Minimizing Variations on the Yankee Dryer

Magnus Högman Valmet AB

ABSTRACT

In the paper and tissue making processes a fiber dispersion, the furnish, is reconstituted into a uniform sheet of desired properties. Past and recent technical advancements in the headbox and forming section, press section, yankee section as well as in the dry end of the tissue machine aim to promote uniformity and minimize variations.

Beside better quality of the final product, improved uniformity leads to increased machine efficiency, reduced energy consumption and opens the opportunity for higher machine speeds.

The yankee dryer is a central part of all common tissue making machines and processes. Its basic design has remained unchanged for over 100 years. For a long time, larger, high performing yankee dryers were supplied only by a few paper machine manufacturers with access to their own specialized foundries. With the development of more reliable, full face thermal spray coatings in the 1990's also steel fabricated yankee dryers became a viable alternative for the manufacturing of creped tissue papers. Today there are many suppliers of yankees, beside the traditional manufacturers, offering seemingly identical dryers. However, on a more detailed level there are distinctions, that ultimately will make the difference of being able to operate efficiently and at high speed or not.

This paper will cover some key areas – from the condensate removal system on the inside to the properties of the shell outside surface – that affect the uniformity and thus the performance of the yankee dryer: areas that have been subject to developments and improvements based on research, experience, and feedback from skilled users, from our first yankee dryer in 1891 until present time.

INTRODUCTION

In the paper and tissue making processes a fiber dispersion, the furnish, is reconstituted into a uniform sheet of desired properties. Past and recent technical advancements in the headbox and forming section, press section, yankee section as well as in the dry end of the tissue machine aim to promote uniformity and minimize variations.

Beside better quality of the final product, improved uniformity leads to increased machine efficiency, reduced energy consumption and opens the opportunity for higher machine speeds.

Tissue Machine Advancements Promoting Uniformity

The strive for uniformity begins already with the stock preparation and paper machine approach system but the tissue making starts in the headbox. It is one of the most critical components on a tissue machine and has been subject to a lot of applied research and development. In the 1970's, the HTB headbox enabled layering tissue grades while running tissue machines at high speeds. In the 1990's, the solid stainless steel SymFlo TIS improved formation and introduced dilution and in 2005, we launched the OptiFlo II TIS headbox with further improved formation and structural design.

The former and press sections have of course also been subject to development. Wire and felt conditioning, cleaning, dewatering, molding and transfers all effects uniformity and for conventional machines the wet pressing is critical. The correct crowning of press rolls and yankee dryer and a well-functioning loading system is a must to ensure uniformity.

A significant development is the Advantage ViscoNip press that has become the new standard for wet pressing of tissue. A flexible liquid filled press body gives the press unique ability to adapt to the yankee dryer shell. This makes the nip load uniform during a wide range of linear loads and results in remarkably flat cross machine dryness profiles.

Another recent development is the Advantage AirCap Heli, a new yankee hood which allows a perfectly even drying profile on one side and improved possibility to correct a non-optimal moisture profile on the other. The arrangement of the crescent headers, normally oriented in machine direction is tilted in cross direction. This results in uniform drying without any footprint from the headers.

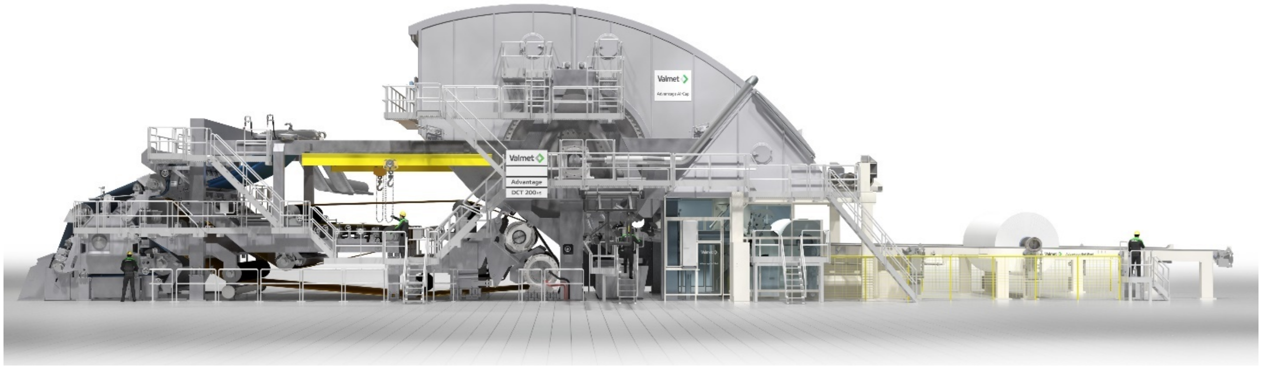


Figure 1. Conventional dry-crepe tissue machine.

In the tissue machine dry-end the current state of the art technology is the Advantage SoftReel B. B stands for Belt and it is the belt in this tissue winding technology that replaces the reel drum in conventional winding systems. The belt arrangement gives improved control over the winding process and allows producing large diameter parent rolls while keeping exceptionally uniform caliper throughout a whole roll.

The yankee dryer is a central part of all common tissue making machines and processes. Its basic design has remained unchanged for over 100 years. But also the yankee dryer has been subject to significant development work and improvements in the areas of safety, performance and reliability. Not the least with the aim to improve its uniformity which is key to being able to operate efficiently and at high speed.

For a long time, larger, high performing yankee dryers were supplied only by a few paper machine manufacturers with access to their own specialized foundries. With the development of more reliable, full face thermal spray coatings in the 1990's also steel fabricated yankee dryers became a viable alternative for the manufacturing of creped tissue papers. Today there are many suppliers of yankees, beside the traditional manufacturers, offering seemingly identical dryers. However, on a more detailed level there are distinctions, that ultimately will make the difference of being able to operate efficiently and at high speed or not.

This paper will cover some key areas – from the condensate removal system on the inside to the properties of the shell outside surface – that affect the uniformity and thus the performance of the yankee dryer: areas that have been subject to developments and improvements based on research, experience, and feedback from skilled users, from our first yankee dryer in 1891 until present time.

YANKEE DRYING PROCESS AND YANKEE DRYER

The conventional yankee drying process is a combination of conductive drying (yankee) and impingement drying (hood). Energy for drying of the tissue is supplied both from high pressure steam condensing inside the yankee cylinder and from hot air blown onto the sheet in the hood covering the yankee surface.

The yankee drying process is very intensive and the entire drying cycle is over in less than half a second.

Main elements of the yankee cylinder are the shell connected to a through-going journal by two heads. The through-going journal is a typical hallmark for a yankee dryer. Beside its primary function as a drying cylinder it also functions as a press roll and transports as well as supports the sheet during the creping process.

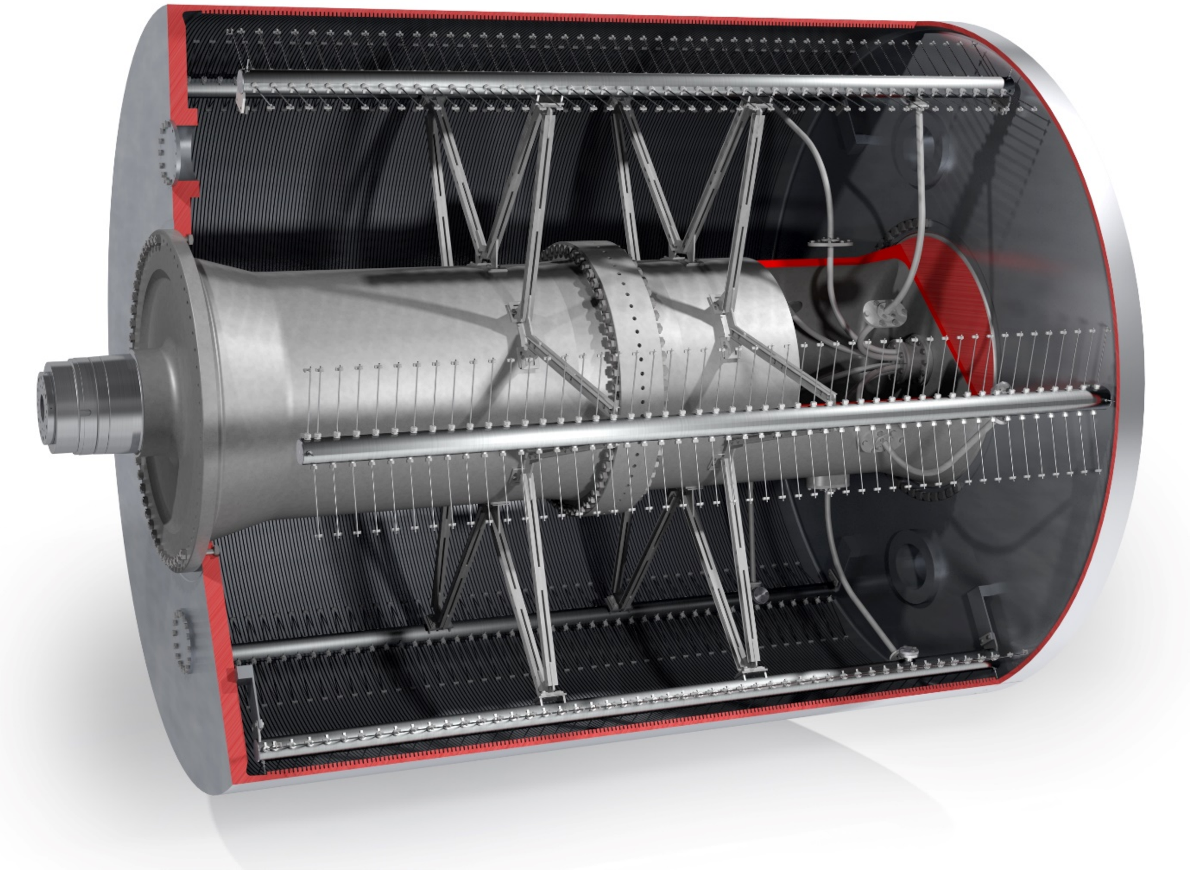


Figure 2. Steel yankee dryer.

Factors affecting the heat flow through the shell and accordingly the drying capacity of the yankee dryer are the steam temperature (pressure), the shell surface temperature, the heat transfer from steam to shell inside, the conductivity of the shell material and the thickness. The average shell surface temperature and sheet temperature being complex functions of several process related variables.

- Steam temperature (pressure)
- Surface temperature
- Heat transfer steam to shell inside, α
- Shell material conductivity, λ
- Shell thickness, t
- *Thermal coating material conductivity, λ_c*
- *Thermal coating material thickness, t_c*

$$Q = k \cdot \Delta T$$

$$\frac{1}{k} = \frac{1}{\alpha} + \frac{t}{\lambda} + \frac{t_c}{\lambda_c}$$

$$\Delta T = T_{steam} - T_{surface}$$

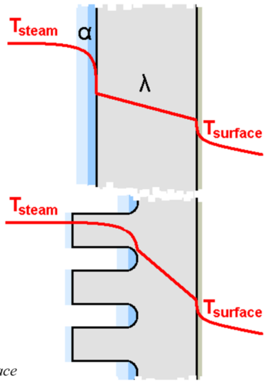


Figure 3. Factors affecting the heat flow through the shell, Q.

With the introduction of the ribbed shell the heat flow could be significantly increased. As the ribs increase the rigidity and strength of the shell, the distance from the bottom of the groove to the outside of the shell can be less than the thickness of a plain shell for the same pressure. In addition, no condensate will accumulate on the vertical sides of the ribs which gives them a very low thermal resistance. The resultant heat transfer from steam to shell increases.

To attain an effective heat flow the inside of the shell must be kept as free from condensate as possible. This is done by the internal condensate removal equipment.

As compared to through air drying (TAD), the yankee drying process is to some extent self-compensating and stable. The heat flow through the shell is increasing with the temperature difference. Colder, wetter, areas on the shell surface will attract more heat flow than hotter, drier, areas.

FACTORS AFFECTING THE UNIFORMITY ON THE YANKEE DRYER

Ingoing variations from upstream sections of the machine will inevitably show up on the yankee dryer. In a conventional process the yankee dryer is part of the press section and unless a flexible press is used, the correct crown fit is vital for the cross directional uniformity. Also, variations in other systems directly in interaction with the yankee dryer, such as the chemical coating showers, the hood and the doctors, will show up on the yankee.

This paper is limited to factors directly attributed the yankee dryer itself. As described in the previous section the heat flow through the shell depends on the thickness, its conductivity and the heat transfer from the steam to the inside of the shell. The very same factors will thus influence variations in the heat flow and dryer performance.

Shell Thickness

In the common manufacturing process, the shell, heads and journals are machined separately. Either from cast iron parts or prefabricated steel plates. The parts are assembled by bolt joints or welding depending on material and design. The assembled yankee dryer's shell is then ground to final dimensions. Normally to a run-out of less than 0.05 mm (2 mils).

Variations in the final shell thickness thus depends on the machining tolerances, the accuracy of the assembly process, in particular the heads to shell assembly, and possible shape changes during the process due to such factors as the release of residual stresses.

Figure 4. Machining of yankee shell.

The crowning of the yankee will result in a thickness variation in the magnitude 1-2 mm (40-80 mils) that is well defined and symmetric in cross direction. Other thickness variations may be harder to predict.

A yankee shell is thin-walled and deforms easily in its radial direction. Deformations of several millimeters can be seen due to its own dead weight. When assembling a bolted yankee it is important to use a bolt torqueing pattern and sequence that allows the heads and shell to center correctly, and to verify this by checking the spigot fit.

Steel yankee dryers with the heads welded to the shell offers entirely new challenges in this regard. The welding process results in temperature gradients and thermal deformations that are virtually impossible to constrain and difficult to control. Without special attention final thickness variations due to direct or indirect welding deformations may easily develop into the range of several millimeters.

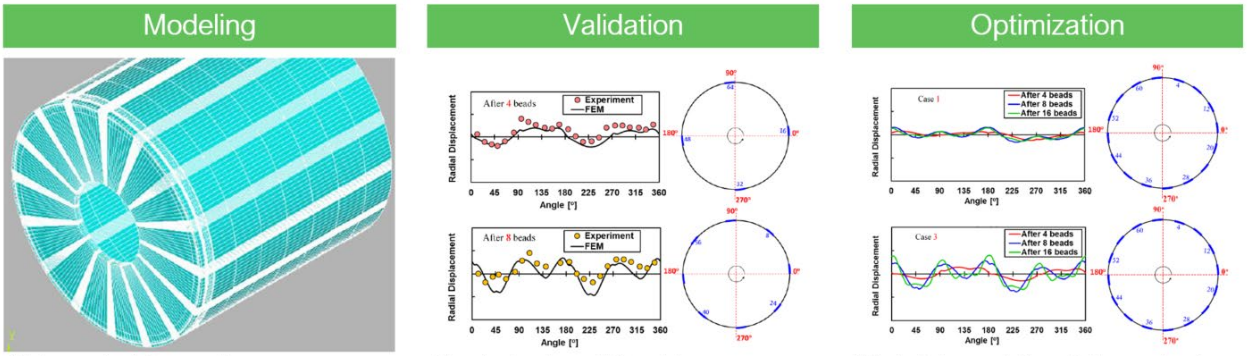
Figure 5. Assembly welding of steel yankee dryer.

Minimizing shell thickness variations.

Variations in shell thickness are minimized by proper heat treatment, ensuring ingoing tolerances by machining shell and heads in a high precision vertical turning lathe and otherwise following strict procedures for the assembly and verification.

In addition, the key for minimizing weld deformations in steel yankee dryers with welded head to shell joint is a joint design that allows for accurate alignment, an optimized weld procedure and frequent control measurements until the head and shell are fixed in position.

We have optimized the weld procedure – with regards minimizing welding deformations – utilizing state of the art welding simulations in combination with practical evaluations.



Modeling

Validation

Optimization

Eight-noded linear elements are used in thermal and mechanical simulations.

Simulation is validated by temperature measurements - using thermocouples - and distortion measurements.

Minimizing welding deformation by optimizing welding sequence, welding speed, bead lengths, pre-heating e t c – through simulation.

Figure 6. Principle of welding simulations – modeling, validation by actual measurements and optimization.

Shell Material Thermal Conductivity

High quality, uniform castings are the foundation for a world class cast iron yankee dryer. All development of the yankee casting technology under last century up to present time has aimed for higher and more consistent quality. All mechanical as well as other physical properties including the thermal conductivity are direct proportional to the uniformity of the casting.

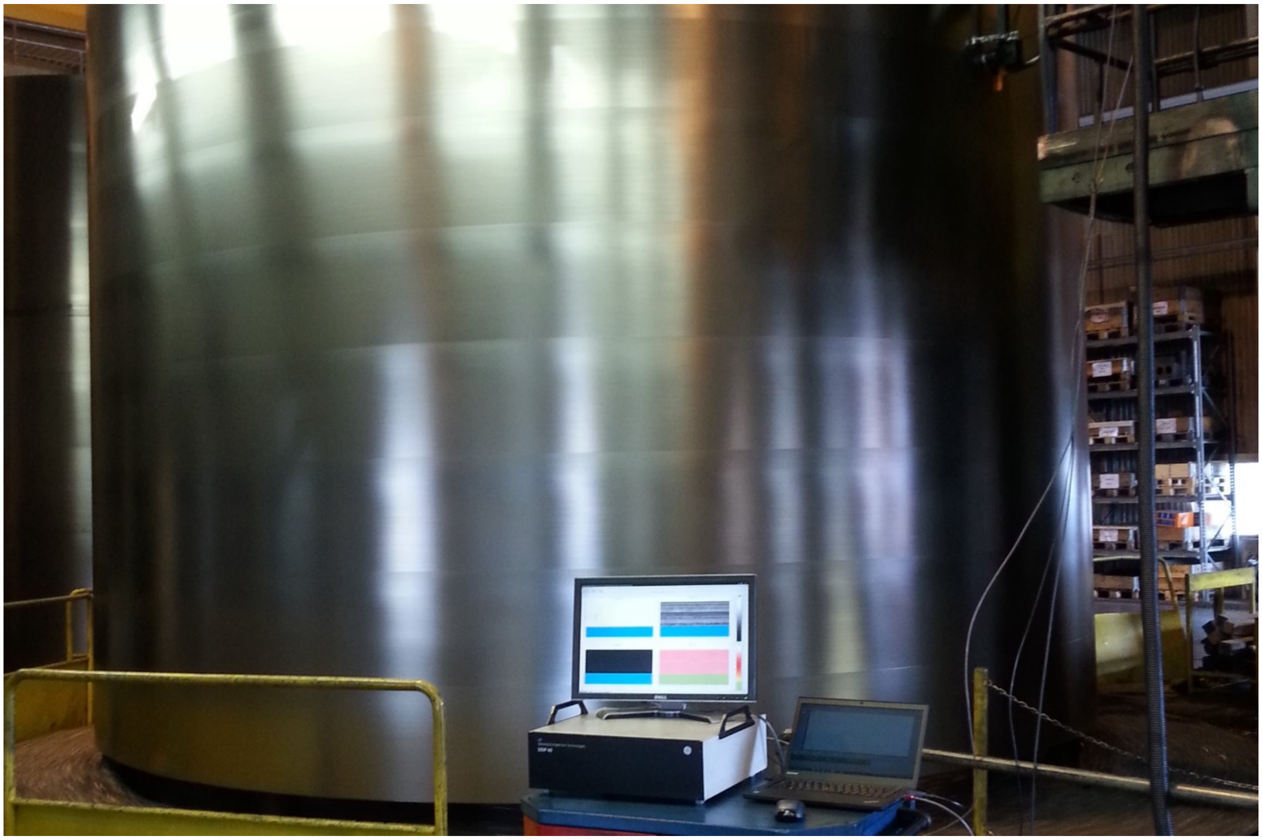


Figure 7. Full face ultrasonic scanning of yankee shell to verify its uniformity.

The same basically apply to the rolled plates used for steel shells. Steel mills develop their processes to produce high quality steel plates with uniform properties and a minimum of defects. Beside verifying the quality of the plates, the biggest challenge for the steel yankee manufacturer is the welding of the shell seams. Depending on the geometry of the weld, the type of filler material used and other welding parameters, the resultant weld and heat affected zone will have a thermal conductivity more or less different from the plates.

Accurately measuring the thermophysical properties of a yankee shell is quite complex. The measurements must be done on separate test pieces and we nowadays employs laser flash measurements through a third-party test institute.

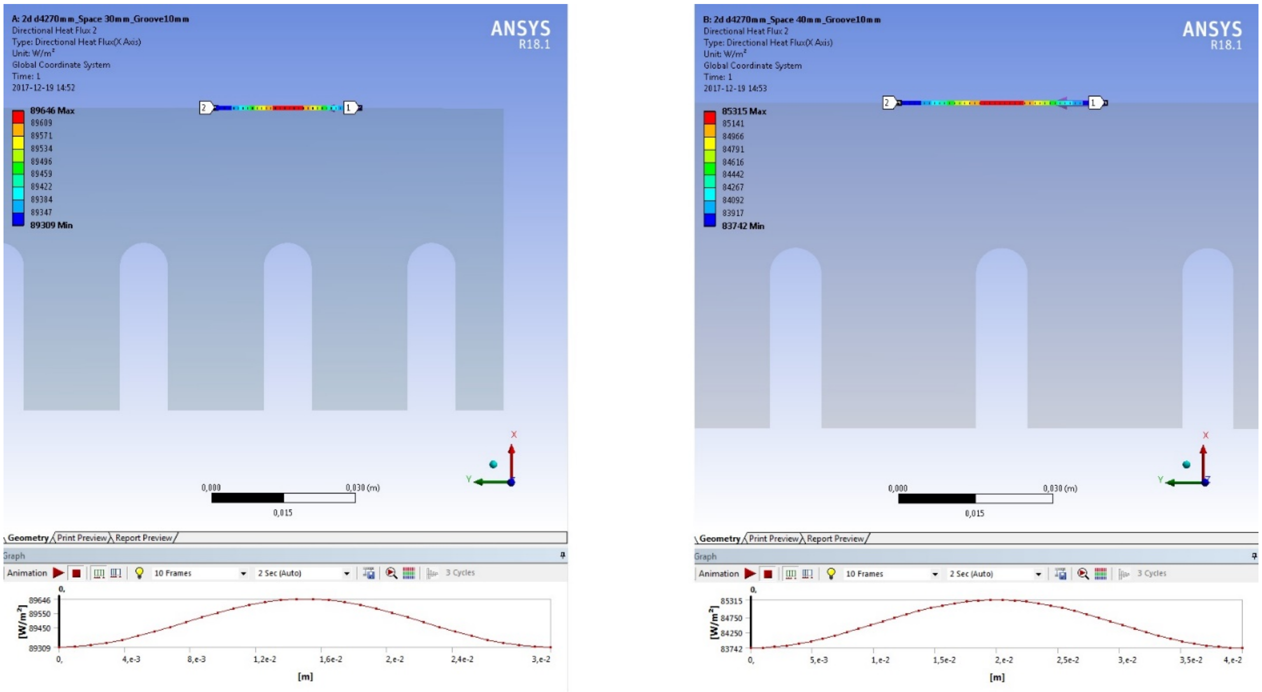
Minimizing material conductivity variations.

As part of the steel yankee development work and the continuous strive to minimize variations many weld samples using different fillers and parameters as well as plates were analyzed to determine the combination with the least difference in thermal conductivity.

Shell Rib Profile

The invention of the internally ribbed shell by Beloit in the 1950's must be regarded as the single most important development step of the yankee dryer. Several studies, both published and internal, have been conducted to understand the heat transfer of ribbed shells. Both theoretical and practical. Typical geometrical parameters are the pitch of the ribs, their width and height and the shape of the groove bottom. Other geometries exist with e g triangular or trapezoidal ribs. Different rib profiles will result in different heat transfer and variations in heat flow and increases with a decreasing root shell thickness.

Optimizing shell rib profile.



A: 2d d4270mm_Space 30mm_Groove10mm
Directional Heat Flux 2
Type: Directional Heat Flux(X Axis)
Unit: W/m²
Global Coordinate System
Time: 1
2017-12-19 14:52

B: 2d d4270mm_Space 40mm_Groove10mm
Directional Heat Flux 2
Type: Directional Heat Flux(X Axis)
Unit: W/m²
Global Coordinate System
Time: 1
2017-12-19 14:53

Figure 8. Heat transfer analysis of different rib profiles.

With a good understanding of how the heat transfers it is possible to define realistic boundary conditions that are the foundation for all numerical analysis. Thermal and structural FEA is then used for the optimization of the shell geometry with the aim to achieve a high and even heat flow while maintaining as much strength as possible (a solid, plain shell of the same total thickness will always be stronger than a ribbed one).

Shell Surface Properties

It is on the yankee surface that paper making takes place. The surface should provide good adhesion for the organic coating and the tissue sheet. It must also be resistant enough against mechanical and chemical wear since the surface is continuously doctored and exposed to process water and chemicals.

Highly alloyed cast iron offers a good papermaking surface due to its hardness and structure. Steel is a stronger but softer material than cast iron and needs to be thermally coated to obtain a harder, more suitable surface for the manufacturing of creped tissue.

A uniform surface, either on a high-quality casting or ditto thermal coating, not only promotes a uniform sheet but wears more evenly. A surface with uniform hardness is generally to be preferred over a harder surface with greater variation.

Due to the application process the conductivity of a thermal coating is significantly lower than for cast iron and steel. Although a disadvantage with regards overall heat transfer it is beneficial for the uniformity since the thermal coating will form a barrier, levelling variations in heat flow. A must for a thin steel shell with weld seams.

Optimizing shell surface properties.

Our Infinikote thermal coating is not just a material but a well proven process solution with several hundreds of applications on cast iron and steel dryers for different grades. It is homogenous with uniform hardness, texture and surface finish and offers high resistance to chemical and mechanical wear. The recently developed Infinikote-2 is a chrome free product with further improved internal structure and increased wear resistance.

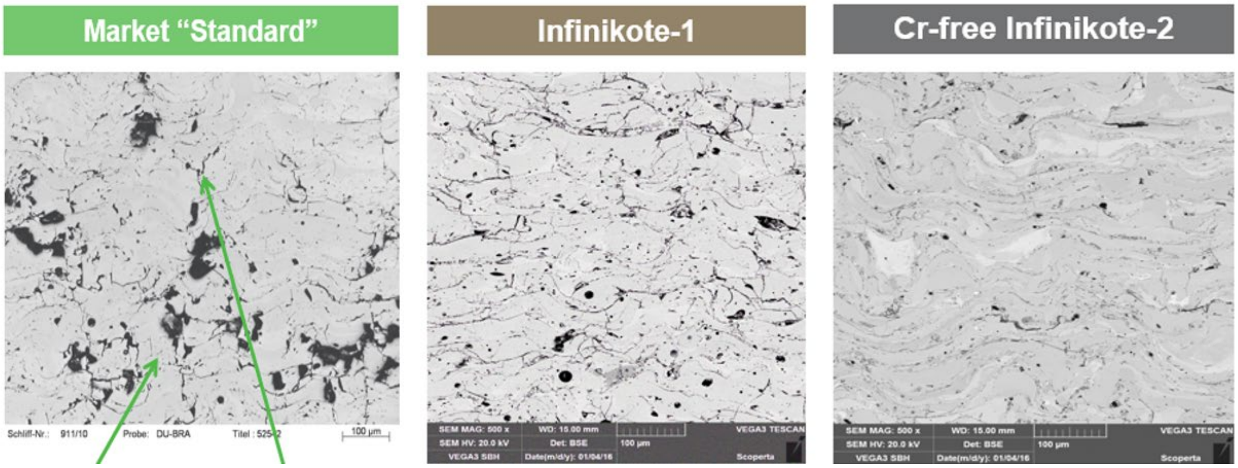


Figure 9. Comparing microstructure of thermal coatings. Arrows points out undesirable oxides and stress cracking.

For tissue making processes utilizing higher than conventional creping doctor loads, like hybrid and TAD processes, we currently recommend a cast iron surface.

Internal Condensate Removal System

A well performing condensate removal system is essential for the efficient and continuous heat transfer from the steam to the inside of the shell surface and for the function of the yankee dryer. The basic method for removing condensate from a ribbed shell is by straw pipes inserted in each groove. The straw pipes are mounted in condensate headers extending cross the shell that in turn are connected to the journal condensate outlet by so called riser pipes. The condensate inside the shell is affected by gravity and especially rotational forces that are considerable at high machine speeds. The driving force to overcome these forces is created by a blow-through steam flow.

For a specific system and operating condition, the amount of blow-through steam flow required to remove the condensate can be estimated by calculating the system resistance curve, also called J-curve. In addition to gravity and centrifugal forces, friction and turbulence losses in the straw pipes and riser pipes must be considered.

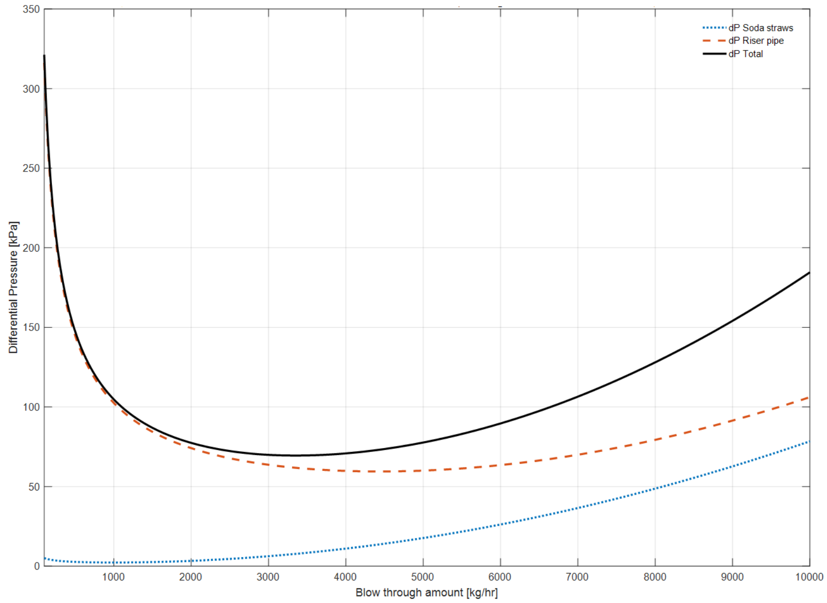


Figure 10. Yankee dryer condensate removal system resistance curve (J-curve).

Optimizing the internal condensate removal system.

The current state of the art condensate removal system is a further development of the original Beloit “outrigger” system. It features curved riser pipes and long, tapered straw pipes mounted in round headers.

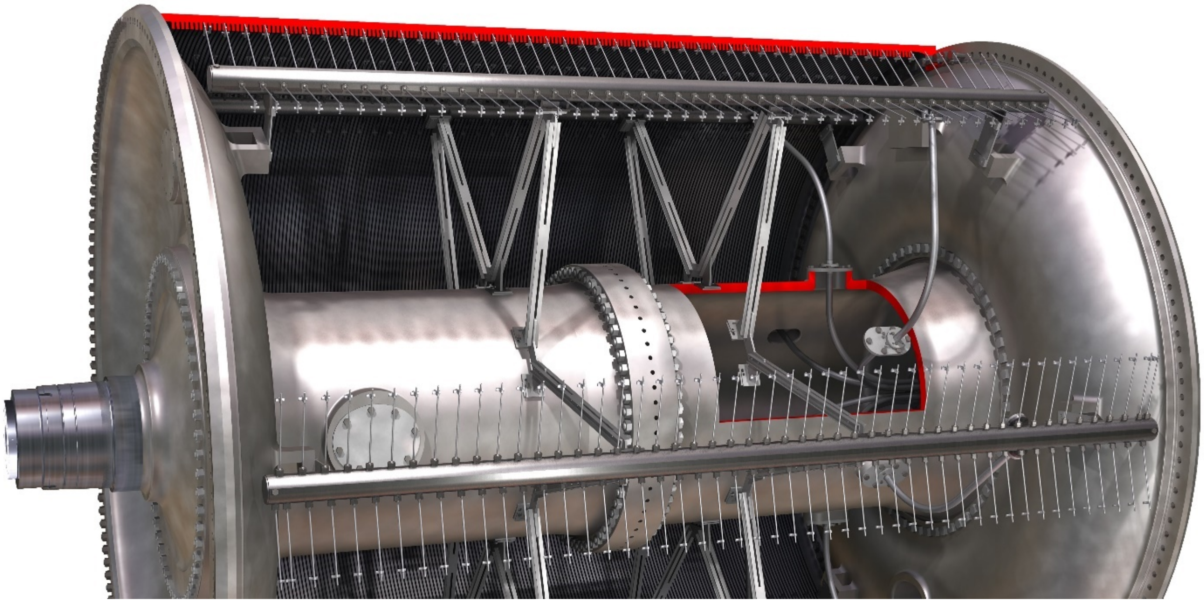


Figure 11. State of the art condensate removal system.

It is a result of both advanced CFD analyzes to better understand the two-phase flow inside the yankee dryer, e g difference between the straws pointing forward and backward and the turbulence around headers, and experience gathered from numerous high-speed installations.

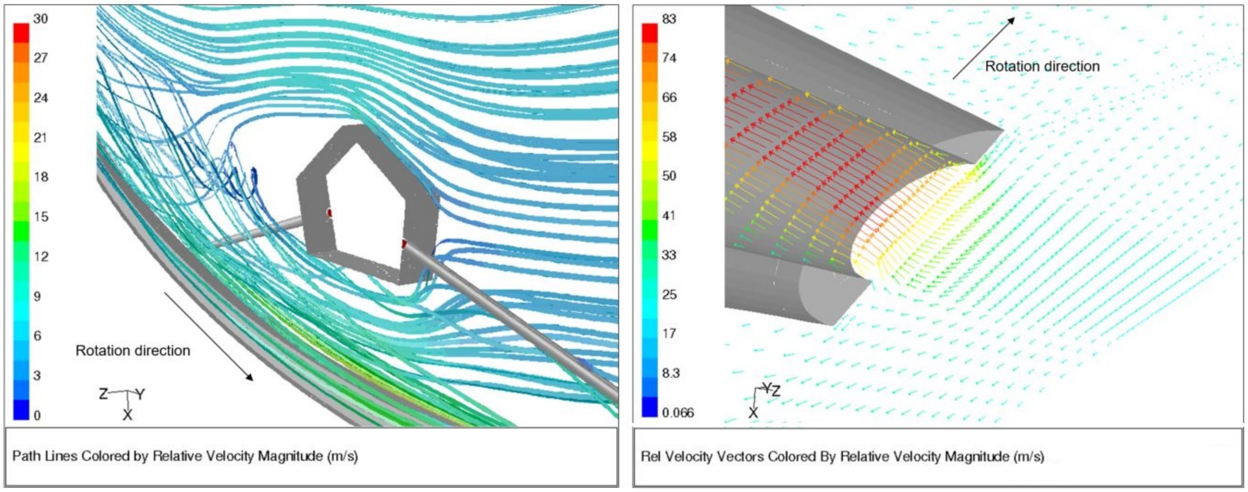


Figure 12. CFD analyzes are utilized in the optimization work of the internal condensate removal equipment.

As with the shell rib profile, there is a compromise between the most efficient – highest - and the most uniform heat transfer when optimizing the internal equipment. Beside correct dimensioning of the open straw pipe and riser pipe areas and velocities and the number of headers and straw pipe pattern, all the following parameters will significantly influence variations: straw pipe clearance, straw pipe geometry, header clearance and header geometry.

Turbulence generators like spoiler clips or bars may contribute to a more even and increased heat transfer at low and medium machine speeds. At higher speeds the condensate doesn't oscillate, and the effect of turbulence generators is negligible. In combination with an outrigger system, spoiler clips will have a negative impact on both heat transfer and uniformity.

Other Aspects of Minimizing Variations

Factors discussed herein relates to the design and manufacturing of yankee dryers and are mostly built in and static. Equal important is the correct operation of the internal condensate removal system and the proper maintenance of said system, as well as the maintenance of the shell surface.

Consequences of Variations

Maybe the most concrete effect of a variation in shell thickness, conductivity or internal heat transfer is uneven drying. Uneven drying will result in reel moisture variations that are normally compensated for by increasing the final dryness, thus increasing energy consumption and reducing the efficiency. In case the machine is drying limited this will result in a speed reduction and loss of production.

Variation	Consequence
▲10% thicker shell, or	▼7% lower k-value
▼10% lower conductivity, or	▼2.7ºC (4.9ºF) lower surf temp
▲20% thicker condensate	▼4% lower heat flow
	▼1.5% lower final dryness, or
	▼3% reduced machine speed

Figure 13. Simplified example of variations resulting in uneven drying. High speed bath tissue. 50/50 drying split.

The effect and consequence of a variation is dependent on many parameters and must be analyzed case by case. A simplified, but actual, example can be seen in figure 13. In this case – a high speed machine producing bath tissue with a nominal 50/50 drying split between yankee and hood - a 10% increase in shell thickness results in 1.5% lower final dryness. The shell thickness increase, in this case, equals 10% lower thermal conductivity or 20% thicker condensate film, and corresponds to a k-value reduction of 7% (see figure 3). Despite the k-value decreases 7%, the heat flow reduces only 4%. This is due to the reduction in shell surface temperature that will increase heat flow and partly compensate for the lower k-value.

Uneven heat transfer also results in uneven shell temperatures and thermal deformations. The most common being hotter areas at the condensate headers resulting in a corresponding shell deformation lobe pattern. The effect may be further reinforced by the press since hotter areas will be higher and subject to more pressing, that reduce the drying load and result in even hotter surface. In the most extreme case this may contribute to the shell deforming into a more pronounced thermal eigenmode and ultimately going out of round.

Uneven surface temperature makes it more difficult to build a uniform chemical coating. This in combination with thermal deformations often result in doctor vibrations, surface chatter and other surface wearing problems.

The coating formation and sheet adhesion will also suffer from an uneven surface texture and roughness.

Non-uniform coating, surface wear and uneven sheet adhesion all negatively affects both the final sheet quality and the efficiency of the paper machine.

SUMMARY – MINIMIZING VARIATIONS ON THE YANKEE DRYER

Minimizing variations is a fundamental aspect of all paper making. Past and recent technical developments of the tissue machine aim to promote uniformity.

Variations on the yankee dryer are minimized by: minimizing shell thickness variations, minimizing thermal conductivity variations, optimizing the shell rib profile, optimizing the shell surface properties and by optimizing the internal condensate removal system.

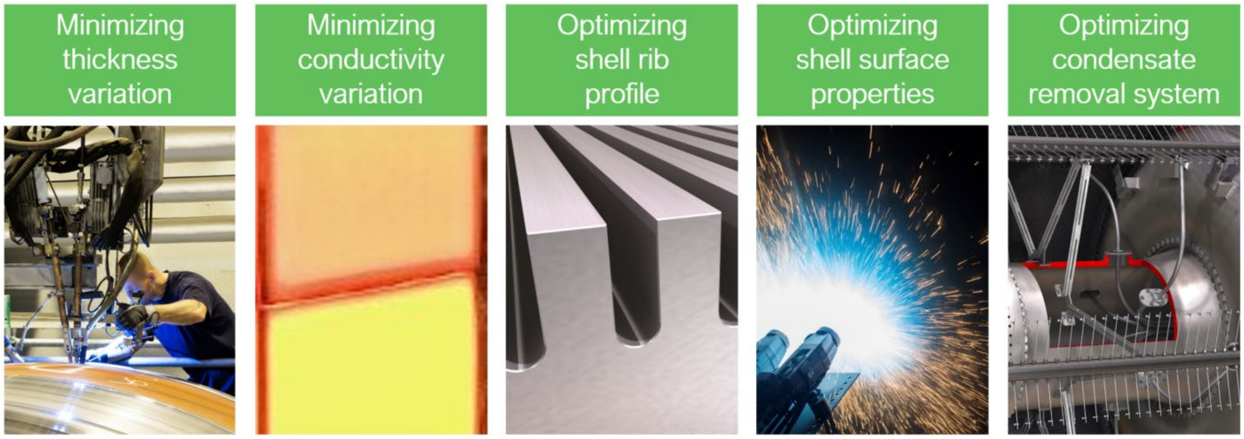


Figure 14. Minimizing variations on the yankee dryer.

High quality, uniform castings are the foundation for a world class cast iron yankee dryer. All mechanical as well as other physical properties including the thermal conductivity and surface properties are direct proportional to the uniformity of the casting.

For steel yankee dryers with the heads welded to the shell, the key to high performance is the ability to control the welding process and resultant deformations. Without special attention final thickness variations due to direct or indirect welding deformations may easily become in the range several mm.

Equal important for a steel yankee' s performance is the thermal coating of the shell surface. It evens out the effect of possible heat flow variations at weld seams and from the ribs. It should be homogenous with uniform hardness, texture and surface finish and offer high resistance to chemical and mechanical wear. The thermal coating is not just a material, the entire application process defines the final surface and distinguish the best from the rest.

A state of the art thermal coating will also enhance performance of a cast iron surface. It will increase its resistance to wear and even out possible variations.

A well performing condensate removal system is essential for the function of any cast iron or steel yankee dryer. It should provide high and uniform heat transfer by efficiently and evenly remove the condensate at all speeds. Beside correct dimensioning of the open straw pipe and riser pipe areas and velocities and the number of headers and straw pipe pattern, all the following parameters will significantly influence variations: straw pipe clearance, straw pipe geometry, header clearance and header shape.

CONCLUSIONS

From being manufactured by a few paper machinery companies with their own specialized foundries, yankee dryers have apparently become a commodity. Today there are many suppliers of steel yankee dryers offering seemingly identical products. Indeed, designs are copied and some machinery suppliers market identical third-party dryers under their own name.

The yankee dryer remains a central part of all common tissue making machines and processes. Both steel and cast iron yankee dryers are important members of our product portfolio. As such they continue to be subject to development work and continuous improvements in the areas of safety, performance and reliability. Not the least with the aim to improve their uniformity.

This paper has identified areas important for minimizing variations on the yankee dryer. Areas where on a detailed level, designs and manufacturing processes differs between suppliers and that ultimately will make the difference of being able to operate efficiently and at high speed or not.

Minimizing Variations on the Yankee Dryer

Presented by:

Magnus Högman
Sales Manager

Tissue Making

1.5 sec

120 km/h (75 mph)

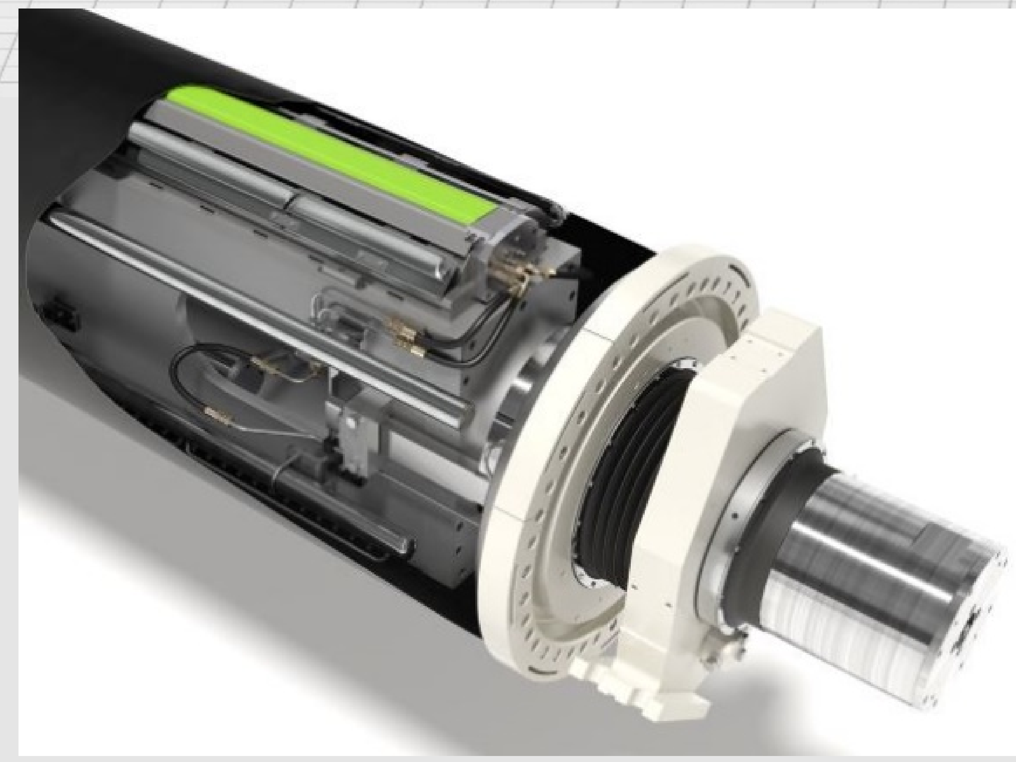
99.8% water

95% dryness

Technologies Promoting Uniformity

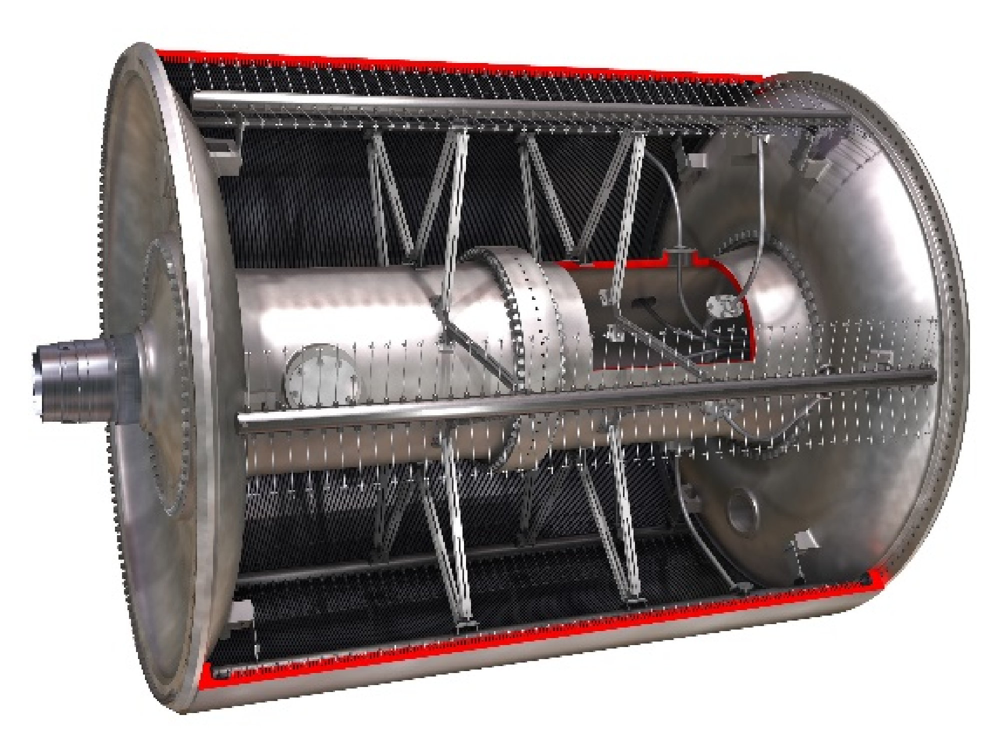
Headbox with dilution

Visconip press

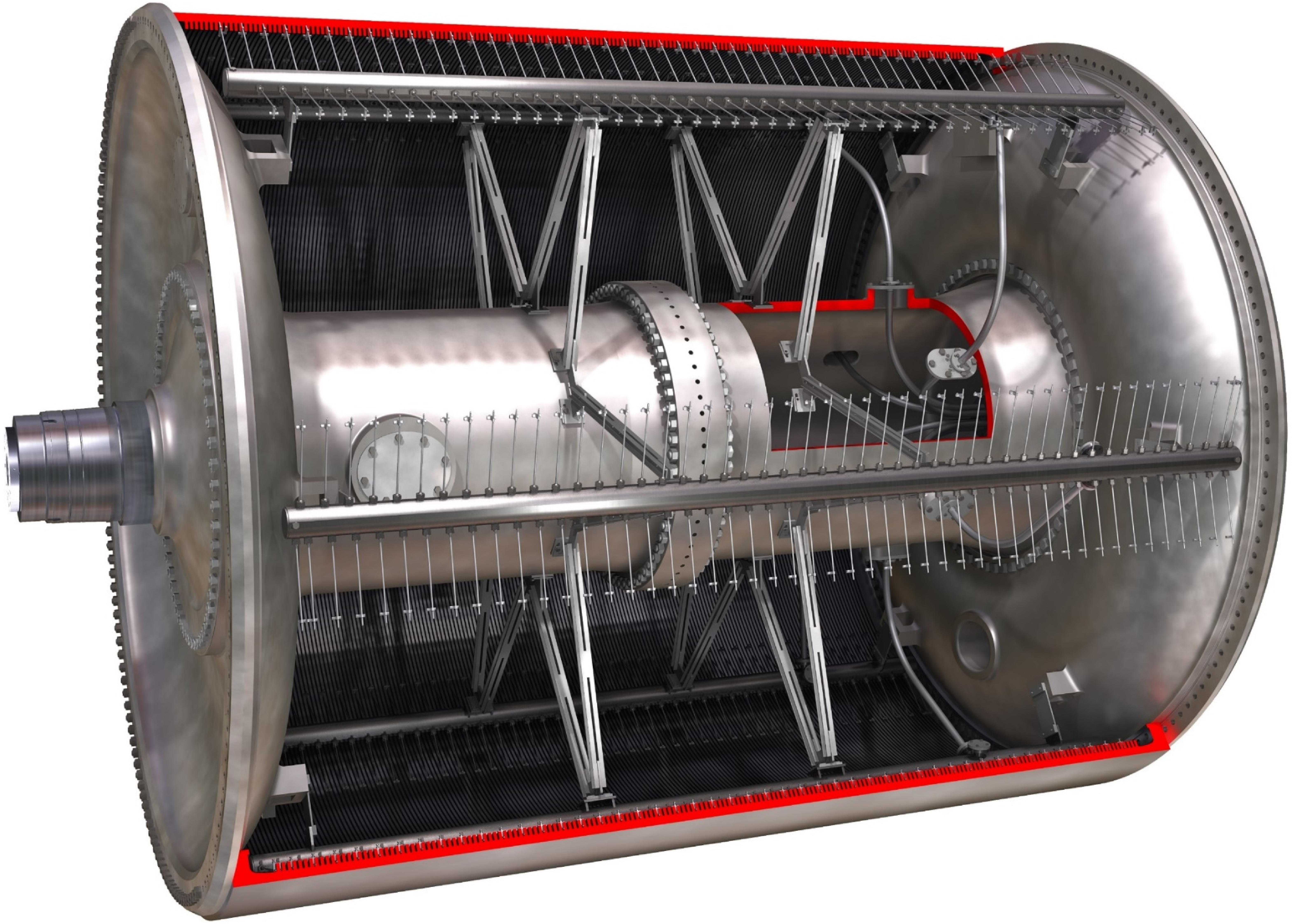


Helical hood

Yankee cast & steel

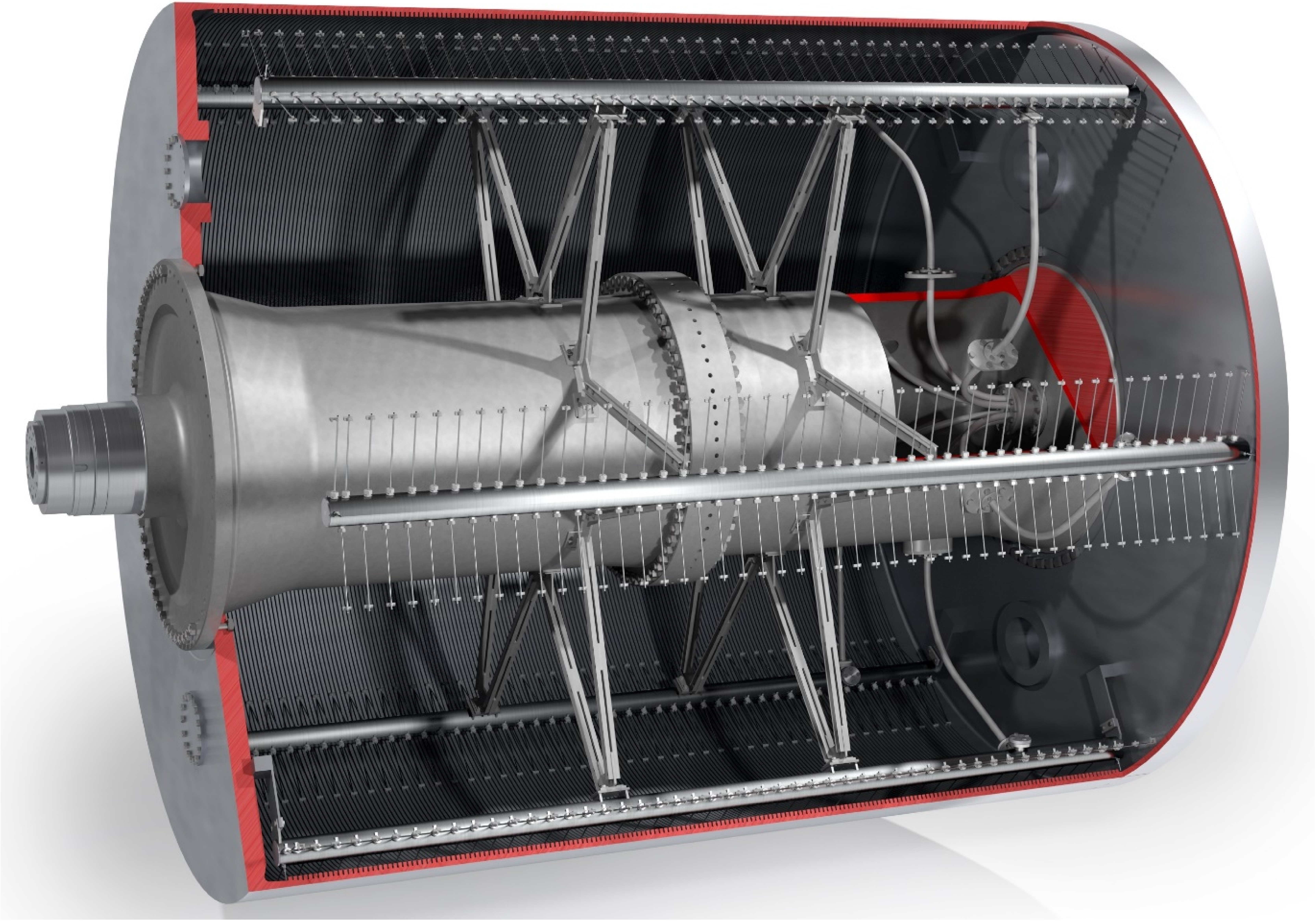


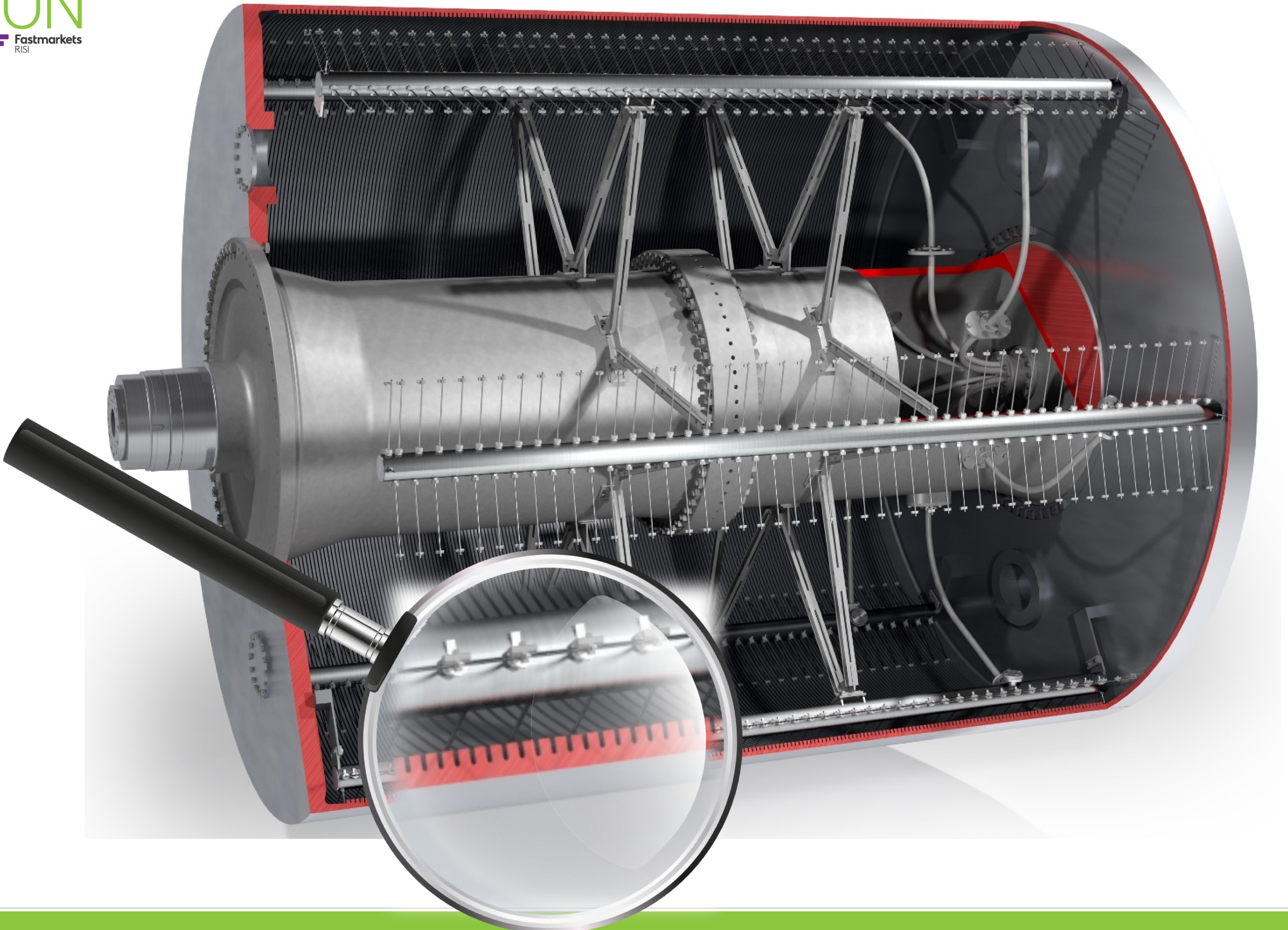
Belted reel



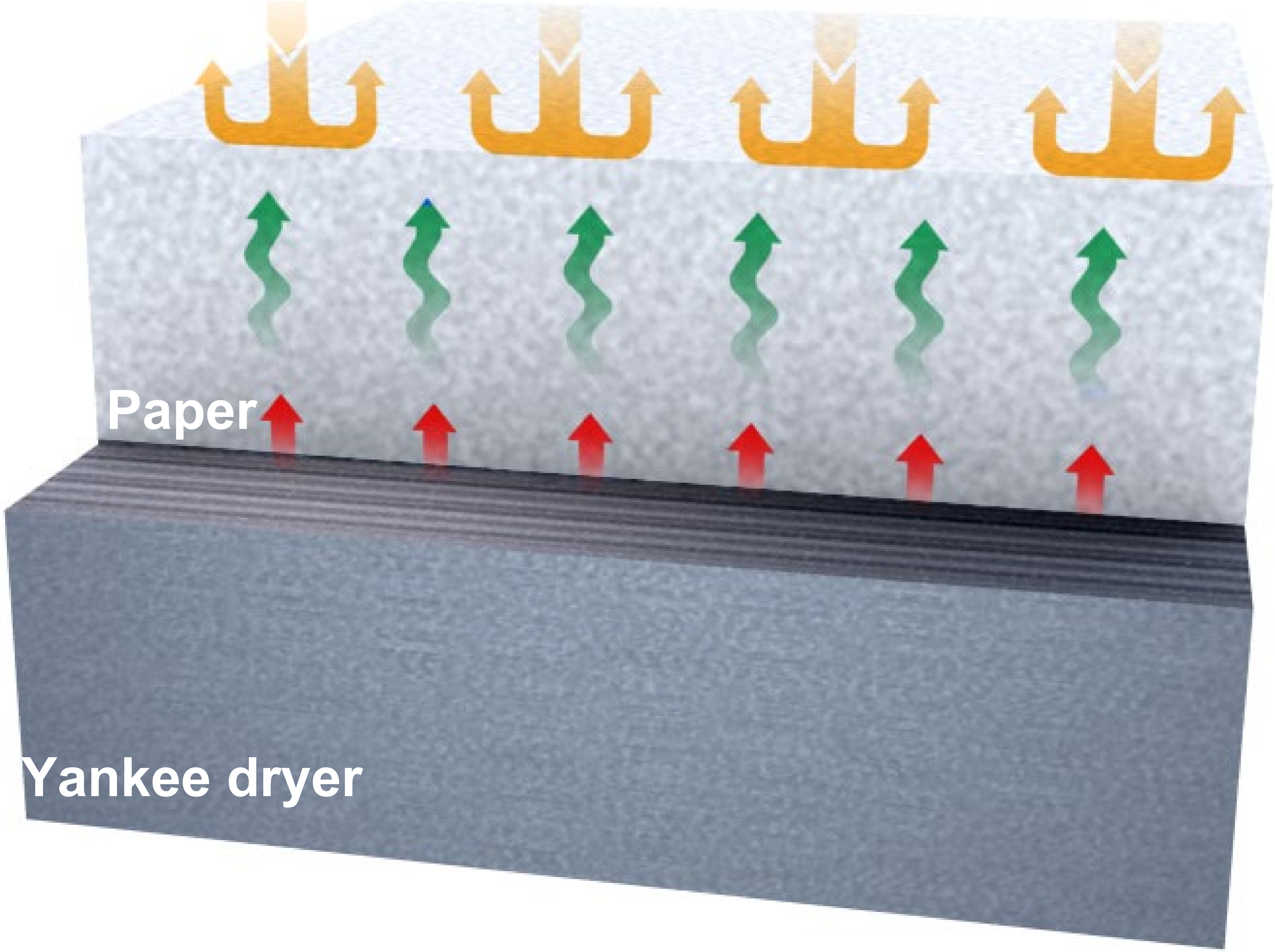
Tissue Making Technologies

	Hybrid			
Conventional	Textured	Rush Transfer	Rush Transfer	Through Air Drying
The most popular tissue machine in the world	Premium quality with swing capabilities	High premium quality with built-in flexibility	Ultra premium quality with built-in flexibility	For the absolute best quality





Yankee Drying Process



Yankee hood air

Diffusion vapor

Conducted heat

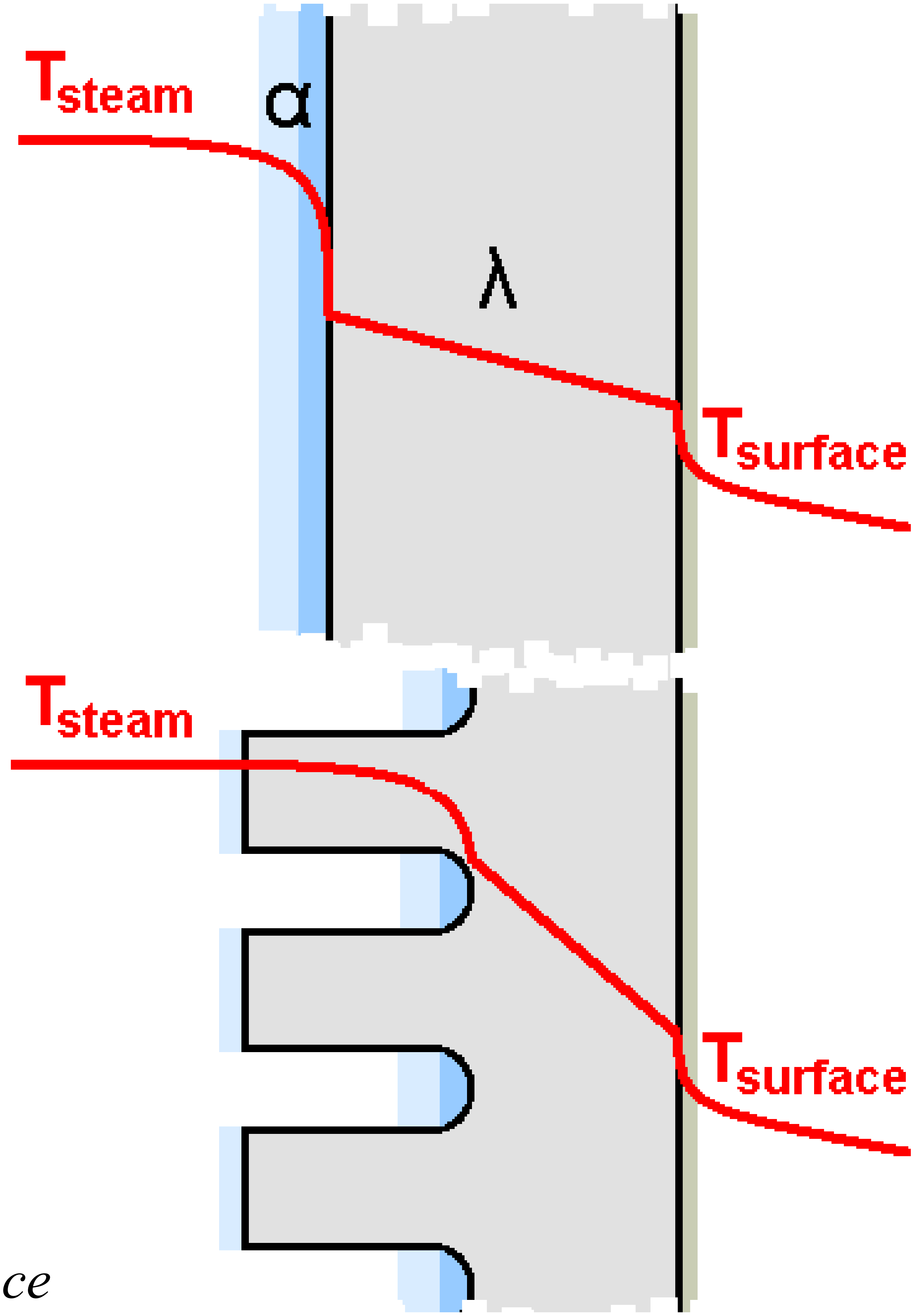
Factors Affecting the Heat Flow

- Steam temperature (pressure)
- Surface temperature
- Heat transfer steam to shell inside, α
- Shell material conductivity, λ
- Shell thickness, t
- *Thermal coating material conductivity,* λ_c
- *Thermal coating material thickness,* t_c

$$Q = k \cdot \Delta T$$

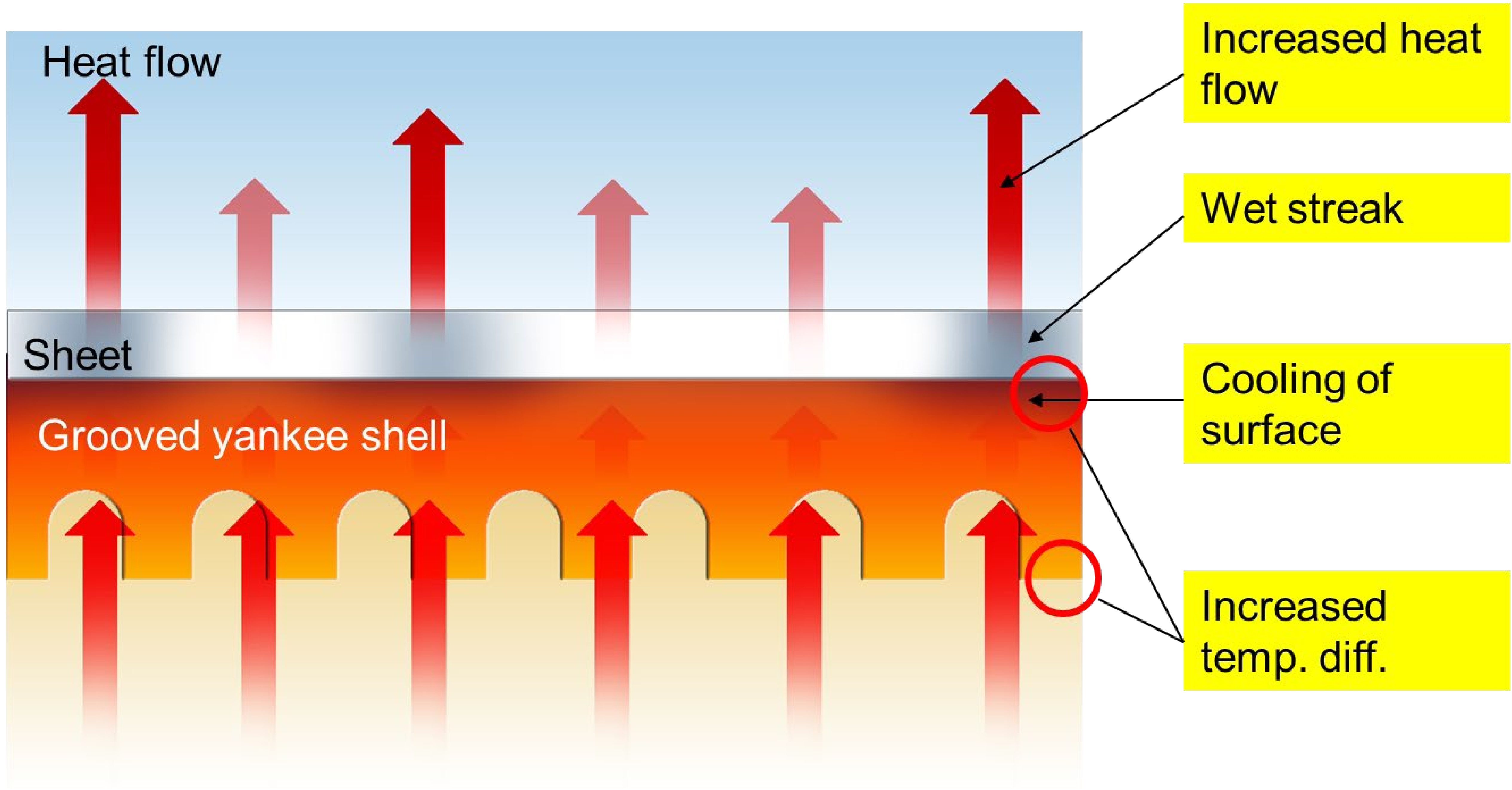
$$\frac{1}{k} = \frac{1}{\alpha} + \frac{t}{\lambda} + \frac{t_c}{\lambda_c}$$

$$\Delta T = T_{steam} - T_{surface}$$



Self Compensation

Yankee drying is stable



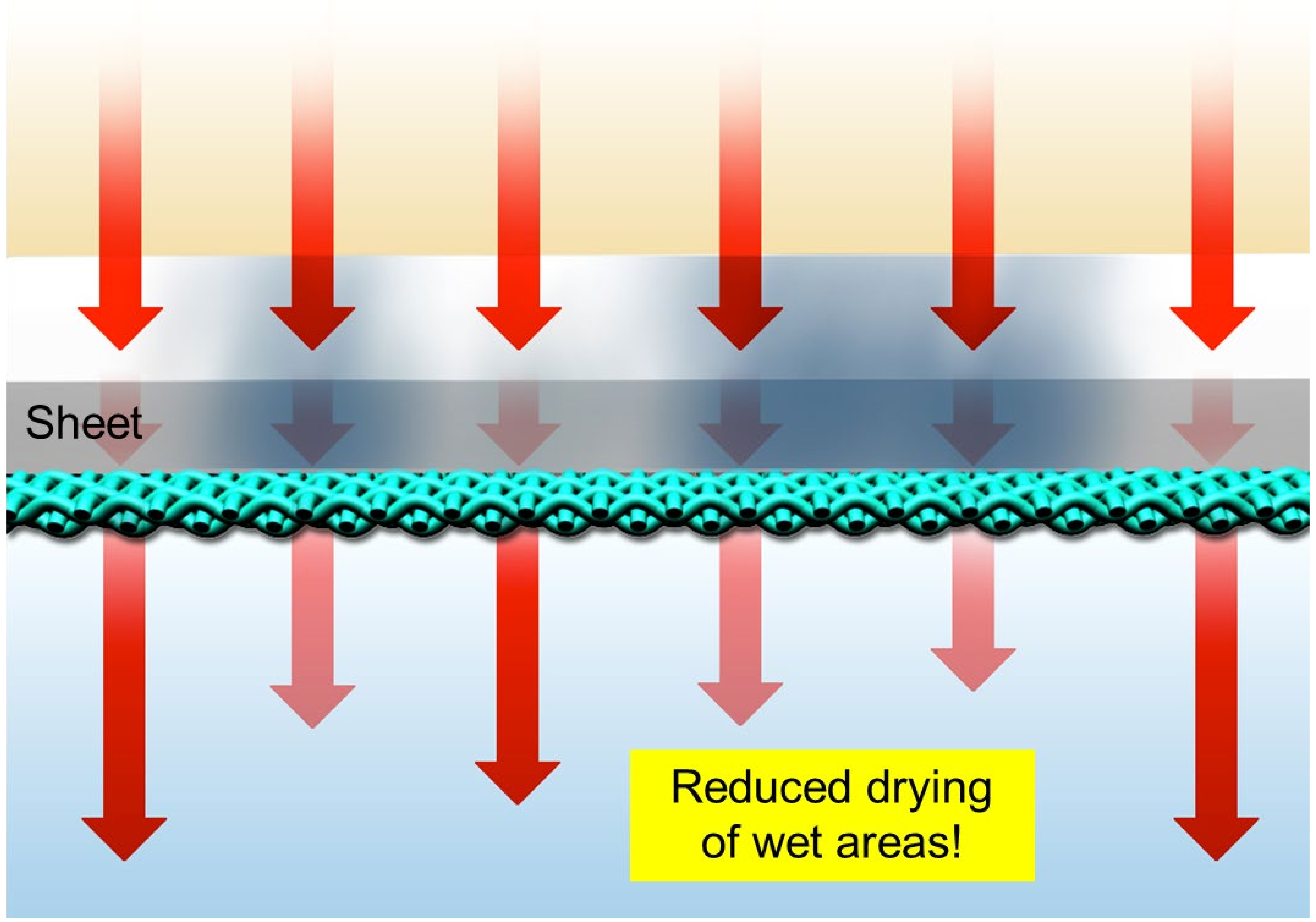
Increased heat flow

Wet streak

Cooling of surface

Increased temp. diff.

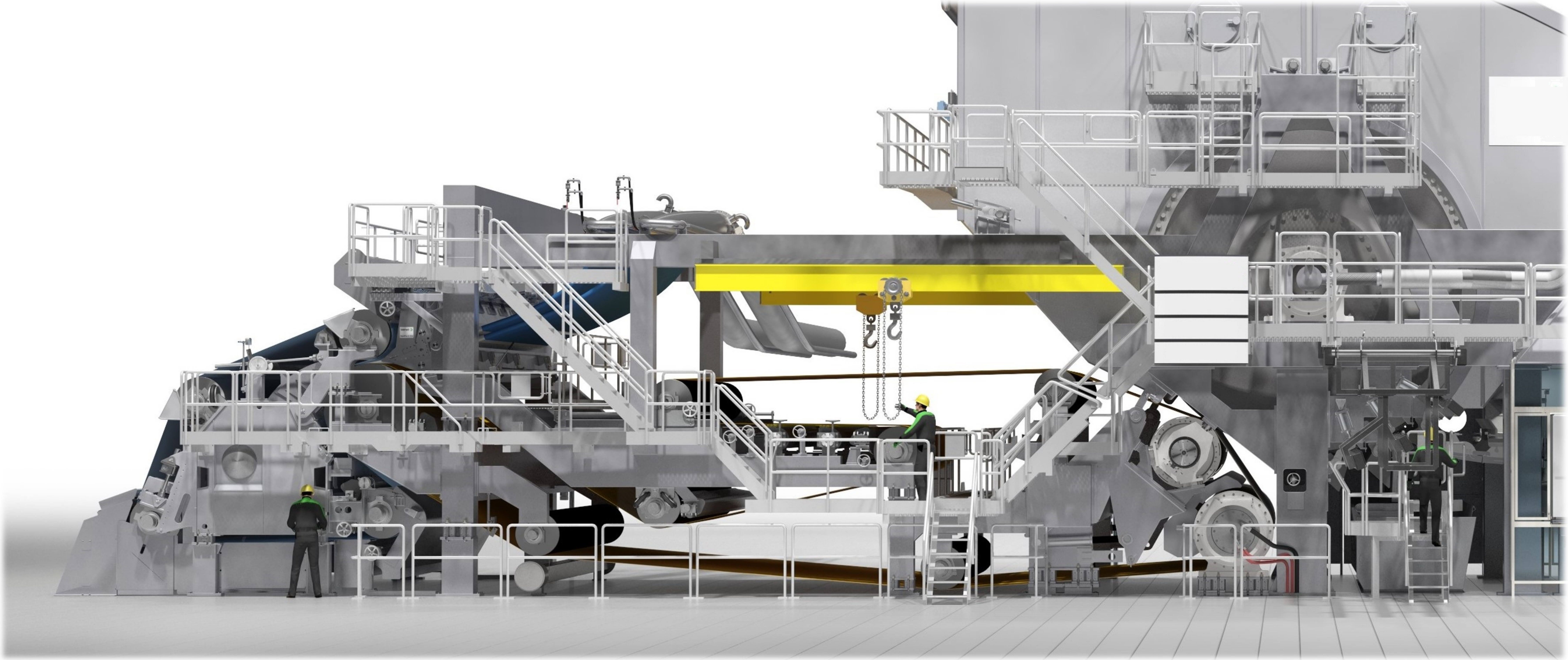
E g TAD drying is instable



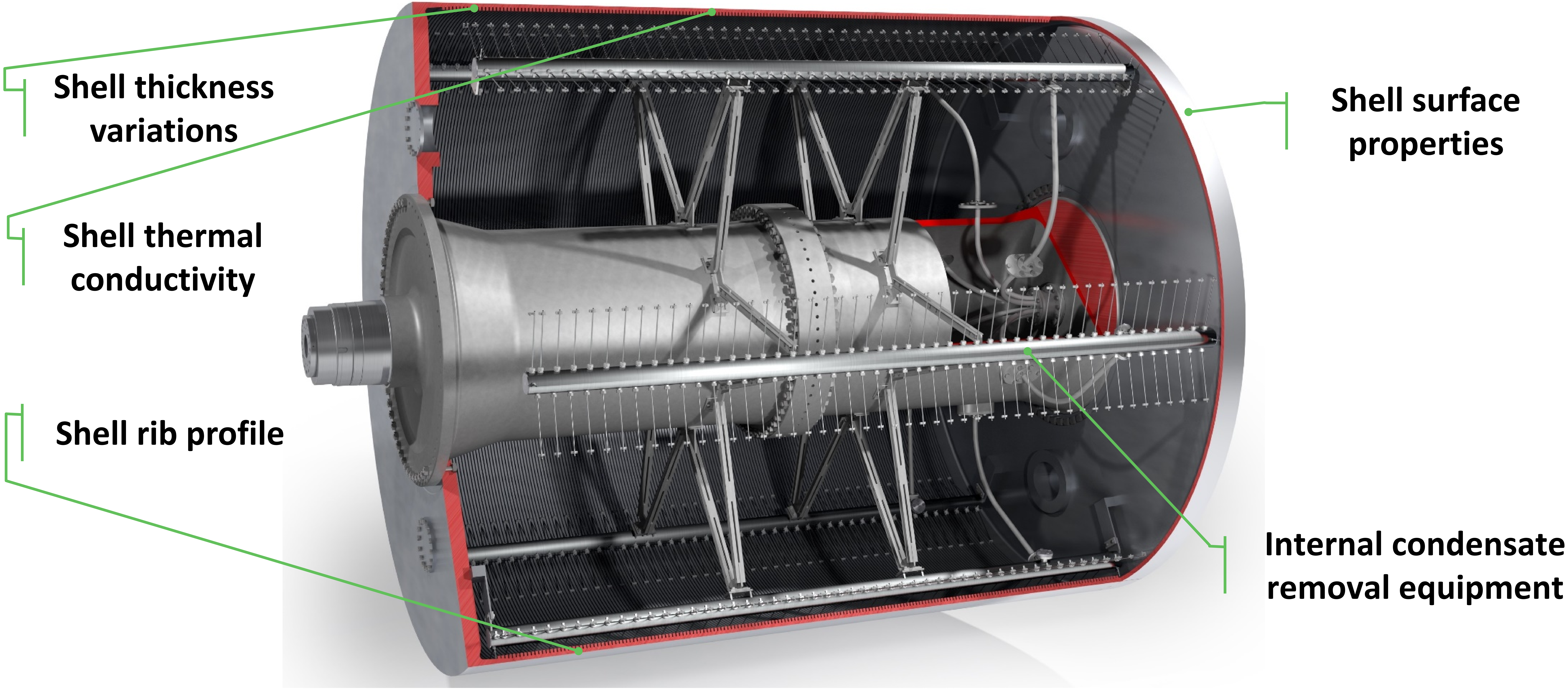
Reduced drying of wet areas!

Factors Affecting the Uniformity

Yankee dryer mirrors process



Factors Affecting the Uniformity



Shell thickness variations

Shell thermal conductivity

Shell rib profile

Shell surface properties

Internal condensate removal equipment

Shell **Thickness** Variations

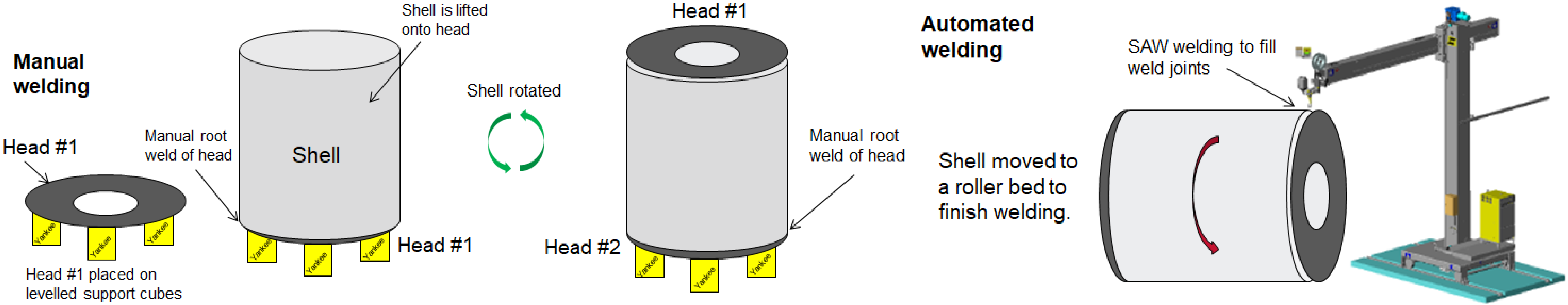

FRORIEP
FRORIEP

Assembly Bolted Design

Procedure

Verification

Assembly Welded Design



Manual welding

Head #1

Manual root weld of head

Head #1 placed on levelled support cubes

Shell is lifted onto head

Shell

Head #1

Shell rotated

Head #1

Head #2

Manual root weld of head

Automated welding

SAW welding to fill weld joints

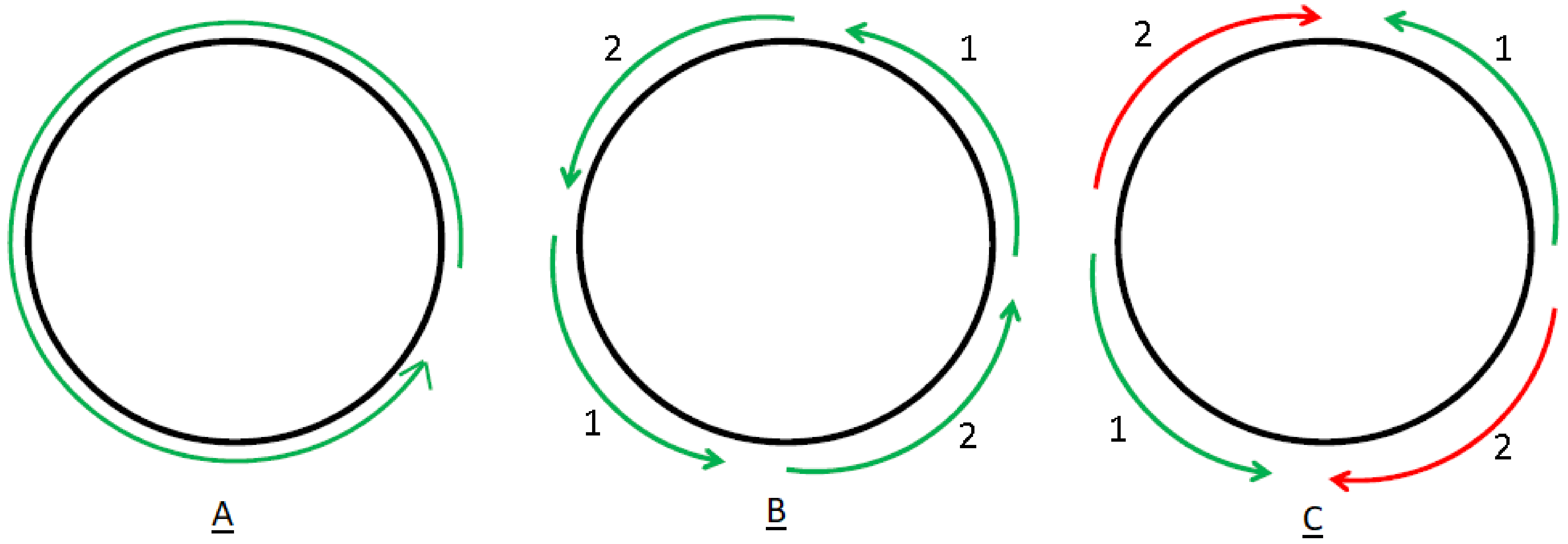
Shell moved to a roller bed to finish welding.

- Direct or indirect welding deformations will result in shell thickness variations.

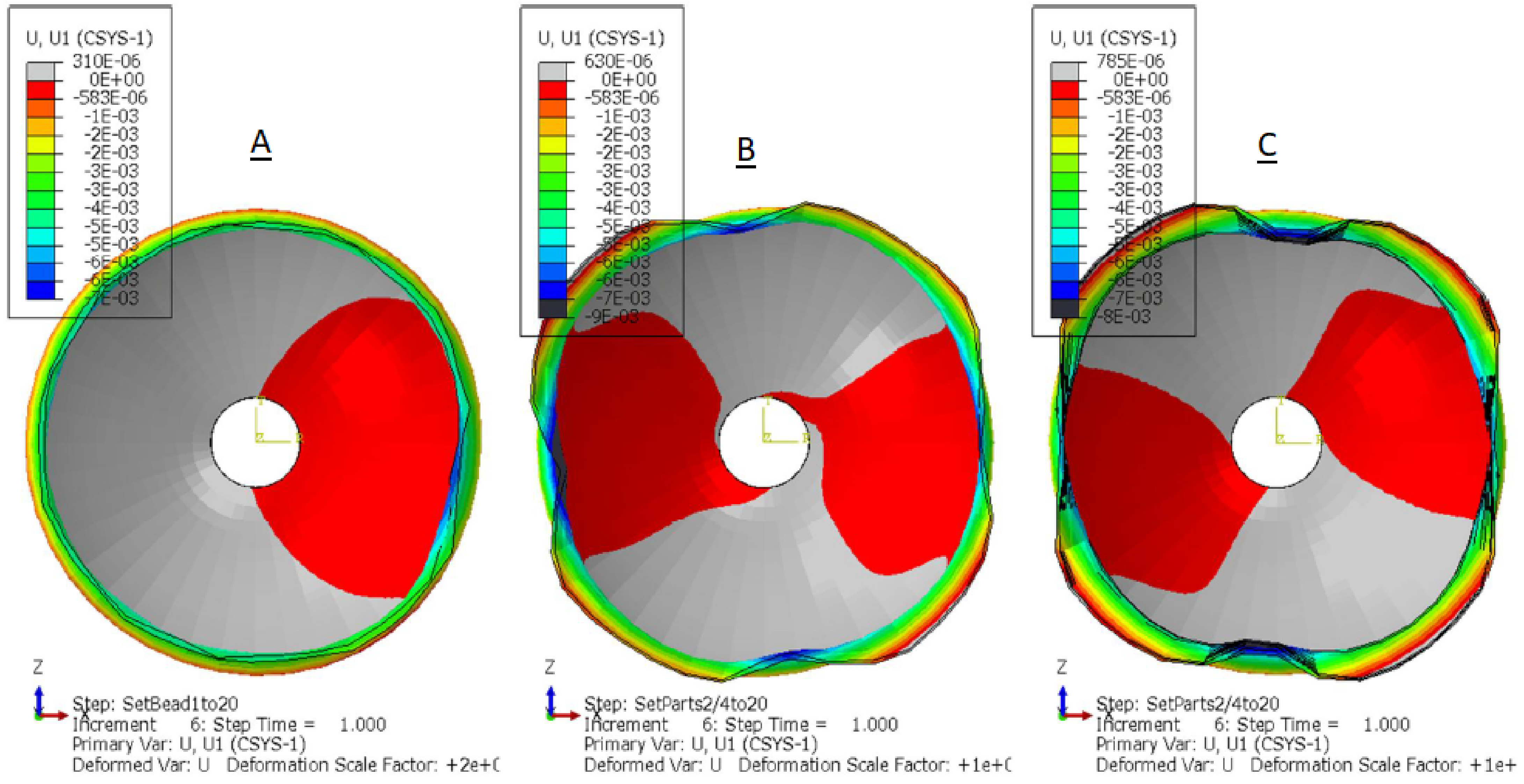
Welding Simulation

Factors in FE welding simulation:

- Weld geometry, bead size, speed, interacting welds…
- Modeling of welding heat sources, pre-heat and interpass temperatures
- Material modeling and properties (physical and mechanical properties 20-1500°C (68-2732°F)for parent and weld materials)
- Post weld treatments



Welding sequence

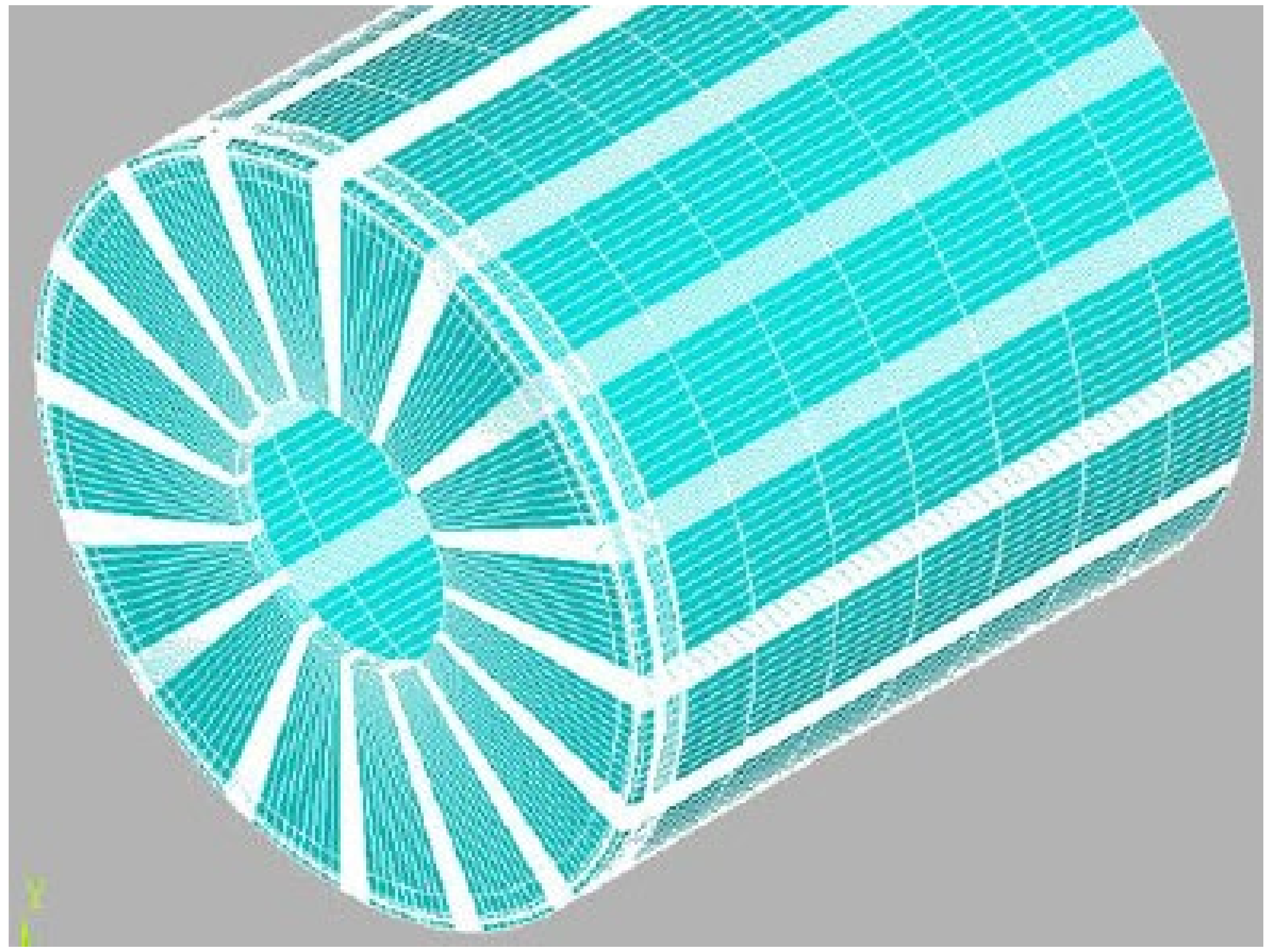


Radial deformation

source: Inspecta

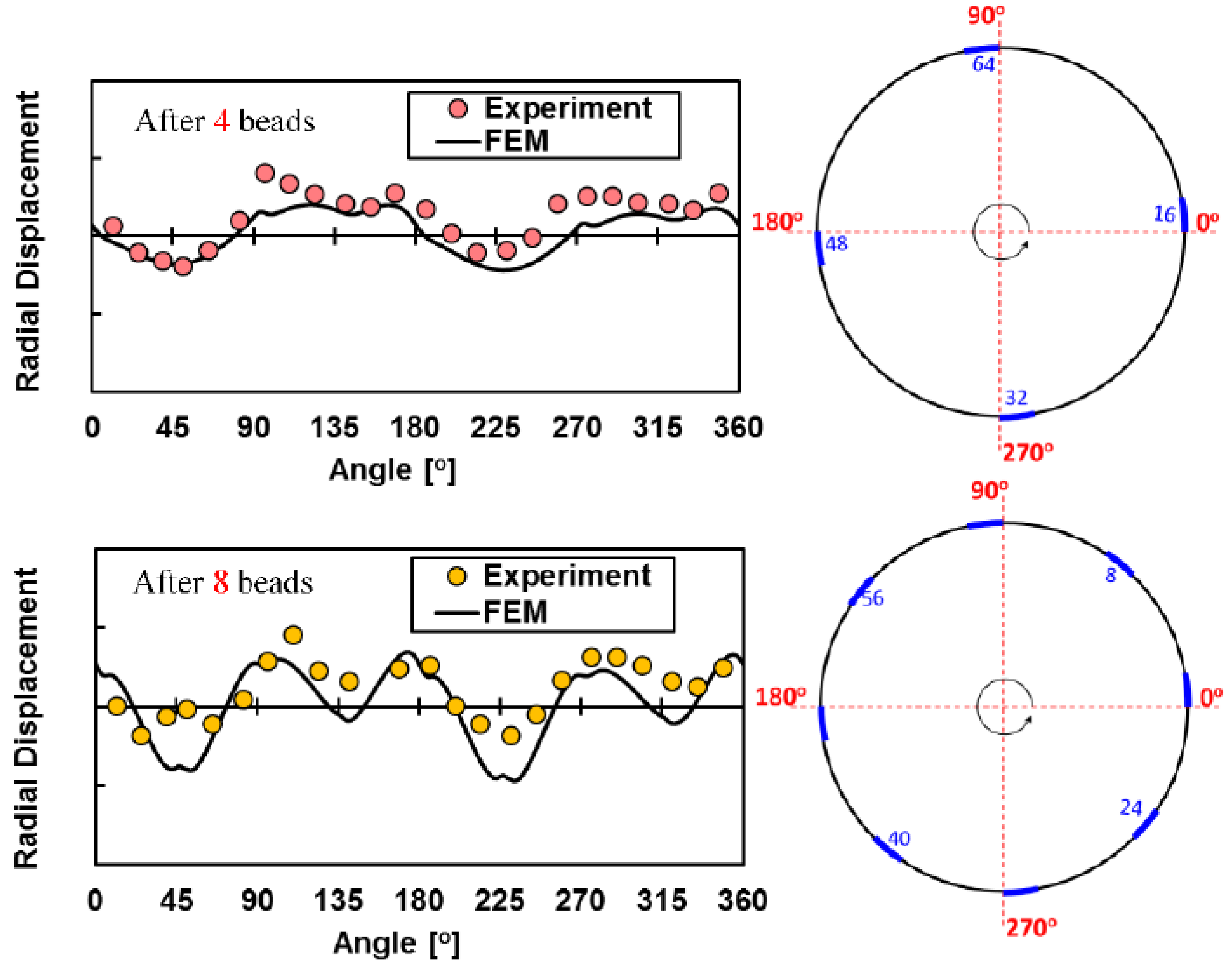
Minimizing Welding Deformations

Modeling



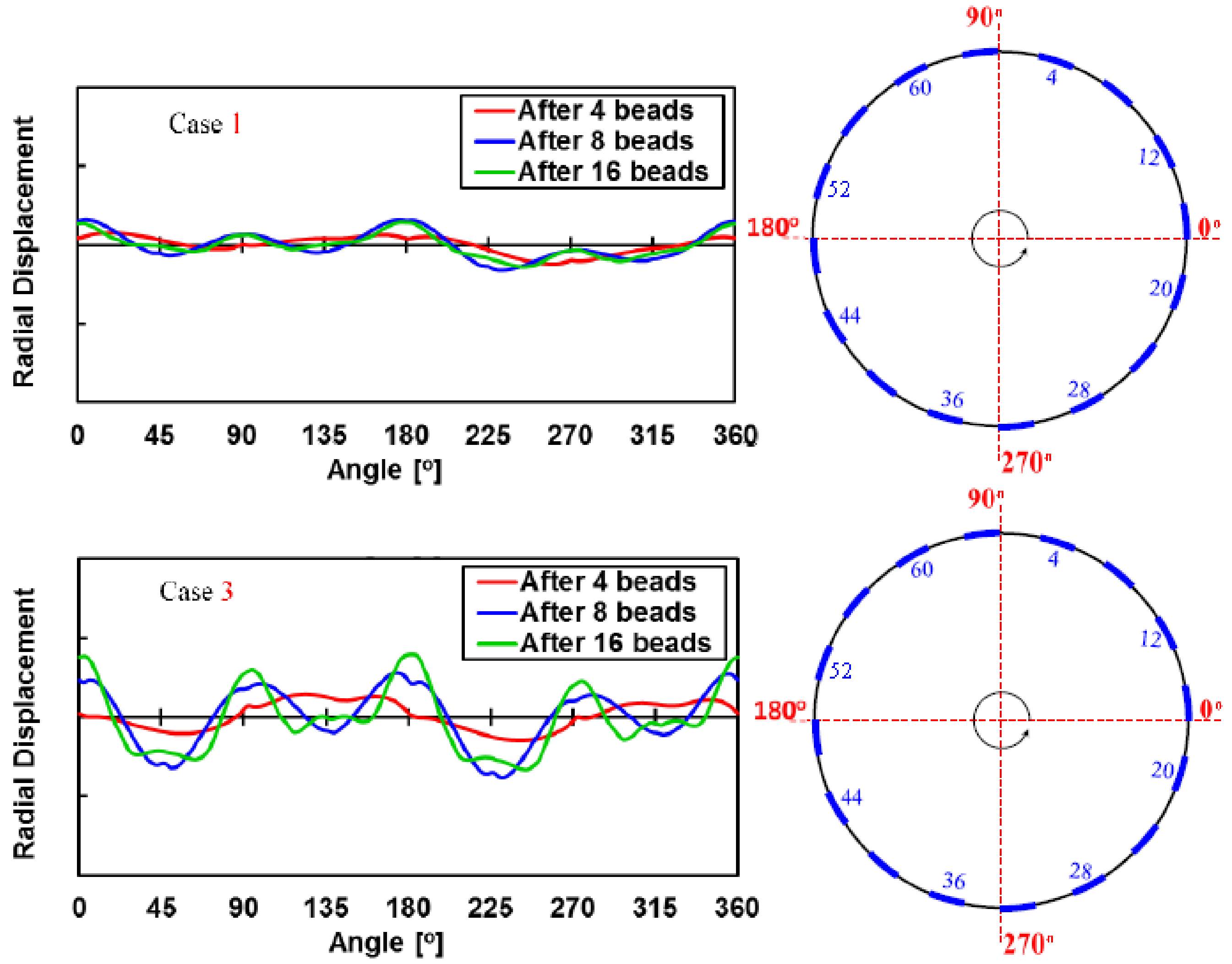
Eight-noded linear elements are used in thermal and mechanical simulations.

Validation



Simulation is validated by temperature measurements - using thermocouples - and distortion measurements.

Optimization

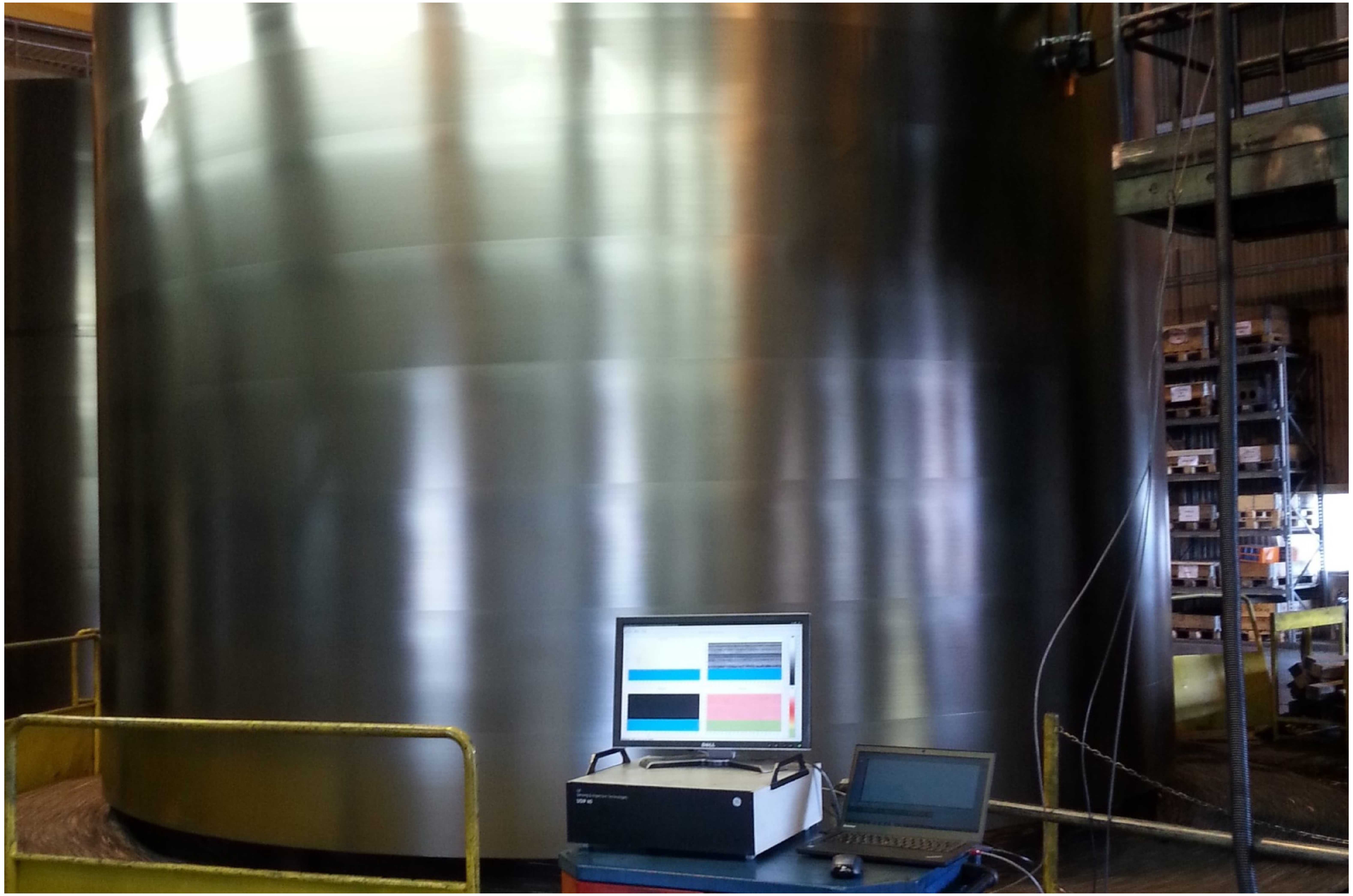


Minimizing welding deformation by optimizing welding sequence, welding speed, bead lengths, pre-heating e t c – through simulation.

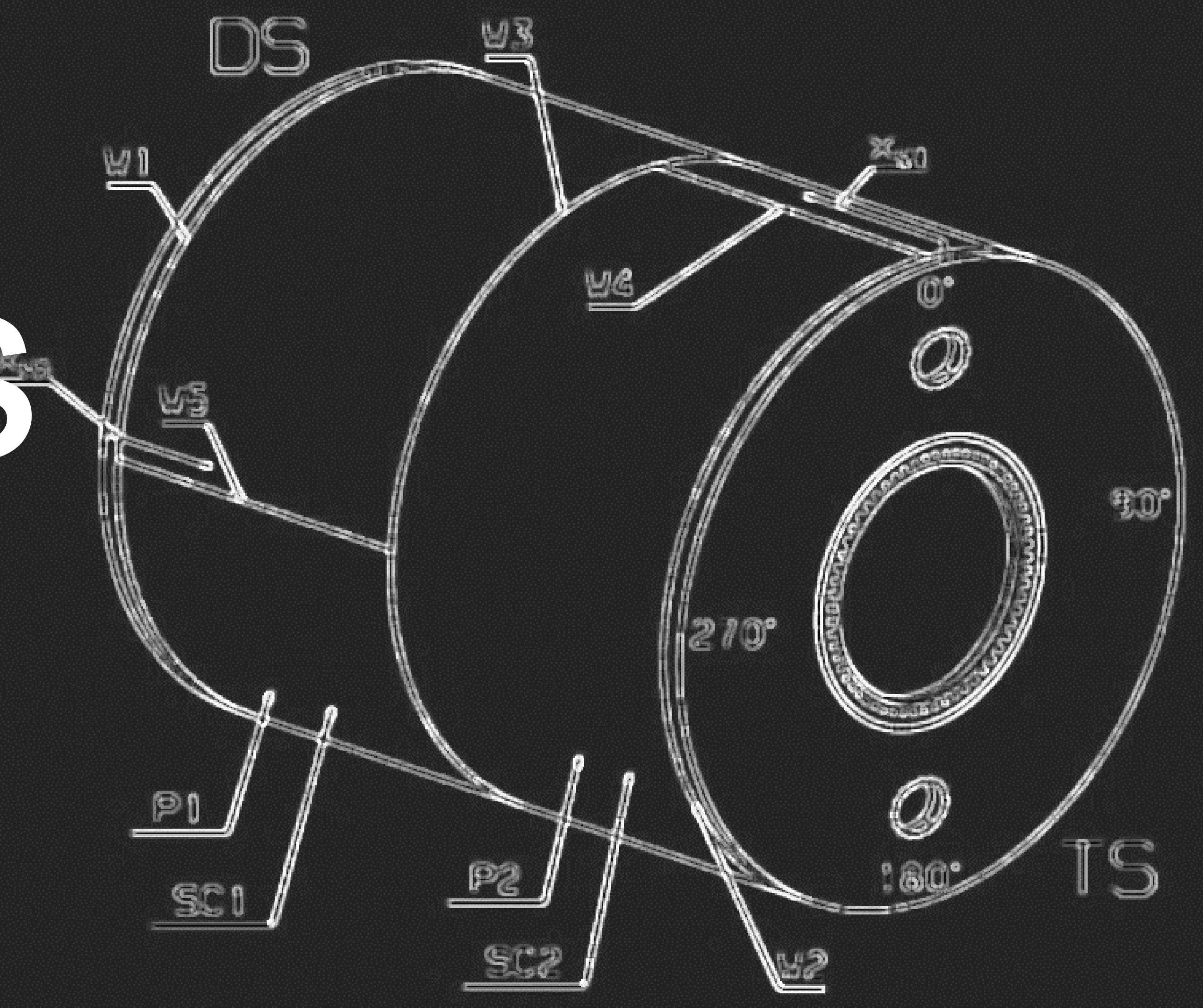
Thermal Conductivity


#900

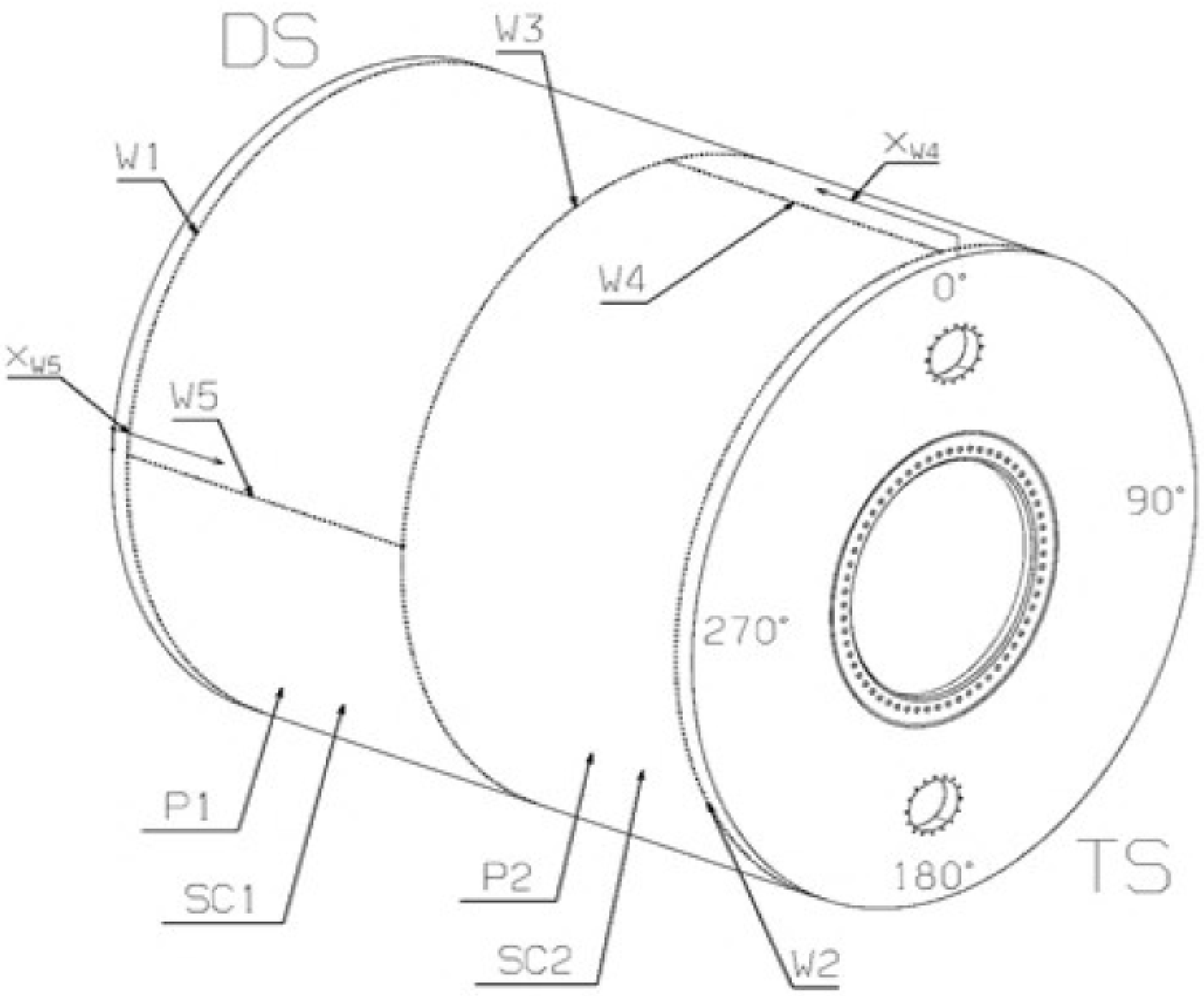
Verification of Casting Uniformity

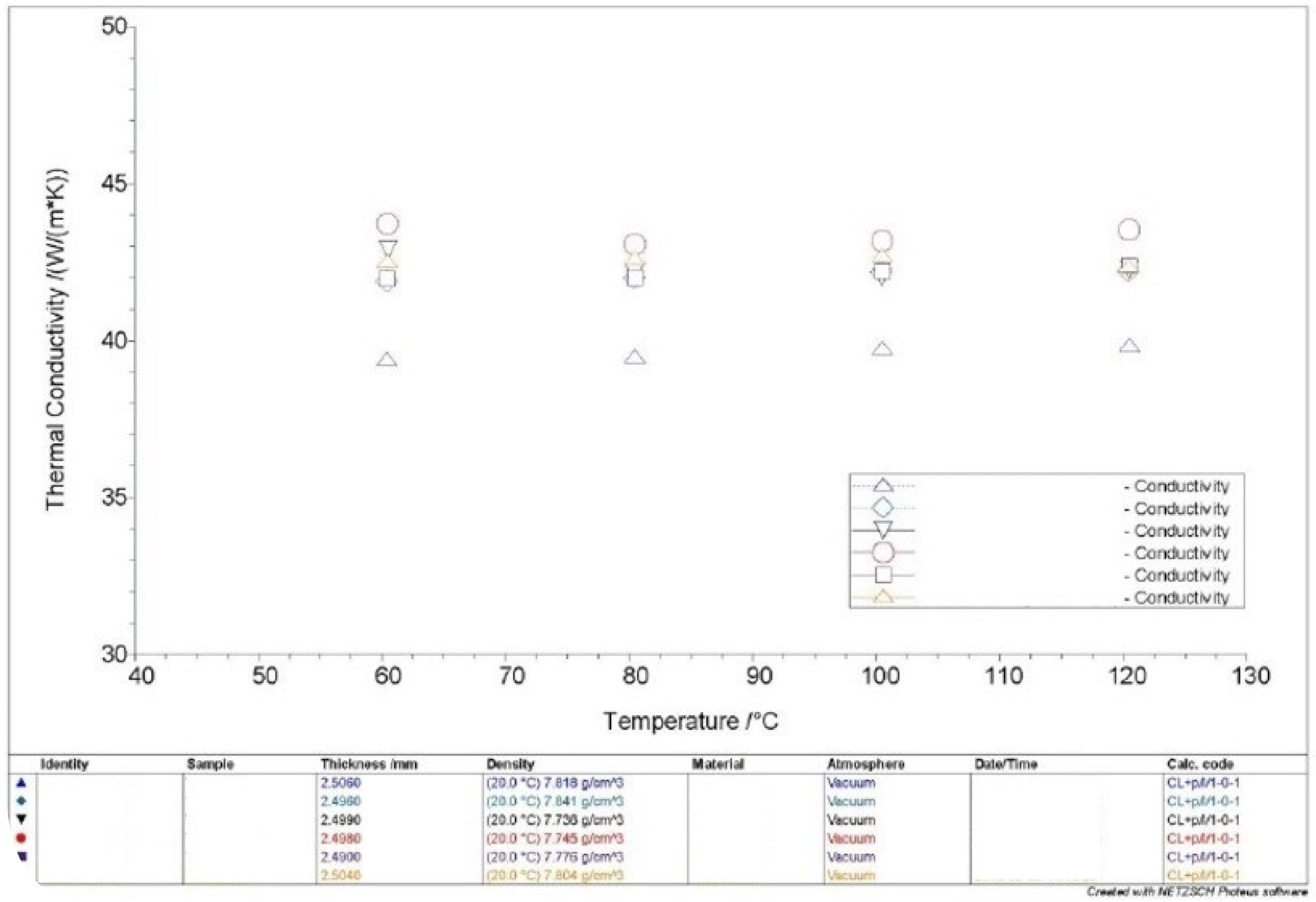


Plates and Welds



Minimizing Conductivity Variations





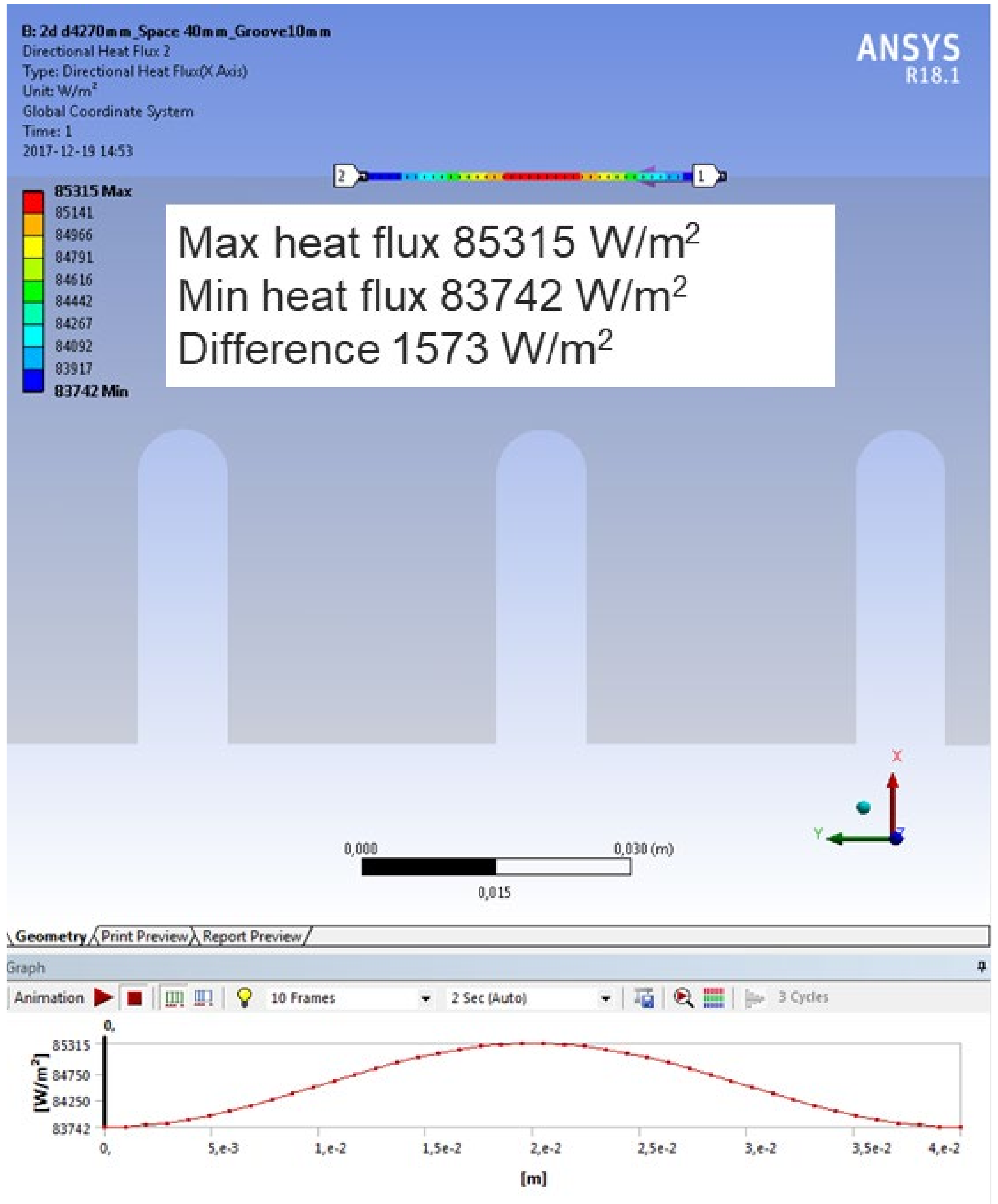
	Identity	Sample	Thickness /mm	Density	Material	Atmosphere	Date/Time	Calc. code
▲			2.5060	(20.0 °C) 7.818 g/cm^3		Vacuum		CL+pl/1-0-1
◆			2.4960	(20.0 °C) 7.841 g/cm^3		Vacuum		CL+pl/1-0-1
▼			2.4990	(20.0 °C) 7.736 g/cm^3		Vacuum		CL+pl/1-0-1
●			2.4980	(20.0 °C) 7.745 g/cm^3		Vacuum		CL+pl/1-0-1
◣			2.4900	(20.0 °C) 7.776 g/cm^3		Vacuum		CL+pl/1-0-1
			2.5040	(20.0 °C) 7.804 g/cm^3		Vacuum		CL+pl/1-0-1

Created with NETZSCH Proteus software

- Thermophysical properties of steel and weld samples are analyzed using Laser Flash measurement to determine optimal combination.

Optimizing Rib Profile

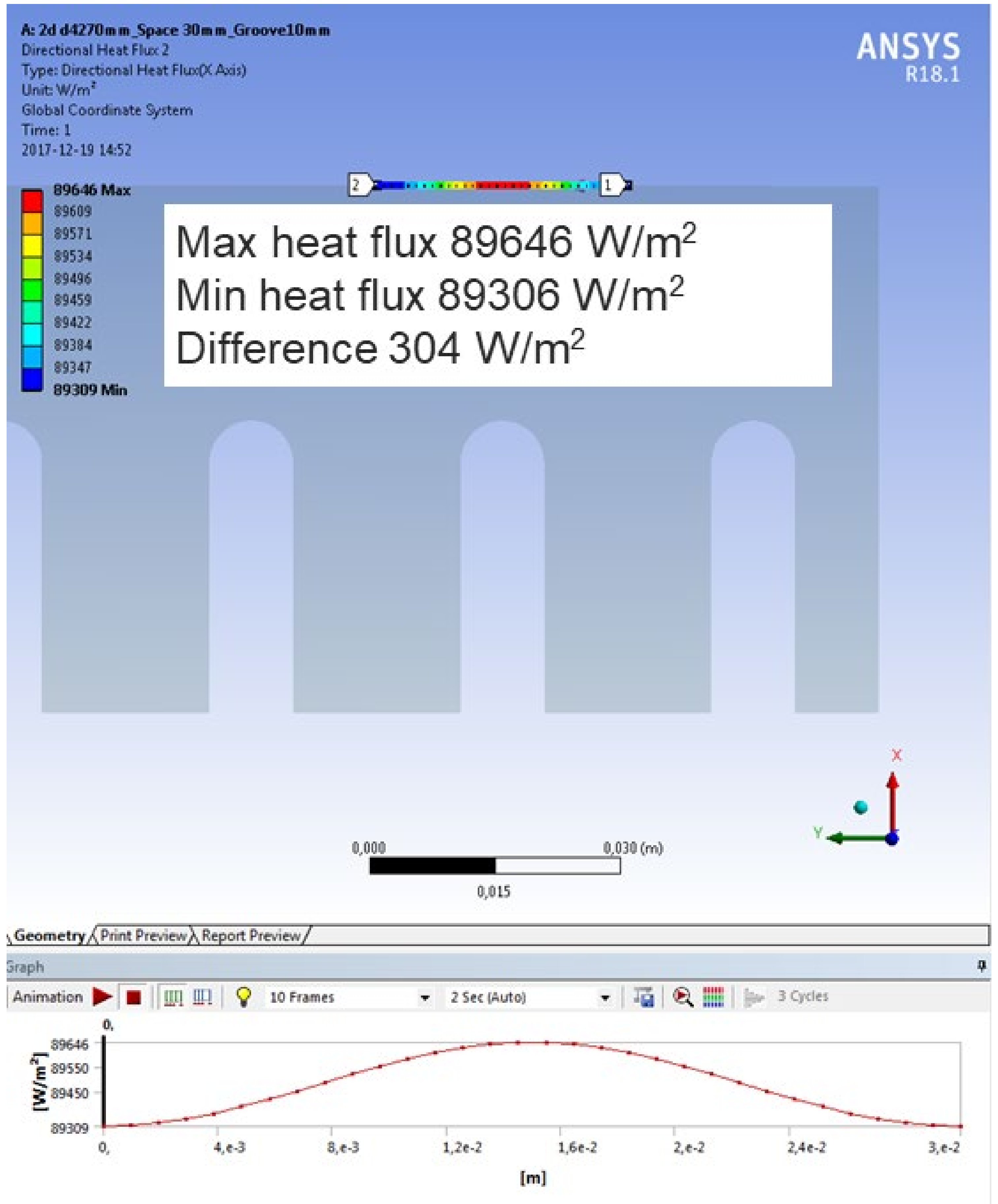
Supplier A



B: 2d d4270mm_Space 40mm_Groove10mm
Directional Heat Flux 2
Type: Directional Heat Flux(X Axis)
Unit: W/m²
Global Coordinate System
Time: 1
2017-12-19 14:53

Max heat flux 85315 W/m^2
Min heat flux 83742 W/m^2
Difference 1573 W/m^2

Supplier B



A: 2d d4270mm_Space 30mm_Groove10mm
Directional Heat Flux 2
Type: Directional Heat Flux(X Axis)
Unit: W/m²
Global Coordinate System
Time: 1
2017-12-19 14:52

Max heat flux 89646 W/m^2
Min heat flux 89306 W/m^2
Difference 304 W/m^2

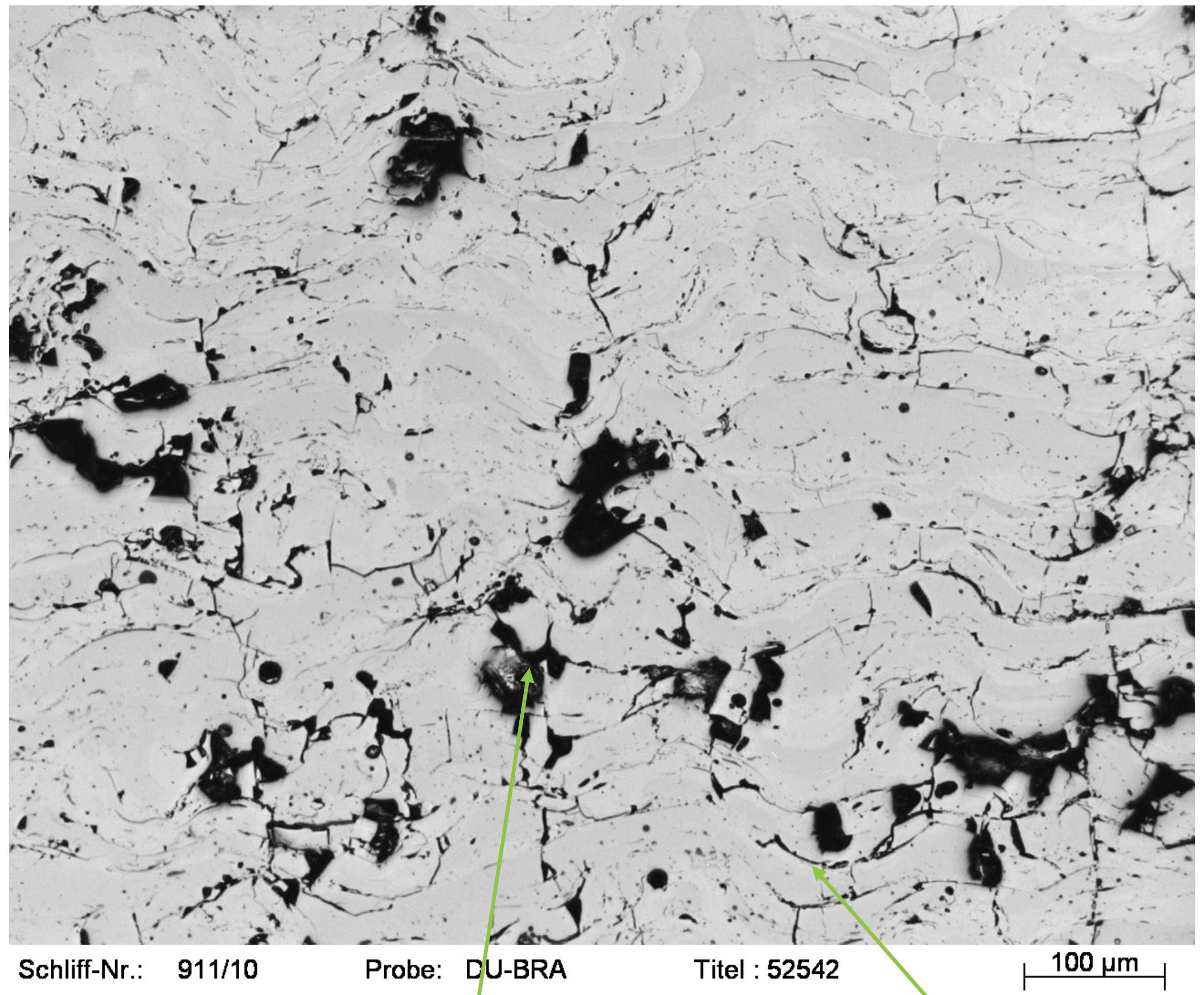
6% higher heat flow, 5 times less variation.

Shell Surface Properties

Thermal Coating

Homogenous and Uniform Coating

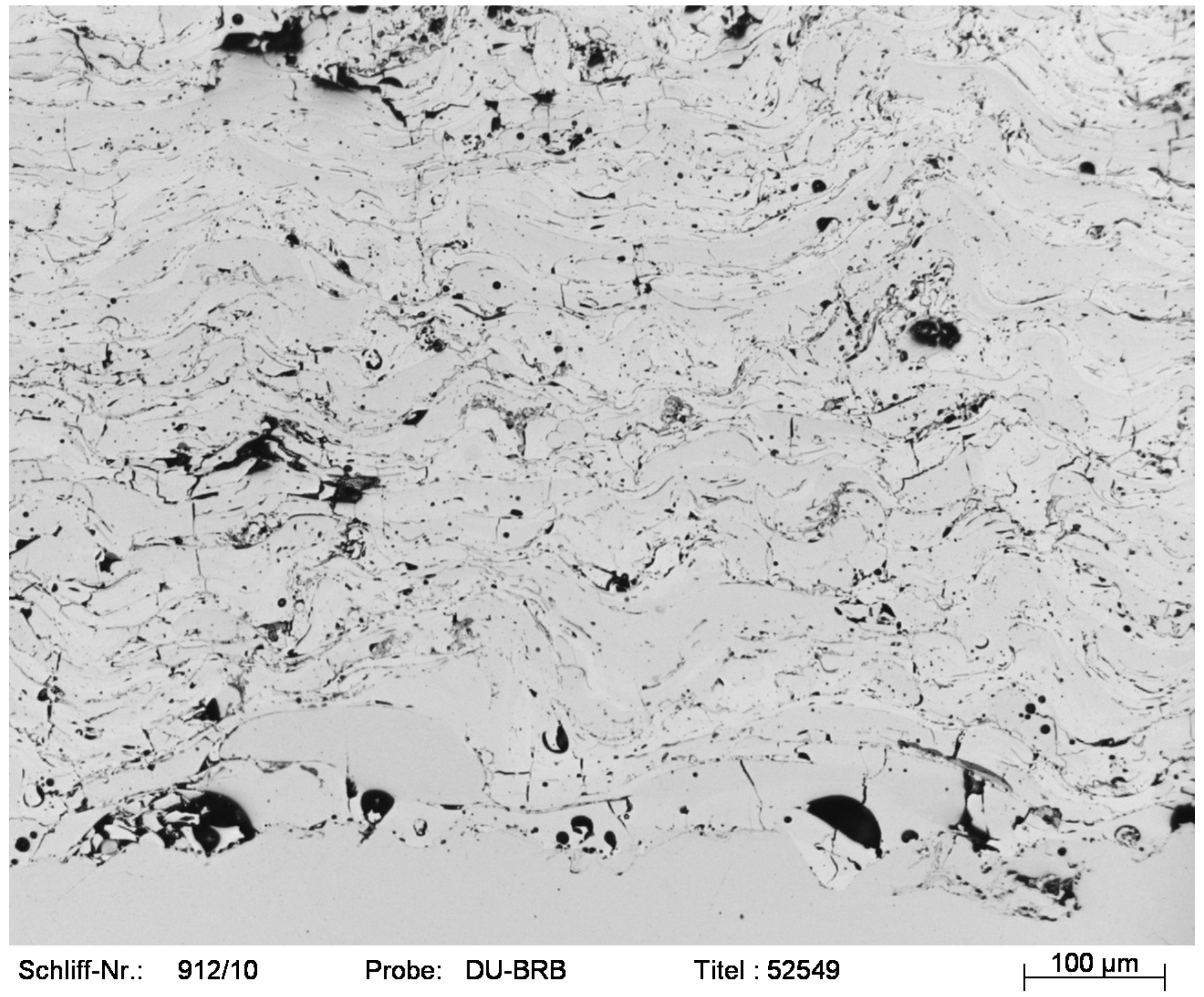
Typical thermal coating



Stress cracks

Un-melted particles,
voids, oxidised particles

Infinikote-1 “B”



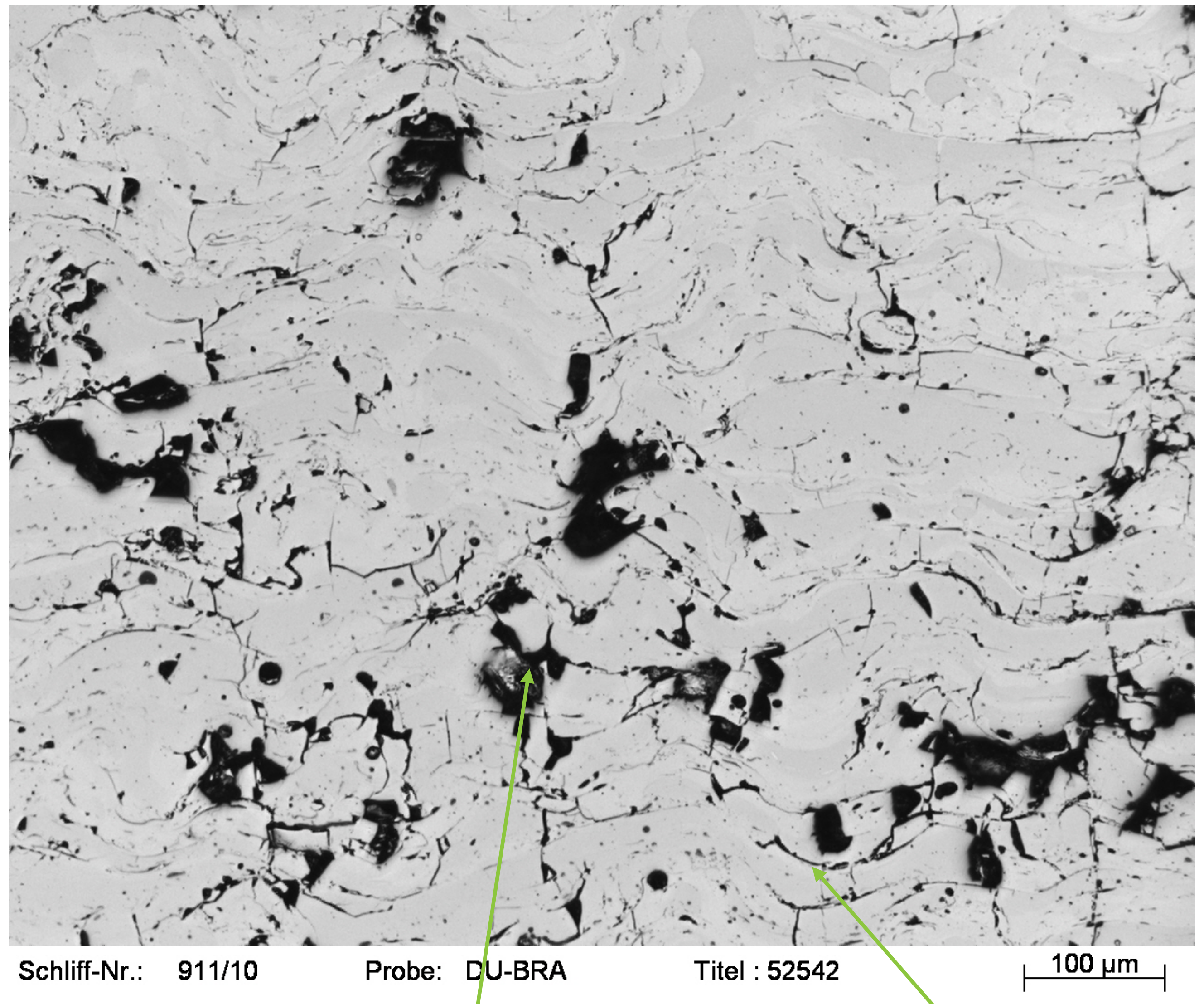
Hardness comparison

Hardness Vickers 0.1 Sample no	Typical Thermal Coating	B
1	1390	1465
2	1561	1452
3	1216	1300
4	1622	1309
5	995	1378
6	1425	1455
7	1600	1442
8	1246	1291
9	1663	1300
10	1020	1368
11	1362	1475
12	1529	1462
13	1588	1309
14	1590	1318
15	924	1388
Average Hv 0.1	1382	1381
Stand deviation	248	72
Hardness Rockwell C	62	57

Coating B variation is 2.5 times less than for Coating A.

Further Optimization

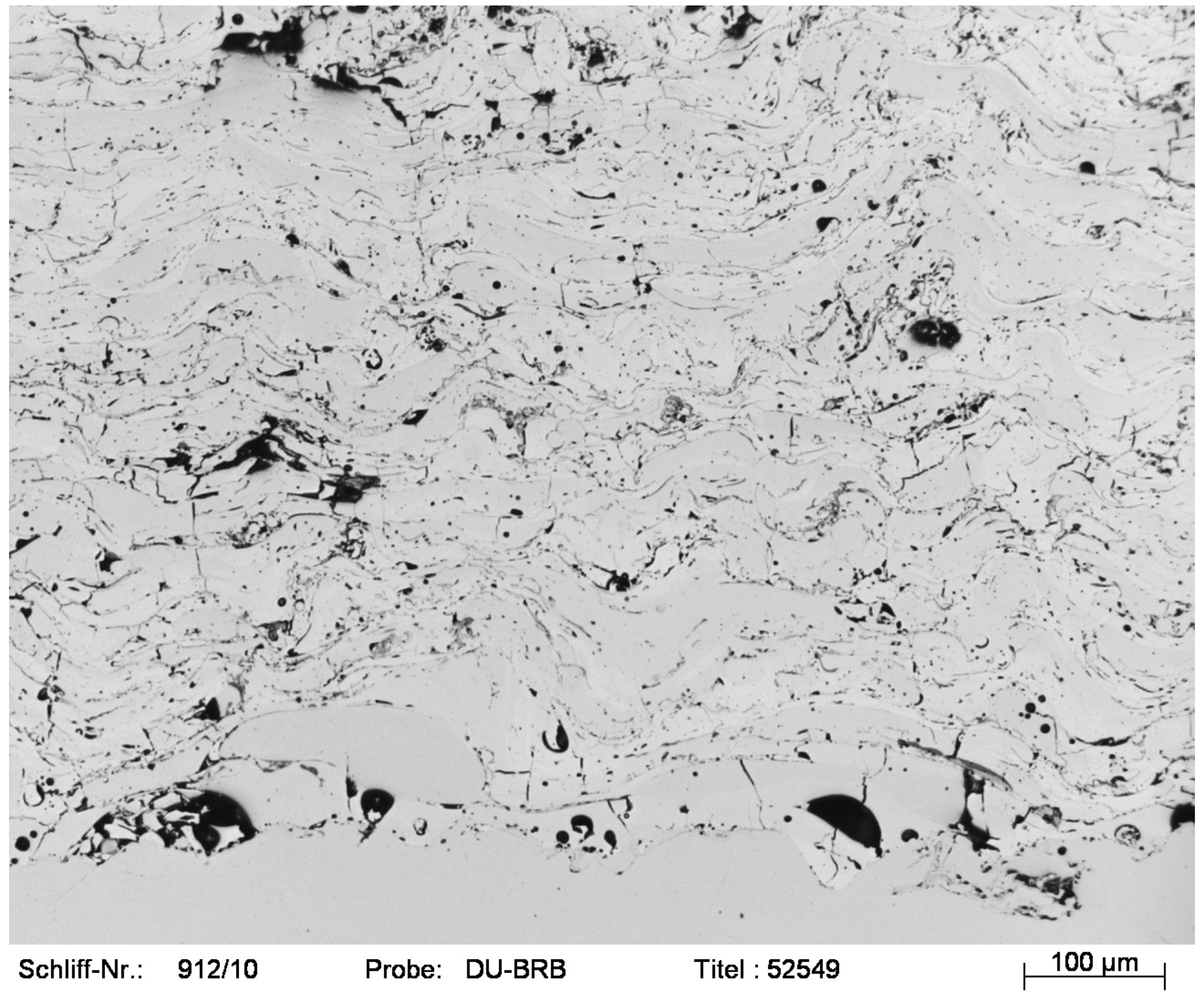
Typical thermal coating “A”



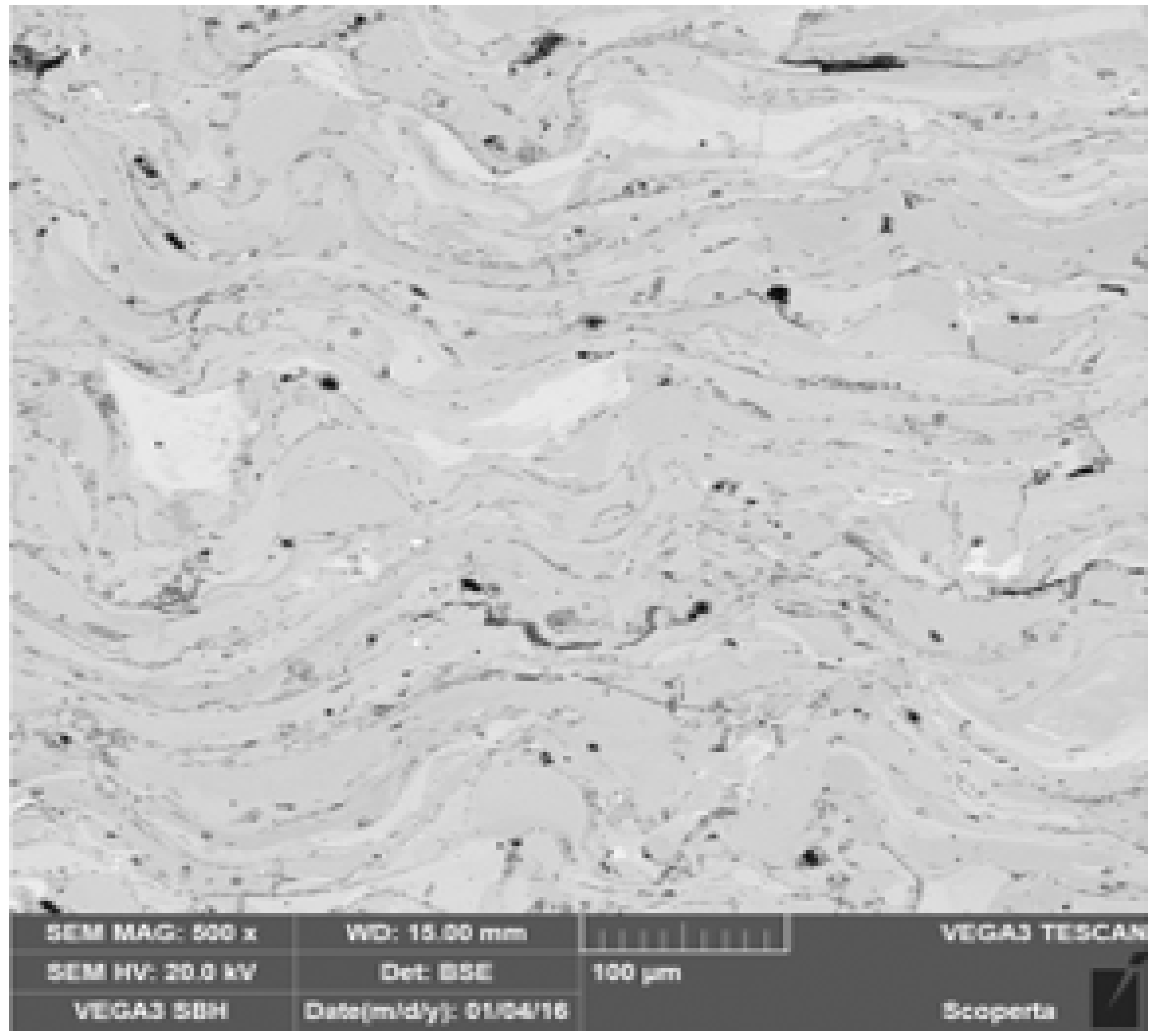
Stress cracks

Un-melted particles,
voids, oxidised particles

Coating “B”



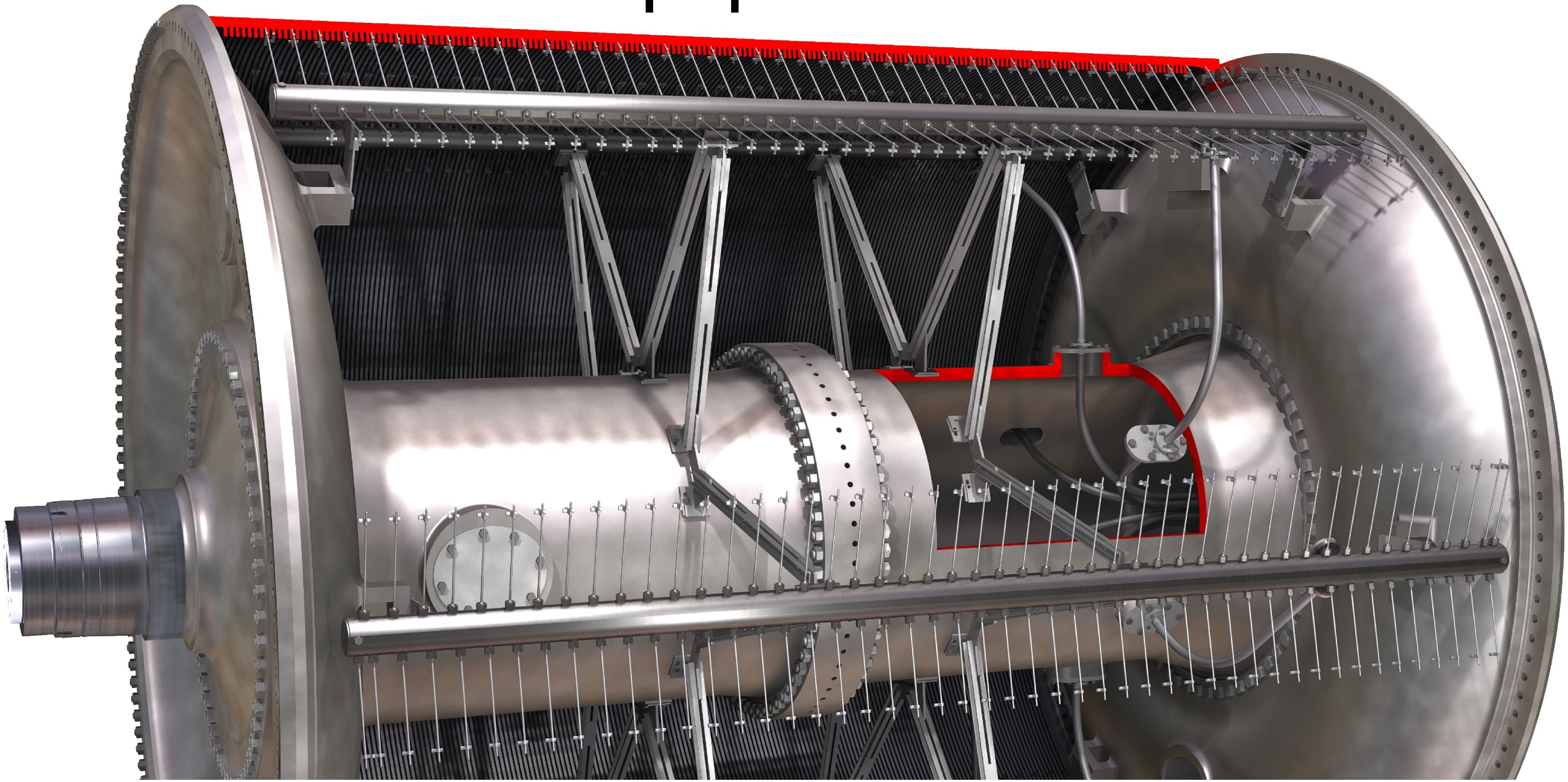
Cr-free Coating “C”



Recently developed chrome-free* Coating C with further improved structure.

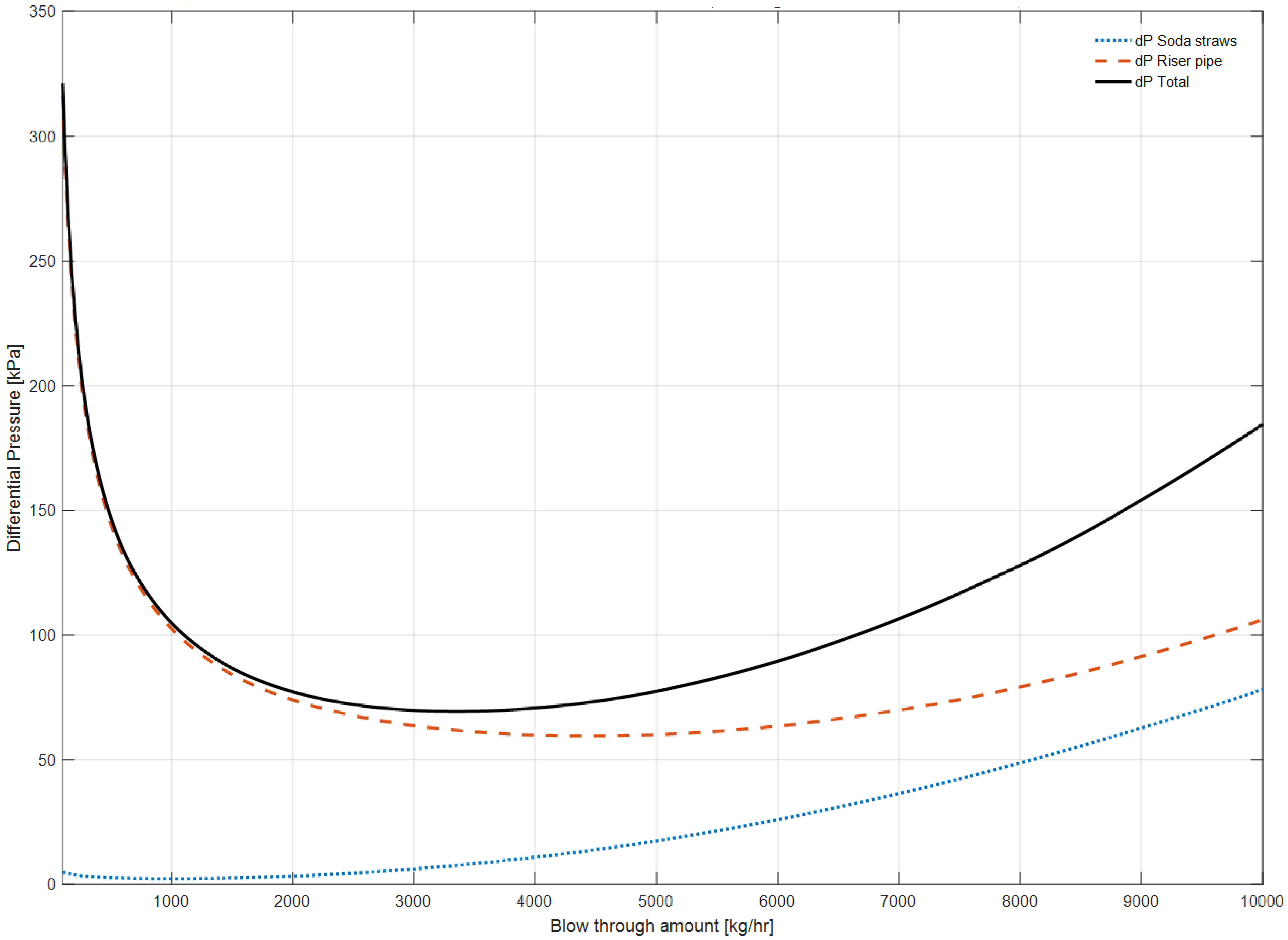
*Thermal coatings of type A and B contains 25-30% chrome.

Internal Condensate Removal Equipment



System Resistance Curve

- AKA “J-curve”
- Flow vs differential pressure
- Steam-condensate flow resistance for a specific internal system at a specific operating condition.
- System resistances:
  - force of gravity
  - centrifugal force
  - friction losses
  - dynamic/turbulence losses
- Two-phase flow

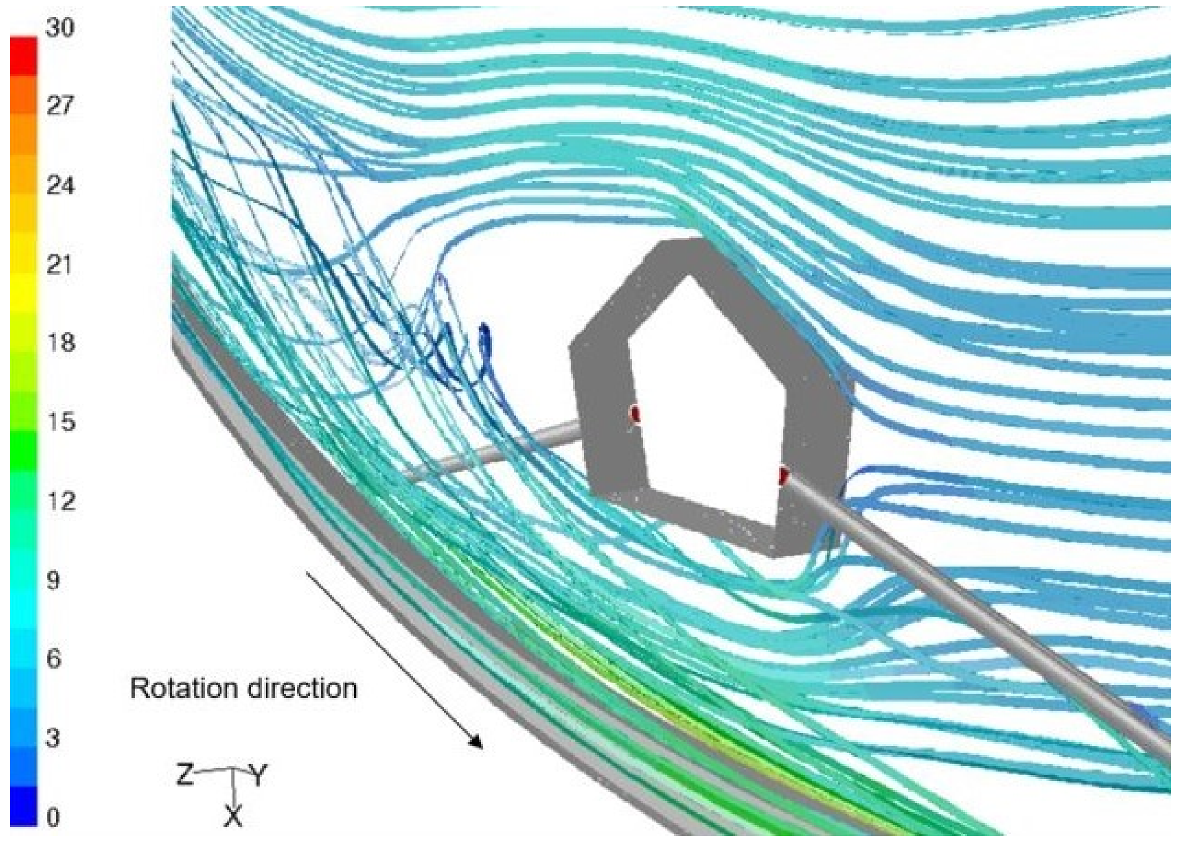


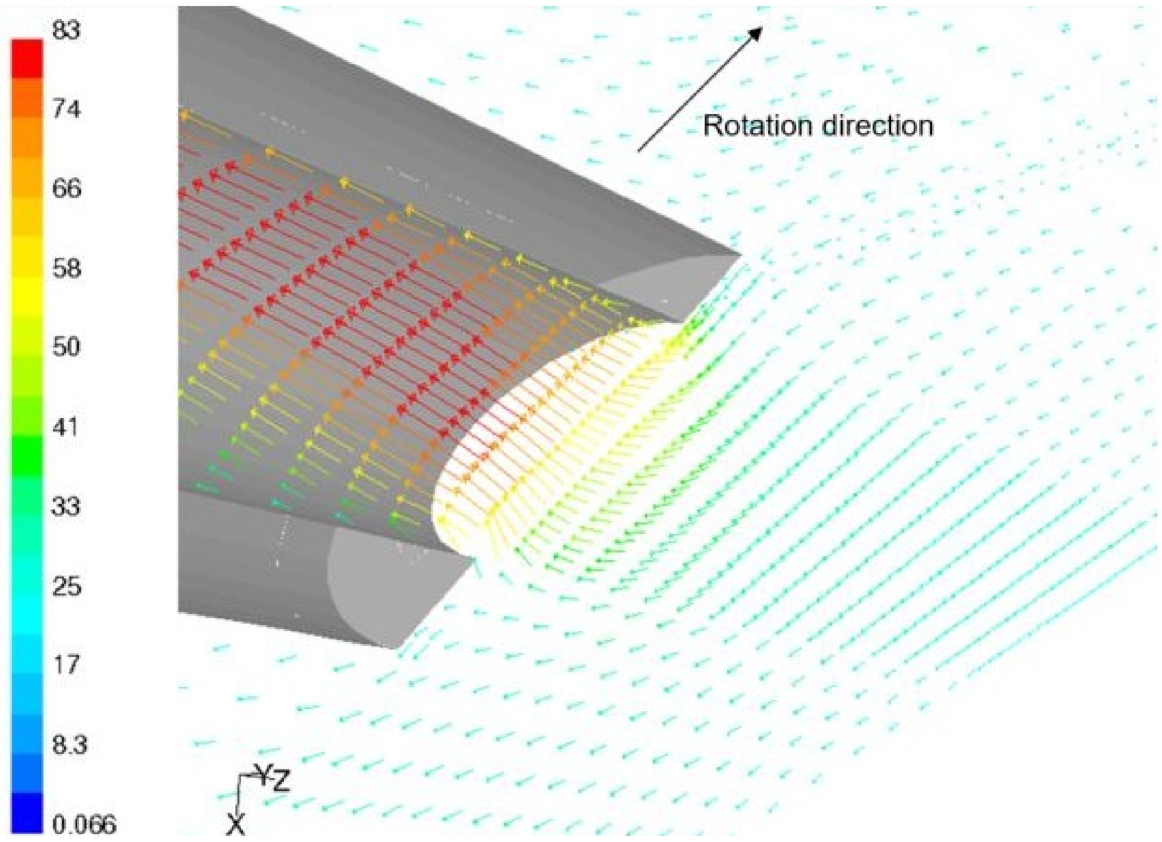
Optimizing for Efficiency and Uniformity

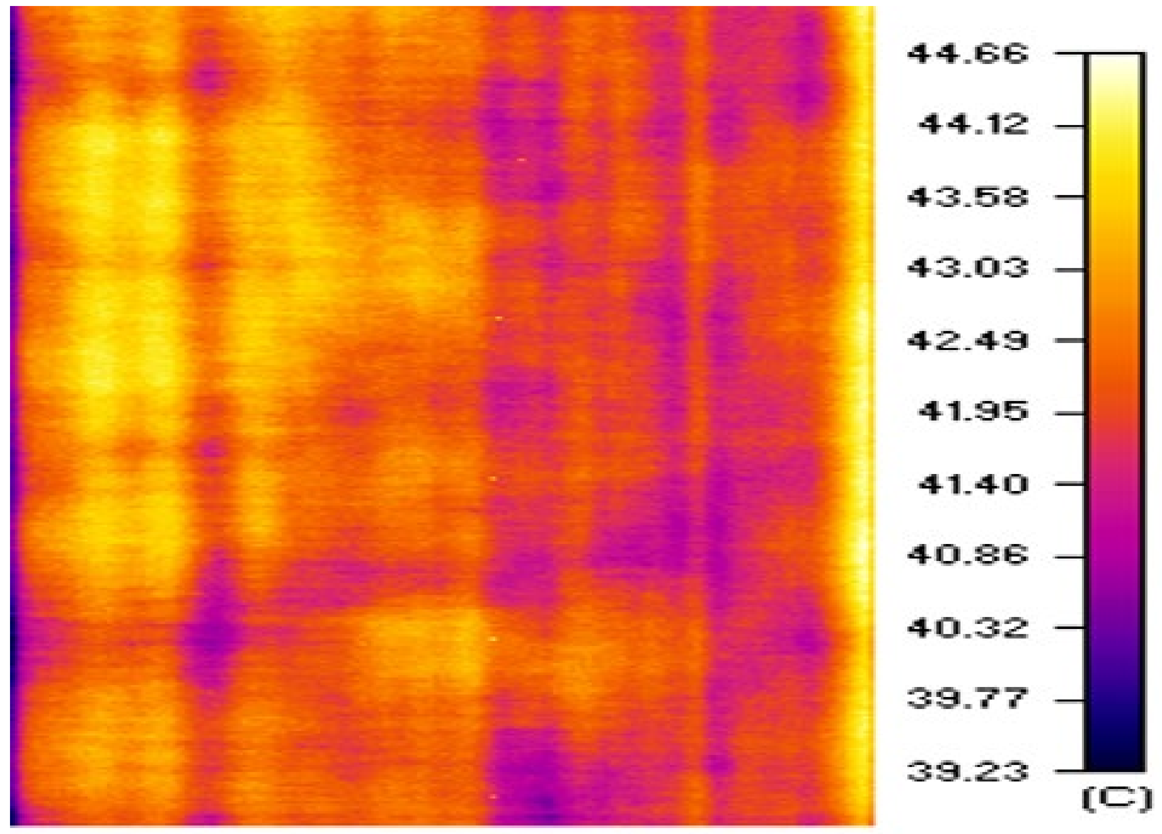
Parameters

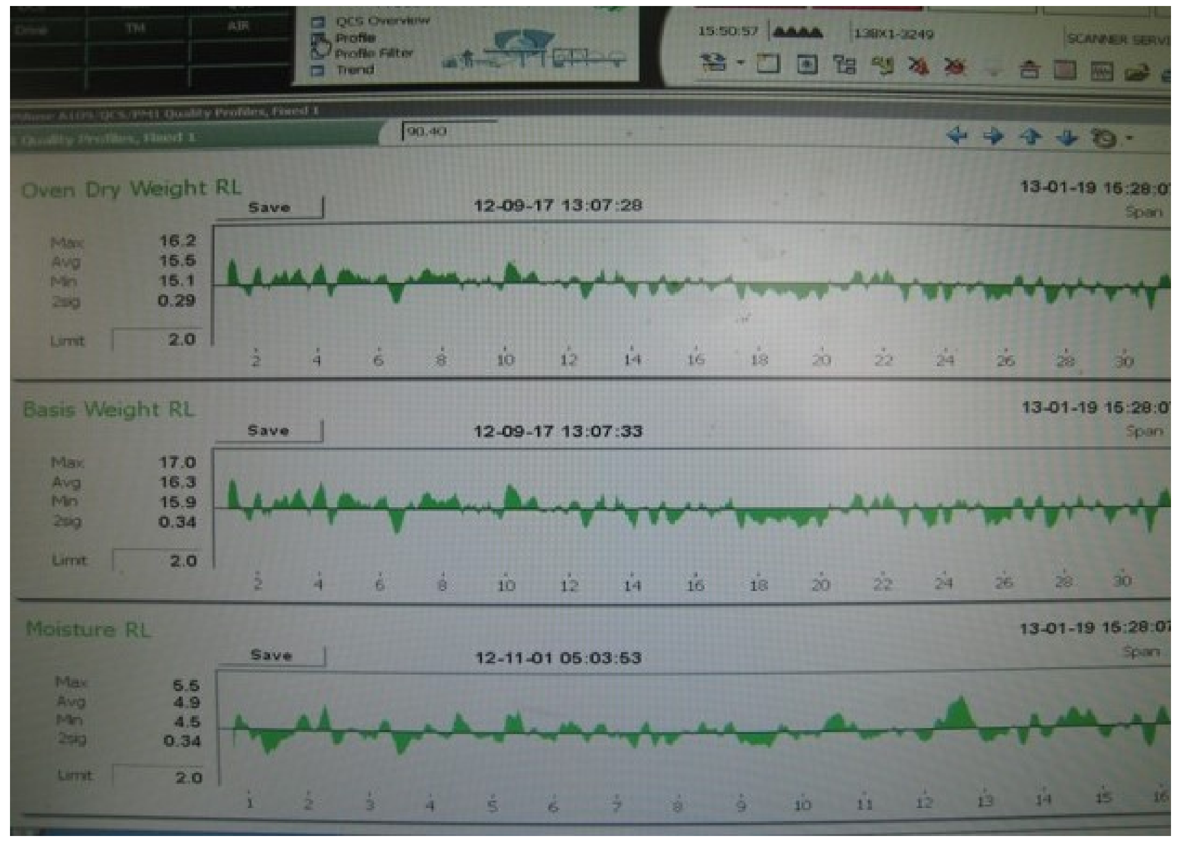
- Tissue making process specifics
- Riser and straw pipe open areas and velocities
- Number of headers, straws and straw pattern
- Straw pipe clearance
- Straw pipe geometry
- Header clearance
- Header geometry

Theoretical & empirical optimization





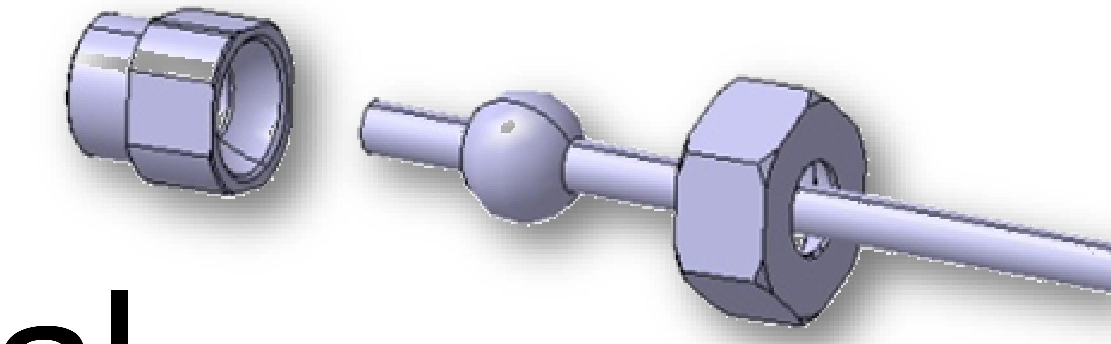




Oven Dry Weight RL
12-09-17 13:07:28
13-01-19 16:28:07
Max 16.2
Avg 15.5
Min 15.1
2sig 0.29
Limit 2.0

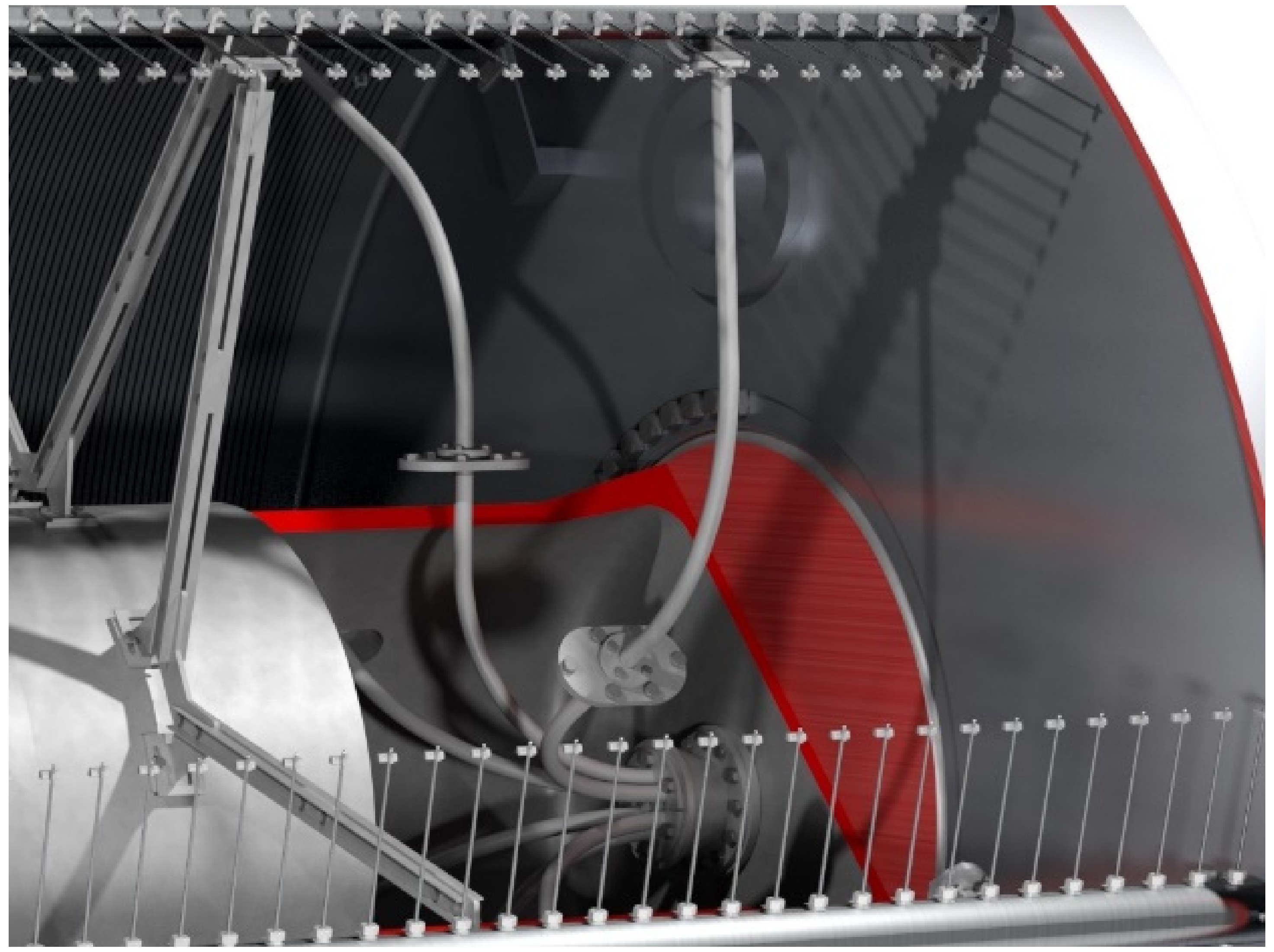
Basis Weight RL
12-09-17 13:07:33
13-01-19 16:28:07
Max 17.0
Avg 16.3
Min 15.9
2sig 0.34
Limit 2.0

Moisture RL
12-11-01 05:03:53
13-01-19 15:28:07
Max 5.5
Avg 4.9
Min 4.5
2sig 0.34
Limit 2.0



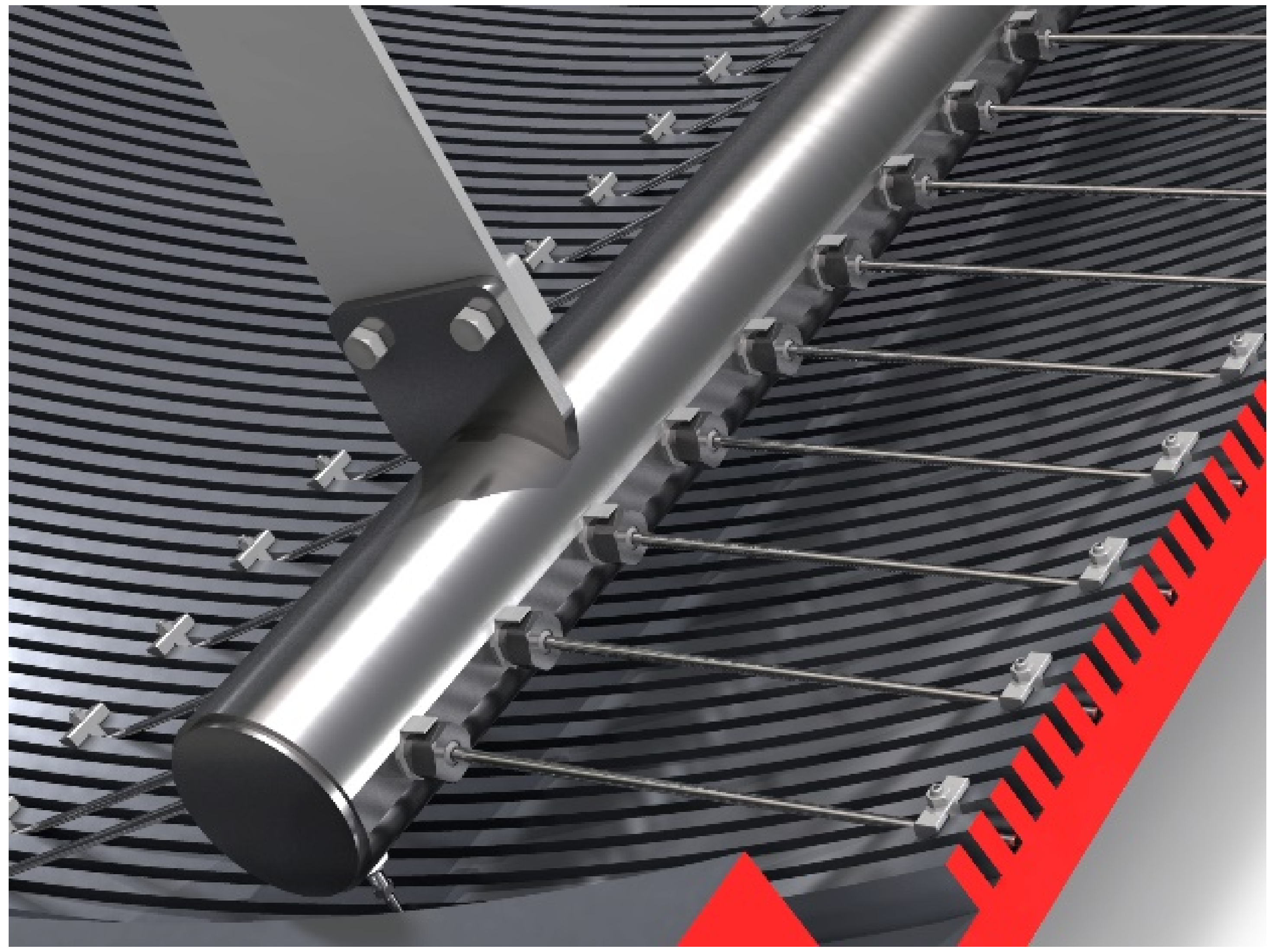
State of the Art Condensate Removal

Curved riser pipes



Curved riser pipes and long, tapered straw pipes for reduced pressure drop.

Optimized header



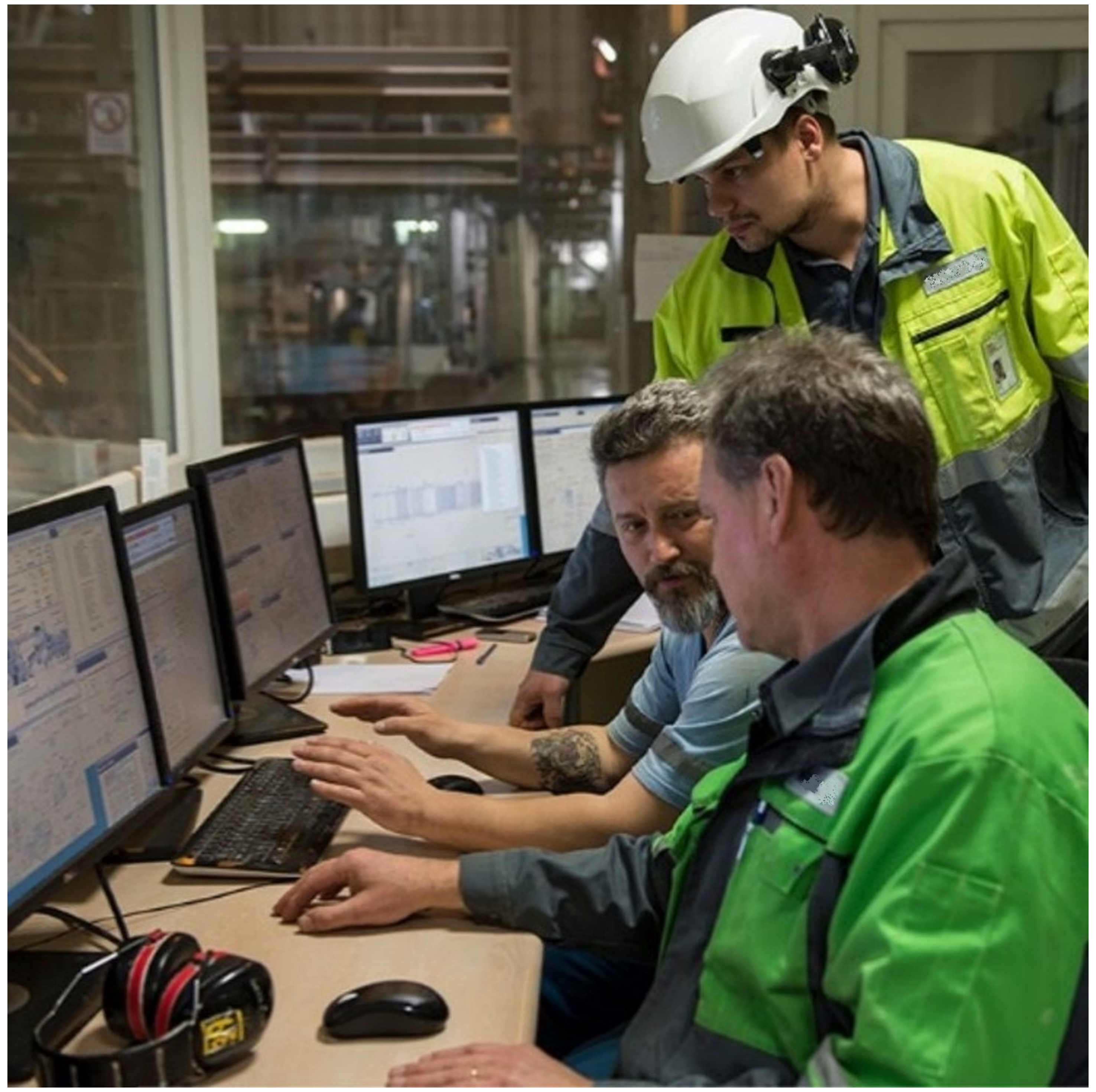
Header shape and location, and straw pipe pattern optimized for reduced thermal imprint and uniform condensate removal.

Tapered straws with holder

Patented spherical joint provides easy, accurate “tension-free” adjustment of straw pipes. Straw holder ensure precise clearance for uniform condensate removal.

Other Aspects of Minimizing Variations

Internals operation



Internals maintenance

Surface maintenance

Consequences of Variations

Uneven Drying

Variation	Consequence
▲ Thicker shell, or	▼ Lower heat flow, less drying
▼ Lower thermal conductivity, or	▼ **Lower surface temperatur**
▲ More condensate, or	▼ Lower final dryness, or
▼ Less surface contact	▼ Reduced machine speed
<u>The opposite apply</u>	
▼ Thinner shell …	▲ Higher heat flow, more drying …

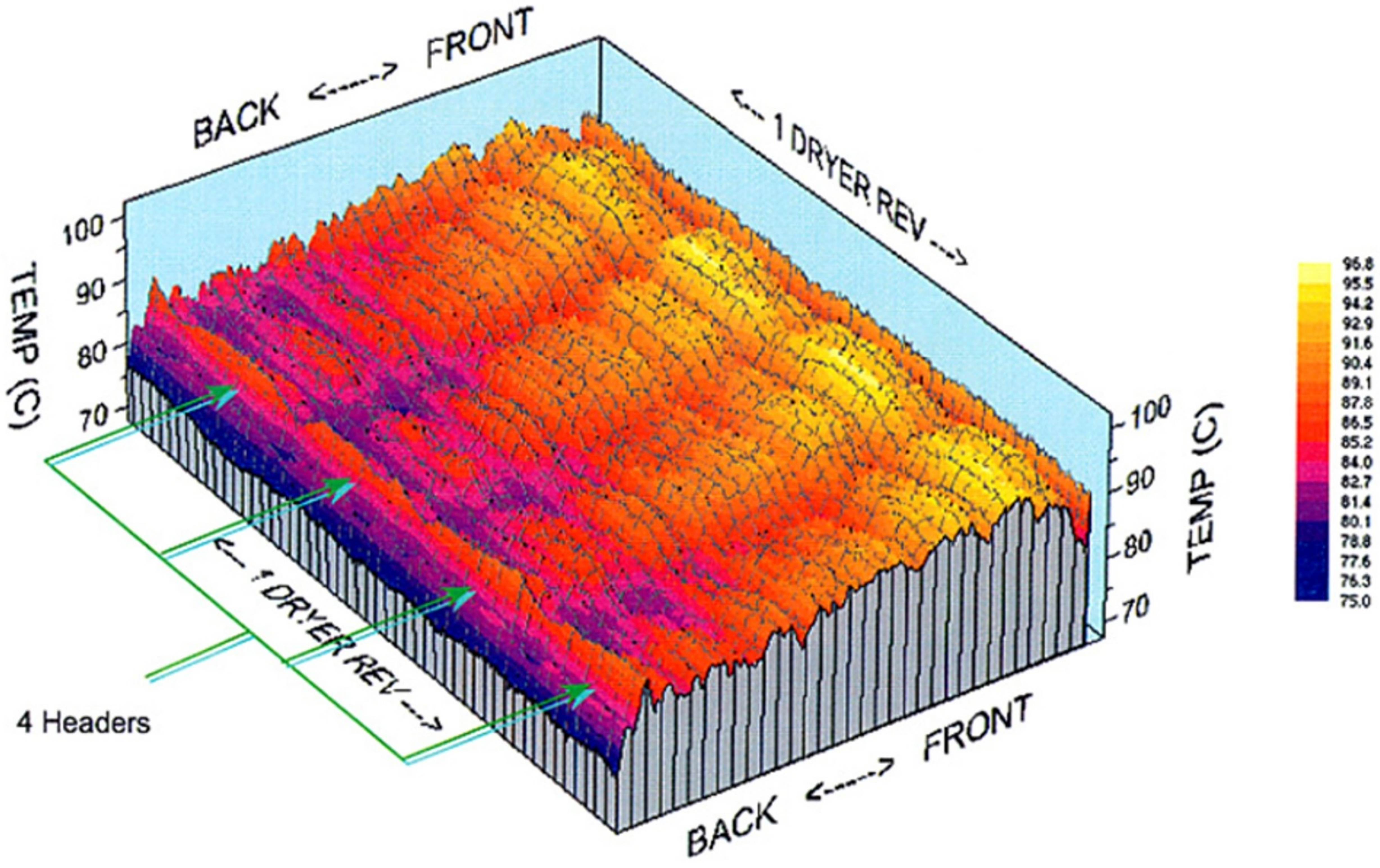
Compensating

Uneven Drying – Example*

Variation	Consequence
▲10% thicker shell, or	▼7% lower k-value
▼10% lower conductivity, or	▼2.7ºC (4.9ºF) lower surf temp
▲20% thicker condensate	▼4% lower heat flow
	▼1.5% lower final dryness, or
	▼3% reduced machine speed

***simplified example for high speed bath tissue production, 50/50 yankee/hood drying split. Many parameters affect the outcome.**

Uneven Surface Temperature



3-D Representation of Typical Yankee Temperature Distribution

source: PROdry

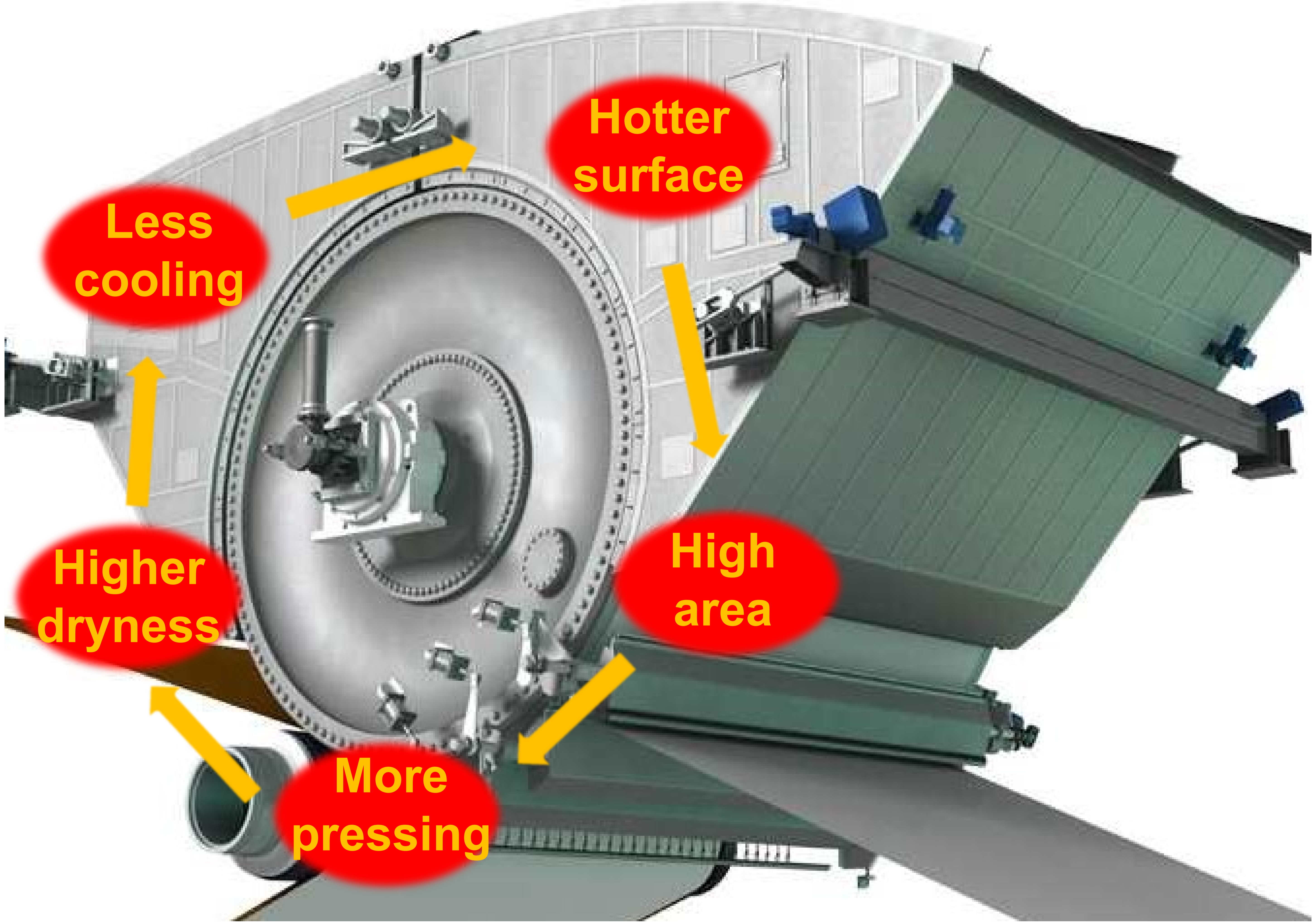
Uneven Surface Temperature or Properties

Coating and creping performance

Surface wear and chatter

TAPPI TISSUECON™ COPRODUCED BY Fastmarkets RISI

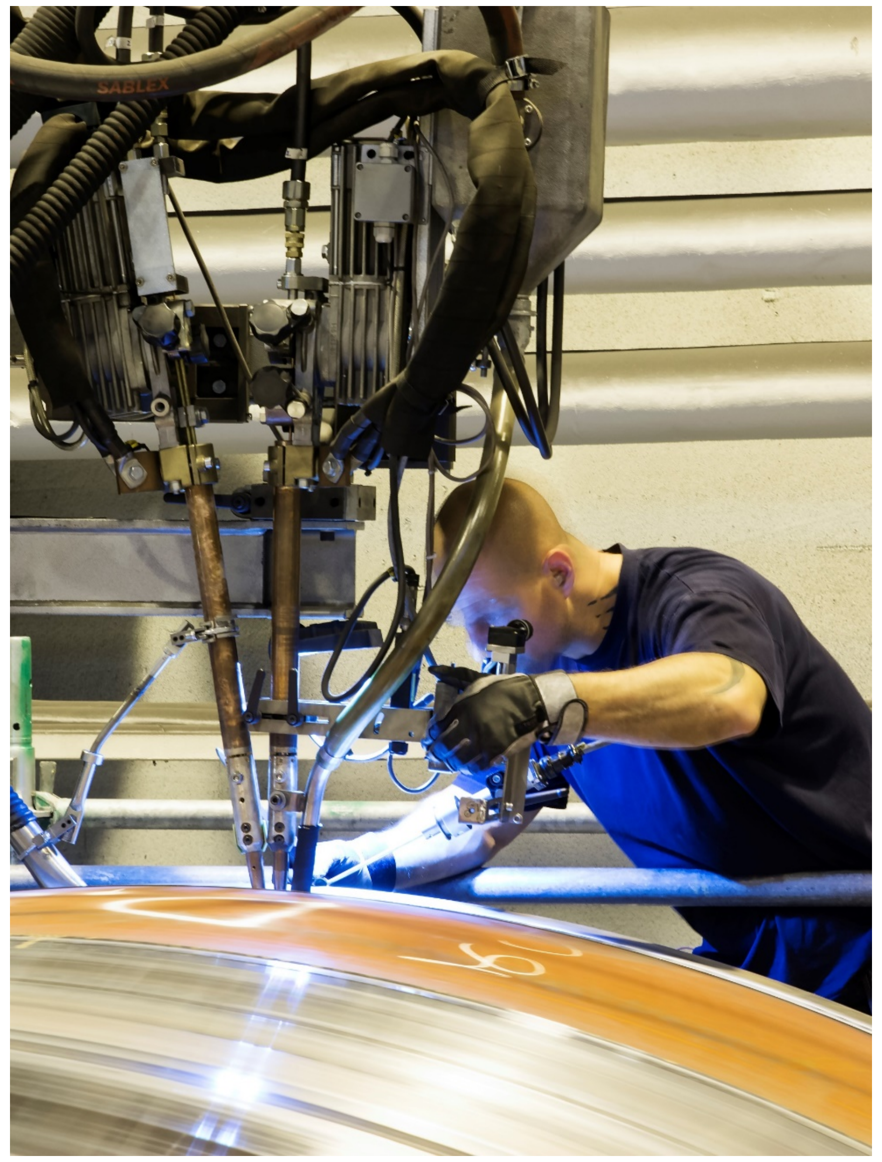
Amplification of Thermal Deformation



Minimizing Variations

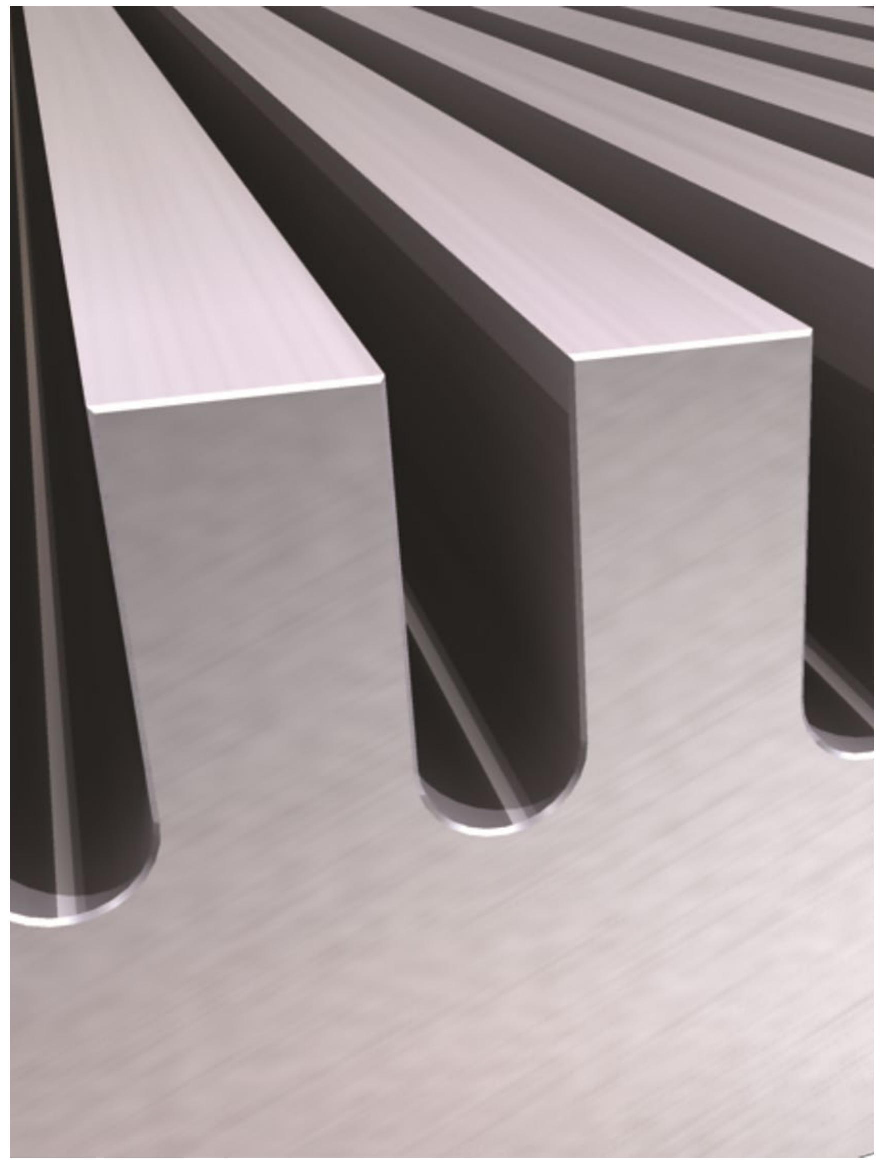
- Variations on the Yankee dryer are minimized by:

Minimizing thickness variation



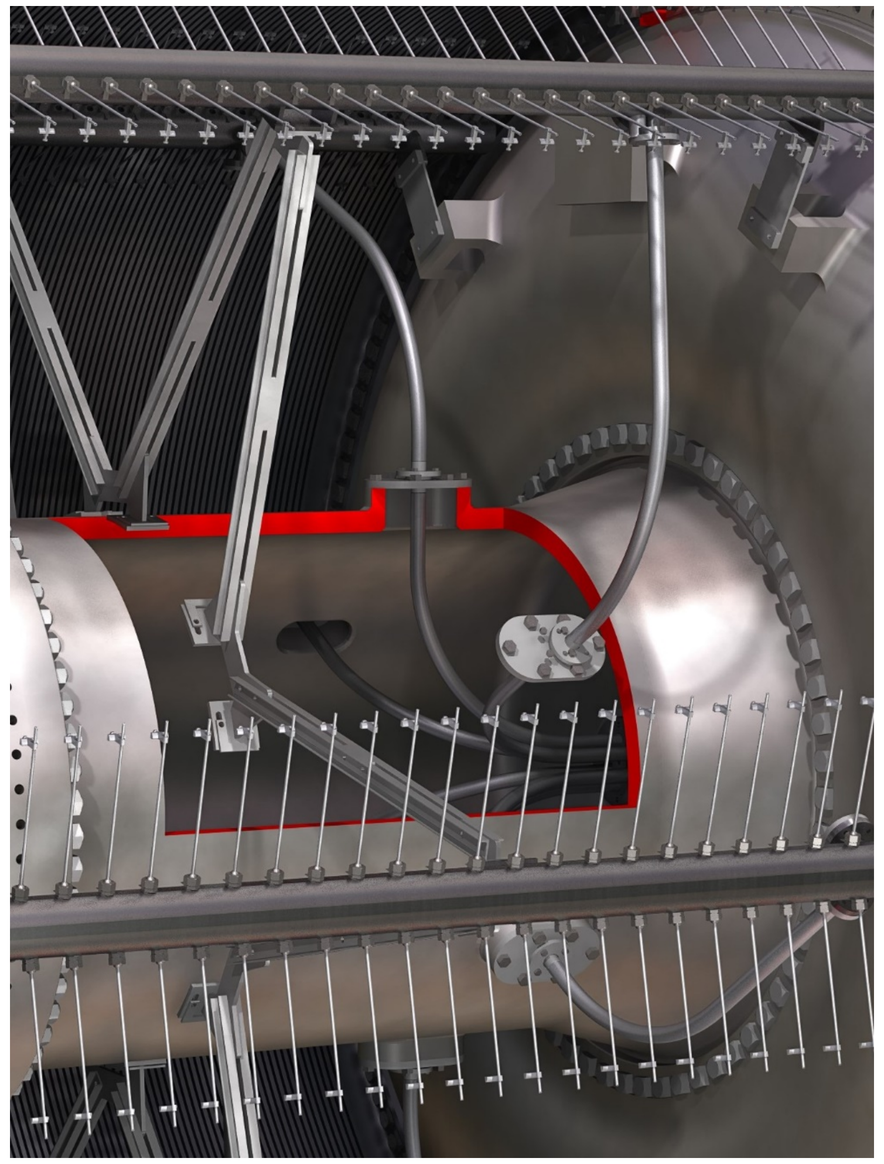
Minimizing conductivity variation

Optimizing shell rib profile



Optimizing shell surface properties

Optimizing condensate removal system



Thank You

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