Paper Dryer Steam Condense Systems :

F. Blezzard

Up to comparatively recently the inside of a steam heated cylinder could not be seen nor evaluated. Too many guesses and conjectures were made, most of them were wrong and to these were added more conjectures compounding unsound information.

When laws of physics applied, all, become simple and apparent.

Those engaged in support process industries (as engineers are) must *serve* the needs of the primary product requirement—in this case the paper Maker.

There is a tendencv for him to over-specify upward "to make sure."

Equally the financial penalty of installing a machine having insufficient drying capacity is so great that (today) all new machine builders over-provide their drying capacity.

This is just about the worst possible combination for the steam system engineer.

Ineveitably on machine start-up external trouble will impose low drying requirements and together with excess drying area (let's start on low grade) there evolves the need "steam engineer—reduce the drying capacity—reduce the surface temperatures". and beyond a quite finitely determinable limit the steam engineer cannot do, so let's state the basic problem.

F. Blezzard, Director Johnson Corporation Ltd., Yorkshire, U.K.

This is because of the temperature pressure relationship of steam.

Whereas circulating water gives up its heat by reducing its temperature (called sensible heat) steam gives up its heat by condensing (called latent heat). The rate of condensing is determined by the saturation temperature and hence the pressure. Throttling a steam supply primarily reduces the pressure, and it will be seen that appreciable temperature reduction soon moves the operation into very low pressures and if. for example, a paper maker need 203°F inside his cylinder the pressure needs be 5" Hg. Or approximately 2.5 p.s.i. vacuum ! how is he going to get his condensate out ?

So let's move from putting steam into a dryer and enquire how we get condensate out, and as a side investigation how this might effect the dryer surface temperature from back-head to tending side (We intend to investigate rotary syphons only-these are now accepted as standard for sophisticated paper machine of medium size upward).

It is obvious that steam condenses on the inner rim of a dryer cylinder. This accumulating condense has to be evacuated through the dryer journal. So there must be a radially disposed pipe (and you can play about with its shape just as much as you want. The following "physics" apply leading the condensate from the inner rim to the centre journal.

This radial pipe is subject to centrifugal forces and these are easily calculable $\left(\text{formula } P = \frac{PV^2}{288g}\right)$ There must also be more dynamic pressure than the mere centrifugal pressure to initiate flow.

So according to this theory to get condensate out of a 5'0" dryer running at 2,000 feet per minute will require, say, 9-lbs. per square inch. And as most modern machines are "staged" into three sections, with the exhaust from the previous section feeding the following section, the minimum pressure across the machine would according to this uninformed guess be 3×9=27 lbs. per square inch and we know this not to be so. (How would a newsprint man accept this). So where is our physics wrong.

Early in 1957 we in U. K. set up a static rig to test our theory that the radial tube of a rotary syphon operates under bi-phase flow. This apparatus was in essence a 1" vertical tube 32-ft. High, steam insulated, dipping into a base tank to which could be fed under regulated conditions saturated condensate and steam.

It was found the condensate could be lifted 32-ft. with only 3-lbs. per square inch pressure, the media within the vertical tube being a mixture of steam and condensate thus effectively reducing the apparent specific gravity of the solution. This experiment contributed to our more sensible thinking when it was realised that 80% wet steam at 15 p. s. i. still has a volume of 2.273 cu. ft. per lb. againt 0.016 cu. ft. per lb. for hot condensate (in other words the apparent density was reduced from 1 to 0.007). Moving this density into the provisionally calculated centrifugal pressure theory and we now have a clue why the rotary syphon needs little more operating steam pressure than the mechanically difficult fixed syphon.

Visualise a rotating syphon working (for this example) with 25% blow-through so this is 75% wet steam.

At this condition and 30 psig pressure the volumetric ratio of steam to water is 196. At 10 psig the ratio is 346 and at 0 psig the ratio is 560.

Thus under this operating condition of a rotating syphon reducing the condensate to zero reduces the volume to be handled by :

At 30 psig $\frac{1}{196}$

At 10 psig $\frac{1}{346}$

At 0 psig $\frac{1}{560}$

And from this we can generalise that the weight of blow-through steam to be hadled for each syphon by the system design is substantially independent of the quantity of condensate provided it is operating under bi-phase flow conditions.

The philosophy of the very small clearance gap of a rotary (or even fixed) *syphon pick-up* tip for optimum performance came from the Johnson Corporation (U.S.A.), and has surely gained acknowledgement if only by being copied (within the patent situation).

Initially on its introduction the criticism of a 1/16" gap (for this approximately is what it is) postulated blocking by debris, early water logging and so on, but in fact increasing of this gap merely results in the condense level building up and itself generating the optimum gap (but in consequence a thicker condensate film)

Basically the minimum gap is mandatory to gain effective performance in a rotary syphon because—

1. It presents orifice generating high velocity in the blow-through (this is the density diluting steam) steam which effectively atomises the condensate.
2. To a limited extent it induces condensate flow.
3. It limits the blow-through steam to an acceptable quantity by virtue of its limited area and turbulent action.
4. In a non-rimming (puddle through raining) condense condition–where it may be thought that the tip would merely be in steam for a large ratio of the ARC traverse it is found that inner circumference of the dryer carries a condensate film and this effectively reduces the free gap even more, thus preventing excess live steam flow.
5. In the rimming condition the condense speed is substantially that of the cylinder (in fact it oscillates for reasons of which we are aware) consequently the Johnson tip picks up all round its periphery, it does not pretend to be a shovel, and thus is most effective in reducing the length of flow that any particle of condensate must make from that position where it is formed to the pick-up position.

The Johnson Corporation (our parent company) set up a 5'0"×24'0" full sized dryer and persisted in the most difficult development to look in and movie photograph the internal action with steam heating and condensate being formed together with condensate removal up to 4,000 ft. per minute.

This finally eliminated conjecture, guesses, guesses based on conjecture but what is interesting is that everything which was observed fits in with just straight simple physics.

Now we must ask what does the paper maker want of his steam system.

He normally needs even cross machine moisture profile.

Freedom from indeterminate cool cylinders.

A temperature gradient along the machine.

Ability to dry to the required specification, not less; not more, if only because it is wasteful selling fibre instead of water but he may as a consequence be in difficulty with his calender, less so on the reel and dry broke is the "very devil".

Further he wants to avoid edge cockle.

These attributes can be substantially contributed to by correct removal of condensate, removal at the right position and at the rate of formation along with all incondensible gases. (supposed methods of inducing steam distribution or internal velocity are relatively ineffectual).

1. By employing the shortest traverse flow of the condensate.
2. By preferably providing a higher temperature in the midposition of all cylinders than at the edges, this compensates for the increased drying effect of the paper edges subjected to more air movement than the middle and also the heat conducted up to the cheeks on to each end of the cylinders.
3. Both these attributes require the condensate removal pick-up tip positioning half way across the dryer or splitting into more than one pick-up about the half way position.
4. By keeping the amount of retained condensate as low as possible, especially in the rimming condition, (still water is a good insulator). Hence again the minimum clearance requirement.
5. By inducing flow of incondensibles towards the syphon tip (keep in mind that incondensibles concentrate just where the steam condenses and forms a good insulator) the revolving syphon not only induces flow but also searches out the position of incondensibles rather than relying on the incondensibles to defuse downward which in fact they do not very readily do in a revolving cylinder.

Consequently The steam system design concept is based primarily on paper making needs plus the physical laws relating to the syphon pick-up characteristics of which the most important are :—

1. Position a close clearance exhaust tip at the mid-position.
2. Rotate it.
3. Eliminate the restraint effect of centrifugal force by inducting flow by an appropriate passage of blow through steam (15% to 25% depending on speed) and at the same time promoting removal of incodensibles by this flow pattern. System design achieves this by ensuring a differential pressure *Across each syphon of approximately 5-lbs. per square inch* (4 psi at low speeds, 8 psi 3,000 ft. per minute).

Note – "Across the syphon".

In this way allowing for some pressure drop in steam and condensate manifolds one may effectively run a three stage machine at a total differential across the machine of 15 psi, (and note use of differential pressure control valves).

We must however enquire into the means of controlling this differential pressure.

Keep in mind that we are dealing with bi-phase flow-a mixture of condensate and steam. If the velocity is allowed to fall by "Pocketing" the condensate will aggregate and thereby it can block a restriction device which may be thought suitable for controlling the differential pressure, and this blocking is unfortunately unstable and indeterminate.

The trick is to separate the condensate from the motive steam; called "Blow through steam" permitting free discharge of the condensate (it can indeed be through traps) but controlling the flow of steam by a signal measuring the difference in pressure of the steam to the dryer (or dryers) and the discharge.

This optimum blow through steam flow again is relative to the machine speed (and controlled by setting of the differential pressure controller). We have already made reference to the need for accommodating the paper makers requirements and the fear that potential failure to provide adequate drying capacity leads generally to the provision of over-capacity.

We can now supplement this with a fairly accurate forecast of the average steam pressure which will be required on an average machine (average as to performance not to size) using a method derived by Johnson Corporation.

It is based on correlation. and the results which it presents are many times very sobering.

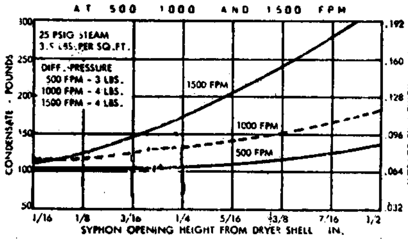
A system of heat balance assessment has been published (and is available from us) wherein the performance of a dryer range may be reasonably calculated.

The real basis is to assess a heat transfer coefficient (U. factor) and as we have our own computer such read-outs are hardly a chore.

One or two examples of read-out were set out on the display and any mill executive is at liberty to have such an assessment read-out for free (of course this requires appropriate information) and a sample form was shown.

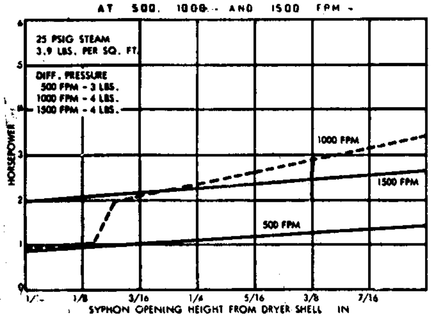
Over a number of years both our parent company and ourselves have been collecting and coordinating the information and we have a library of effective "U" values and in a reasonably responsible way can provide compartive assessments of the operating effectivity, but in any case our own technical department use this system as a basis of steam

RESID COND VS. SYPHON OPENING HEIGHT AT 500 1000 AND 1500 FPM



As the syphon opening height was increased from 1/16″ to 1/2″, there was an increase in the residual condensate at each of the speeds recorded here. The effect of syphon clearance was much greater at 1500 FPM because the condensate was rimming in all of the tests.

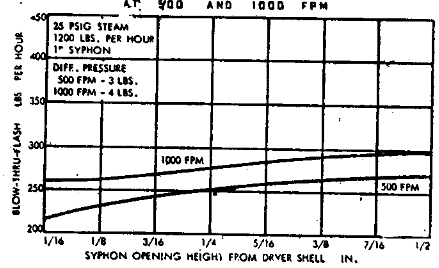
HORSEPOWER VS SYPHON OPENING HEIGHT AT 500, 1000 AND 1500 FPM



There is a gradual increase in the required power as the syphon opening is increased at speeds of 500, 1000, and 1500 FPM. The sudden change in the 1000 FPM curve is because the condensate was rimming at settings of 1/16″ and 1/8″, and cascading at the greater clearances.

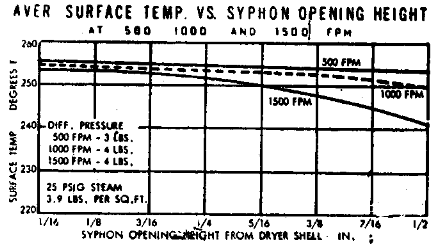
system design paticularly in relation to the effect of maximum/minimum running and starting load conditions.

BLOW-THRU VS SYPHON OPENING HEIGHT AT 500 AND 1000 FPM



The amount of blow-thru steam leaving the dryer increases as the syphon opening is increased, at a given speed when all other conditions are held constant. Only a slight effect is noticeable at the 1000 FPM speed where condensate rimming was observed at the 1/16″ and 1/8″ opening heights, and cascading took place at the greater openings.

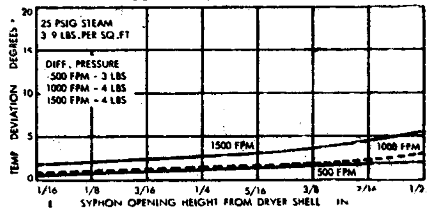
AVER SURFACE TEMP. VS. SYPHON OPENING HEIGHT AT 500 1000 AND 1500 FPM



The 500 FPM curve here indicates that the syphon opening height has very little effect on average dryer surface temperatures at speeds below rimming. The 1000 FPM curve shows that no temperature drop was experienced, because of the condensate rimming condition which existed, in the tests with 1/16″ and 1/8″ of syphon clearance.

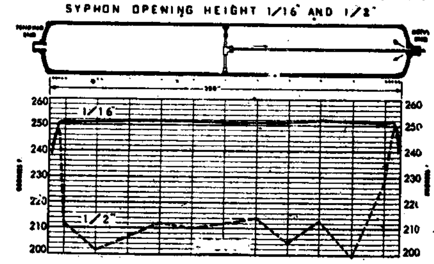
For there is more trouble with waterlogged cylinders than possibly any other factor in paper drying.

TEMP DEVIATION VS. SYPHON OPENING HEIGHT AT 500 1000, AND 1500 FPM



Surface temperature deviations were found to increase as the syphon opening height was increased, at all speeds studied. Though the increase was nominal at the below rimming speeds, it climbed from 2° to 6° at 1500 FPM, with clearance increases from 1/6″ to 1/2″.

SURFACE TEMP. PROFILE COMPARISONS-2000 FPM SYPHON OPENING HEIGHT 1/16″ AND 1/2″



The two curves shown are photographs of the average surface temperature profiles of Test No. C-2002-M and Test No. C-2016-M, and correspond with the edge condition photographs in Figures 53 and 54. In the 1/16″ syphon clearance test the average temperature was high and uniform all of the way across the dryer except at the extreme ends where it fell 12° or 13°. The test with 1/2″ of syphon clearance yielded erratic temperatures across the main part of the dryer, and a very sharp rise at both ends.