



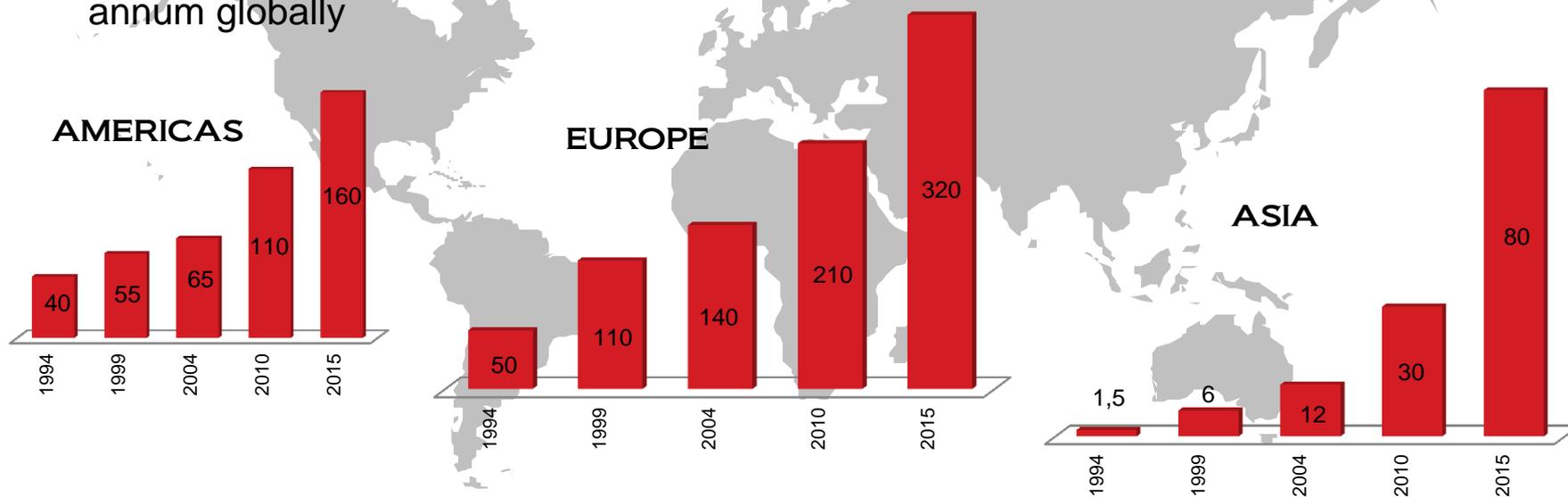
Low-E Market & Coating Technology for architectural Glass Applications

Grenztech Coating Technology

Coated Glass for Architectural Applications |

General Remarks and Global Demand

- Energy conservation legislations are being aggravated worldwide on a regular basis and push manufacturers towards smart solutions for windows and facades for commercial as well as for residential buildings
- PVD offline coated glass is more and more dominating and replaces online pyrolytic coated glass due to much better optical and thermal performance data
- As of today more than 500 Mio m² of architectural glass is being PVD coated per annum globally



Total World in 2015 >> approx. 560 Mio m² / year

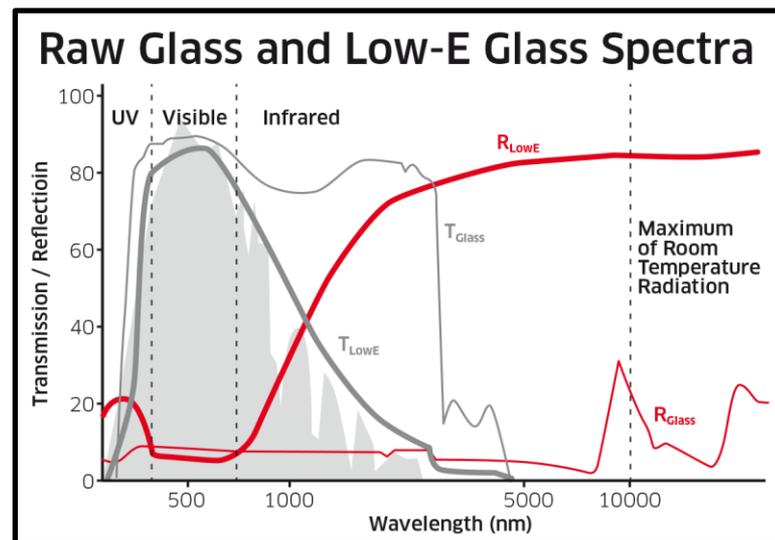
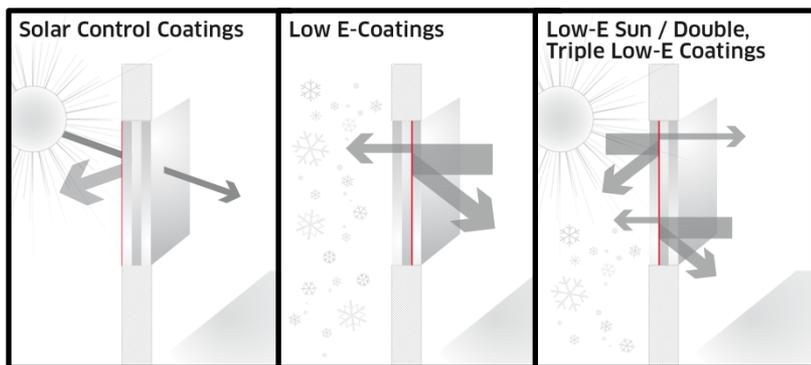
Low-E Market in Europe, US and MEA

- Sales prices for standard Low-E products are still on a very low level ... dropping energy prices over the last 2 years do not help to change this
- Temperable and double Ag Low-E became commodity products
- Triple Ag Low-E is still a niche product while everybody prepares to be ready for it's production within the next 2-3 years
- Electrochromic glass products remain to be too expensive with no noticeable market shares up to date
- More and more extra thin glass for automotive and also architectural applications is being requested to be coated with sophisticated layer stacks
- Requests for extra large substrates (up to 15 meters in length) to be processed (incl. PVD coating) are coming up more and more

Investment Activities in Europe, US and MEA

- PVD coater base in the US is running on almost full capacity with focus on standard products (SLE and DLE) and low product mix figures => no major new investments on the horizon so far
- Europe is pushing production of commodity products towards the eastern regions (Poland, Russia, FSU-countries ...)
- Several new coating facilities planned, already under construction or recently fired up in the MEA region for sophisticated products on a moderate portfolio level
- Installed coater base receives frequent upgrades in order to push productivity and performance figures for existing products

Coated Glass for Architectural Applications | Performance Requirements and Data

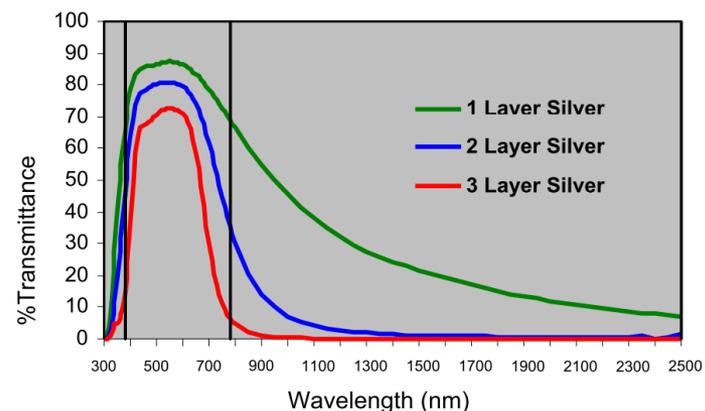


Parameters of a Low-E coating

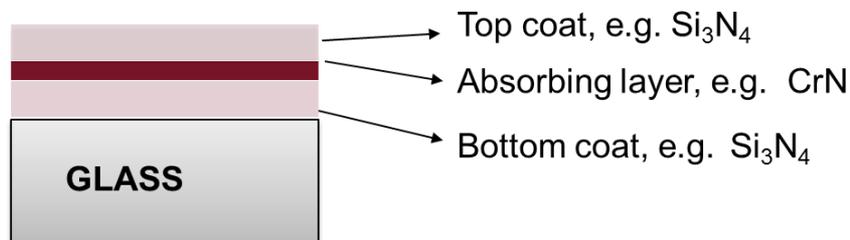
- Transmission $T_y [\%] \leftrightarrow L^* \quad (380-780\text{nm})$
- Reflection $R_{y \text{ (glass/film)}} [\%] \leftrightarrow L^*$
- Colors a^*, b^*
- Emissivity $\varepsilon [\%] \leftrightarrow R_{sq} [\Omega_{sq}]$
- Mechanical stability Brush-test (washing machine)
- Chemical stability $\text{SO}_2 / \text{NaCl}$ -spray-test / climate-test
- Stray light loss haze [%]
- Color shift (HT) $\Delta E = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2}$

Parameters of a complete double/triple glazing (IGU)

- U-value / g-value / shading factor / shading coefficient
- Solar heat gain / k-value



Coated Glass for Architectural Applications | Thin Film Layer Stacks



SOLAR CONTROL COATINGS

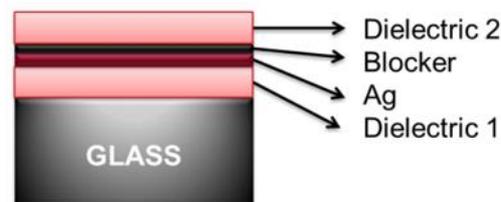
Light Reduction and Color Effect for Commercial Buildings
 Monolithic application possible

SC

LOW-E COATINGS

High visible light transmission / energy saving / neutral colors for residential buildings

Structure of Low-E Coating



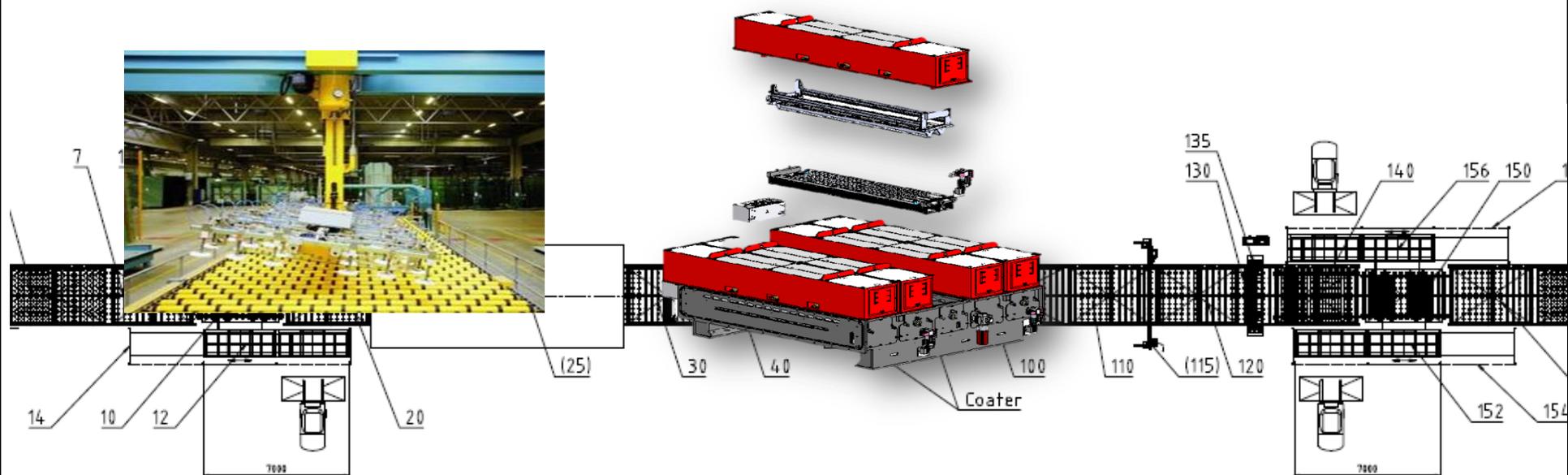
LE

Coating Tools for today's State of the Art Layer Stacks

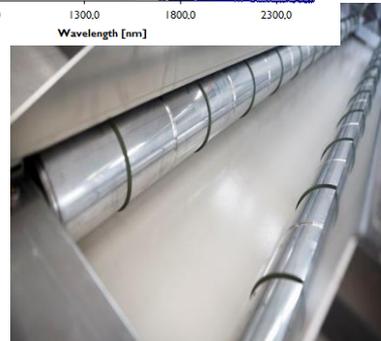
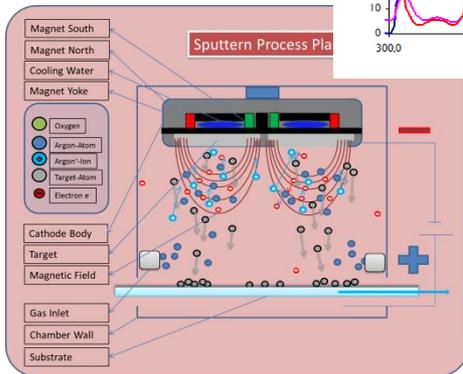
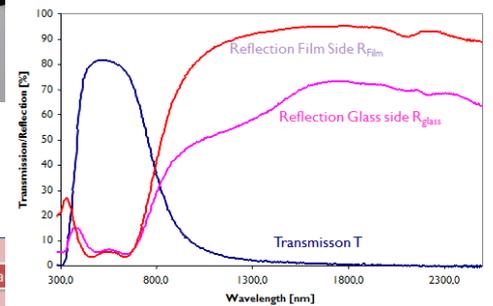
- In order to stay profitable coating facilities have to be optimized in order to run on highest possible product yield figures
 - ✓ Improvement of campaign times adjusted to given product portfolio
 - ✓ Enhancement of loading factors by intelligent hard-and software concepts
- The rotatable technology is available for all common materials being used for architectural glass applications
- Step by step the pulsed DC technology will replace the given MF technology. Higher deposition rates and more user friendly processes result in a more economical deposition of complex layer stacks

GB Coating Technology | Scope of Supply

- Fully automated coating equipment to produce Low-E and Solar Control layer stacks for architectural glass applications
- Spare parts, retrofit and upgrade services for existing coating lines
- Technology and process services for the entire worldwide installed PVD coater base



GB Coating Technology – Our Competence



We are delivering in depth process expertise in the field of large area coating in general and in the field of architectural glass in specific to ramp up the success story of our client

We are the one and only supplier on this planet to deliver the complete in house made coating equipment package of your needs, consisting of:

- PVD Coater
- Loading/unloading equipment
- Quality inspection equipment
- Ramp up of your specific products to full production scale

GB Coating Technology | The Grenzebach Expertise



- One step ahead of our competition - in-depth knowledge of the coating platforms as being delivered over the last 30 years
- Offering the major features of the existing legacy platforms (modular coater / compartment coater) combined with latest developments to please all existing demands from the market as of today
- Technology team with more than 200 years of experience across all disciplines (Sales, Engineering, Product Mgmt, Project Mgmt, Installation, Startup, Technology Support)



Sourcing & Manufacturing

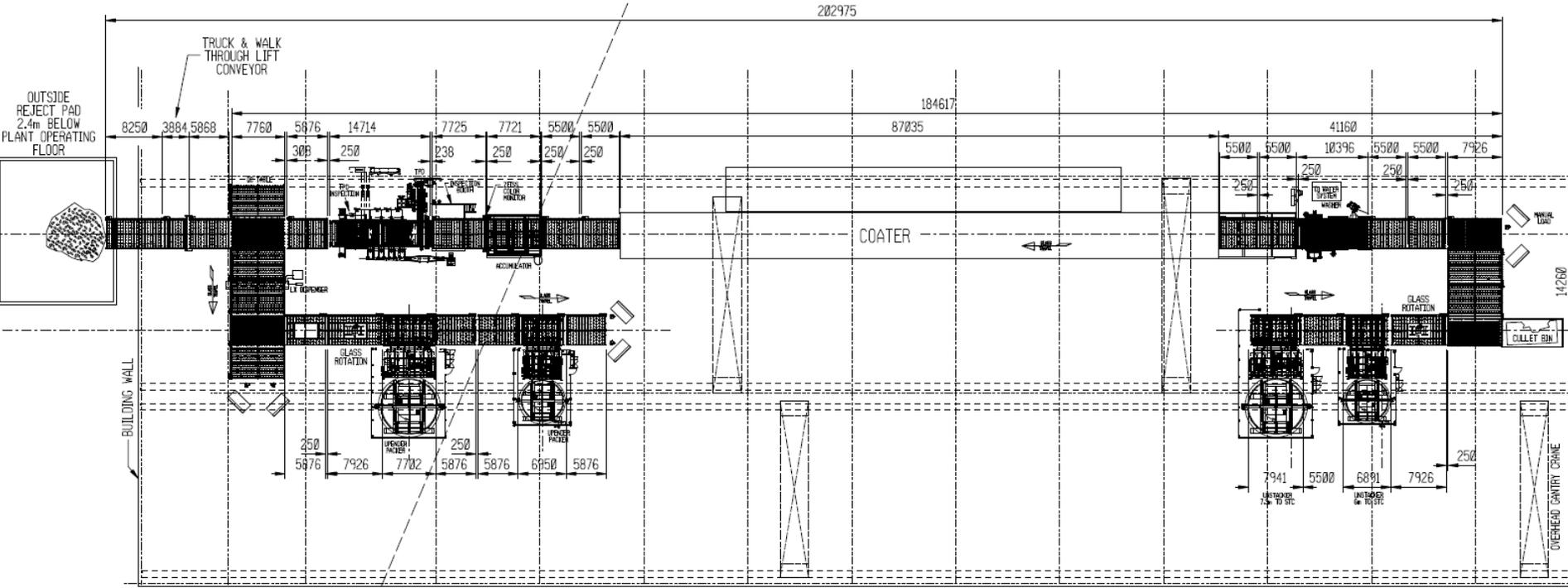
Many experienced options for sourcing of material & key components:

- Hamlar, Germany
 - Newnan, Georgia, USA
 - Jiashan, China
- } inhouse GB manufacturing
- Qualified US supply chain from former OEM supplier
 - Qualified European supply chain from existing OEM suppliers

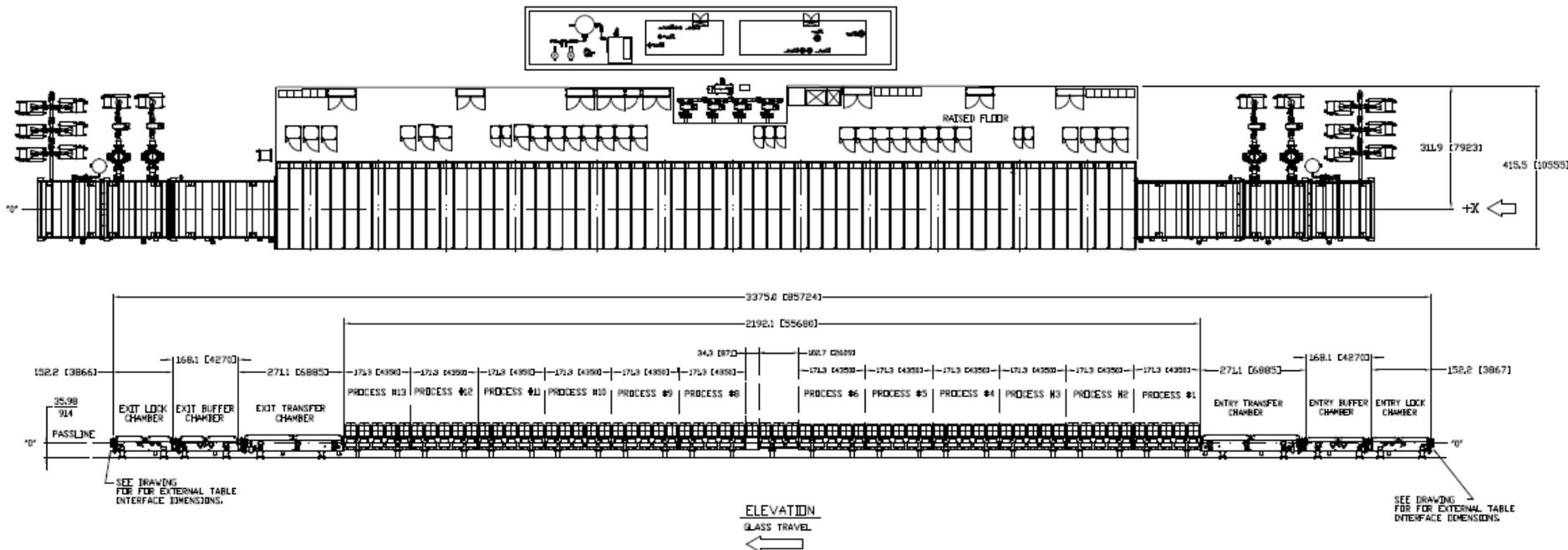
Integration of sub units and components at qualified locations



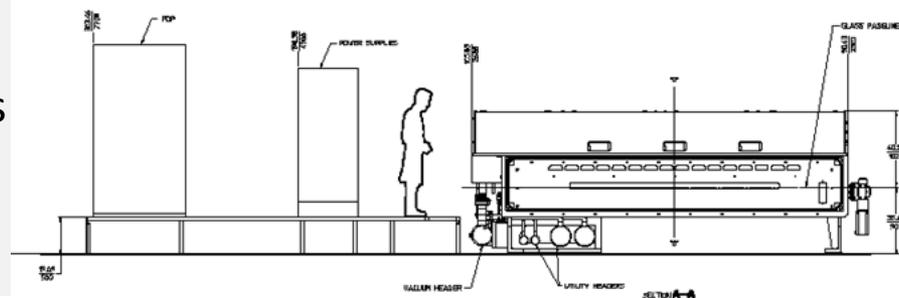
Exemplary Line Layout



Exemplary Coater Layout



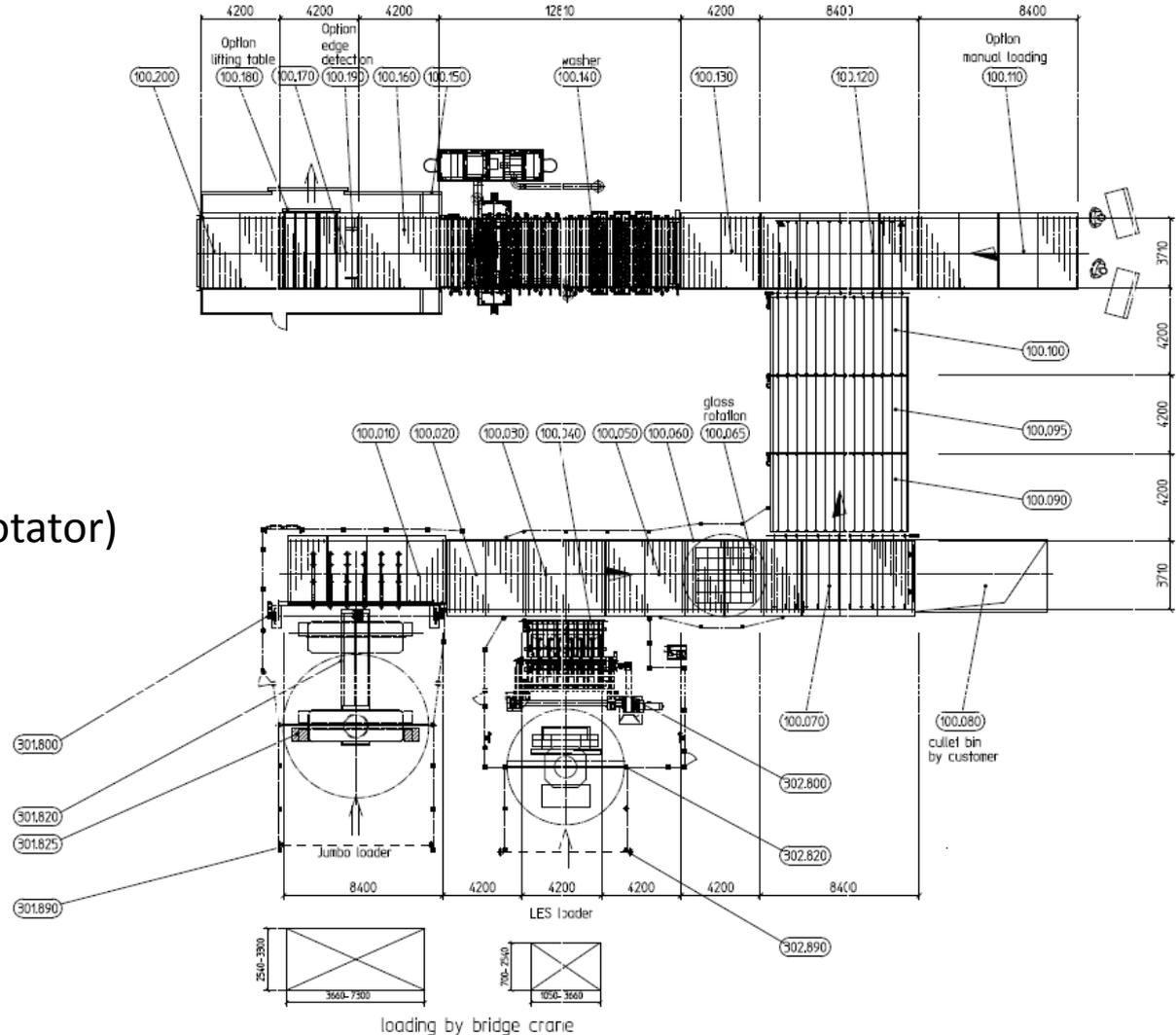
- Raised floor to eliminate trenching
- Low floor loading to minimize civil works (< 4.5 kg/m²)
- Single connection points for utilities



Exemplary Grenzebach Coater Handling

Coater Load End

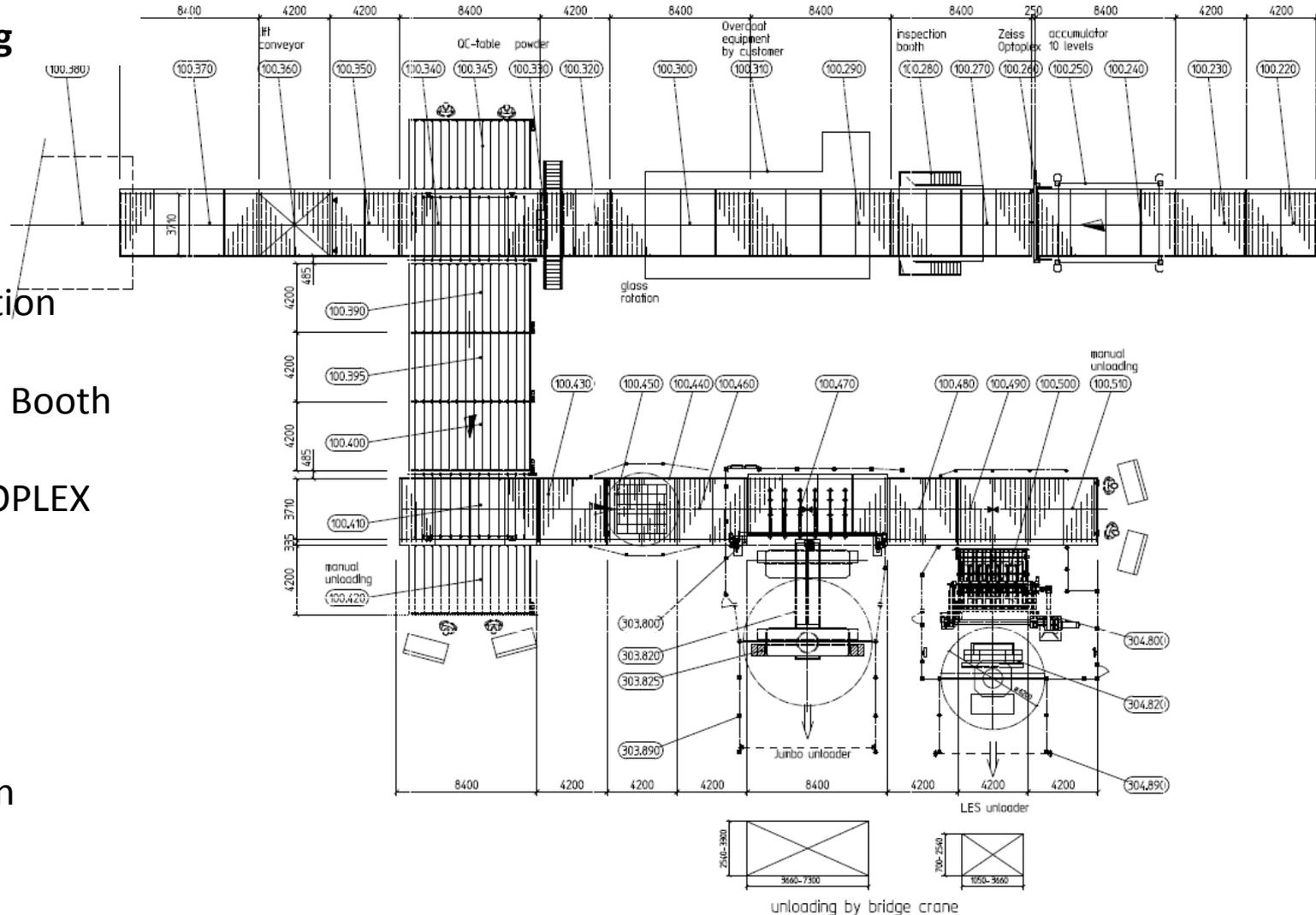
- Jumbo un-stacking
- LES un-stacking
- In-coming rack handling
- Glass handling solutions (conveyors, transfers & rotator)
- Washing



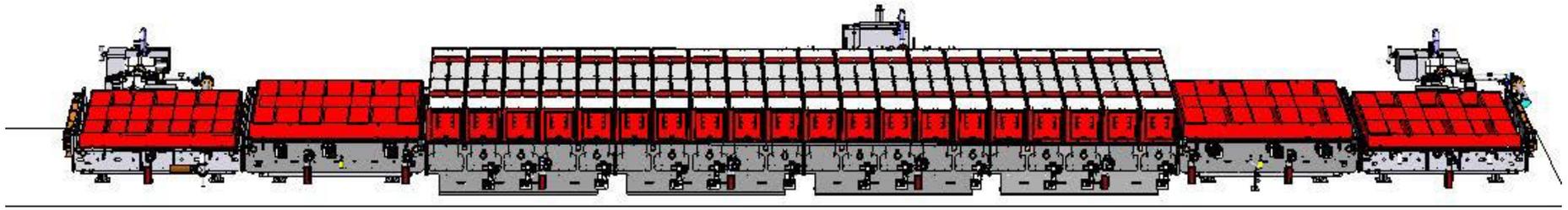
Exemplary Grenzebach Coater Handling

Glass Un-Loading

- Accumulation
- Inspection Booth
- Zeiss OPTOPLEX
- Protective Overcoat
- Powder Application

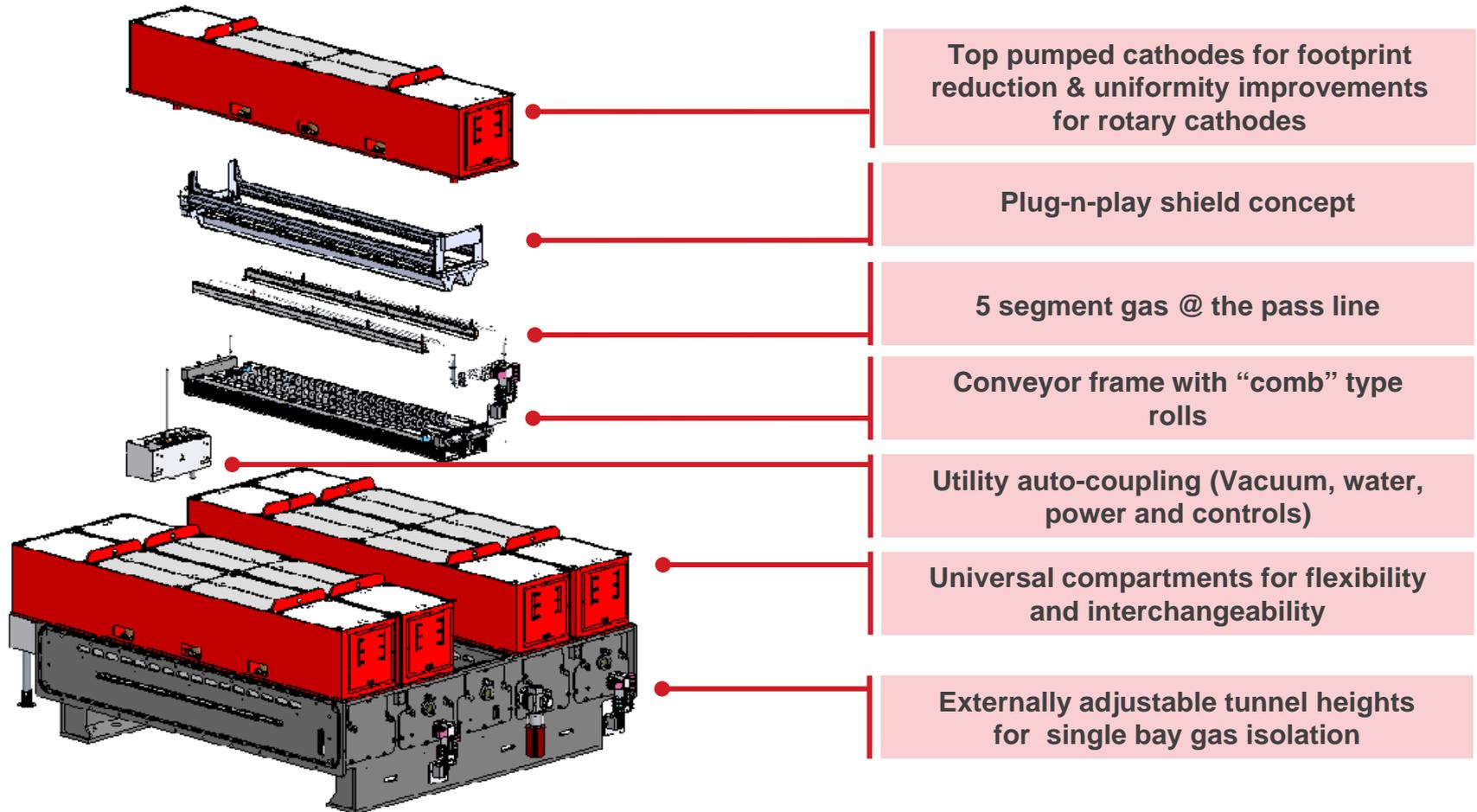


Coater GB 3300



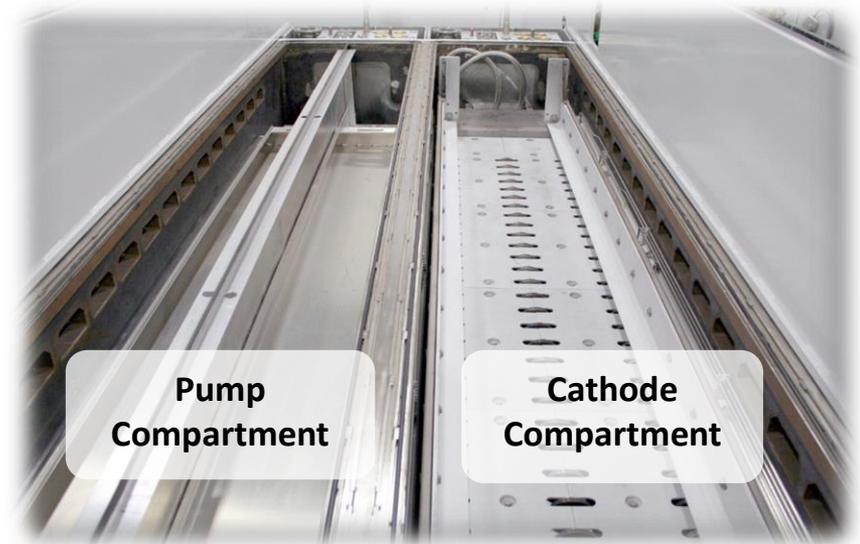
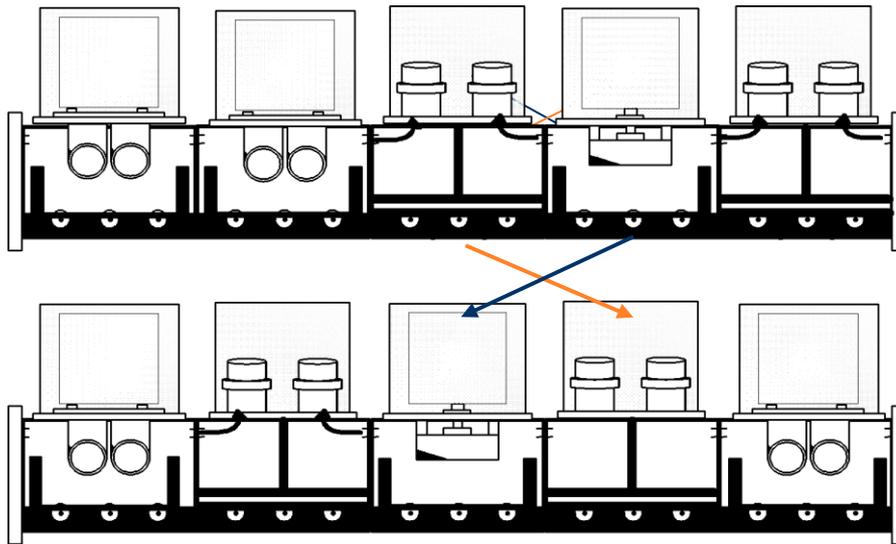
- **Flexibility**
 - highly configurable platform to meet current and future production needs
- **Technology**
 - rotatable cathodes, advanced process control, stable process environment, new innovation...
- **Serviceability**
 - “plug-n-play” rapid exchange design, maintenance valves for quick turnaround times, self maintenance of critical elements.
- **Productivity**
 - low cost of ownership with high productivity

Coater GB 3300 – Process Section



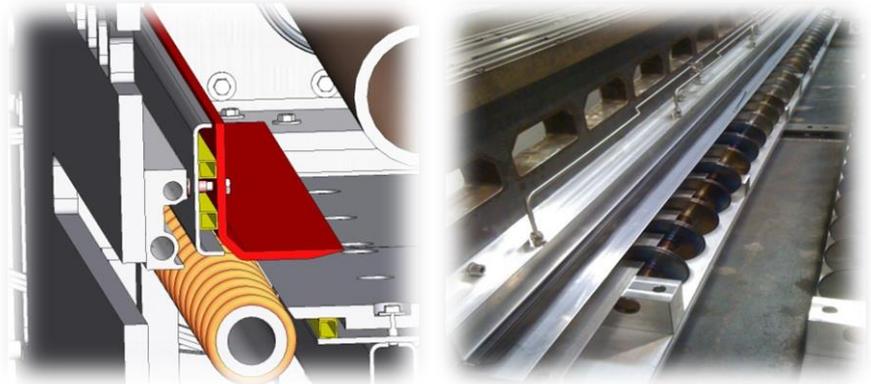
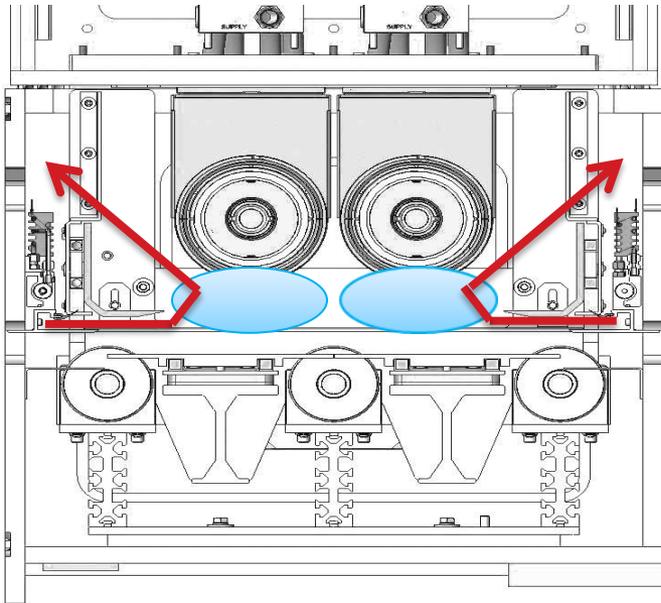
Universal Process Compartment

Pumps, cathode and spares are interchangeable



- Widest compartment (870mm) available for most stable process conditions
- Tub shield for ease of maintenance
- Adjustable gas separation tunnels
- Ready to accept dual planar cathodes

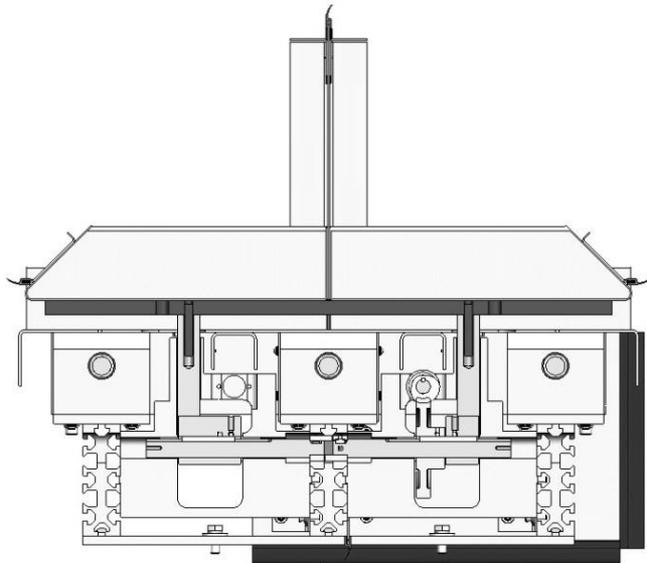
Universal Process Compartment



Gas Delivery System & Drop-in Shielding

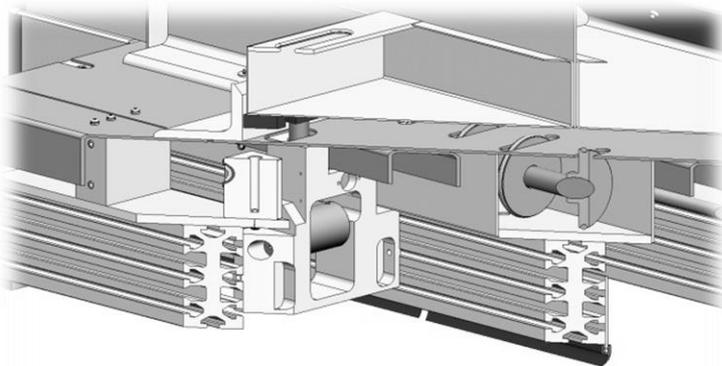


- Gas delivery just above glass passline
- Sputter area between pumping and gas delivery
- Shielding optimized for debris management

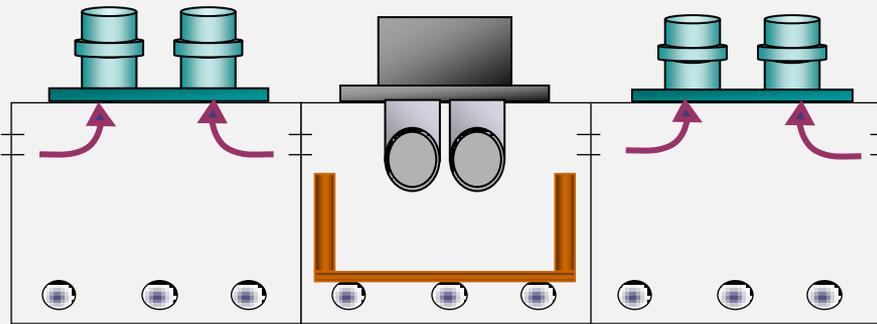


Pump Compartment – Externally Adjustable

- Designed for gas isolation up to 30:1 in a **single** compartment
- Pump lid unchanged from traditional design
- Externally adjustable tunnel heights to maintain optimum isolation with varying substrate thickness
 - Accommodates glass thickness from 2mm to 19mm
 - Height set from the control console, and verified with material packet
 - Internal sensor measures and reports height at each position
- Removable light weight top tunnel without impacting lift mechanism

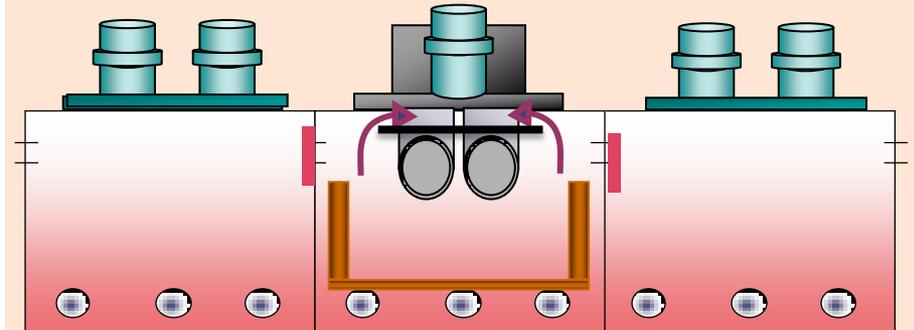


Traditional Compartment Pumping



- Process pumping to adjacent compartment
- Gas isolation requires minimum 2 compartments
- Side-by-side cathodes generally limited to 2

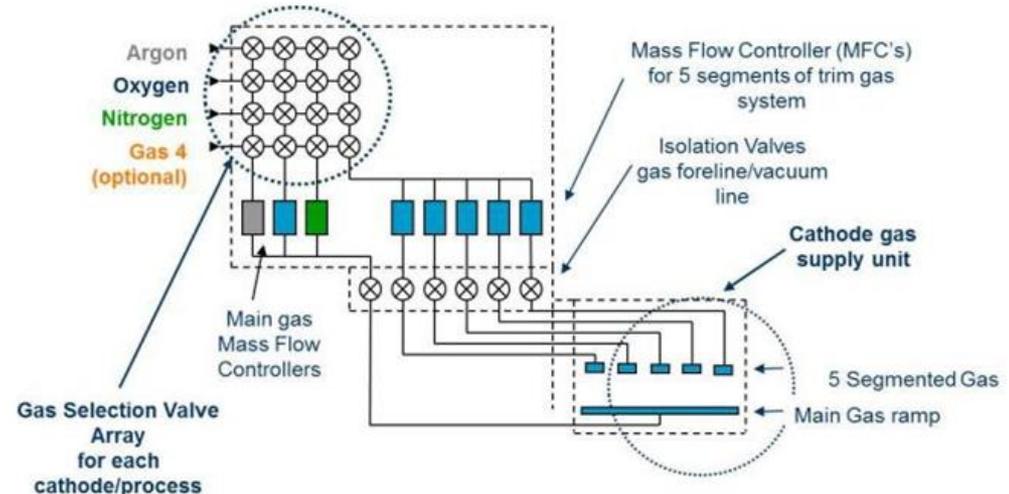
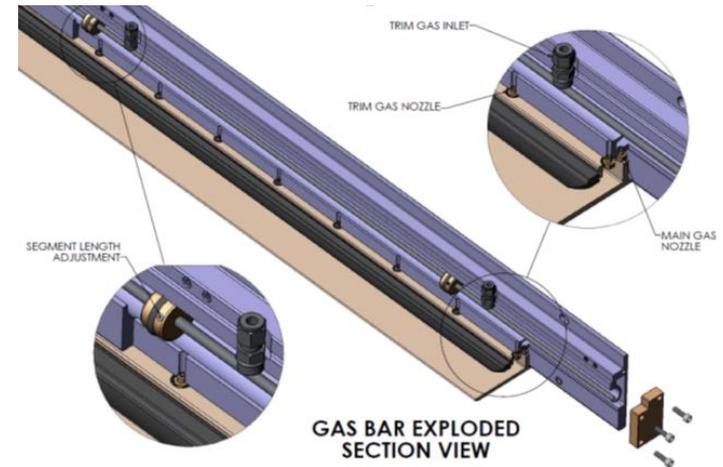
Top Pumping Layout



- Process pumping directly above the cathode
- Adjacent compartments required only for isolation pumping
 - Pumping slots between side-by-side cathodes can be closed or open
 - Isolation between adjacent cathodes with pump slots closed = 4:1
- Quantity limitation of side-by-side Cathodes only due to isolation requirements

Versatile Gas System

- Up to three gases can be selected and mixed in main distribution line.
- Gas segments can run any one of up to four gases
- Each gas segment can run as low as 1% of total gas flow
- Quantity of gas segments can be adjusted
- Quantity of nozzles per gas segment can be adjusted



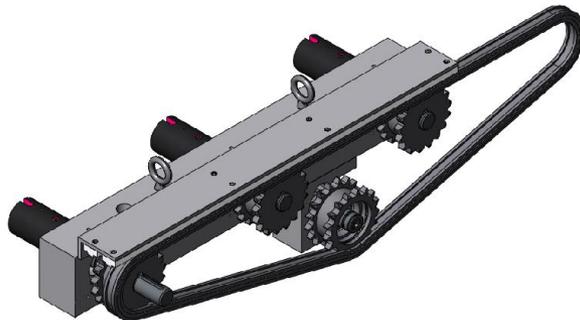
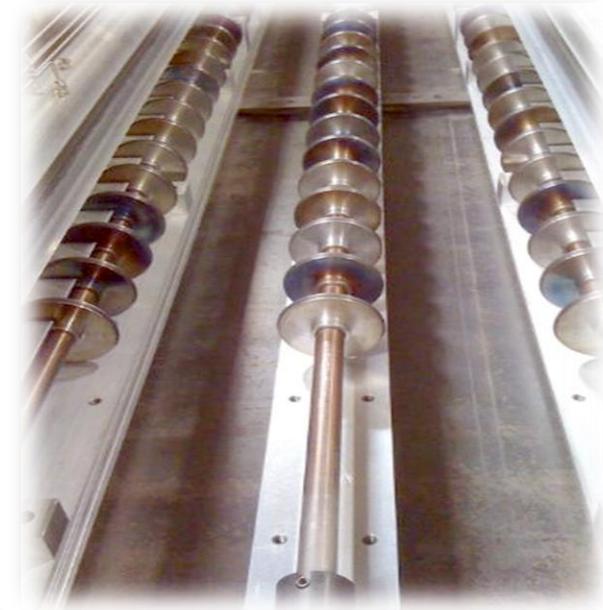
Pressure Control loop using CM

- Fixed flow mode also available

GB 3300 – Process Zone | Transport System

Process Zone Transport System

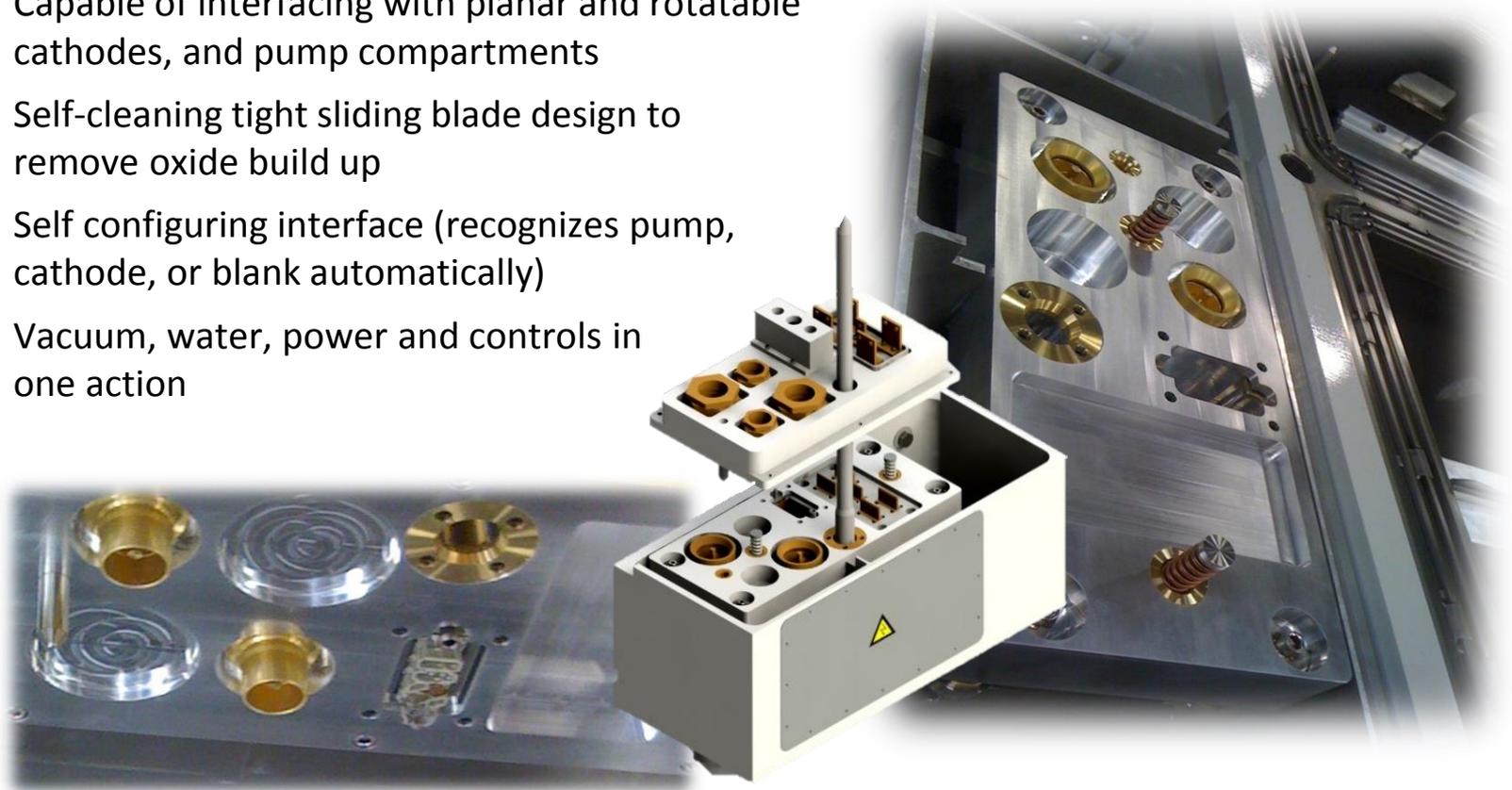
- Heavy duty chain drive utilizing a drag chain concept for reliability and maintenance
- Common conveyor section for all universal compartments
- Process roll is a wheel and shaft assembly mounted to a support rail for industrial environments
 - Designed to allow for a very deep deposition shield (user adjustable)
 - Universal conveyor module electrically floats to prevent electrical discharge
 - Roll can be removed without disturbing chain drive



Universal Electrical & Utility Interfaces

- Capable of interfacing with planar and rotatable cathodes, and pump compartments
- Self-cleaning tight sliding blade design to remove oxide build up
- Self configuring interface (recognizes pump, cathode, or blank automatically)
- Vacuum, water, power and controls in one action

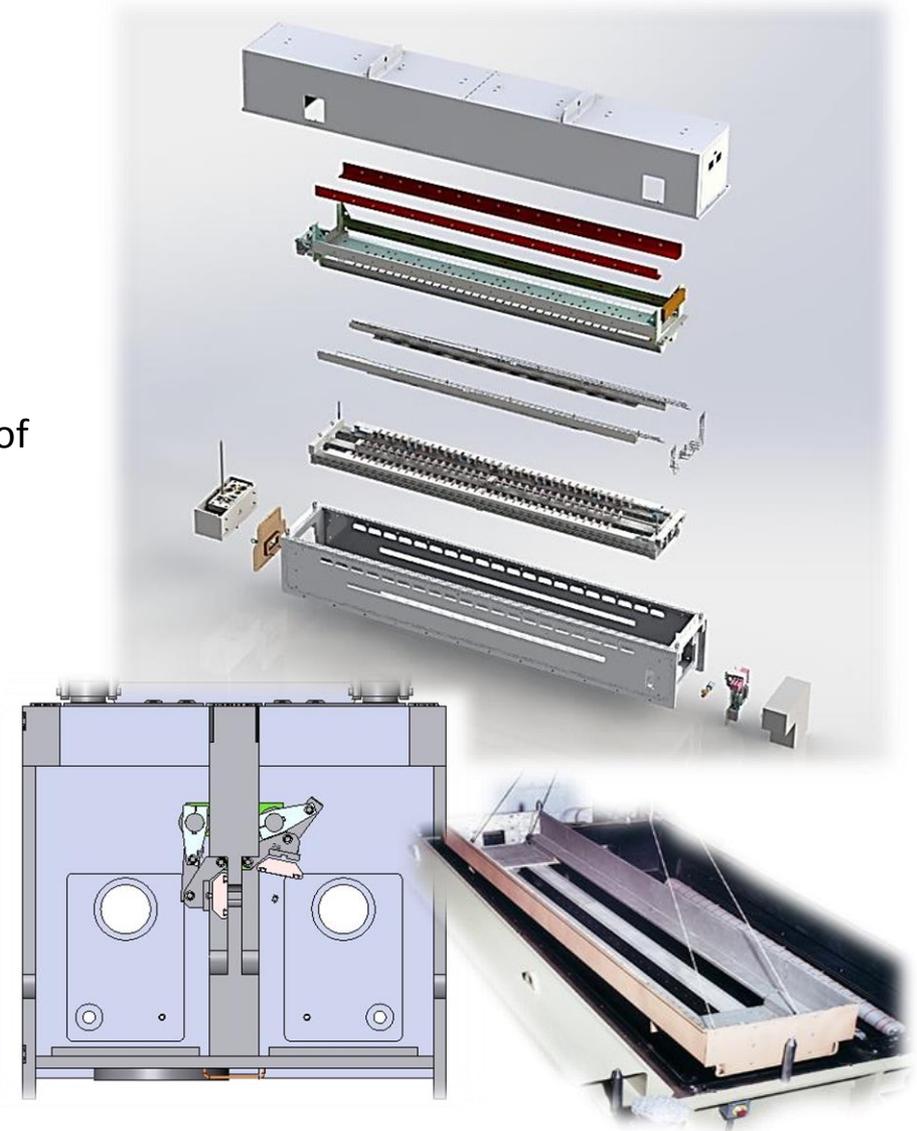
Self-aligning Compartment Chamber Interface



Self-aligning Compartment Lid Interface

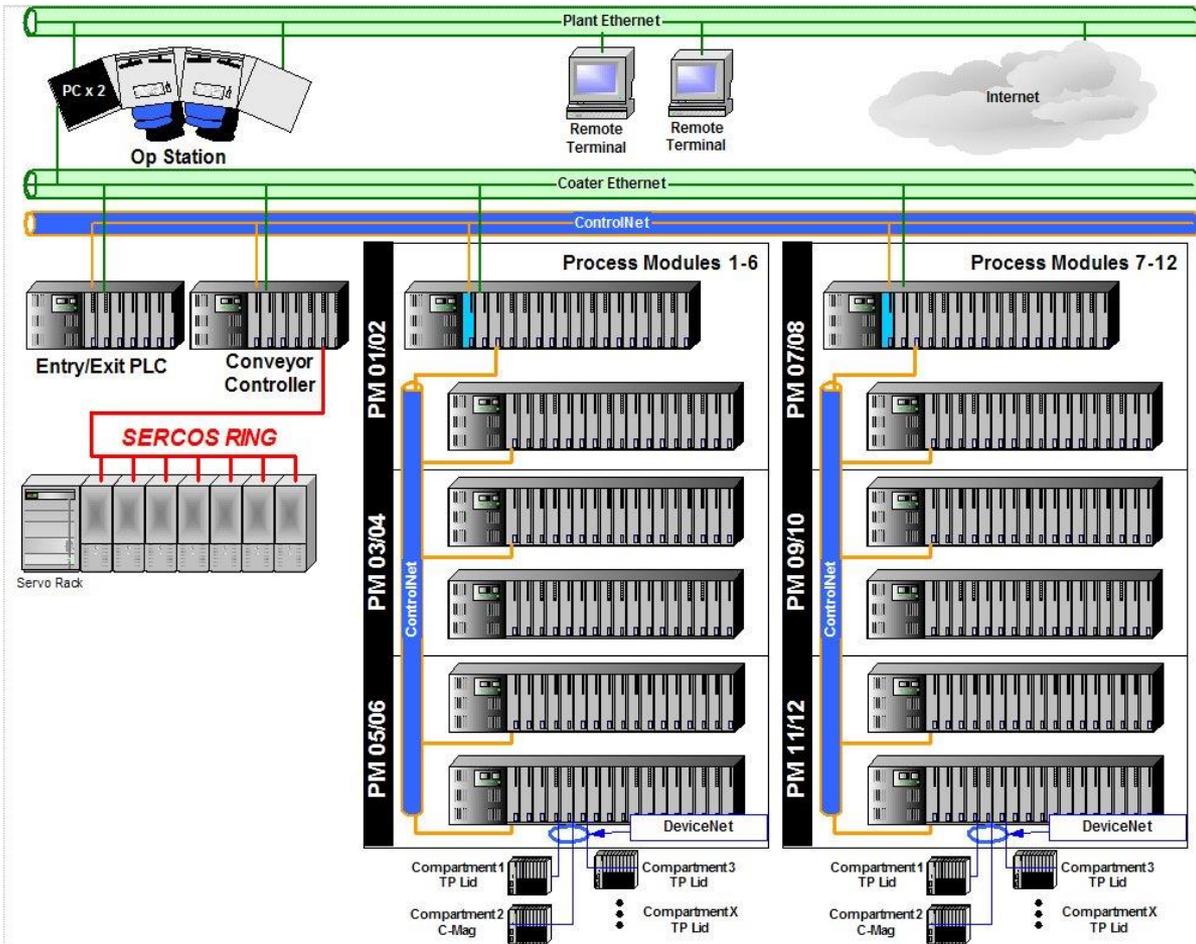
GB 3300 – Serviceability

- “Plug-n-Play” Design
 - Top mount cathode
 - Single piece removable shield
 - Universal conveyor module
- Self-aligning cathode interface
 - Enables simple cathode swaps and ease of target changes
- Maintenance valve
 - Reduces recovery time
 - Twin EZ-way valves
 - Functions as a pump Compartment



SUPPLIER	CATHODE TYPE	OPERATION MODE
	Single Rotary	DC pDC
	Dual Rotary	AC DC pDC
Grenzebach SP-MAG®	Single Planar	DC pDC
Grenzebach DP-MAG®	Dual Planar	DC pDC





Control System Architecture

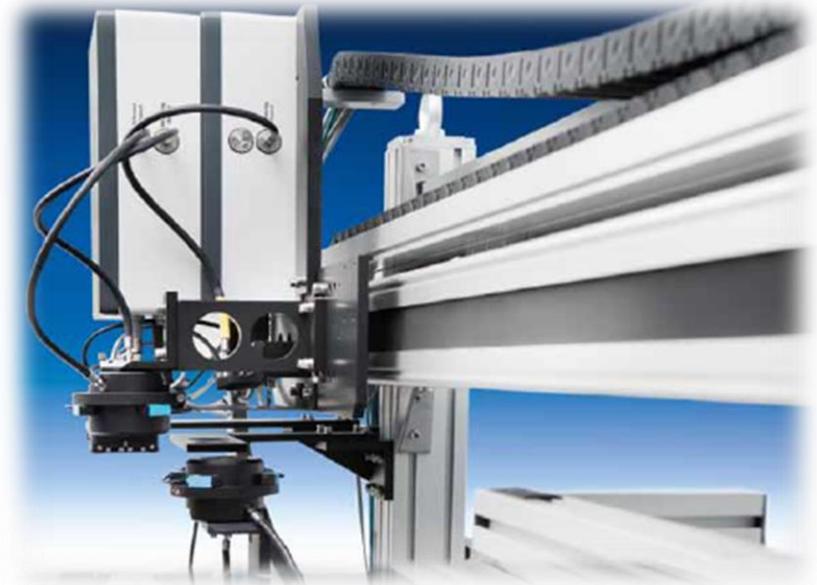
- Allen-Bradley Control Logix
- Siemens S7
- Programmed using on proven native tag-based modular code
- 3 PLCs:
 - Entry/Exit Lock, Process, Conveyor
- ControlNet to field-distributed I/O
- ControlNet for inter-PLC communications
- DeviceNet to field-level devices

OPTOPLEX P

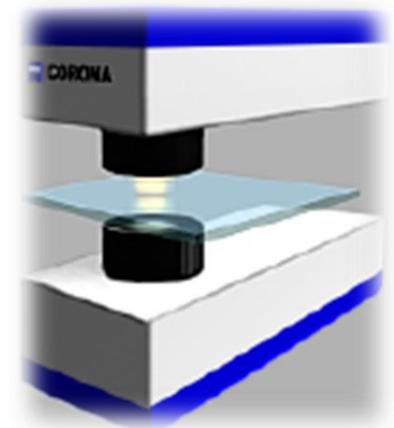
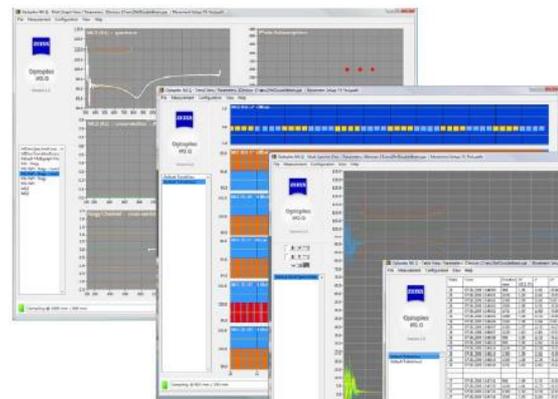
- In-situ measurement of T_y at any location between the coating positions
- [Option] In-situ measurement of sheet resistance at any location between the coating positions

OPTOPLEX Q

- Ex-situ measurement of T_y and R (film side and/or glass side) over the complete substrate width at quality inspection station outside of the coater
- [Option] Ex-situ measurement of sheet resistance over the complete substrate width at quality inspection station outside of the coater

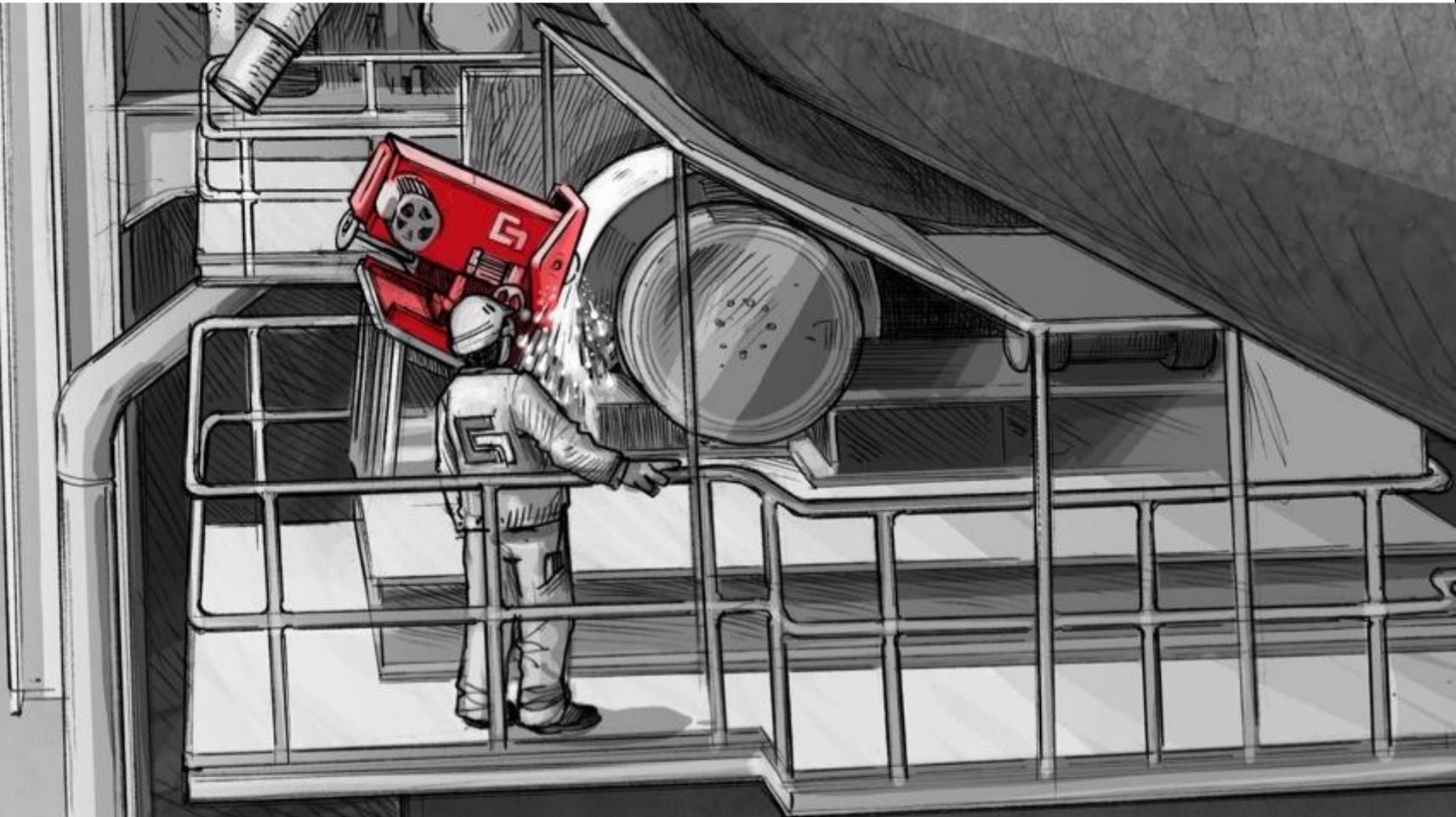


We make it visible.



Grenztech Coating Technology | Summary

- Grenztech is the only save choice for a single-supplier turnkey coating line
- Grenztech offers a PVD coating system with unique features for highest productivity and ease of maintenance :
 - Robust heavy duty chain drive concept
 - Tub shield and roller package concept
 - Dual planar cathode compatibility
 - Adjustable tunnels for improved gas isolation
 - Top pump capability for reduced coater footprint
 - Integrated HMI system for complete turnkey system
- Worldwide manufacturing and service organisations
- Global service presence with 24/7 hotline service
- Commitment to the global glass manufacturing & processing industry on a long term basis
- Local support via subsidiaries and agencies based worldwide (e.g. Jiashan, China / Newnan, USA / Seoul, Korea / Pune, India)



Service

Spare Parts	Component Refurbishment	<ul style="list-style-type: none">▪ Cathode End Block Refurbishment
Upgrades	Control Retrofit	<ul style="list-style-type: none">▪ Cathode Upgrade / Extension Additional Cathods▪ Vacuum System Upgrade e.g. Upgrade of Pumps▪ Control Retrofit e.g. S5 → S7▪ Layer Stack Development Uniformity & Precision▪ Increase of Throughput
Re-configuration		
Process Optimization	Technical Consulting	<ul style="list-style-type: none">▪ Layer Stack Optimization Uniformity & Precision▪ Technology Support





Thank you.

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