

GLOBAL BENCHMARKING OF LONG ROLLING

INSTITUTE OF ROLL DESIGN
OCTOBER 2023 MEETING

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1 GLOBAL BENCHMARKING OVERVIEW

- Market segments
- Market pressures
- Investment routes considered Globally

2 ULTIMATE FLEXIBILITY

- Combination rod and bar mill

3 REBAR TECHNOLOGIES

- Routes to maximizing productivity with integrated mini-mills
 - HYQST – 1,000,000 tpy
 - FINE GRAIN - 1,300,000 tpy
 - HYBRID - 1,300,000 tpy
- Key Equipment
 - Powered Slitter
 - eDrive No-Twist Mill
 - eDrive Mini-finishing Mill
 - Water Cooling Line
 - Divide Shears
 - Bar Braking Pinch Rolls
 - Rotary Entry System

4 INTEGRATED MINI-MILL

- Endless Bar Production (EPB)

5 SUMMARY

Long Rolling market segments

Automotive Segment

- High Carbon – Tire Cord & Bead
- Alloy Steels – Suspension, torsion bars, drive shafts
- Welding Wire – Sub frame joints etc.
- Spring Steel – Suspension Springs, Seat Springs
- Bearing Steel – Ball Bearings, Wheel Hubs
- Cold Heading – High strength fasteners
- Free Cutting – Engine Block Components

Infrastructure Segment

- High Carbon – PC Strand – Prestressed concrete applications
- Alloy Steel – Plant
- Construction wire and rebars

Energy Segment

- High Carbon – Conducting wire ropes
- Alloy Steels – Power generation systems
- Bearing Steel - Power generation systems
- Cold Heading – High strength fasteners

Consumer Durables

- High Carbon – Springs, Tools
- Alloy Steels – Gears
- Spring Steel – Bed Springs

Market pressures are Globally shared

Outside Forces

- Green Steel initiatives driving increased EAF production
- Gas costs
- Electricity costs
- Scrap costs and availability
- All other steel additive costs and availability
- Logistics delays and costs
- Changing local and global regulations
- Political pressures
- Taxes and subsidies
- Competitor pricing and investments
- Long rolling push to catch up to flat rolling

Internal Forces

- Site competition (conversion cost war)
- Labor volatility and shortage
- Management volatility and shortage
- Pace of change with market trends
- Short term gains delay long term planning
- Sales driven urgency

Investment routes considered across markets and regions – 2 focus areas

Construction grades and rebars

- High-speed rebar for reduced secondary processing
 - Fine Grade production
 - HYQST production
 - Hybrid rolling solutions
- Mini-mill production
 - Regionalized focus market
 - Wide range of production rates with tailor-made link of the steel plant through the rolling mill based final products and production goals

High added value steels

- Flexibility to serve more customer demand
- Reduced secondary processing, value add to customer
- Utilizing processing trends for lower costs
- Thinner margins than past driving innovations

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Hyundai Steel – Mill Profile for 3-Outlet Combination Mill for Quality Steels

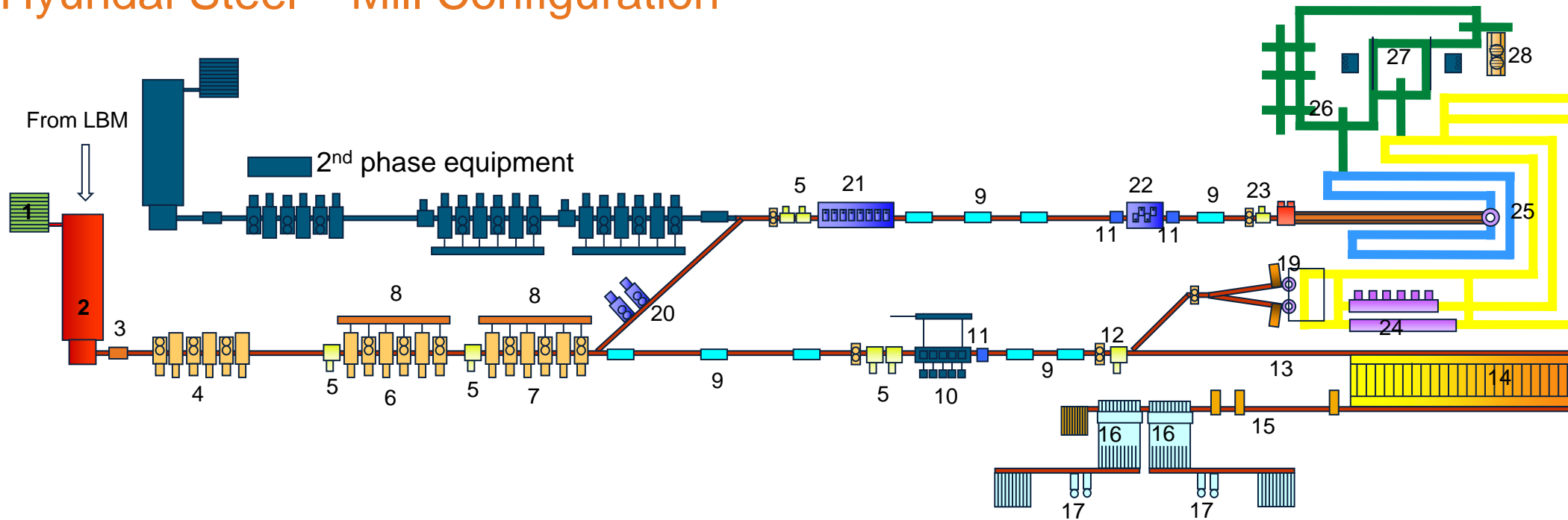
- Automotive grades
 - Carbon Steel (56.5%)
 - Low Alloy Steel (7.2%)
 - Special Alloy Steel (22%)
 - Free Cutting Steel (0.3%)
 - Spring Steel (7.5%)
 - Bearing Steel (6.5%)

Plant data

Annual capacity	800,000 t 1,200,000 (2 nd Phase)
Billet Sizes	150 – 150 mm
	180 – 180 mm
	200 – 200 mm
	5, 10, and 12m lengths
Furnace Capacity	160 t/hr 320 t/hr (2 nd Phase)
Product Range	5,5 – 26,0mm wire rod (50%)
	16,0 – 60,0mm bar in coil (12%)
	16,0 – 100,0mm straight bar (38%)
	18m/s for straight and BIC 110m/s for wire rod



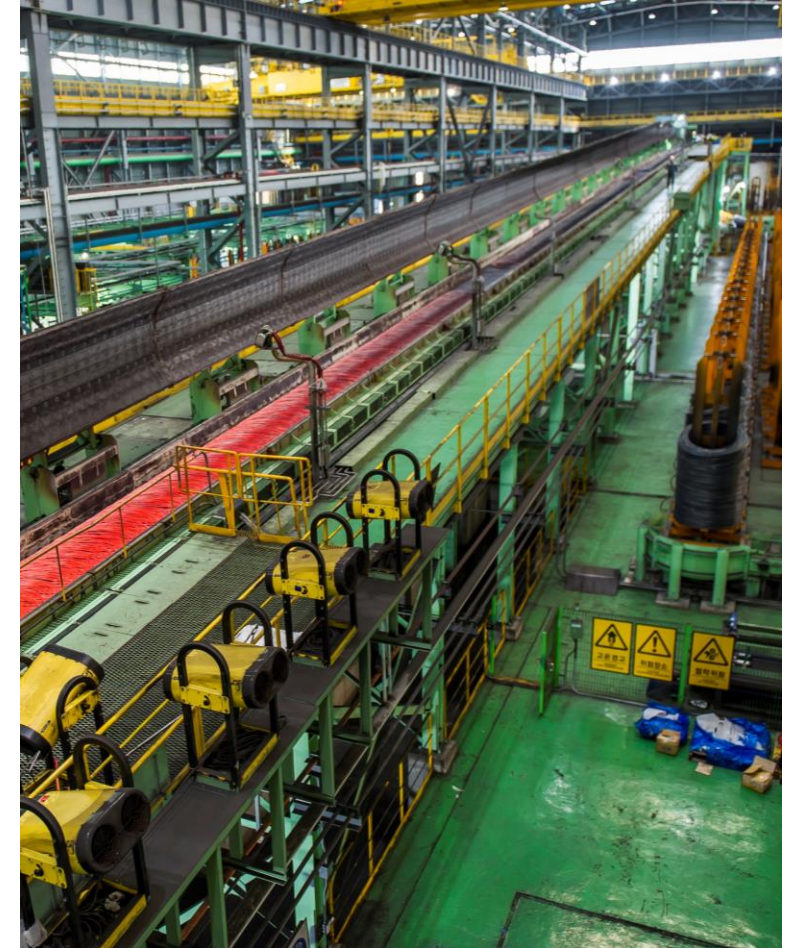
Hyundai Steel – Mill Configuration



- | | | |
|------------------------------------|--|----------------------------------|
| 1. Cold furnace charging equipment | 10. Kocks Finishing Mill | 19. Pouring Reel |
| 2. Re-heating furnace 160 t/h | 11. Measuring gauge | 20. 250 "VEE" pre-finishing mill |
| 3. High pressure water descaler | 12. Flying dividing shear | 21. "VEE" NO-TWIST® mill |
| 4. Roughing train | 13. Entry way to cooling bed with A.S.D. | 22. Reducing sizing mill |
| 5. Hot flying shear | 14. Cooling bed | 23. Pinch roll and Laying head |
| 6. Intermediate train | 15. Cold cut abrasive disk saws | 24. Coil air blowing station |
| 7. Pre-finishing train | 16. Bundle forming station | 25. Vertical stem pallet system |
| 8. Stand quick change device | 17. Binding machines | 26. Horizontal C-Hook system |
| 9. Cooling section | 18. Bundle unloading | 27. Horizontal coil compactor |
| | | 28. Coil unloading |

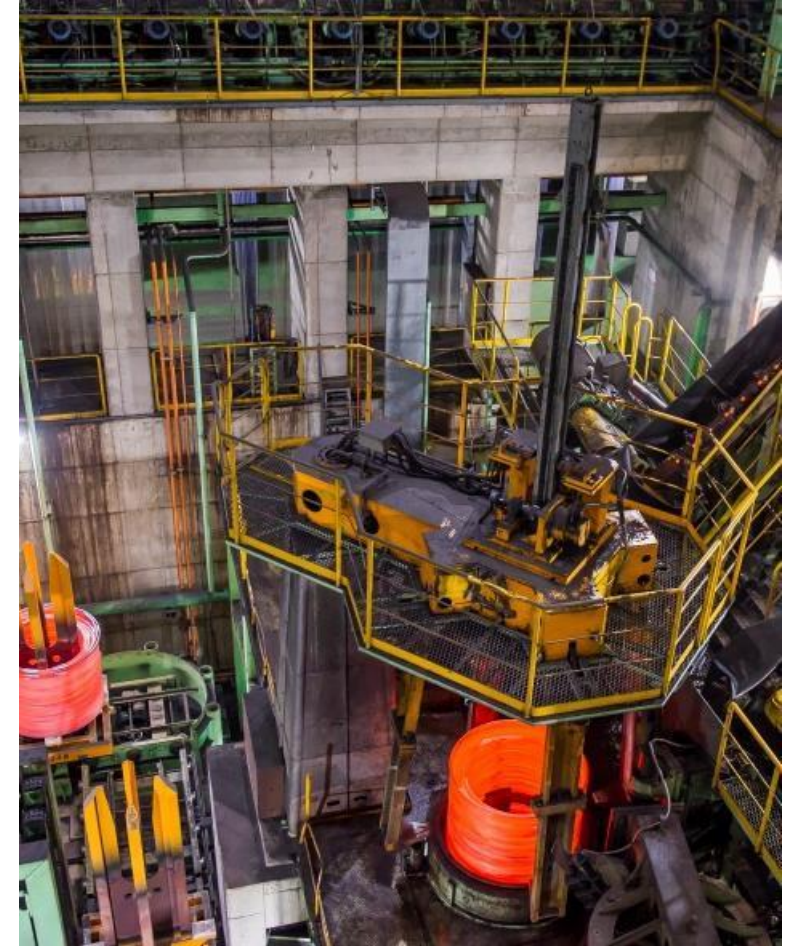
Hyundai Steel - Wire rod line

- Morgan Vee Pre-Finishing Mill (2 x 230 stands) feed from the bar intermediate mill
- Morgan Vee No-Twist[®] Mill (8 x 230 stands), preceded by pinch roll, shear arrangement and sidelooper
- Tension monitoring system, rod size gauge and waterboxes
- Morgan Reducing/Sizing Mill (230/150)
- Tension monitoring system, rod size gauge and waterboxes
- Morgan Intelligent Pinch Roll and Morgan High Speed Laying Head
- 11 Zone Stelmor[®] Conveyor (pictured)
- Stepless reform station to collect wire rod rings as they leave the Stelmor Conveyor
- Integrated Vertical Pallet system with the Bar in Coil outlet
- Coils moved to horizontal C-hook system for compacting



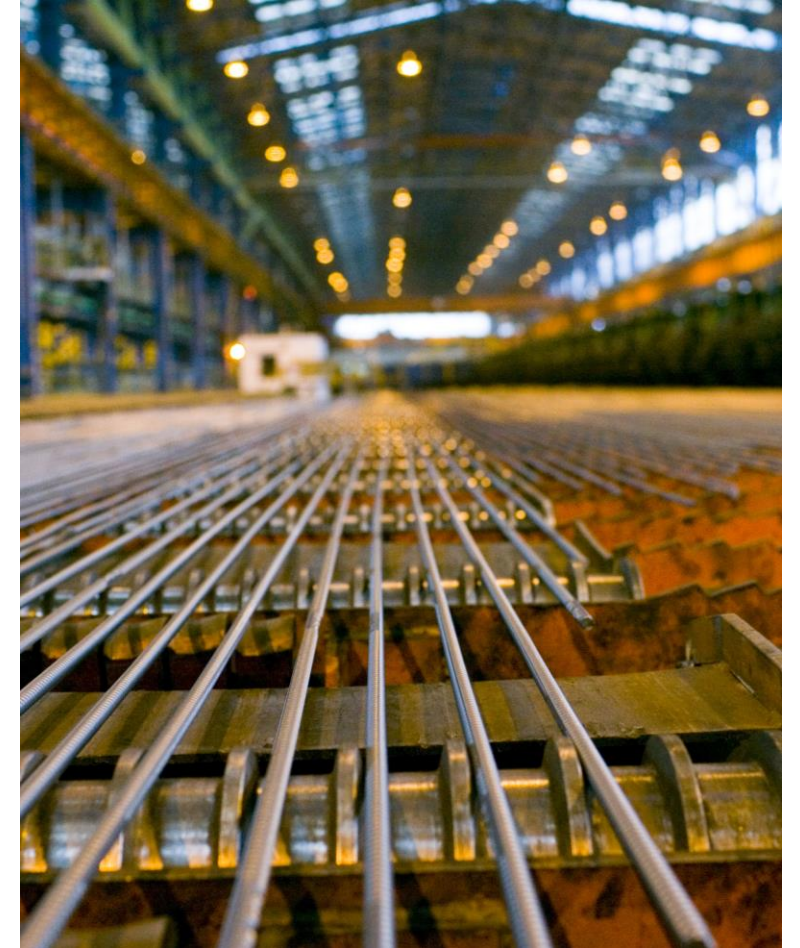
Hyundai Steel - Bar in coil line

- Finished bars rolled in Kocks sizing mill
- Traversing waterboxes, pinch roll, shear group and switch to Bar-in-Coil outlet with powered roller tables
- 3-Roller guide pouring reel turndown to entry pinch rolls
- 3-roller curved guide head for minimized surface defects
- Transfer to vertical stem pallet coil handling (pictured)
- Air blowing stations or Heat Retention tunnel option for post processing
- Vertical stem pallet coil handling system for bar-in-coil and wire rod coils, with trimming station, vertical strap coil compactor and unloading station.



Hyundai Steel - Straight bar outlet

- Roller entry to cooling bed with brake slide
- Abrasive disc saw outlet for SBQ bars
- Bar counting device, chain transfer, bundling stations tying machines
- Bar finishing facilities with straightening, peeling and chamfering and centerless grinding in next building bay



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Rebar Processing Routes - Introduction

- The fundamental process to achieve mechanical properties are with adjustments to the billet chemistry
- Hot rolling of rebars is a dying process, with the focus to reduce or remove high-cost alloying elements (Mn, Vanadium) to achieve Yield Strength, Tensile Strength, Elongation, etc.
- To reduce the expense of alloying there are two (2) predominant rebar processing routes used globally:

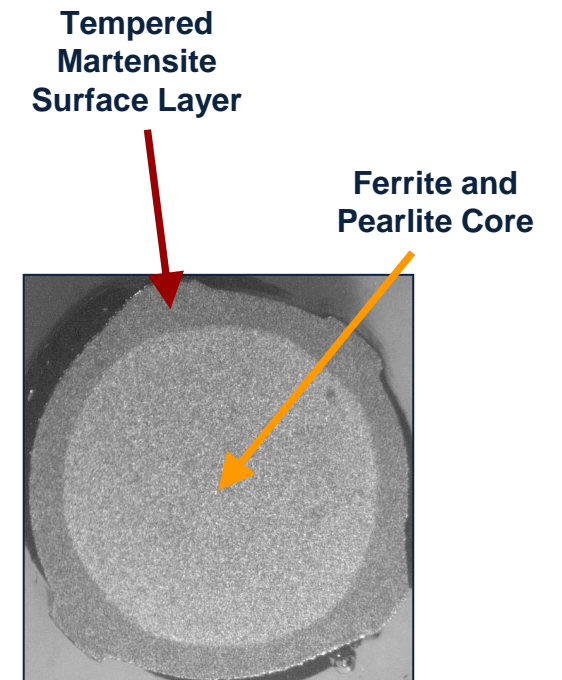
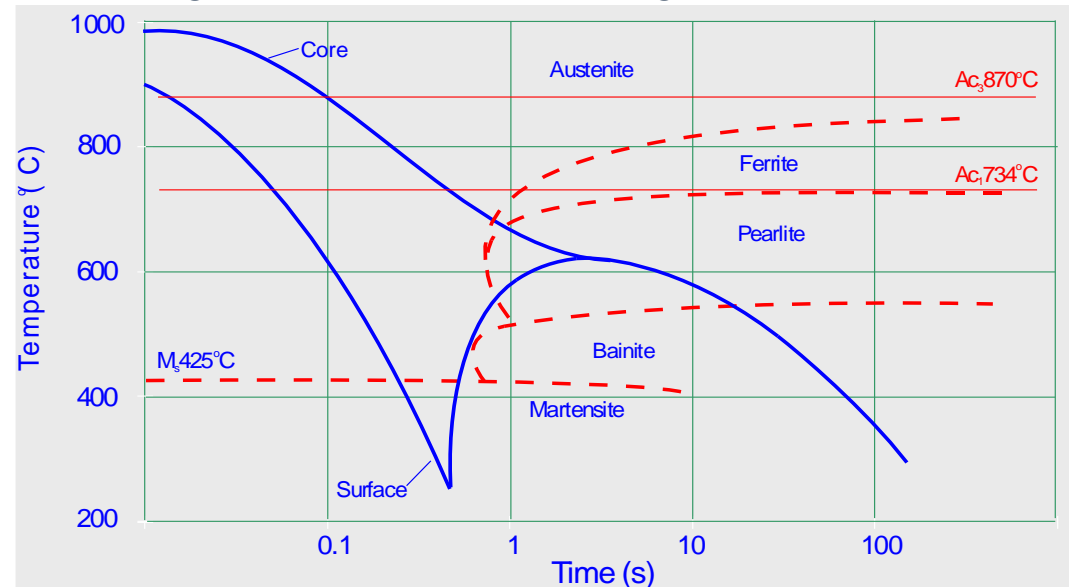
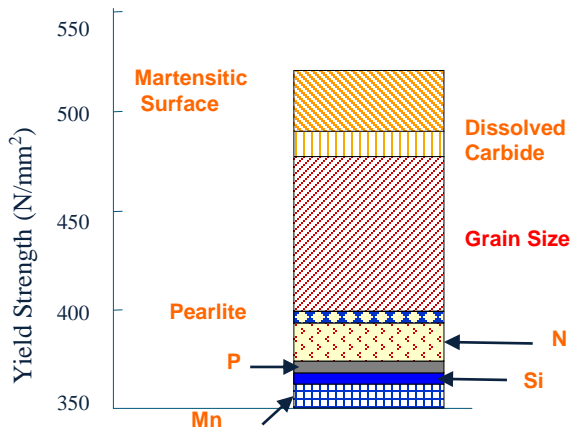
1. Quench and Tempered Processing (Thermex, Tempcore, HYQST)
2. Fine Grain (Thermo-mechanically rolled with no martensitic ring)

With today's technology a third processing route has developed using a hybrid of above two standard processing routes to achieve Seismic / earthquake rebar with further enhanced billet chemistry

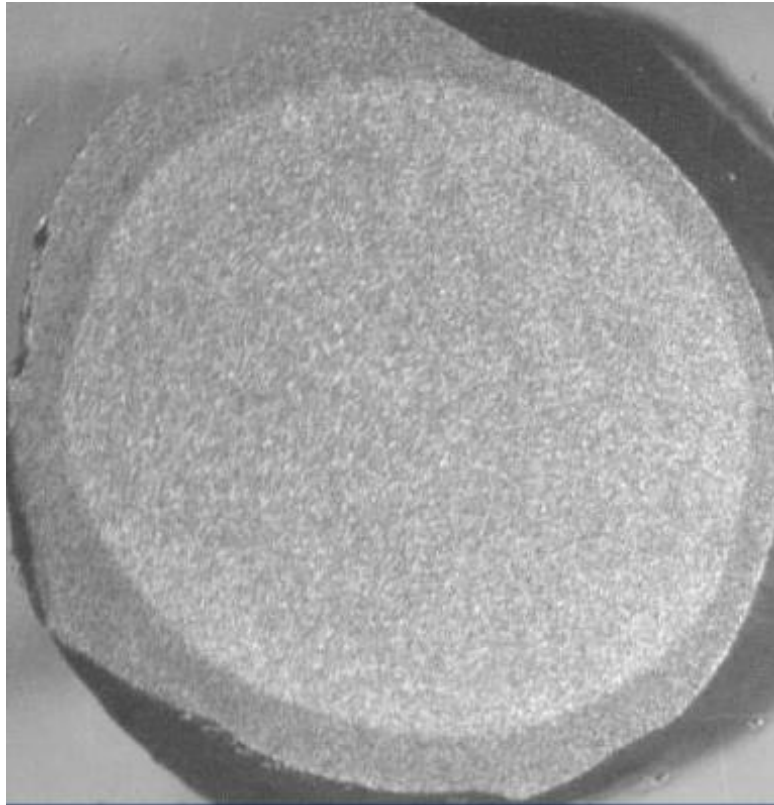
3. Hybrid - Fine Grain with Quench & Tempered Processing

HYQST Quench & Tempered Rebar Processing

- High yield strength is produced by a combination of fine grain size and self tempered martensitic surface
- Rapid cooling immediately after finished rolling to lock in the grain structure
- Quenching reduces the surface temperature below the Martensitic start temperature to form low carbon Martensite
 - The shell is self tempered as the remaining heat from the core dissipates.
- TS/YS ratio between 1.08 ~ 1.15 for general and weldable grades



HYQST Process costs for USA reference plant using Micro alloying for ASTM 615 Grade 60



HYQST Production

General chemistry

C wt%	0.206
C eq%	0.37
Mn wt%	0.96
Si wt%	0.21
V wt%	None
Ts/Ys	1.18

Micro alloying

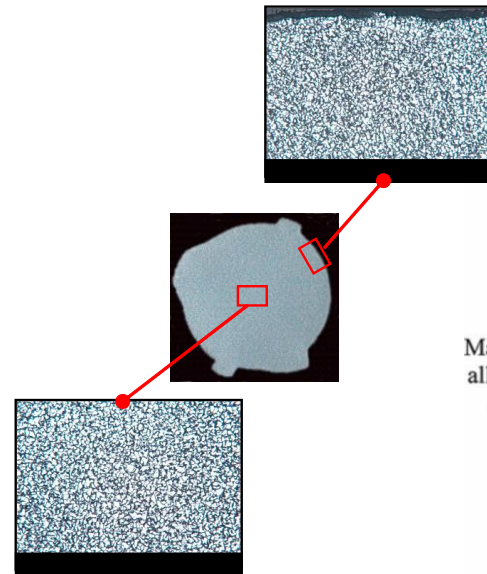
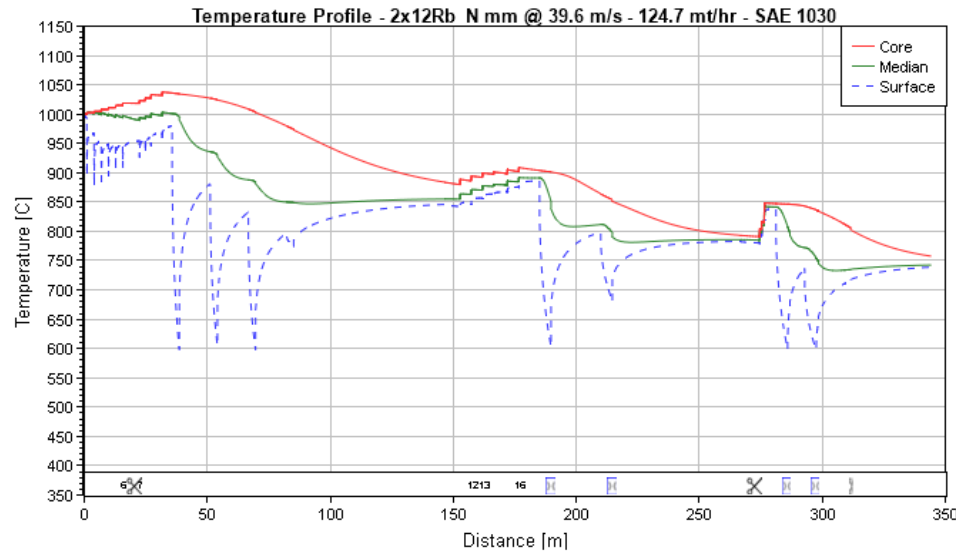
General chemistry

C wt%	0.264
C eq%	0.52
Mn wt%	1.25
Si wt%	0.19
V wt%	0.036
Ts/Ys	1.25

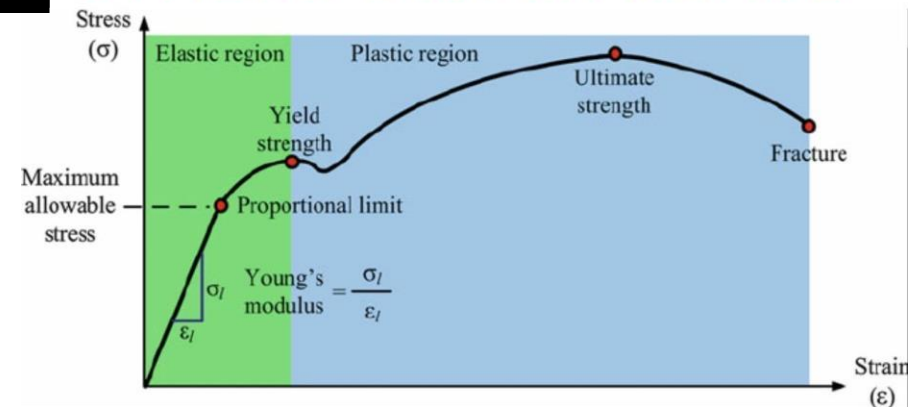
Annual Production 500,000	USD/KG (fall 2022)	HYQST	Micro Alloying
C	0.66	\$ 68,123	\$ 87,358
Mn	1.74	\$ 835,992	\$ 1,088,531
V	19.00	\$ -	\$ 340,417
		\$ 904,115	\$ 1,516,306
	Savings per Year	\$ 612,191	

Thermo-mechanical (Fine Grain) Rebar Processing

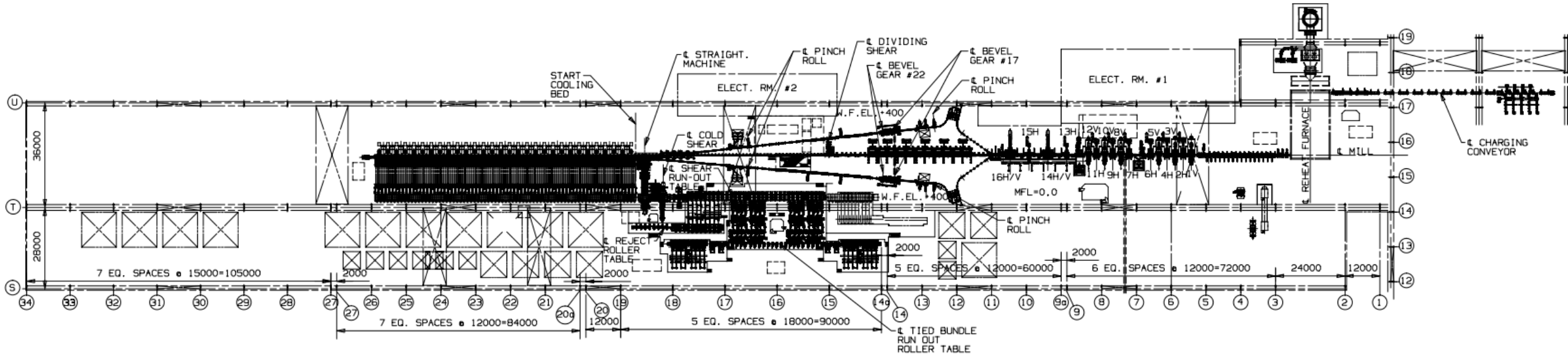
- Hall-petch Yield Strengthening is produced by a creating a fine crystalline (grain) structure
 - By lowering the processing temperature into the finishing stands a finer grain sizes can be achieved
- Limitation on the number of finishing stands are present, due to temperature regeneration while plastically deforming the product into the final shape
 - Thermo-mechanical rolling of the finished product is limited to six (6) or less to generate a uniform fine grain size
- Hard cooling is avoided to prevent martensite formation. Target finishing stand entry temperature is $\leq 800^{\circ}\text{C}$
 - No Martensitic ring is permitted on the product surface, only spot martensite on the leading edge of the ribs may be allowed.
- Typical TS/YS ratio > 1.25 for Seismic / earthquake grades



STRESS STRAIN CURVE

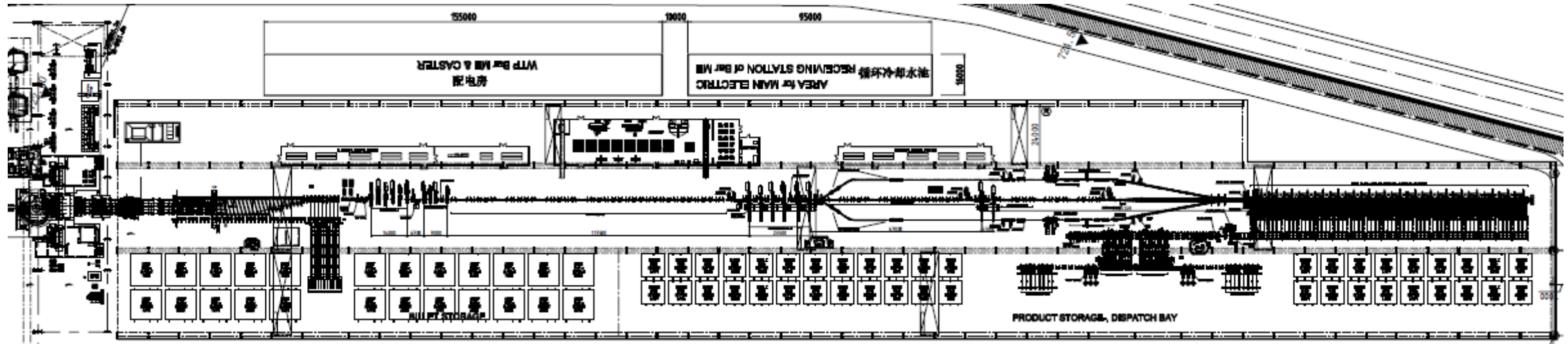


High Speed Rebar (HYQST) – 8 to 40 Rb - 1,000,000 tpy



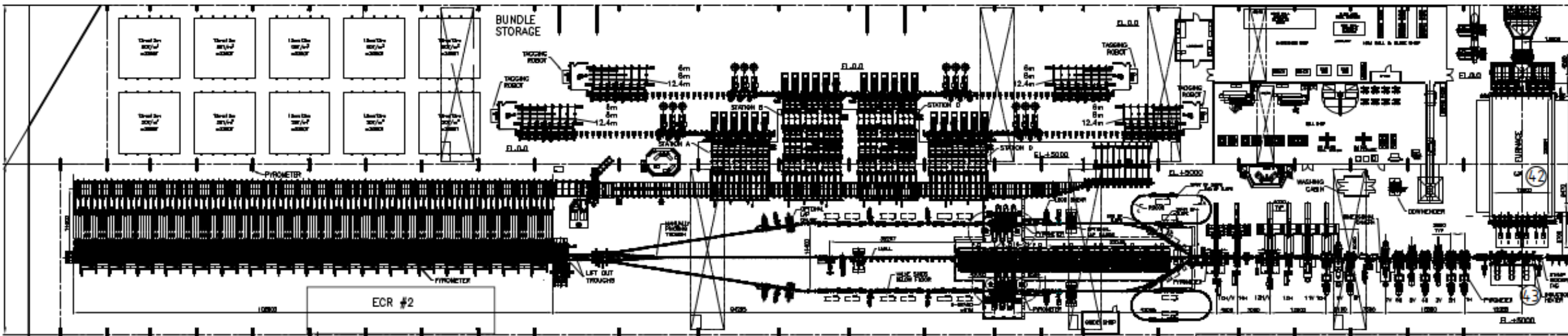
- Billet: 165 x 165, 12 m
- Total No. Stands: 22
- Mill Length (Stand 1V to Exit Cooling Bed): 280 m
- Size Range: 8 to 40 Rb
- No. Mill Stands: 16
- High Speed Line: 8 to 20 Rb
- No. No-Twist Mill Stands: 6
- Low Speed Line: 20 to 40 Rb
- Cooling Bed Length: 90 m
- Rolling Rate: 211.8 tph
- Low Speed Cooling: 130m, (11) Waterboxes
- Max speed: 35 m/s
- High Speed Cooling: 84 m, (6) Waterboxes

High Speed Rebar (Fine Grain) – 12Rb to 40Rb – 1,300,000 t/y



- Billet: 165 x 165, 12 m
- Size Range: 12 to 40 Rb
- High Speed Line: 12 to 22 Rb
- Low Speed Line: 25 to 40 Rb
- Rolling Rate: 249.4 tph
- Max speed: 41 m/s
- Total No. Stands: 22
- No. Mill Stands: 18
- No. No-Twist® Mill Stands: 4
- Cooling Bed Length: 108 m
- Intermediate Mill Cooling: 107m - (6) Waterboxes
- Low-Speed PFM Cooling: 68m & 107m - (4) Waterboxes
- Low Speed Post Finishing Cooling: 107 m, 3 Waterboxes
- High Speed Pre-NTM Cooling: 90m, 2 Waterboxes
- High Speed Finishing Cooling: 82m, 2 Waterboxes
- Mill Length (Stand 1V to Exit Cooling Bed): 450 m

High Speed Rebar (Hybrid) – 10Rb to 40Rb – 1,300,000 t/y

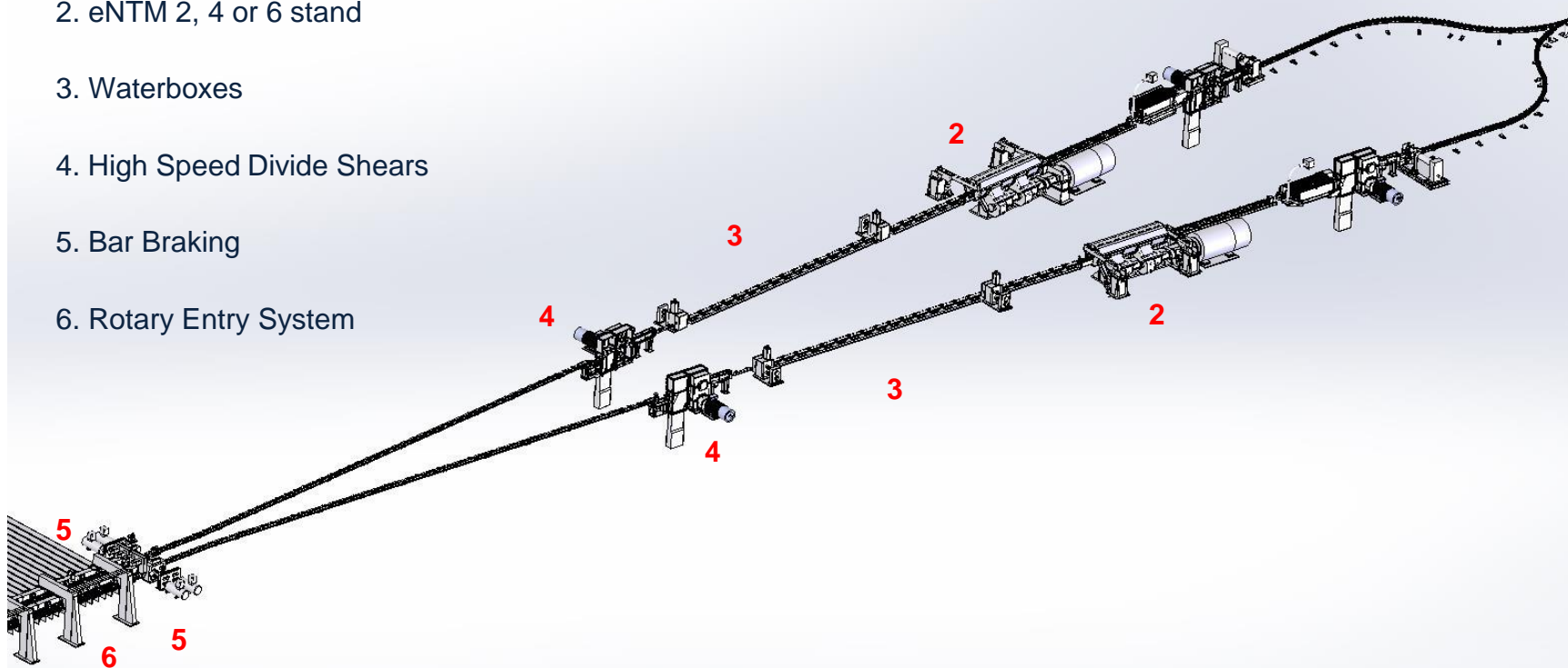


- Billet: 150 x 150, 12 m
- Size Range: 10 to 40 Rb
- High Speed Line: 10 to 22 Rb
- Low Speed Line: 25 to 40 Rb
- Rolling Rate: 257.6 tph
- Max speed: 48 m/s
- Total No. Stands: 21
- No. Mill Stands: 15
- No. No-Twist® Mill Stands: 6
- Cooling Bed Length: 102 m
- Low Speed Cooling: 145m, (14) Waterboxes
- High Speed Pre-NTM Cooling Loop: 84 m, (3) Waterboxes
- High Speed Pre-NTM Cooling: 44m, (1) Waterbox
- High Speed Finishing Cooling: 100m, (6) Waterboxes
- Mill Length (Stand 1H to Exit Cooling Bed): 295 m

High Speed Rebar Outlet – Key Equipment

Key Equipment Technology:

1. Powered Slitter
2. eNTM 2, 4 or 6 stand
3. Waterboxes
4. High Speed Divide Shears
5. Bar Braking
6. Rotary Entry System



High Speed Benefits:

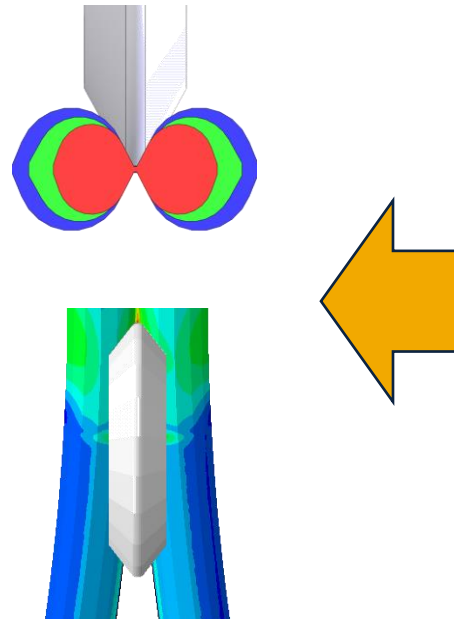
- Reduced cobbles
- Simplified setup (Single Family)
- Reduced wear parts inventory
- Reduced roll & guide inventory
- Controlled variation in weight tolerance
 - Powered Slitter
 - Balancing of slit section in stands
- Improved tension control
- Composite rolls in main mill train – Extended life (> 3000 t/pass)
- Carbide rings on No-Twist Mill – Extended life (> 2,000 t/pass)
- One (1) bar per notch on cooling bed – reduced delays at cold shear

Key Equipment – Powered Slitter

- Fixed to the mill centerline
 - Motor driven top and bottom roller match stock speed
 - Tool steel rolls provide longer life and quick change
 - Rigid RE on the powered slitter provides more accurate setup
 - Extended life > 20,000 T vs 4,000 T
 - Provides accurate slitting $\pm 2\%$ area for improved RES performance
 - Traverses ON/OFF line for dummying
- HYQST – Powered Slitter located before No-Twist Mill
 - FINE GRAIN & HYBRID – Powered Slitter located two (2) stand before No-Twist® Mill



Powered Slitter with Roller Entry Guide



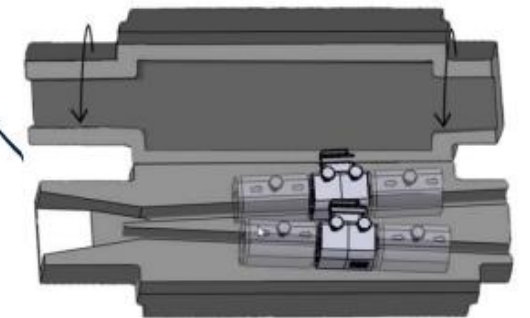
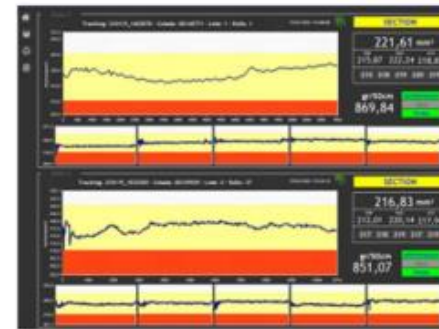
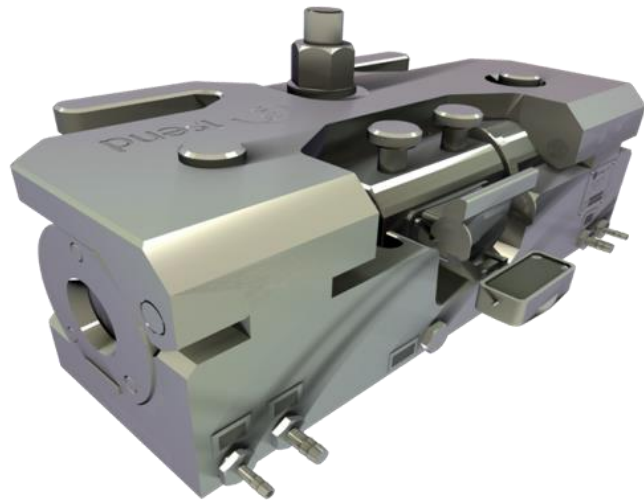
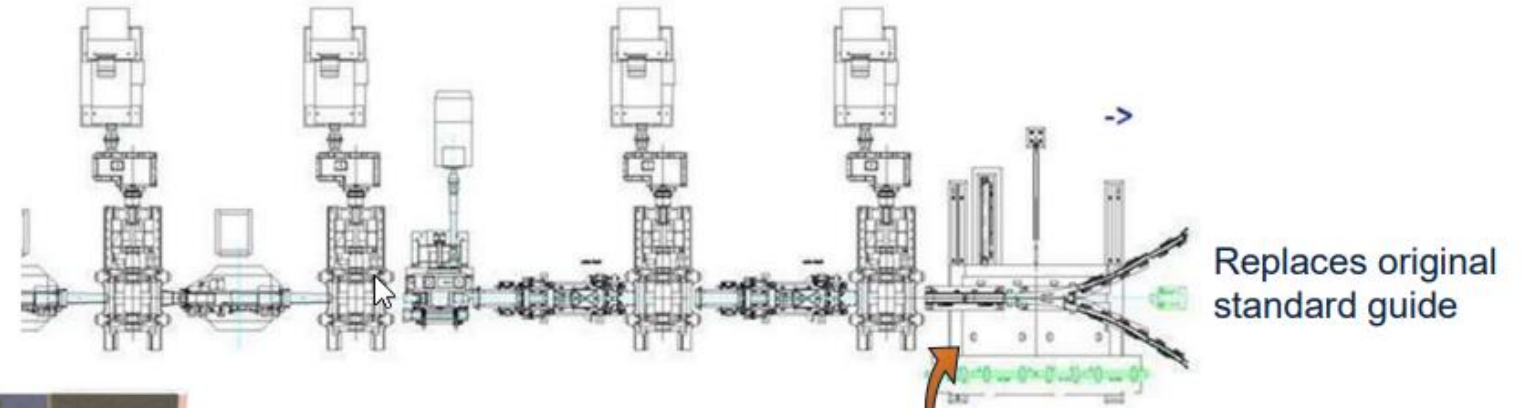
Slitting Process



Typical Slitting Guide Arrangement

Key Equipment – Mass Flow Sensors

- Accurate measurement of the slit section area alarms operator to adjust the RE guides at dog-bone to maintain area balance feeding the No-Twist Mills
- Fits into existing trough section for easy installation.
- Accuracy 1% on diameter



Key Equipment – eDrive No-Twist® Mill



High Speed Rebar Mill with 4-stand 250 eDrive NTM

- Reduced CAPEX, compared to a traditional tied NTM.
- Reduced OPEX, power and water consumed for rolling stands only
- Low Voltage power system and standard motors (4, 6 or 8 pole)
- Increased 230/250 roll housing capacity for Lower temp rolling
- Max size 25.4 mm for all processing routes
- Inter stand ratios are limitless to suit the process requirements
- Reduced roll wear, or increased roll life between dressings
- Reduced maintenance only stands rolling are operational
- Reduced roll inventories (No more roll set families)
- Reduced oil system requirements
- Process/rolling flexibility - reduced families and setups
- Remote powered roll parting under load option

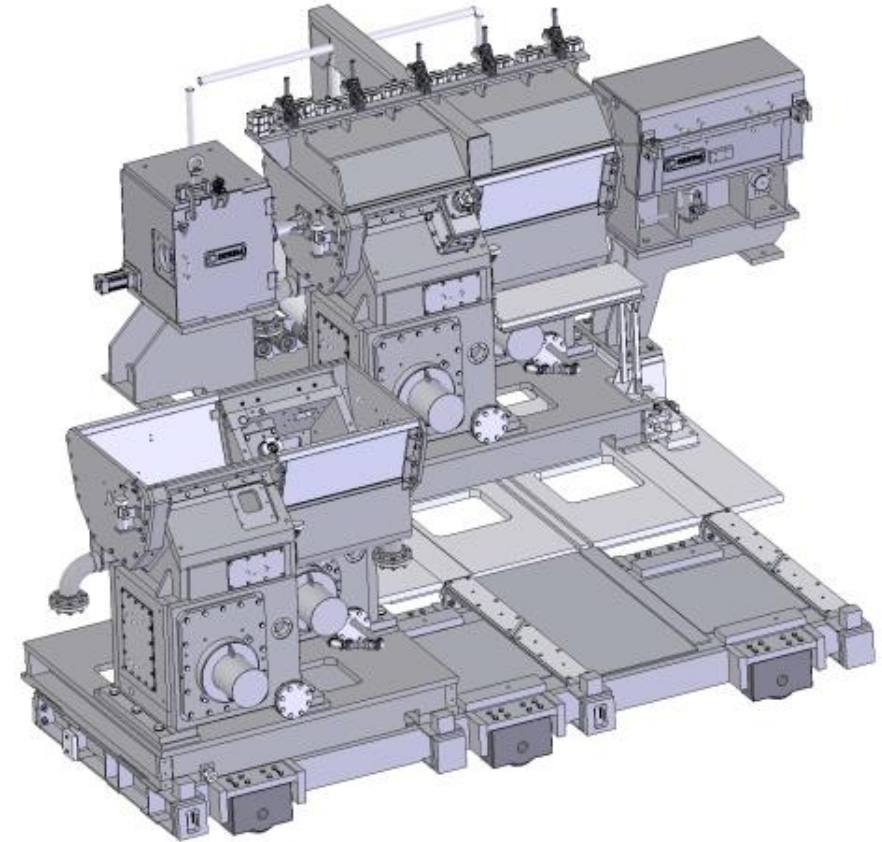
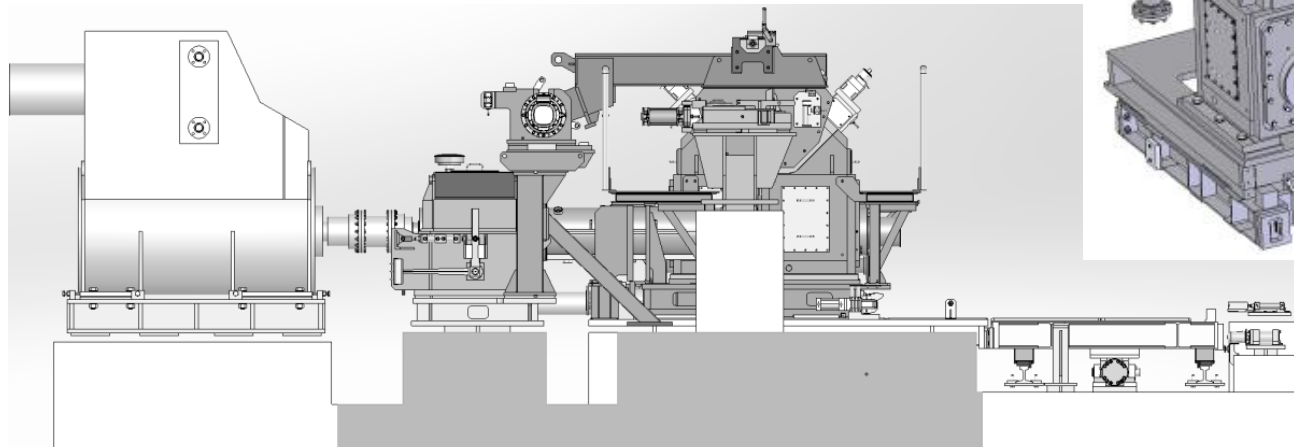


eNTM Drive Arrangement & Stand Configuration

Key Equipment - eDrive Mini-Finishing Mill

Same features as the eNTM, plus the following:

- On/Off-line capability with quick change transfer car (< 5 minutes)
- Reduced downtime – ALL roll changes occur Off-line
- Dummy troughs in cobble cover – fast change time between products
- Automatic service couplings for ALL utilities
- Single or 2-speed clutchable external drive to reduce motor power and eliminate dummyming forward for higher production rates
- Interchangeable roll units for reduced spares
- Horizontal motors
 - Easier access for maintenance
 - No thrust bearing required
- Reduced civil foot-print



Key Equipment – Waterboxes and cooling nozzles

- Split bore investment cast stainless steel HYQST nozzles
- Open nozzles for inspection and cobble removal
- Replaceable inserts and end caps reduce maintenance cost
- Water boxes can be fixed on-line, lift out by crane or traversing
- High-speed line intermediate pinch rolls between water boxes used to pull the bar to overcome water resistance with carbide rings to extended life.
- No pinch rolls required on Low-speed line as water speed > bar speed



HYQST Split Bore Nozzle Arrangement

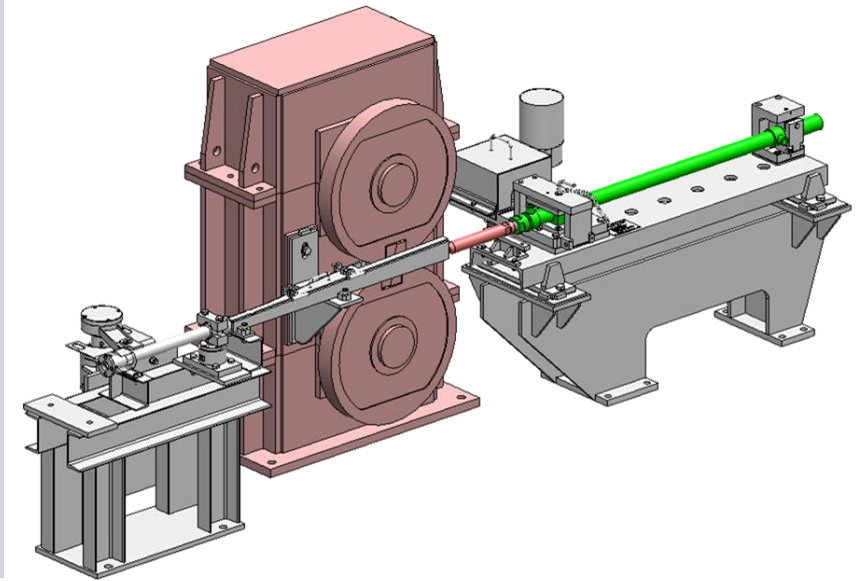
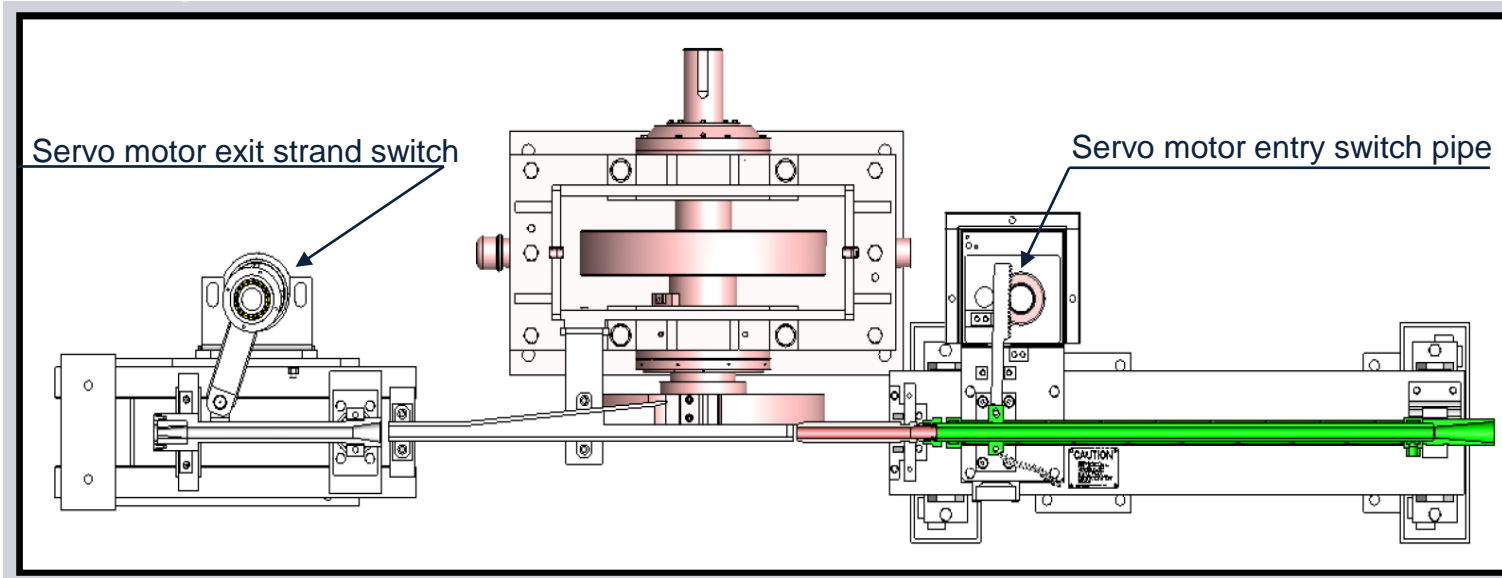


HYQST Traversing Water Box Arrangement



HYQST Fixed Water Box Arrangement

Key Equipment – Continuously Rotating Shears



High Speed Line - Divide Shear to Cooling Bed
Crop, Divide & Chopping Shear

- Range of sizes in the family:
 - 680R12 – 8 to 25 Rb at 45 m/s
 - 680R36 – 8 to 40 Rb at 45 m/s
 - 800R12 – 8 to 25 Rb at > 50 m/s
 - 800R30 & 800R53 – 20 to 63 Rb at < 30 m/s
- 4 blades, 1 wide for divide cut and 3 narrow for chopping scrap cut
- 3 paths – Mill line / Divide / Scrap cut
- Divide to master lengths, prior to cooling bed entry

Key Equipment – Bar Braking Pinch Rolls

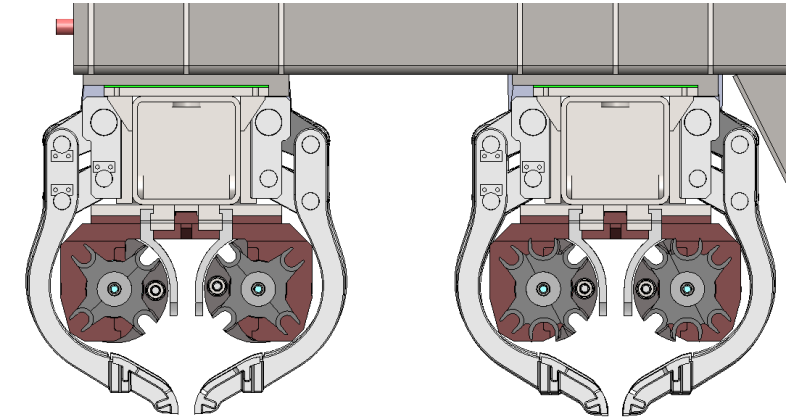
- Decelerates small high-speed product at Rotary Entry System (RES) for accurate positioning on the cooling bed
- Maintains large low speed products into RES for accurate positioning on the cooling bed
- 1:2 Increaser to reduce motor power and inertia
- Single or double pinch rolls for hard (HYQST/HYBRID) or soft (Micro Alloy/Fine Grain) braking
- Individually driven pinch rolls in common gear box for reduced distance to the Rotary Entry System (RES) for maximum reset time
- Carbide ring option for increased roll life
- Pneumatic pinch force control for fine adjustment of braking rate without deforming the ribs
- Quick change of the rolls between groove profiles
- Limited groove profiles to cover the size range: 3 grooves for 8 to 22 mm or 5 groove for 8 to 40 mm
- Fixed and traversing On/Off-line for access for roll and guide changes



Dual Bar Braking Pinch Rolls Arrangement

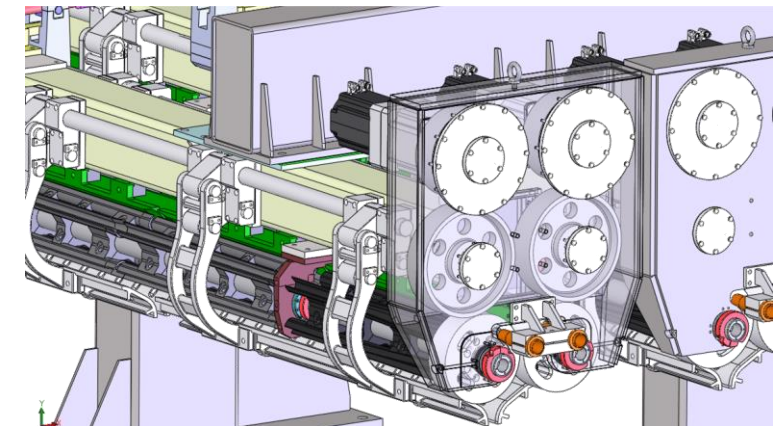
Key Equipment – Rotary Entry System (RES)

- Used for single or two strand applications
- High speed rolling to the cooling bed with max design speed of 50 m/s
- Guaranteed speed of 45 m/s for 8 & 10mm
- Four (4) channel system for small size range (8 to 25 mm)
- Six (6) channel system for larger size range (8 to 40 mm)
- No brake slide required for above rebar production (8 to 40 mm)
- One (1) bar per notch
- Bar fully stopped before dropping onto cooling bed
- Two (2) position drop down guides (small & large sizes) to reduce drop distance, bounce and jack strawing
- Front and rear drive through servo motor for fast and accurate positioning and eliminate torsional wind-up
- Modular in design for any length cooling bed
- Four times the guide life compared to twin channel (typical experience)



RES
4 – channel
Size (8 – 25) mm

RES
6 – channel
Size (8 – 40) mm



Front & Rear Drive Servo Motor

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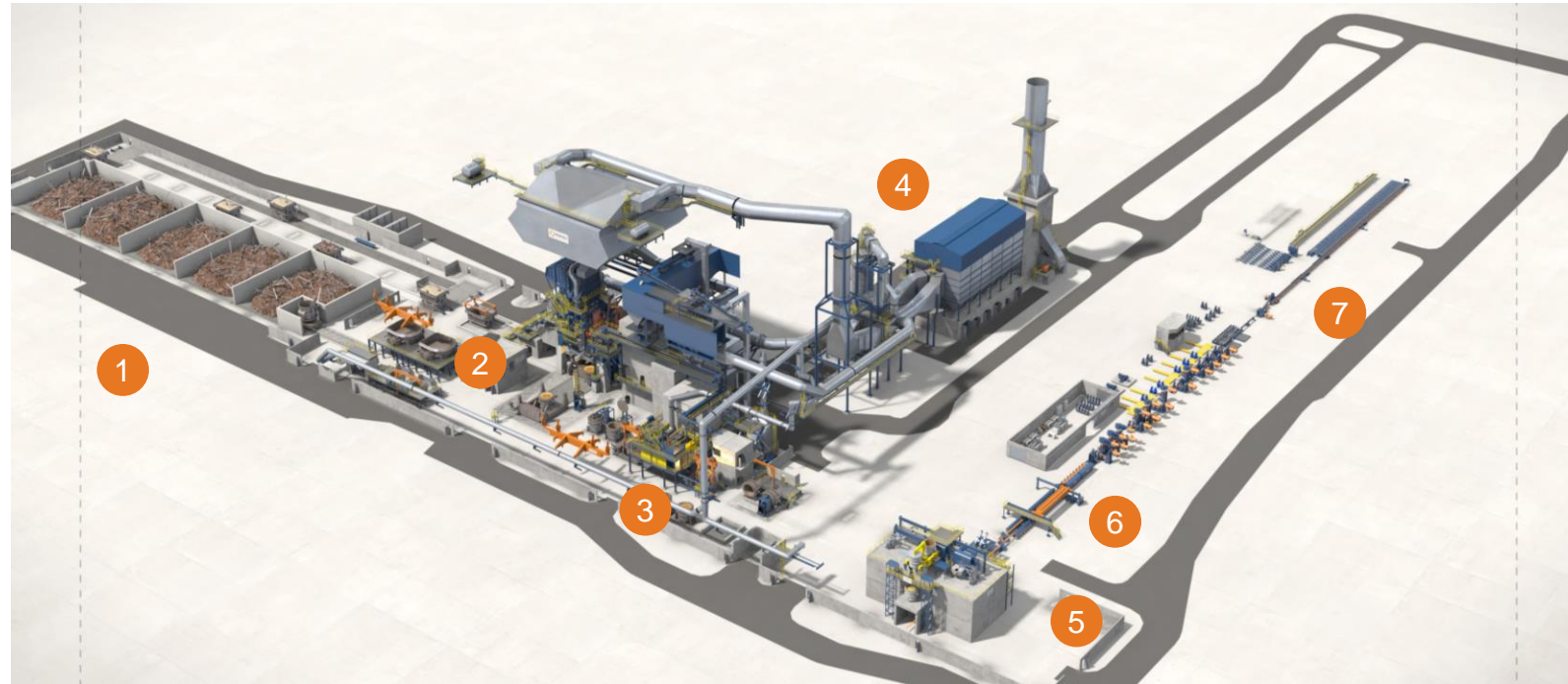
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Integrated Mini-Mill for Long Products

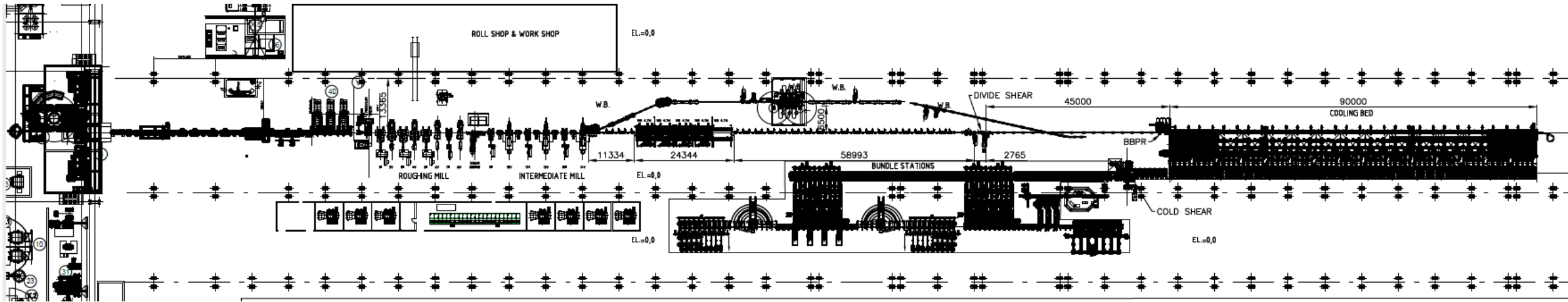


Layout optimized for minimum CAPEX and maximum production efficiency

- Automated scrap yard, directly connected to EAF Quantum
- Single-bay layout minimizing covered areas and cranes
- Single or twin Ladle furnace to match EAF short tap-to-tap time
- Quick setup operations (e.g., EAF Quantum quick shell change)
- Extended automation

- | | | | |
|----------------------|---------------------------|--|------------------------------|
| 1 Scrap yard | 3 Ladle furnace | 5 Billet caster | 7 High-speed bar mill |
| 2 EAF Quantum | 4 Dedusting system | 6 Endless Bar Production (EBP) connection | |

Endless Bar Production (EBP) for 500,000 t/y



EBP process features

Production rate	80 t/h
Cast section	160x160 mm
End products	rebar 8 to 43 mm
Covered area	360 x 50 m

Caster

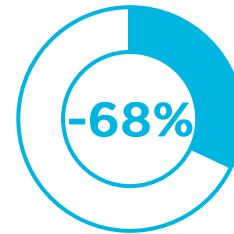
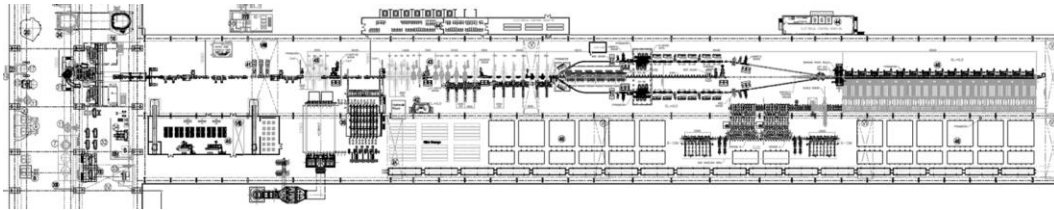
Single-strand high speed caster	
Caster radius	10 m
Mold type	high-speed tube mold
Design casting speed	6.7 m/min

Rolling mill

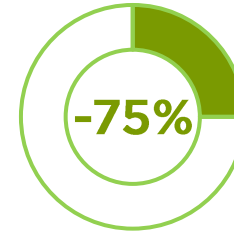
16 no-housing stands + 6-pass eNTM
HYBRID – Fine Grain and HYQST Quench & Tempered Rebar Processing
High-speed rebar outlet with Rotary Entry System

Effective solutions with low conversion cost

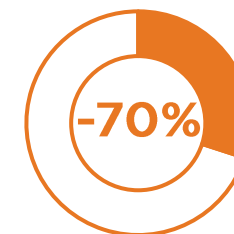
Endless Bar Production



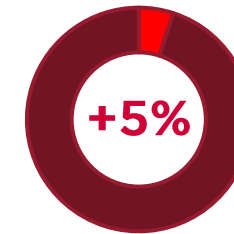
Energy



CO₂



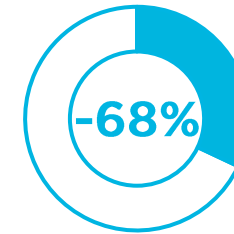
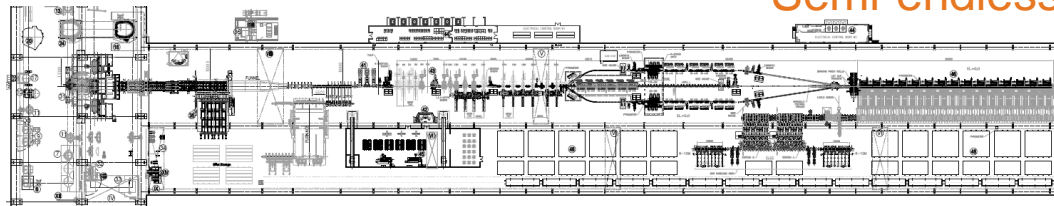
Yield loss



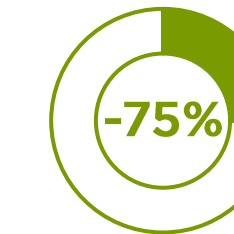
Production

-11 \$/t

Semi-endless



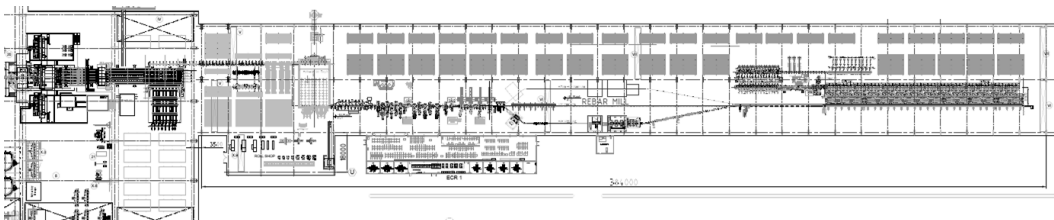
Energy



CO₂

-8 \$/t

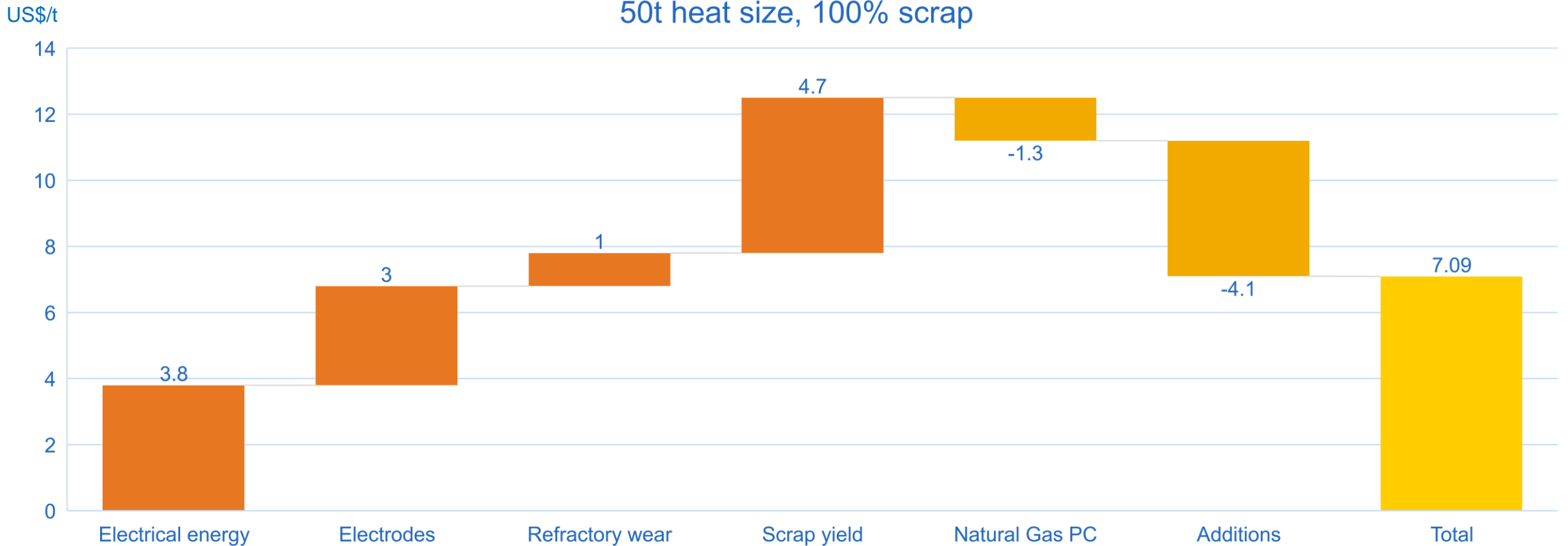
Conventional, cold charge



(baseline)

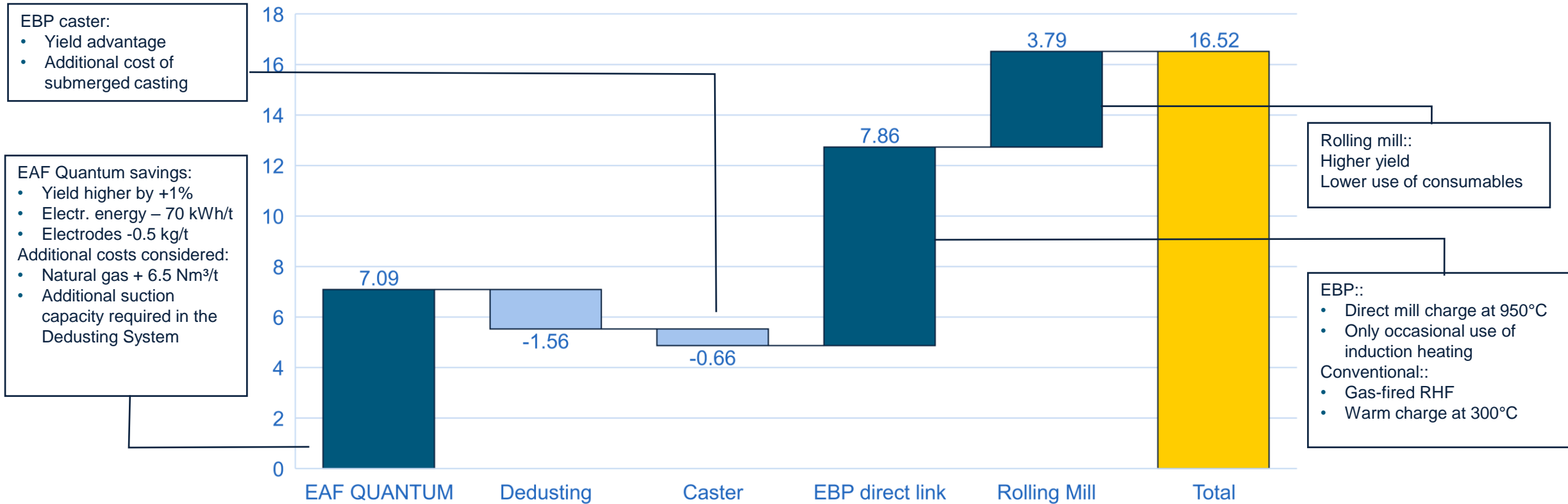
EAF Quantum - Opex advantage example

Opex comparison EAF Quantum vs. conventional
50t heat size, 100% scrap

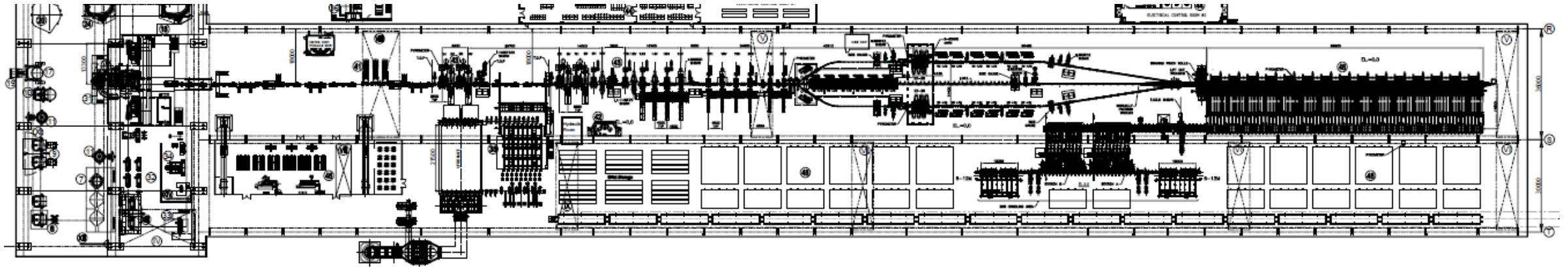


EAF Quantum + Endless Bar Production - Opex advantage example 16.5 \$/t (5.5 \$/t from EAF Quantum, 11 \$/t from EBP)

OPEX advantage vs. conventional plant solution



EBP for 1,000,000 t/y – Adapted for production and processing methods



EBP process features

Production rate	150 t/h
Cast section	235 mm CS
End products	rebar 8 to 43 mm
Covered area	455 x 66 m
Optionally, billets sq.160 mm x 12 m can be produced and rolled (cold charge)	

Caster

Single-strand high speed caster	
Caster radius	12 m
Mold type	high-speed tube mold
Design casting speed	6.7 m/min

Rolling mill

22 no-housing stands + 2x 6-pass eNTM	
HYBRID – Fine Grain and HYQST Quench & Tempered Rebar Processing	
High-speed rebar outlet with Rotary Entry System	

Trends are not only Regionalized but Global

The market is shifting everywhere, with the change in methods for producing construction grades

Margins are shrinking in high added value steel markets, forcing flexibility for increased product sizes and steel grades

Safety is pushing Long Rolling to provide improvements to equipment, processes and operations

Green Steel driving steel plant advancements

Ever increasing energy costs and steel plant emissions are key drivers to linking the steel plant and rolling mill

There are options to consider for all market segments and customer demands

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USA

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THANK YOU