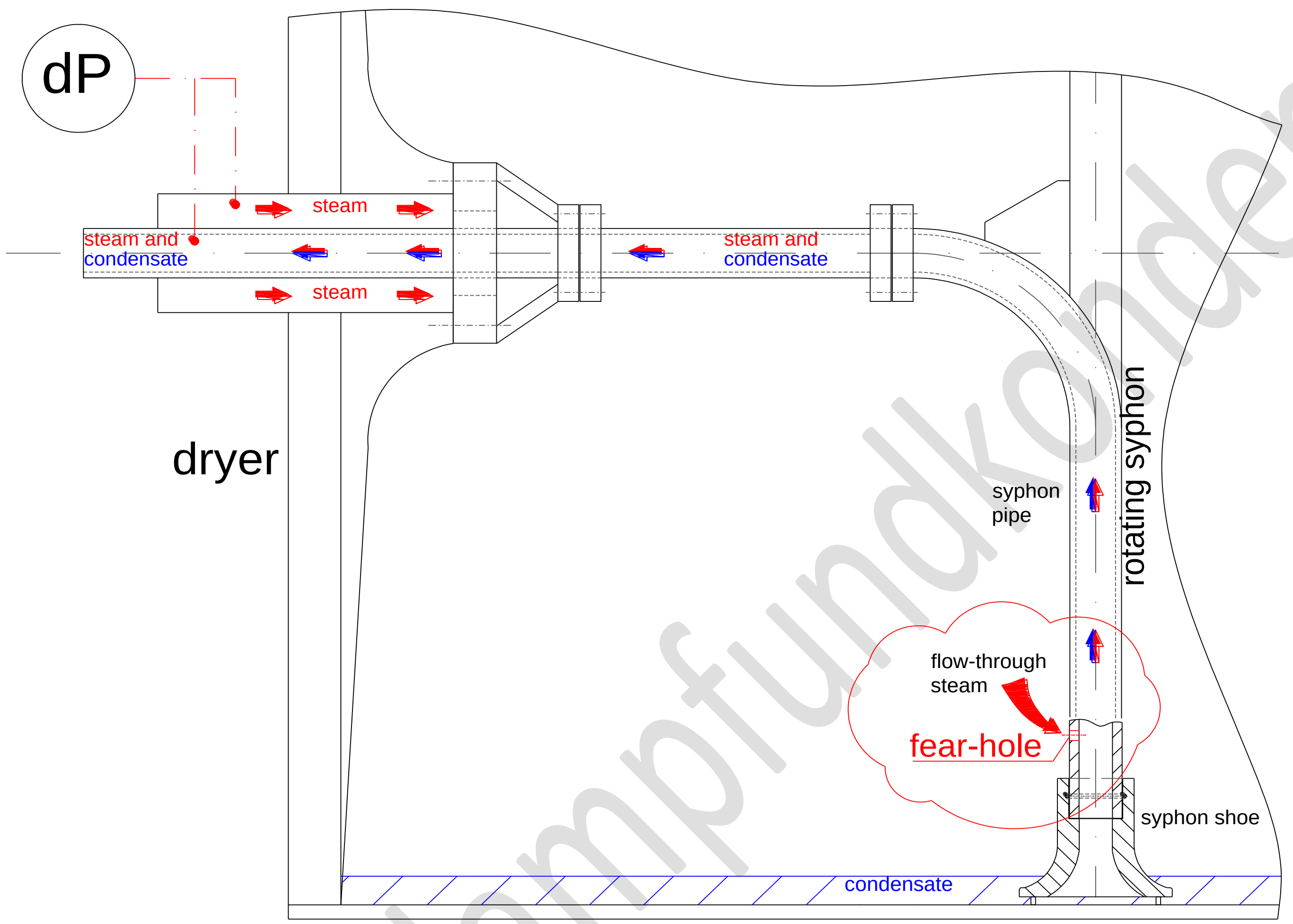
Rotating syphons and steam joints require a regular maintenance. At every routine standstill some steam joints should be checked in regard to broken or rubbed steam coals. That does not take much time. As described above, rotating syphons require a higher amount of flow-through steam. The mixture of steam and condensate flows through the syphon tube very quickly and gets to the horizontal tube to the steam joint. Because of the high flow speed of the steam and condensate mixture, erosions arise in the horizontal tube,



The tube is washed from inside. The erosions arise especially in flow direction behind the welded seam of the tube flanges. Because of these erosions, the wall thickness of the tube is reduced. From outside this can only be realized, when tiny holes are arising. At this stage only experienced staff is able to realize the weak material at a visual check. The holes become bigger and bigger and eventually the horizontal tube breaks and the syphon falls into the dryer. Once these holes have arisen, also problems with the differential pressure will arise. Then the steam does no longer flow as flow-through steam through the syphon shoe, but takes the direct way through the holes in the horizontal tube, However, without flow-through steam, no transport of condensate. If the damages are high, you may raise the differential pressure as high as you want, however the condensate only flows out of the dryer, after it is half full.

The "fear-hole" at rotating syphons

The stationary syphons are provided with a drill hole shortly above the syphon shoe. This drill hole is also called "fear hole". If the flooding of the syphon shoe is not yet too strong resp. too high, it will be possible to get the drainage started again with the help of this hole and a moderate raising of the differential pressure. The arrangement as well as the size of this drill hole may vary from one supplier to the other.



How does the "fear-hole" work?

At flooding the steam, which is necessary for whirling, can no longer flow under the syphon shoe. Because of the differential pressure the steam however flows through the fear-hole. Thus condensate is whirled in the syphon tube and swept along. So the experienced papermaker may achieve a drainage of the dryer again. Has the flooding been reduced, the steam flows again under the syphon shoe and the usual drainage starts again.

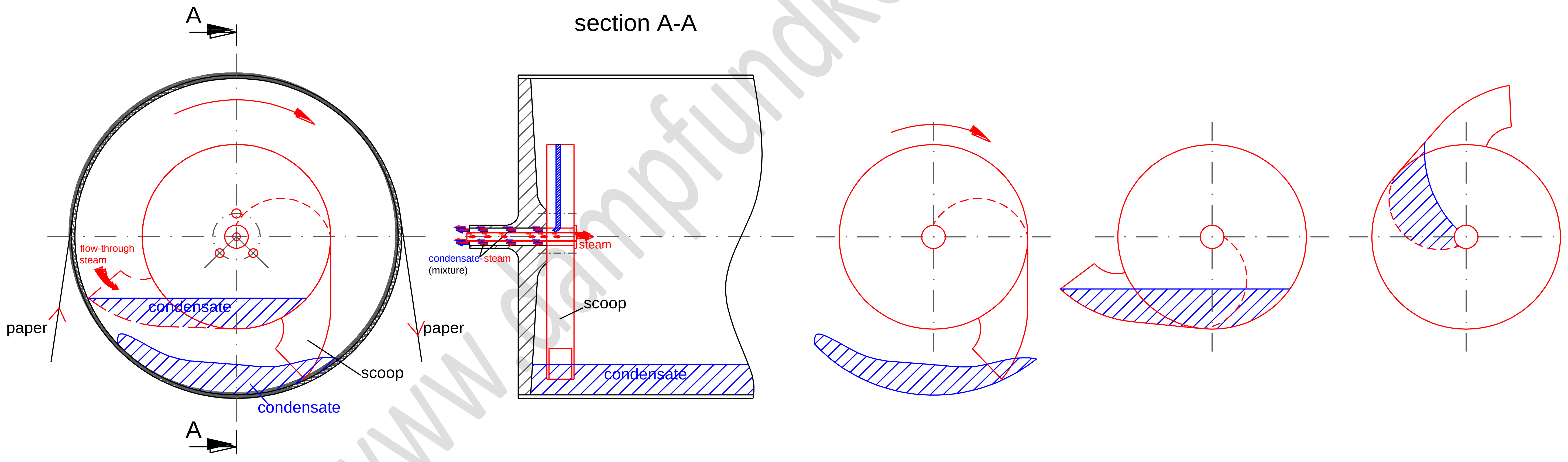
The scoop

Formerly the paper machines have been operated at low speed. Technical engineering has not been experienced enough to keep a corresponding mechanical drainage like today. In order to reach the desired drying of the paper nevertheless, the contact between paper and dryer had to be kept for a long time. And of course, also the drives of the dryer and of all rotating parts have not been fully developed. Still today you may inspect at some paper machines transmission shafts resp drives with the help of big gears. Additionally there are paper machines which cannot be operated at high speed because of the high surface weight. These are the cardboard machines. A cardboard machine producing for example cardboard for beer mats, is operated at a speed of ca. 50 m/min. Corresponding to the slower paper machine, drainage systems have been developed. These drainage systems are called scoop or scoop syphon.

As described in the paragraph of the syphons, a waterring in the dryer is formed only at a speed of ca. 500 m/min. As of this speed the condensate is pressed uniformly by the centrifugal force to the inside of the dryer (see paragraph above). Below the speed of 500 m/min a condensate pit arises. In case the speed drops below 500 m/min, scoops are used.

Simple illustration of the structure and function of a scoop

dryer with scoop



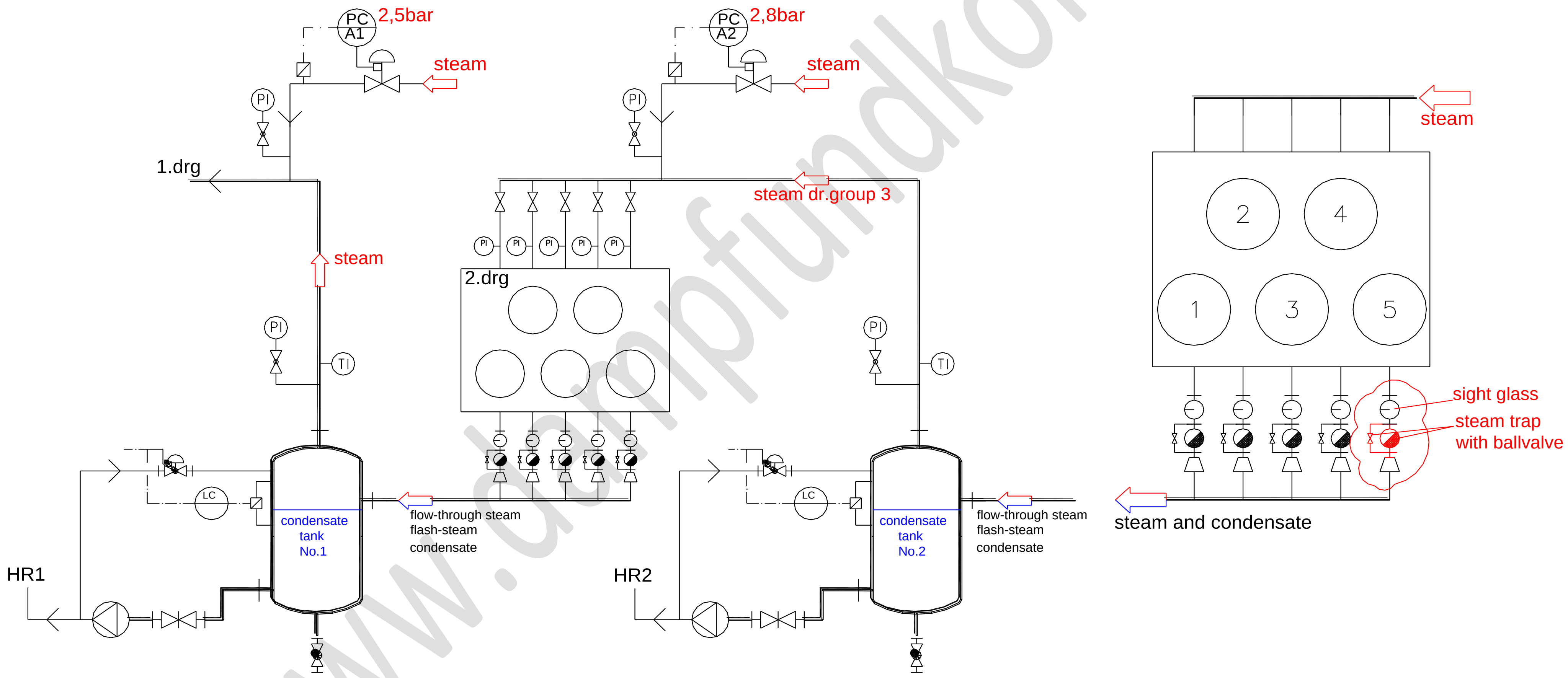
Structure and function

The structure of a scoop does not require many explanations. Either the scoops are made of cast steel or of blank sheet. The scoops are fixed to the cylinder cover by big screws. The scoops are too big for the transport through the manhole of the dryer. If you want.to change over the dryer to a more modern syphon, mostly the syphons are disassembled in the dryer and cut into pieces. Thus the mass is reduced, which the dryer has to move along. The cutting is performed wither by a big angle grinder or by a plasma torch. This is hard work and may take 4 – 6 hours per dryer. The dryer has to be sufficiently ventilated within this time.

The function is self-explanatory: the condensate is collected because of the rotations by the scoop and flows through the horizontal tube to the steam joint. The drainage is performed mechanically without any flow finesse as at the stationary or rotating syphon. Because of the engineering of the scoop with the big aperture for collecting condensate and the different heating pressure between the drying groups, also steam flows through the same aperture. As described above, this steam is not used for drainage. The dryers which are equipped with scoops are often provided with a steam trap in order to limit this flow-through steam.

At the scoop no differential pressure between steam flow-in und condensate flow-out is necessary.

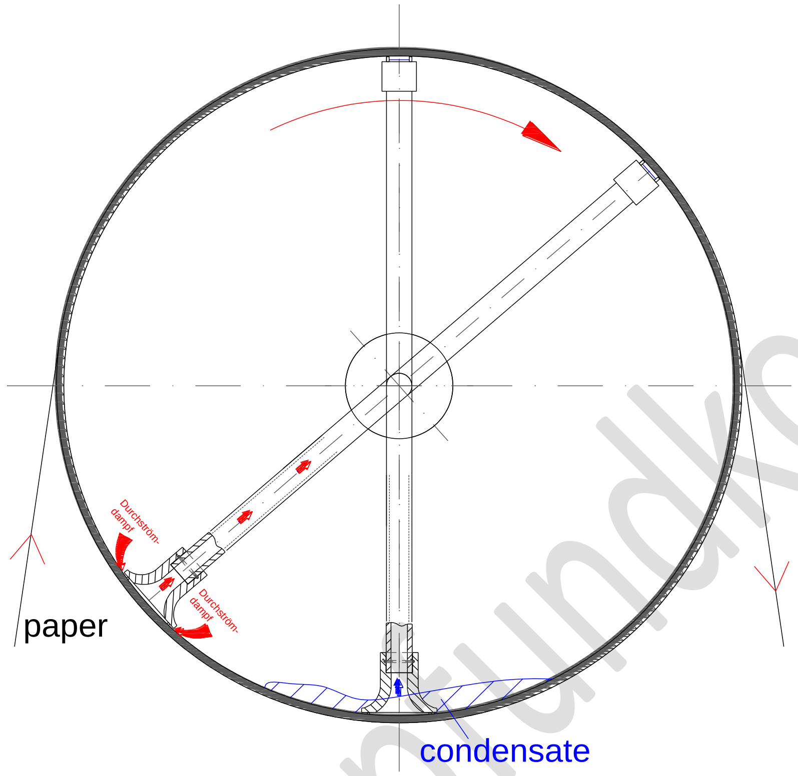
The scoops are indestructible. Flooding of a dryer, which is equipped with a scoop, only works when the condensate discharge is prevented at the steam joint or when the dryer rotates too fast with waterring speed.



Sometimes small pressure- and temperature-resistant ball valves are installed as bypass for the steam trap. With the help of these valves you may adjust a small amount of flow-through steam.

The modern scoop syphon

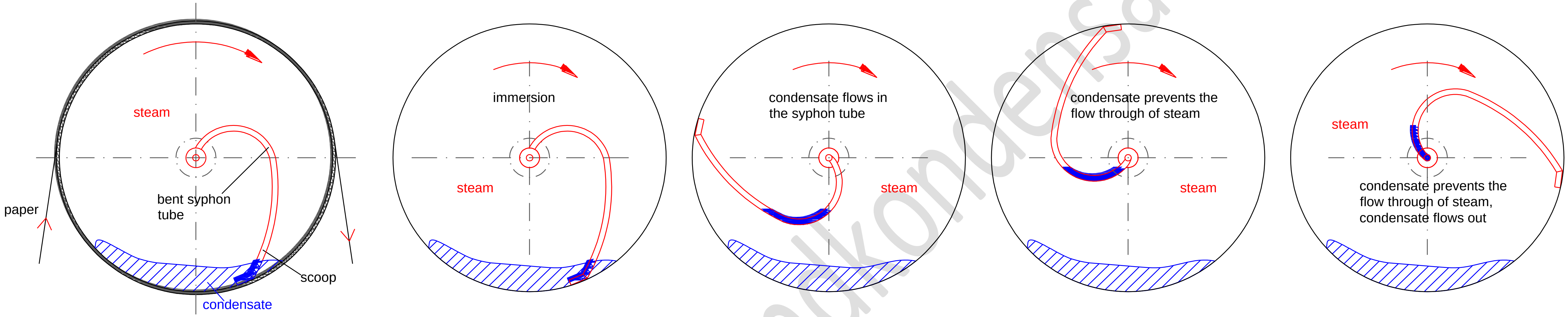
As described above, there are paper machines or rather cardboard machines which cannot be operated with high speed because of high surface weight. You could also use rotating syphons at these cardboard machines. The arising high amount of flow-through steam however, is a problem. Why? Because the dryer rotates far below waterring speed. Condensate pit is arising. If the rotating syphon immerges into this pit, at once the drainage will start. But if the syphon shoe is beyond the pit because of the rotations, only steam will flow.



You could also use a stationary syphon. However the effect that the condensate flows to the steam joint without any differential pressure, would not exist because of the low rotational speed. You would have to support with a differential pressure of 0,3 bar – 0,5 bar. It would be wrong to invest in a steam joint with stationary syphon.

That's why a scoop has been designed, which scoops the condensate without differential pressure and prevents the steam from flowing through.

Simple illustration: The way of the condensate to the steam joint



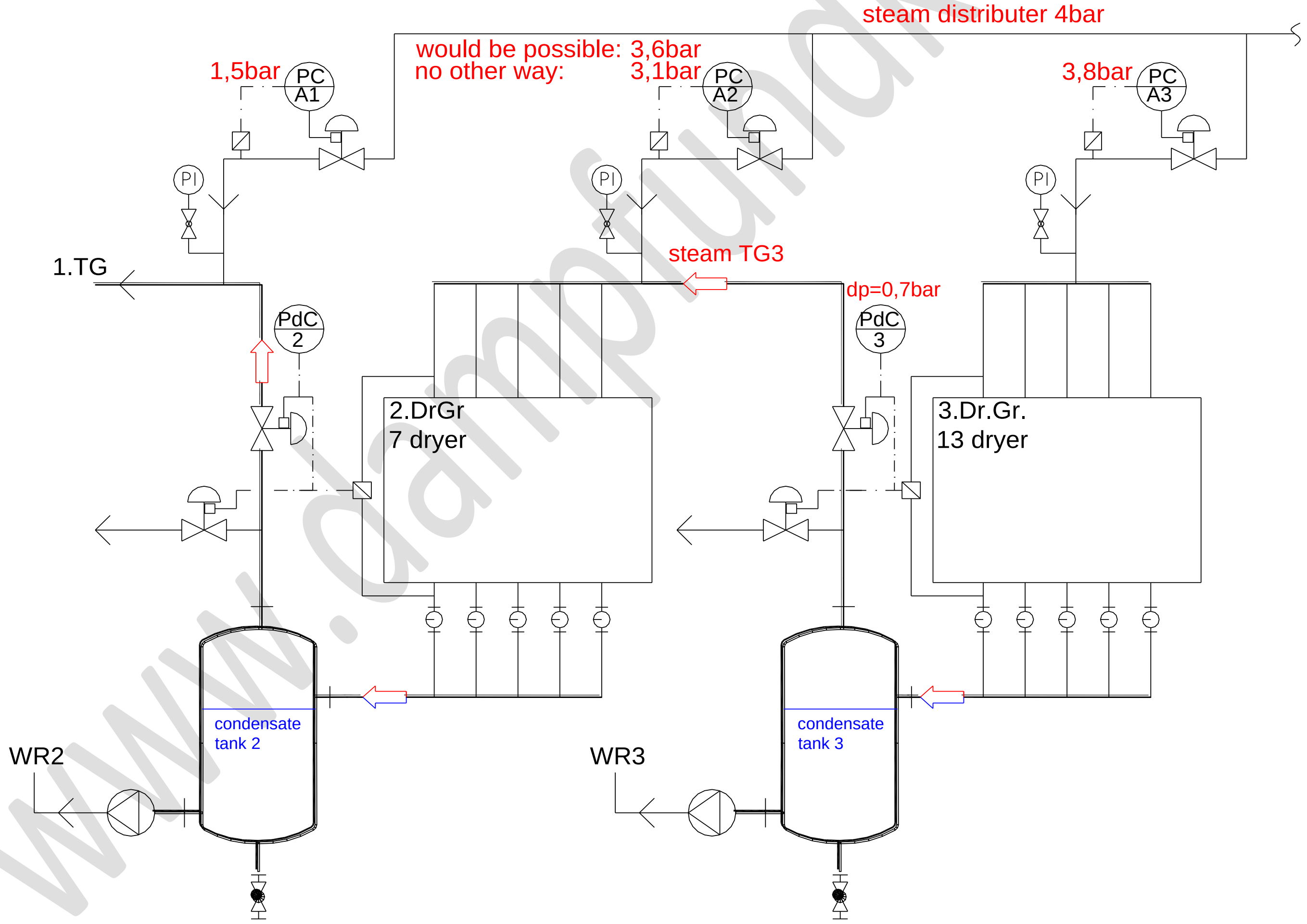
The scoop syphon is equipped with a bent syphon tube. After the condensate had been taken, it flows through this bent tube and closes the tube until the next immersion. Only the steam amount, which is in the syphon tube at the moment of the immersion in the pit, can flow to the steam joint.

Epilog to the drainage systems

After the mechanical drainage in the wire and press section the drying of the paper at dryer 1 starts by heating the dryer with steam. It's important for the production that the drainage system in the dryers is adjusted to the speed and the steam requirement. It's of no use to invest in modern technology and achieve a high mechanical drainage, but in the drying section there is a bad drainage efficiency and thus poor drying! Condensate in the dryer decelerates the production.

The theoretical steam requirement is thermodynamically defined by the heat transfer from the dryer to the paper. According to the simple formula Heat-in = Heat-out you may define the steam amount like a heat exchanger. In this simple formula the wastes at the heat transfer are not considered. The operation manager may influence the amount of wastes and thus the increase of the actual steam requirement. Also by regular maintenance of the steam joints and of the drainage system, the steam consumption for drying can be reduced to the necessary rate.

Drying surface can be wasted, if the drainage system is wrongly designed, damaged or antiquated. What is the relationship between drying surface of the dryer and the drainage system? The answer is easy! Depending on the applied drainage system, the amount of differential pressure, which is required for drainage of the dryer, is more or less. To keep the differential pressure between the drying groups as low as possible, may increase the production. Imagine that a maximal steam pressure of 3,8 bar in the 3rd drying group and 3,6 bar in the 2nd drying group would be necessary. The lower steam pressure in the 2nd drying group would only be necessary to let the flow-through and flash steam flow from the 3rd drying group in the second one. But at a machine speed of 850 m/min rotating syphons are applied, which require a differential pressure of ca. 0,6 bar – 0,7 bar for the drainage at this speed.



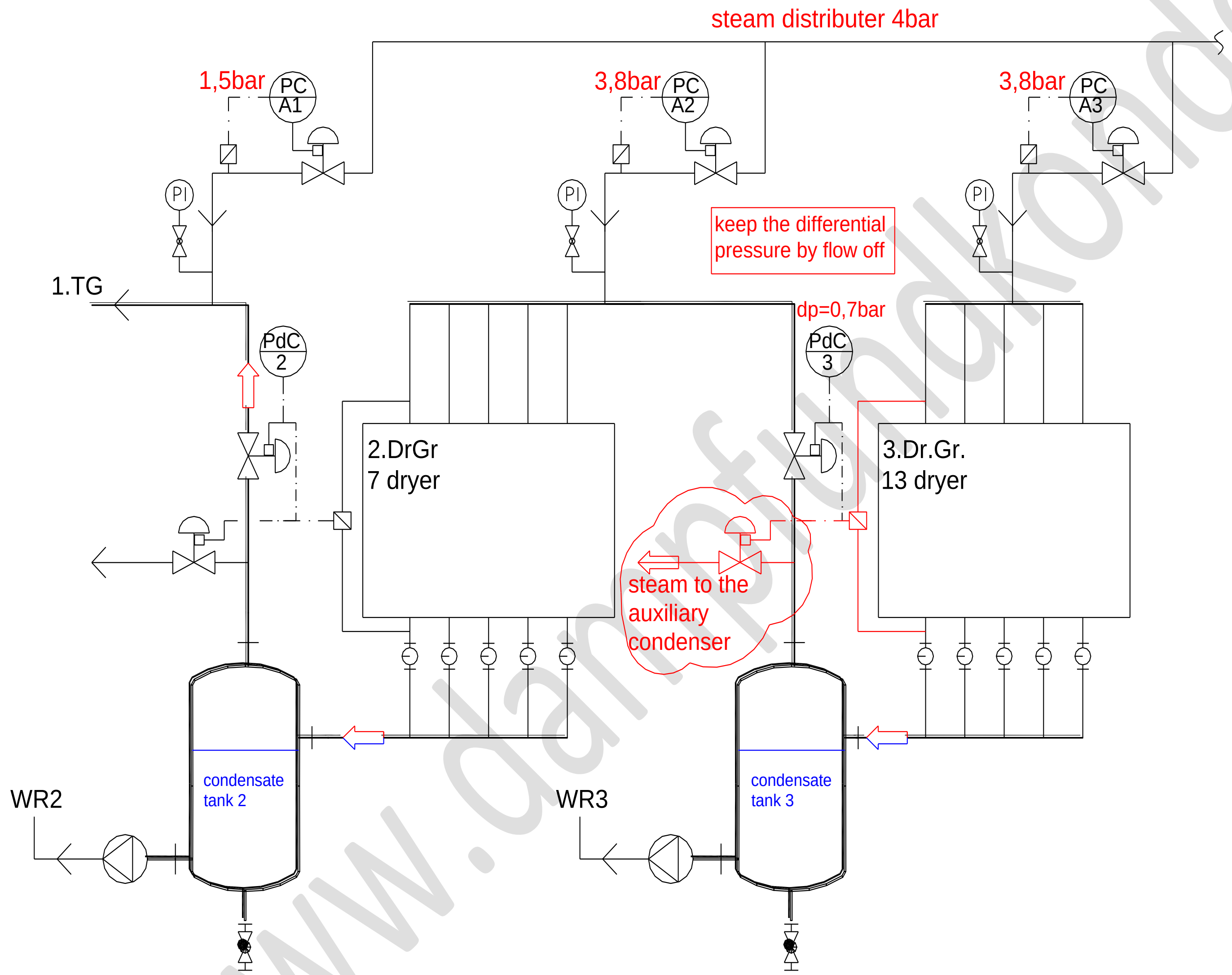
This would mean that the dryers could dry more, but are not allowed to, because the differential pressure for the syphons in the 3rd drying group determine the steam pressure of the 2nd group. Thus the really available drying surface or rather the available drying capacity is not utilized.

In some papermills they disassemble ring chamber orifice plate in the steam pipes in order to achieve 0,1 bar more in steam pressure (waste of pressure via the orifice) and thus to increase the production. So there is high potential for production increase in the reduced steam pressure of 0,7 bar.

How can you adjust the heating pressure (steam pressure) in the 2nd drying group also to 3,8 bar in spite of the assembled rotating syphons!

There are two possibilities:

Keep the differential pressure by flow-off to the auxiliary condenser = energy loss

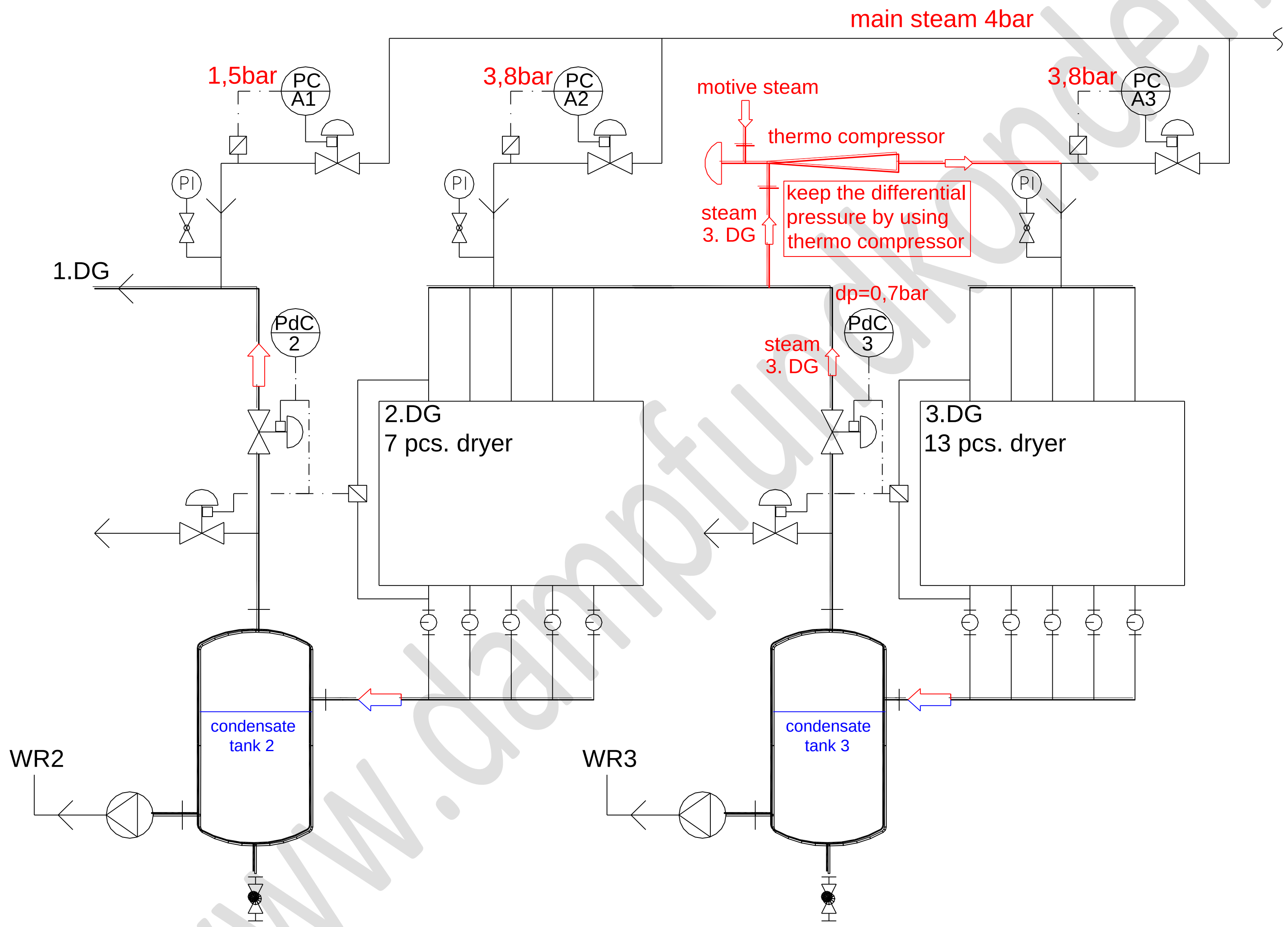


The flow-through and flash steam, which basically could be utilized for the heating of the 2nd drying group, flow to the auxiliary condenser. There high amounts of cooling water for the condensation of the steam are necessary. Part of the arising warm water could be utilized for the cleaning systems of the pm (cleaner). What to do with the rest of the warm water?

Keep the differential pressure by using a thermo compressor

By using a thermo compressor the flow-through and flash steam can be sucked out of the 3rd drying group and again be utilized for the heating of the 3rd drying group. This will only work, if a maximal motive steam is available for the compressor. Otherwise the amount of mixed steam is too big. The reason for this will be explained in the chapter referring to compressors. If there is no appropriate steam at the pm, it can be worthwhile to install a separate piping for the motive steam from power house to pm, after you have checked the economic benefit by using a thermo compressor.

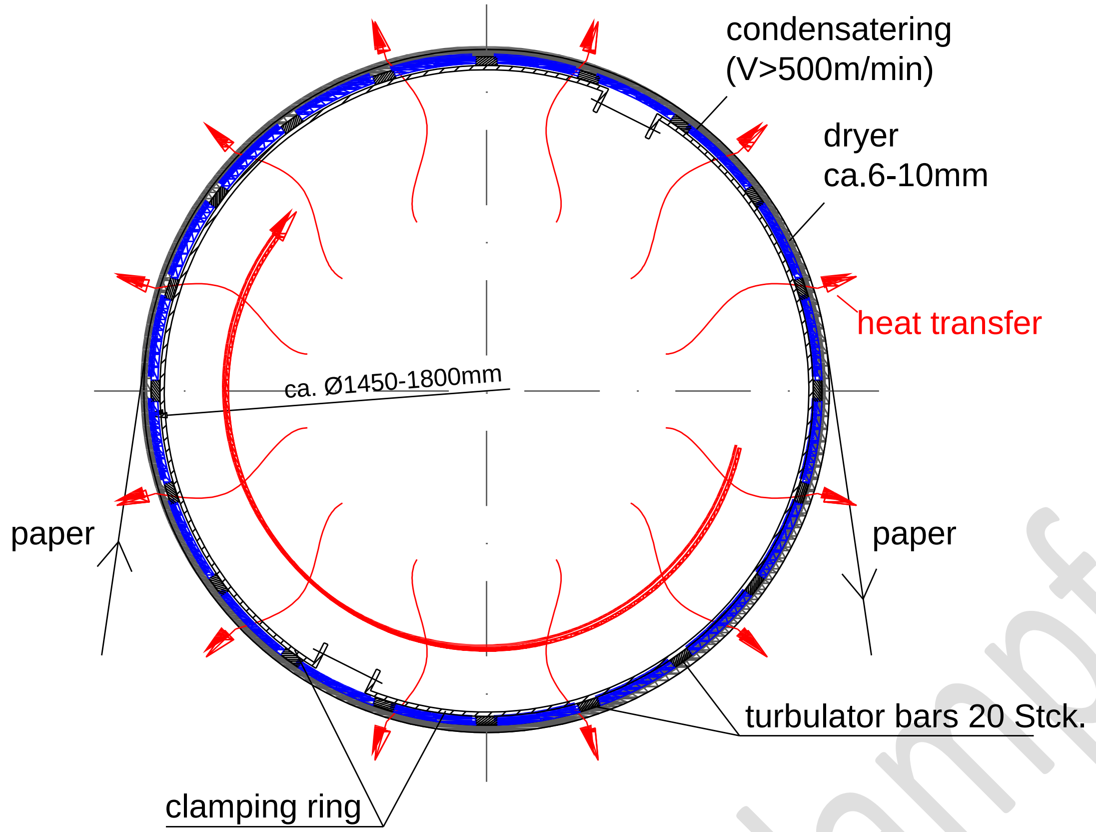
Colloquially the application of a thermo compressor for keeping the differential pressure may be described as "… the drying group is bathing in its own juice…"

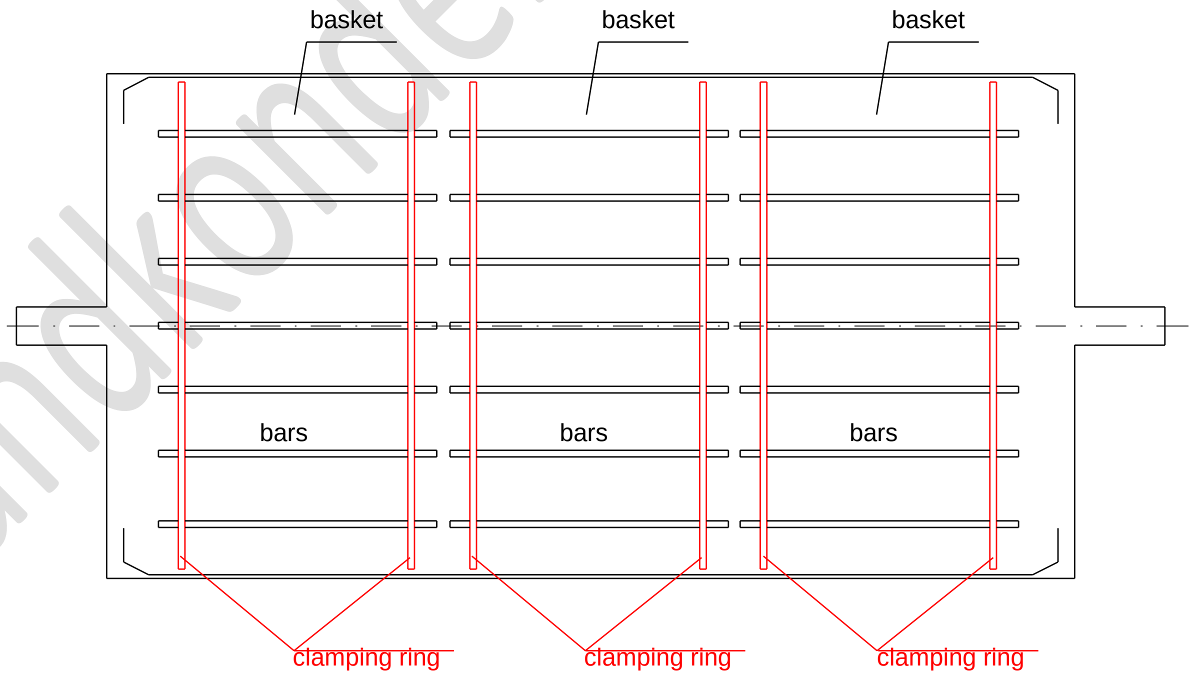


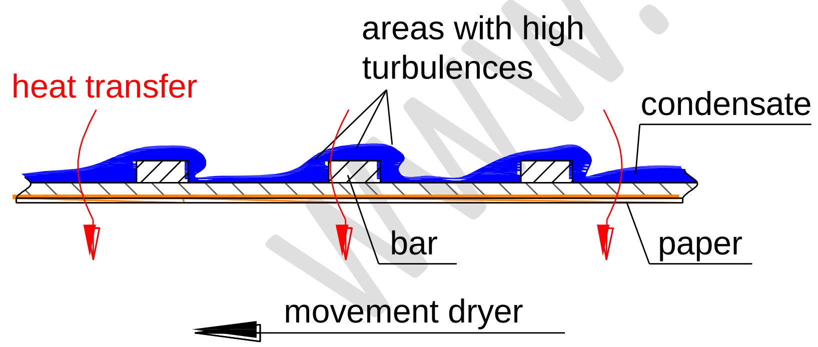
What does turbulator bars disturb in dryers?

What are turbulator bars?

Turbulator bars are square profiles made of steel, which are assembled in the axis of the dryer to the perimeter. These profiles may also be designed as hollow profiles. The number is different and depends on the manufacturer and his philosophy, usually 20 – 25 pieces. Depending on the operating width of the dryer the bars are installed in different so-called baskets. Every basket has 2 or 3 pieces of clamping rings – depending on the length of the bars. The clamping rings are bent in such a way that they press the turbulator bars according to the internal diameter of the dryer with the help of springs or screws to the internal surface of the dryer. The turbulator bars are screwed or pinned to the clamping rings so that they remain at the same position and cannot glide off. There have been “specialists” who have pinned the turbulator bars to the dryers, i.e. in the dryer a high number of drillings had to be performed!







Why turbulator bars?

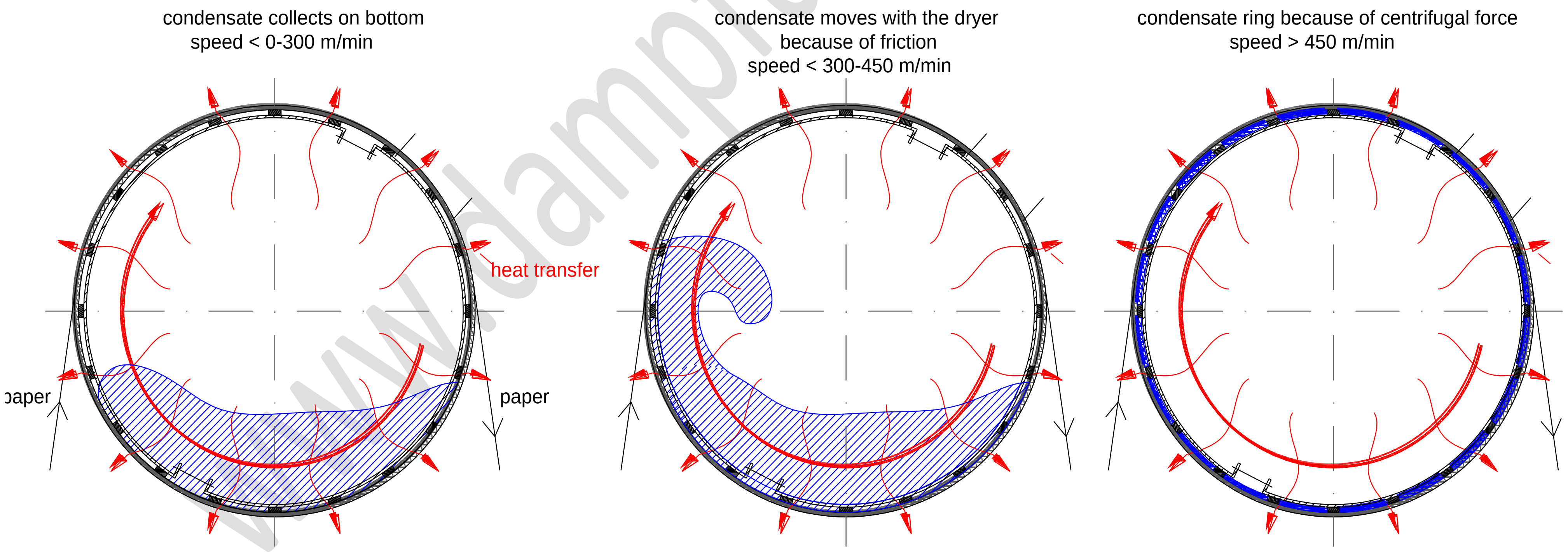
In former times paper machines have not been operated in such high speeds as today. The dryers were rotating below waterring speed. The name "waterring speed" is usual, but not really correct. In the dryers there is no water, but condensate. The condensate collects at a speed up to 350 m/min as pit in the dryer. At a speed of more than 350 m/min the condensate is accelerated by friction to the dryer. At a speed of more than 500 m/mina condensate ring arises because of the centrifugal forces. This closed condensate ring acts like an isolation. It cools the steam before it has achieved the internal of the dryer. The heat transfer gets worse. The condensate ring cannot be removed at once because of the mechanical drainage by the syphon. The condensate has to flow off into the direction of the syphon first.

Note: *To think the syphon is sucking the condensate out of all corners of the dryer, is wrong! How can a rotating syphon, which may be assembled at the center of the dryer, suck the condensate from the leading side or the driving side? That does not work. The syphon does not function as a vacuum cleaner. The condensate flows to the syphon exclusively because of the centrifugal forces. At the syphon the condensate layer is the finest. The longer the distance to the syphon, the thicker is the condensate layer. The centrifugal force however functions as a surface force uniformly to the condensate layer. A thick layer (hill) or a fine layer (valley) is immediately balanced. Thus a constant flow of condensate and level balance to the syphon arises.*

The condensate ring and thus a worse heat transfer can't be prevented. Therefore the condensate ring has to be minimized. Experts argue about the question, which thickness is the right one. On the one hand they say as fine as possible, on the other hand they say, a thickness of ca. 6 – 8 mm is better. The thickness is adjusted by help of the distance between syphon and dryer.

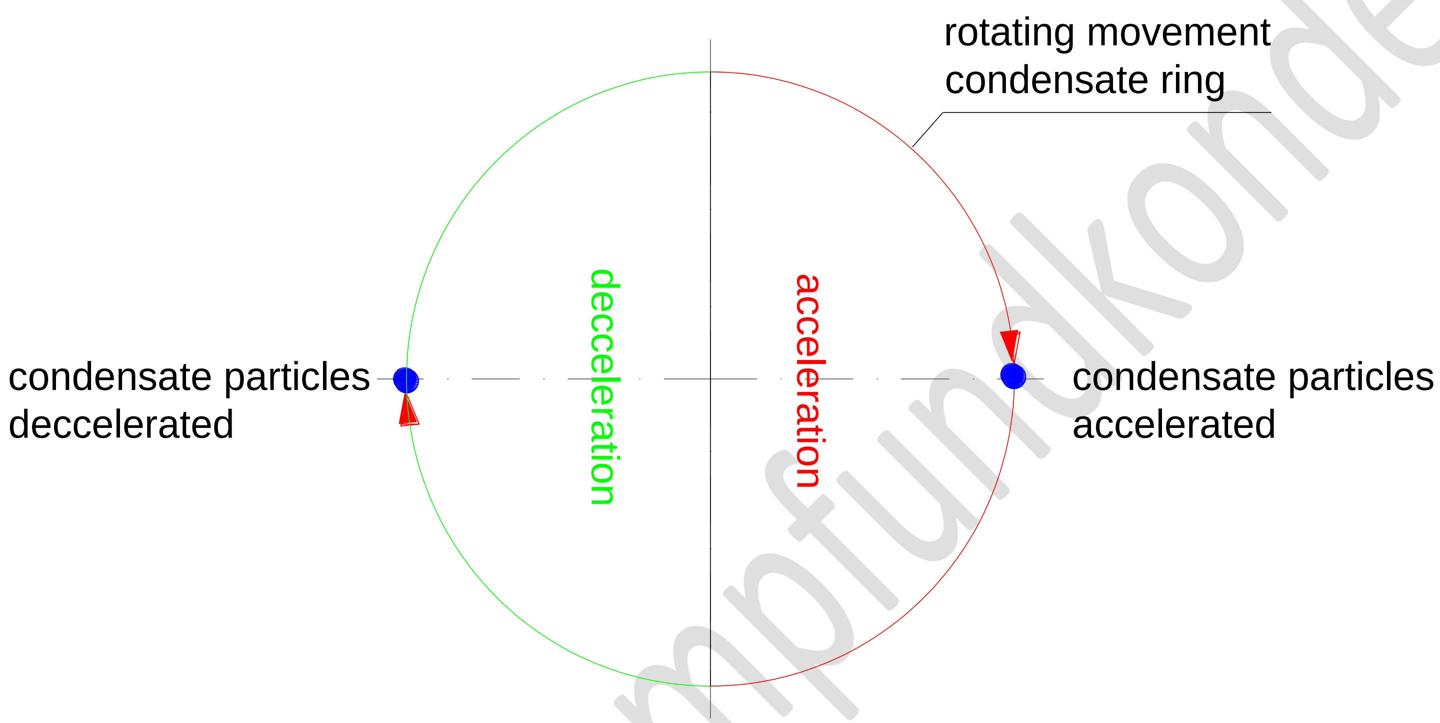
Why do you need turbulator bars? When the dryer starts rotating, the turbulator bars are flooded by condensate. Thus around the turbulator bars areas with high turbulences are arising. And as you know from heat exchangers, high turbulences improve heat transfer. Additionally the turbulator bars cause the extension of the dryer surface. This extension as well improves heat transfer.

As already described, different flow states of the condensate are caused by the different rotating speeds of the dryer. You may compare this to a washing machine.



If somebody wants to do further research on the dependence of centrifugal force to condensate flow in the dryer, he may easily do as follows. You take a bucket and fill it to the half with water. Then you start rotating the bucket around the shoulder axis, first very quickly, then more and more slowly. Depending on the rotating speed, you will get wet! If you imagine that the dryer rotates with a speed of 600 – 1200 rot/min, you understand that the condensate is pressed to the internal surface. Without reduction of the specific weight of condensate, it cannot flow out of the dryer easily.

With increasing rotating speed the centrifugal force presses the condensate stronger to the internal surface and the turbulator bars are no longer flooded to such an extent as at smaller rotating speed. But also at higher speeds the turbulator bars are useful and improve heat transfer. In order to generate the necessary turbulence at the turbulator bars, another effect is used, the gravity.



The condensate particles are accelerated as well as decelerated in the dryer as a result of gravity. These contrary minimal forces generate the turbulence at the turbulator bases.

How reasonable is the installment of turbulator bars to the dryers 1 – 5?

There are also dryers at a pm, at which the surface temperatures must not be too high. At special papers such as crepe paper, photo paper or money paper etc. a special heating curve of the dryer of the first drying group is requested by the papermakers. As already described in part 1 on page 8, at most paper machines a heating curve does not exist in reality because of the different nominal values of the individual controls and the resulting different steam temperatures in the dryers.

Besides, many designers of steam and condensate plants do not know the relation between pressure reduction and minimum termperature reduction. And as the temperature at the dryer 1 is still too high, the vacuum is reduced more and more. A simple steam cooling for the dryers of the first heating group would easily secure that the steam temperature before the dryer is within the range of the temperature of saturated steam.

In short: It is very difficult to achieve a heating curve below 100°C. Additionally it makes no sense to assemble turbulator bars in order to improve heat transfer.

Summary:

The condensate in the dryer acts as an insulator. With the use of turbulator bars the heat transfer improves. Thereby the drying of the paper is faster. With the installation of turbulator bars it is possible to increase the production significantly. The increase of production may about 5% - 8%. With the turbulator bars, the heat transfer is more uniform. This also improves the moisture profile. The installation of turbulator bars is easy and quick. There is no need for special staff. It takes 3-4 hours for the installation in one dryer. The company Lang-Regler has extensive experiences with use of turbulator bars.