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Glass tempering: Energy saving possibilities in glass quenching

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seeing it through®

There are several ways to reduce the energy consumption of glass tempering cooling, which are not yet very widely used.

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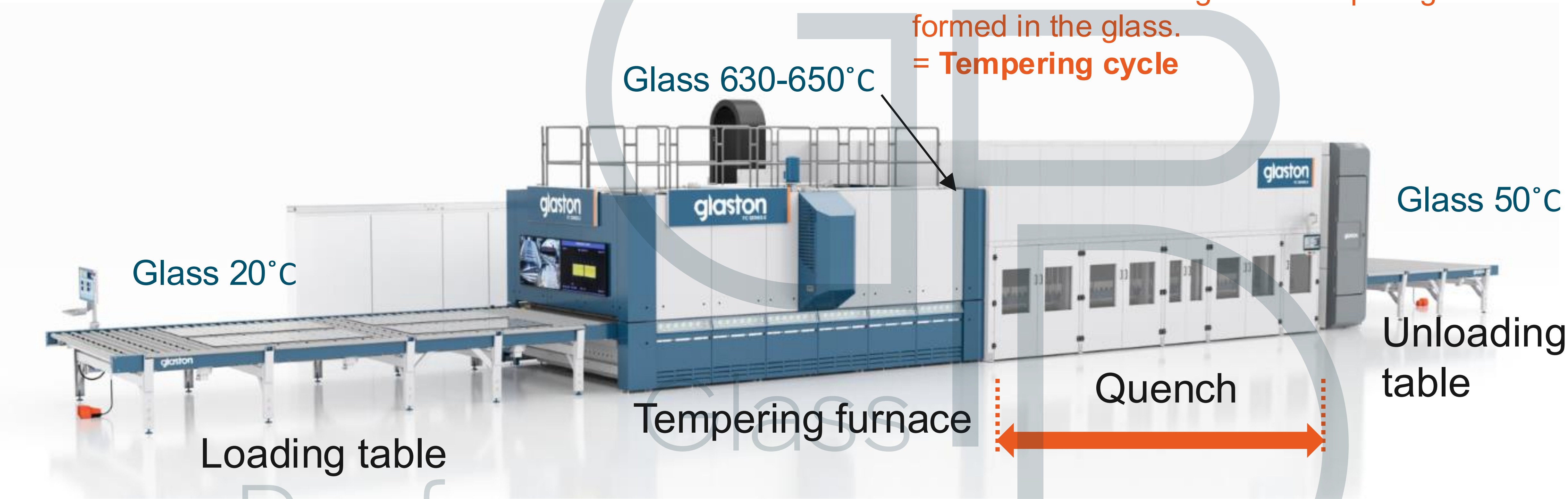
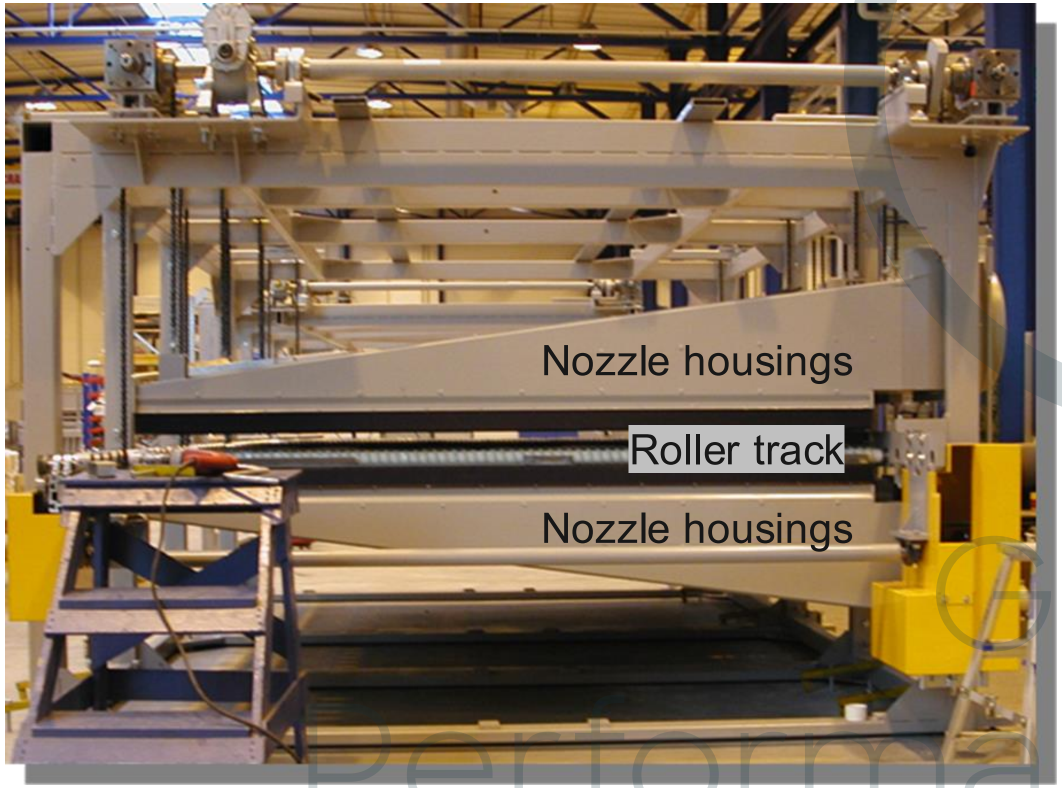
Glass tempering line

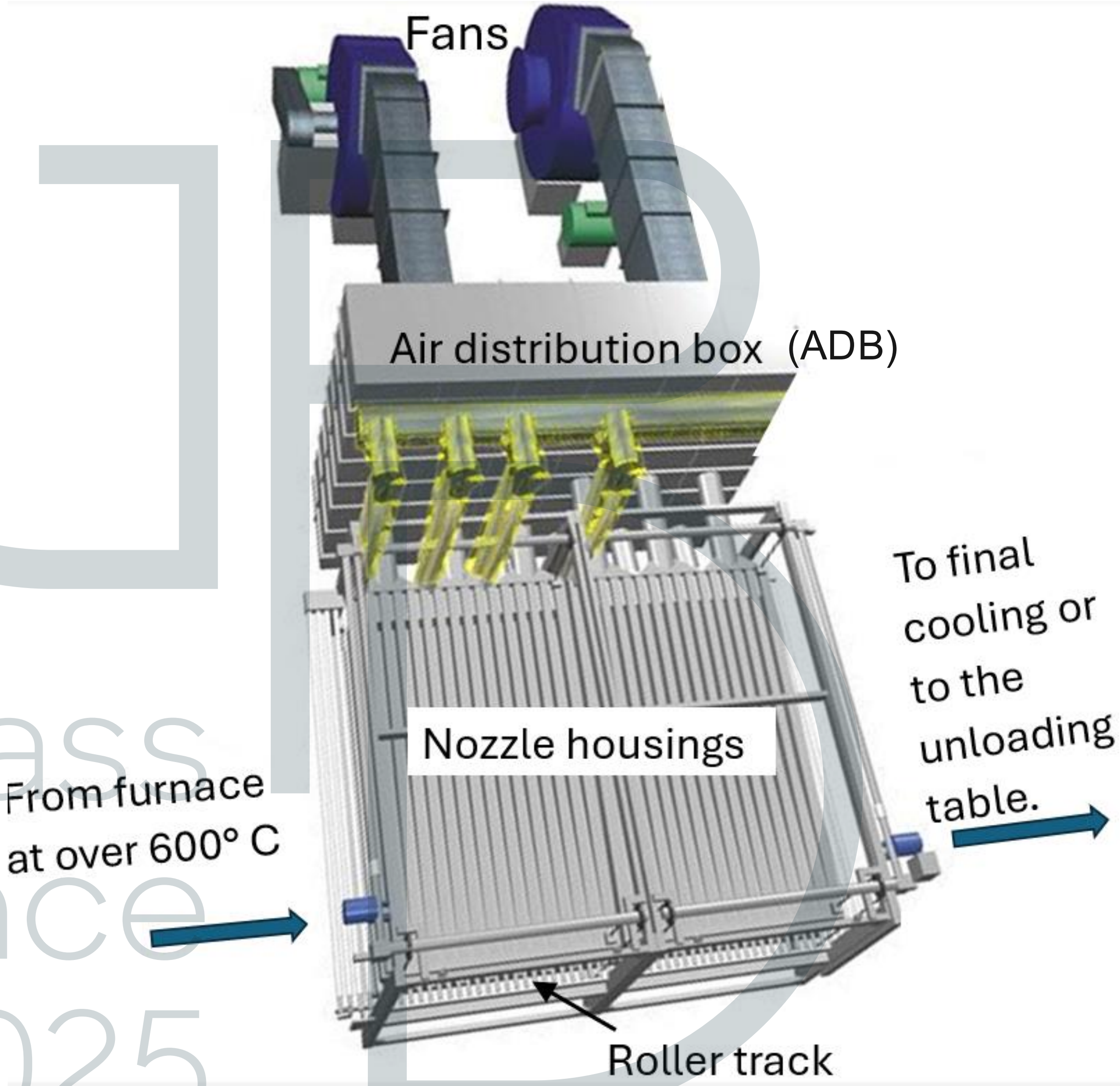
Quench cools the glass from over 600°C to approx. 450°C at the cooling rate at which the desired degree of tempering is formed in the glass.
= **Tempering cycle**



In quenching apparatus in which the glass moves back and forth the quench handles also the **cooling cycle** from 450 to about 50ºC.

Glass tempering quench apparatus





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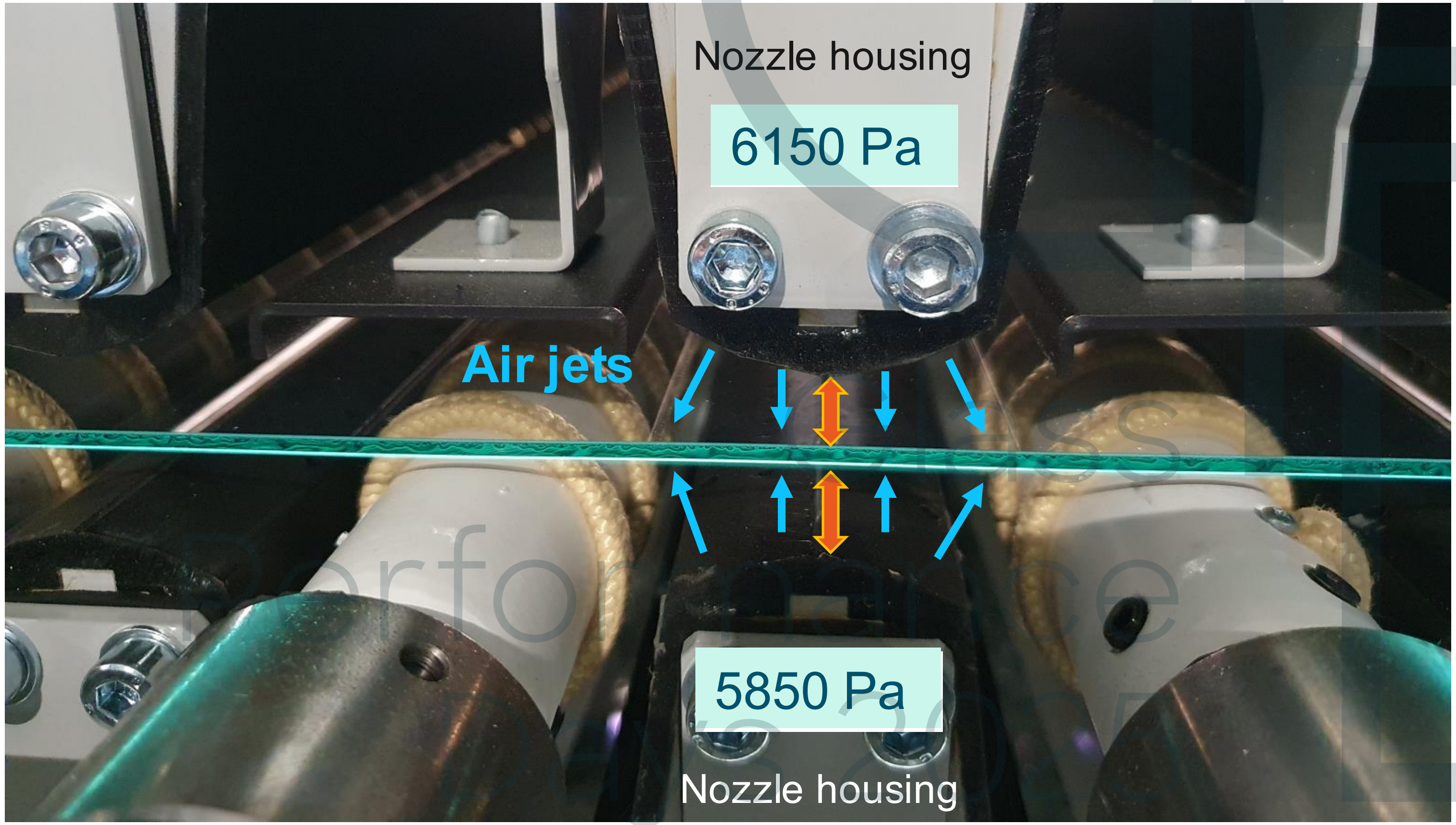
Possibilities to control quenching

Blowing pressure level depends on glass thickness. It is adjusted by changing the speed of the fan impeller.

With air balance valve in ADB the difference of blowing pressure on top and bottom side can be adjusted.

Blowing distance can be adjusted separately on both sides.



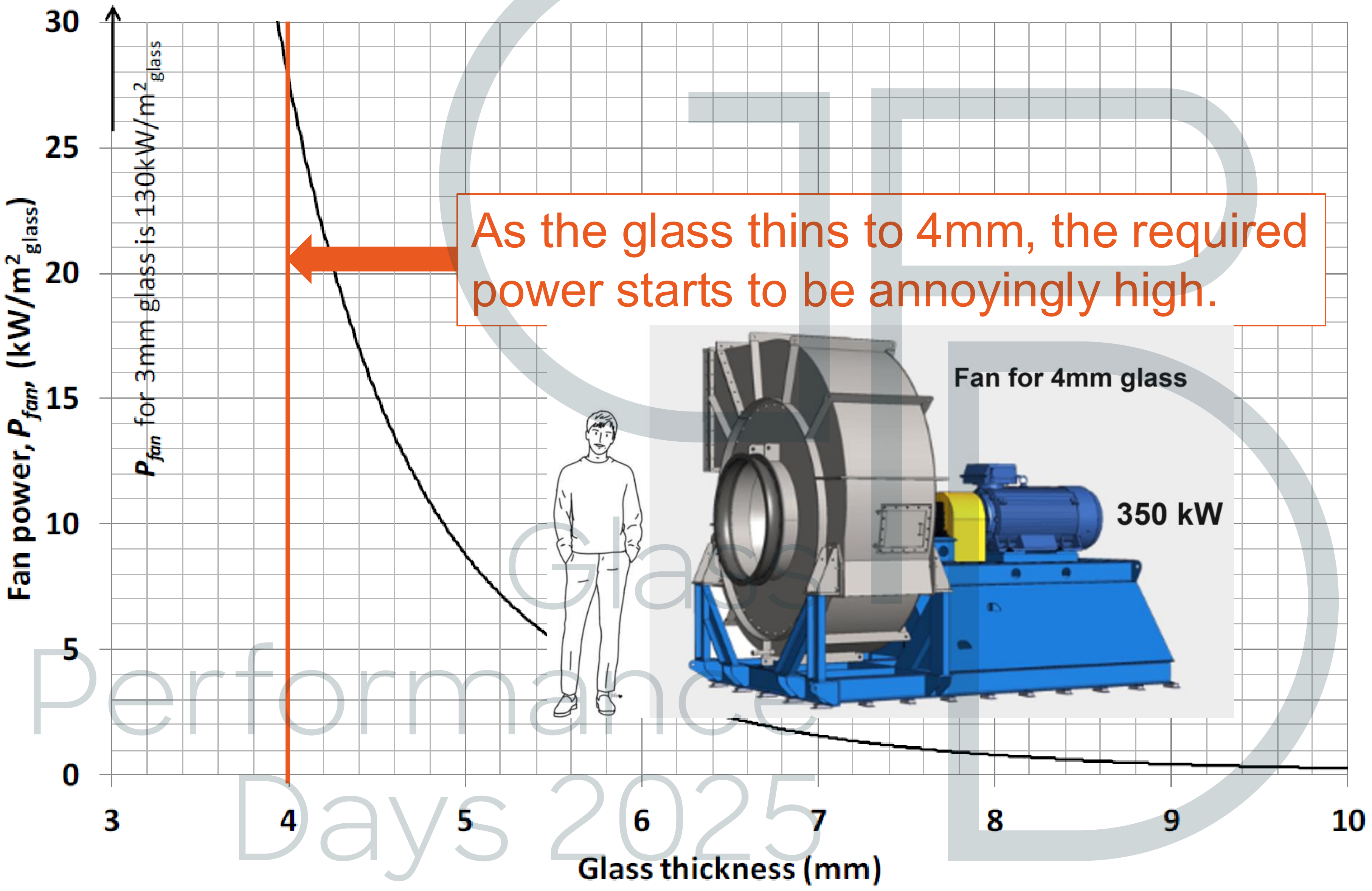
These controls are used to keep glass as flat.

Air jet cooling is a simple and effective method of tempering glass, where cooling can be controlled in many ways.

It is almost perfect method.

Challenges in thin glass quenching with air jets

Fan motor power needed for quenching



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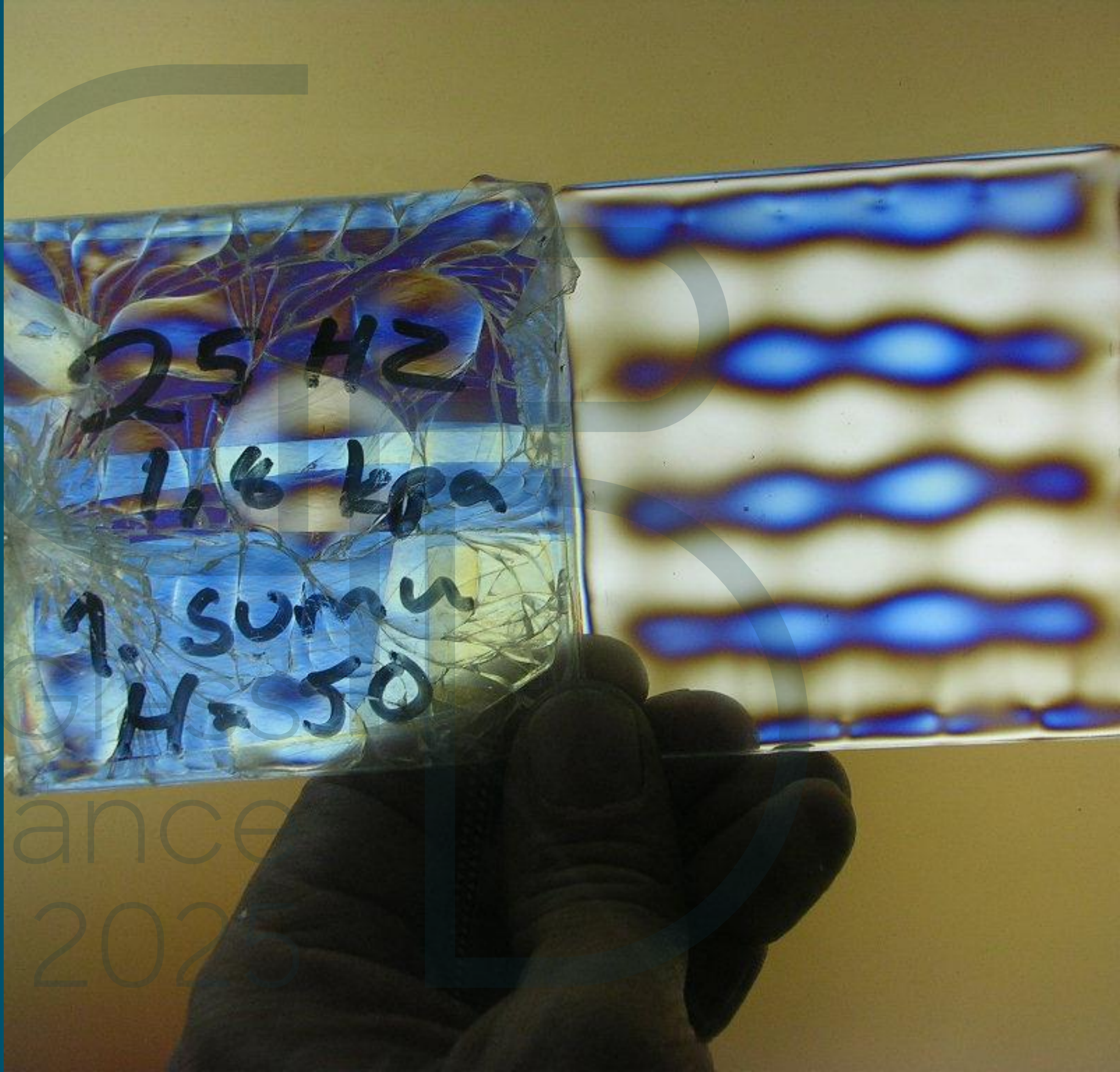
Industry efforts to challenge glass air jet quenching technology

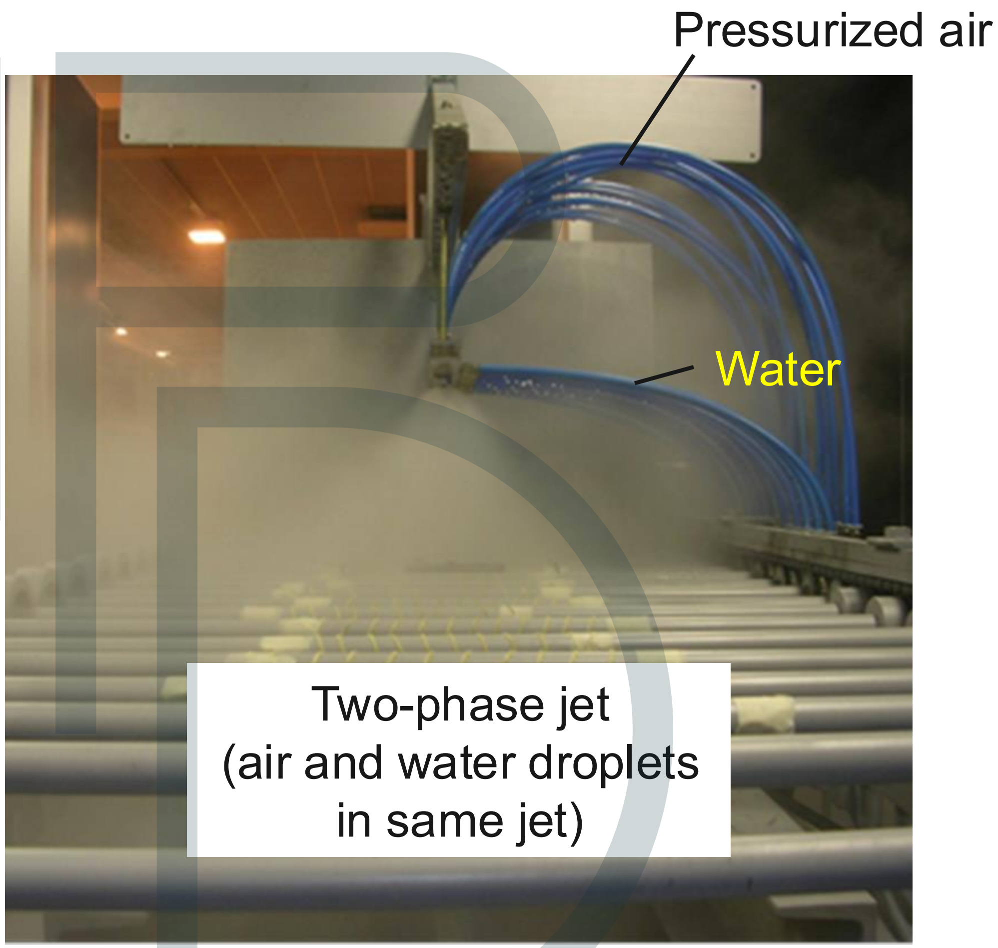


Glass quenching by water spray

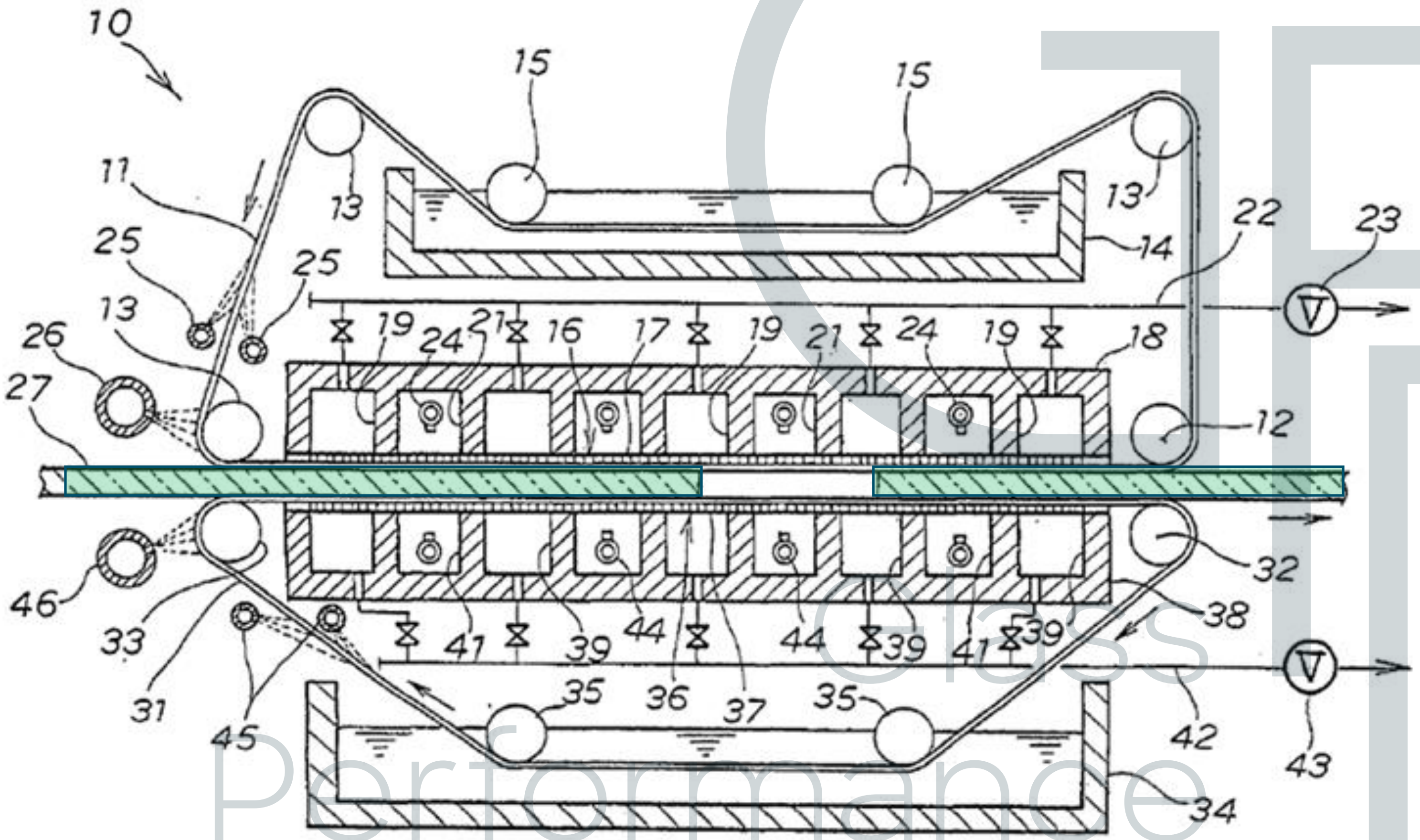
The idea is that the water droplets evaporate when they hit the glass and thus increase the cooling capacity.

In glass water mist tempering attempts glass is cooled with two phase jets or separate air and water spray jets.

- Water is broken down into droplets in a nozzle using compressed air.
  - The formed two-phase jet is used cooling as such or be further mixed with the fan generated air jet.
- The water is broken down into droplets hydraulically (high pressure, small nozzle size) and blown to glass together with fan generated air jets.



Quenching of a glass by contact



Device for tempering glass between wet belt conveyors.
Device adds water evaporation cooling to pure contact quenching.

The idea is that the heat is efficiently conducted away from the glass to the cold object that touches it.

Patent application US2004/0107733A1: Method and apparatus for forcedly cooling sheets of glass and tempered sheet glass. Nippon Sheet Glass Co. Ltd, 2004.

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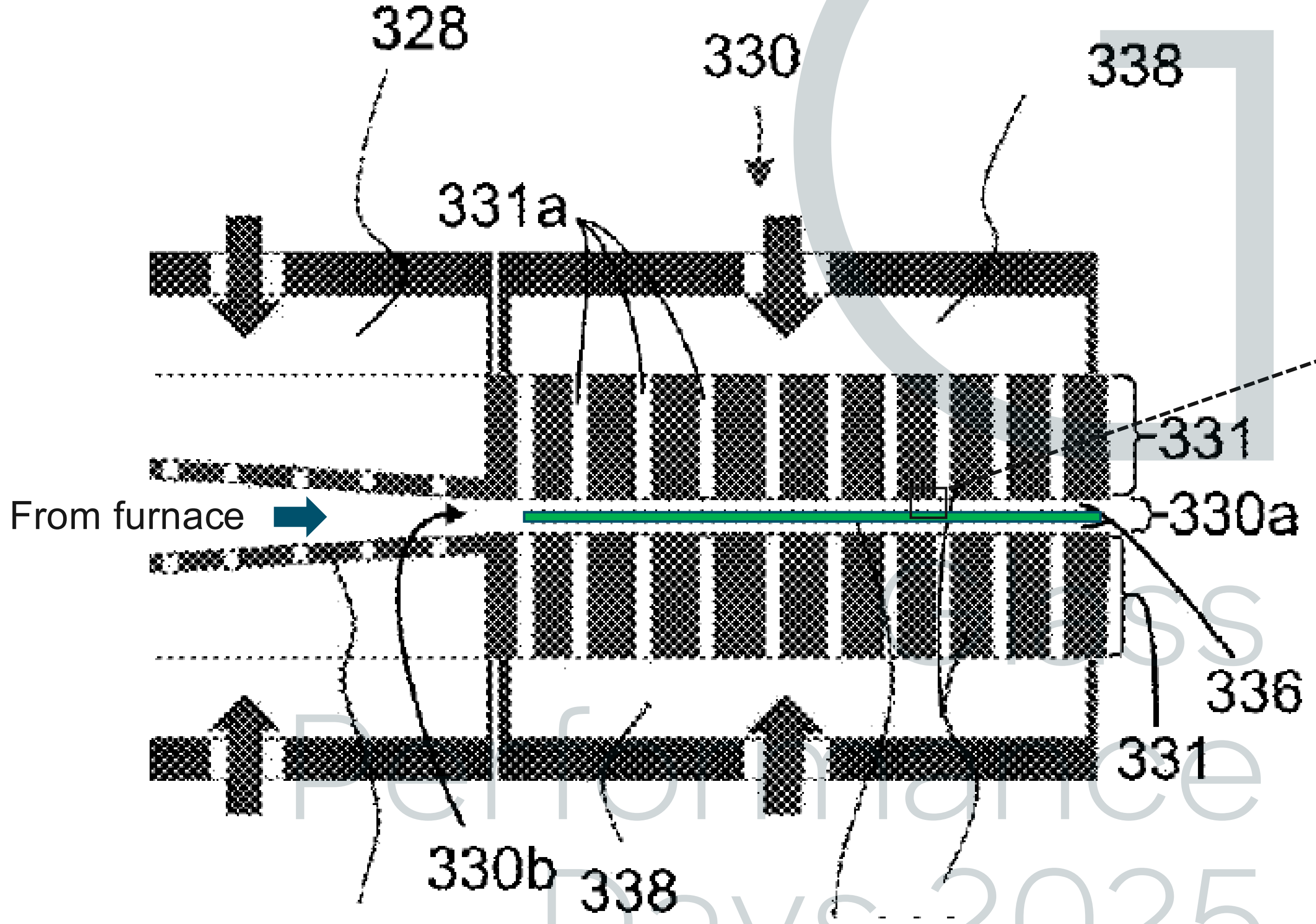
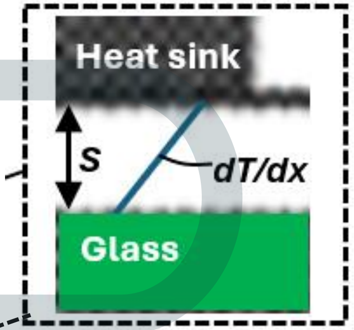
Quenching of glass with the help of gas thermal conductivity



S = thickness of the gas gap



The idea is that narrow gas gap conducts the heat from the glass to the heat sink effectively.

Heat transfer coefficient *h*

$$h = {}^{k}/_{S}$$

k(air)=0.05 W/(mK)

S = 0.05 mm

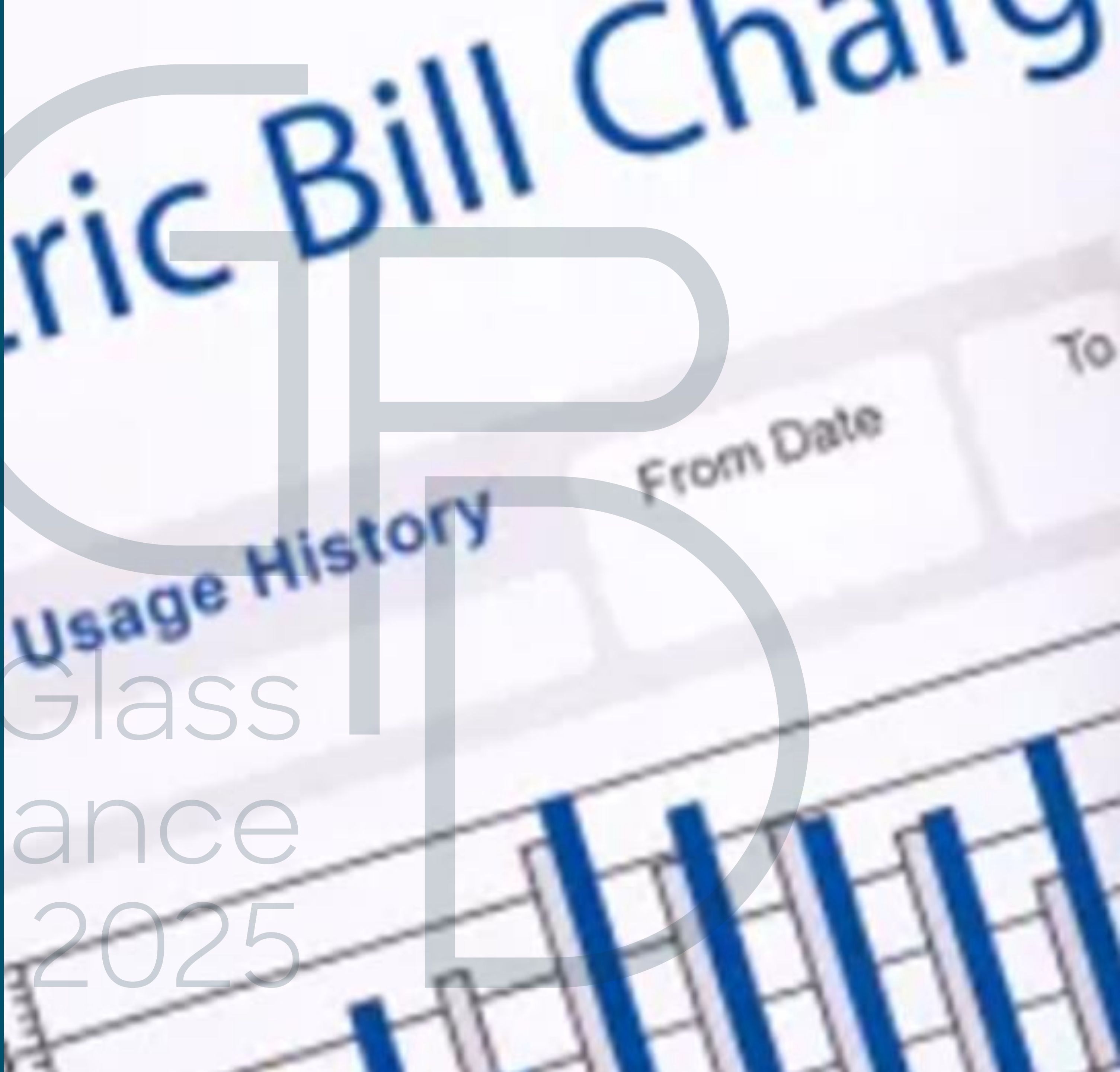
➔ *h* = 1000 W/(m^2K)

Patent US9296638B2: Thermally tempered glass and methods and apparatuses for tempering of glass. Corning Inc., 2016.

The possibilities of the technologies that challenge glass quenching with air jets seem small, at least in large-scale solar and architectural glass tempering.

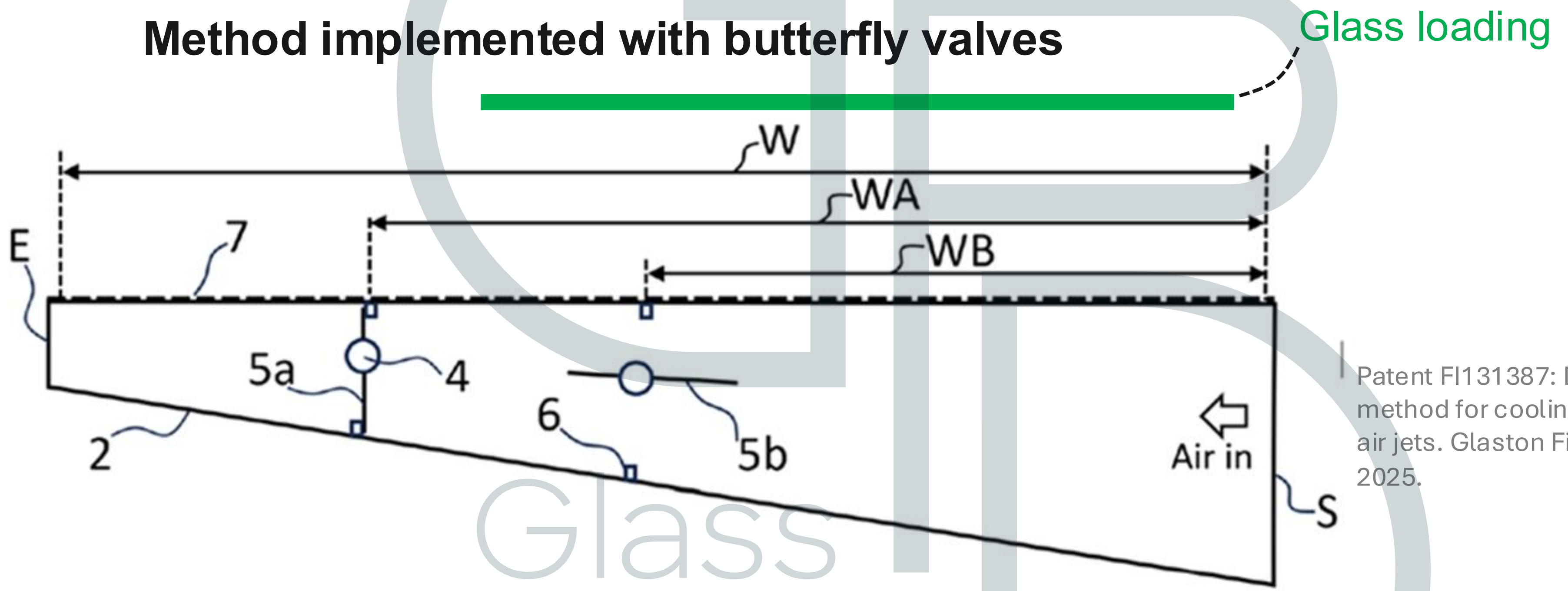
Air jets will be used.

Possibilities reduce energy consumption in glass air jet quenching



Elimination of unnecessary blowing along the width of the quench

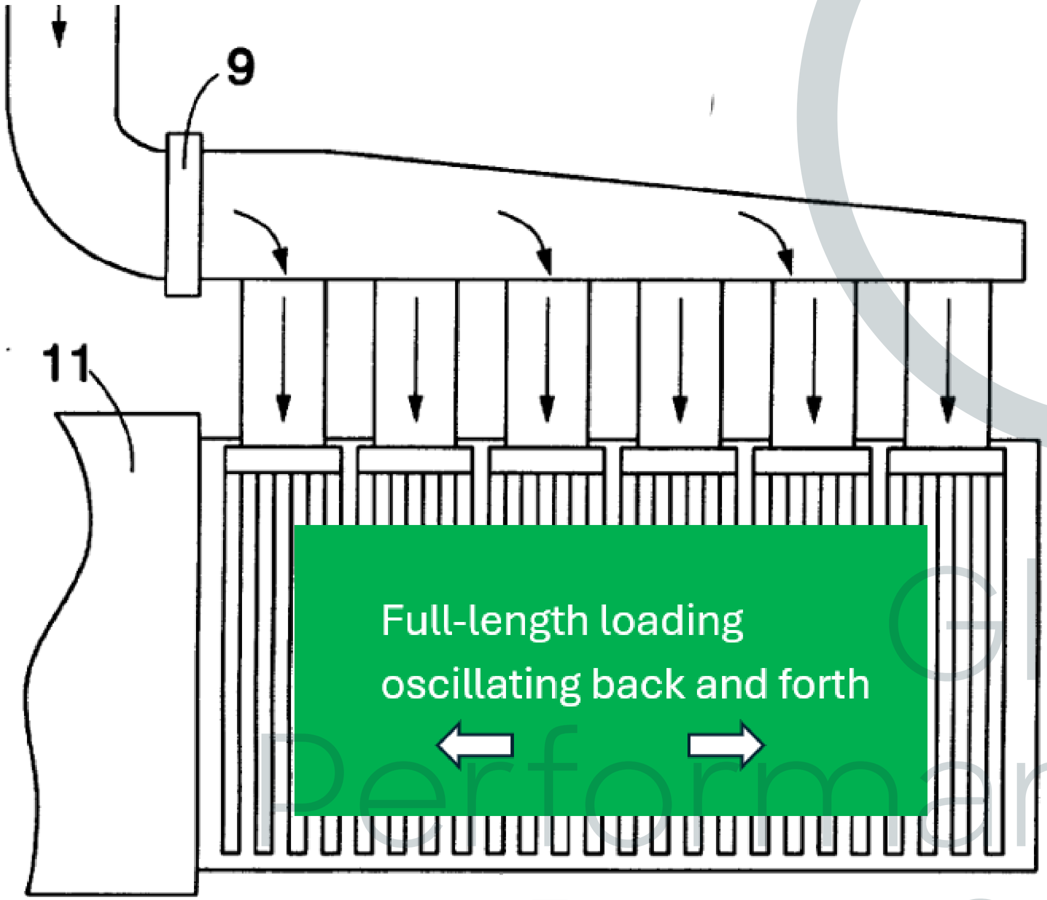
Method implemented with butterfly valves

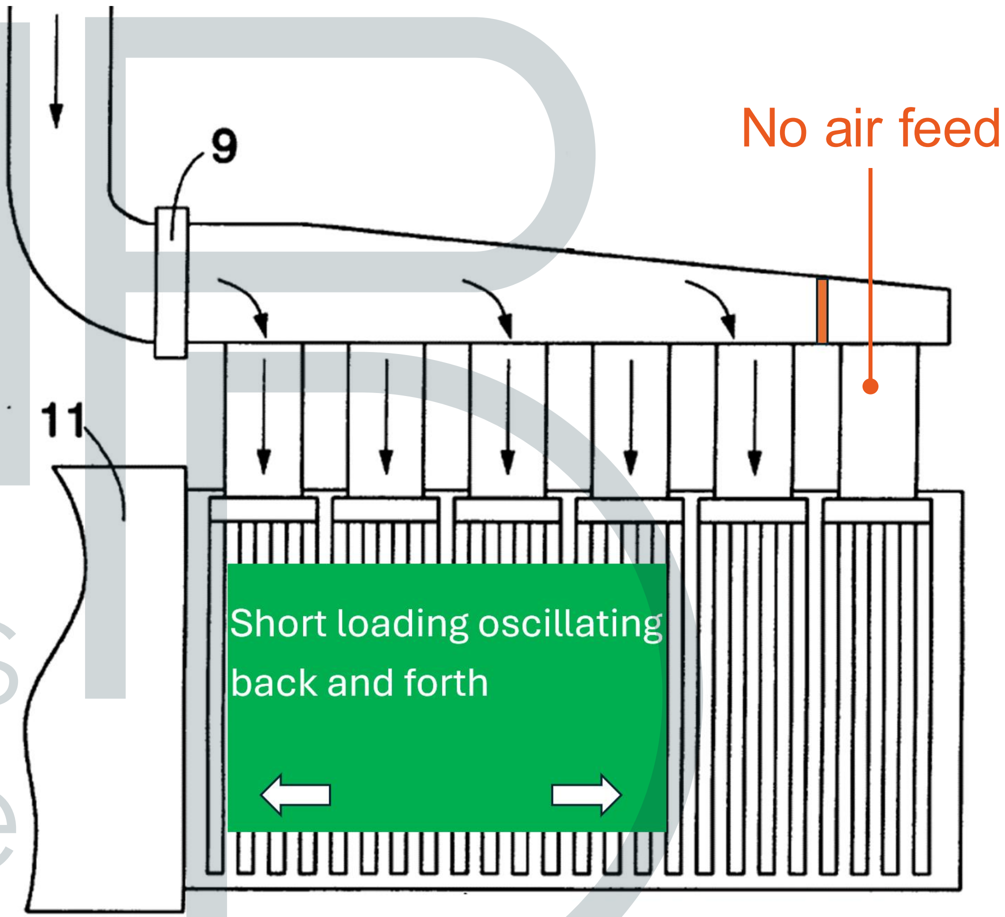


Patent FI131387: Device and method for cooling glass with air jets. Glaston Finland Oy, 2025.

If the sensors detecting the width of the glass loading find that the glass loading does not reach the width controlled by the perforated plate or butterfly valve, blowing to this length is prevented.

Elimination of unnecessary blowing along the length of the quench





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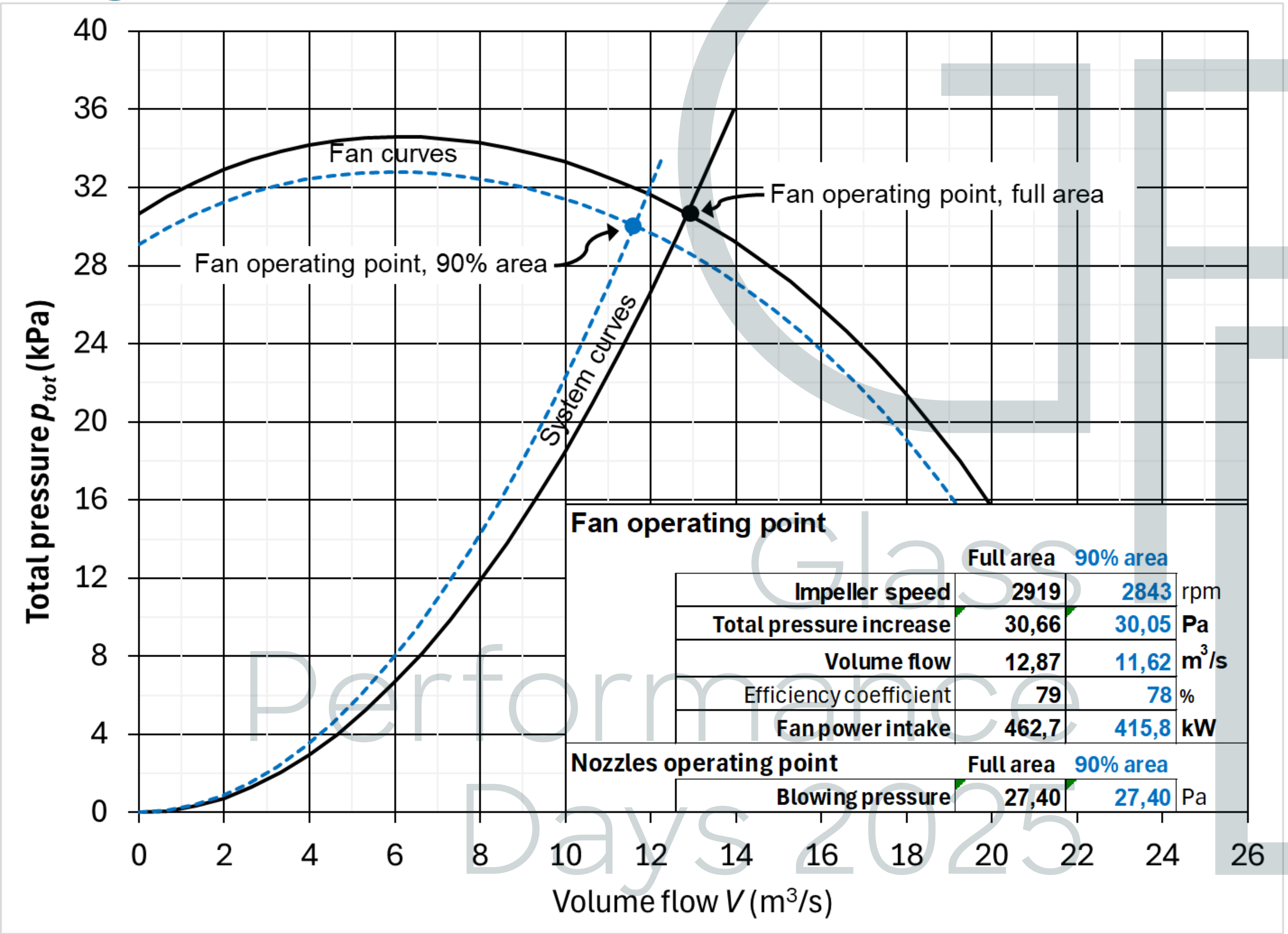
Elimination of unnecessary blowing along the width or length of the quench



Fan operating point	Full area	90% area	
Impeller speed	2919	2843	rpm
Total pressure increase	30,66	30,05	Pa
Volume flow	12,87	11,62	m^3/s
Efficiency coefficient	79	78	%
Fan power intake	462,7	415,8	kW
Nozzles operating point	**Full area**	**90% area**	
Blowing pressure	27,40	27,40	Pa

The relative reduction in fan motor power corresponds to the relative reduction in the blowing area.

→ **10% blowing area reduction saves 10% fan motor power.**

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Fan impeller made of carbon fiber to instead of steel

- The ability to ramp down rotation speed during idle phases and then accelerate to full speed in seconds differentiates carbon made impeller from steel one.
- This offers significant energy saving for cyclic processes.

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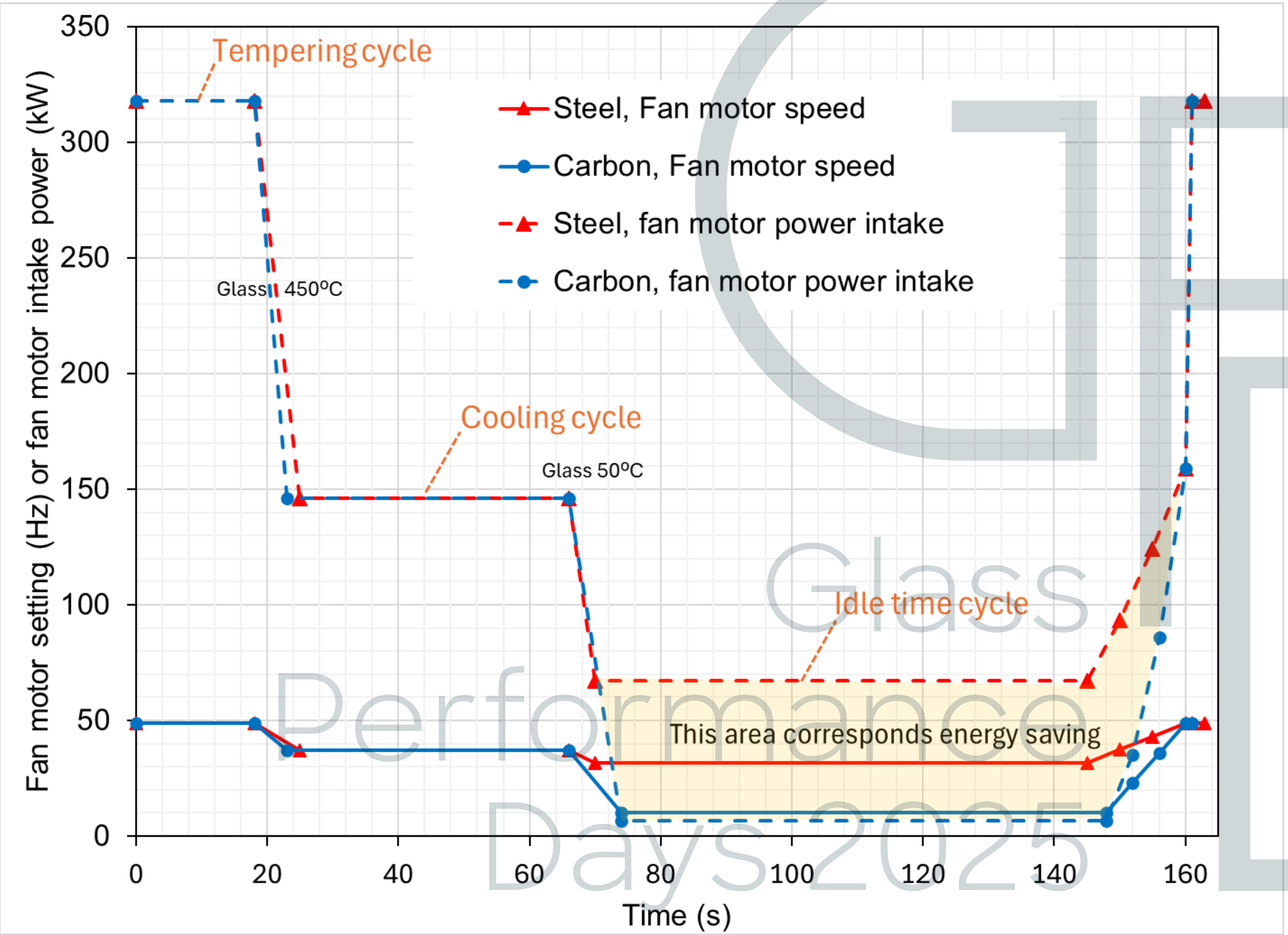
Carbon fiber vs. steel in quenching cycle of 4mm glass loading



The area between the fan motor power curves corresponds to the difference in energy consumption, which is 1.4 kWh per glass load.

This corresponds to a reduction in electricity consumption of about 25%.

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Cooling of air used in quench, example 3mm glass tempering

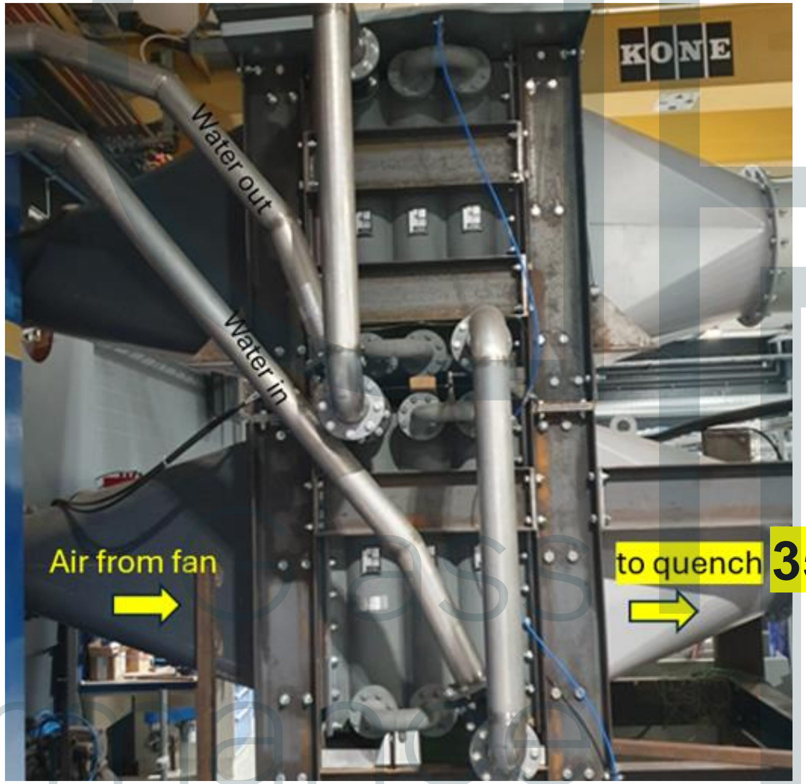
Fan

- Air at fan inlet 20˚C.
- Air pressure increase in fan 25 kPa.
- Air temperature at fan outlet ≈ 45˚C.

20˚C → **FAN** → **45˚C**

$\Delta T_{air} \approx \Delta p \text{ in } kPa$

Air cooling device between fan and quench



35˚C

Quench

- Air temperature in quench ≈ 35˚C.
- Thus, air temperature decrease in air cooling device is 10˚C.
- This allows 3% reduction of fan impeller speed leading to 6% lower blowing pressure.

➢ **Electrical power taken by a fan motor decreases 9%.**

Examples of estimated annual savings

Large oscillating type quench, typical production rate				**Main production 4mm and 6mm glass**
Annual electricity consumption in quenching		**200**	MWh/year	
Annual savings	Blowing width reduction	**20**	MWh/year	when average width reduction is 10%
	Carbon impeller	**40**	MWh/year	
	Air cooling	**0**		it's not worth it when thinnest glass is 4mm

High production rate continuous type solar glass tempering line				
Annual electricity consumption in quenching		**3400**	MWh/year	
Annual savings	Blowing width reduction	**340**	MWh/year	when average width reduction is 10%
	Carbon impeller	**0**		does not help in continuous type lines
	Air cooling	**260**	MWh/year	when average drop in air temp is 10ºC

Design of glass quenching system

- Basic design of quenching system also offers some energy saving possibilities.
  - Decreasing of pressure losses.
  - Better fan efficiency.
  - Dimensioning of nozzle array.
  - More precise control of tempering cooling.

Check out my GPD2025 paper!

3.5. Design of glass tempering cooling system

From the energy consumption perspective, it is particularly important that the tempering cooling system with fans, air supply ducts, and nozzle housings has been designed with this in mind.

Pre-planning for sales quotations begins with calculating how much tempering pressure is needed to meet customer requirements (the thinnest temperable glass) in the conditions of the factory location. The significant oversizing of the tempering fans leads to a higher asking price due to the rising price of the fan and electrical equipment it needs. Meanwhile, significant undersizing easily leads to problems and expensive backorders later. However, the only factor affecting energy consumption in fan sizing is that the fan's good efficiency range coincides with the tempering process's operating points. In this respect, the sizing is unlikely to completely fail. Despite this, more accurate dimensioning brings up to 3% continuous energy savings. However, the manufacturer of a glass tempering machine often has to take commercial matters into account when choosing a quench fan. The purchase price for dozens of identical fans is significantly lower than for dozens of fans tailored for different processes. In some cases, the sale of a customized fan as an additional option would allow further energy consumption savings.

Pressure losses in the blowing ducts are a significant addition to energy consumption. It is particularly important to design the ducts to avoid additional pressure losses. In this respect, the design is often at least quite successful, yet further development brings 2 to 5% energy savings if practical obstacles do not significantly limit the space allowed for air ducts.

The current blowing housings with their nozzle systems are already quite optimized in terms of energy consumption. However, sufficient convection uniformity is also an important criterion in their design so that the impact of air jets on the tempered glass does not form a residual stress pattern (anisotropy) that disturbs the eye. However, it is obvious that with the development of the nozzle system, it remains possible to achieve energy consumption savings of at least a few percent.

More precise control of tempering cooling is one option with energy-saving potential. For example, savings are made by not tempering the glass to an unnecessarily high residual stress in relation to the requirements of safety glass standards. Inventions such as [13] help with this.

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Conclusions

In a typical batch type glass tempering line for mixed size glass production about 200 MWh of electricity is consumed per year for glass quenching, which corresponds about 50 tons of CO_2 emissions in EU.

- The energy consumption increases as production and the size of the tempering line increase, and when the average thickness of the glass decreases.
- In a continuous type high-capacity solar energy glass tempering line, the consumption is even tens of times higher.

- **In conclusion, there are clear possibilities to cut this energy consumption and CO_2 emissions.**

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For energy saving investments the payback period and/or the reduction of CO_2 -emissions must be attractive to get possible users convinced.

These are strongly dependent on the expected tempered glass production volumes/thicknesses of the potential user.

Contact ***mikko.rantala@glaston.net*** to get case-specific estimates.