

**RENOLD** | Tooth Chain

**Perfectly Aligned for Glass**  
Silent Chain Technology  
for the glass industry





*Safe, robust, and efficient. The glass industry is demanding. Drive and transport solutions not only need to reliably master operating processes, they also need to be highly resistant to harsh conditions and incredibly efficient. Inverted tooth chains cover all these requirements. They offer precise running characteristics, guarantee a long service life, and enable layouts optimized for specific applications with the utmost efficiency. And they have no qualms when it comes to high temperatures.*

# Experience for the glass industry

Automation solutions with inverted tooth chains from Renold ensure cost-effective production

## Tailor-made for your application: drive and transport solutions with inverted tooth chains

The diverse tasks and working conditions in the glass industry require solutions that are just as varied. Based on a comprehensive product program and specific configurations, we have geared our spectrum of services toward our users to consistently offer solutions that are specifically tailored to their applications. With unparalleled product quality and expert service. Automation solutions with inverted tooth chains from Renold help you to significantly increase the service life of your systems, minimize downtimes, and ensure cost-effective production in the long term. Our inverted tooth chains master these goals – every day, around the world.

- ➔ Technology leader for inverted tooth chain applications
- ➔ Unparalleled variety – the right inverted tooth chain for every application
- ➔ Over 100 years of experience, active worldwide

Together with our customers, we have developed a broad product portfolio that is precisely tailored to meet the needs of the industry. The result? Products, systems, and solutions that are best in class in all respects and exactly fit your purpose. Talk to one of our industry experts available throughout the world.

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# Quintessential clarity

*The very essence of clear-cut. Bottles, windshields, aquariums – without glass, we'd see far less, whether from the inside or out. This is only one facet of this fascinating material that enriches our lives in so many areas that we often take it for granted.*



# Glass – a natural part of all

## The industry sectors: production and finishing as diverse as the products themselves

The glass industry has become highly diversified. Specialized production processes have developed, with the emergence of completely new work processes. We have been instrumental in shaping these developments and can provide the right solutions for nearly all drive and transport tasks in the individual sectors with inverted tooth chains. All solutions were created with practical situations in mind, in close cooperation with end-users.



Hollow glass industry

*Glass containers, glass packaging for beverages, food, cosmetics, pharmaceuticals, gastronomy*



Sheet glass industry

*Vehicles, sheet glass for the construction industry, interiors*



Specialty glass industry

*Solar industry, medical technology, optics, illumination, precision mechanics, glass for electronic devices, fiber optics*

## The markets: glass products are an integral part of our daily lives

Glass is a highly versatile and malleable material. It also offers unique characteristics which make it indispensable in numerous products. Today, glass not only plays an important role as an object of everyday use but can be increasingly found in new areas – in research, science, and numerous cutting-edge industries.

- Food and beverage packaging
- Household, gastronomy, furnishings
- Motor vehicles, electrical devices
- Windows, facades, construction industry
- Optics, solar, research, science
- Medicine, pharmaceuticals, cosmetics
- Chemical and general industrial applications

## Requirements for the efficient production of glass products are constantly increasing

The glass industry needs to ward off a growing number of competitors and confidently counteract efforts to replace glass with other materials. These two main trends demand future-proof solutions and maximum efforts in the areas of innovation and efficiency.

- Improved functionality
- Increased cost-effectiveness
- Absolute quality assurance
- Greater energy efficiency
- Optimum machine safety
- Total cost of ownership

Cost-effectiveness throughout the entire lifecycle (TCO) of a machine or system is the key decision-making factor. Drive and transport solutions with inverted tooth chains ultimately provide the best results due to their extremely low-wear and reliable functioning.

# The fascination of glass – a retrospective

## Unceasing radiance and charisma

We will never know how the discoverers of this unique material felt thousands of years ago as they first created this extraordinary composition. Although the first glass-like objects are only distant relatives to the optical brilliance and radiance of modern glass products, these inventors gave life to a new fascination. And, with that, a history of success: from its earliest beginnings to its emergence as a skilled trade, up to contemporary industrial production, the manufacture of glass has developed into an important industry.

Glass is an ideal combination of **beauty and function**. Glass conveys **lightness and transparency**. It features a wide variety of shapes, delicate structures, and brilliant colors.

**Glass is fascinating** and lends a special radiance to many contexts.

Glass has fascinated for millennia and continues to do so today



3000 B.C.

1500 B.C.

500 B.C.

16. th c.

Glass melting begins in Egypt. First organized production of glass

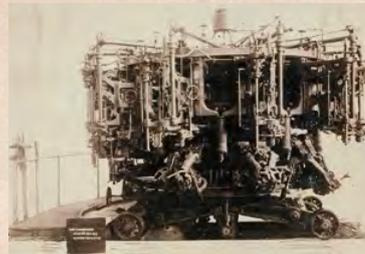
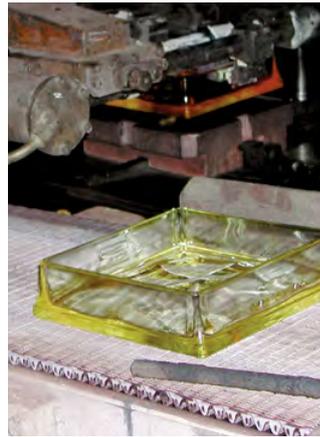
Independent trade with pressing and melting in molds

Invention of the blowpipe in Phoenicia (first glasses)

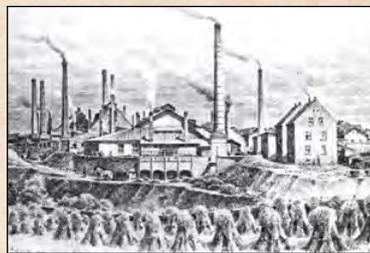
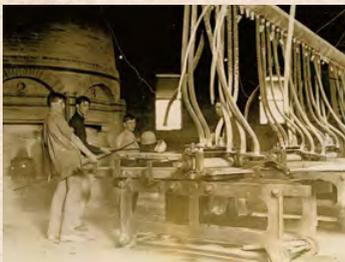
Glassmaking reaches Venice (Murano) and Germany.

# From its first hour

Part of industrial production from its first hour: inverted tooth chains as drives and conveyor elements for hot glass transport



## Start of industrial production



1886

The first glass blowing machine from Ashley and Arzwell (approx. 100 bottles/h)

1905

1908 Beginning of inverted tooth chain production in Germany  
Owens + Bock invent the first fully automatic bottle blowing machine

1923

Pilkington + Ford: continuous rolled plate glass for automobiles

1927

First use of an IS-machine

1930

Drives with inverted tooth chains enable higher speeds

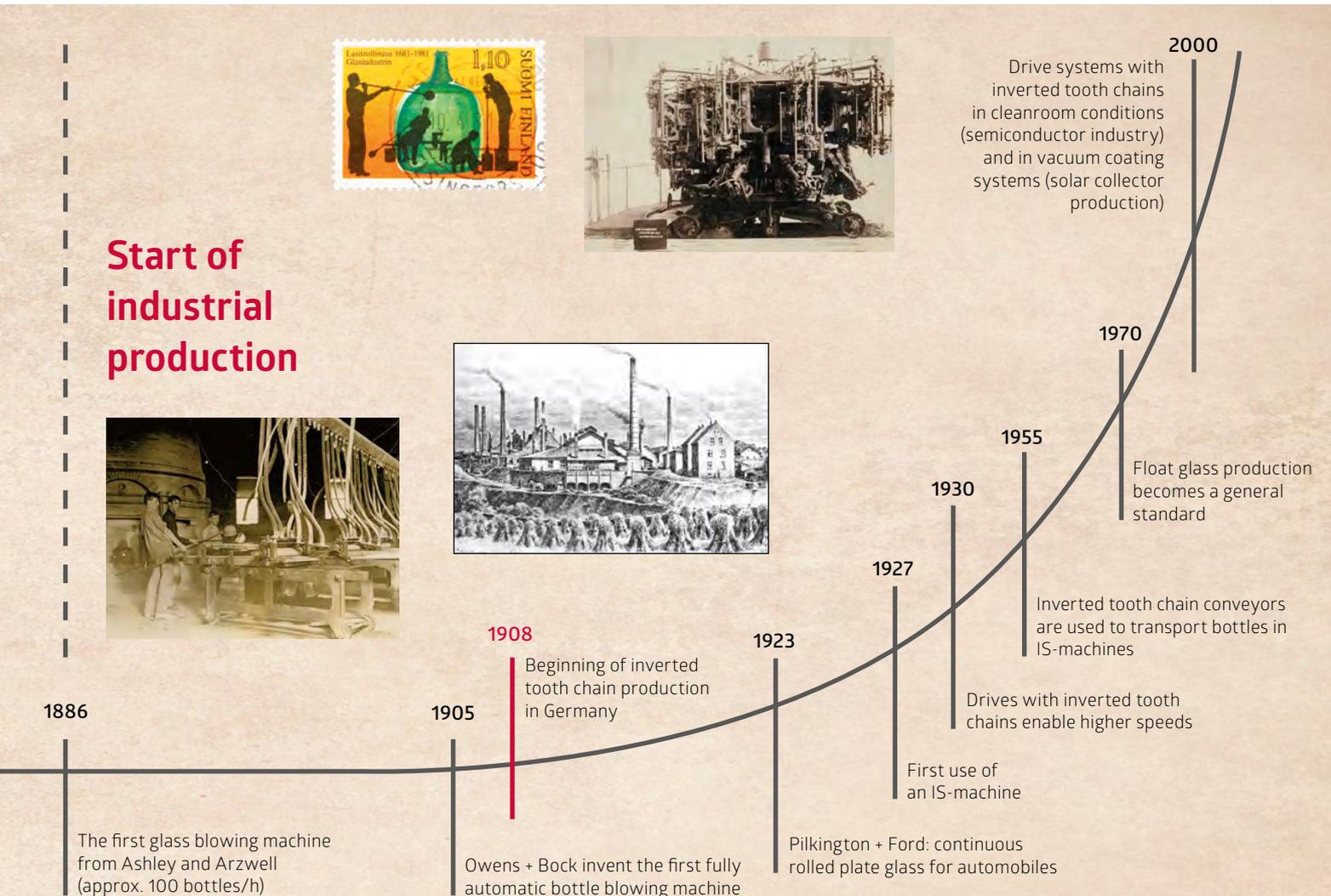
1955

Float glass production becomes a general standard

1970

Drive systems with inverted tooth chains in cleanroom conditions (semiconductor industry) and in vacuum coating systems (solar collector production)

2000



# From the raw material to the individual product

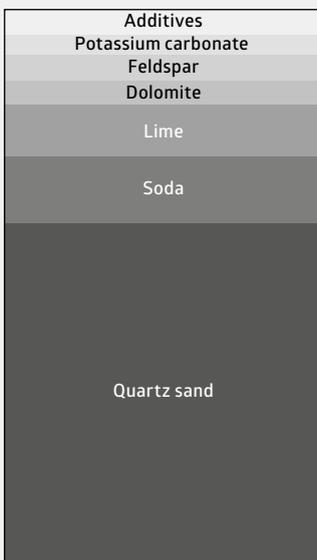
The basic processes in glass production remain the same: mix, melt, shape, anneal, cool.

*Nevertheless, the heat is on: speed, reliability, and accuracy are of the essence. It's precisely these qualities that make our inverted tooth chains ideally equipped to handle all production processes.*

**Glass production: consistently throughout the millennia**  
 Sophisticated products increasingly rely on certain "extras" and small, yet critical details. However, the basic process stages in glass production remain the same, whether in hollow glass, sheet glass, or the wide variety of segments in the specialty glass industry. A specific mixture is melted, transferred to an individual shape in various processes, and finally undergoes finishing to create the final product. Our inverted tooth chains work as drives in forming machines and ensure safe transport of products in all segments of the glass industry.

- ➔ Glass melting, followed by individual process steps
- ➔ Initial processing in specific forming machines: blow molding, float, bending, drawing, pressing, casting
- ➔ Annealing, quality control, and cooling

## What is the composition of glass?

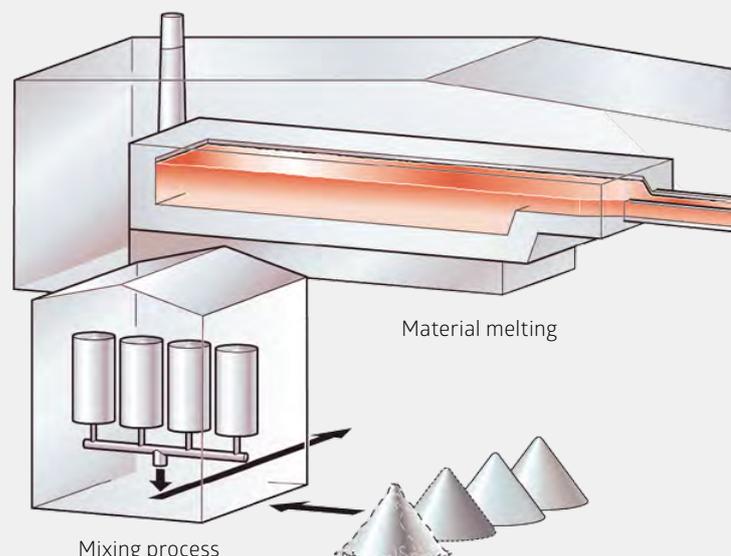


Glass consists exclusively of natural and nature-identical anorganic substances and is fully recyclable.

The actual selection and proportions of basic materials and additives determine its quality. The main raw materials are quartz sand (70%), sodium carbonate (13%), and lime (10%), as well as feldspar, dolomite and potash. Quartz sand is increasingly replaced by recycled glass in some areas.

Basic material composition

## Example: hollow glass production process



# Inverted tooth chains: ideal for hot materials

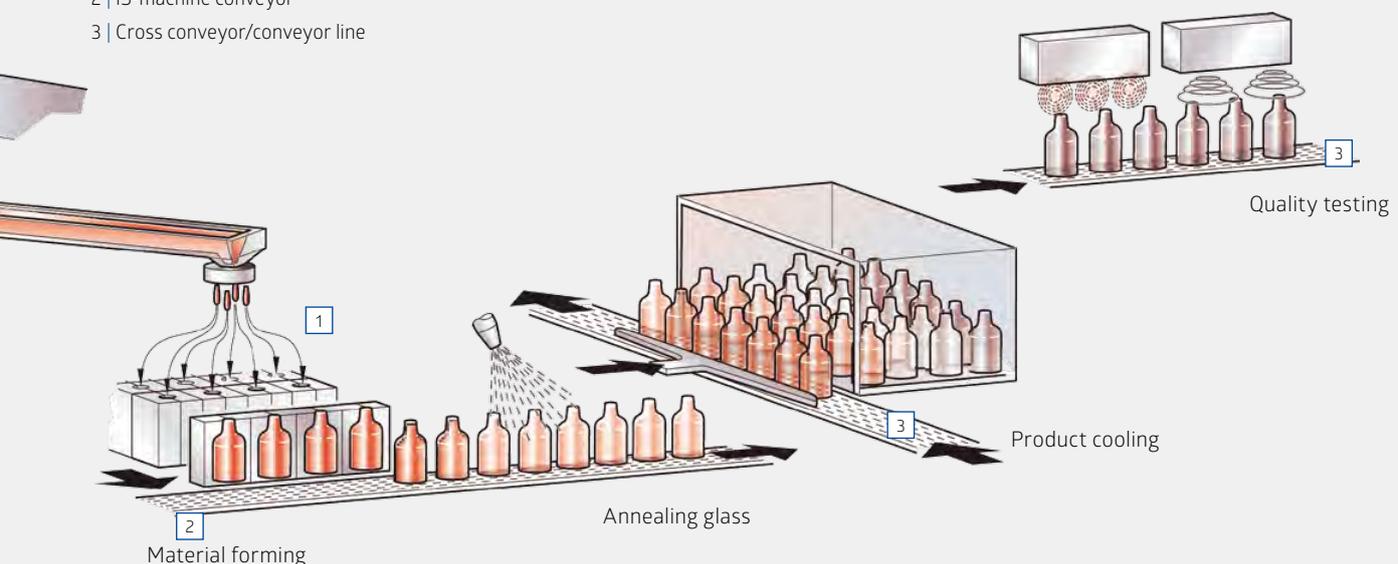
## Safe, reliable driving and gentle transport

Whatever the tasks our inverted tooth chains take on in your production processes, they guarantee trouble-free continuous operation. All inverted tooth chains are temperature-resistant up to 450°C and the drive chains operate at speeds up to 50 m/s. Our drive chains feature smooth, precise operation with minimal chain link impact and extremely low, even wear.

The interlocking power transmission eliminates slippage. Inverted tooth conveyor chains are among the lowest-wear transport systems on the market. The Renold rolling pivot joint minimizes elongation, which has a positive impact on the service life of the chain. Optimized link plate forms provide even larger sliding areas.



- 1 | Chain drive/take-out gear
- 2 | IS-machine conveyor
- 3 | Cross conveyor/conveyor line



# Automated glass production

Drive and transport solutions in automatic glass production must meet special requirements



## Demanding working environments and materials

- Adequately assess temperature characteristics
- Minimize sliding friction, abrasion, and wear
- Reliably control the cooling process
- Eliminate complications during “flame polishing”
- Account for various factors during hot-end coating
- Optimize problematic transport conditions through a specific inverted tooth chain layout
- Implement energy-efficient solutions

## Drive technology – hot products demand speed

Hot liquid: when it comes to this medium, every second counts. A firm grip, precise movement, repeatability, and speed are essential. For our drives, rapid motion is no unusual feat, but rather common practice – whenever it’s needed, around the clock.

## Conveyor lines for products above 500°C

For conveyor lines in the immediate vicinity of the forming machine, two factors are essential. First, they need to easily withstand the high temperatures of hot glass and, second, they must support the cooling process. Renold inverted tooth chains are specifically designed to meet these challenges.

# Function, quality, efficiency



## Reliable handling of a highly sensitive medium

The tasks required of drive and transport solutions in glass processing are highly demanding. The machines operate under extreme conditions and liquid glass is highly sensitive during processing. To achieve consistent quality and avoid waste, numerous factors must be taken into account – from the installation situation to temperature behavior.

- Ensuring consistent glass quality
- Reducing reject rates
- Guaranteeing process reliability

With our expertise and the individual configuration of inverted tooth chains, we can find the right solution for every application – whether your focus is on driving or transport. With specific inverted tooth chain types, pitches, link plate forms, materials, and optional extras.

## Important questions from practical applications and our product-specific answers

### Elongation behavior

The elongation behavior of an inverted tooth chain refers to the operation-related elongation of the chain under tensile stress. After a certain amount of elongation, the chain ceases to run smoothly and must be replaced.

### Cooling

In glass production, especially during transport, properly regulated cooling is important for the gradual stabilization of hot products.

### Installation situation

Every machine, system, and application requires an individually configured solution that is ideal for the specific installation situation, including spatial conditions.

### Temperature behavior

In terms of temperature behavior, both the product throughout the production process as well as the operating characteristics of the inverted tooth chain must be taken into account.

### Choice of materials

The properties of the inverted tooth chain materials must be optimized for the specific application conditions.

### Variety

A comprehensive range of individually configurable products, components, and optional extras is required to cater to the wide variety of applications in the glass industry.

(See the quality guidelines starting on page 18 for more on these topics)

## Conveyor chains in the hollow glass industry

Whether as an IS-machine conveyor or a cross conveyor in front of the furnace – inverted tooth conveyor chains offer ideal guiding characteristics

### Long service life, reliable transport

Rolling pivot joint with low sliding friction, link plates with FE-optimized contours made of high-strength heat-treated steel or stainless steel, laser-welded outer links, sprockets with hardened involute toothing for smooth, impact-free meshing – there are plenty of reasons why inverted tooth conveyor chains offer consistently precise and reliable operation. Factor in the virtually unlimited options to tailor the inverted tooth

chains to the specific requirements of equipment and overall applications. Renold inverted tooth chains – the polished solution for glass.

- Low-vibration, smooth operation
- High production speeds
- Low reject rate for increased efficiency
- Minimal sliding resistance



#### Machine conveyor on IS-machines

Machine conveyors take the hot bottles and transport them to the ware transfer. Their features: stable standing surface, high resistance to abrasion, minimal spacing at the machine bed, low sliding friction, air permeability for conveyor cooling, minimal heat withdrawal by the chain, heat resistance even during preheating, chemical resistance against annealing agents.



#### Cross conveyor at the cooling furnace

Cross conveyors take over the previously stabilized glass containers and transport them to the cooling furnace. Their features: a stable standing surface, high abrasion resistance, minimal spacing at the cooling furnace, low sliding friction for easy shifting, resistance against thermal stress caused by radiant heat, and chemical resistance against annealing agents.

# Drive chains in the hollow glass industry

20% faster, durable, consistently accurate – the take-out gear with inverted tooth chain drive is the superior solution

## Higher productivity, lower costs

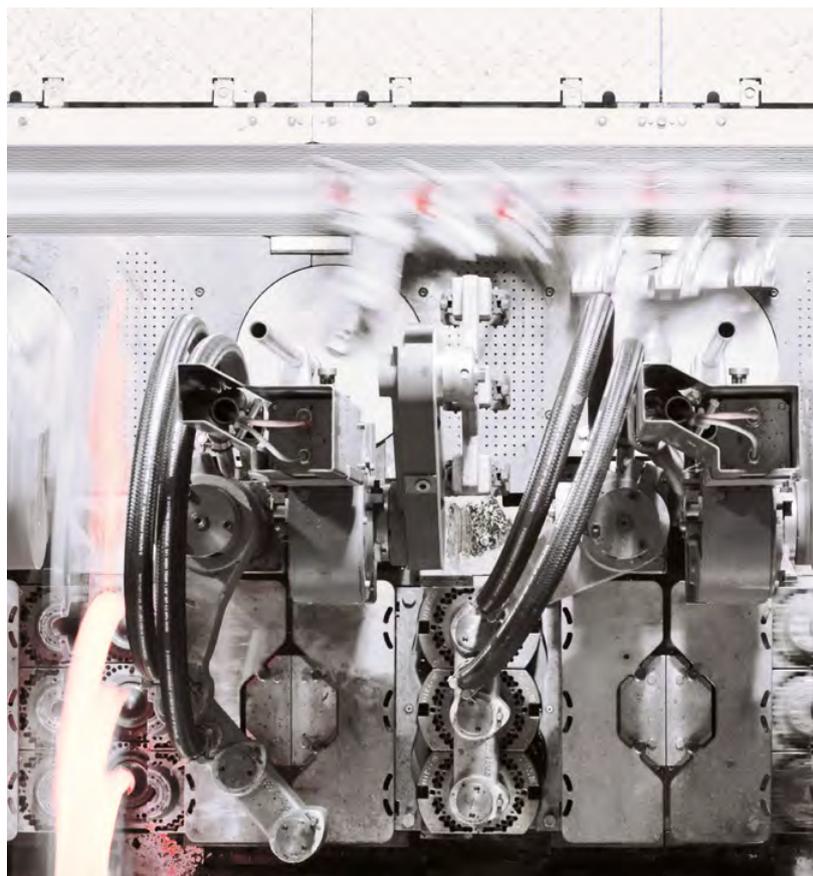
Whether for shaping on a blowing machine or precisely coordinating the movements of a rotary table system – inverted tooth drive chains are always the right choice when smooth running and accuracy count. On IS-machines, our inverted tooth drive chains in the take-out gear ensure power with precision.

- ➔ Reduced downtimes
- ➔ Improved dynamics
- ➔ Increased temperature resistance
- ➔ Considerably longer service life compared to belt drives

Using a Renold inverted tooth chain in a take-out gear helps hollow glass manufacturers to reduce costs by increasing productivity. The longer service life means less downtime for maintenance and repair work on the IS-machine. With optimum dynamics, the installation of an HPC type inverted tooth chain from Renold can reduce the installation width and weight of the drive components.

In the take-out gear, wear of the drive element must be reduced to a minimum to ensure exact positioning in the long term. Inverted tooth chains with a two-pin rolling pivot joint with hardened axle and rolling pivots maintain smooth operation and thus ensure repeatability of the swivel motion, even over a long period.

The HPC type inverted tooth chain used in the take-out gear generates almost exclusively low-wear rolling friction and is suitable for speeds up to 50 m/s.



**Take-out gears for IS-machines**  
Inverted tooth chains achieve a significantly longer service life compared to toothed belts.

## Applications in the sheet glass industry

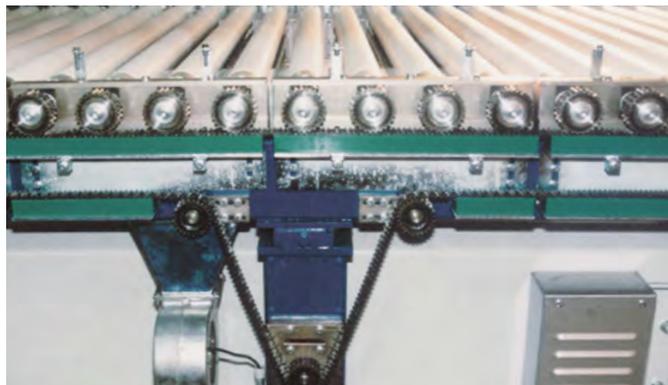
High-precision drives with inverted tooth chains ensure smooth processes in sheet glass production

### Roller drives in the furnace for bending and annealing sheet glass

While inverted tooth chains are primarily required for transport during hollow glass production, in the sheet glass industry, they are mainly used for high-precision drives. The variable construction of inverted tooth chains and custom configuration of inverted tooth chain drives permit a wide range of applications.

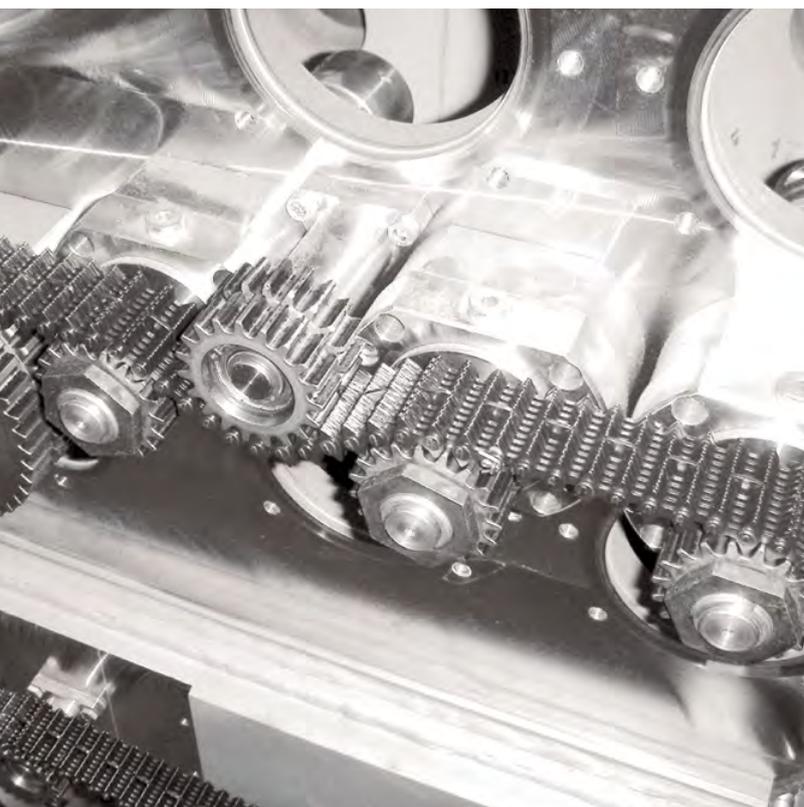
- High temperature resistance, robust operation
- Low-vibration, smooth operation
- Utmost precision and play-free reverse operation

A widespread field of application is the production of glass panes and automotive glass. Biflex inverted tooth chains are used to drive long roller tables, where raw glass components are heated in a controlled manner for subsequent bending or annealing.



### Driving long roller tables with Biflex

*During the annealing process for glass sheets in the roller hearth furnace, uniform synchronous running is critical. Slip-free drive system with Biflex inverted tooth chains. No backlash during reversing with two motors based on the master-slave principle.*



### Biflex inverted tooth chains in vacuum coating equipment

*Roller drives with specially coated inverted tooth chains for use in vacuum applications, both inside and outside the system (above: inside, at left: outside).*

# Applications in specialty glass industry

Extremely hot or sensitive, small or large?  
Our inverted tooth chains have seen it all

## Drive and transport solutions for a wide variety of products

In addition to their attractive technical properties, the absolute flexibility of individually manufactured inverted tooth chains makes them ideal for nearly every application. Regardless of whether the product is large and heavy or small, lightweight, and prone to tipping, our inverted tooth chains are well-equipped for all situations, from transport to drive applications. They can implement strong forces, torques, and high speeds as reliably as unerring precision – for both fast and slow-moving applications.

- ➔ Suitable for vacuum applications
- ➔ Also for glass articles without a standing surface
- ➔ For crystal glass and small glass products
- ➔ For robust and heavy glass products



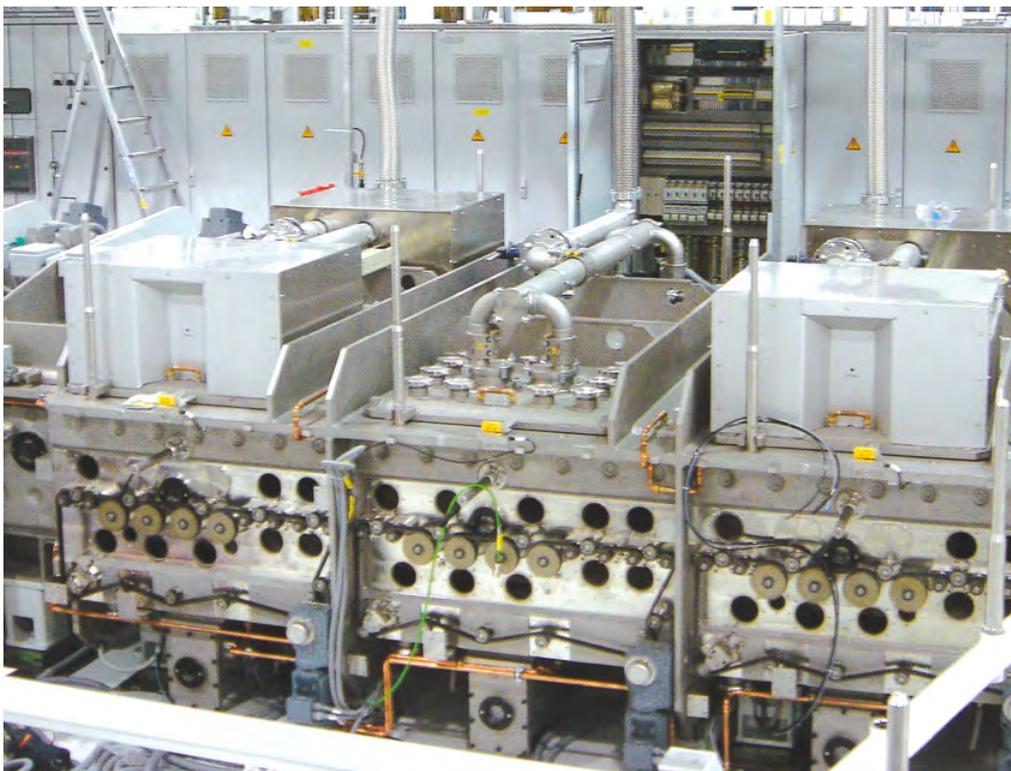
### **Special version for small glass products**

*Individually adapted inverted tooth conveyor chains for a flask production line.*



### **Medical glassware**

*A single Biflex inverted tooth chain is used for the synchronous rotation of all 32 forms in a forming glass lathe for processing glass vials.*



### **Roller drive for vacuum coatings**

*Complete drive system suitable for special requirements in vacuum coating applications.*

## Inverted tooth chains are spot on

Toothed chains work fast, precise, and quiet – best arguments for efficient automation

*Skill through and through. Professional equipment, talent and experience, a secure position and a focus on the essentials. The perfect mix provides the basis for optimal results.*

*We've made sure all our pieces are strategically aligned for the glass industry.*



### Over 100 years of inverted tooth chain experience in every detail

Quality has a tradition. We have worked in close cooperation with the glass industry for decades to consistently optimize our products and systems. All this helps our customers to meet rising demands for higher production speeds, a larger PTM net yield, and longer service lives. Renold inverted tooth chains not only fulfill today's requirements, but are also a future-oriented technology with unique advantages.

### A multitude of strengths by design

The inverted tooth chain is a cohesive network of sturdy links. It is made of numerous link plates and profile pins. The result: a powerful and flexible chain drive that can be perfectly adapted to the task at hand.

### Arguments for automation solutions with inverted tooth chains from Renold

We have perfected our inverted tooth chain technology and maintain the world's largest delivery program.

- Pivot joint with 2-pin system, laser-welded outer links, unique rounded edges
- Continuous optimization and product variety
- Application-specific versions
- Inverted tooth chains and sprockets from a single source
- Individual configurations based on modular concept
- Wide range of materials, constructions, guide types, pitches





### Continuous optimization of link plate forms

Improvement through experience. Renold consistently translates practical knowledge into new product solutions. One example is the enlarged contact surface for inverted tooth chains with an extended pitch. Compared to multiguides, the problem of vertical wear caused by abrasion on the teeth is reduced across the entire chain width.

### Special versions and optional extras

Each day is different from the next. With special link plates and specific contact surfaces, the wide range of applications for inverted tooth conveyor chains can be broadened even further. Ceramic supports are one example for especially gentle transport with minimal temperature loss.

### Laser-welded outer links

Laser-welded inverted tooth chains have a smooth contact surface on both sides and can be routed directly alongside the dead plates in the IS-machine or the side rails. Minimum side gaps ensure reliable transfer on the machine conveyor and to the cross conveyor as well as easy sliding of the products into the cooling furnace.

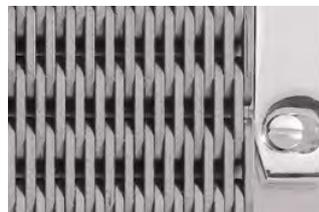
- ➔ Connecting links with uniform plate width
- ➔ No lateral movement of joint pivots
- ➔ Larger side surface prevents lateral wear



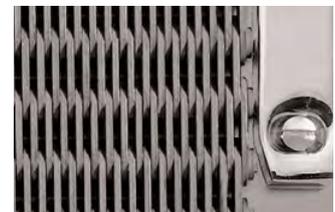
Ceramic elements at the hot end



Ground longitudinal profiles



Laser-welded



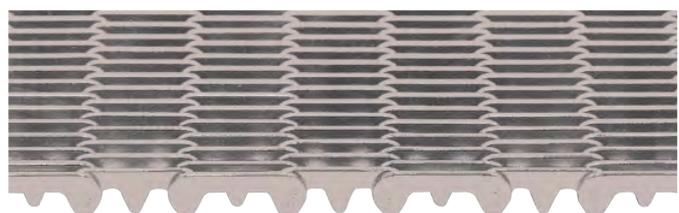
Riveted



Workpiece support for bulb components



Precise table top version based on tooth chain



TRILEG: link plate form with extended pitch

### Why are inverted tooth chains with rolling pivot joints the right choice?

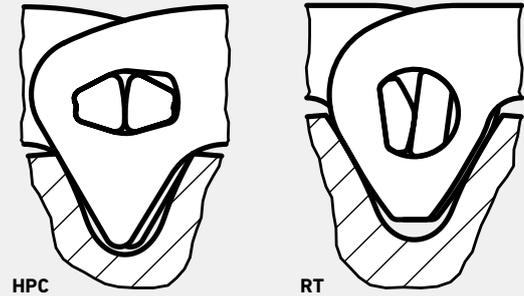
One of the main reasons that account for the superiority of Renold inverted tooth chain solutions is the unique two-pin rolling pivot joint. An axle pivot rolls against a rolling pivot. The pivots are pressed into the link plates under tensile force, preventing any further movement. Because the pins maintain permanent contact, the layout of the inverted tooth chain has no impact. Inverted tooth chains with rolling pivot joints therefore permit a variety of design options and can be tailored to individual production processes and requirements. Because the link plates are static in relation to the pins, any loss of strength due to thermal strain is insignificant. With their low friction coefficient, inverted tooth conveyor chains can also be operated without any lubrication.

Conversely, on the one-pin joint the link plates slide onto an oval pin as they mesh with the sprocket. This results in wear on both the pin and the link plates. Because the holes punched in the link plates are usually not cylindrical, the surface pressure between the pin and link plates is increased, creating additional wear.

### One-pin joint: increased wear, lower strength, lubrication required

The number of link plates is also critical. A greater number of link plates on the pin reduces surface pressure and elongation. This is why manufacturers of these chains usually prefer a tighter construction. However, this can be detrimental to effective belt cooling. Because inverted tooth chains in the glass industry are subject to high thermal loads, the material loses its strength. The service life can only be extended by reducing the friction coefficient  $\mu$ , for example with lubricants – highly problematic in glass production, since high temperatures can result in charring. Lubricants can also have a counterproductive effect in combination with annealing agents. Instead of reducing the friction coefficient, an increase occurs.

### Optimal joint kinematics



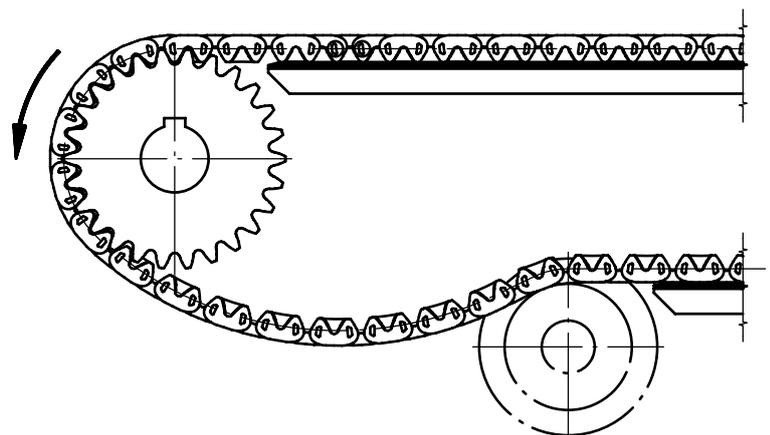
### Two-pin rolling pivot joint

With the 2-pin joint, only rolling friction occurs as the chain meshes with the sprocket. Sliding friction is virtually eliminated; less force is used and natural wear minimized. The drives consume significantly less energy.

### Interlocking connection: inverted tooth chain and sprocket

The correct meshing of chain and sprocket is a prerequisite for trouble-free, continuous operation. All relevant dimensions and profiles are optimally aligned to achieve slip-free movement.

Whenever technically feasible, sprockets are manufactured according to the specific needs of the customer. The design of the toothing is adapted to the guide type of the selected inverted tooth chain. Of course, all special versions are also available with guide slots for various chain widths and can be prepared for center and side guides. C45 steel sprockets with hardened tooth flanks are used as a standard with proven resistance to wear. For an even longer service life for cross conveyors subject to extreme thermal loads, without compromising on strength, we also use vacuum-hardened tool steel.



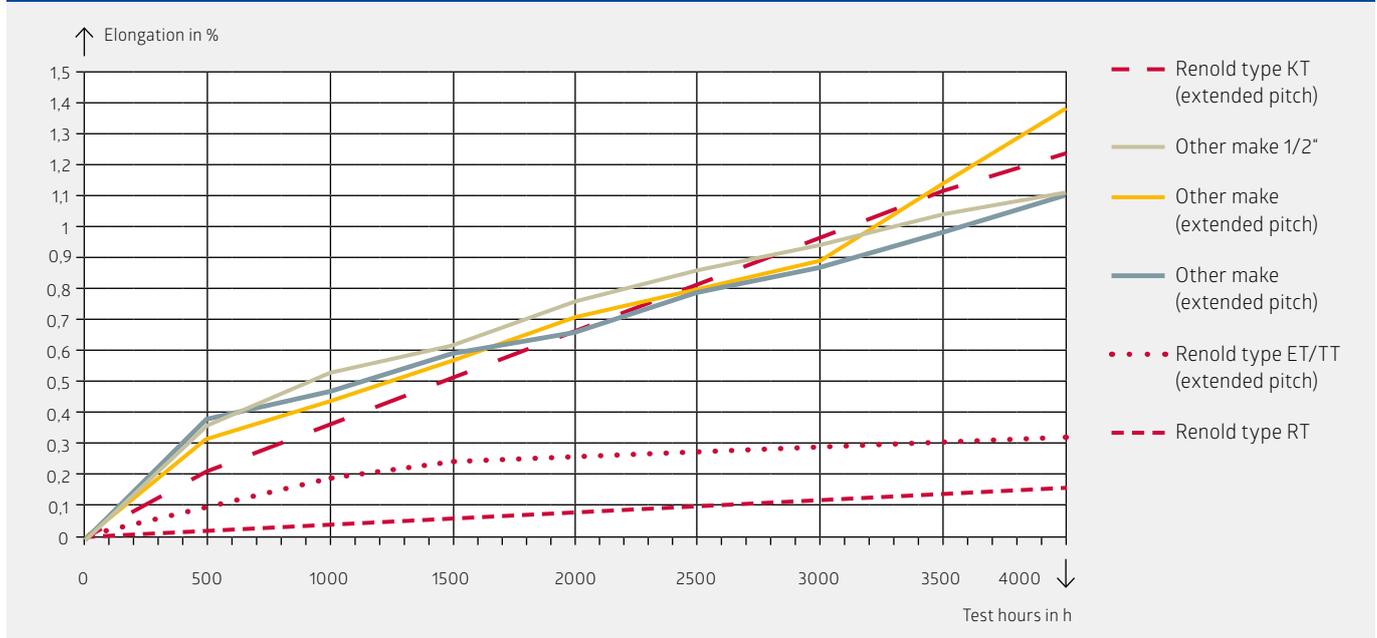
### Elongation

Due to sliding friction and increased wear of the joint, elongation in 1-pin chains can be up to three times higher than in 2-pin systems. Renold 2-pin rolling pivot joint with hardened axle and rolling pivots only creates rolling friction. Over time wear also occurs at the contact line of the pins; however, this wear is evenly distributed on both pins as well as the inner and outer links. The meshing conditions remain constant over the entire period of use. These characteristics are the basic prerequisite for precise angle synchronization in applications for the hollow glass industry.

As shown in the diagram, studies have demonstrated that the elongation of inverted tooth chains is up to three times less

with rolling pivot joints instead of single pin joints. Single pins generate constant sliding friction which accelerates wear. Renold rolling pivot joints only generate rolling friction. For an RT type inverted tooth chain, this means a minimal elongation of 0.17% after approximately 4000 test hours, i.e. about 1.7 mm elongation per meter of the chain. This horizontal wear is negligible when it comes to the performance and reliability of inverted tooth chain applications. Inverted tooth chains with a one-pin system, in contrast, exhibit an elongation of approximately 11 to 14 mm per meter, based on a comparison with Renold KT type chains as an example for single pins.

**Chain elongation in inverted tooth conveyor chains, dry running, no load, 1/2" and 1 1/2" extended pitch Test speed v = 1 m/s**



### Rolling friction/sliding friction

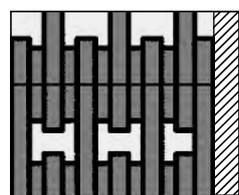
With a simple comparison of friction coefficient  $\mu$  for rolling and sliding friction, it's easy to see that rolling friction requires far less force.

#### Friction coefficient: steel on steel

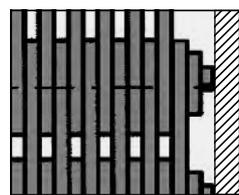
Sliding friction  $\mu = 0.1$ , rolling friction  $\mu = 0.01$

Picture a tricycle and a sled: the tricycle uses rolling friction and has a greater ease of motion than a sled with sliding friction. Sliding friction also depends on the sliding quality of the material. This is negligible with rolling friction.

### Laser-welded outer links



Rolling pivots are laser-welded in the outer plates of Renold inverted tooth conveyor chains. The rivet heads no longer protrude and the belts can be placed flush to the sides without any gaps.



This increases the operational reliability of the chain and the chain width remains constant throughout its service life.

### Inverted tooth drive chains in the hollow glass industry

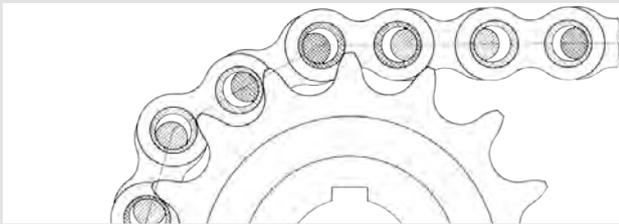
Glass is a special product. It places highly specific demands on production equipment and tools for production and processing. The main requirements include:

High temperature resistance, since glass is often processed at temperatures above 500°C.

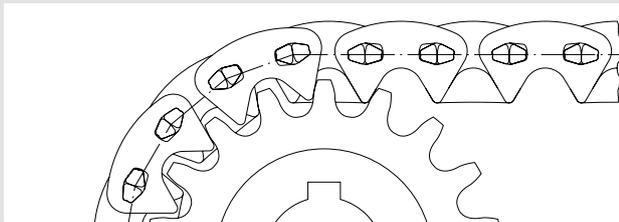
High requirements for drive synchronization and accuracy, since even minor deviations can leave marks or scratches on the product, and glass is fragile after cooling.

Wrap drives are drives that enable the cost-effective implementation of larger center distances. Various drive elements, such as belts, roller chains, and inverted tooth chains are available. Belts, regardless of whether toothed, flat, or wedge-shaped, can usually be ruled out, since the temperatures are too high. Roller chains often lack the required accuracy due to sliding friction and wear. Inverted tooth chains with rolling pivot joints are the only viable option ideally equipped to meet all requirements and should always be the first choice.

### Comparison roller chain and inverted tooth chain



Roller chain



Inverted tooth chain

The graphic shows a roller chain shortly before failure due to elongation. Friction and wear is visible between the pins and bushings. Because the pitch of the outer links now varies from that of the inner links, the chain is also prone to running on different swing diameters. The result is jerking in the sprocket and a jolting, uneven drive.

On the inverted tooth chain, it is clear that there is no friction between the pins and bushings; instead the two pins roll against each other. If wear does occur, the inverted tooth chain readjusts its swing diameter and can continue to run without jerking.

### Example: Chain drive for shaping on a blowing machine

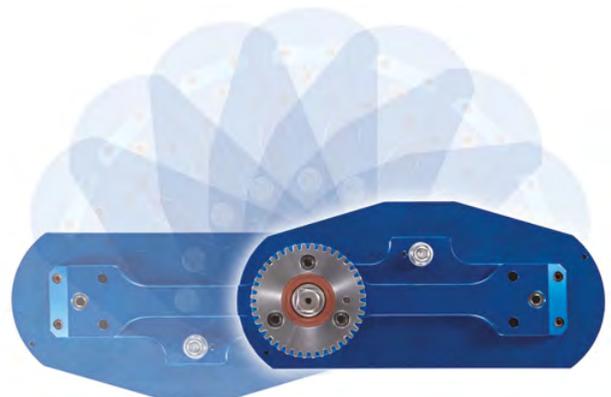
Inverted tooth drive chain for shaping on a blowing machine for the production of high-quality drinking glasses (goblets/wine glasses). An inverted tooth chain at each of the 18 stations drives the mold for the bowl, an additional inverted tooth chain rotates the stem to weld it to the bowl. Both parts must be rotated with equal precision in order to join the elements. The application uses an HPC inverted tooth chain. A special feature: both drives are positioned laterally, i.e. with vertical axes.



### Example: Take-out gears in container glass production

These gears are used to lift glass while it is still glowing out of the IS-machine and onto sheets from which the glass items are shifted onto an inverted tooth conveyor chain. The rotation usually does not exceed 180° by much; the entire gear housing is rotated. The gear rotates around the drive shaft, enabling a swivel motion.

A difficult factor in this process is repeated reversing with relatively high accelerations. Inverted tooth chains meet these demands over a long period. They are unaffected by radiant heat and continuous directional changes with rapid accelerations. In addition, the drives demonstrate exceptional precision and robustness.



### Inverted tooth drive chains for the sheet glass industry

The variable construction of inverted tooth chains allows chain drives to be precisely configured to meet customers' needs. Renold manufactures inverted tooth chains with pitches from 5/16" to 2 1/2" and in 4 different performance classes for drives, enabling an optimum configuration of individual drives.

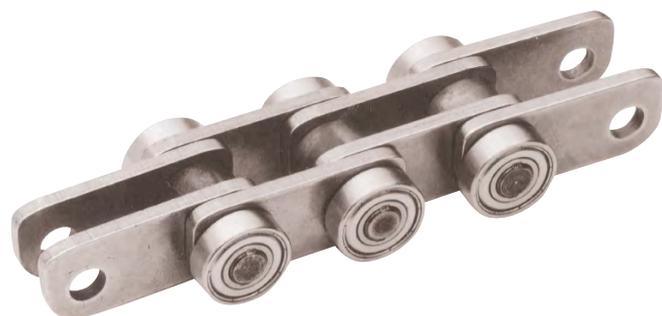
#### Example: Vacuum glass finishing and solar glass production

Vacuum applications demand special provisions for a chain drive. To prevent contamination of the vacuum, all parts must be grease-free. Moreover, the friction coefficient  $\mu$  for sliding friction with steel on steel in the vacuum increases up to 1.0. Outside the vacuum, this coefficient is just 0.1.

The conveyor roller drives are equipped with wrap drives to reduce friction losses. To achieve the same rotational direction of the conveyor rollers, an additional sprocket must be installed between every other roller, which ensures wrapping on the conveyor rollers and thus enables a uniform direction of rotation. The requirement of absolutely no oil or grease on the inverted tooth chain drives is achieved through a special procedure: a coating is applied to every individual component of the inverted tooth chain. An additional side benefit: this coating prevents direct steel-on-steel contact. The higher friction coefficients in the vacuum are counteracted and energy is saved.

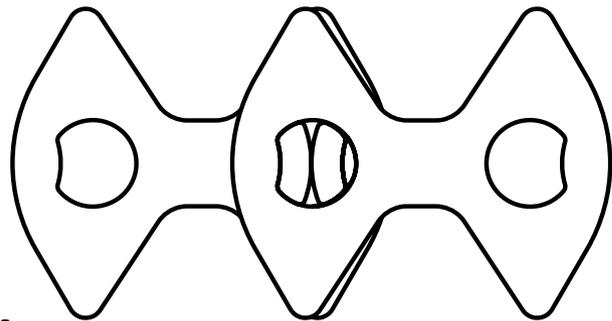
#### Special case: large-scale automotive glass production

Mass production of automotive glass usually employs roller drives. However, they are not used for reversing; instead, the pre-heating zones are configured as conveyor belt furnaces. These furnaces can measure, for example, 40 m in length and contain hundreds of rollers. The drive for these rollers is not interlocking, but operates exclusively based on friction. Renold manufactures special chains for these furnaces that are highly precise to ensure that all conveyor rollers are at exactly the same height. These drives also use a motor control based on the master/slave principle. This should not reduce backlash, but prevents stick-slip effects that can occur over large conveying lengths.



#### Example: Biflex inverted tooth chains for play-free driving of long roller tables

Biflex inverted tooth chains are widely used in the sheet glass industry in the production and finishing of automotive glass. They are used to drive long roller tables. Raw glass components are often heated on roller tables for subsequent bending or annealing. To save space and maximize energy efficiency in the furnace, the sheets are moved back and forth on the rollers. Because the plasticity of glass increases at higher temperatures, this movement must occur without any play. Play means backlash during directional changes and thus the uneven rotation of conveyor rollers. The result is scratches in the finished product.



Biflex

The inverted tooth chain acts as a lantern gear underneath the conveyor rollers. It is continuously tensioned by two motors in a master/slave configuration. The chain slack is tensioned via an omega with a simple weight or a pneumatic cylinder. Sprockets with corrected toothing engage with the lantern gear. By engaging the slide rail below the lantern gear, and in some cases through the weight of the conveyor rollers, the toothing also meshes tightly with the lantern gear. This makes the entire system free of play and the rotation of all conveyor rollers is synchronized with the exact same speed and in the same direction.

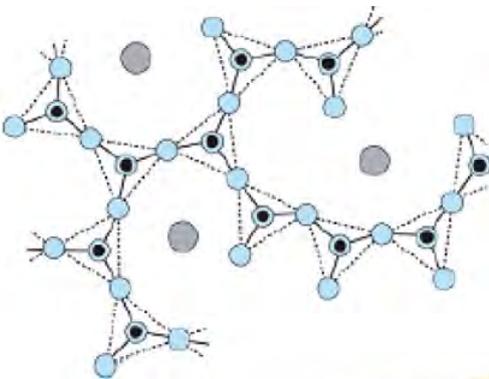


### Why is transport so critical in hollow glass production?

The glass product comes out of the IS-machine with a temperature of over 500°C and must be gently and reliably transported to the individual processing stages. However, the product is not yet fully stabilized and is highly delicate. Additional production steps are required along the path from the IS-machine to the cooling furnace. First, belt cooling stabilizes the product. The next step is hot-end coating. Transport must be accomplished without any slippage to ensure that the product stays properly positioned. The spacing between the products is reduced in the ware transfer for optimum space utilization in the cooling furnace. Contact between the products must be avoided at all costs.

### Base cracks

To withstand harsh operating conditions, inverted tooth chains are usually made of high-strength heat-treated steel. Like all metals, steel is an excellent heat conductor, which presents a problem: the glass needs to cool down during transport in order to stabilize, but at the right rate. If the hot product makes contact with the inverted tooth chain, heat flows from the glass to the chain. The inverted tooth chain dissipates warmth from the glass more quickly than it can be resupplied by the surrounding glass. This results in areas with different temperatures at the contact points with the glass, creating tension that can become visible through micro-cracks (base cracks). When the product is cooled with air on the belt, this effect does not occur. Air acts as an insulator so the glass can continue to supply adequate warmth and cool down slowly and evenly.



### Flame polishing

During flame polishing, burners on the conveyor belt partially melt the product surfaces. Inverted tooth chains can sustain damage from exposure to high temperatures. Stainless steel can provide an adequate solution for these applications.

### Hot-end coating

Hot-end coating smoothens surfaces and creates an excellent surface for subsequent cold-end coating. Coating agents in combination with lubricants can damage the inverted tooth chain. However, there are steps you can take to protect the quality of inverted tooth chains. Don't hesitate to ask!

### Ways to regulate the cooling process

First, the melt itself is a decisive factor. A high alkaline content (Arabic: "al qalya" = potassium carbonate) reduces the tendency towards base crack formation. Potassium carbonate or potash is a network modifier and fluxing agent. Network modifiers alter the properties of glass by depositing atoms in the quartz network and therefore disrupting the even network structure. As a fluxing agent, potash lowers the melting temperature and thus the processing temperature. A lower processing temperature means a smaller temperature difference between the glass and the inverted tooth chain, and thus a reduced heat transfer from the glass into the chain. An additional factor in preventing base cracks is the design and shape of products. The base of a bottle is curved inward and the remaining circular ring equipped with additional fluting. This reduces the contact surface with the inverted tooth chain considerably.

Finally, the construction of the inverted tooth chain has a significant impact on cooling processes. Tightly constructed chains have a larger closed surface than those with spacers or an openly configured extended pitch.

### The right material

Should a combination of all measures not eliminate base cracks, stainless steel inverted tooth chains could help to solve the problem. Steel with a high nickel content reduces the withdrawal of heat from glass, which is determined by thermal conductivity, measured in W/m K (watt per meter kelvin). Compared to heat-treated steels, the use of stainless steel reduces the withdrawal of heat by an approximate factor of 3. This also reduces energy consumption and cuts down on melt quantities.

### Thermal conductivity of steel grades

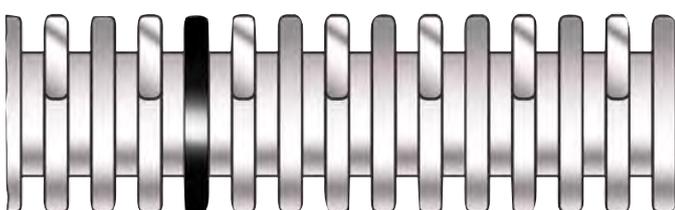
Steel grade	W/m K
Carbon steel	Approx. 50
Heat-treated steel	Approx. 50 to 45
High nickel alloy steel Stainless steel	Approx. 27 to 10

### Improved sliding characteristics

Some glass bases have minimal contact with the inverted tooth chain. This disrupts the sliding quality when shifting the products on and off the chain. The same applies to angled fluting in the glass base. Renold has developed a solution for these challenges: toothed plate edges are rounded off in an extra work step.

This keeps the contact area to a minimum while reducing sliding forces. In addition, the risk of toppling during lateral shifting is minimized, which is especially important for tall, top-heavy products. As shown in the figure, rounded edges can cut the forces required for lateral shifting (both static and sliding friction forces) by roughly one half.

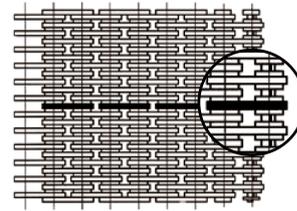
- ➔ Reduces the risk of base cracks
- ➔ Reduces toppling in topple-prone bottles
- ➔ Reduces the sliding resistance of glassware
- ➔ Improves sliding properties



RS inverted tooth chain with rounded link edge

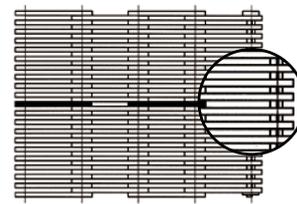
### The right layout

Inverted tooth chains have a lamellar design, which always results in a gap between the individual link plates. The additional integration of spacers and/or the use of extended pitches increase this gap, which promotes cooling. Here are just a few examples:



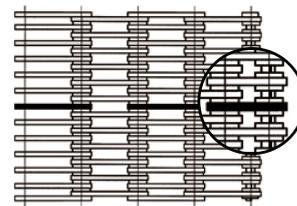
#### Layout 1

Standard layout with a surface air permeability of 22%. This inverted tooth chain is the basis for comparison with other versions, i.e. 100%, Type RS-200-CL.



#### Layout 2

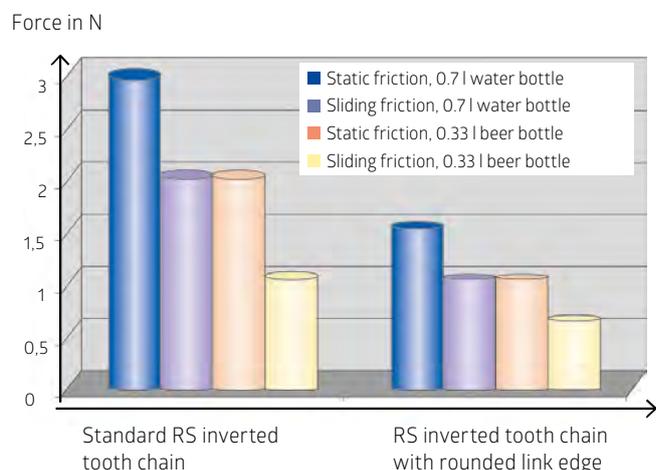
Extended pitch. Air permeability = 31%, type TT-200-CL.



#### Layout 3

Extremely open extended pitch. Air permeability = 53%, type TS-200-CL.

### Forces for shifting bottles





**Advantage: individual construction**

Compared to other providers, Renold not only offers 1.5 mm link plates in several different constructions, but also 2 mm link plates with six additional construction combinations. This is the largest range of inverted tooth chain versions worldwide. The possibilities are virtually endless.

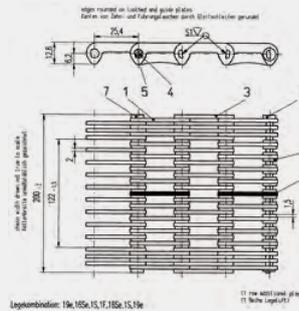
This wide range of configuration options only provides an advantage in combination with knowledge about critical factors. The main objective is usually to implement a suitable compromise for systems and the products to be manufactured. In addition to the specific functionality of the inverted tooth chain, existing installation situations, and belt cooling requirements, the type and properties of the product itself play a key role. Often, individual testing, combined with specific experience, is required to find the best solution. Rely on advice from our experts: deciding on the perfect system is their daily business.

**Individual construction/Toothed chain types**

- RS =** Standard for universal use. Suitable for medium-sized and large products. Air permeability approx. 22%.
- RT/RD =** For small glassware and products prone to tipping. Air permeability approx. 12%. Limited belt cooling.
- TT/ET =** Suitable for universal use, also for small glassware and products prone to tipping thanks to a level surface. Air permeability approx. 31%. Good belt cooling.
- TS/ES =** For medium-sized to large products. Air permeability approx. 53%. Excellent belt cooling. Highly suitable for glasses with a solid base or large volume.

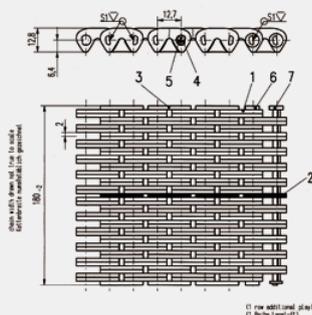
**Inverted tooth chain layout**

These design examples illustrate the wide variety of customization options for inverted tooth conveyor chains to implement highly specific functions.



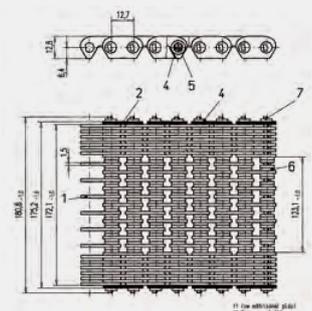
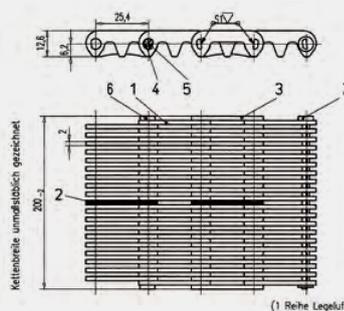
**Design example**

Special layout combining high tensile force and an air-permeable surface.



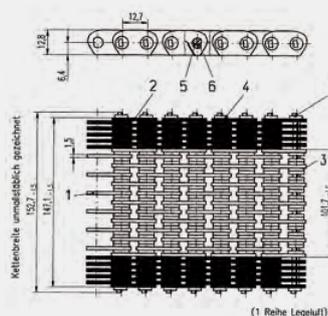
**Design example**

Special layout for tightly configured chains with a homogenous surface; improved cooling with extended pitches.



**Design example**

Special layout combining tensile force and an open surface with areas for decreased surface pressure.





# In dialog with our customers

## Based on proven expertise and a first-class product portfolio

Our understanding of cooperation goes well beyond the boundaries of individual projects. We are constantly in dialog with our customers and are always a competent contact for both technical and economic questions. Our cross-technology expertise creates the solid foundation for our work.

- ➔ Inverted tooth conveyor chains
- ➔ Inverted tooth drive chains

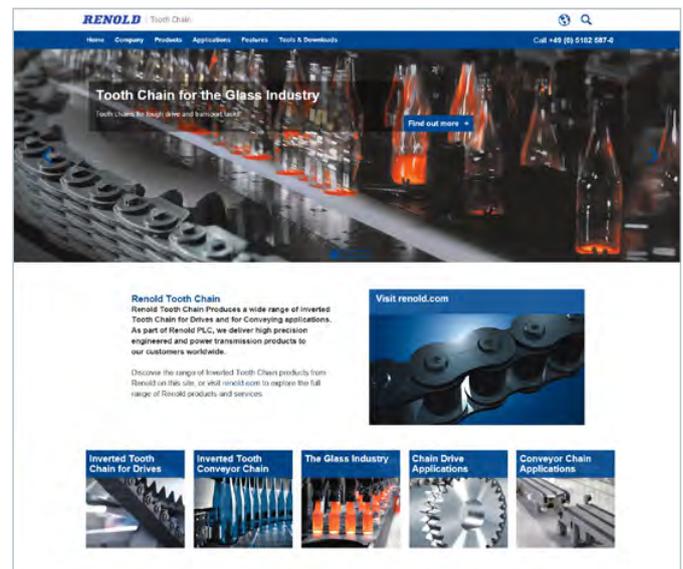
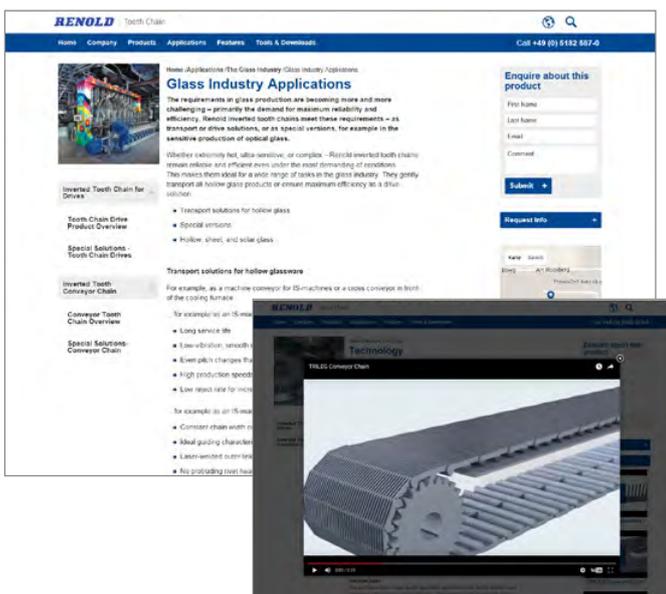
Understanding our customers allows us to respond more quickly and gives us a head start in achieving tailor-made solutions. Thus, we always remain close to the action and ensure the technological lead for our customers.



## Around-the-clock information

The Renold Internet Portal never sleeps. Our Internet pages contain a wide variety of technical details for our product spectrum.

- ➔ Product highlights
- ➔ Internet platform with online tools



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