The “Uralmashplant” JSC is a key equipment supplier for basic industry sectors: mining, metallurgical, and oil-and-gas industries.

In 2013 the “Uralmashplant” marked its 80s anniversary.

The main shareholder of the “Uralmashplant” is the “Gazprombank” JSC, one of the three largest Russian banks.

Today, the “Uralmashplant” JSC is a company providing the state-of-the-art engineering, welding, metal-working, mechanical assembly, and tool production works.

**Main product assortment includes:**

- **Mining equipment**
  - walking and track-type draglines,
  - track-type open-mine excavators,
  - cone and jaw crushers for all crushing stages,
  - ball and rod grinding mills, semiautogenous and autogenous grinding mills,
  - concrete-production equipment.

- **Metallurgical equipment**
  - sintering equipment,
  - indurating equipment,
  - blast furnace equipment,
  - continuous casting machines,
  - rolling equipment,
  - press-forging equipment,
  - rolling mill rolls

- **Oil-and-gas drilling equipment**
  - complete movable, stationary, and cluster drilling rigs with loading capacity from 160 to 600 tons,
  - drilling equipment packages.

- **Handling equipment**
  - heavy cranes for metallurgical works,
  - handling equipment for nuclear plants,
  - general purpose special and bridge cranes.

- **Power equipment and nonstandard equipment**
  - hydraulic turbine units,
  - transfer and homogenizing equipment units.

A company development strategy is aimed at creating a world-class machine-building company able to fully fulfill customers' needs for modern equipment.
Since 1962 Uralmashplant has been manufacturing continuous casting machines. At that time, the drawings were designed according to the project of Gipromez and equipment of the vertical continuous casting machine was manufactured.

In 1963, our engineers offered a new configuration of curvilinear type CCM with smooth unbending of the strand in two-phase condition. Development of such machines made it possible to increase the casting speed and capacity of the machine and, simultaneously, to reduce its height.

Since 1974, Uralmashplant has changed over to designing of the advanced slab continuous casting machines of curvilinear type.

The scope of supplies is an indicative of great experience in creation of metallurgical equipment. About 80 continuous casting machines of different design and propose are designed and put into operation at the Customers' in Russia and abroad.

In the last ten years, our specialists have implemented a great number of revamping and modernization projects for slab casters.

Simultaneously, they continue to build new machines. The domestic CCMs of new generation with the capacity of over three MTPA of world quality casting blocks have been applied in industry.

For the period from 2002 to 2006, the scientists, engineers and process men of the company received the prizes of the Government of the Russian Federation and Cherepanov's awards for creation and introduction of the domestic CCMs of new generation, development and introduction of new processes and equipment.
# Continuous Casting Machines for Slabs

## Main specifications

<table>
<thead>
<tr>
<th>Type of CCM</th>
<th>Curvilinear with radial or vertical mould</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of strands</td>
<td>from 1 to 4</td>
</tr>
<tr>
<td>Process length</td>
<td>from 20 to 40 m</td>
</tr>
<tr>
<td>Length of vertical section</td>
<td>from 2 to 3 m</td>
</tr>
<tr>
<td>Unbending section length</td>
<td>from 3 to 7 m</td>
</tr>
<tr>
<td>Arc section radius</td>
<td>6-12 m</td>
</tr>
<tr>
<td>Length of copper mould walls</td>
<td>900-1000 mm</td>
</tr>
<tr>
<td>Section of castings: thickness</td>
<td>150-315 mm</td>
</tr>
<tr>
<td>width</td>
<td>575-2520 mm</td>
</tr>
<tr>
<td>Maximum length of slabs after cutting</td>
<td>12 m</td>
</tr>
<tr>
<td>Steel ladle capacity</td>
<td>80-385 t</td>
</tr>
<tr>
<td>Tundish capacity</td>
<td>20-55 t</td>
</tr>
<tr>
<td>Number of mould oscillations</td>
<td>to 400 min$^{-1}$</td>
</tr>
<tr>
<td>Mould oscillation amplitude</td>
<td>0-12 mm</td>
</tr>
<tr>
<td>Casting speed</td>
<td>to 2 m/min</td>
</tr>
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</table>
## Continuous Casting Machine for Blooms and Combined CCM Main specifications

<table>
<thead>
<tr>
<th>Type of CCM</th>
<th>Curvilinear with radial or vertical mould</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of strands</td>
<td>from 1 to 6</td>
</tr>
<tr>
<td>Process length</td>
<td>from 20 to 30 m</td>
</tr>
<tr>
<td>Length of vertical section</td>
<td>from 2 to 3 m</td>
</tr>
<tr>
<td>Unbending section length</td>
<td>from 3 to 6 m</td>
</tr>
<tr>
<td>Arc section radius</td>
<td>8-12 m</td>
</tr>
<tr>
<td>Length of copper mould walls</td>
<td>900-1000 mm</td>
</tr>
<tr>
<td>Section of castings:</td>
<td></td>
</tr>
<tr>
<td>thickness</td>
<td>200-300 mm</td>
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<tr>
<td>width</td>
<td>200-450 mm</td>
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<tr>
<td>Maximum length of blooms after cutting</td>
<td>12 m</td>
</tr>
<tr>
<td>Steel ladle capacity</td>
<td>80-200 t</td>
</tr>
<tr>
<td>Tundish capacity</td>
<td>20-50 t</td>
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<tr>
<td>Number of mould oscillations</td>
<td>to 400 min⁻¹</td>
</tr>
<tr>
<td>Mould oscillation amplitude</td>
<td>0-12 mm</td>
</tr>
<tr>
<td>Casting speed</td>
<td>to 3 m/min</td>
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</table>
# Section Continuous Casting Machine

## Main Specifications

<table>
<thead>
<tr>
<th>Type of CCM</th>
<th>Curvilinear with radial or vertical mould</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of strands</td>
<td>to 6</td>
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<tr>
<td>Process length</td>
<td>from 15 to 30 m</td>
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<tr>
<td>Unbending section length</td>
<td>from 0 to 5 m</td>
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<td>Arc section radius</td>
<td>5-14 m</td>
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<td>Length of copper mould walls</td>
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<td>Section of castings:</td>
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<tr>
<td>- thickness</td>
<td>100-200 mm</td>
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<tr>
<td>- width</td>
<td>100-200 mm</td>
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<td>Maximum length of billets after cutting</td>
<td>12 m</td>
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<tr>
<td>Steel ladle capacity</td>
<td>to 250 t</td>
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<tr>
<td>Tundish capacity</td>
<td>10-45 t</td>
</tr>
<tr>
<td>Number of mould oscillations</td>
<td>to 400 min⁻¹</td>
</tr>
<tr>
<td>Mould oscillation amplitude</td>
<td>0-12 mm</td>
</tr>
<tr>
<td>Casting speed</td>
<td>to 4 m/min</td>
</tr>
</tbody>
</table>
Types of CCM
- \( u \geq 1 \text{ m/min} \) – with vertical mould, bending and unbending
- \( u \leq 1 \text{ m/min} \) – with radial mould and unbending

Condition of straightening section forming – steady strain rate
- \( \varepsilon = \text{const} \)

Condition of pitch selection
- \( \varepsilon_D = 0.21501 - 0.00034L + 0.12155v^2 \), where
  - \( \varepsilon_D \) – admissible deformation over solidified front (%)  
  - \( L \) – a distance from meniscus (mm)  
  - \( v \) – casting speed (m/min)

A varied length of bending section is 1.5 – 2.0 m while of unbending section is 2.5 – 7 m. The longer sections of straightening are used for the purpose of minimizing the basic radius and height of CCM.

Basic radius is 6-12 m depending upon the strand thickness. Decrease of basic radius and height of CCM is achieved by optimizing the straightening section length.

Minimum metallurgical length – completion of solidification in the last segment, with the maximum casting speed.

Example of the modern version of process channel for slab continuous casting machine
Design

- mould
- a removable block with hydraulically-operated mould oscillation mechanism
  - stationary frame
  - oscillating frame with supports to receive mould
- housing with base supports for removable block with oscillation mechanism and bending zone supports
- roller section №1
- bending zone
- roller segments: rigid or hydroficated segments with a function of soft reduction
- rollers of segments, bending zone and section №1
- with internal cooling over the whole length of CCM
- working surface of roller body is deposited with anti-corrosive wear-resistant material
- gas-cutting machine complete set or gas-cutting equipment of gas cutting machine
- trimmer of rotary type
- stamping machine
- slab handling device
- dummy bar introduction and storage device
- cooling system with filtration units
- hydraulic drive system and lubrication system with completing components produced by the well-known world manufacturers
- auxiliaries, including lifting cross members and tools
- dynamic strand secondary cooling system
- dynamic strand soft reduction system
- slab quality control system
- H = 900 – 1000 mm
- walls with milled channels
- cooling system – once-through, separate for every wall
- service life of walls with wear-resistant nickel coating - 140 thd tons
- quick immersed nozzle change device
- automatic holding of metal level in the mould with an accuracy of ± 2 mm
- a possibility of optimization of strand cooling directly under mould by using water-cooled suspended rollers under the mould
Design features

Mould oscillation mechanisms
- of four-eccentric, spring type with electromechanical drive
- of spring type with hydraulic drive

Bending zone with cooled rollers
- water-cooled rollers
- water-cooled frame
- a number of roller bearing supports – 3-4
- is made as one-piece with the vertical section or separately from it (section №1)
- roller diameter – 150-180 mm
A set of headers for water-and-air cooling of strand is located in the bending zone.

The points of water and air supply to the headers are connected automatically with the respective pipes laid over the CCM housing when bending zone is placed on the base supports of the removable block.

Rollers and housings of the roller bearing supports are equipped with internal water cooling system.
Design features

Segments

All segments are of the similar design type, the lower and upper holders are interconnected by means of columns.

The upper holder accommodates a drive roller. The latter is pressed to the dummy bar and strand with the help of hydraulic cylinder.

The holders carry three-point rollers.

The rollers are set to the respective opening by means of change spaces for the segments without “soft reduction” and by means of positioning system for the segments with “soft reduction”.

Rollers and housings of the roller bearing supports are equipped with a system of internal water cooling.

The working roller surface has wear-resistant anti-corrosive coating.
Technological decisions and packages

For mould
- a system of quick remote control of the strand width during a series of heats
- automatic systems to control a level of molten metal in mould, to measure the mould movement parameters
- breakout warning system

For secondary cooling zone
- a multi-row circuit of spray nozzle arrangement with automatic cooling width control which enables cooling of strands of all dimensions and steel grades to be carried out on the basis of “edge heat insulation” concept without re-arrangement of headers
- organization of a dynamic coolant consumption control system with EXPRESS feedforward and DINAMIKA v 1.0 feedback on the basis of “hot profile” concept makes it possible to keep the minimum temperature stresses and to avoid entering shortness interval

For casting of high-grade steel
- a system of soft reduction incorporates EXPRESS and DINAMIKA modules based on the solidification kinetics calculation and designed to track the borders of the soft reduction zone
- automatic control of UGMO positioning settings with calibration of control algorithms by means of pyrometric heat profile control
- probing of soft reduction zone by means of KGZMO algorithm developed on the basis of analysis of the inquiry results of the readings of pressure sensor and hydraulic cylinder rod motion transducer

For prediction of different defects
- automatic quality control system AQCSP that takes a decision on inspection operation necessity
Strand quality control system
Incorporates 3 subsystems

- dynamic secondary cooling system (DSCS)
  - tracks in real-time mode the condition of heat profile, thickness of strand skin, position of pool end
  - controls coolant consumption optimally
  - responds, quickly, to the casting speed change
  - takes account of casting speed, steel grade composition, specified cooling rate, superheat temperature of molten metal in tundish, mould heat extraction, heating of CCM

- soft reduction system (SRS) – reduces content of pores in the central part of strand

- automatic system of strand quality prediction (AQCSP)

All subsystems are joined to form the automated mathematical complex in combination with the instrumentation and automatics system.
Dynamic system of CCM secondary cooling

With the CCM designed and supplied without soft reduction system, algorithm of the dynamic secondary cooling system (DSCS) incorporates only one dynamic coolant consumption control module.

When CCM is supplied complete with soft reduction system, an algorithm of the dynamic secondary cooling system includes two modules.

EXPRESS module
- dynamic coolant consumption control module
- module of skin thickness and loop end position tracking

EXPRESS module in real-time mode
- tracks
  - temperature profile
  - strand skin thickness
  - loop end position
- controls coolant consumption, optimally, to keep steady temperature profile in case of casting speed change
- ensures quick response to casting speed change at the expense of reading once per second
  - takes account of
    - actual casting speed, including transient modes
    - steel grade composition
    - specified cooling rate
    - upperheat temperature of molten metal in tundish
    - could heat extraction
    - eating of CCM (a factor of cold machine at the beginning of heat series)

EXPRESS model

1. tundish
2. mould
3. strand
4-6. secondary cooling sections
7-14. elements of control and automatics system
**Purpose of the system**
Elimination of axial looseness by bearing the soft reduction segments against the strand in the solidification ending point which depends on the casting speed and chemical steel composition.

**Principle of soft reduction**
The principle of soft reduction lies in holding the molten metal pressure at the end of solidification for compensation of vapor formation by creating the conditions under which molten metal moves to the solidification borders.

**Type of soft reduction:** dynamic

**Dynamic soft reduction system of CCM-2 incorporates**
- hydroficated segments № 6-16
- software of level 2 for Automatic process control system

**Software structure**
- Dinamika module – calculation of soft reduction zone borders
- module of hydraulic soft reduction cylinder control (HSRCC) – calculation of positioning settings and soft reduction segment control

[Diagram showing molten metal and crystals with continuity break]

formation of pores along the solidification borders without soft reduction

in soft reduction, vapor formation is eliminated at the expense of no-break feeding of solidification borders
Automatic system of strand quality prediction (ASSQP)

The principle of operation of ASSQP lies in application of the expert system. The expert system incorporates a set of rules used to take decision on every billet. The decision is taken on the basis of the billet history, beginning from melting of steel and ending by casting in CCM, providing for operation of mould, secondary cooling system, stretching system, roller guide and speed modes.

Purpose of ASSQP – prediction of fitness of the billets for the next process stage without their preliminary cooling and examination.

Operation of ASSQP

- automatic prediction of every billet quality
- conclusion on fitness of the billet for use according to the order
  - FIT without preliminary examination
  - EXAMINATION in case of deviation from the quality standards
  - determination of defect category in case of EXAMINATION signal
    - surface defects
    - non-metallic inclusions
    - internal defects of microstructure

Distinctive features of the system

- fully automated collection of data from the units in the workshop, metal production, CCM subsystems, template laboratory
- continuous automatic additional training of the system: all information about casting process is processed by a computer and is used for correction of assessments done by expert system without participation of human being.
Automatic process control system of CCM

- casting of steel under automatic conditions
- submission of the full required information to the maintenance personnel

Automatic process control system is a two-level hierarchical system:

- sic level (level 1)
  - communication with control objects
  - measurement, storage, accumulation and analysis of the process parameters
- op level (level 2)
  - optimal process control against mathematical model
  - process visualization
  - process archiving and record-keeping
Basic level (level 1)

**Makes available**
- amount of molten metal in steel ladle
- molten metal level in tundish
- molten metal temperature
- metal level in mould
- mould oscillation parameters
- a process of heat pick-up from narrow and wide walls of mould
- a process of cutting strand to length
- parameters of mechanical and electrical equipment
- lubrication system parameters
- drive loads
- process control by operator
- heat conditions of secondary cooling zones
- emergency parameter deviations and protection functioning
- passing of strand via roller system and roll tables of CCM

**Control**
- level of molten metal in tundish
- metal level in mould
- mould oscillation mechanism drive
- drives of CCM rollers
- mould heat conditions
- heat conditions of secondary cooling zone
- equipment cooling process
- a process of strand cutting to length
- gas-cutting machine
- roll table
- slab handling device

**Sub-systems of basic level**
- casting platform
- mould 2000y
- weight measurement
- strand
- cooling
- gas-cutting machine
- slab handling device
CONTINUOUS CASTING MACHINES

Top level (level 2)

**Controls the process against mathematical model**
- optimizes casting rate
- makes available a process visualization
- prepares the required information about slab
- prepares the documents and reports on casting
- controls strand cooling in transient processes against the secondary cooling model
- calculates the optimal strand cutting
- backs up the information on CCM for long-term storage
Main process control posts of CCM

Main control post
From control post 1 the operator selects the CCM operation conditions and process conditions to carry out control of

- mould oscillation
- roller system drives
- a process of strand and CCM equipment cooling

Gas-cutting control post
From control post 2 the operator controls

- gas-cutting machine
- swarf granulation unit
- roller system drives when ending casting

Control post desks
- control of all CCM mechanisms by means of programmable logic controllers (PLC)
- control of mould oscillation frequency versus the casting speed and steel grade
- measurement of every strand casting speed by means of pulse transducers
- automatic acceleration and slowdown of CCM to the casting speed specified by the operator
- distribution of loads between the drives of roller system of every strand
- control of frequency converter operation, automatic repeated assembly in case of failure and automatic connection of reserve ones during casting
- optimal control of cooling water flow rate, supplied to every secondary cooling zone with due account of casting speed and steel grade
- remote control of control valves from the working station
- ergonomics
- modern design
The largest projects implemented from 2001 to 2006

2001-2003
- Reconstruction of two slab continuous casting machines, MMK JSC. These machines are the most efficient machines in the world (3 million tons per year)

2006
- CCM № 2, SEVERSTAL JSC, capacity of 2.5 mil tons per year
- CCM № 5, MMK JSC (new), capacity of 2.2 mil tons per year
Examples of technical decisions used in the last CCM

Lay-out decisions used in reconstruction of open-hearth plant at MMK JSC

- Mounting of large (250x1250...2350 mm) two-strand slab CCM along casting bay as opposed to cross mounting of the section CCM in the same plant

- Original mounting of casting platform, with the tundish carriages running over the circle and turn center displaced relative to the ladle turret axis
Examples of technical decisions used in the last CCM

Original design of ladle turret with Г-shaped arrangement of levers, CCM № 5, MMK JSC

Layout decisions made it possible

- to refuse from building of new bay for transportation and storage of slabs which is required for the version with cross CCM arrangement
- to use the existing railway tracks for product shipment
- to use one crane in process and in equipment repairs
- to perform casting both through one and simultaneously through two slide valves
Lay-out decisions

Minimizing of the customer's expenses in the project of reconstruction of CCM № 5, MMK JSC

- according to this project, the existing roller sections, beginning from the second one, have been attached to new vertical section and bending section
- this decision allowed the customer's expenses to be reduced thanks to using the existing equipment (more than 600 tons) of the acting CCM

Minimizing of the customer's expenses in the project of reconstruction of CCM № 2, SEVERSTAL JSC

- according to this project, reconstruction touches only part of the casting platform
- dummy bar introduction device (DBID) is located on the traveling platform that runs over the existing section of the casting platform. Dummy bar is taken from CCM, with DBID being on the platform, while when introduction of the dummy bar occurs DBID travels to the casting platform of new level
<table>
<thead>
<tr>
<th>Description of equipment</th>
<th>Location</th>
<th>Qty.</th>
<th>Supply year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconstruction of Conveying finishing line rollers</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
<td>1</td>
<td>2013</td>
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<tr>
<td>Modernization of Secondary cooling system of CCM № 5</td>
<td>Russia, Novolipetsky Iron and Steel Works</td>
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<td>2012</td>
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<td>CCM № 1 curvilinear type (modernization)</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
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<td>Design engineering of slit mold for CCM № 2 and CCM № 3</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
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<tr>
<td>Reconstruction project of system steamremoval CCM №№ 1,3,4</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
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<td>Removable blocks with mould oscillating system with hydraulic drive for CCM №№ 1, 2,3 ,4</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
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<td>2010</td>
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<tr>
<td>Ladle Turret</td>
<td>Russia, Magnitogorsk Iron and Steel Works</td>
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<tr>
<td>Ladle Turret</td>
<td>Russia, Nizhny Tagil, NTMK</td>
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<td>Modernization of Secondary cooling system of CCM № 2</td>
<td>Russia, Orsk, Ural Steel</td>
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<td>2008</td>
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<tr>
<td>CCM № 1 of curvilinear type (modernization) Capacity of 2 000 000 tons per year</td>
<td>Russia, Magnitogorsk, Magnitogorsk Iron and Steel Works</td>
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<td>CCM turret Hoisting capacity – 2x500 t</td>
<td>Russia, Magnitogorsk, Magnitogorsk Iron and Steel Works</td>
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<td>CCM turret Hoisting capacity – 2x240 t</td>
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<td>Bloom caster (together with SMS Demag)</td>
<td>Russia, Orsk, Ural Steel</td>
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<td>CCM of curvilinear type (together with SMS-Demag) Capacity of 850 000 tons per year</td>
<td>Russia, Taganrog, Taganrog Metallurgical Works</td>
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<td>CCM of curvilinear type (together with SMS Demag) Capacity of 850 000 tons per year</td>
<td>Russia, Polevskoy, Seversky Tube Works</td>
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<td>CCM № 2 of curvilinear type (reconstruction) Capacity of 2 500 000 tons per year</td>
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<td>CCM № 5 of curvilinear type Capacity of 2 200 000 tons per year</td>
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<td>CCM № 3,4 of curvilinear type (reconstruction, the second phase) Capacity of 3 000 000 tons per year</td>
<td>Russia, Cherepovets, Severstal</td>
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<td>CCM of curvilinear type (together with Danieli) Capacity of 1 000 000 tons per year</td>
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<td>Russia, Cherepovets, Severstal</td>
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<td>CCM № 3,4 of curvilinear type (reconstruction, the first phase) Capacity of 3 000 000 tons per year</td>
<td>Russia, Cherepovets, Severstal</td>
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<td>CCM № 2 of curvilinear type (together with VAI) Capacity of 750 000 tons per year</td>
<td>Russia, Cherepovets, Severstal</td>
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<tr>
<td>CCM No.2 of curvilinear type (reconstruction) Capacity of 1 500 000 tons per year</td>
<td>Russia, Cherepovets, Severstal</td>
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<td>2000</td>
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</table>