

# VAINOX® — Latest Developments in VAI Stainless Steel Casting Technology

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*The unique characteristics of stainless steels, particularly at elevated temperatures, demands special solutions for continuous casting. As a leading supplier of stainless steel casters worldwide, VAI offers a series of advanced technological solutions which ensures high operational reliability and best product quality. The following paper describes the main features of VAI's VAINOX® stainless steel casting technology and outlines a number of application examples and operational results.*

Parole chiave: acciaio inossidabile, metodi di produzione

## INTRODUCTION

The rapid increase of stainless steel production over the last years can partly be attributed to the penetration of stainless steel applications into new market segments. Due to new technological developments and process technology improvements, this trend will most probably continue.(1) (2) The average production growth of approx. 7% over the last 25 years led to a stainless steel production of approx. 17 million tons by the end of 1998 (Figure 1).

During the last years there has been a dramatic increase in stainless steel melting and finishing capacity in Finland, India, Korea, Spain, Sweden, South Africa, Taiwan and many other countries (Figure 2).(2)

The major net-exporters of stainless steel, i.e. the net trade of exports minus imports, are Japan and Western Europe. The main net-importers comprise North America and China, Figure 3.(2)

Today, approx. 75% of world stainless steel production is comprised of hot- and cold-rolled strip, produced in the classical process EAF – converter – continuous casting route. Of the 17 million tons produced in 1998, 75% consisted of austenitic and 25% ferritic grades.

Due to the steady improvement in meltshop efficiency, the introduction of continuous casting and other process rationalization steps, the sales prices for stainless steels have dropped by more than 40% during the past 25 years. Due to the economical crisis in Asia and Russia the worldwide demand declined in 1998, leading to lower prices and lower profit margins for stainless steel producers. Some analysts(3) expect a 2% decline in the consumption growth for stainless steel beginning in 2000.

Stainless steelmaking companies will have to work harder to maintain their profitability levels. Cost cutting together with a technology edge and robust business strategies are opportunities to excel in a market characterized by cyclical downturns as well as to be in a better strategic position during periods of increased stainless steel consumption.

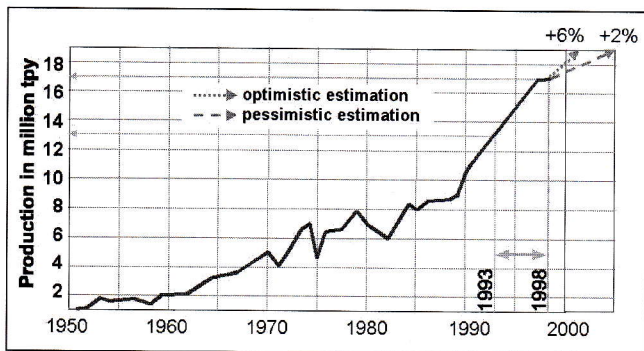
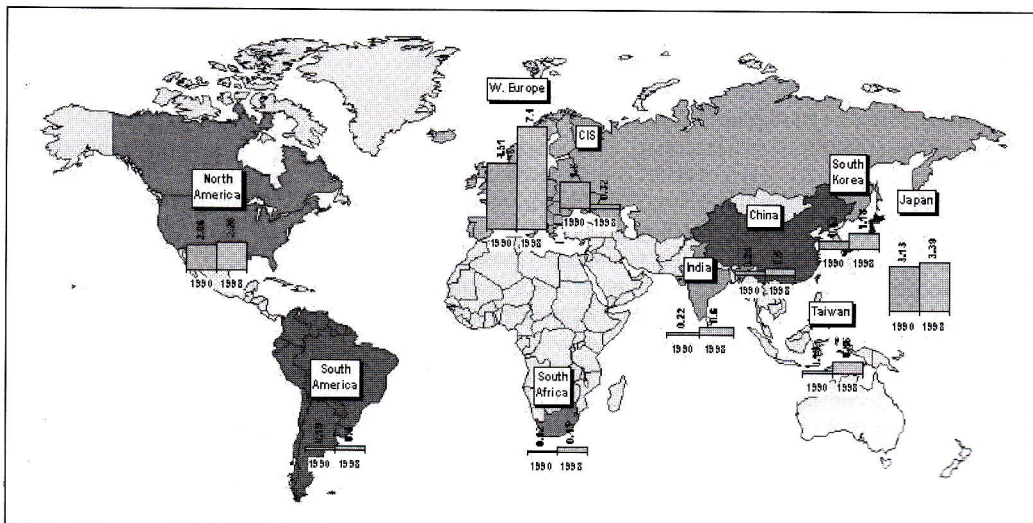


Figure 1: Worldwide Stainless Steel Production.

## PROPERTIES OF STAINLESS STEELS

Physical properties are not only important for the successful application of stainless steels in diverse fields, but also determine the optimum caster design. Since most literature sources(4) (5) generally only describe physical properties of stainless steel up to a maximum temperature of 1000 °C, VAI conducted several test series to investigate, among other properties, the thermal expansion, elongation and ten-

Figure 2: Stainless Steel Production of Major Regions.



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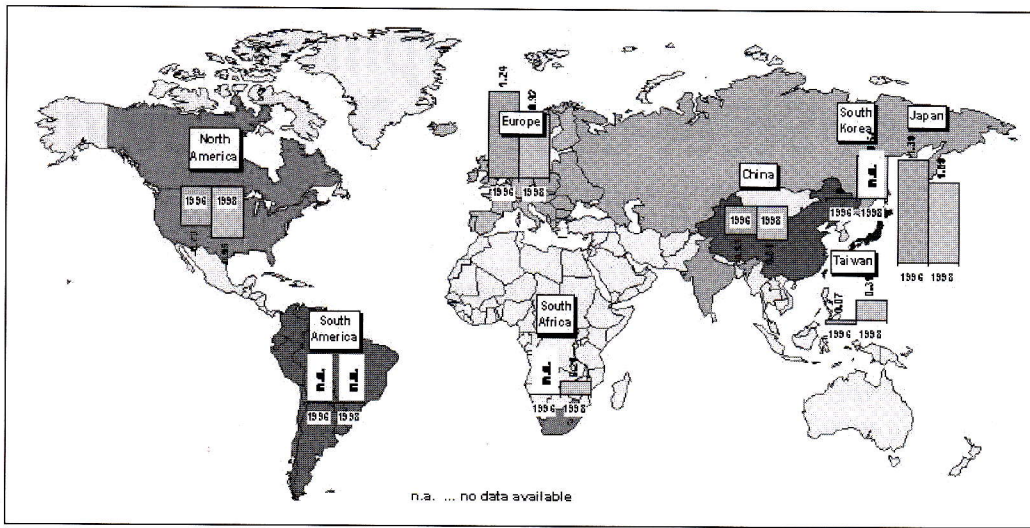


Figure 3: Most Important Stainless Steel Net-Importers.

Figure 4: Thermal Expansion and Heat Conductivity of Stainless Steel at Elevated Temperatures.

stainless steel strength of stainless steels at elevated temperatures exceeding 1,000 °C (Figures 4 and 5).

Due to their varying chemical composition, stainless steels show a wide scatter in their physical properties. (6) A comparison of a typical ferritic, austenitic and a 0.2% carbon steel grade at 1200 °C reflects:

- A significantly lower thermal expansion factor for ferritic steel compared with an austenitic grade (Figure 4)
- A continuous increase of heat conductivity from 200 °C to approx. 1300 °C for all stainless grades, as opposed to the 0.2% carbon grade (Figure 4)
- A tremendous increase of elongation under load for the ferritic AISI 430 as opposed to the austenitic and carbon grades (Figure 5)
- A decrease of tensile strength for all test grades with increasing temperatures (Figure 5).

All of these differences in the properties of stainless steels have to be taken into account for the proper design of a continuous casting machine.

CLASSIFICATION OF STAINLESS STEELS

Stainless steels can be divided into five families. Four are based on the characteristic crystallographic structure of the alloys: ferritic, martensitic, austenitic and duplex (austenitic plus ferritic) and the fifth family, the precipitation-hardenable alloys, is based on the type of heat treatment used rather than the microstructure.

The Schaeffler diagram (Figure 6) graphically illustrates the relationship between the composition and microstructure of stainless steels. The four families differentiated by their microstructure can be clearly seen.

Ferritic stainless steels are so named because of their body-centered-cubic (bcc) crystal structure. These alloys are magnetic and cannot be hardened by heat treatment. In general, ferritic steels do not have particularly high strength.

Austenitic stainless grades constitute the largest family in terms of number of alloys and usage. They cannot be hardened by heat treatment, however, they are nonmagnetic and their structure is face-centered-cubic (fcc). They possess excellent ductility, formability and toughness, even at cryogenic temperatures. This family can be substantially hardened by cold work.

Martensitic stainless steels are similar to iron-carbon alloys that are austenitized, hardened by quenching and then tempered for increased ductility and toughness. These alloys are magnetic and their heat-treated structure is body-centered tetragonal (bct). In the annealed state they are generally cold formed and cold worked. Increasing carbon content increa-

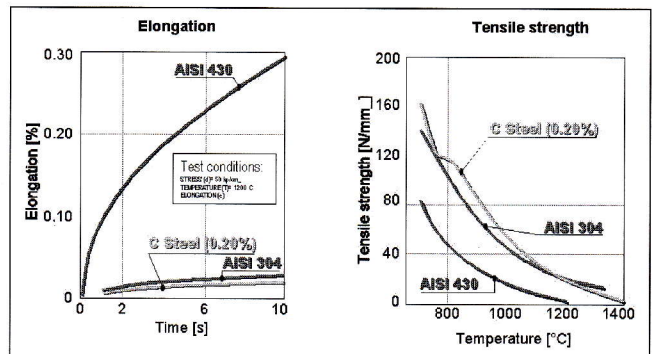
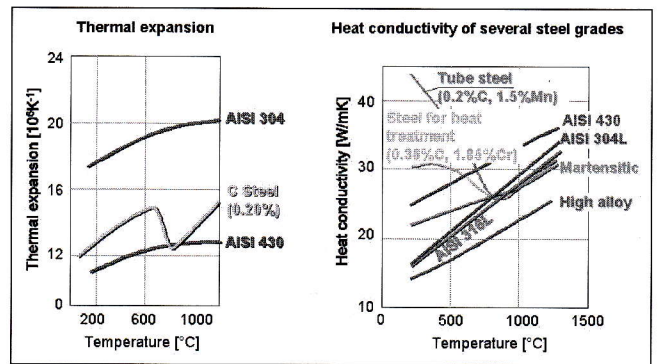


Figure 5: Elongation and Tensile Strength of Stainless Steel at Elevated Temperatures.

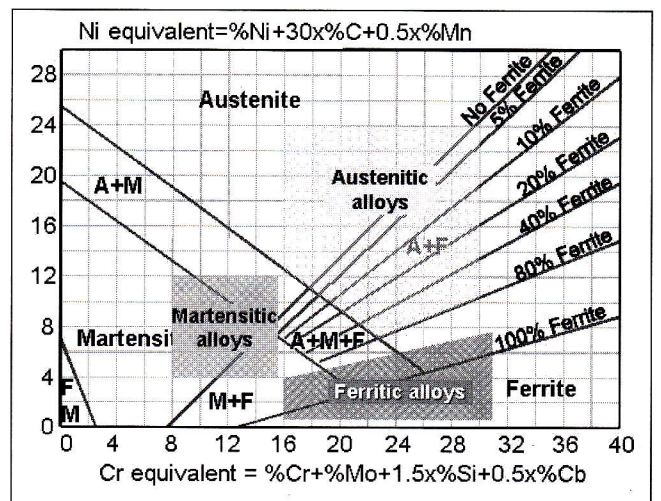


Figure 6: Schaeffler Constitution Diagram for Stainless Steels.

	Composition				Examples	Applications
	C %	Cr %	Ni %	Others %		
austenitic	• unstabilised	0.03	18	9	X 5 CrNi 18 10	304 Household Articles Food Industry
	• stabilised	0.05	18	10	0.5 Ti	X 6 CrNiTi 18 10
heat resistant	0.06	25	20	2 Si	X 15CrNiSi25 20	314 Heating Furnaces, Boilers
ferritic	• unstabilised	0.05	17		X 6 Cr 17	430 Interior Decoration, Washing Machines, Off Gas Systems, Waggons
	• stabilised	0.03	12	0.3 Ti	X 6 CrTi 12	409
martensitic	0.46	13			X 46 Cr 13	420C Cutting Articles

Figure 7: Classification of Stainless Steel Grades.

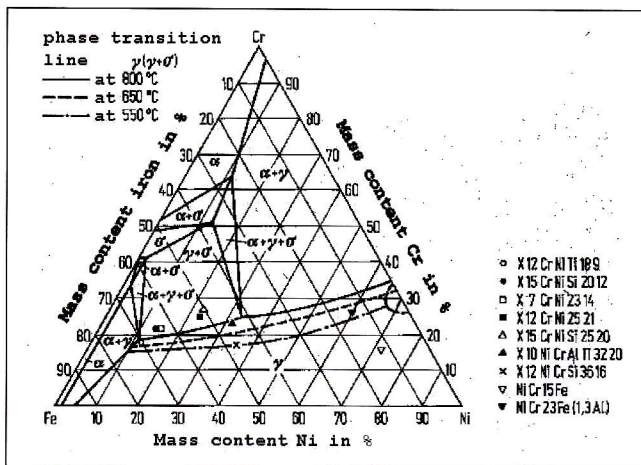


Figure 8: Iron-Chromium-Nickel-Ternary Phase Diagram.

ses strength, but decreases ductility and toughness. Duplex stainless steels are chromium-nickel-molybdenum alloys that are balanced to contain a mixture of austenite and ferrite and are magnetic. Their duplex structure results in improved stress-corrosion cracking resistance, compared with the austenitic family, and improved toughness and ductility, compared with the ferritic alloys. Precipitation-hardenable (PH) stainless steels are chromium-nickel grades that can be hardened by an aging treatment. Typical applications and chemical compositions of stainless steel families characterized by their crystallographic structure are illustrated in Figure 7.(7)

CHARACTERISTIC SOLIDIFICATION PHENOMENA

The solidification behavior of stainless steels can be described by the iron-chromium-nickel ternary phase diagram (Figure 8).

The solidification pattern in the boundary system Cr-Ni is eutectic and changes into a peritectic structure at the boundary system Fe-Ni. The transition lies at approximately 75% iron, i.e. most stainless austenitic steels solidify in the region of eutectic solidification (Figure 9).

Ferritic chromium steels solidify with a ferritic structure as illustrated for a 0.05% C-chromium steel in the iron rich corner of the Fe-Cr-C system (Figure 10a).(5) The ferritic grades solidify partly into austenite and then transform in reverse into ferrite.

The binary phase diagram for a 0.2% C martensitic steel is shown in Figure 10b.(5) As carbon stabilizes austenite up to approx. 0.4% C, the austenitic area is extended to higher chromium contents, thereby increasing the austenitic portion,

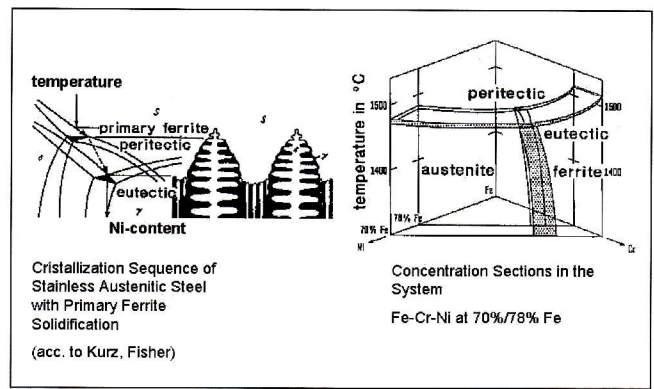


Figure 9: Solidification of Austenitic Stainless Steel.

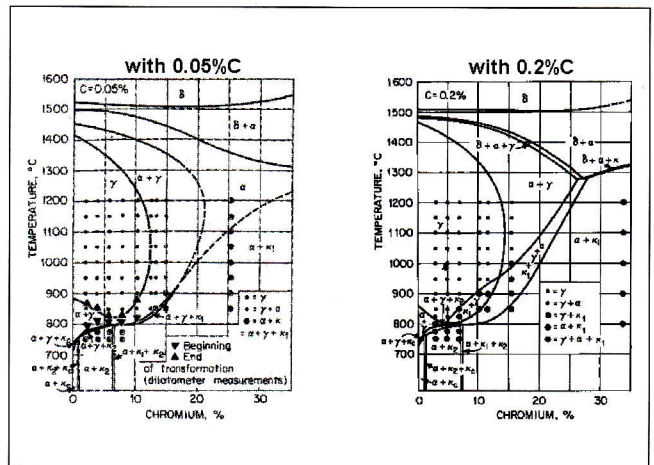


Figure 10: Section Through the Fe-Cr-C System with a) 0.05% C and b) 0.2% C.

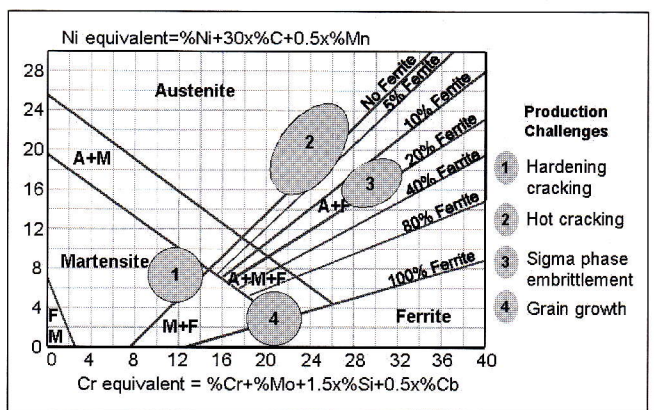


Figure 11: Characteristics of Stainless Steel Grades.

i.e. transforming into martensite, the principal hardening component of martensitic steels.

Due to the characteristic solidification patterns, the Schaeffler diagram can be used as a tool to describe typical phenomena for the various alloys (Figure 11). It is well known that steels solidifying mainly ferritic are not crack sensitive during casting. Steels with a predominantly or fully austenitic solidification display a high crack susceptibility. Consequently, a special machine design and specific operational parameters have to be chosen for casting steel grades such as, e.g., AISI 300, 310, 314 and 316.

Other characteristic production problems for the various stainless alloys, including hardening cracking for martensites, sigma phase embrittlement of austenites and strong grain growth promoting the creeping behavior of ferrites, can also be derived from the Schaeffler diagram. With re-

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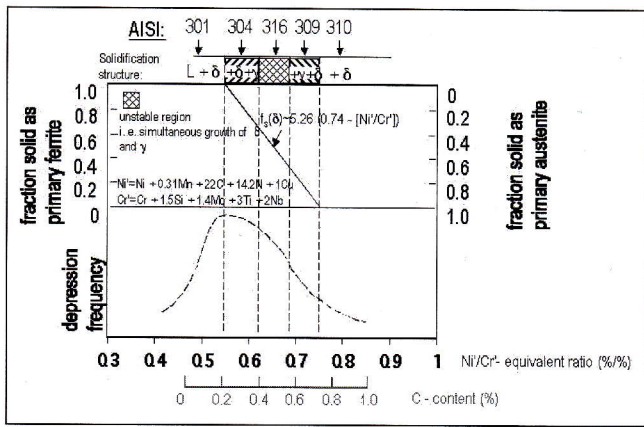


Figure 12: Effect of Primary Ferrite Fraction on Depression Frequency for Austenitic Steels.

gard to as-cast product surface quality, some stainless steel producers have reported an increased depression frequency with increasing primary ferrite fractions (Figure 12).(14) The ferrite in primarily austenitic solidifying steel shows an M-shaped distribution of the delta ferrite over the slab thickness (Figure 13).(8) The reason for the change of delta ferrite is the increasing ferritic content with decreasing solidification speed. In case of a primarily ferritic solidification an A-shaped ferritic distribution is found across the product thickness.(6) (7)

**CASTER DESIGN REQUIREMENTS**

Considering the unique physical properties of stainless steels, each section and system of the continuous casting machine must be carefully designed in order to assure the highest-quality of the cast products (Figure 14).

**Nonmetallic Inclusions**

In order to minimize the nonmetallic inclusion content in flat products a straight mold design is of paramount importance to avoid the distinct entrapment of inclusions in the so called "quarter band" inside the product. To avoid excessive slag carryover from ladle to tundish and from tundish to mold, the use of electromagnetic slag detection devices has

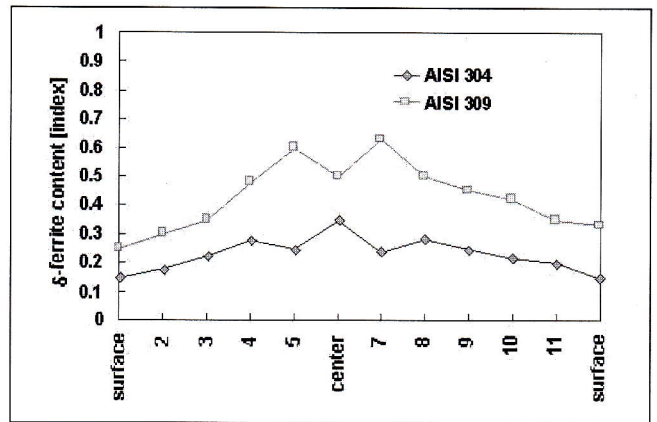


Figure 13: Delta Ferrite Distribution in Austenitic Slabs.

proven to be advantageous towards improving steel cleanliness and yield. The use of tundish furniture and a tundish shape that minimizes both nonmetallic inclusions and tundish skull should be standard in all stainless steel casters (Figure 15).

A tight shrouding system is a prerequisite for avoiding oxygen and nitrogen pick-up. Specifically for titanium-stabilized steels with its high affinity to nitrogen a tight shrouding system and an exact and stable mold-level control system is of importance to avoid TiCN-inclusions (Figure 16). TiCN inclusions on the as-cast product must be removed by grinding in order to avoid inclusion lines on the rolled product. Besides surface quality deterioration, TiCN inclusions impair the castability and consequently the caster availability. The design of the submerged entry nozzle and the submergence depth are decisive parameters for nonmetallic inclusion control and optimization of product surface quality. VAI has carried out extensive water model tests and finite element analyses in order to achieve the best product quality results regardless of casting dimensions and casting speed (Figure 17).

**Surface Quality**

One important parameter for achieving a high surface quality is a uniform heat flux in the mold. Depending on the product mix, two advanced copper plate designs for a cassette-type solution were developed by VAI for both slab and

Product Requirement	Caster design aspect
Minimization of nonmetallic inclusions	Tundish Tundish furniture Tight ladle shroud and SEN SEN Straight mold Exact mold level control CAQA/C
Excellent Surface quality	SEN DIAMOLD Mold copper Exact mold level control Hydraulic DYNAFLEX oscillator Secondary Cooling Continuous bending and straightening CAQA/C
Excellent internal quality	Low superheat casting (Tundishheating) Stiff strand guide segment Intermediately supported roller Small roller pitch Continuous bending and straightening Automatic Strand Taper Control (ASTC) Electromagnetic stirring (EMS) CAQA/C

Figure 14: Product Requirement—Caster Design.

Figure 15: Tundish Design and Tundish Furniture.

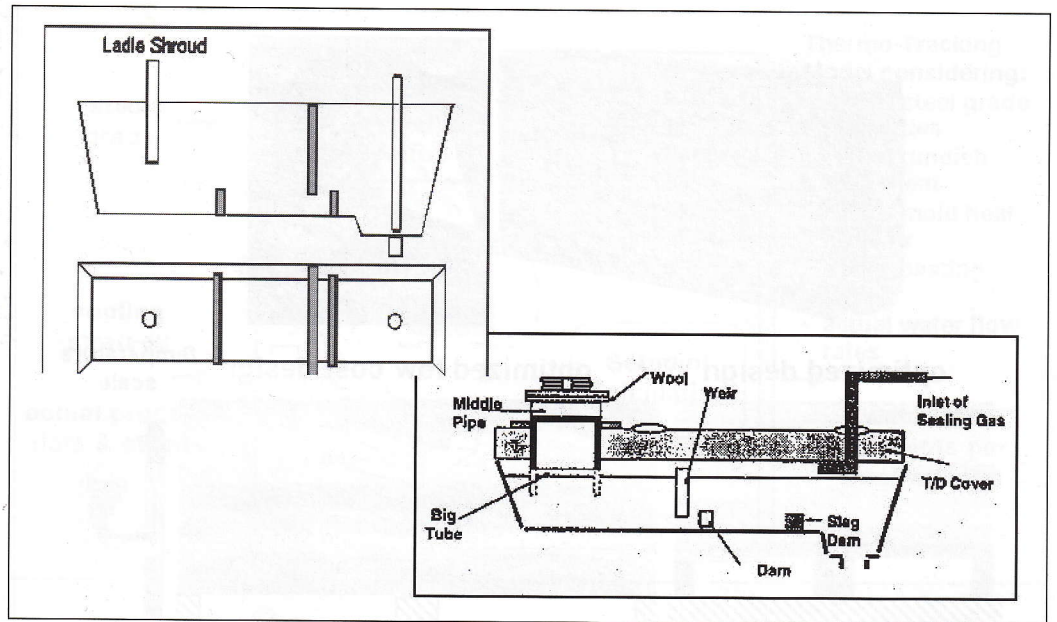


Figure 16: TiCN Slab Surface Inclusions.

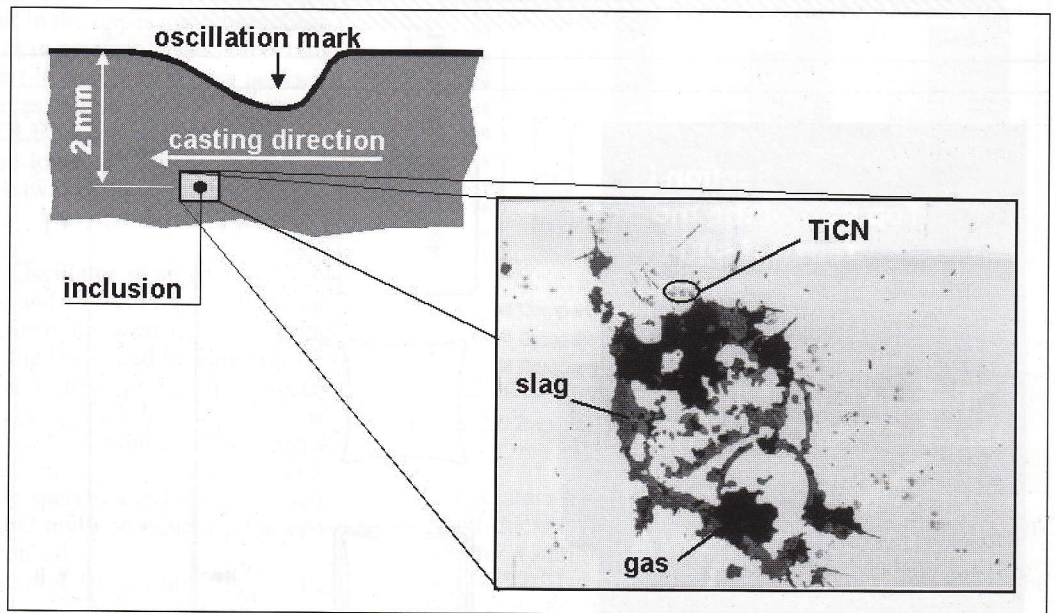
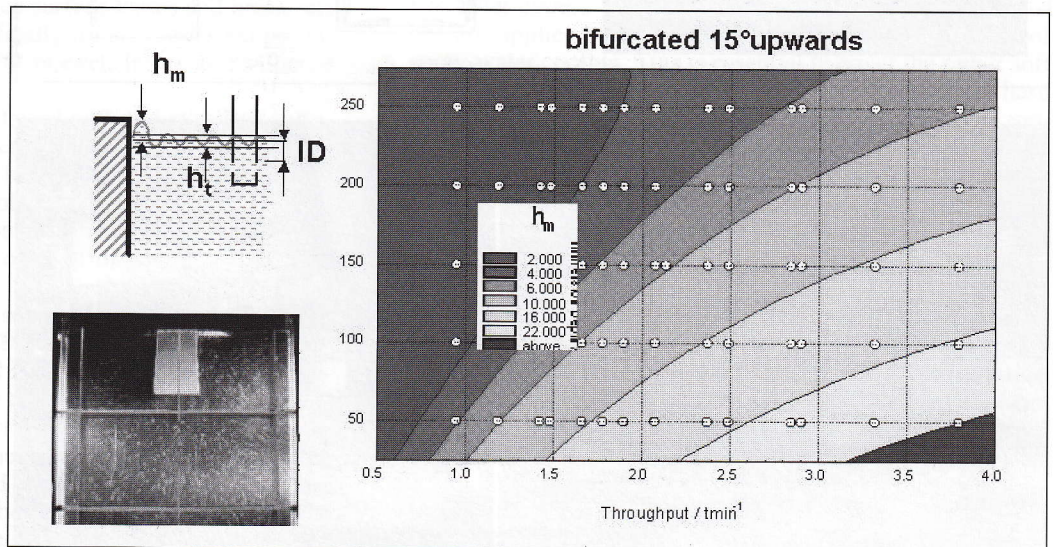


Figure 17: SEN Water Model Tests.



bloom molds (Figure 18).(9) (10) For ferritic steels with a strong creeping tendency at elevated temperatures a high-heat flux is preferred for achieving a stiff shell and thus reduced bulging in the strand guide system. The correct ca-

sting powder with the appropriate powder properties is also decisive for attaining a defect-free product surface. For billet casters the challenge in the area of the mold is the combination of:

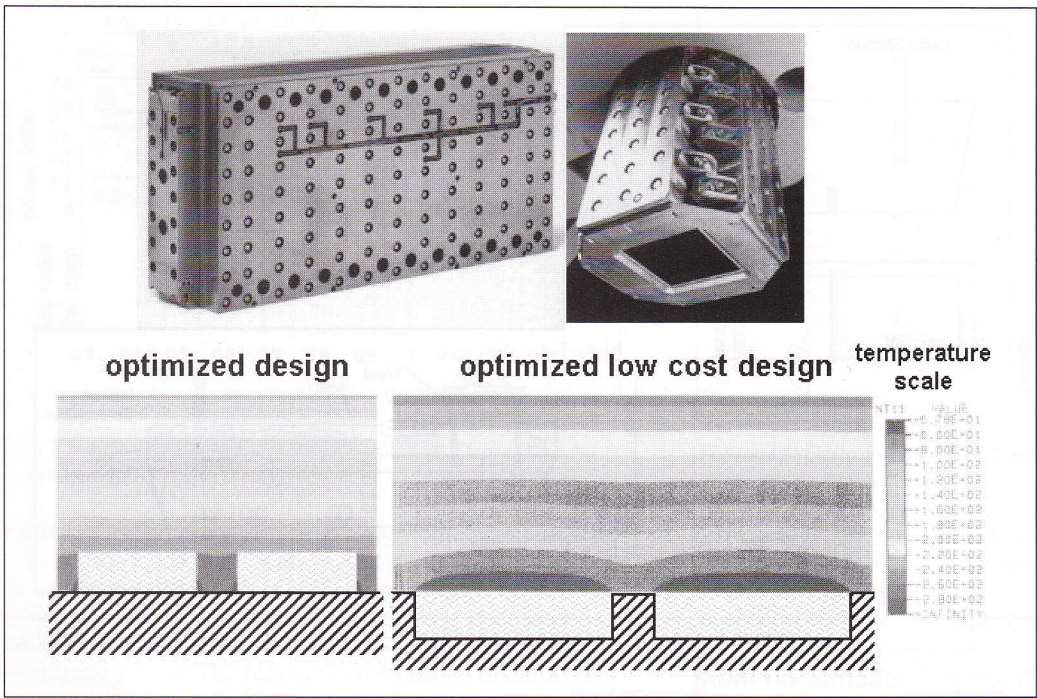


Figure 18: Advanced Cassette-Type Mold Copper Plates.

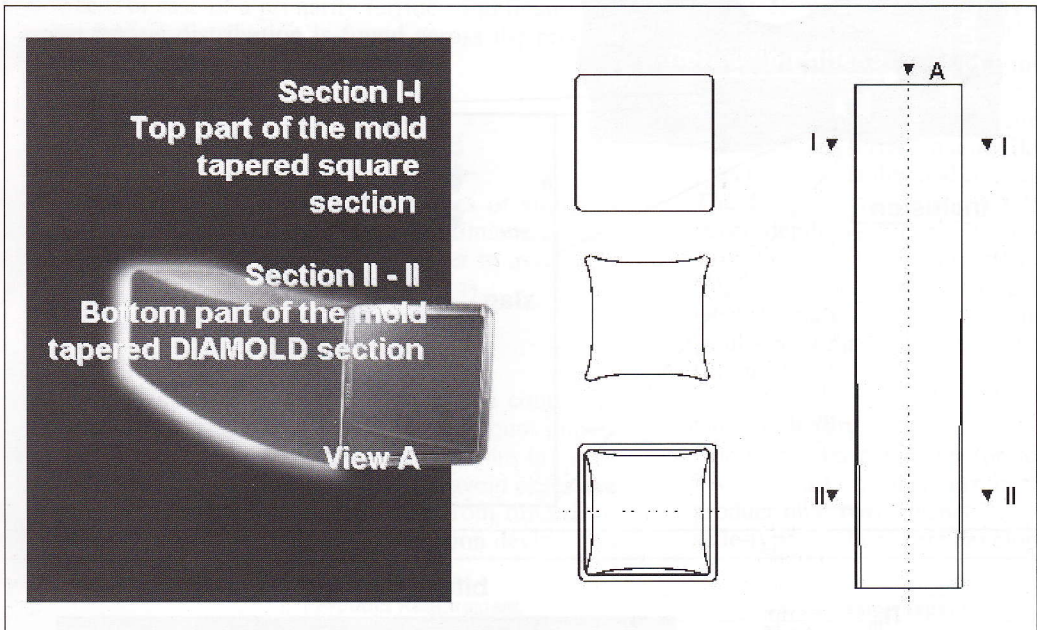


Figure 19: DIAMOLD Mold Geometry.

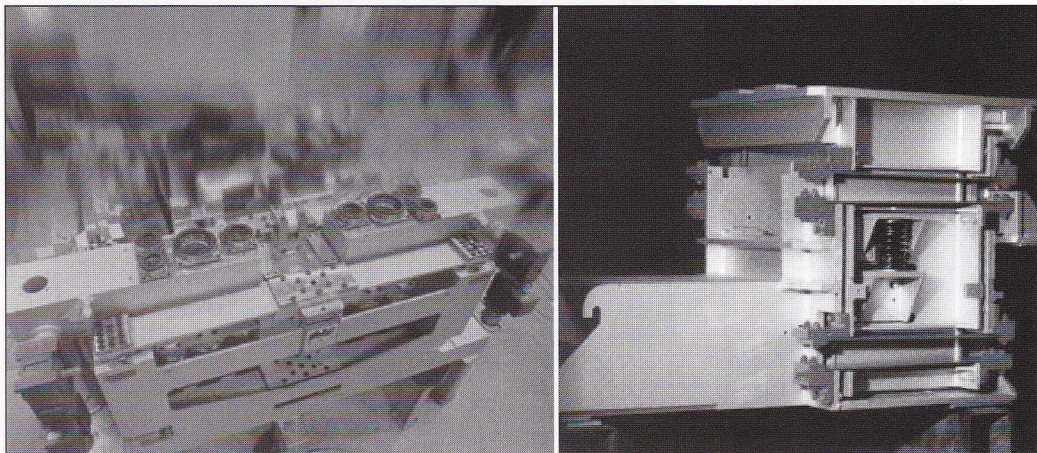
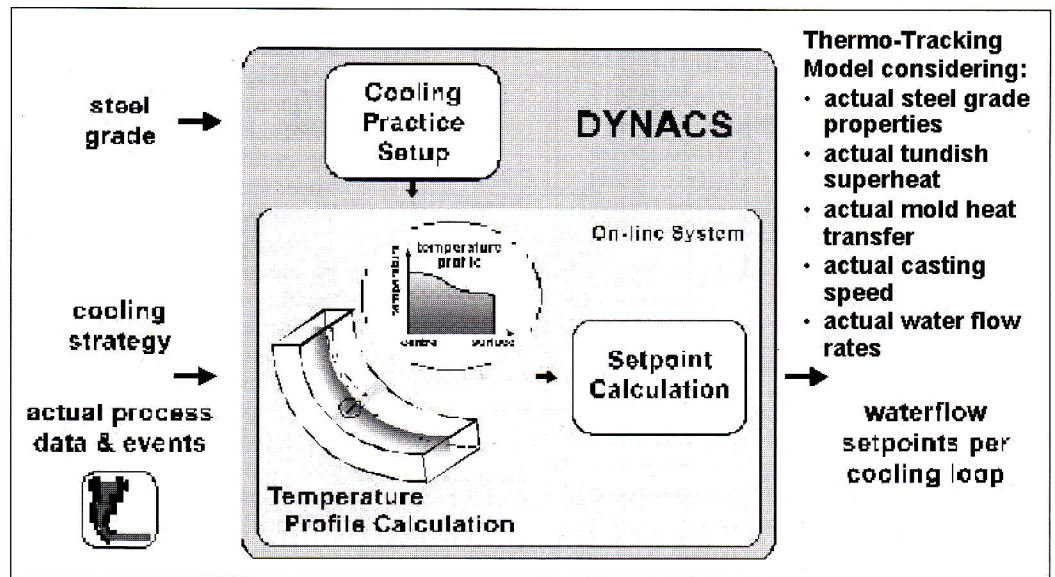


Figure 20: DYNAFLEX Oscillator.

- Rapid heat transfer from the steel to the mold tube, essential for uniform strand shell growth, and
- The physical properties of different stainless steel grades,

predominantly thermal shrinkage, which vary to a high degree. DIAMOLD(19)(20) mold technology (Figure 19) ensures

Figure 21: DYNACS® Secondary Cooling.



best contact behavior between the strand shell and copper tube due to the excessive taper in the upper mold tube. Conventional conicity would result in pressure peaks, especially in the corners of the lower part of the mold. These peaks in turn cause high frictional forces. These forces are avoided by using the specific DIAMOLD shape where the taper disappears in the corners of the lower part of the tube, thus guaranteeing a smooth withdrawal of the strand with optimum heat transfer and therefore best surface and subsurface quality.

The DYNAFLEX Hydraulic Oscillator is an essential tool for improving surface quality and to increase yield and caster availability (Figure 20). Due to the wear-free leaf-spring precision guiding system and the lever- and bearing-free design, the DYNAFLEX oscillators have proven to be extremely maintenance friendly. The special design features of the DYNAFLEX oscillator provide metallurgical and operational advantages leading to an improvement of surface quality. Specifically at low casting speeds, a reduction of oscillation mark depth is achievable and consequently the product grinding losses can be reduced.

At high casting speeds a higher powder consumption (9) (10) (11) results in a greater casting reliability and safety with reduced risk of break-outs. Since surface losses and breakouts are a major cost factor specifically for stainless steel producers, the return of investment is even faster as compared with carbon-steel producers.

The success of this system started with the excellent surface-quality results of the inverse oscillation practice at AK Steel Mansfield, OH/USA, which allowed for the direct hot-charging of the slabs to the rolling mill without surface conditioning. (11) VAI is now in a position to offer standardized and customized hydraulic oscillation systems for slab, bloom and billet casters.

For the optimization of the surface and internal quality of the cast products, DYNACS®, an advanced secondary cooling model, was developed. (13) DYNACS® is based on on-line tracking of the complete thermal state of the strand, including the crater end monitoring (Figure 21).

DYNACS® determines online the temperature profile of the strand considering the actual water flow rates, the casting speed, the steel grade and the superheat temperature. The fully dynamic model calculates the water flow setpoints for each cooling zone based on the temperature profile and the selected cooling strategy, which can be:

- Bulging limiting control (considering shell thickness, ferrostatic pressure and roller pitch)
- Surface-temperature control (aiming at a specified surface

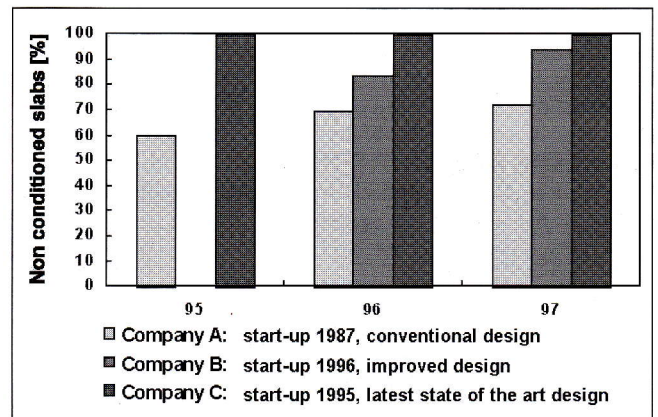


Figure 22: Product Conditioning Ratio.

- temperature in each cooling zone)
- Shell-thickness control (optimizing the soft reduction effect for a stationary soft reduction zone)

DYNACS® also calculates the thermodynamic state of the strand, including the residual internal energy.

For billet casters four independently controlled cooling zones are applied to manage the required high flexibility of spray-water cooling. This is essential to cover the rather soft cooling requirements of martensitic grades and the hard cooling demands of ferritic grades. With this solution a more homogeneous cooling is possible to reduce surface and internal stresses in the strand and to achieve a better product quality.

Product surface losses and the ratio of cast products processed without surface conditioning are mainly determined by the product mix, final product requirements by the endusers and, of course, by the caster design and automation level. Figure 22 illustrates the effect of the caster design features on the slab conditioning ratio. (12) (14) (15) Although a direct comparison of the conditioning ratio due to the aforementioned parameters is difficult, a trend to lower grinding ratios with improved equipment design is recognized.

#### Internal Quality

Low superheat casting is the standard practice for steel grades prone to center segregation. For ferritic stainless steels high superheat casting promotes the growth of columnar crystals which affect the material properties. Figure 23 reflects the influence of the tundish superheat and the extent of the coarse columnar structure, respectively, on the rid-

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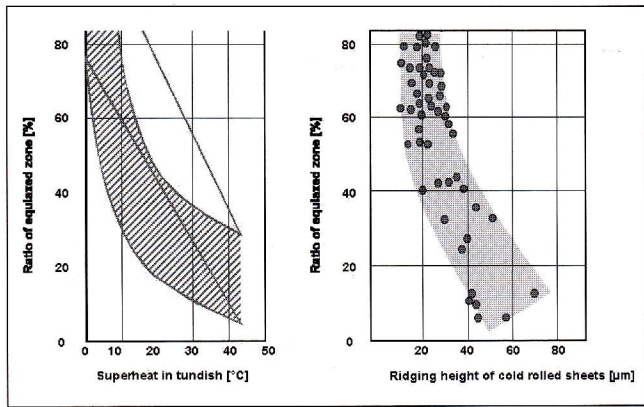


Figure 23: Effect of Equiaxed Zone on Ridging Severity.

ging, roping and the associated anisotropy of material properties.(16)

As there exists a strong correlation between superheat and the amount of equiaxed solidification, plasma tundish heating can maintain a low superheat with a tight temperature tolerance (Figure 24).

Electromagnetic stirring of ferritic grades in the strand guide is another means to minimize the amount of coarse columnar structure (Figure 25). A typical and efficient position of the stirrer in a slab caster is the bender area, where it can easily be removed by a manipulator. In billet/bloom casting the use of an external mold stirrer, which remains in the ma-

chine during mold exchange, has proven to be most efficient and economical.

For billet casters 4-hole subentry nozzles reduce mold-powder entrapments due to minimized turbulence at the steel meniscus as well as facilitate heat transfer from the steel to the mold through the initiation of a rotation motion in the lower steel bath area.

The most important design feature for most quality aspects is an appropriate roller geometry (Figure 26). Due to the high creeping rate of ferritic steels at elevated temperatures, rollers of narrow diameter must be installed as closely together as possible compared with carbon-steel casters. Needless to mention—it is also necessary to reduce the product interface strain and the strain rate by continuous bending and straightening for achieving the highest internal and surface product quality. To minimize roller bending during transient casting conditions, a split roller and a rigid segment design is of paramount importance. This avoids internal cracking and center segregation of the strand. VAI has developed a unique roller concept, named I-STAR (for Intermediately Supported Trans-Axle Roller), which minimizes roller bending even with small roller diameters and additionally ensures sufficient strand support with a minimized bearing housing width.(17)

VAI's new segment generation, the SMART® segment, allows for an automatic online strand taper adjustment during casting and a very fast thickness adjustment during restraining.(9) (10) Automatic Strand Taper Control (ASTC) in combination with the DYNACS® secondary cooling model

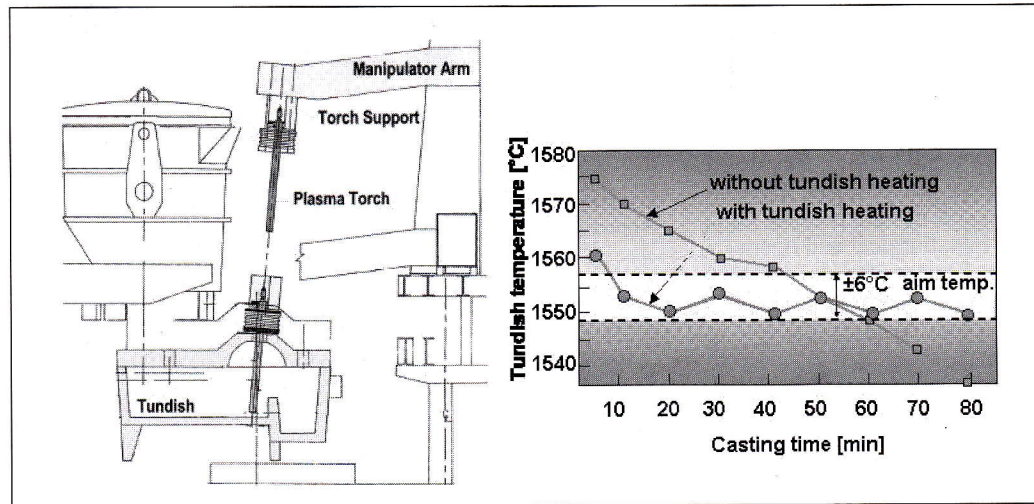


Figure 24: Plasma Tundish Heating.

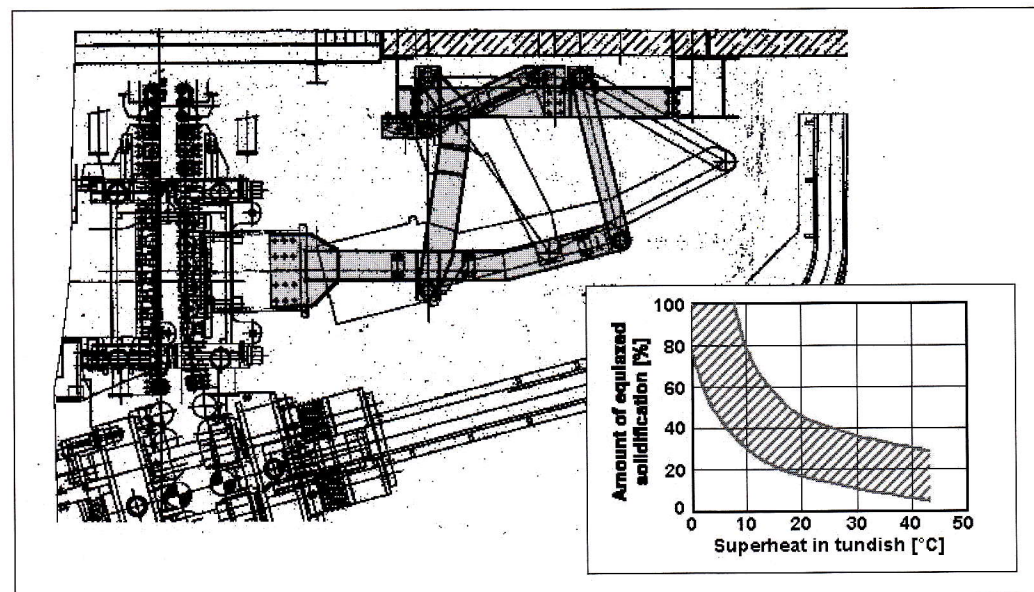


Figure 25: Positioning of Electromagnetic Strand Stirring in Slab Caster.

Figure 26: Roller Geometry for Stainless Steel Slab Casters.

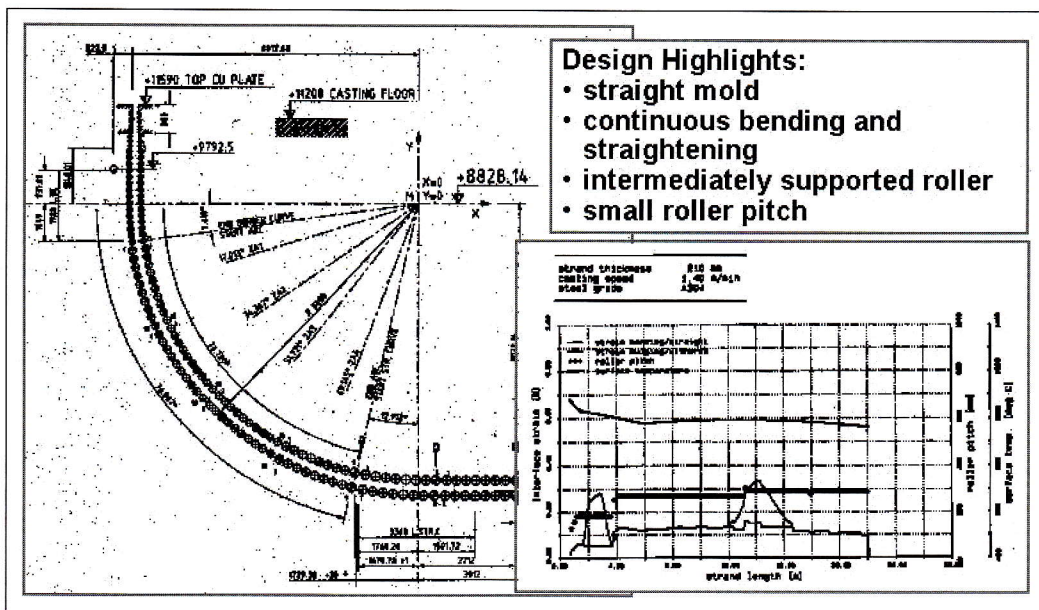
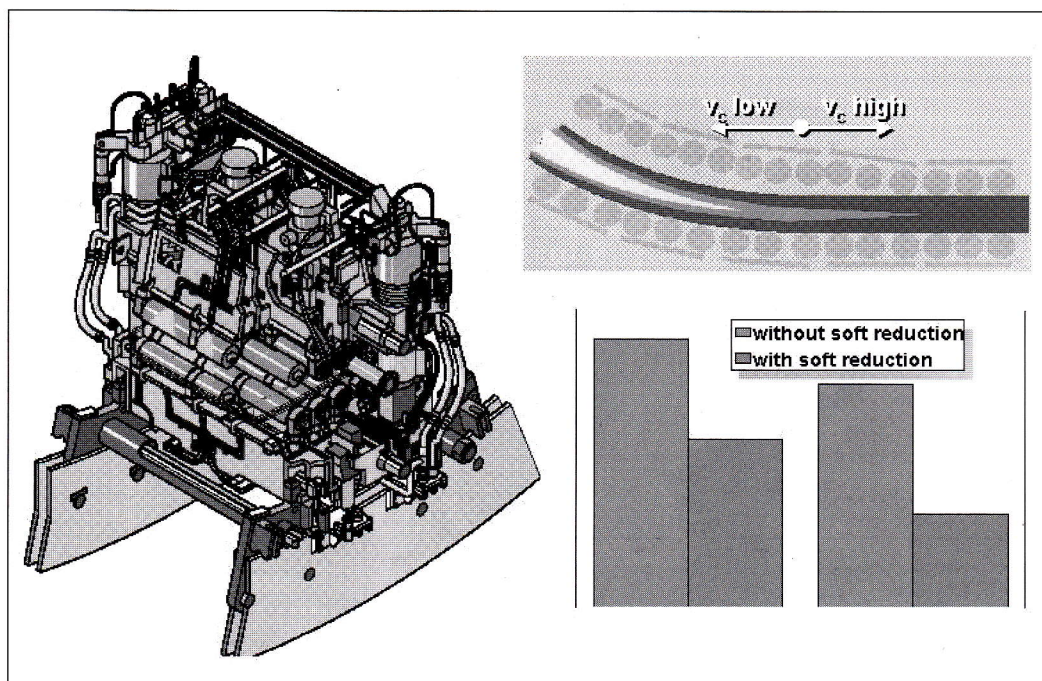


Figure 27: SMART® Segment and ASTC.



enables best-yield internal quality to be achieved (Figure 27). In addition to an improved internal quality, which is of particular advantage for plate products, the SMART® strand guide increases the caster availability and productivity by greatly reducing the thickness changing time.

VAI has also developed a unique computer-aided quality assurance/control system (VAI-Q) system in close cooperation with the Austrian steel producer VOEST-ALPINE Stahl Linz, Austria(18) and several other steel companies. As of August 2000, this advanced tool for quality control has been implemented in various versions in more nearly 70 casters worldwide.

Quality planning is carried out on the basis of the quality requirements of the final product (Figure 28). The system provides production parameters for each subsequent production step which are derived from the given chemical composition of the steel and the required product specifications. All quality-relevant process data are continuously monitored and recorded during production. A knowledge-based, quality-prediction system makes online forecasts about the expected final product quality on the basis of the tracked process pa-

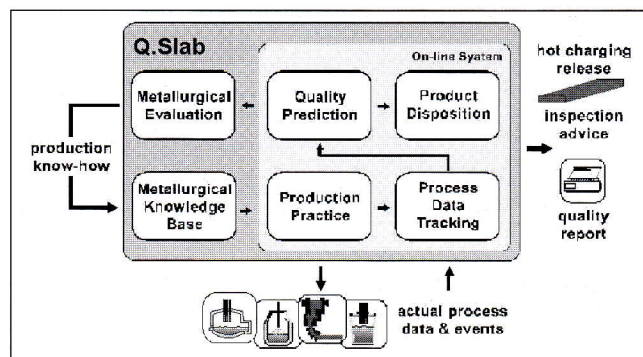


Figure 28: VAI-Q (CAQC) Quality Control System.

rameters and the metallurgical expert knowledge stored in the computer.

With this tool it is possible to automatically identify products which do not meet the specified quality parameters. VAI-Q then determines whether conditioning or reassignment to a less demanding order is necessary.

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**STAINLESS STEEL CASTER EXAMPLES**

VAI has become the world market leader in the supply of stainless steel slab and billet casters. In the following several examples of VAI stainless steel caster installations are outlined.

**POSCO Pohang Works**

In August 1996 POSCO started up its No. 2 stainless steel-making plant with a thick stainless steel slab caster.(14) The main design data are seen in Figure 29.

In order to produce high-quality clean steel the teeming ladle is equipped with a slag detector system for minimizing slag carryover into the tundish. To prevent reoxidation, argon or nitrogen, depending on the steel grade, is used for gas sealing of the tundish. A plasma heater maintains a tight superheat tolerance in the tundish for ferritic grades. Highest product quality is assured by the use of a straight mold with an electromagnetic level control system, a four excenter mechanical oscillator, an electromagnetic stirrer in the bender area and a rigid strand guide with I-STAR rollers.

The layout of the finishing facilities of the POSCO No. 2 stainless steel plant represents a modern conventional approach for stainless steel slab processing (Figure 30).

In order to reduce space for slab cooling, certain steel grades are quenched in a water basin. Insulated hoods allow controlled cooling of martensitic grades and the availability of grinding machines ensures that only prime product quality is sent to the reheating furnace for rolling.

**AK Steel Mansfield**

AK Steel Mansfield, Ohio/USA, is an example of a "brown-field" investment which features the installation of a medium-thick slab caster and a reheating furnace directly in front of the existing rolling mill.(11) (12) By linking individual processes to a continuous process, intermediate steps such as slab storage, inspection, grinding and reheating are eliminated. The entire product mix is directly hot charged into the equalizing furnace (Figure 31).

Due to an optimum utilization of the heat content in the strand, the direct linkage of the stainless-steel continuous caster and the hot-rolling facilities results in high energy savings, simplified logistics, reduced personnel requirements and just-in-time production.

The AK Steel Mansfield medium-thick slab caster is equipped with a cassette-type mold with optimized copper plates, a hydraulic DYNAFLEX oscillator, rigid strand support with intermediately-supported rollers (I-STAR) and a DY-

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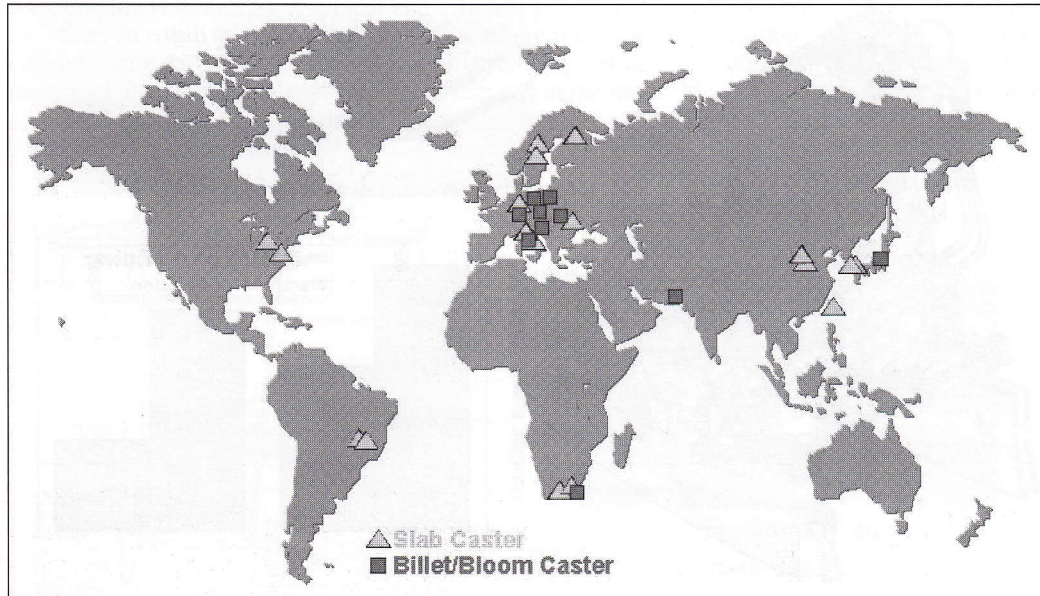


Figure 29: POSCO No. 2 Stainless Steel Slab Caster, Republic of Korea.

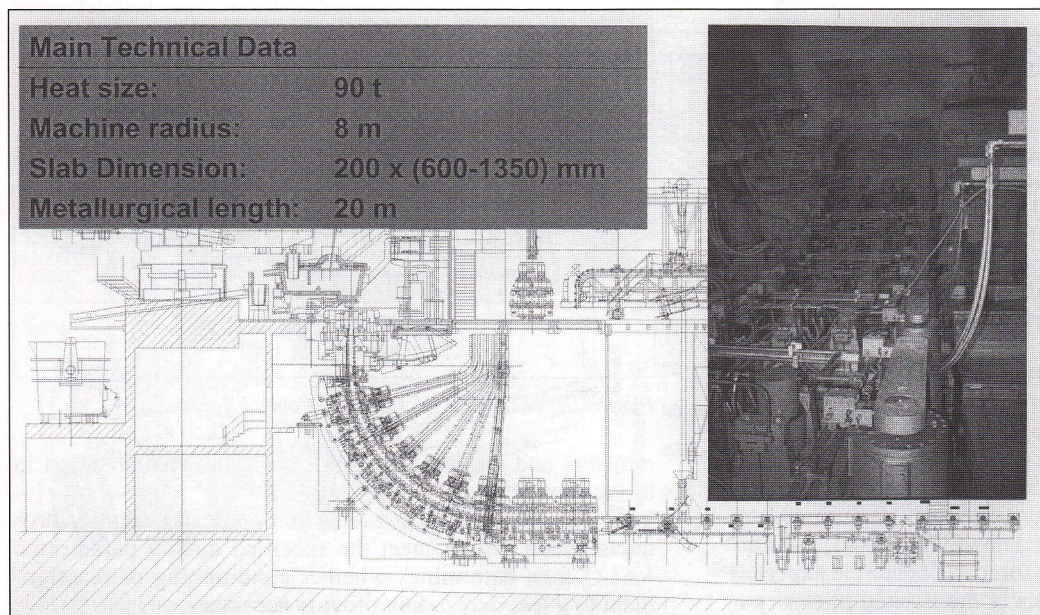


Figure 30: Finishing Facilities at POSCO No. 2 Stainless Steel Plant.

Main Technical Data	
Heat size:	90 t
Machine radius:	8 m
Slab Dimension:	200 x (600-1350) mm
Metallurgical length:	20 m

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Figure 31: Process Route at AK Steel, Mansfield, Ohio, USA.

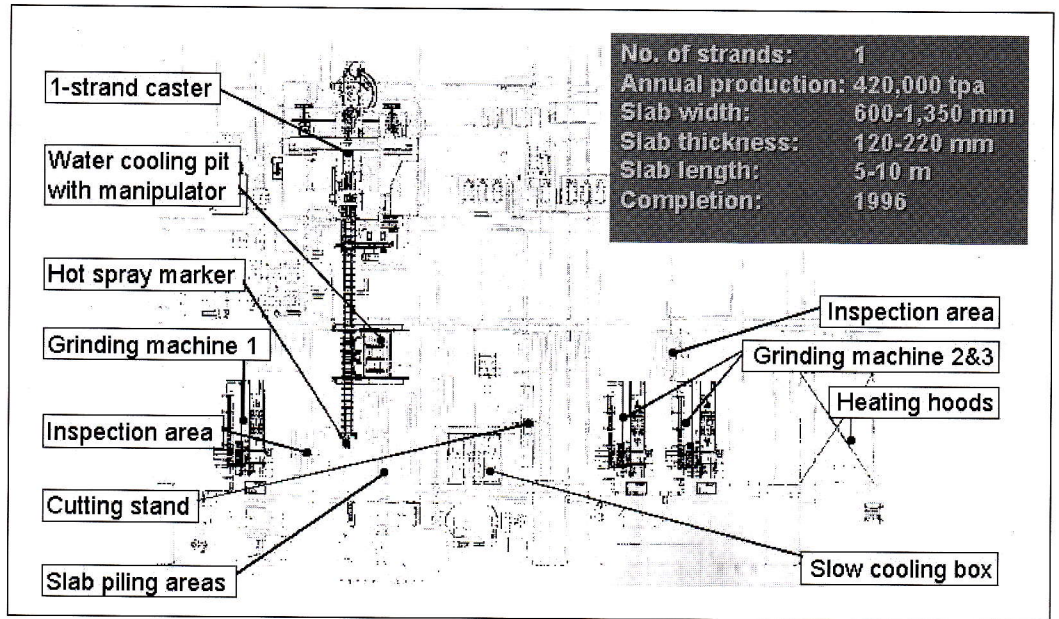


Figure 32: AK-Steel, Mansfield Medium Thick Slab Caster, Ohio, USA.

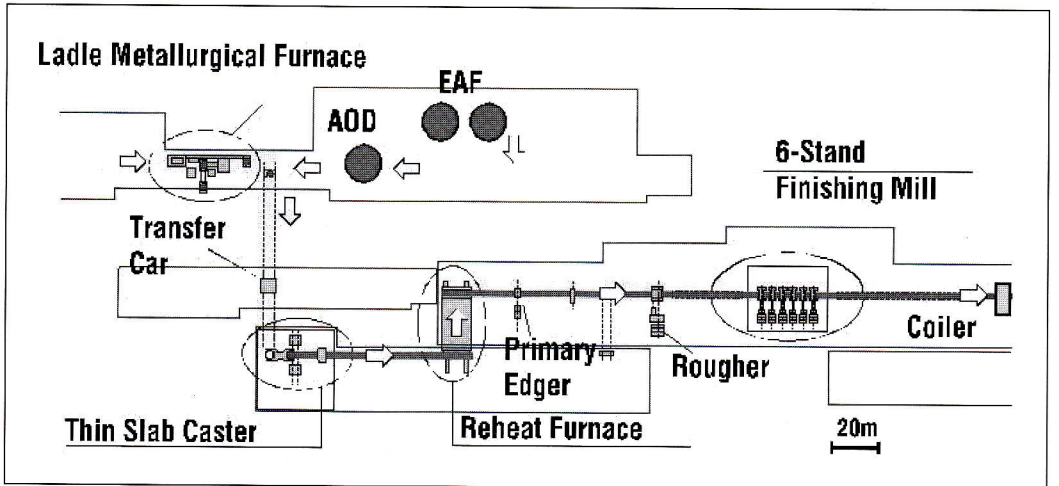
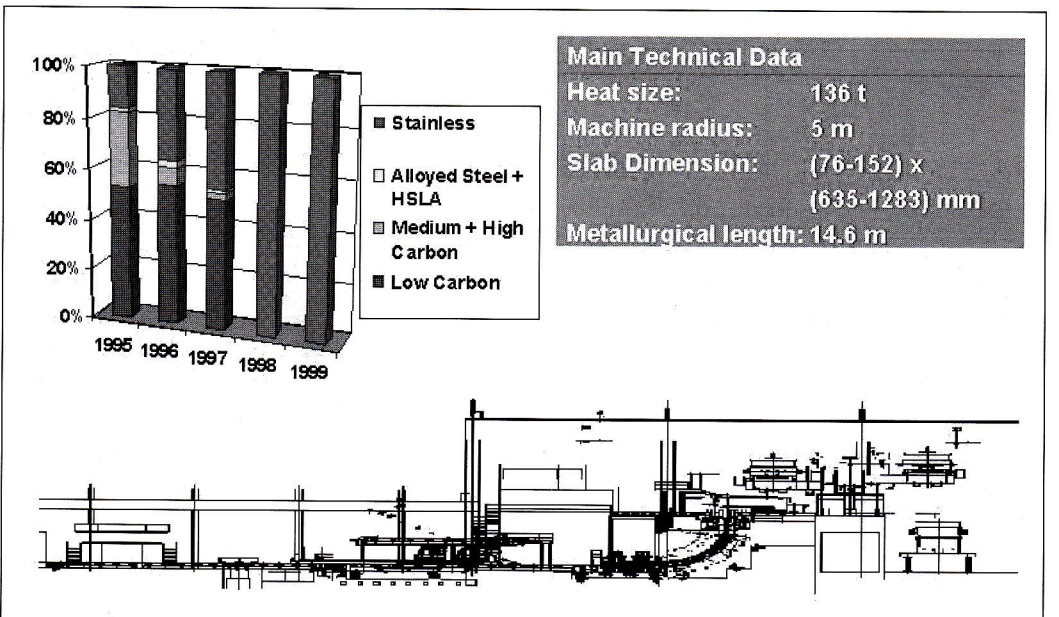


Figure 33: 1-Strand Stainless Steel Slab Caster at Outokumpu Oy, Tornio/Finland.



NACS® secondary cooling model (Figure 32). These solutions in combination with VAI-Q (the previously outlined computer-aided quality assurance package) are the key factors which enable the production of even Ti-stabilized ferritic slabs without surface conditioning.

OUTOKUMPU OY

Outokumpu Oy, Finland, placed an order with VAI in 2000 for the supply of a new single-strand stainless steel slab caster (Figure 33). In addition to the latest state-of-the-art fea-

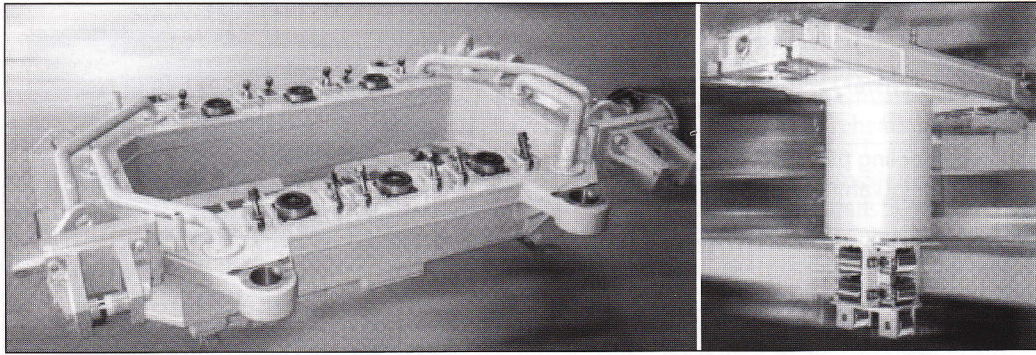


Figure 34: Stainless Steel Triple Casting Mold with Mold Adapter Frame.

Heat size:	125/150 t
No. of strands:	1
Radius:	9 m
Length of containment:	22.2 m
Slab thickness:	170 - 240 mm
Slab width:	800 - 1,650 mm

Figure 35: 1-Strand Stainless Steel Slab Caster at Outokumpu Oy, Tornio, Finland.

<p><b>Special features</b></p> <ul style="list-style-type: none"> <li>→ Diamond</li> <li>→ Dynaflex</li> <li>→ Mold stirring</li> <li>→ Air mist cooling</li> <li>→ Rigid dummy bar (tiltable)</li> <li>→ Soft Reduction</li> <li>→ CAQA system</li> </ul>	<p><b>Cast grades</b></p> <p>high carbon steels</p> <p>quality steels</p> <p>special steels</p>	<p><b>Technical data</b></p> <p>Type of furnace: EAF</p> <p>Heat size: 50 t</p> <p>Annual capacity: 230 000 t</p> <p>Number of strands: 3</p> <p>Section range: sq 100-160 mm</p> <p>rd up to 160 mm</p>
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Figure 36: VAI Hydraulic DYNAFLEX Oscillator at VALBRUNA Bolzano, Italy.

tures, the caster will be equipped with a new optimized segment generation which combines the benefits of low maintenance costs and design features for assuring highest product quality.

**Combi-Casters**

For a small production output of billets in addition to slabs, stainless combi-casting offers an economic solution for combining the production of long and flat products in a single caster unit (Figure 34).

The revamping/investment costs include tundish and tundish flow control modifications, installation of twin or triple molds, including an adapter frame, a new mold-control system, a modified primary and secondary cooling system, installation of new dummy bar heads and modification of the torch cutter and runout roller table.

Examples for the successful implementation of combi-casters include the twin-bloom caster at the No. 1 Stainless Steel Plant at POSCO Pohang Works and the triple-billet caster at AVESTA-SHEFFIELD, Degerfors/Sweden.

**DIAMOLD/DYNAFLEX Installation**

The first stainless steel billet caster equipped with DIAMOLD technology and the DYNAFLEX hydraulic oscillator is in operation at Acciaierie Valbruna, Bolzano/Italy (Figure 35).<sup>(21)</sup> This equipment is currently installed in one of the three strands of the billet caster. As a special feature, soft reduction is also applied, thus setting new standards for flexibility and product quality in stainless steel billet casting.

At Valbruna the production of top-quality products at minimum production costs is ensured by an inline VAI-Q quality assurance system.

**OUTLOOK**

Undoubtedly, the biggest quantum leap in stainless steel-making technology is offered by strip casting. After a joint process optimization together with Acciai Speciali Terni and CSM, a commercial size, pre-industrial strip-casting plant successfully started up at KTN Krefeld/Germany in December 1999. Since USINOR joined the partnership with Thyssen Krupp Steel and VAI, the appropriate name EUROSTRIP® was assigned to this major strip casting cooperation.

The pre-industrial strip casting plant is the first of its kind in Europe. The initial capacity will be 100,000 t/a for strip thicknesses of 1.5–4.5 mm at strip widths of up to 1,450 mm (Figure 39).

The enlargement of the Krefeld plant's annual capacity to 400,000 t/a is already foreseen in the second phase. The goal is to reach the full industrial stage as soon as possible in order to enable the company EUROSTRIP® to commercially market the process. VAI will be the exclusive supplier of EUROSTRIP® facilities.

**CONCLUDING REMARKS**

The prerequisites for an optimum design of stainless steel continuous casters is a comprehensive knowledge of physical properties of stainless steels at elevated temperatures and the understanding of the various solidification characteristics.

Based on continuous development and the excellent cooperation with its customers, VAI has become the world market leader in the supply of stainless steel slab casters. Emphasis has been placed on a robust and flexible design characteri-

zed by reliability, availability and ease of maintenance.

The greatest challenge, however, is the optimization of EUROSTRIP® at KTN's Krefeld works to industrial maturity. EUROSTRIP® will provide substantial savings in investment and operating costs and currently represents the most exciting new development in stainless steelmaking. Major technological changes can be expected early in this millennium in the stainless steelmaking industry.

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Figure 37: Cross Section of the Single-Strand Billet Caster at MICROSTEEL, Durban, South Africa.

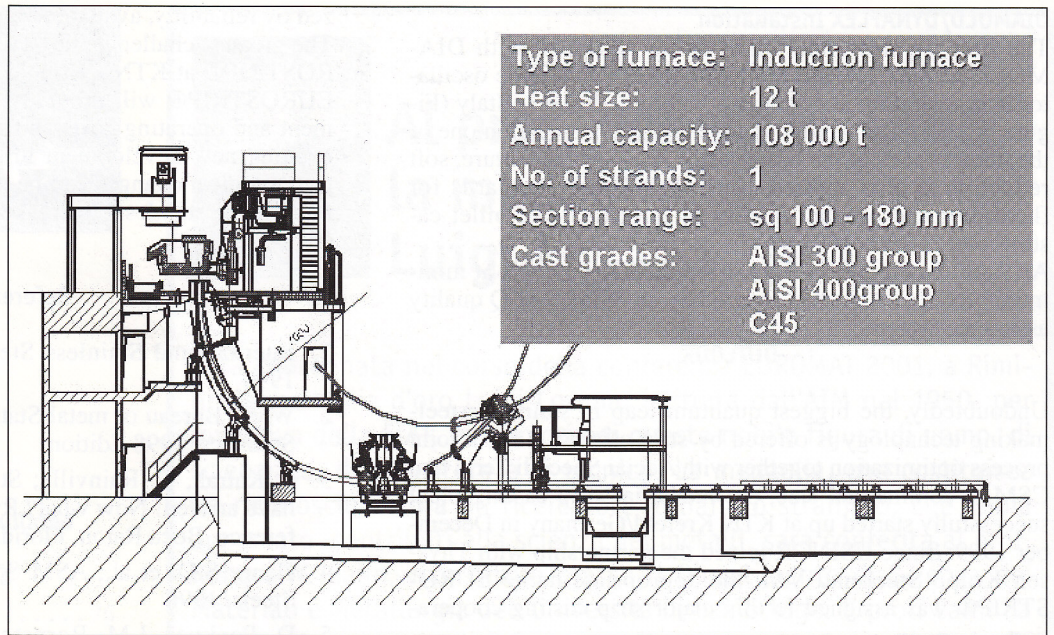


Figure 38: Typical Hot Direct Charging Layout.

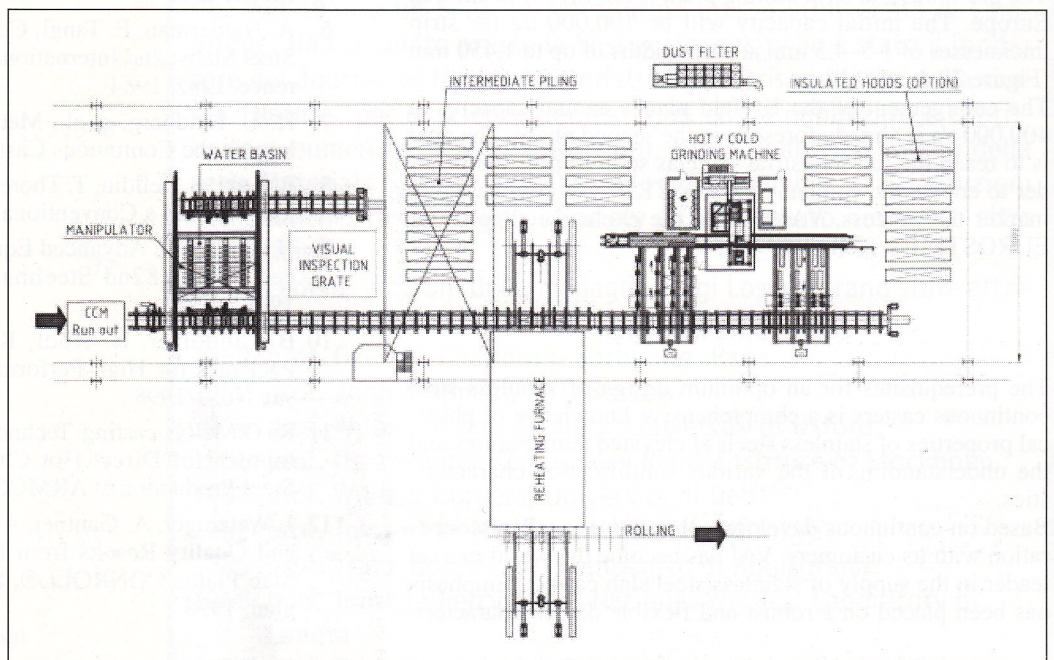
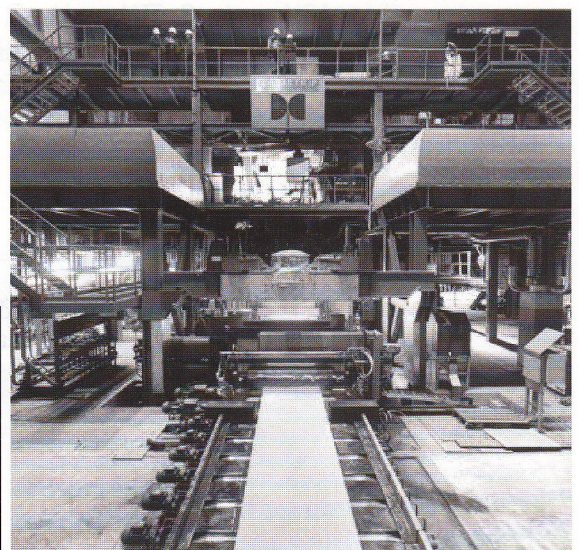


Figure 39: EUROSTRIP® Plant at KTN Krefeld, Germany.

Successful start-up of PIP on Dec. 12, 1999  
 • Commissioning phase first half of year 2000

Heat Size:	90 t
Tundish Size:	17 t
Strip Width:	1100 -1450 mm
As Cast Strip Thickness:	1.5 - 4.5 mm
Casting Speed:	15 - 140 m/min



MEMORIE

5/2001