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/UNIDO publ/. /Expert report/ on ~~advanced technology/ for~~ secondary steelmaking and continuous /casting/ of /steel/ (based on experience in /USSR/) — covers (1) steel /refining/ ladle processes, prevention of impurities (2) secondary steelmaking methods: /vacuum/ processing, inert /gas/ blowing, powdered materials injection, combined steel processing; /economic aspects/ (3) principles of continuous casting; its economic advantages when combined with /ingots/ casting into /moulds/; variants, & problems of /automation/; implications for /developing countries/. Gives information on continuous casting plants in various countries. /Recommendations/ /factory layout/, /diagrams/, /bibliography/. Additional references: /powder metallurgy/, /process control/, /advanced technology/. ~~/Restricted/~~.

Moscow
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Recent development of secondary steelmaking and continuous casting of steel

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Content

Abstract

The given abstract gives a reader an information about the present situation and perspectives trends in secondary steelmaking and continuous steel casting.

The first part deals with the steel refining ladle processes. The main detrimental impurities influence on steel quality and the general means of preventing them are analyzed there. The principle secondary steelmaking methods are examined in detail: vacuum processing, inert gas blowing, powdered materials injection, combined steel processing. Economic aspects of the problem are considered there.

The second part gives the analysis of the present continuous steel casting situation. Continuous casting principles, separate installation units purpose and operation are investigated. Economic advantages of continuous casting cooperated with periodical ingot casting into moulds are demonstrated. Variants of continuous casting units arrangement in steelmaking shops are given. Special attention is devoted to continuous casting automatisation problems. Recommendations towards continuous casting application in developing countries are given.

The problems discussed in abstract are given in appendices. The principle secondary steelmaking methods definitions and their brief characteristics are given first of all. Information about principle continuous casting and steel ladle processing units having been installed within recent two-three years or which are going to have been constructed this year is given.

The specific characteristics of horizontal continuous casting units contructions and operation are shown. Continuous casting perspective trends: "hot charge", direct rolling, sheet (strip) production, etc. are examined.

The existing problems solution at [illegible] finite Iron and Steel plants are examined.

Abstract will be helpful to determine steelmaking production development trends in developing countries.

Introduction

1. Even though many alternative materials appear, steel will still remain the basic material for industrial development for many years. This fact may be proved by almost simultaneous development of the world steelmaking and industrial development indices for the last century, Fig. 1, [I].

2. Modern steelmaking production is being developed in two trends:

- creation highly productive oxygen converters at the plants with a complete metallurgical cycle, equipped with secondary steelmaking and continuous steel casting departments. Mainly liquid iron with a small quantity of scrap additions is used as a charge in such shops;
- by means of mini steel-plants construction, equipped with electric arc furnaces using scrap or direct reduction products as a charge.

3. In industrialized countries both trends are realized in most cases. However, lately construction of large plants with a complete metallurgical cycle has been slowed down in industrialized countries. At the same time technical progress in elaboration of electric arc furnaces,secondary steelmaking systems and continuous casting units have turned out small plants into an effective means of sorted rolling, rods and small sections productions. If there is sufficient scrap quantity and cheap electric power, then mini steel plants get wide application.

4. In developing countries ways of development in metallurgy depends on local conditions. In such cases, when a country posseses its own ore resources, the construction of plants with a complete metallurgical cycle is economically expedient.

5. Mini steel plant is the plant which produces steel from scrap or metallized pellets in electric arc furnaces. Mini plant has continuous casting installations, secondary steelmaking sections, small section rolling mills and wire rolling mills. These plants produce mostly commercial sorted rolling, rods and small sections. Their annual production capacity usually ranges from 100.000 up to 500.000 tons, but in some cases it may reach 1 mln. t. In a number of cases plants with annual capacity less than 100.000 t. are called micro plants.

6. According to the way of production mini steel plants may be of two types: plants producing one type of production (e.g. for

reinforced bars) or plants producing a wide variety of steel grades to provide a region with the required production. Besides, these plants are distinguished by the capacity and technological scheme.

7. Modern Iron and Steel production scheme in all cases includes a steelmaking unit proper (oxygen converter or electric arc furnace ; one or a number of secondary steelmaking installations and continuous casting). The steelmaking unit problem is charge melting, its partial refining and heating up to the desired temperature. But final refining, deoxidation and, if necessary, steel alloying is done at secondary steelmaking installations. That provides a considerable steelmaking units capacity increase at a simultaneous steel quality increase. Continuous casting provides a considerable metal saving (increases the yield) while decreasing production cost.

8. Lately steel quality is paid decisive attention to service properties and rejection quantity. It is determined by steel composition detrimental impurities content and their presence form in a metal at items operational t^{o}. In other words, steel quality mostly depends on refining degree and solidification conditions.

9. The Selection of secondary steelmaking methods and continuous casting installations for each specific case depends on a lot of factors: production assortment, the desired level of service properties, raw materials resources, political and economic situation in the givm region (in the given country). Only taking into account a combination of these and a number of other factors, steelmaking production development methods may be chosen.

10. The main factors determining steel quality and also technical and technological characteristics of the installations, secondary steelmaking and continuous casting steel methods will be examined below.

Part A. Secondary Steelmaking

a) Short historic development

1. A modern period of Iron and Steel production development is characterised by constant increase of steelmaking units output, the produced steel grade improvement and their qualitative characteristics increase. That provides the decrease of specific metal consumption, energy resources and labour expenditures during production, metal processing and metal application.

2. Output increase of modern steelmaking units (converters and, especially, electric arc furnaces) is achieved by the performed operations decrease. The main objectives of such units include charging materials melting, bringing the melt to the desired t^o and partial refining, mainly from carbon. Basic steel refining and also deoxidation and alloying is done in ladles by secondary steelmaking methods. That enables, for example, to exclude a reduction period from a classical electric furnace process.

3. The most important factors characterising steel quality increase are detrimental impurities contents decrease and providing metal melting with still narrower composition and t^o variations limits. In combination with micro and macro alloying methods and heat treatment of steel it will provide strength characteristics and plasticity properties increase. Secondary steelmaking is considered to be a perspective way of development.

4. In 50-s continuous casting was introduced into steelmaking production and then extended its development. This method renders high requirements to the produced steel quality: it must contain as little detrimental impurities as possible, it must be homogeneous in composition and t^o. Optimum secondary steelmaking technology is the necessary condition for the high quality continuous casting production.

5. Steel refining in a ladle has been applied by metallurgists for a long time. And steel deoxidation in a ladle has already got its application. Even before WW II Perren method for metal desulphurization got its application. In late 30-40-s vacuum steel processing started its industrial development. However, all these technological variants (excluding deoxidation in a ladle) has a particular character and were used for solving certain problems.

6. Only continuous casting development made metallurgists pay special attention to steel refining in a ladle. From that moment

practically a new technological method in steel production started its formation - steel processing in a ladle. At present, these methods got wide application in metallurgy and are called "secondary steelmaking".

b) Classification of technological processes

1. The main purpose of secondary steelmaking is quick and effective implementation of a number of technological operations as compared with conventional steelmelting units: The secondary steelmaking makes it possible to do the following:
- homogeneous metal t°;
- homogeneous chemical composition;
- alloying and bringing chemical composition precisely to the desired one;
- final deoxidation;
- non-metallic inclusions removal;
- metal desulphurization;
- metal degasing (hydrogen and nitrogen removal);
- decrease of undesirable non-ferrous impurities content;
- metal t° regulation;
- deep metal decarburization;
and also a number of other particular problems.

2. To solve all the abovementioned problems at a time is rather difficult. As a rule, only part of them is solved simultaneously. Sometimes only one of the above mentioned methods is used, and sometimes several at a time.

3. At present, secondary steelmaking methods are used for the production of hundreds of millions tons of mass production steel, secondary steelmaking units being available at all qualitative metallurgy plants. Metal produced both in electric furnaces, in converter and in open-hearth furnaces is subjected to ladle refining.

4. Rapid secondary steelmaking spreading is explained by the following factors:
- continuous steel casting method got wide application that requires precise(and standard from heat to heat)t° and metal chemical composition regulation, and it also requires a standard high quality metal for casting; as a result practically all the steel cast at continuous casting units is processed by secondary steelmaking methods;
- classical double-slag technology in electric furnaces using secondary steelmaking may be substituted by a single-slag process without slag pumping-off (heat time, electric power expenditure, labour expenditure etc are reduced);
- converter or open-hearth heat technology and their operation control is simplified, i.e. there appears a possibility to blow a metal with oxygen towards low carbon content with further carburi-

cation and temperature correction in a ladle;
- the scope of special purpose steel grades is constantly increasing (e.g., for thoroughfare pipelines) which are generally difficult to be produced with conventional heat technology;
- the scope stainless steels and other low carbon steel and alloys production has increased;
- secondary steelmaking processes application enable to change radically the structure and the type of the applied ferroalloys and deoxidisers towards essential requirements decrease according to their composition and their corresponding to the reduction of prices.

5. The following methods of secondary steelmaking got wider application:
- vacuum metal processing;
- inert gas metal blowing;
- powderformed materials injection into a metal;
- metal processing with artificial slags or with specially prepared alloying composition;
- simultaneous application of several technological methods.

6. At present, there is a great number of variants of each of the secondary metallurgy methods. Only the main methods will be examined further and the most interesting examples to author's opinion will be shown in fig. 2 .

7. The list of the existing ladle processing methods is quite big, and in a number of cases the same letter identifications corresmnd to different processing methods. To make the possibility to use the literature easy, there is a list of abriviations of different processes adopted in periodicals in Appendix 1 .

c) Description, review and appraizal of the technological process and equipment/facilities.

I. Vacuum metal processing.

1. When the pressure above the metallic melt is decreased the course of all the reactions, carried out at gas phase formation is facilitated:

- carbon affinity to oxygen is increased as a result the reaction $[C] + [O] = \{CO\}$ is facilitated;
- gas solubility in steel is decreased, accompanied by the reaction $[G] = \frac{1}{2} G_2$.

2. During vacuum steel processing:

- oxygen content dissolved in a metal is decreased;
- dissolved hydrogen and nitrogen content is decreased;
- oxide non-metallic inclusions content in a metal decreases;
- a metal is stirred, becomes homogeneous in t^o and composition as a result of a large number of gas bubles emission. When a metal contains an increased number of non-ferrous metalls additions (lead, antimony, tin, zink etc.) a noticable part of them evaporates during vacuum processing.

3. At present hundreds of various design ladle vacuumation units work seccessfully in steelmaking shops in the world. The most widely used methods are shown in fig. 3 .

4. The simpliest method is vacuum processing in a ladle located in a vacuum chamber. However, this method is less effective, particularly during vacuumat. processing in relation to quite large metal masses ($\leq 40 - 50$ t). This is connected with the fact that only surface metal layers are subjected to vacuum effects. The pressure in bulk will depend on a metal column height:

$$P = P_o + P_f + P_c$$

where P - pressure in a gas buble; P_o - pressure in a vacuum chamber; P_f - ferrostatic metal and slag pressure; P_c - capillary pressure.

Moreover, a necessary uniformity in a metal composition after deoxidizers and alloying elements introduction is not reached because of weak stirring of the whole metal bulk during ladle degassing: according to the above mentioned equations a gasforming process is being developed only in surface metal layers.

5. Stirring effectiveness increases only during inert gas metal

blowing in a ladle or electromagnetic stirring in used. It should be taken into consideration that during inert gas blowing heat losses may be added to usual ones as a result of the blown gas heating during ladle soaking and tapping. During electromagnetic stirring there is no such a drawback but it requires more complex and expensive equipment. Lately inert gas blowing in vacuum has got wide application for small capacity ladles (15-30 t). In this case deoxiders and alloying elements are added into a ladle from a bunkes also placed in a vacuum chamber.

6. Degasing processes taking place during steel vacuum processing have a diffusion or absorbtion-kinetic character. That means that a degasing speed depends either on a gas mass-transfer in a metal in bulk towards its surface or on the transfer through that surface. In both cases a relative surface of a metal-vacuum contact influences the process speed in both cases. Thus, metallurgists' desire to increase a specific surface is quite clear .

7. A specific surface during teeming from a ladle into a ladle or from a ladle directly into the ingot mould has got considerable development. In this case a stream, falling into a vacuum chamber, disperges into small drops. Therefore, a specific surface metal-vacuum contact increases several times and that provides high degasing effectiveness. Due to a number of difficulties of an organization character this vacuum processing method hasn't found wide application in industry. It is used as a rule only during large ingot casting.

8. DH and RH methods have got wider application. There is no data available so far to give preference to this or that method. And they are almost equal in application: a number of these or those units in the world is almost the same.

9. During DH method under a ferrostatic pressure effect a metal is sucked into a vacuum chamber (nearly 1,5 m). The chamber is raised in certain periods of time (but the end of the refractory pipe should remain sink in a metal in the ladle), and a metal flows into a ladle. Then the chamber goes down and a new metal portion is sucked in again - thus this method is called "cycling degassing". In some variants of this method the chamber remains immovable and a metal with a ladle makes a motion. Fig. 4 .

10. During circulation degasing a vacuum chamber has two refractory pipes through where a portion of metal is sucked into the chamber. Then inert gas started to be blown through one of the

refractory pipes. As a result the metal is raised upwards through the refractory pipes and through the second one the metal flows into the ladle. Thus, metal circulation through the unit begins, fig. 5.

11. Degasing conditions during vacuum processing with various methods are different and thus the level of gases content is different which can be reached as a result of vacuumation. The best results may be reached during non-deoxidized metal vacuum processing as much of the dissolved oxygen is present there, that intensifies carbon oxidation reaction $[C]+[O]=\{CO\}$. The observed intensive boiling makes calculate the ladle volume so that to prevent a possible metal splashing from it.

12. Experience has shown that hydrogen removal goes intensive enough, having the pressure in a vacuum chamber lower 50 Pa. Modern double-steam pumps may provide pressure of 10 Pa.

13. High quality refractories are required to produce cycling and circulation degasing chambers expecially for refractory pipes production. Increased processing t°, a longer pressure in a ladle and intensive stirring typical for ladle degasing made it possible to use conventional ladle stoppers lined with chamotte. Stoppers turned out to be substituted for slide gates and chamotte lining for a more resistant dolomite or magnezite.

14. It should be taken into consideration that a noticable steel temperature fall in a ladle may occur. It requires certain metal reheating (by 40-50°) in a steelmaking unit. The rehe ing may be reduced at the expense of good vacuum chambers lining heating. During their preheating to 1500°C metal t° fall during vacuum processing does not exceed one degree per min.

15. If DH and RH methods are equal in the degree of hydrogen removal, then there is another possibility to influence the impurities removal process in RH method by means of intensive transforming inert gas supply. It is of special importance during steelmaking with extremely low carbon content.

The research has shown that metal circulation intensity increases due to the gas expenditure increase up to 1500 l/min and during further increase it doesn't practically change. Decarburization of the melt occurs on a free metal surface in a camera, on the drops surface of the spouting metal in a chamber and on the gas bubles surface in a sucking tube. At the increase of the gas expenditure supplied into a sucking pipe decarburization intensity noticably increases, carbon portion (up to 30-40%) being increased, and it is oxidized on the drops surface of the spouting metal and also on the gas bubles surface. In 13 min. of processing at the transported gas expenditure 5000 l/min, carbon content decreases to 0.001%.

16. According to data [2] during low carbon steel production vacuum processing provides standard carbon content decrease in a finished metal (Fig. 6). Hydrogen removal degree in vacuum processing makes up 35-72% (increases with its initial content growth) in average after degasing 1.82 cm^3/100 gr less hydrogen than conventional steel. Nitrogen content in a metal during vacuum treatment doesn't change practically but during casting it increases due to steel contact with air. In general in degasing steel ingots nitrogen content is 0.0026% less than in conventional steel ingots.

17. It is stated in many research works that even expenditures decrease (energy, first of all), connected with metal heating necessity after hot deformation aimed at hydrogen content decrease in it cover vacuum processing expenses.

18. To intensify a decarburization process vacuum units are supplemented in a number of cases with simultaneously oxygen metal blowing. High degree decarburization can be achieved at such units, oxygen blowing causes a further decarburization. It is this method that has made the basis of the so-called "vacuum oxygen decarburization" (VOD-process). A typical unit for VOD-process is shown in Fig. 7 .

19. As far as circulation degasing units is concerned decarburization process is accelerated when oxygen is introduced for metal blowing or forced air cooling directly in a circulation chamber. Such a process (Fig. 8) worked out by Japanese companies, is called RH-OB. Usually one of the two methods of oxygen supply is used:-submerged oxygen supply through one or two tuyuers, each consisting of two concentric pipes between which protective gas is supplied (Ar, N_2 or CO_2);

- oxygen supply through one or two tuyuers into the space above the bath in a chamber or through the top (under the angle) to the metal surface coming to the vacuum chamber.

Decarburization speed is higher in case of submerged oxygen supply, processing time being considerably shortened. It is established that CO_2 is better used as a protective gas. In case of a high chromium melt processing chromium oxydation decrease is observed [3] .

20. To get very low carbon concentration is especially important for high chromium stainless steel and also for some special steels and alloys. The problem of getting low carbon concentration without noticeable chromium losses is solved in vacuum, together with decarburization the processes of gas and non-metallic inclusions removal from the bath take place.

21. To get low carbon content during vacuum processing it is necessary to provide a metal with oxygen. As a decarburization process takes place mostly on the phase boundary, it is desirable to have good bath stirring. For this aim inert gas blowing method through a porous brick in the ladle bottom is more often used for this purpose. However, in this case the operation lasts long enough, especially when a semiproduct with a comparatively low carbon content is processed.

22. As an example the data of Krupp Sudwestfalen AG Plant may be given, where heats from two arc furnaces, one with 30-40 t and the other 80-90 t capacity are treated by VOD-process. A vacuum unit is located in a teeming bay. It consists of two chambers equipped with tuyuers for oxygen melt blowing. The unit is equipped with a transport system of alloying materials supply from bunkers to the ladle through a vacuum gate. In 90% cases a final carbon content less than 0.015% is achieved. Oxygen content in the process of oxygen blowing goes up to 0.05% but in the end of blowing it goes down to 0.005% and in a finished metal - up to 0.0020%. Hydrogen content decreases from 3.8 to 1.8 cm^3/100 gr. Sulphur content in case of a lime slag and fluorspar presence in a ladle may be decreased to 0.005%. Lead (up to 0.0010-0.0020%), zink (up to 0.0010%) etc are removed during vacuum processing.

23. Vacuum steel processing methods are constantly improved, new more simple methods are being found to solve new problems. PM method worked out by one of the Japanese plants, may serve an example. A method scheme is shown in Fig. 9 . 100-t heat of the converter metdl is processed at a unit of such a type. The possibility of highly effective work without deep vacuum is mentioned as an advantage. The main PM-process parameters are: cylinder - 300 mm internal diameter, 600 mm - external diameter, length - 3000 mm, working gas argon, pressure $\sim$ 10 atm; vacuum pumping-off intensity 10m^3/min; pumping duration $\sim$ 1 sec; pumping-off duration < 5 sec; submerging depth - 500 mm; operating pressure 0.5 - 1.5 atm.

The essence of the method is alternative argon and vacuum pump switching on and switching off, a metal in a cylinder (or in a ladle) starts extremely pulsating as a result, providing a high refining degree.

24. Thus, vacuum processing "in a pure state" gradually gives way to vacuum processing in combination with other ladle processing methods (argon blowing, slag processing etc.). New variants of vacuum processing organization are being worked out, particularly continuous processing variants. Japanese company Nisshin Steel K.K. proposal of continuous vacuum metal treatment in a tundish on the way from a steel teeming ladle to CC mould is shown as an example in Fig. I0 , a Stream vacuum processing unit at the plant in Lipetsk (USSR) is shown in Fig. II .

II. Inert Gas Metal Blowing

1. The transfer of refining, deoxidation and alloying processes from a steelmaking unit into a ladle has required elaborations of effective metal stirring methods. It is provided by inert gas blowing. In cases when good slag is formed onto the metal surface, stirring facilitates an assimilation process with such non-metallic inclusions slag. The inert gas bubbles mass facilitates gas emission processes as in this case surface metal-gas interaction is being considerably developed.

2. From a technical point of view, large metal masses blowing process with inert gases in a ladle are simpler and cheaper than vacuum processing, that's why inert gas blowing is substituted for vacuum processing where necessary; however inert gas blowing should be considered to be accompanied by metal temperature decrease.

3. In a general case during inert gases metal blowing:

1) gases content in a metal decreases;

2) energetic melt stirring occurs, non-metallic inclusions removal in slag processes are facilitated; metal composition is made homogeneous;

3) conditions of carbon oxidation reaction are facilitated;

4) metal temperature decreases.

4. Nitrogen is often used for metal blowing containing no nitride forming elements (chromium, titanium, vanadium, etc). In temperature interval 1550-1600°C the process of nitrogen dissolution in liquid metal does not get noticable development.

5. Inert gas expenditure usually makes up to 0.5 m^3/t of steel. Depending on liquid steel quantity in a ladle with the same argon expenditure steel temperature makes up to 2.5°C/min. (without blowing a metal in a ladle is cooled with 0.5-1.0°C/min.)

6. The selection of a blowing method is of great importance. Inert gas blowing in ladles is distinguished as top and bottom blowing, fig. I2 .

7. One of the important operations in a technological line of steel processing with a neutral gas in ladles is oxidized "furnace" slag cutting-off with special units. The presence of oxidized slag complicates homogeneous steel chemical composition and increases deoxidizers loss. Aluminium oxidizes more intensively: within 5-8min. of blowing its content in steel decreases twice as much. Slag composition is changed (iron oxides content decreases) and steel rephosphorization is developed: phosphorus content is increased by

0.002 - 0.005 %.

8. The refining processes degree depends on blowing intensity and duration (i.e. finally, on inert gas expenditure).

Blowing with gas expenditure up to 0.5 m^3/t of steel is enough for chemical composition and metal temperature averaging, blowing with the intensity up to 1.0 m^3/t influences metal refining from non-metallic inclusions; to achieve appreciable results in degasing it is necessary to use inert gas ~ 2-3 m^3/t of metal.

9. Combining inert gas blowing with artificial slag processing enables to increase abruptly the effectiveness of slag application, as energetic stirring during blowing increases with a surface contact value. If a ladle where processing is done, is covered with a cover, inert gas atmosphere between a cover and a slag surface prevent a metal from oxidation, and heat losses value enables to lengthen the time of a metal contact with liquid slag. The so-called CAB-process technology worked out by NSC company (Japan) is based on this principle. As shown in Fig. I3 the given technology provides the presence of the desired composition of artificial slag on the metal surface in a ladle.

The so-called SAB-process is used by the company when a certain quantity of the oxidized final slag passes into a ladle from a melting unit, fig. I4.

10. If a metal is overheated in a steelmelting furnace there are three methods of achieving a required t° (cooling) [4]:

- argon blowing if necessary, temperature decrease does not exceed 10°C;
- height scrap addition if necessary to decrease temperature by 10-20°C;
- slab application for cooling by 20°C and more.

11. While introducing microalloying and correcting additions it is necessary to take into account metal temperature change (+ "increase", - "decrease") for 1 kg of the introduced additions [5]:

Ferrovanadium 35% V	- 0.89
Ferrotitanium 30% Ti	- 0.68
Ferrotitanium 65% Ti	+ 0.29
Ferrosillisium 45% Si	- 0.76
Ferrosillisium 65% Si	+ 0.62
Silicomagnasium	- 0.81
Ferromanganese	- 1.77
Silicocalcium 30% Ca	+ 0.99

Secondary aluminium (pig) - 9.96
Primary aluminium (wire) + 2.22
Graphite - 5.64

12. When it is necessary to stir a metal under slag for a long period of time, electrodes are plunged into the lid which covers the ladle and the bath is heated. In these cases the use of conventional chamotte as a ladle refractory material is excluded, as a long contact of liquid mobile, high basicity slag withe chamotte lining, consisting of silica and alumina quickly brings lining out of order. It is necessary to line ladles with basic high refractory materials (dolomite or magnezite).

13. Combining inert gas blowing with ladle lining replacement for the basic one enables to achieve a considerable decrease of metal pollution with oxygen. If during conventional technology Al_2O_3 in deoxidized aluminium steel has reached values 10^{-8}-10^{-9}, then the product reached value 10^{-11} while using basic lining ladles during argon blowing. The results received during steel vacuum processing cycling degassing at Yawata Works (Japan) are shown as an example in Fig. I5 .

14. A processing scheme called AIS is shown in Fig. I6 . According to this method in the course of vacuum processing the metal is shifted both under electromagnetic stirring and under argon blowing action. According to this principle vacuum processing is done at ASEA-SKF type units. It is necessary to consider that argon performs two purposes: stirring and intensification of gas emission and decarburization processes due to partion pressure decrease of carbon oxide in bubbles going through the bath.

15. During top blowing cylindrical nozzle is usually applied. In recent years blowing through slit nozzles has got wide application. Such a blowing method intensifies metal stirring and provides deeper melt degassing at the expense of cavitations phenomena formation. The special degassing effectiveness is reached while combining crevice nozzles blowing with further vacuum processing by DH and RH methods.

16. The influence of inert gas metal blowing on partial carbon oxide pressure formed during carbon oxidation is used while working out such a process as argon-oxygen decarburization (AOD-process). AOD method is widely used in stainless steels and other chromium-

bearing steel grades production. $(Cr_2O_3) + 3[C] = 2[Cr] + 3\{CO\}$ gas reaction equilibrium during carbon oxide partial pressure pCO decrease is shifted to the right and, as a result, good oxygen assimilation is provided. During blowing mixture composition is changed, decreasing oxygen consumption and increasing argon consumption. Thus, alloys with very low carbon content are produced without noticable chromium losses.

17. Various units constructions for AOD-process are given in fig.I7 . Comparative AOD-process simplicity and economy promoted its rapid application. By the beginning of 1982 a number of AOD-converters exceeded 100, including 24 - in casting shops[6]. Providing low carbon content level, concentration decrease of sulphur, oxygen, nitrogen and hydrogen dissolved in steel, AOD-process became known not only for stainless steel production but also for heat resistant alloys, tool and electrotechnical steels. In many cases carbon steels after refining by AOD method have the level of plasticity 1.5-2.0 times higher than the same types of steel during conventional heating within the whole trial temperature range. The largest AOD-converter (160 t capacity) operates in steelmaking shops at Armco Plant in Butler (USA), a large AOD-converter (65 t) operates in casting shops at George Fisher UD plant in Switzerland [6].

18. Intensive inert gas blowing as well as vacuum processing change essentially physical properties of the melt. In its turn in this case teeming may be done at temperatures 10 - 20°C lower than a metal, undergoing no processing of the type.

III. Powdered Materials Metal Blowing

1. Powdered materials metal blowing (or powdered materials injection into a metal) is aimed at providing maximum contact of blowing-in solid reagents with a metal, maximum speed of reagents interaction with a metal and high degree of blown reagents application.

This method also has such an advantage that a reagent is blown into a metal by a gas-carrier stream, which influences a metal to a certain extent. A gas-carrier may be oxidizer (e.g., oxygen or air); reducing agent (e.g., natural gas), neutral gas (e.g. argon). Slag mixtures and also metals or metal alloys are used as blown reagents.

2. Materials injection method may be used for volatite reagents introduction (calcium, magnesium) into a metal (in a neutral or reducing gas stream) or elements introduction, which pairs have high toxicity (lead, selenium, tellurium). Among the existing variety of metal processing methods with powdered materials a method of strong deoxidizers and desulphurisers injection into a metal in a ladle got wider application.

3. The essence of the technology lies in various mixtures injection in an inert gas stream into a metal in a ladle (covered with a lid or without a lid through an additional "stopper" at the side, at the bottom, etc.) Powders of different composition are used for injection: silicocalcium, CaSi + CaO + CaF_2 mixture , CaO + CaF_2 mixture, Mg + CaO + CaF_2 mixture, silicocalciummagnesium alloy in a mixture with lime, Ca + CaF_2 + Al mixture, etc. Depending on the purposes, the technology may be used for desulphurization, carburization (during graphite injection), increasing of nitrogen content, alloying, deoxidizing etc. There is various equipment available for the operation, and the process variations are differently called.

4. In Sweeden the method was called "Injection Metallurgy", and the equipment for injection is to be indicated by SL (Fig.I8).Thus for example, Uddeholm Company applies a powder injection unit for steel desulphurization intended for hydraulic pipe production, desulphurization and deoxidation periods in electric arc furnaces are reduced. Desulphurization is done by injecting silicocalcium powder deep into the metal (61% Si, 32% Ca). Within 6 min of injection S content decreases from 0.020% to 0.008%, non-metallic inclusions content is also decreased. Metal fluidity considerably increases,

teeming conditions being improved.

5. Lining composition renders considerable influence on refining effectiveness. It was established that for steel desulphurisation and deoxidation basic lining should be used. Chamotte lining does not promote metal refining.

6. In West Germany the method of powdered reagents injection into a metal is called TH-process. The method is aimed at powdered alkaline-earth metal introduction by inert gas blowing stream into steel through a tuyuer into a ladle. The tuyuer is submerged very deep into steel [7]. Alkaline-earth metals are introduced as commercial Ca-Si alloys, Ca and Mg carbides in a granular form. Steel with extremely low inclusions content, uniformally distributed, of globular form, which are not deformed in a hot rolling process, is produced as a result of processing. Alkaline-earth metals introduction into the melt in a ladle with basic lining provides high melt deoxidation degree and creates favourable conditions for sulphur removal up to values 0.002%. Oxygen content is within the level 0.0006 - 0.0008%. The given method application enables to transfer the refining process completely into the ladle. In a number of cases there is no necessity to use vacuum processing. Alkaline-earth metals consumption makes up 0.97 kg Ca/t or 0.38 kg Mg/t of steel. There is available data that TH-method enabling to get 0.0002%S is of special interest to the shop using scrap.

7. In the USA, Canada and in some other countries a method of calcium-bearing materials injection into a metal is called CAB-process. Liquid steel is tapped into the ladle, covered with a lid afterwards, through which the tuyuer for calcium injection (and sometimes magnesium) by argon stream blowing is introduced [8]. Calcium is evaporated and rising together with argon bubbles binds sulphur into sulphide CaS, assimilated with slag. The produced steel ingot, therefore, contains 0.010%S as solid spherical non-deformed during rolling non-metallic inclusions 10 mkm in size, uniformally distributed along the ingot cross-section. In conventional steel risidual non-metallic inclusions 100 mkm in size have lower melting t^o and are strongly drawn in the direction of rolling. As a reagent, providing desulphurization and deoxidation, magnesium is used.

8. Thorough investigation of metal quality received during Ca and Mg injection into a metal, carried out at Buderns AG (W.Germany) Plant has shown that achieving S ≤ 0.004% concentration almost

complete steel isotropy is provided. To get sulphides of absolutely globular form and small size less than ≤ 0.003% S is required to be received. Desulphurization degree increases as far as the t° at which processing is done and calcium consumption is increased (up to 1.5 kg/t). Magnesium injection makes it possible to produce a metal of higher purity than during calcium injection, it being connected with better removal of the formed oxide inclusions. The difference in deoxidizing calcium effect, injected as CaC_2 and as silicocalcium is not observed.

9.The powder injection into the metal in a ladle method is also used to produce steel with a regulated nitrogen content and also alloying with silicon, nickel, molibdenum, tungsten. Thus, at Smedjebacken plant (Sweden) a new method of low sulphur nitrogen-bearing steel production was introduced for metal blowing in a ladle with mixtures containing calcium cyanamide $CaCN_2$.

Metal is tapped into a ladle lined with high alumina refractory. Cantiliver rotary crane lowers a tuyuer lined with melted high alumina lining material into the ladle. The depth of the submerged tuyuer 2.5 m. The injected mixture content (in %): $CaCN_2$ 55, CaO 33, C 12. Mixture density is 2.0 kg/gm^3. The gas carrier - N_2. During mixture injection besides nitrogen saturation such processes as carburisation, deoxidation and desulphurization take place. Blowing also influences both non-metallic inclusions content and form. Such a method of nitrogen introduction into a metal enables to examine nitrogen increment with a satisfactory accuracy depending on its quantity with the introduced calcium cyanamide. According to data [9] nitrogen assimilation when introduced as $CaCN_2$ makes up 75 - 100%.

10. Fludspar addition to calcium bearing materials (for better inclusions slagging) does not always give a desirable effects. For low carbon steels magnesium mixtures + fluospar and magnesium + calcium + fluospar injections turned out to be more effective. Mg+Ca mixture application enables to increase the total materials expenditure and to provide getting high purity metal. To prevent secondary oxidation steel, processed in such a way, could be cast in a neutral atmosphere (or under vacuum).

Processing with powders in a ladle while blowing without a lid leads sometimes to a certain nitrogen content increase in a metal.

11. Experience has shown that calcium alloys injecting combined with slag processing and argon blowing decreases S content to

0.001% and leads to spheric form CaAl inclusions formation [IO].

During the injection process calcium interacts not only with sulphur but both with oxygen and oxides. The result of these reactions may be subdivided into 3 states, depending on calcium quantity, introduced into a metal. In the first stage (up to 1.5 kg/t CaC_2) though desulphurization goes in proportion to the introduced calcium quantity, maximum values are not reached. Besides, MnS inclusions presence is observed. On the other hand, calcium interacts with Al_2O_3 inclusions, being formed during Al metal deoxidation process before powder injection. At this stage pure Al_2O_3 inclusions in steel quickly disappear and transfer into mCaO x n Al_2O_3 inclusion types. These inclusions are distributed along the ingot cross-section and don't form accumulations. By the end of the stage m/n proportion reaches value 2 and the inclusions are called 12 CaO - 7 Al_2O_3 type inclusions. Calcium content in liquid steel don't change and remain at 0.003% level.

At the second stage (up to 2.5 kg/t CaC_2) desulphurization continues but its speed decreases abruptly. Sulphur content in liquid steel decreases up to 0.003%. MnS inclusions rarely occur in an ingot. First stage inclusions 12 CaO - 7 Al_2O_3 type almost disappear and Ca (O,S) type inclusions are formed. These inclusions are very small in size and quantity. Calcium content in metal increases and reaches 0.005%. If CaC_2 is continued to be injected, the third stage with CaC_2 2,4 kg/t consumption starts. It is characterised by practically constant sulphur content in a metal. Calcium content in liquid steel constantly increases. Ca (O,S) type inclusions quantity in a billet increases in proportion to the introduced calcium quantity.

12. Calcium renders positive influence not only as desulphurizer and deoxidizer but also as a reagent, affecting the speed of inclusions removal. It is explained by the fact that calcium presence promotes alumina inclusions shift into liquid calcium aluminates, for different steel grades calcium changes alumina accumulations over liquid aluminates, if calcium quantity is 3 times more than the total oxygen content in bath. This process in its turn promotes acceleration of inclusions removal from a metal.

13. Secondary metal oxidation processed in a ladle decreases processing effectiveness considerably and decreases the stability of the achieved quality indices. Moreover, it is stated that such surface-active impurities, both oxygen and sulphur content decrease

in metal results in noticable nitrogen content increase in metal, when contacted with air. The addition of fluospar into the injected mixture can prevent nitrogen concentration increase.

14. Besides the injection method strong deoxidizers or deoxidising mixtures (as a powder) introduction in the metal has got wide application. Deoxidisers and deoxidizing mixtures are placed into a steel shell as a wire. This method is called Wire-feeder-process. In case of aluminium application an aluminium wire can be used. The wire may be introduced both into a ladle and into the mould (during continuous casting) or directly into the ingot mould. Special equipment [II] designed for wire application of square, triangle, multifaced and round cross section with 3 - 20 mm diameter and automatic control of wire introduction speed are used for this method application.

15. In Japan Hitachi Cables Ltd company produces 50-100 kg wire coils, called Ferrokal. The wire core consists of calcium or Ca + Al, the protective housing content: 0.10% C, 0.25-0.45% Mn, the surface is protected with special coating from atmospheric effects Wire diameter 4.6 - 7.0 mm. Protective housing thickness 0.2 mm. Ca/Al proportion changes from 10 : 0 to 10 : 10 [I2].

16. The other new aluminium introduction methods into steel are the processes first applied by (US Steel Corp., USA) MA-RK processes. These are processes of producing completely deoxidized and partly deoxidized (semikilled) steel by means of liquid aluminium. The equipment for the process includes a gas furnace for aluminium melting, pumps for liquid aluminium introduction into a metal, into ingot mould, an appropriate branch pipe and control devices. Al consumption in MA-RK method is 0.75 - 1.0 kg/t, in MA-RS method is two times less. Applying MA-RS method the yield from an ingot to slab makes up 86-88%, higher than in conventional technology (82-84%). As Al is introduced in a liquid state, it practically dissolves immidiately and uniformly is distributed along the whole ingot cross-section, as a result its losses during secondary oxidation and non-metallic inclusions quantity in metal are decreased.

IV. Combined Secondary Steelmaking Methods

1. The main drawbacks of some metal processing methods are:
- the necessity to overheat liquid metal in a melting unit to compensate the metal t° fall during processing in a ladle;
- limited interaction on a metal (only desulphurization or only degassing etc.)

The best interaction results in metal quality are achieved while using combined methods. However, it is necessary to complicate units design and to use a more sophisticated equipment for their implementation.

2. Ladle metal processing may be produced by combined methods:
- in a conventional steelteeming ladle with chamotte lining and with a vertical stopper;
- in a steelteeming ladle with high refractory materials lining and sliding gate type stopper;
- in a steelteeming ladle equipped with a lid;
- in a steelteeming ladle equipped for bottom gas blowing or gas-powder mixture injection through the fixed devices in the bottom;
- in a unit-ladle with a lid (arc) through which electrodes are submerged, heating the metal during processing;
- in a converter type unit with oxygen, argon, vapour etc. metal blowing.

3. The example of secondary steelmaking methods, enabling to heat a metal during processing ASEA-SKF process, which appeared in Sweeden in 1964 and a simpler Finkl-process worked out later in the USA. The first method is a vacuum processing method where besides induction stirring the metal is top heated with electric arcs. Metal may be hold in vacuum for a long time period. That provides high refining degree from detrimental impurities. In some cases a certain slagforming quantity is also added under metal inductor stirring. Such a method is sophisticated and expensive, but high metal quality approves expenditures. Due to that factor the given method has got wide application, fig. I9.

4. In Finkl-process stirring is done by an easier method - argon blowing. Besides, a ladle is in stationary position in Finkl-process, that makes metal processing while producing it in large quantities easier. There is quite a number of such a type of process variations [I3-I5].

5. LF-process worked out in Japan has got quite wide application. The process in such a state as it has been suggested includes

mixing with argon metal blowing in a ladle, arc heating and metal processing with synthetic slag, being argon stirred. The capacity of units-ladles in different plants ranges from 30 to 150 t. The process provides not only getting the desirable chemical composition and metal t^o, but also non-metallic inclusions quantity decrease as a result of sulphur and oxygen removal that has led to considerable mechanical properties improvement. Such a unit may be installed in any steelmelting shop.

6. In many cases the technology is organized in such a way that metal heating should be avoided in ladle processing. Aliguippa, Jones and Laughin Steel (USA) plant experience may serve an example. The following changes have been introduced into the technology to increase metal purity and surface quality: tapping metal t^o increase by 10^oC, chamotte ladle lining substitution for high alumina ($\geqslant 70\% Al_2O_3$); porous bottom tuyuers application instead of submerged (chamotte) for flowing purposes; slag mixture addition (CaO/CaF_2 = 3 : 1) 9 kg/t in quantity; intensive argon metal blowing through bottom tuyuers during tapping and less intensive within 3-5 min after tapping is over; metal casting into ingot moulds having thoroughly cleaned internal surface without lubrication; protection from secondary oxidation by material gas. Such a technology was called "pure steel production technology". The portion of the first grade production has grown from 20 to 80% when applying that technology.

7. Stainless steel production in combination with oxygen converter and vacuum processing method elaboration may serve an example; this method was called LD-RHOB-process as it combines LD-converter application, ladle circulation degassing (RH-process) and oxygen blowing (OB-process).

The process includes the following stages (fig. 20):

- ladle iron desulphurization in ladles by mixing the supplied onto desulphurizer iron surface with a special stirring device;
- iron blowing in oxygen converter (dephosphorization and decarburization);
- metal tapping from converter, its separation from slag during tapping and metal reteeming into the converter, the metal has the content: $\leqslant$0.10% C, 0.010% P and 0.010% S; metal temperature 1690-1700°C (stage a);
- high carbon ferrochromium addition and its dissolution in a metal during secondary oxygen blowing (melt composition becomes the

following: 0.50 - 0.80% C, 0.020 - 0.035 % P, $\leqslant$ 0.009% S and $\geqslant$ 16.5% Cr; melt t° 1740-1770°C (stage b);
- metal tapping into a ladle and RH vacuumation with simultaneous supply oxygen into chamber for decarburisation. After that operation metal content becomes: 0.04 - 0.06% C, 0.020 - 0.035% P, 0.009% S, 16.30 - 16.50% Cr, metal t° 1590°C (stage c).

The new process advantages are:
- high productivity;
- low chromium losses;
- easily controllable chemical metal composition and low detrimental impurities concentration;
- possibility to get quite low carbon and nitrogen concentration in the produced steel.

8. VAD-process may be an example of the combined process with vacuum processing, argon blowing and synthetic slag mixtures injection. The unit consists of the chamber, mounted on the self-movable platform, and a vacuum pipeline in s stationary arc (but not in a chamber).

The performed operation technology is the following:
- ladle location in VAD-chamber and argon blowing (without vacuum)
- metal sample selection for chemical analysis and chamber with ladle shifting to the slag (with FeO and P_2O_5 content) pumping-off sector; chamber with a ladle position change to VAD-unit, arc covering and vacuum processing with heating (or without it). Heating is done with electrodes submerged through the arc;
- CaO, CaF_2 and new slag Al are introduced by adding simultaneously with vacuum processing and argon blowing is continued;
- 20-25 min after such a processing chemical composition and t° (electric heating) correction is done in vacuum;
- after required results have been achieved vacuum processing is ceased and a chamber with a ladle are transported to the teeming site.

When it is necessary to get S $\leqslant$ 0.004% CaC_2 or silicocalcium is additionally injected into the metal. The produced steel may be intended for large capacities for fluidized gas, active pipelines, boring offshore sites, nuclear power stations, special units for chemical and oil chemical industry etc production.

9. There occur some difficulties in phosphorus removal in ladle metallurgy methods. However, this problem can be solved of metal reteeming method is used. The technology applied at one of the

Sumitomo (Japan) Company plants may be mentioned as an example. The ladle with non-deoxidized converter steel is placed into VAD-chamber. To decrease dephosphorising slag capacity CaO, CaF_2 and scale respectively 15; 3 and 3 kg/t of steel are introduced, making CaO content in slag up to 60% and Fe_{total} to 12%. Argon is bottom blown into the ladle; 20 min later phosphorus content decreases to 0.005% (at metal temperature 1630°C), slag is pumped off and usual operation is performed [I6].

10. A more sophisticated technology is adopted at Nippon Kokan Company Plant (Japan) where metal is poured into the ladle and 12-20 kg/t of lime and 2-15 kg/t CaF_2 is added, then steel is heated in VAD-unit and dephosphorized in VAD-unit, then dephosphorising slag is poured out and a new 40-50 % CaO composition is poured; 35-55% (FeO + MnO), produced in a special furnace. CaF_2 is also added and again is argon and oxygen blown in VAD-units. Such a technology enables to get 0.0005% P in some cases and conventionally 0.0011 - 0.0015% P [I7].

11. The technology of producting "extrapure" metal for special purposes was called LFR. This process has been widely used in Japan [I8]. The technology description, adopted by electric steelmaking shop at Muroran Co Steel Works, Japan is given below as an example. The equipment of LFR unit makes it possible to perform practically all technological operations on super deep removal of such impurities as oxygen, nitrogen, hydrogen, carbon, sodium. The arc heating stand and two ladle vacuum processing stands are included into a unit set.

Ladle processing effectiveness is greatly increased by argon metal blowing through porous stoppers.

d) Field of application

1. Modern steel production technology in converters and electric steelmaking furnaces require steel refining in ladle methods to be applied. It ensures steelmaking units production increase, energy and material resources consumption decrease, steel quality increase. Without these methods application continuous steel casting development is impossible.

2. Secondary steelmaking methods application is one of the main technological approaches in metal quality improvement in modern steelmaking shops. Ladle steel processing has become an indispensible part of a technological process designated for high quality steel production. Besides a number of technological operations such as degassing, deoxidation, bringing to perfection according to chemical composition and temperature is carried out by ladle processing. That brings to the required conditions to produce a wide range of steel grades with a limited alloying additions content, it being extremely important to ensure stable properties of metal production.

3. At present a wide range of secondary steelmaking methods are available in metallurgy. Methods or their combinations choice to solve certain problems is determined by their purposes and depends on local conditions. The principle secondary steelmaking methods possibilities are given in Table .

4. It is shown below what problems should be solved by ladle processing due to steel purpose and grade.

Purpose, steel grade	General processing aim	General influence on steel quality
plate	Hydrogen removal, oxide inclusions amount decrease	purity improvement, thermal processing simplification, mechanical properties improvement
sheet	Decarburisation, oxide inclusions amount decrease	Surface defects decrease, plasticity increase
Electrotechnical sheet	Decarburisation to carbon content less than 0,01%, deoxidation, alloying absorbtion increase	annealing duration decrease, magnetic properties improvement

For tubes	Oxide inclusions amount decrease	Macrodefects quantity decrease
For wire	the same	Plasticity increase
Rail	Hydrogen removal	Thermal processing simplification
Structural carbon	Oxide inclusions quantity decrease	Plasticity increase, macrodefects quantity decrease
Structural low alloy	Deoxidation, non-metallic inclusions decrease, hydrogen removal	Macrodefects quantity decrease, grain sizes regulation, frequency increase when ultrasonic control, stabilization
Bearing	Oxide inclusions quantity decrease	Length of service increase at oscillation, macrodefects quantity decrease
Spring	Oxide inclusions quantity decrease, hydrogen removal	Wear resistance increase
Tool	the same	the same
Corrosion resistant	Decarburization, chromium absorbtion increase	Surface defects quantity decrease
For castings and packings	Hydrogen removal	Blows formation prevention

Table I

Technological operations industrial application and ladle processing methods for solving definite metallurgical problems ("+"- the problem is solved;"-" - the problem is not solved; "0" - the problem is partly solved).

Technological operations and ladle metallurgy methods	steel processing methods	homogenization	chemical composition correction due to alloying additions	deoxidation (without Al)	metal purity increase	inclusions transformation
1	2	3	4	5	6	7
Inert gas metal blowing for stirring:						
blowing proper for stirring		+	+	–	0	0
having refines slag on metal	SAB MHE CAS	+	+	0	0	0
Processing by injection method (when refined slag is present on metal)	SL, TH	+	+	+	+	+
Calcium wire introduction	SCAT	+	+	+	0	+
Steel heating (ladle-furnace, where metal heating is done when refined slag is present or in inert gas presence in atmosphere)	LF, AP	+	+	+	+	0
Vacuum processing:						
in stream	BV	+	0	+	0	–
in ladle arranged in a vacuum chamber:						
degassing proper		+	+	+	0	–
degassing with heating when refined slag is present on metal	VAD ASEA-SKF	+	+	+	+	0
metal degassing with oxygen blowing	OD	+	+	+	+	–
Portional:						
degassing proper	DH, RH	+	+	+	+	–
degassing with oxygen metal blowing	RH-OB RH-O	+	+	+	+	–

content C	S	N	decr N	heating and t° equalizing	melting unit production increase	limitation compensation of furnace electric power	large quantities of alloying additions	P content decrease	continuous casting, "heat per heat"	production programme expansion	low C-Cr steel production
-	-	-	-	-	-	-	-	-	+	0	-
-	+	-	-	-	-	-	-	-	+	0	-
-	+	-	-	-	+	-	-	-	+	+	-
-	0	-	-	-	-	-	-	-	0	0	-
-	+	-	-	+	+	+	+	+	+	+	-
+	-	+	0	-	-	-	-	-	-	0	-
+	-	+	0	-	-	-	-	-	0	0	-
+	+	+	0	+	+	+	+	+	+	+	-
+	-	+	0	-	+	-	-	-	-	+	+
+	-	+	0	-	+	-	-	-	0	+	-
+	-	+	0	-	+	-	0	-	-	+	+

Part B.

Part B

Continuous Steel Casting

a) short historic development

1. Method of continuous steel casting is one of the considerable achievements in metallurgy of steel. Continuous casting installations application makes it possible to receive all advantages typical for continuous units: high productivity, yield and quality production increase, production expenditure decrease, raw materials and energy reserves economy. Therefore, labour conditions are improved,air and water basins pollution is reduced and conditions for complete mechanization and automatization of steel casting are created.

2. Modern continuous casting unit represents a sophisticated technological, mechanical, hydraulic and electronic equipment complex, including: a steelmelting stand
- tundish;
- mould;
- oscillation mould mechanism;
- supporting elements and secondary cooling zone units;
- ingot transportation unit;
- a dummy-bar with the mechanism for its introduction and cleaning-up;
- unit for continuous casting ingot shearing into equal length;
- equipment for water supply into the mould and secondary cooling zone;
- electric equipment;
- control and automatization devices.

3. Continuous steel casting units are the installations which provide a finished billet or slab production from liquid steel. These ingots directly go to the rolling mills without blooming and slabing. As shown on fig. 21 liquid steel from steelmelting ladle go to a tundish and then to a watercooled mould. The solid steel shell is formed in the mould and according to its form and section corresponds to a finished ingot. Partially a solidified ingot (with liquid core) by means of transport system -pulling stand-goes to a secondary cooling zone where complete solidification occurs. The solidified ingot is sheared into equal length pieces and by means of the movable table or other transport means the finished ingots are directed into the rolling shop or storage department.

4. Before pouring a dummy-bar with the section of the cast

ingot is introduced into the lower part of the mould. A dummy-bar forms a movable bottom in the mould and provides cohesion with the solidifying ingot. In the course of metal filling the mould and the strong metal cohesion with the dummy-bar a drawing unit starts operating and a partially solidified metal (a solid shell with a liquid core) is drawn into a secondary cooling zone.

5. To form a strong shell mould walls are made of the material possessing high thermal conductivity (e.g. copper) and are intensively water cooled. To reduce friction between the solidified metal shell and the mould walls solid or liquid lubrication such as oils, carbonhydrites or exothermal and thermoisolating mixtures are added onto the metal surface. In addition, to prevent the break of the shell the mould makes oscilated motion by means of special mechanisms.

6. From the mould the solidified ingot partially occurs in the secondary cooling zone. It consists of supporting elements and units providing ingot cooling. Supporting elements must prevent ingot shell deformation and its breakthrough under ferrostatic pressure action. Cooling is usually carried out by water spraying the ingot surface. Water expenditure depends on ingot drawing speed and casting steel grade.

7. Thus, the whole heat is produced in a single continuous ingot. At some plants the technology "melt per melt" is performed through the same tundish unit. According such a technology up to 10 melts one by one is poured.

8. As any continuous process from organizational point of view continuous casting is extremely simpler and economically more advantageous than periodical casting into ingots. It follows from where the two casting processes are compared according to operation and time. The main advantage of the continuous casting are as follows:

- a much higher yield at the expense of top and bottom parts of the ingot,
- absence of ingot mold preparation shop,
- strip department absence,
- absence of equipment for ingot preheating before blooming or slabing,
- blooming/slabing shop absence,
- considerable capital investment reduction,
- the required area reduction as compared with the area necessary for periodical casting,

- manpower requirements reduction, labour conditions improvement, labour productivity increase,
- a higher quality ingot achievement,
- possibility to cast ingots according to the section approaching the finished product section,
- continuous casting process can be easily automatically controlled.

9. These advantages have shown that continuous casting to a great extent has already seized the sphere of slab production for widestrip and plate mills and it is widely used for billets and bars. It has got exclusive rights at mini steelplants with the capacity up to 1 mln.t., which operate according to the technology of electric arc furnace - continuous casting - small capacity rolling mill.

10. Lately a constant growth of the amount of steel produced by continuous casting have been observed in the world. The higher rates of growth of continuous steel casting and capital investments are observed in Italy and Japan. First in FRG and France the rates of growth were not high but then raised to the level of Italy and Japan. And still USA, Canada and especially USSR fail to keep pace with them. The reason lies in the limited number of new Works where CCs could be immediately constructed. At the existing plants the fact when clogging and billet mills are turned out of operation or substituted for CCs is not always justified.

11. According to the International Iron and Steel Institute data the overall number of installations in the world is approaching 1200: the total number of installations suitable for slab and bloom casting makes up nearly 300, for blooms and round billets casting - about 250, for small sections about 650. Within a period since 1980 10 slab and 5 bloom CC have been constructed and put into operation annually.

?) Classification of Continuous Casting Installations

1. At present a large number of various continuous casting installations have been put into operation. This depends on the requirements towards steel grades, ingot quality and installations capacity. The installations are classified according to a number of characteristics: ingot type, installation composition, mould movement character, technological axis location.

2. According to the ingot type the installations are classified as slabs, blooms and billets. The slab units have rectangular section with the side proportion more than 3-4. Ingots in the form of a round, a square or a rectangular with a small side proportion may be cast at bloom and billet stands.

3. According to the composition the installations are classified into one strand and multi strand units. The capacity increase is achieved by metal pouring from a steel ladle into several strands simultaneously. Usually sorted billets units have 4-8 strands, slab units two strands. Lately 4 strand slab units have been constructed.

4. Installations are classified into continuous and semicontinuous casting. At continuous casting units ingots are sheared into equal length pieces that enables to perform melts by means of "melt per melt" method. During semicontinuous casting the ingot length is made for construction characteristics which are selected to simplify and cheapen devices in certain production conditions. In this case, if necessary, ingot shearing is done outside the device.

5. According to the mould movement the following unit types may be distinguished:

- with oscillation motion. A definite period of time the mould moves together with the ingot or even takes the lead over it and then returns to its initial state. The main number of continuous steel casting installations refer to this type;
- with unmovable mould. Horizontal units refer to this type;
- with a mould moving at an ingot speed. That provides the ingot shell sliding absence in relation with the mould and thus, friction absence between them. That reduces the shell break probability at high casting speeds. Rotors, where casting speed is 2-3 times higher than at conventional units, refer to this type.

6. According to the technological axis location continuous cuting installations are classified into the units with the

constant axis curve up to the final ingot solidification and units with the variable technological axis at a solidification section, Fig. 22 .

7. The following units with constant technological axis curve refer to these installations:

- vertical and vertical with bending. Ingot bending is done after complete solidification to put a technological axis into a horizontal position. For the units like that casting speed and therefor their productivity is limited. As a result along with the casting speed growth the so-called metallurgical length increases (liquid phase depth). The increase of vertical units metallurgical lenth causes ferrostatic pressure growth of the liquid phase and load increase on back up elements of the secondary cooling zone. That results in a considerable increase of the equipment quantity, units height growth and, consequently, deap pits or high towers construction. The experience of vertical units operation has shown it is reasonable to use them at a metallurgical length up to 12-14 m;
- radial, having constant curve radius at metal solidification participation. In this case the metallurgical length having the same ferrostatic pressure increases and correspondingly the casting speed and units capacity increase;
- inclined-rectilinear or inclined-radial. Essential unit height decrease and, thus, ferrostatic pressure enables to reduce equipment mass to a large extent and therefore units cost;
- horisontal units. Their technological axis is located at 7-12° angle towards the horizon. The units have the same advantages as the inclined.

8. The units with a technological axis of the variable radius include:

- curvelinear units with radial mould. In this case the mould and the secondary cooling zone part has constant curvature, and another part - a variable one. In this part of secondary cooling soft straightening of the ingot with liquid core takes place. The units like that at the same vertical and radial height can have quite a large metallurgical length and thus, a higher productivity;
- curvelinear units with vertical mould. In these units after a small section of a secondary cooling zone the ingot bending starts. Ingot straightening may ocuur after complete solidification or with liquid core.

9. At present radial and curvelinear units have got advantageous application. In converter shops, as a rule, curvelinear units are installed, in electric steelmelting shops - radial unis. In the shops with little capacity horizontal units have got wide application.

c) Basic Equipment for Continuous Steel Casting and Their Technological Purpose

1. Steelcasting stands are an integral part of modern installation technological equipment. They provide metal supply in ladles to the unit, weighing and ladle setting in a required position, pouring process, ladle substitution at the speed enabling to make pouring by a "melt per melt" method. They also provide the units operation independent of the organization situations taking place in the shop. According to the construction and operation principle two types of stands - bridge and rotary. They all are considered to mount two ladles.

2. Bridge stands more along the working site providing ladle shifting from the reserved position into the operating one. At present stands like that are not installed. Stands like that are cumbersome, need big location sites and powerful supporting constructions. In general they exist in old shops.

3. Rotary stands are designed as supporting rotary towers, fixed at individual bases. They are equipped with the rotary mechanisms and a plate for ladles, fig.23. The stands like that provide steel pouring ladle transfer from the reserved position into a working one by rotating two plates round their common axis. At present there is a great variety of such units distinguished by arrangement schemes, construction methods of rotating mechanisms, elevating mechanisms and other elements.

4. From the steelteeming ladle the metal goes into a tundish. The tundish mission is pouring conditions stabilization. The investigators have shown lately that to improve metal quality tundish capacity should be increased. (it also facilitates serial pouring) As a result tundish capacity of modern installations has grown up to 40-70 t.

5. Due to the lining type and its preheating temperature before pouring tundishes are classified into 3 categories:
- conventional tundishes with the heating t^{o} 1100-1200^{o}C. As a rule their lining consists of 3 layers: thermal isolating, armature and operating;
- high temperature tundishes with the preheating t^{o} up to 1600^{o}C. The application of tundishes like that enables to decrease metal temperature during tapping from the melting unit at 50^{o}C;
- unheated, where thermal isolating plates are used as the operating layer of lining. Silica and a fiber materials make up the contents

of the plates possessing extremely low thermal conductivity and thermal capacity.

6. The stability of the continuous casting process is to a large extent determined by the operation of the dozing devices. Today the killed steel pouring is performed with the metal feed into the mould by means of submerged shrouds, Fig.24, operating in combination with the slagforming mixtures laid onto the metal meniscus surface. The general requirements to the shrouds material brought to thermal resistance, errosion resistance under slag and metal action, and sufficient strength at high temperature. One of the materials is amorphous quarts. Freaquently used shrouds are made of graphite,high alumina refractories have low thermal resistance.

7. The mould performs the functions of the primary refregirator and formbuilder, providing the desired form of the ingot cross-section. According to the operation principle it is a heat exchanger which main mission is to create necessary conditions for intensive convective heat exchange from a liquid metal. The obligatory condition for the mould operation is to provide a solid shell with the strength exceeding ferrostatic pressure of the coming metal from the mould and drawing forces. Mould may be block, built-up and tobular.

8. Block moulds are made of forged or cast copper blocks with the thickness up to 200 mm. Holes are drilled in the walls to let the cooling water go through. The produced copper block is fixed to increase strength in a steel shell, fig.25. The moulds like that cause wall deformation that negatively affects the ingot quality. Moreover, such moulds are expensive.

9. Tobular moulds are made of weldless copper pipes with the wall thickness 5-20 mm. The made tobules of the given cross-section profile are inserted and packed top-down in a steel shell. The cooling water is circulated in the space between the tobule and the shell. One of the variants of the tobular mould construction is shown on fig.26. Tobular moulds are widely used when billets, rods, hollow small section ingots are cast. They are quite cheap and enable to acheive fast pouring speed and are convenient in production and operation.

10. Built-up moulds are made of four separate copper plates. They may be thinwalled (5-20 mm) and thick walled (up to 100mm).

Assembled and tight together by bolts the plates form a construction with the copper working surface. Such moulds are used for rectangular sheets and large blooms casting as strong wall hardness enables to stand ferrostatic pressure considerably without deformation, fig 27.

11. The built-up moulds constructions enable to change quickly the width of the cast ingot. That is achieved by the narrow walls shift, inserted between the wide ones. Such a shift is performed by means of different mechanical or electromechanical drives. The existing constructions provide the mould profile changes without a continuous casting break.

12. The oscillation mechanism is designed for making conditions preventing liquid metal break-through from the mould. The ingot shell formed during pouring in the mould adheres to the walls in several points. Thus, the ingot stops moving towards the mould. Due to the efforts drawing the ingot the shell break may occur. If the new shell of sufficient strength fails to be formed at the break place, the liquid metal break-through will occur at the mould outlet. Therefore the conditions providing complete "healing" of the break place or it occurance prevention should be made.

13. To solve the raized problem it is necessary to stop the ingot shell movement towards the mould for a while. It is achieved by imparting reciprocated motion or oscillation to the mould. During movement when the mould is lowered at the ingot drawing speed the solidified layer width and its strength increases. The return to the initial position takes place at the speed 2-3 times higher the ingot drawing speed. However at such oscillation modes the shell breaks cannot be prevented completely.

14. The mould movement modes according to trapezium and sinusoid laws. In this case the movement speed changes: at a certain fraction of time the mould lowering speed increases, taking the lead over the drawing ingot speed. The so-called negative sliding occurs under the action of which the ingot shell undergoes contraction deformation. Thus, in case of the crust break occuring at the movement upwards, its broken edges are shifted and packed, healing being increased.

15. While selecting this or that movement mode the possibility to achieve maximum casting speed, its stability, characterized by the crust break absence and the ingot surface quality, are valued. Trapezium law providing casting stability is preferable from these

points of view. Sinusoid law enables to simplify a drive construction and increases an oscillation mechanism service life. However casting stability worsens.

16. It should be stated that reciprocated mould movement modes envisaging ingot forestalling, are characterized by the surface quality worsening. It can be seen in transverse folds formation on the ingot surface with the depth 0.1-0.5 mm. Fold formation occurs at the moment when the mould starts to be ahead of the ingot due to the movement speed. The formed thin crust contracts, a liquid metal is poured between the crust and the mould walls and the fold is formed. In the fold area aglomeration of non-metallic inclusions is formed, fig 28.

17. The folds character is determined by the adopted law of the mould oscillation. According to the trapezium law they are rougher than at sine law. And still in all cases there is surface quality dependence on the ingot drawing speed, frequency and mould oscillation amplitude. Thus to receive the required surface quality casting conditions optimization is necessary: oscillation frequencies and amplitudes depending on the drawing speed.

18. The cooling mode in a secondary cooling zone must provide a minimum complete solidification duration and the surface and internal defects absence. The following requirements are put to the secondary cooling system:

- monotonous ingot surface temperature decrease till the complete solidification;
- along the entire zone the surface temperature must be in the plastic deformation temperature region of the given steel;
- uniform temperature distribution along the ingot surface;
- the possibility of cooling intensity and secondary cooling zone length regulation depending on the steel grades, speed and liquid phase depth;
- system operation reliability within a long period of time.

19. Secondary cooling intensity is required to be maintained at the same level so that a complete solidification finished at the zone end at the given output, but the ingot surface temperature was not lower than 800°C. It should be taken into account that a considerable cooling intensity increase doesn't cause a noticeable solidification increase. That promotes only surface overcooling and different defects occurance. The secondary cooling mode depends on the steel grade, profile and ingot size, casting speed. Steels

possessing high strength and plasticity at temperatures close to solidification temperatures and undergoing no phase transformation during cooling are cooled with maximum intensity. Steels more complex in composition, possessing phase transformations are cooled less intensively.

20. The main technological function of the secondary cooling zone is creation of optimum conditions for complete continuous casting ingot solidification. The liquid phase duration at modern units makes up 15-40 m depending on the ingot section and casting speed. Cooling is accompained by:

- thermal tension depending on cooling conditions;
- stretch tension caused by friction and drawing forces;
- tension under ferrostatic pressure of the liquid melt;
- forces connected with the ingot bending and its further straightening.

The joint influence of these factors determines tension deformation cast ingot state and, as a result, its quality.

21. The secondary cooling zone construction must respond the following requirements:

- to provide a thorough ingot support at the mould outlet, where the shell thickness and its mechanical strength is minimum;
- to exclude distorted ingot forms under ferrostatic pressure action;
- to reduce stretch tension in an ingot shell. arising from the pulling forces action;
- to provide optimum heat removal and its regulation depending on drawing speed and cast steel grades;
- to provide a rapid substitution of the secondary cooling zone units.

22. Ingot drawing is done by means of rolls system. The rolls are pressed to the drawn ingot by means of hydraulic or spring mechanisms. Besides rolls system of ingot drawing there is also a "walking beams" system where drawing and cooling is done by means of flat moulds, alterately pressing the ingot coming from the mould and moving it downwards.

23. The length of the secondary cooling zone is determined by the drawing speed and the cast ingot section size. The solidification process must be finished by the movement of ingot shearing for curvelinear units, by the moment of its straightening for

radial and for vertical and horizontal units by the moment of coming into the pulling stand.

24. There are two cooling methods in a secondary cooling zone: water and mist. During water cooling water spraying is done by means of special "mechanical" sprayers. In this case water supplied at 0.25-0.35 MPa pressure passes through the nozzle of a certain configuration. At the expense of pressure changes it is thus devided into the drops of 0.2-1.0 mm size and as a flame of a flat , oval or round form it goes onto the cooled surface. However, the liquid density along such a flame section varies and is accompanied by cooling inhomogeneity. As a result ingot zones located alone the flame axis are overcooled. It may cayse thermal cracks formation.

25. Mist cooling does not have such drawbacks. It allows to achieve a soft and regulated cooling according to the required mode for the given steel grades and casting speeds. At present there is a great number of mist cooling. (Fig. 29) They include:

- mist mixture formation in special separately located mixers with the further mixture transportation to the ingot;
- mist mixture formation directly before its supply onto the ingot by a separate water and air supply;
- mist mixture is formed directly before the sprayer.

Each of the methods have its advantages and drawbacks. The latter is likely to be a more perspective irrespective of its relative complexity: it is more reliable in operation and provides practically any cooling intensity.

26. One of the main technological units of any continuous steel casting installation is the unit for ingot shearing into equal length pieces. Such a unit is installed at the end of the technological line at its horizontal (vertical) sector. The ingot t° in that place constitutes about 900°C that limitates a number of shearing methods. Taking into account that in all cases ingot shearing must be produced without its movement stops, all shearing devices are provided with the certain transportation mechanisms. Gas-oxygen cutting, hydraulic shears and impulsive cutting are usually applied for shearing.

27. Gas cutting is distinguished by a relative simplicity and reliability. Usually acetylene or a propane-butane mixture is used as technological gases. Two cutting torches are usually used on slab units and on bloom units - one cutting-out knife. In spite of

its wide application gas cutting results in 1-2% decrease of the yield, requires great technological gases expenditure, scale removal systems, pollutes the environment and occupies a rather large area.

28. Metal shearing with hydraulic shears doesn't have wastes and doesn't pollute the environment. A high shearing speed enables to locate the equipment compact and that to a large extent reduces a total area occupied by the shearing sector and reduces a technological unit line. Besides this method application is limited by a large equipment body, its cost and considerable operational expenditures. Moreover, the equipment complexity and hard operation conditions decrease its operational reliability degree. That's why the hydraulic shears is more reasonable while casting expensive complex alloying steel grades and alloys.

29. Impulsive cutting is based on the blast energy application principle causing simultaneous two cutting-out knives movement, directed one towards the other. Natural gas mixed with air is used, as a blasting agent. The impulse shearing devices are characterised by wastless metal shearing, device compactness, high shearing speed, small mass and relatively inexpensive in operation. Their large disadvantage is a high noise level, vibration and pollution. More often they are used on multistrand sorting device casting small ingots sections.

d) Specific characteristics of horizontal CC

1. In the whole, horizontal CCs consist of the same elements as other units types, but there are some principal distinctions that make a technological axis important as far as general arrangement and construction of certain assemblies is concerned, Fig. 30 . Thus, a tundish is replaced by a special metal receiver, which in its turn is connected directly with the mould. The mould arranged horizontally makes the mould less cumbersome, as its construction operates in conditions of relatively low and constant in value ferrostatic pressure. The same reason makes the construction of the whole secondary cooling zone supporting system simpler. At the same time in spite of a lot of incontestable horizontal units advantages they possess a number of serious constructive problems, determining both their operating ability and cast metal quality. The main problems are: resistance of the metal receiver assembly connection with the mould and ingot drawing regime selection. The attempts to solve this problem today have led to the production of a sufficient number of various CCs types, that can be grouped according to ingot drawing method:

- periodical drawing from the motionless mould;
- constant drawing of two billets in opposite directions of the oscillated mould;
- constant drawing from the mould oscillated independently from the metal receiver or in combination when connected rigidly to each other;
- motionless billet formation by means of the mould, periodically going along the axis, building up the ingot face.

All these unit types have their advantages and drawbacks which determine their application to a larger or less extent. At present, the first and the second types have got wider application.

2. Metal receiver provide stable metal supply into the mould irrespective of its level in it and in a steelteeming ladle, nonmetallic inclusions floating-up, melt protection from secondary oxidation, metal distribution along the mould if there are several strands available. Metal receivers may be applied by various unit for metal heating with inductors, inert gases metal processing, sliding gates for metal consumption regulation, etc. The principal metal receiver difference from a tundish is protective steelteeming shrouds and dozimeter units as stoppers or sliding gates absence

as metal enters the mould which is closely linked with a metal receiver by a special metal pipe.

3. Metal receiver assembly connection with a mould is the main horizontal CC elements as it determines not only its operating ability but it influences the selection of an ingot drawing method to a certain extent, thus, the whole unit construction. The assembly is like a pipe made of a refractory material with connecting a metal receiver with the mould. The connection of the mould copper shell must be dense enough to exclude metal penetration and solidification in the joint between them.

4. The above mentioned pipe operates in complicated conditions. It is subjected to abrupt temperature variations as a result of periodical replacement of the solidified crust by liquid melt during drawing cycles. Besides, a very dense metal freezing often occurs at the metal surface. During drawinf the crust used to separate with the refractory.

5. Periodical ingot drawing from immovable mould has got wide application. It solves the problem of connection pipe resistance, as the mould remains immovable when rigidly connected with the metal wire.

6. Positive results have been reached in traditional application of reciprocating mould motion. In this case a metal doesn't go to the mould face but into the middle through the hole in the upper wall. Such a method makes it possible to draw simultaneously two ingots in opposite directions.

7. Good results have been reached in ingot drawing from the mould, rigidly connected with a metal receiver and making jointly reciprocating motion according to sine law. However, such a scheme realization is possible when small metal receiver capacities are available.

8. In a number of constructions continuously cast billet is drawn in opposite directions. A round billet 120 mm in diameter or blooms with 150x150 cross-section at a drawing speed 1 m/min may be produced at the unit. As there is no linking assembly between a tundish and a mould, large section billets may be cast at such a unit.

9. Moulds of the horizontal units operate in conditions distinct from other CC types moulds operations. Primarily it concerns increased ferrostatic pressure in the zone of the initial crust formation. The increased ferrostatic pressure promotes contact inten-

sification of the solidifying crust with the mould walls at the contact place of metal supply. Thus heat is abstracted here much intensively than in vertical and curve lined moulds.

10. According to the construction horizontal moulds as a rule, are of shell typen as at present cast billet cross-sections have relatively small cross-sections. Further on, it will be possible to use assembly constructions when transversal ingot sizes are increased.

11. Combined mould constructions where shell length doesn't exceed 100-250 mm and the remained part is made of either graphite or spring-loaded copper stack coolers have got wide applications. When round ingots are cast, copper-graphite moulds where one end of the graphite pipe is in the metal receiver and the other is in the watercooling mould, good results have been received. In this case such a construction operates as pipe for metal but to protect a graphite pipe surface from wear it should be coated with protective layers.

12. Secondary cooling zone construction of CC is much simpler than in other units types as it generally performes only cooling functions. Relatively low and constant ferrostatic pressure level in a secondary cooling zone as compared with other CC types makes it possible to refuse complex supporting systems, substituting them by conventional rolls for ingot shift. Cooling methods and intensity are determined by both sizes and sections of the cast ingot cross-sections, and metal grades. When small cross-sections billets are cast air cooling may be only used, with large cross-sections - water or mist cooling.

13. At present as it has been already mentioned work on constructing and introducing new horizontal CCs types are still in progress all over the world. Low units type and little equipment mass make them inaccessible in price as compared with other units types. Thus, metal capacity coefficient ratio of equipment mass in kg to annual production in tonns for horizontal units makes up 3-4, for curve-lined 5-6, for vertical 7-12. Liquid metal height decrease and ferrostatic pressure decrease for an ingot crust gives and opportunity to exclude billet defects such as different internal cracks, which may occur in a secondary cooling zone of the curve-lined units, secondary oxidation processes development decreases abruptly.

14. Low height horizontal CCs enables to construct such units in steelmaking shops buildings without high constructions and pits

without special cranes and hoists. It decreases capital investments per unit by 36 - 44% and specific capital investments in continuous casting department by 12-20% [19].

c) A layout of a steelmaking shop with continuous casting units

1. It is difficult to draw the main principles of CC location in the shops where a portion of steel is cast into ingot molds and continuous casting is used simultaneously. They may be located in the end of the bays where casting into ingot molds is done both perpendicular and parallel to their axes; in the bay adjusted to the casting one, Fig. 3I ; separate buildings, etc. During steel casting only by continuous methods a special department, which may be either located in a separate building or may be included into the main shop building, can be introduced.

2. While designing continuous casting departments, the creation of the optimum cargo streams system, providing minimum department capacity and area, and the necessity to locate not only CC but the following equipment and sections should be taken into consideration
- methods and equipment for supplying ladles with liquid steel to CC;
- equipment for a quick steelteeming ladles and tundishes change;
- maintenance section and tundishes preparation;
- secondary metallurgy equipment for steel refining;
- systems for cast billets transportation to the storehouses and to the rolling shop;
- equipment maintenance and storage sections.

3. At present, two systems of equipment location in the shop are used: linear and block. The block system has got application generally in converter shops with high output. CCs are usually located in a linear system in the main building bays; where electrosteelmaking shops have considerably low output. That decreases capital outlays and provides rational labour organization, fig 32,33.

4. The shop plan with 1.0-1.2 mln ton annual output is shown as an example in Fig. 31 . The distinguishing features of the shop are a special bay for granular materials supply, steel casting simulteneously into ingot molds and at CC, scrap charging into discharge bastets directly from the van.

The shop has the following bays:
- charging (A)
- granular materials (B)
- furnace (C)
- teeming (D) with the ladle maintenance department (1)
- shortened bay (D) where one CC (12) is located.

Electric furnaces (4) with transformers (5) are located at the border of furnace and teeming bays; at the end of the furnace bay in sections ares maitenance is done.

5. In this shop steel scrap is transported in vans along the railways (8) and is charged on stands (9) into discharge baskets which are further supplied along railways (11) into the furnace bay. Granular materials go into bunkers (10) and then in ingot molds directly into the furnace. A ladle with steel is transported from electric furnaces to a vacuumator (13) and to the teeming sites (2) or it is arranged on the teeming ladle car that transported a ladle into the CC bay. For maintenance steelteeming ladles are transported to the department (1).

6. Shop department layout where casting is done only continuously is shown as an example in fig.35 . The department is connected with the main building by teeming ladle car ways (1). The bay I is designed for ladle processing. A vacuumator (2) and argon metal blowing unit (3) is located there. The bay II is for steel distribution along CC. In the bay III CCs with rotating stands (4) are located in one line. The bay IV is designed for billet shearing; the bay V - for their transportation.

f) Automatic Process Control

1. The most important elements of modern continuous steel casting units are automatic control systems. Computer devices serve a safe measure for stable technological equipment work.

2. Computer devices in the CC control systems perform still more complicated functions that may be generally concluded in the following:
- nominal casting parameters data calculation and printing for the personnel;
- technological information collection, processing and its presentation to the personnel for making control solutions;
- control and signalization of the main technological casting parameters deviations from the standard;
- real time recommendations calculation and printing for maintaining contact schedule, providing stable joint operation of steel making and continuous casting department;
- information accumulation of casting modes for further analysis and technology improvement;
- casting summary documents certification and printing;
- secondary cooling mode control;
- printing recommendations for ingot shearing.

3. At present CC automatization upholds the following general casting process regulation and control systems:
- tundish and mould level stabilisation control;
- ingot cooling mode control in the mould and in a secondary cooling system;
- ingot shearing into standard length process control;
- final casting phase control.

4. CC automatization flow-chart is shown in fig.36.

5. Two general metal level regulation methods in the mould have got wide application:
- metal expenditure change which goes into the mould at a constant drawing speed. This method is used while casting with a stopper or with a sliding gate;
- a drawing speed change at constant metal expenditure which goes into the mould. This method is used while casting without a stopper through the submerged shrouds.

6. Radioisotope sensor and halogen meter are often used as a metal level detector. The executive mechanism changes the stopper position in the first case[20]. In the second changing the billet drawing speed. Automatization enables to keep the metal level stability in the mould within ± 5 mm from the required one.

7. The systems of secondary cooling mode automatic regulation solve the problem of optimum distribution of the cooling water expenditures along the unit technological axis, depending on the casting speed. Computer systems application enable to automatise completely the CC secondary cooling system. The experience has shown that computer application ensures to keep billet surface temperature accuracy within 40°C.

8. At present there is no opportunity to give certain recommendations on any control and management means and methods for continuous steel casting in definite conditions. Practically every company works out and recommends its control and management methods. Therefore, only some examples of solving this problem are given below.

9. Automatic control system with wide computer application for curve line CC type, 2-strand for slabs and 4-strand for blooms, andstrip hot rolling mill heating furnaces at Sin Nippon Satatsu[2I]. System functions are traditional:

- billet casting speed regulation;
- secondary cooling programme provision;
- ingot standard length calculation;
- providing billet heating regime in the furnace and data collection due to the main production indices.

Central computer performs general production control and is linked with separate production sectors computers, which receive commands according to continuous casting schedule and send current operation data of this or that equipment groups to the central computer. Communication channels between separate sectors computers are used for technological operations coordination.

One processor controls CC and heating furnace operation, the other - circulation steel degassing system operation, fig.37 Any of the two processors may serve two sectors at a time. At the upper level a computer controlling CC operation is connected with the central computer. At the lower level CC main equipment is controlled by a microprocessor and programme logical control units, determining operations sequence. Optimum cooling regime for each steel grade is achieved by a methematical model.

Central computer makes data collection from all subsystems for operation quality of the whole technological line estimation. 33 parameters are introduced by the system, 63 - by an operator and 30 - are calculated out of the whole data array. Central computer makes up production outlay and give appropriate commands to production control subsystems.

The described system application has promoted technological processes stability increase, defects quantity decrease and energy resources economy.

10. Structure scheme control of 6-strand bloom CC Demag-CFEM for Sacilor (France) is given in Fig. 38 . This system is equipped by:

- logical control units for technological process operations sequence;
- strands automatic control units;

- controlling computer;
- computer for display and printer units control;
- a set of measurement and regulation devices.

Automatic control system operates on bloom geometry data base, steel mass in a steelteeming ladle, drawing speed and cooling intensity. It enables to transfer to distance control of both one strand and the whole CC technological regime. A complex of six independent automatic regulation subsystems is used for distict operation of each strand:

- strand control on controlling computer instructions base;
- location determination and signals of electromechanical equipment operation rhythm violation;
- data collection and processing of the whole strand equipment operation;
- CC ingot standard length control.

Controlling computer functions include:

- communication with an operator;
- operated phase selection at each strand (seed elevation or teeming);
- casting parameters calculation (speed, cooling regime);
- standard length calculation for billet shearing;
- defects data determination and collection;
- strand regulation automatic control systems and the received data processing;
- dialogue with display and printer computer control units.

The whole complex implements the following functions:

- functional curves dynamics control;
- curves printing;
- data storage and cooling characteristics alteration;
- ingot surface defects determination and emergency signals appliance;
- drawing up casting progress report, indicating metallurgical production defects occurance and billets in real time mode coding;
-optimization of shearing in a given length function and the remain ed metal mass in a tundish;
- casting data collection (mass , heat number);
- equipment operation automatic tracking;
- communication with intrashop system information.

1 . According to "continuous casting - direct rolling" processes introduction, quality slab classification and their suitability for direct rolling decision must be taken at the billet shearing stage. The system introduced at Sin Nippon Satatsu Works is given in Fig. 39 . The system is built due to hierarchical principle and it includes central computer, controlling computer, executive regulator. Central computer performs general equipment operation regimes calculation and gives instructions to the controlling computer on slab casting and shearing production programme basis for each strand. The controlling computer collects data on billet quality in a real time mode and on that basis calculate billet length.

g) Techno-economic effectiveness

1. Techno-economic effectiveness of continuous casting application as compared with periodical ingot casting is a result of its advantages formulated in previous items. The advantages are so sizable that ingot casting shops are being built nowhere with an exception of special cases. Moreover, practically all companies, having ingot casting shops are aimed at their CCs reconstruction building.

2. There is quite little information about continuous steel casting units construction at Iron and Steel Plants. It is specially concerned with the construction price and the staff number. Besides, it is difficult to find out from the available data what is included into the construction price. In spite of the reliable economic data it is necessary to state a constant growth of the continuous steel casting units number.

3. In App. 3 there is data about the construction of 131 continuous casters for the last three years. The given data show that more than ½ of all the constructed installations are put into operation in developing countries. Among the industrialized countries USA and Italy more intensively construct CCs (as it was mentioned above many industrialized countries, e.g. Japan, have almost completely gone over to continuous casting). CC are mainly constructed at mini-works.

4. When mini-steelplant is constructed low capital investments is a distinguishing feature. For example, constructing two mini-steelplants by Nucor Company capital investments per liquid steel ton make up 275 US $ while for the works with a complete metallurgical cycle the outlays make up 1000-1600 US $/t [2I]. The comparison of capital investments structure at the plant of different type is shown in table.

5. According to "Societe Francaise de minore produits" Company calculations [22] labour expenditures at Mini-Works with 1 mln t/yr capacity are 2,8 times less at scrap operation and 2,0 lower while using sponge iron, table 3. According to "Raritan River Steel" Company data labour expenditures at Mini-Works production constitutes 1,5 man.hour/ton as compared with 6,1 man.hour/ton at Works with a complete cycle [23].

6. Thus, Mini-steelplant development which are to comprise secondary steel making and continuous casting installations, is connected with the following economic advantages:

Capital Investments structure, dol./t. cast steel — Table 2

Outlays items	Works type		
	with complete cycle	mini-plants working on scrap	mini-plants working on direct reduction iron
Warehouse premises, transport, etc.	200	50	50-100
Aglomeration, coke, and blast furnace production	250-300	-	-
Direct reduction	-	-	150-200
Steelmaking production	150-250	150-250	150-250
Total	600-700	200-300	350-550
Amortization and financial expenditures, % from billet price	36	13	24

Labour Expenditures on Steel Production at Mini-Works and at Works with a Complete Cycle — Table 3

works type	steel capacity mln t/yr	personnel number x)	labour expenditures, man.hour/t steel
mini-plant working on scrap	0.2	180	1.530
	0.5	240	0.816
	1.0	450	0.765
on direct reduction	0.5	380	1.156
basis	1.0	600	1.020
Plant with a complete cycle	1.0	1,250	2.125
	2.0	1.650	1.403
	4.0	2.300	0.978

x) without a rolling shop personnel

- specific capital investments make up about 20%;
- running costs make up 50%;
- labour productivity is 3-4 times higher than for the works with a complete metallurgical cycle;
- short design and construction periods and a quick cover of expenditures;
- high profits per item of production due to low specific capital investments, minimum transport expenditures, simple production process, flexible technological schemes enabling to react quickly on a state of the market;
- a higher ecological cleanleness.

7. A more detailed estimation and selection of any method and continuous casting installations depends on local region conditions and a definite production aim.

g) Prospects and trends for future development

1. At the initial stages of continuous casting development the equipment was relatively simple; the necessity to increase reliability and operational units flexibility has resulted in design complication and capital outpays increase. Lately the equipment has started to be simplified and CCs are required to be cheaper. The investigation of capital investments on "British Steel" UK, continuous casting equipment has shown that specific capital outlays per ton of rated capacity increases with the cost billet section value and moderately decreases with the output increase. Further CCs development will result in their considerable height and capital outlays decrease. A low construction height will promote billet homogenity increase as a result of ferrostatic pressure decrease and equipment maintenance will be simplified.

2. Continuous steel casting processes and equipment improvement is developed in several trends simultaneously, the following ones being the main:
- steel refining methods elaboration and their introduction in the course of continuous casting;
- elaboration of hot charged methods without ingot cooling or direct rolling, i.e. combination of continuous casting with a rolling mill;
- an ingot cross-section approximation towards a final product cross-section;
- horisontal CC development;
- separate units constructions improvement.

3. At present, work has been carried out on the application of a tundish as a refining device where metal can be refined from non-metallic inclusions and corrected on chemical composition, can be deoxidized and it can even regulate a grain size in a continuous casting billet. Lately tundish capacity has increased from the initial (6-10) to 20-25, then to 40-50 t and at present it has reached 70-80 t.

To optimize metallurgical processes in a tundish it is necessary:
- to decrease metal secondary oxidation;
- to prevent crater formation on a metal surface;
- to prolong liquid steel presence in a tundish as much as possible;
- to provide metal homogenity supplied into each mould.

It is provided by special design ladles application, stream shielding from the contact with the atmosphere during pouring from a steelteeming ladle into a tundish, fig. 40 using portions in a tundish, argon blowing, refining by means of ceramic filters.

4. Modern steelmaking production is oriented at energy saving of direct rolling or "hot charged" rolling into preheating furnaces. In these cases blooms or slabs are supplied into rolling mills either immediately (after little heating in re-heating furnaces), or after heating in conventional furnaces where billets are supplied in a still hot state. A technological scheme recommended by "Mannesman Demag" Co is shown in fig. 4I , it gives a view of a low construction height CC, being used as a teeming unit. Similar examples of the units are given on fig. 42,43 .

5. Joining continuous casting processes and the continuous rolling processes into a single technological method is one of the major technological problems of iron and steel production improvement and effectiveness. In general, solving this problem enables to exclude capital investments for equipment oriented at manipulation with etching and also for separated cooling, transport, storage and ingot feeding into preheating furnaces, and to reduce expenditures on equipment for heating before rolling, to reduce fuel and energy consumption for heating initial ingots before rolling at the expense of great use of continuous casting ingots heat after casting, to increase the yield due to the rolling ingots butts and metal waste reduction during heating before rolling, to increase labour productivity due to a smaller personnel and the possibility of complete production process automatization.

6. In 1968 "Voest-Alpine" Co, Austria constructed a radial CC for 140x140 mm ingot casting, which having passed the secondary cooling zone and isolation chamber where t° is equalised according to the ingot section, it goes to the four high strand rolling section according to HV scheme (alternative horizontal-vertical position). After squeezing to 80x80 mm size the ingot is sheared into the desired length.

7. Vniimetmash, USSR has built an experimental installation for continuous casting and ingot rolling. One strand radial CC, is included into a technological line with induction heating installation continuous casting mill with four-high strands and a flying. Ingot with 10500 mm² section was cast at 2-3 m/min speed and was rolled totally into 84 mm diam., the output speed making up 5-6 m/min.

8. In 1968 "Badische Stahlwerks" Co, FRG constructed an installation for casting and rolling 100x100 mm ingot. Initial ingots 130 x 14 mm are cast at 2,8 m/min speed at four-strand radial CC. In each strand with 20-22 t/h capacity ingots go to the due strand with grooved rools without heating where they are squeezed to 100x100 mm section, then are sheared into the desired length.

9. The similar installation was built by "Georgetown Steel" in USA. In each of the four strands 130x145 mm ingot from the radial CC passes through the heating furnace and duo strand where it is squeezed to 100x100 mm and then sheared. The annual productivity makes up 135,000 t.

10."SMS Schleomann-Siemag", FRG its branch US company "SMS Engineering" and "SMS Concast", Switzeland, worked out CC for strip casting directly (in the same line) connected with the wide stripped hot rolled mill. The first such a complex of equipment is being built at "Newcor" Works, USA. CC capacity makes up 820,000 t/yr at a maximum casting speed 6 m/min. A strip (thin slabs) 50 mm thick and maximum widths up to 1350 mm will be cast at the installation with stationary mould; the strip in a hot charged will be fed into a wide stripped rolling mill. Such a scheme reduces essentially a technological line from steel melting to rolled strip. Furnaces for slab heating and the whole group of roughing strands are not necessary, which were inevitable during hot rolling at a wide stripped mill before.

Continuous casting strip goes through a simple equalizing (temperature) furnace with the rolled bottom and is rolled directly in four strands of the quarto finishing strands up to the minimum 2,5mm thickness. The hydraulic installation of CVC rolls.
The mill is designed in such a way that the fifth may be added for rolling a still thinner strip (band). Further a unit for laminar cooling and a winder for a strip 12.7 mm wide is included into the equipment. Casting capacity corresponds to the traditional slab CC.

11.Slab CC N5 at Fukujama Works, Fig. 44 , reached 200,000 t per month output. More than 100,000 t per month is produced by direct rolling method, the record being 134,000 t/month. Specific fuel consumption in heating furnaces reduced to 672,000 and less At present, owing to high quality refractories application long casting cycles (more than 6-8 hours) without tundishes replacement can be achieved.

12. Some examples of thin billets continuous casting methods are given below.

13. New technology of thin ingots continuous casting should corresponds to a number of conditions [24]. It is most important that the product should not be worse in quality than the material produced by classical continuous casting. A very good continuous casting ingot surface quality should be especially taken into account as surface processing would be unacceptable from the point of working capacity and material losses. The internal quality of the ingot size and dendrites form, segregations, inclusions, porosity etc - must be appropriate so that after further deformation the desired properties of the finished product should be achieved. If a thin strip (foil) up to 0,1 mm thickness may be produced with the amazingly high surface quality and edges accuracy due to the increase of the cast strip thickness, there still occur many problems connected with the surface uneveness and oxidation, mirco and macro frequency, size precision and in a thick strip - even with central (axial) blow holes and porosity. As a result of high solidification speed thin ingots have finer cast structure (the distance between dendrites, silphide inclusions size) and lower macro segregation, i.e. in general favourable initial structure is produced and the mentioned conditions may be expected to be satisfied.

14. The new CC to be cast for mass consumption must have the same productivity as classical CCs. This means that thin continuous casting ingots must be cast at high speed. At equal productivity (t/h) casting speed for slabs with the same width is inversely proportional to thickness, for billets and rods thickness is inversely proportional to the second grade of casting speed.

Casting speed of continuously cast ingots corresponding to hot rolled strip should make up 20 m/min and more.

15. In 1984 "SMS Schloemann-Simag" company, FRG finished the elaboration of the continuous casting trial installation for producing sheet ingots. However, there has been already practical experience in solving such a problem at the experimental "Tysson" installation.

The proposed construction differs from the already known but it makes it possible to use some slab CCs units, such as tundishes with liquid steel feeding into the mould through shrong, stational mould, oscillation mould mechanism, back up rolls system and secondary water cooling. The technology of ingot casting with low thickness and high speeds may be realized in a short period of time without great efforts. The experimental installation has the following parameter:

strip width, mm	1200-1600 (is regulated)
thickness, mm	30-50
casting speed, m/min	6,0
steel grade	all ordinary steel grades for hot sheet rolling
CC type	vertical with bending

The received experience of the flat ingot casting at Bushhuttene has shown that there are great opportunities for further development of the classical continuous casting. Combining directly liquid steel processing with hot rolling production, the iron and steel production structures so far adopted undergo certain changes. In the near future capital investment growth necessary for the hot rolling strip mills construction is expected to take place. Thus, today new alternative technological processes are sure to be worked out.

16. The "Haselete", USA continuous casting installation between two bands represents one of the few highly productive installations with a movable mould for steel casting into ingots close to the finished product sizes.

CC model is shown schematically on fig. 45.
The same general principle is used for thin slabs and rods casting.

A number of programmes of thin slab casting on the "Haselete" type CC have been worked out and put into operation.

17. Since 1984 "United States Steel Corporation" - "US Steel" and "Betlihem Steel", USA have been carrying out joint investigation in the field of thin slabs casting;

the programme has been planned for a five-year period. "Haselete" company (CC proper), "Harlison - Walker Refractories", USA (refractory elements for feeding liquid steel into the mould) and "Westenhouse", USA (magnetodynamic drives) - joined the programme.

The systems of feeding liquid steel into the mould which must provide ingot surface high quality are paid great attention to. At the first casting stage ingots will have 25x430 mm transverse section.

18. For the "Newcor Steel" company, USA CC with 370 mm length, 1320 mm width mould and 38 mm thickness ingot. CC is supposed to operate in complex with compact rolling mill which is to be put into operation in the end of 1988 or 1989 and will produce steel sheets for rolling, lining and other purposes.

19. Since 1983 at "Sumitomo Kirdzury Koge" Works, Casima, Japan, CC with band mould where slabs with maximum 600 mm width has been working. The main technological installation parameters are given below.

CC type	"Haselete"
installation length, m	69
casting speed, m/min	max. 15 (in practice 4-5)
slab sizes, mm:	
thickness	20-60
width	600
mould angle of inclination, degrees	6-15
mould length	2,9
band cooling	with water spray at high speed
secondary cooling	with water shower
pouring, $t^{o}C$	1550-1580
casting steels	low carbon killed AI and manganese killed AI

The maximum capacity of the pouring ladle is 50 t, of the big tundish - 8 t; from the big tundish steel goes through shrouds, enabling to regulate pouring speed, into the small tundish with 2 t capacity and then through the pouring refractory chute passes to the band mould. The pulling rolls are moved from asynchronous driver, synchronized with the drive motor by CC proper. Slab sheering is done by gas burner with the maximum speed 2 m/min. Slabs are automatically packed into stack with the height up to 800 mm and with the length 10.000 mm.

Steel feeding into the movable mould is regulated automatically according to the results of the stream speed measurement between the big and the small tundishes and due to the steel mass in the small tundish (by means of special sensors). The required band speed of the movable mould is calculated from these data. During work breaks pouring unit filling is controlled by the optical method and pouring and drawing speed is controlled correspondingly. The accuracy of the movable mould filling makes up ± 10 mm.

20. The variant which has got the symbol RCC (rotational continuous casting) seems to be perspective and since 1975 it has been worked out by "Hitati", Japan; since 1983 "Korf Engineering", FRG has been working in this field. At present two industrial installations has been in operation: one "Tokoyama" company in Nagoya, Japan, the other - "Stahl und Walzwerk Mavienthutte", Austria.

The essential difference of RCC process from the classical CC is the intensive steel cooling in the mould. That can be achieved both as a result of a longer (2,5 times) contact (and a larger contact surface) between the ingot and the mould, and due to the relative ingot and mould movement (there occurs no friction between the mould and the ingot during drawing of the latter).

Steel enters the mould from the tundish. The band linking the track-strand along the wheel perimeter (rotor) is pressed to the wheel by the two rolls and drawn by the third roll. The band is 1,6 mm thick and is made of low carbon steel and is water cooled outside from the sprayers. The casting wheel crown is made of a copper alloys and is cooled by the running water from inside. To facilitate ingot drawing from the casting wheel, the strand in the wheel has trapesiform profile (the internal side is shorter than the external). The casting ingot partially solidified is squeezed out from the wheel by the roll mounted on its lower part. The water cooled plate cooling the ingot is located between the roll and the wheel. Drawing is performed by the wheel and pulling rolls (simultaneously regular) with the synchronized drive. The vertical stand transforming trapesiform section ingot into the rectangular is located at the outlet of the installation then goes horizontal stand where the ingot is rolled into billets.

21. The CC scheme where steel passes between the rolls underneath is shown on fig. 46 . The rolls are made of the high conductivity

material, e.g. copper, and is water cooled inside. The butt ends of the rolls are sealed. The cast strip goes through a pair of regular rolls then is rolled into the desired thickness in the subsequent pair of rolls.

22. The other casting variant is shown on fig. 47 . The angle may be changed here from 30 to 60 degrees. Liquid steel passes between the rolls along the chute. The water cooled ro ls are lubricated, for example, with graphite, molibden desulphide, glass, etc. Directly after casting the strip is cooled by air then by water. The cast strip also passes through regular rolls and then it is rolled into the desired thickness in the following pair of rolls.

23. The main problem of casting between the rotating rolls is withdrawing of large amount of heat from the mould. For example, low carbon steel strip 1,27 mm thick is cast, thermal stream 5 MWt/m^2 is required to be withdrawn. The selection of the cooling method is impeded by a great temperature overfall between the cooling environment and the ingot, that causes a considerable thermal tension. It is also important to realize optimum melt supply according to the rolls rotation speed, gap between the rolls and the length of the ingot unsolidified core (for instances, at small gap between the rolls and great squeezing strength on the rolls in the ingot core, a considerable reverse liquation may occur).

According to the way of the melt supply there may be distinguished the so-called flat spray casting, casting with melt drawing, die casting, melt casting by spraying.

24. In the USA by means of casting on quickly rotating cooling roll "Allegeny Ladlam Steel" makes a strip from corrosion resistant steel with 300x2 mm section. Another CC which will produce a strip with 600x2 mm section is expected to be put into operation. "Westenhouse" and "Armco Steel", USA, have started joint casting process elaboration of the strip 75 mm wide and from 0,7 to 3 mm thick, made of low carbon steel at the speed up to 400 m/min. Similar investigations are carried out by "National Steel" Co, USA. Four US steel producers - "Armco Steel","Betlihem Steel","Inland Steel" and "Wirton Steel" cooperate in strip casting technology elaboration for direct cold rolling.

25. In Japan "Nippon Kindzoku Koke" casts a strip 300 mm wide and 1-3 mm thick, made of corrosion resistant steel 18-8 type at the installation, schematically shown on fig. 48 (melting mass

300 kg). The lower stainless steel roll is 1020 mm in diam., the upper soft steel roll of standard quality 200 mm in diam., both rolls are water cooled from the inside. The pouring chute mouth, made of alumographite with ceramic coating, is profiled due to the lower roll curve. The process may be also performed without the upper roll which in this case is raised upwards. The cast strip is coiled without tension. The circumferencial rolls speed makes up 20-30 m/min, cooling speed 10^4 °C/min. The strip undergoes etching, then cold rolling (50% squeesing) and annealing (1150°C, 2 min). Temporary resistance 575 N/mm^2, fluidity limitation 259 N/mm^2 and relative elongation 56,2% have been reached.

26. Flat-shaped ingots are suggested to be cast on CC, consisting of massive water cooled wheel (rotor), located across the ingot from its inner side; smooth "infinite" band, coming into contact with the ingot from the external side which by means of rolls system takes the shape of a cylinder (round); two segment bands located on the wheel and limiting the ingot from the sides (they all form the mould) and then the back up rolls system, secondary cooling system, strain roll of the segment bands, the mechanism for solidified ingot separation from the wheel and the system of the segment bands back up rolls. The smooth band motion speed is synchronized with the wheel speed. The rescribed CC must allow to cast ingots from 6 to 80 mm thick and from 10 to 1500 mm wide at high speed and without defects.

27. There is an installation scheme for a thin metallic band casting (fig. 49). Liquid metal is supplied onto the internal surface of the rotating hollow cylinder with large radius. Cooling system (water sprayers) are located on the external cylinder side. The solidifies band is recommended to be deformed with rolls before coiling.

28. The possibility of direct ingot casting with little sections that make direct continuous casting ingots rolling application more probable and economically advantageous, open new perspectives before horizontal CCs first while casting sorted ingots with little sections and thinner slabs.

29. "Technik Guss" company exports horizontal CCs for casting alloy steel and cobalt alloy ingots with 5-15 mm in diameter or carbon and alloy steels with 35-75 mm in diameter [25].

At such installations continuous casting of high alloy rods with 3-12 mm in diam. is carried out for further drawing or for rolling round or square section rods with 25-60 mm diam. Semiindustrial six strand horizontal CC (Steel Casting Engineering)Oringe, USA for rod continuous casting has acquired productivity 1,5 t/h for one strand and annual productivity reaches 50.000 t.

30.The method of producing thin slabs by horizontal continuous casting is worked out within an international research programme by "British Steel" [26] . The method is based on the principle of retarted upper and lower metal layers solidification that provides good surface quality and inclusions floatation. The installation h with a 4-tonn ladle for slab casting with 75 x 500 mm section in diameter, at about 10 m/min casting speed has been built at one of the works. Movable mould made up of iron segments is mounted on rails. Heat isolating facility is introduced into a mould before casting and the bottom and the strand walls are closed. Pouring is done through the tundish chute, metal level height in the mould is controlled in the course of the process and steel consumption is regulated by the sliding gate.

31."Danieli", Italy, possessing a ten yeat experience in constructing and operating horizontal CCs has designed a special installation with electromagnetic mixing for small section ingot casting. The distinguishing feature of the installation that has got the name EBM is a little construction height thus giving a number of advantages.

The combined electromagnetic mixing provides good metal and ingot surface quality.

The main installation parameters are the following:

Machine type	"Danieli" EBM 502
Ingot section, mm	from 80x80 to 140x140

Casting speed, m/min	from 0,5 to 6
Steel mass, t	30
Steel type	quite and alloy killed
Strand number	2

32. Until recently the development of classical CCs has been accompanied by capital investments growth which has been in general compensated by the increasing installations productivity. Later certain hopes were set on horizontal CCs that demand less capital investments. At present continuous casting processes are believed to be perspective where the tundish and the mould are combined; such installations are attractive for producers of special and alloy steels. CC with very low height, being a compromise between vertical and horizontal installations, may serve alternative solution.

33. Lately notable success has been achieved in:

- tundish lining elaboration;
- systems of metal supply into a mould;
- mould constructions and their materials;
- secondary cooling systems;
- methods of external effects on a crystallizing metal;
- CC mechanisms work.

These questions are described in detail below.

34. New wearresistant refractory types have been worked out for tundish lining on the basis of zirconium oxide, borum nitride, silicon carbide and their mixtures; new heat isolating concrete masses, including double-layer with an operating and heat isolating layer; dry dolomite materials of special granular metric composition on heat resistant resin basis; refractory materials reinforcement, preventing their deoxidation, etc.[27] It enables to decrease refractory consumption, to lengthen their survice life and to provide longer operation during "heat per heat" operation within more than 12 hours.

35. Slag forming mixture selection for each certain case and casting conditions promotes billet surface quality increase. Mixtures consist of a number of natural materials. When they are supplied onto the metal surface in the mould they are melted at 1100-1200°C and form an isolating lubrication film between the crust of the cast billet being formed and the mould wall. The film prevents steel cohesion with the copper mould and decreases friction between them. Besides, cast mixture reduces heat losses by radiation, absorbs and dissolves floating non-metallic inclusions, prevents oxygen and nitrogen supply into the metal from the air.

36. Modern slagforming mixtures consist of smelted calcium and other additional silicates: fluorspar, petelite, graphite materials as coke dust or soot , soda etc. Basicity, viscosity, temperature and mixtures melting speed are regulated by these additions.

37. In a number of cases the possibility to change mould width in the casting process at new CCs, e.g. in Japan, cast ingots sizes are changed about 250 times a week, that promotes direct ingot hot rolling technology to be widely applied. Combined ingot casting enables to produce a wide slab, two slabs of smaller width or several narrow ingots in one strand; 41 CCs of the type are being constructed and operated. One of the advantages of the combined casting is high productivity.

. In some cases wear resistance of the copper plates for the mould is increased by galvanized chromium (60-80 mkm) or nickel

(0.5 - 4.0 mm) coatings. Such coatings expenditures are rather high and their economy must be estimated for each case separately.

38. At "Rasorback Steel", USA plant the mould with lance cooling is being operated, . that increases casting speed considerably (1.3 times) at the expense of heat abstraction intensity increase. Moreover, such a construction provides slab surface quality improvement as a result of the possibility to regulate cooling along wide slabs faces .

39. Practically all new CCs are equipped by electromagnetic stirring devices. That ensures billet macrostructure improvement, particularly mixtures segregation decrease and also surface quality improvement. Steel grades cast at CC expand in quantity. By the beginning of 1987 about 400 CC strands were equipped by electromagnetic stirring units.

40. Electromagnetic units have started to be applied, the speed of the metal stream leaving the submerged shroud hole, becomes slower as a result. To retard the stream, stationary electromagnetic field directed perpendicular to the metal stream is used. Using the device it is possible to decrease twice metal motion speed in the mould, to increase ingot shell solidification and to decrease narrow ingot faces

The reason for metallurgists constant interest towards continuous ingot casting close to the finished products by its sizes lies in essential production process simplification and energy saving

41. New methods of a mechanical part - CC with multipoint bending gradual ingot straightening decrease tension that takes place in the ingot during bending, many CCs having built lately have acquired vertical moulds which increases the stability of casting, increase casting speed and ensure ingot quality improvement;

Tundish capacity increase at powerful CCs; minimal steel mass in tundish makes up 30 t which provides continuous casting within 6 min.

42. Deformation at a secondary cooling sector at present rigid systems with the low step of back up rolls and their low diameter (up to 360 mm) is optimized.

43. Instruments and control devices, including microcomputers; they are constantly improved and has become the vital necessity of process stability, casting ingots high quality at high casting speeds .

h) Fields of application

1. In principle there may be different limitations in continuous casting application, viz.:

- economic;
- due to steel grades;
- due to a cast section;
- due to the product quality.

2. Practically, in all cases continuous casting is economically more effective than periodical ingot casting. Works with low output make an exclusion: in this case, if annual steel output makes up less than 25-35,000 t., additional grounds for CC construction effectiveness should be given.

3. There are no principle limitations for different purposes continuous steel casting. First, steel for only mass production was cast at CCs, then continuous casting of low alloy steels was developed and now high alloy steels are also cast. Lately special steel continuous casting has got wide application. For example, "Steel Casting Engineering" Co has worked out a horizontal CC for continuous casting of nickel, copper-nickel and chromium alloy wires and rods .

4. There are no principle limitations from the standpoint of a cast billet section. At present, a sheet 20-60 mm thick, a strip 1.0-1.5 mm thick, rods and wires from 3 to 60 mm dia. etc., slabs and blooms of practically any desired Cross-section are cast at CCs

5. The steel quality produced during continuous casting is higher than during casting into ingots. There are defects or they are rather week being connected with the impurities segregation,shrinkage etc . Typical defects of a continuous casting billet may be removed by secondary metallurgy refining methods and by external effects on a solidifying metal.

6. The selection of the unit constructions, separate construction units and continuous casting technologies is determined first by raw materials and energy resources cost, requirements to production quality and commodity market.

i) Recommendations for industrial implementation in developing countries

1. From all points of view - economic, productive, qualitative, ecological, industrial safety - continuous steel casting is sure to have essential advantages as compared with a periodical steel casting into ingots. Newly constructed or reconstructed shops both at mini-plants and at plants with a complete metallurgical cycle h ave continuous steel casting departments.

2. The selection of the unit constructions and continuous casting technologies is determined by the local conditions and depends on certain raw materials and energy resources available, on the metallurgical production character requirements towards production quality and commodity market.

3. The most widely used unit type at modern Iron and Steel Works is a radial type unit with a large curve radius (more than 6 m). Ingot and slab units make a large portion among newly introduced and designed agregates. Optimum secondary steelmaking technology and modern continuous casting technology are considered to be the necessary methods for high quality continuous casting production made by CC.

4. For developing countries units with low constructive height horizontal type and traditional type units with ingot bending (curve radius 3-6 m), being worked out and introduced, at present are considered to be the most perspective ones. Units like that are characterized by low capital outlays on construction, considerable technological flexibility, great safety and convenience in operation as compared with traditional CCs.

5. Elaboration of CC constructions, providing semiproduct production with sections approaching the finished products sections is a perspective trend in the field of continuous steel casting. That enables to carry out further processing of such a product only at a finishing mill.

6. At present, only energy saving technologies such as "hot charged" operation and direct rolling are being developed. In this case CCs are regarded as an integral part of a technological line which closely is connected with the previous ladle equipment and subsequent rolling equipment. Casting process automatisation enabling to produce a metal with a high and stable surface quality is an obligatory condition for such technologies. In this case an intermediate surface cleaning (in the interval between a continuous

casting process and a rolling mill) is not needed.

7. High productivity of continuous casting units, the required metal quality, labour and power consumption saving may be achieved only when new hardware components and computer equipment is introduced. Besides the control functions of the main technological parameters and the production process control, modern CC automatic system performs simultaneously the diagnostics of the whole equipment. That decreases non-productive time losses and saves power inputs.

Thus high quality of continuous casting billets is ensured by the following factors:

- metal preparation for casting, including argon and vacuum processing, thorough temperature control, quantity and non-metallic inclusions form regulation;
- strict CC adjustment and systematic mould position and secondary cooling rolls control relative to a CC technological axis;
- metal protection measures from secondary oxidation and cooling along the entire process: steelteeming ladle - tundish - mould;
- highly resistant refractories application for a teeming ladle and tundish lining and metal protection measures;
- automatic metal level regulation in a tundish and a mould, mechanized system mixture supply into the mould;
- slag mixtures application providing surface high quality requiring practically no cast ingot cleaning;
- secondary cooling method excluding internal defects occurance in billets;
- electromagnetic mixing application aimed at cast billet internal structure improvement and casting temperature interval expanding;
- rational organisation of cast billets control and rating.

Fig. I

Indices of world steel production and industrial production 1800 - 1980.

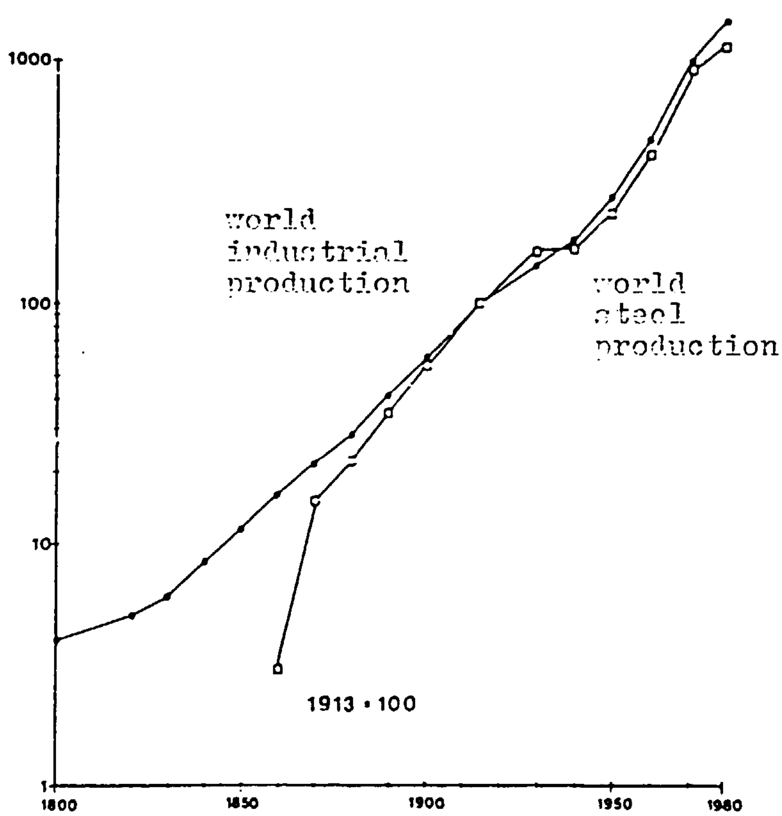


Fig. 2

Secondary steelmaking general processes.

1 - steelmaking unit

2 - ladle processing (decarburization, desulphurization, degassing, deoxidation)

3 - steel treatment in a ladle without vacuum

4 - vacuum processing

5 - argon blowing

6 - refining in a ladle

7 - stream vacuum processing and in a ladle

8 - vacuum processing (DH and RH methods)

9 - processing without preheating

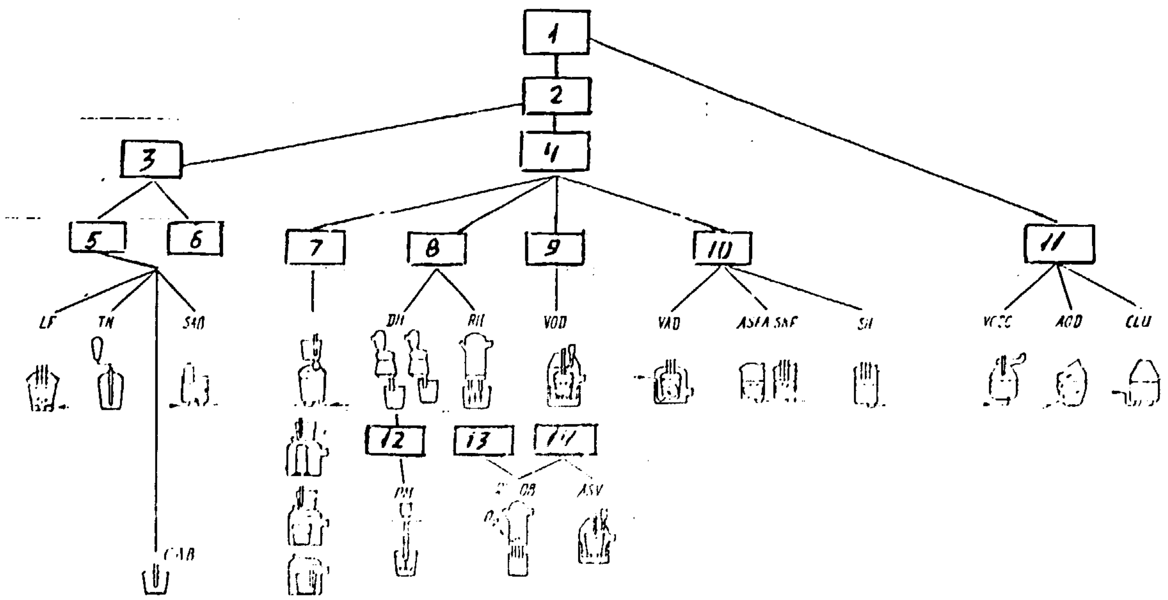
10 - processing with steel preheating in a ladle

11 - special methods

12 - PM-method

13 - RH-OB method

14 - ASV-method



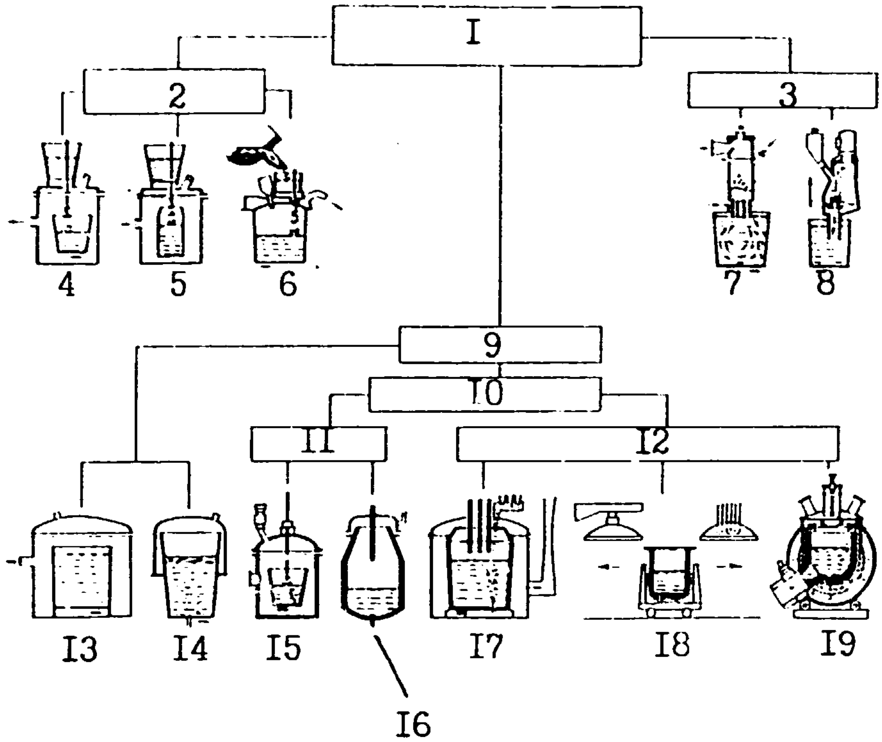


Fig. 3

1 - liquid steel vacuum processing methods;
2 - when tapped and teemed;
3 - by portions;
4 - when poured from ladle to ladle;
5 - when steel is teemed;
6 - when tapped;
7 - circulation degassing;
8 - cycling degassing;
9 - ladle processing;
10 - heating means;
11 - chemical;
12 - physical;
13 - in ladle in vacuum chamber;
14 - in vacuum ladle;
15 - oxygen blowing in vacuum;
16 - oxygen and argon blowing in vacuum converter;
17 - arc heating in vacuum;
18 - induction stirring in vacuum and arc heating;
19 - in induction channel vacuum furnace.

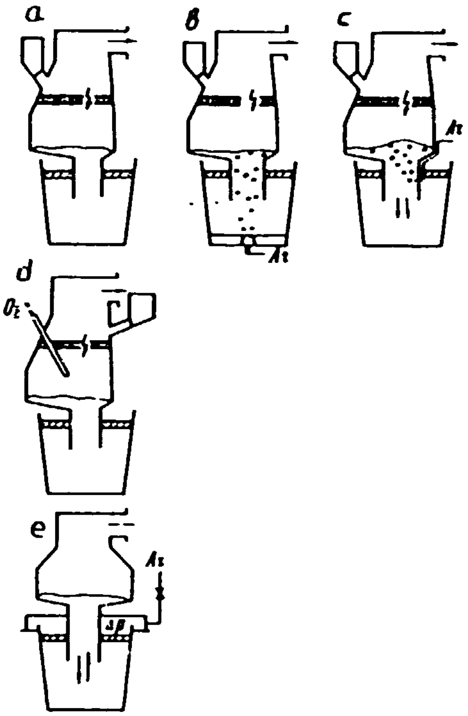


Fig. 4

DH - method.

a - conventional variant;

b - with oxygen blowing;

c - with slag processing;

d - with argon blowing through a stopper;

e - with argon blowing through the lance.

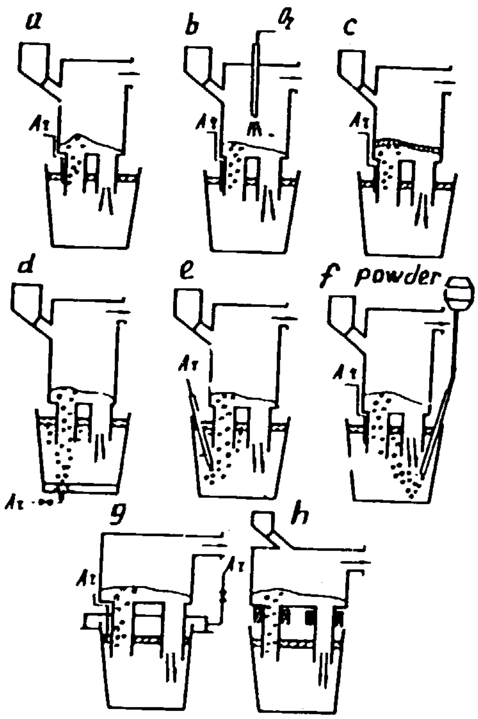


Fig.5
RH-method

a - conventional variant
b - with oxygen blowing
c - with slag processing
d - with argon blowing through bottom
e - with argon blowing through lance
f - with powder blowing
g - with blowing at increased ladle pressure
h - with electromagnetic pump

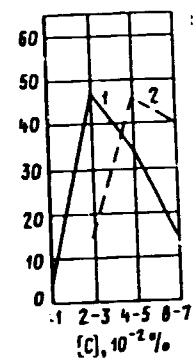


Fig. 6

Frequency carbon content distribution in 08Ю steel.

1 - vacuum processed steel;

2 - non-vacuum processed steel.

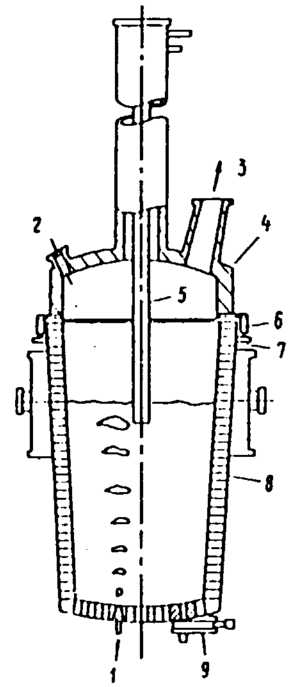


Fig. 7 VOD - process unit.

1 - argon supply;
2 - observation window;
3 - to vacuum pumps;
4 - ladle cover;
5 - oxygen lance;
6 - water cooling compression;
7 - ladle flange;
8 - steelteeming ladle;
9 - slide gate.

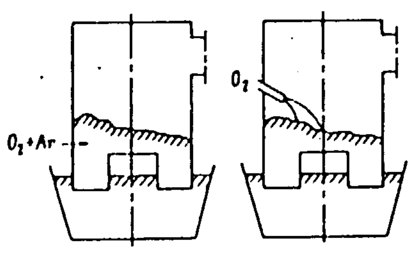


Fig. 8
RH-OB process scheme.

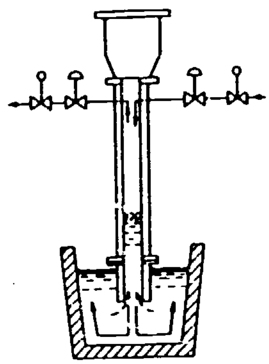


Fig. 9

PM-process scheme.

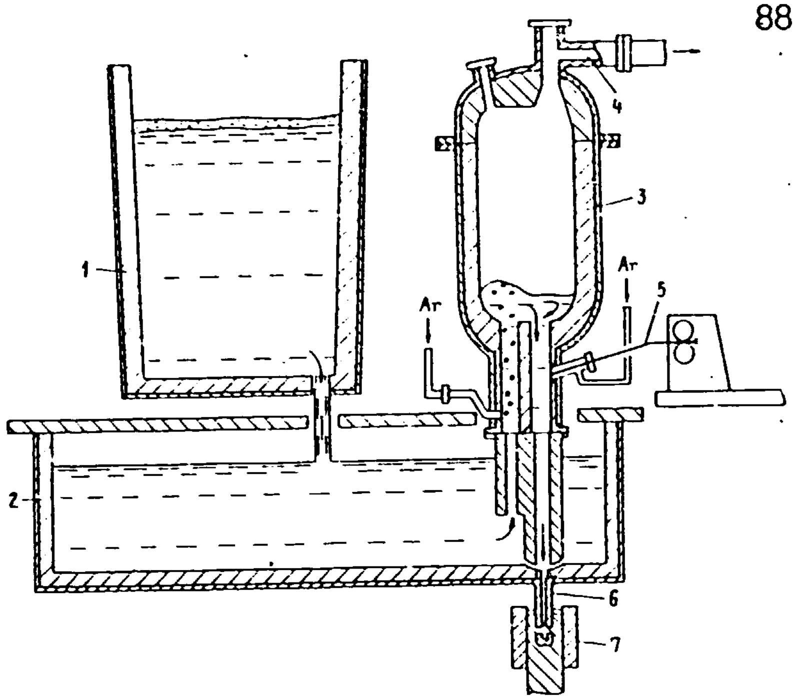


Fig. IO

Process scheme of continuous vacuum processing when cast at CC.

1.- steelteeming ladle;
2 - tundish;
3 - vacuum chamber;
4 - to vacuum pumps;
5 - device for deoxidizers introduction;
6 - submerged shroud;
7 - mould.

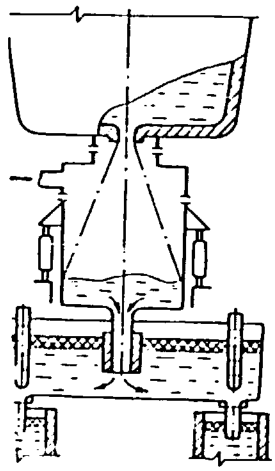


Fig. II

Steel vacuum processing scheme

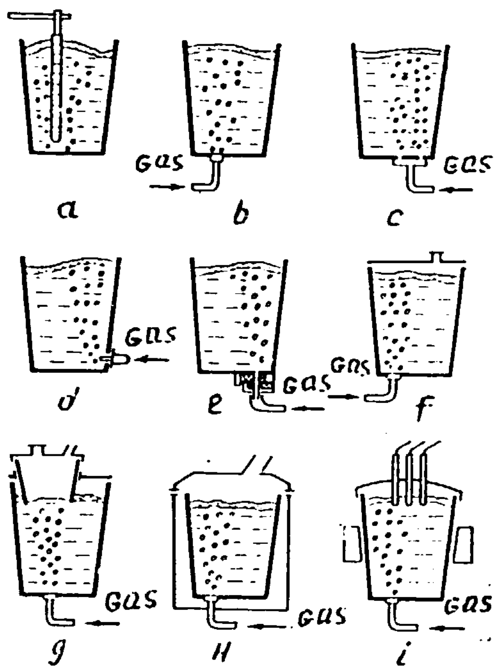


Fig. 12 Methods of steel blowing in ladles by Inert Gas:

a - top blowing
b-i - bottom blowing
g-i - with artificial slag.

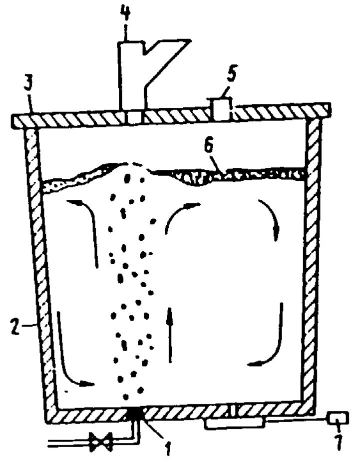


Fig.I3
SAB-process

1 - porous stopper
2 - ladle
3 - refractory cover
4 - gas removal hole
5 - window
6 - artificial slag
7 - slide gate

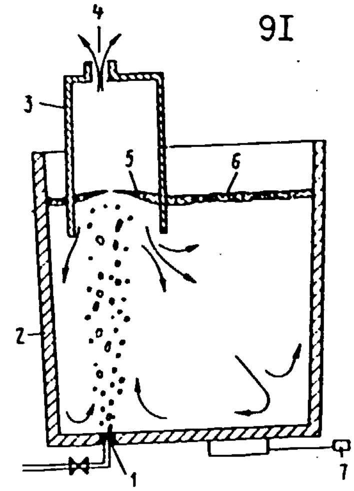


Fig. I4
CAB-process scheme

1 - porous stopper
2 - ladle
3 - refractory cover
4 - gas removal hole
5 - artificial slag
6 - oxidizing slag
7 - slide gate

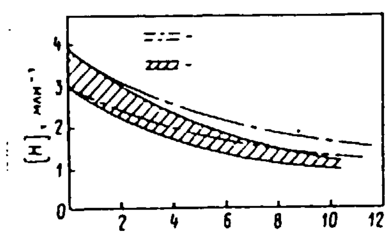


Fig.I5
Argon blowing influence
when processed by DH-method.

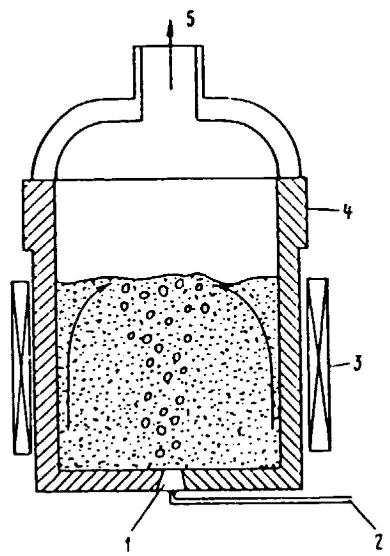


Fig.I6
AIS-process scheme.

1 - porous stopper;
2 - argon supply;
3 - induction coil;
4 - ladle;
5 - to vacuum pump.

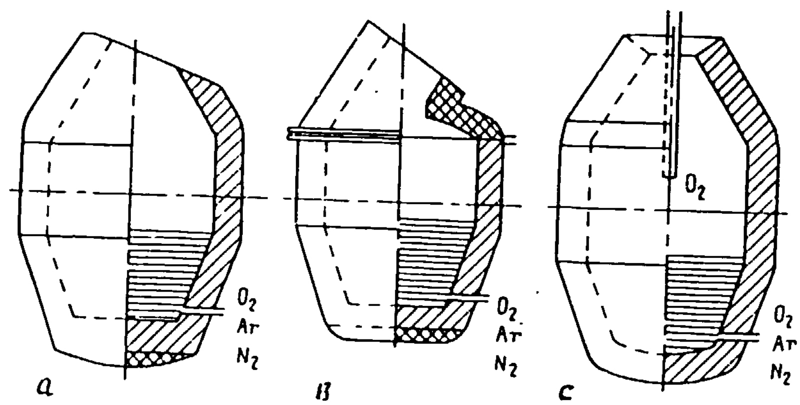


Fig. 17

Converter types for AOD-process.

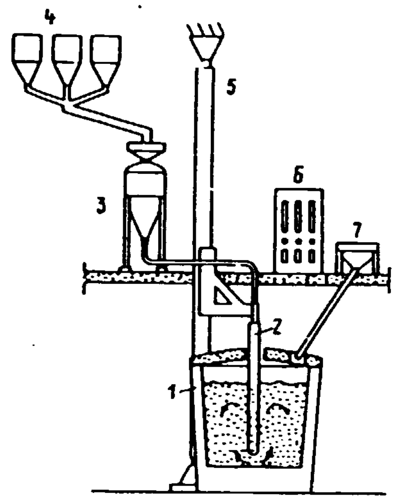
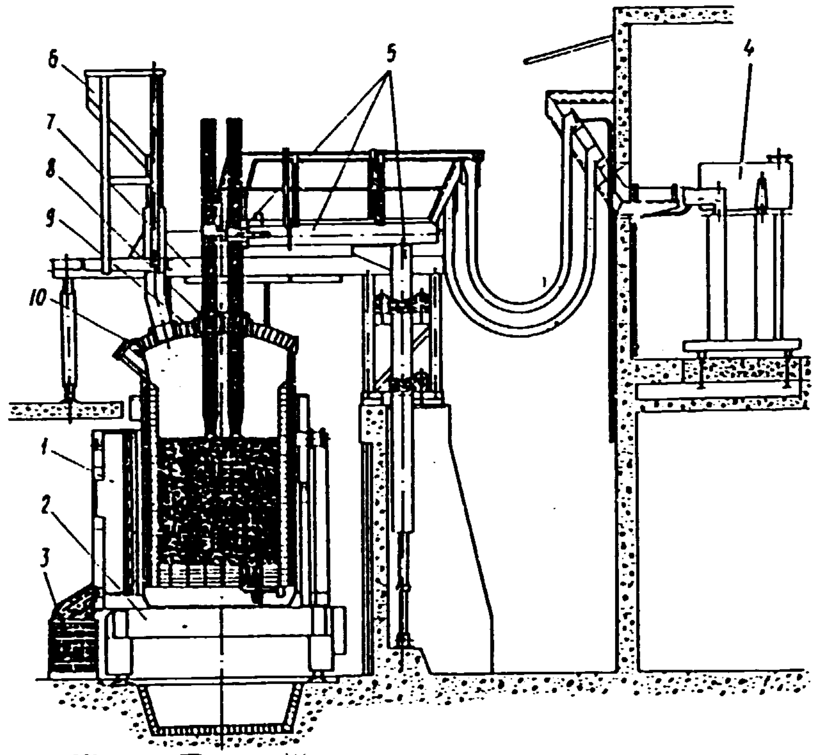


Fig. I8

Scheme of SL unit for powdered materials injection into ladle.

1 - ladle with steel;
2 - refractory lance
3 4 - bunkers
5 - rack
6 - [illegible] system of management
7 - deoxidizers and alloying additions



a

Fig. 19 a

ASEA-SKF unit at preheating stands (a)

1 - device for electromagnetic stirring;

2 - car;

3 - water cooling cables;

4 - transformer;

5 - electrodes holder;

6 - bunker-dozemeter for alloys;

7 - device for arc lifting;

8 - compression;

9 - water cooling caisson;

10 - arc ring;

11 - observation window;

12 - telecamera;

13 - vacuum system with dust collector;

14 - bunker for alloying additions introduction under vacuum.

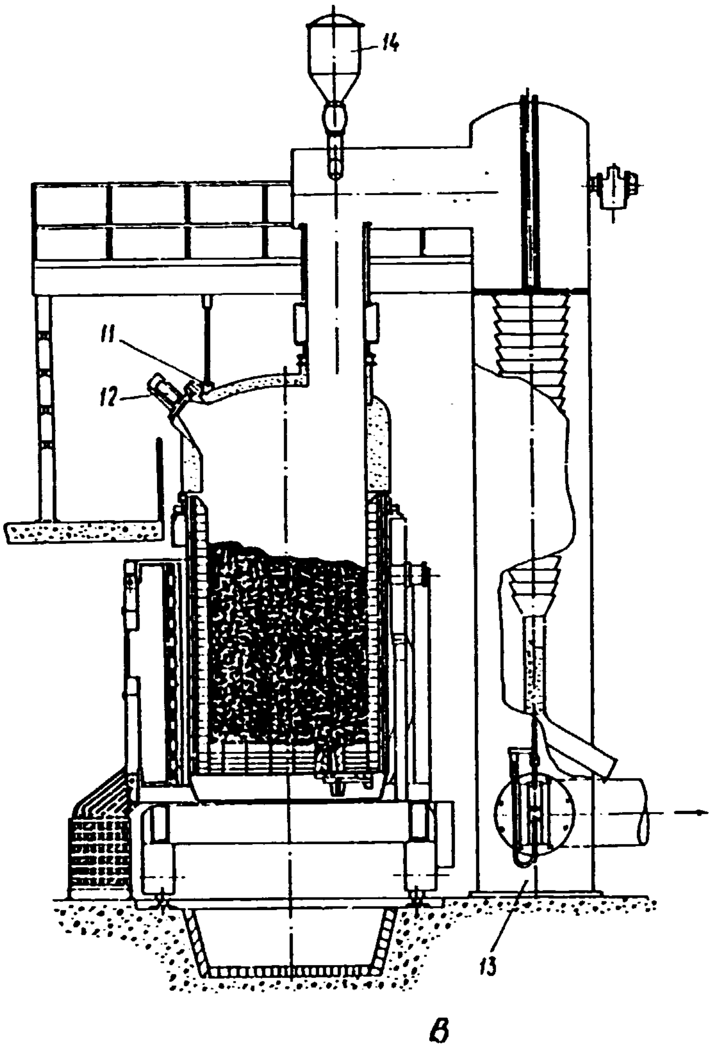


Fig. I9 b
ASEA-SKF unit at vacuum processing stands.

1 - device for electromagnetic stirring;
2 - car;
3 - water cooling cables;
4 - transformer;
5 - electrodes holder;
6 - bunker-dozemeter for alloys;
7 - device for arc lifting;
8 - compression;
9 - water cooling caisson;
10 - arc ring;
11 - observation window;
12 - telecamera;
13 - vacuum system with dust collector;
14 - bunker for alloying additions introduction under vacuum.

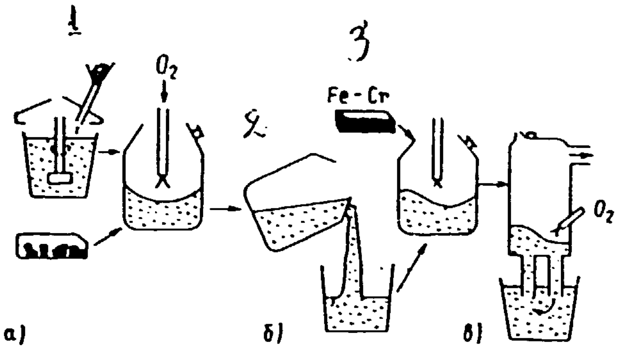


Fig. 20

Stainless steel production by LD-PH-OB process scheme.

1 - iron desulphurization;

2 - slag separation from metals;

3 - high carbon FeCr.

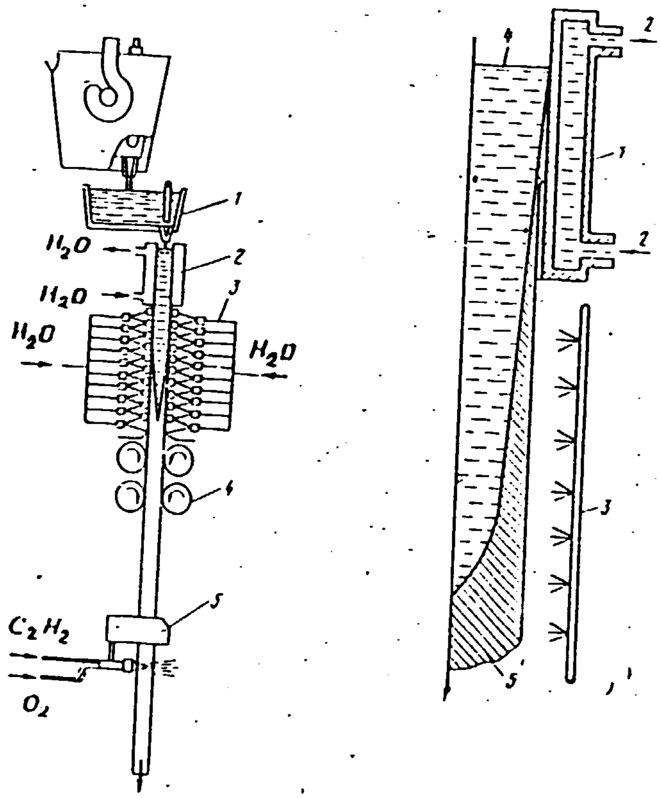


Fig. 2I
CC principal scheme.

1 - tundish;
2 - mould;
3 - secondary cooling;
4 - drawing rolls;
5 - billet shearing.

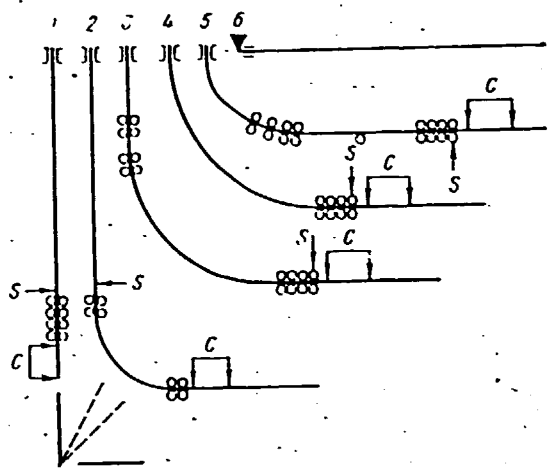


Fig. 22

Principle CC schemes.

1 - vertical type;

2 - vertical type with bending;

3 - with vertical mould, short vertical part and further bending;

4 - radial type

5 - with bent mould and growing bending radius (curve-line type);

6 - horizontal type (or inclined);

C - bullet shearing zone;

S - solidification end.

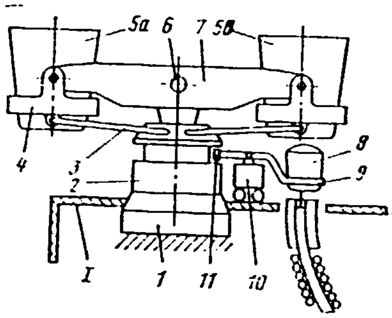


Fig. 23

CC rotating stand.

1 - platform base;
2 - platform;
3 - draught;
4 - racks for ladles;
5 - steelteeming ladles;
6 - axis;
7 - console;
8 - tundish;
9 - frame;
10 - car.

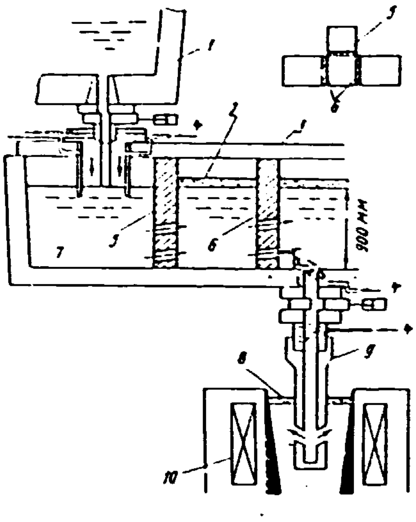


Fig. 24

Scheme of metal protection from secondary oxidation on the way to steelteeming ladle

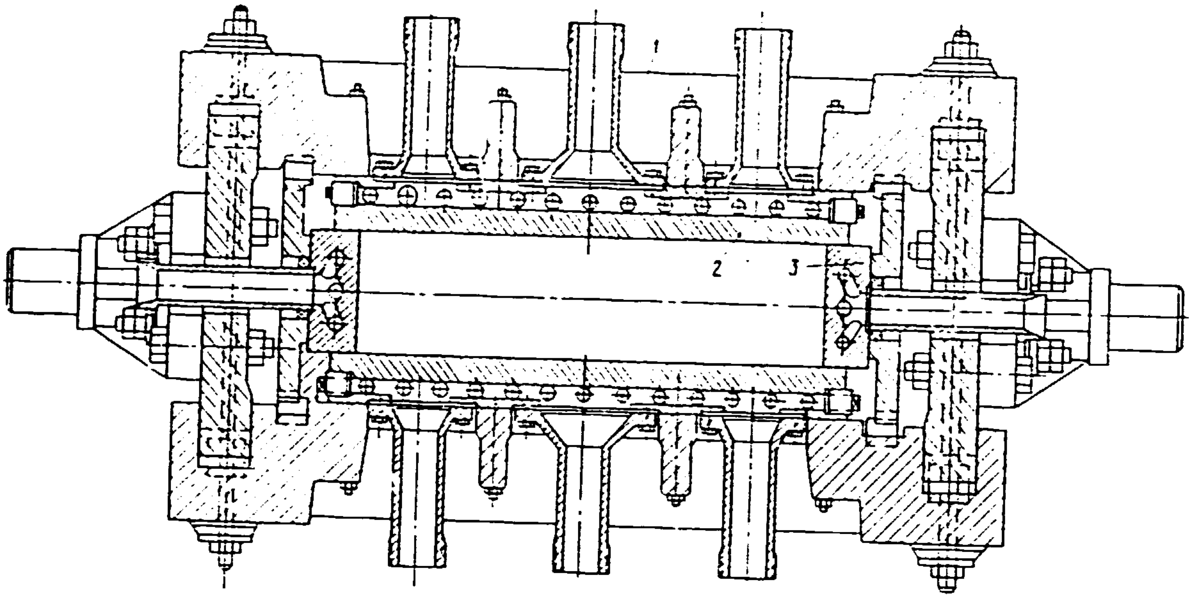


Fig.25
Slab CC mould

1 - steel shell
2 - wide copper walls
3 - narrow copper walls

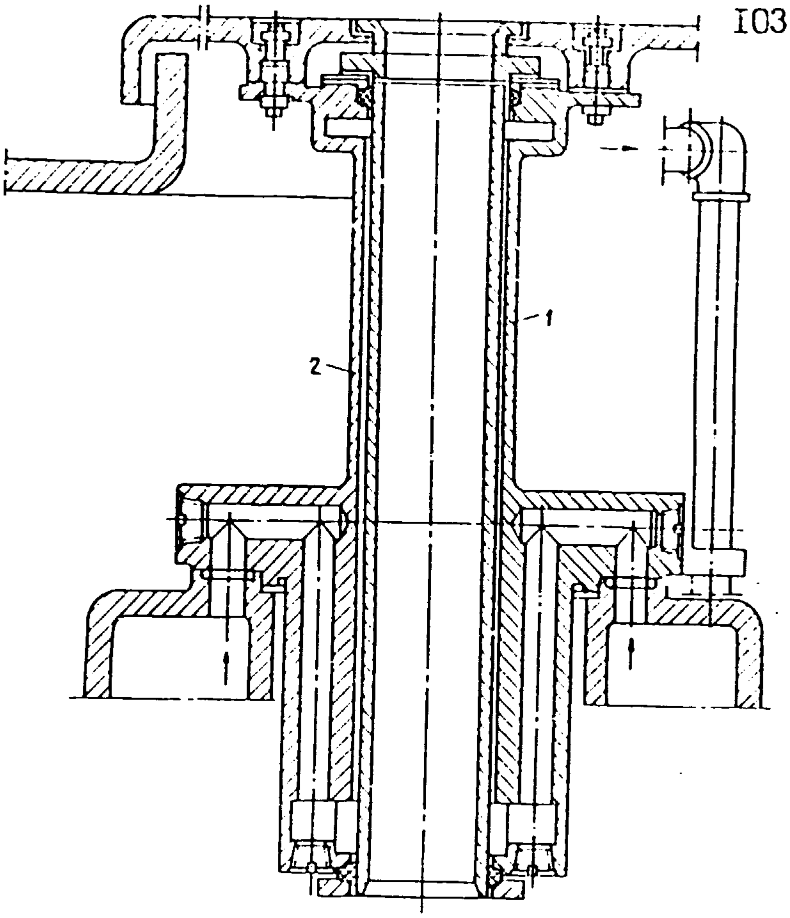


Fig. 26
Tobular mould
1- copper
2- steel

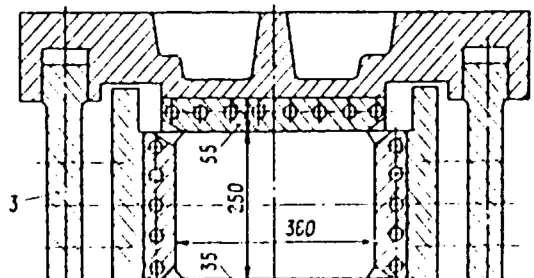


Fig. 27
Build-up mould
1- copper
2- steel

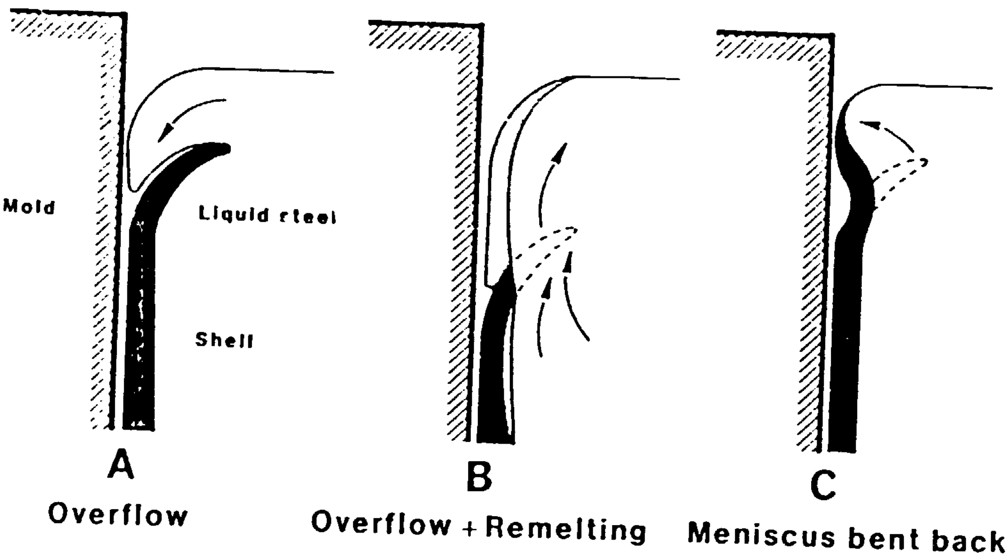


Fig. 28 *Three main mechanisms for the formation of oscillation marks.*

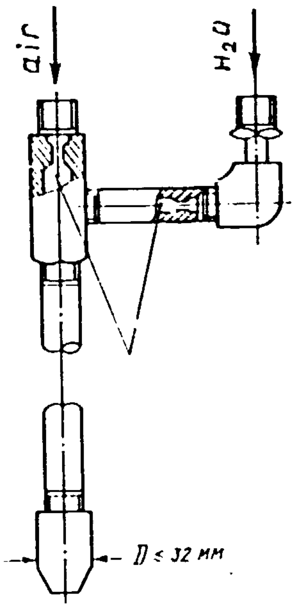


Fig. 29

Example of mist sprayer construction.

Air-water-consumed diaphragm

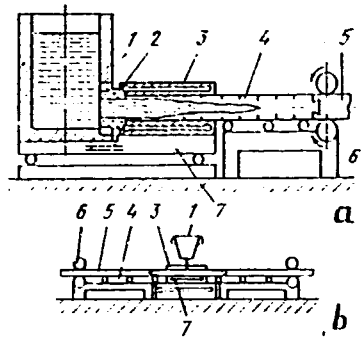
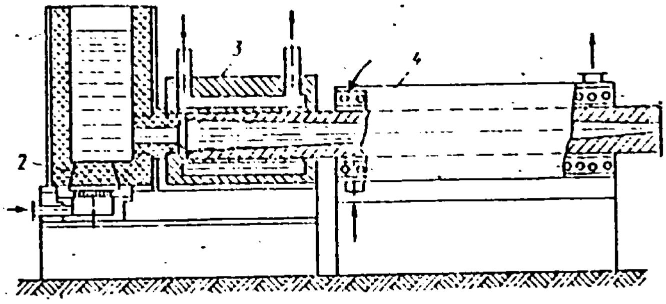


Fig.30

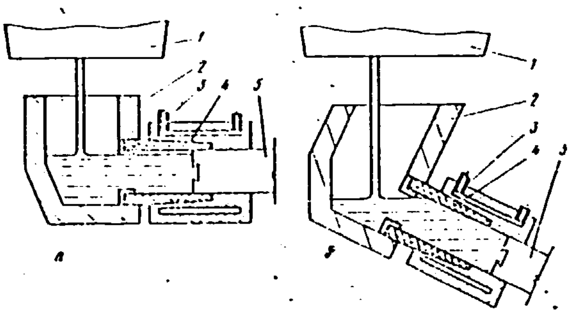
CC horizontal scheme.

a - with single ingot drawing
b - with double ingot drawing

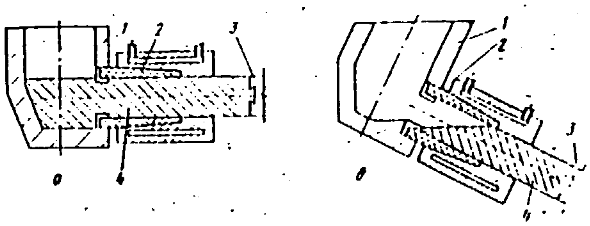
1 - metal receiver
2 - feeder
3 - mould
4 - ingot
5 - seed
6 - rolls
7 - oscillating car



a.



b.



c.

Fig. 30

a

CC horizontal type scheme

1 - metalreceiver

2 - porous stopper for inert gas metal blowing

3 - mould

4 - inductor

b

Scheme of mould filling at horizontal and inclined CC.

1 - steelteeming ladle

2 - metalreceiver

3 - protective ring

4 - graphite mould

5 - seed

c

Final teeming scheme.

1 - metalreceiver

2 - mould

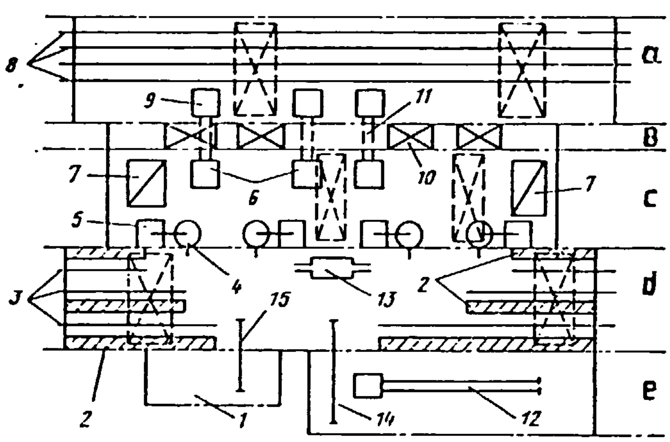
3 - seed

4 - billet

Fig. 31

Layout of electric steelmaking shop with casting into ingots and at CC.

Departments: A - charge; B - granular materials; C - furnace; D - teeming with department 1 for ladles preparation; E - shortened for CC; 2 - teeming sites; 3 - railways; 4 - electric furnaces; 5 - transformers; 6 - bays in furnace sites for baskets with scrap transportation to the operating site; 7 - electric furnaces arcs maintenance department; 8 - railways; 9 - stands for charging baskets; 10 - bunkers; 11 -railways; 12 - CC; 13 - vacuumator; 14,15 - transversal ways.



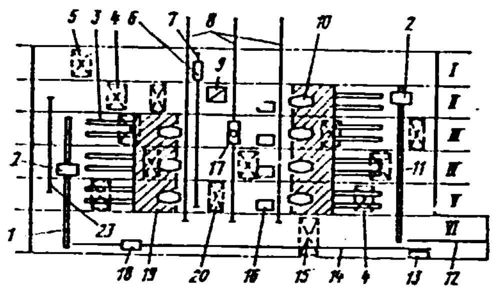


Fig. 32

Outlay and section of continuous casting department with block units location.

1,7,8,11 - transversal railways ;

2 - approach table - car;

3 - CC teeming ladle car;

4,5,15,20 - crane;

6 - car;

9 - stand for vacuum processing;

10 - rotating stand;

12 - approach table;

13 - push cart;

14,23 - railway;

16 - unit for steel blowing in a ladle;

17 - teeming ladle car;

18 - slab car;

19 - CC operating site;

21,22 - crane ways.

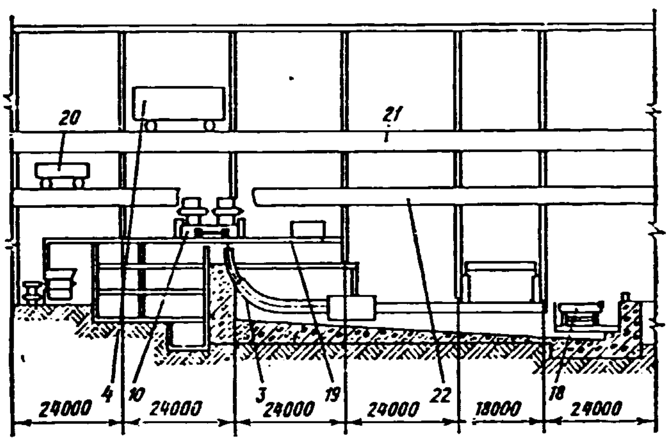


Fig. 33

Outlay and section of continuous casting department block units location.

1,7,8,11 - transversal railways:

2 - approach table - car;

3 - CC teeming ladle car;

4,5,15,20 - crane;

6 - car;

9 - stand for vacuum processing;

10 - rotating stand;

12 - approach table;

13 - push cart;

14,23 - railway;

16 - unit for steel blowing in a ladle;

17 - teeming ladle car;

18 - slab car;

19 - CC operating site;

21,22 - crane ways;

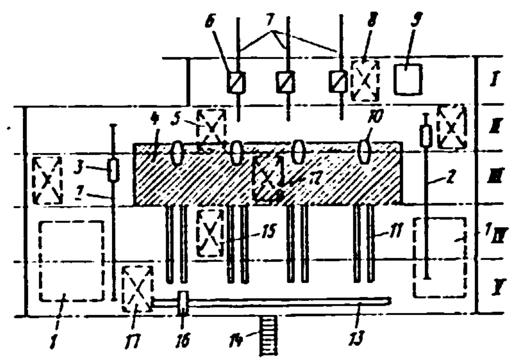


Fig. 34

Layout and section of continuous casting department with linear units arrangement.

1 - equipment maintenance department;

2 ,13 - transversal ways;

3 - cars:

4 - CC operating site:

5,8,12,15,17 - cranes;

6 - units for argon blowing:

7 - teeming ladle car ways:

8 - crane:

9 - vacuumator:

10 - rotating stands:

11 - CC approach table;

14 - approach table;

15 - car.

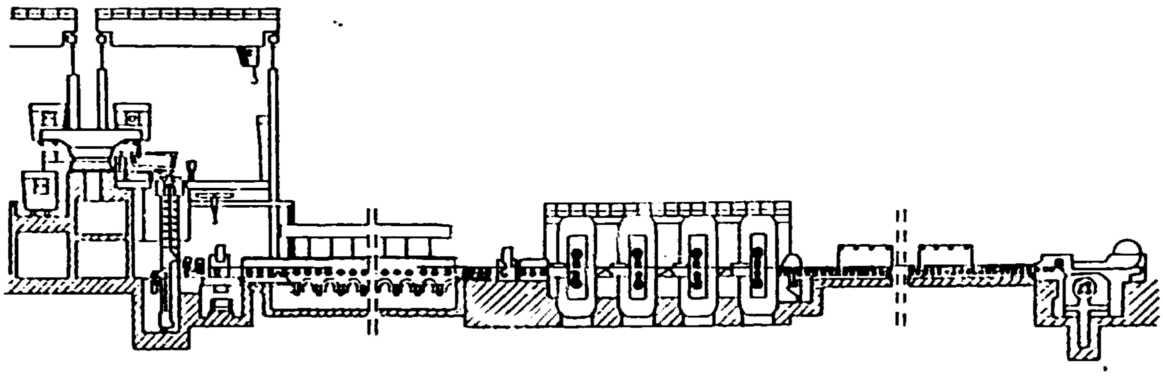


Fig 35. CC + rolling mill:
1 - CC ; 2 - Furnace ; 3 - rolling mill ;
4 - cooling.

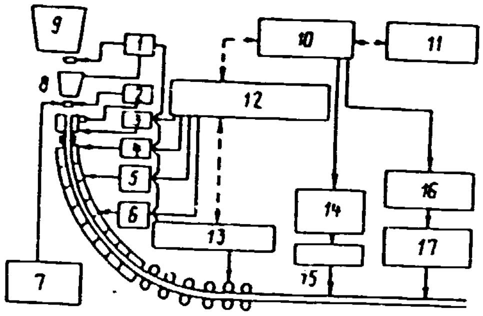


Fig. 36

CC automatization flow-chart

1 - metal mass in a tundish
2 - metal level in a mould
3 - water expenditure in a mould
4 - water distribution in a secondary cooling zone
5 - water expenditure
6 - water turn-off in a secondary cooling zone
7 - slag forming mixture supply
8 - a tundish
9 - a pouring ladle
10 - a computer
11 - a controlling computer
12 - automatic system regulator
13 - drawing speed
14 - standard length
15 - gas cutting device
16 - marking programme
17 - marking device

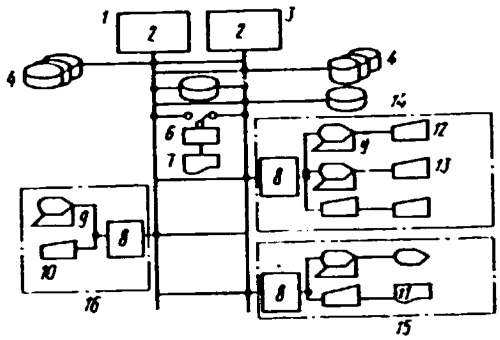


Fig. 37
Contol system hardware.

1 - vacuum processing system
2 - central computer
3 - CC and heating furnace
4 - external memory on disks
6 - 8 - input-output device
9 - displays
10 - console
11 - printer
12 - 16 - console
14 - shops
15 - by furnace
16 - vacuum chamber

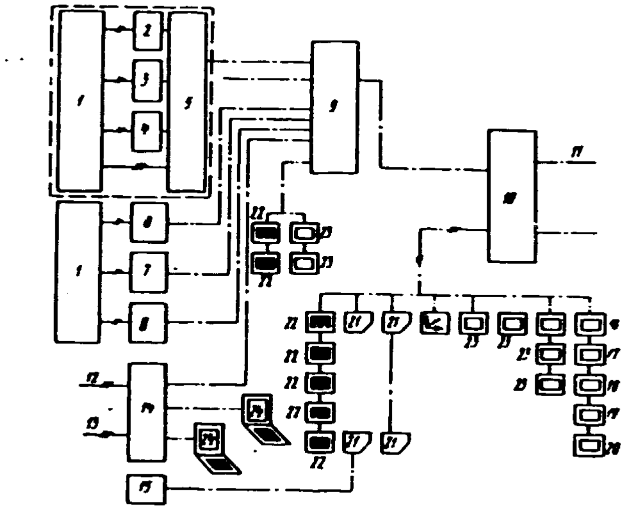


Fig. 38

Structural scheme of automatic control system and bloom CC control.

1 - electric feeding
2 - oxygen supply unit
3 - probe selection unit
4 - marking device
5 - strands control
6 - pumping device
7 - hydraulic equipment
8 - auxiliary equipment
9 - control computer
10 - display and printer control computer
11 - data from steelteeming ladle
12 - consumption, pressure and temperature measurement
13 - ventilation control
14 - devices for automatic control
15 - metal defects control
16-20 - consoles (19- quality services; 17 - by shearing;
16 - CC; 18 - master; 20 - maitenance services)
21 - printer
22 - coloured displays; 23 - black-and-white displays
24 - monitors.

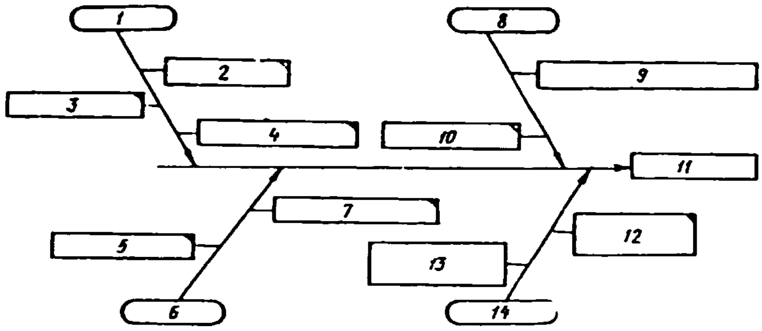


Fig. 39

Structure of "continuous casting-direct rolling" automatic control system.

1 - high temperature slabs production

2 - secondary cooling regulation

3 - metal liquid zone end position regulation

4 - slab faces heating

5 - squeezing forces in billet regulation

6 - billet quality control

7 - classification according to billet quality

8 - CC automatization

9 - CC automatization mode (start/stop)

10 - slab width change

11 - technological process parameters control and regulation

13 - oxygen converter process "continuous casting-direct rolling" coordination with hot rolling process

12 - process coordination with every slab rolling

14 - production programmes coordination

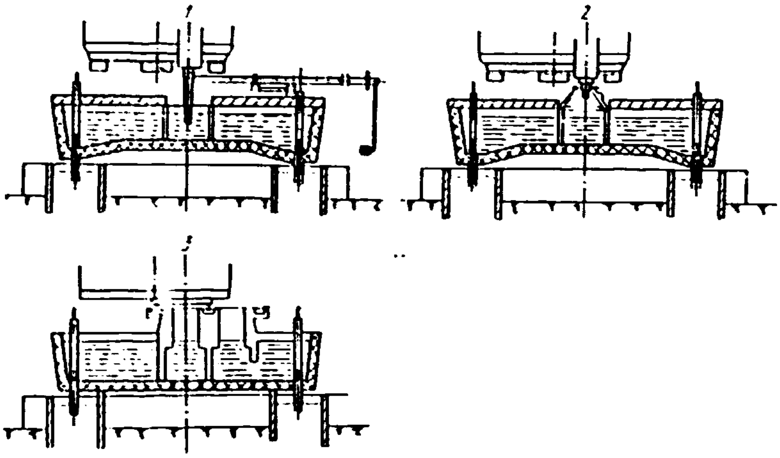


Fig. 40

Stream protection between steel-teaming ladle and tundish.

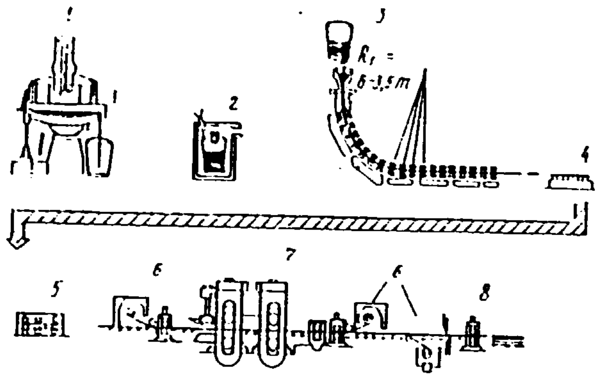


Fig. 4I

Sheet production technological line recommended by "Manesmann Demag"

1 - arc furnace
2 - ladle processing
3 - CC
4 - heat system
5 - temperature equilizing furnace
6 - coiler
7 - mill
8 -

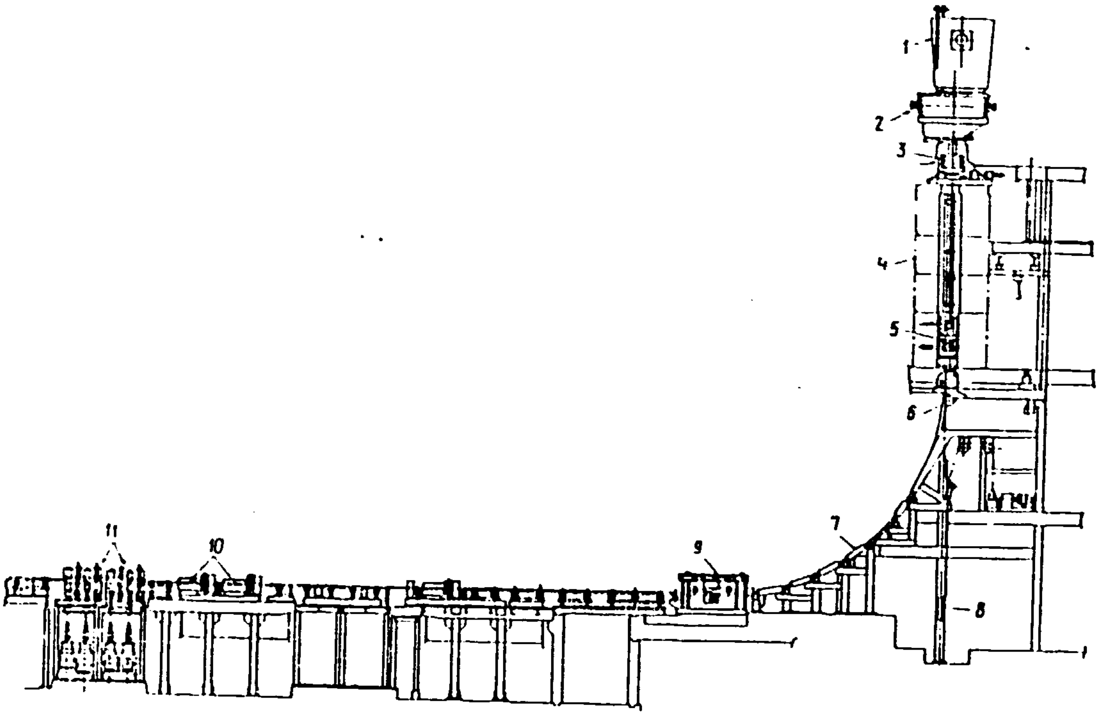


Fig. 42

Strip continuous casting unit   South Works

1 - liquid metal
2 - temperature sensor
3 - tundish
4 - lower roll
5 - upper roll
6 - cast ingot
7 - shearing unit
8 - pyrometer

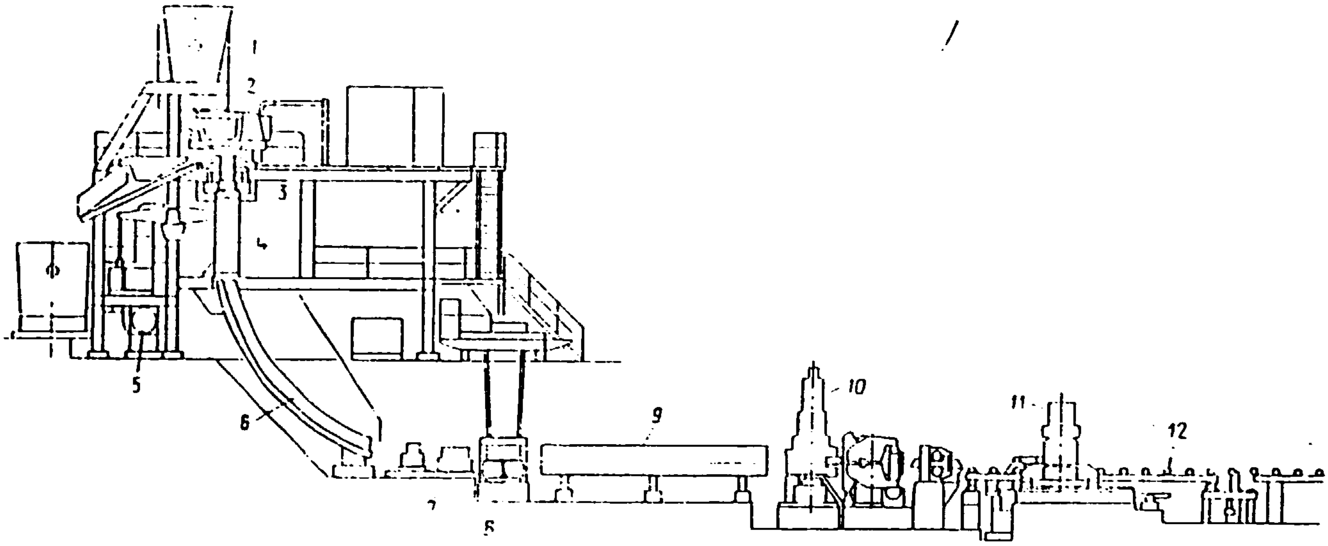


Fig.43
Strip continuous casting unit Steel Works Ltd.

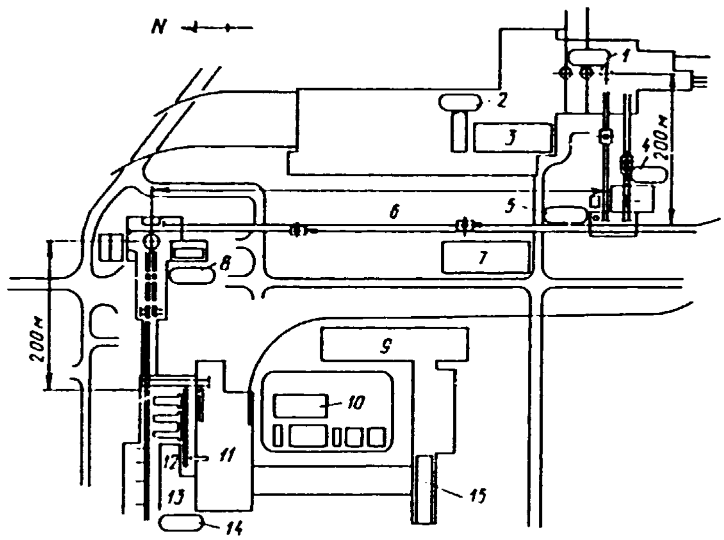


Fig. 44

CC N5 technological line at Fucujama.

1 - three oxygen converters

2 - CC N1

3 - ladle preparation sector

4 - two circulation degassing units

5 - two vacuum processing units with slag introduction

6 - steelteeming ladles transportation line

7 - reverse water supply circulation degassing units

8 - CC N5

9 - slabbing N3

10 - reverse water supply CC N5 section

11 - slab storehouse

12 - vertical descaler

13 - roughing stand N2 and N3

14 - hot rolling wide strip mill N2

15 - segments preparation sector

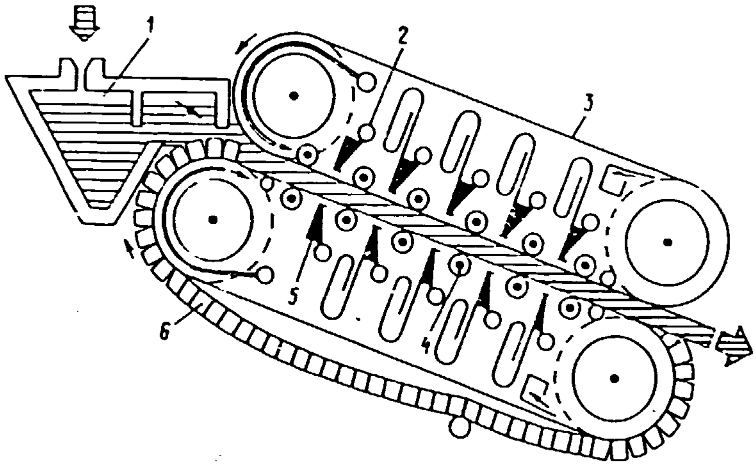


Fig. 45
Haselete unit scheme

1 - liquid metal supply
2 - water supply for cooling
3 - steel strip
4 - rolls
5 - water output
6 - densing from narrow faces sides

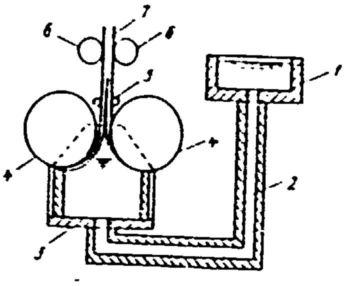


Fig.46
Steel plate continuous casting unit.

1 - upper bath with liquid metal
2 - liquid metal supply
3 - lower bath
4 - rotating rolls
5 - rolls
6 - rolling mill rolls
7 - cast billet

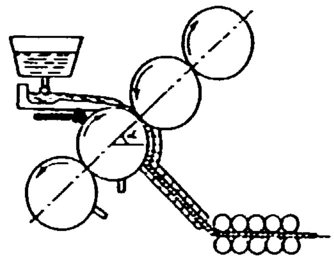


Fig.47
Strip continuous casting unit

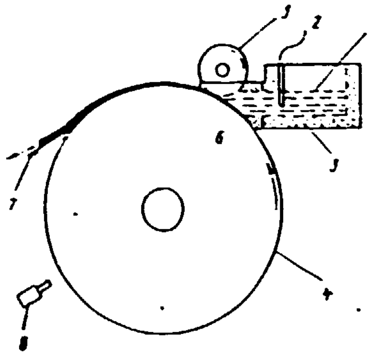


Fig. 48

Nippon Kindzoku Koge unit for strip continuous casting

1 - liquid metal liquid
2 - temperature sensor
3 - tundish
4 - lower roll
5 - upper roll
6 - cast billet
7 - cutter
8 - pyrometer

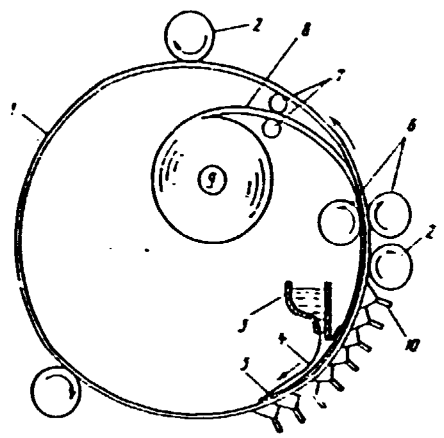


Fig. 49
Scheme of metallic strip casting onto rotating cylinder internal surface

1 - total cylinder
2 - driving rolls
3 - liquid metal injection unit
4 - injected liquid metal
5 - solidified crust
6 - squeezed and back-up rolls
7 - rolls
8 - thin strip
9 - coiler
10 - water cooling sprayers

Appendices

Appendix 1

A list of indications of different processes, steel processing methods etc., adopted by technical literature

ABS - (Aluminium Bullets Shooting) - steel deoxidation in steel method by "shooting" with aluminium "bullets" in the metal in a ladle.

AIS - (Argon Induction Stirring) - argon metal blowing in a ladle in combination with induction mixing.

AOD - (Argon Oxygen Decarburization) - metal blowing (usually in a converter) with a mixture consisting of oxygen and argon (in some cases argon is completely or partially substituted by nitrogen

AOD-CB - (Counter Blow) - metal bottom blowing in a converter with an argon-oxygen mixture at simultaneous top oxygen supply into the converter aimed at partial carbon oxide reburning.

ASEA-SKF (ASEA and SKF company) - a unit for ladle metal processing in a ladle, including equipment for vacuum metal processing when the ladle is covered with a vacuum-dense arc-lid, with equipment for covering a ladle with another arc through which electrodes for metal heating during its processing pass, and also with the inductor located round the ladle, ensuring metal stirring during its processing (vacuum processing or preheating). Vacuum processing and preheating are carried out in turn. Besides induction stirring argon bottom blowing in a ladle is to be done. High basicity refining slag is deposited onto the metal surface.

BEST (Bohler Electro Slag Topping) - the process of electroslag billet production made by Bohler method at Vereinigte Edelstahlwerke AG (Austria). After vacuum processing and top teeming into water cooled extension top a portion of liquid metal is supplied where a consumed electrode (electrode consumption 6.4% from the ingot mass) is introduced and electroslag replenishment is done. Replenishment process lasts 24 hours, segregation content and properties heterogenity are practically removed, large mass ingots are cast.

BV-method (Bochumer Verein, West Germany) - steel casting into ingot mould located in a vacuum chamber (metal stream goes through vacuum space).

CAB (Capped Argon Bubbling) - metal stirring with argon blowing the metal being under artificial slag layer in a ladle, covered with a lid.

CAB (Calcium Argon Blowing) - metal blowing process in a ladle with powdered calcium-bearing materials (e.g. silicocalcium) by argon spray.

CAD (Computer Aider Design) - design with computer.

CAS (Composition Adjustment by Sealed Argon) - processing method provided with argon bottom blowing unit, refractory chamber is lowered from the top (above the place where argon is introduced), additions are introduced through it into a metal inside the chamber, metal surface is clean from the final furnace slag.

CLU (Creusot-Loire French Company and Swedish Uddeholms Company) - low carbon steel production by oxygen + semiproduct vapour mixture, received in a conventional electric furnace, in a converter with bottom tuyers.

CPF (Combined Process Furnace) - electric arc steelmaking furnace with bottom tapping (through the bottom) by intensive arc and walls cooling, provided with powerful transformers and gas burners and isolated from the media by a chamber shell.

D-ESHF (Demag Electro Slag Heat Furnace) - reprocessing in a stationary electric arc furnace (metal tapping through the bottom) by metallized charge wide variations on carbon content and metalization degree with continuous metalcharge, by the operation with a large layer of formed slag and by special slagtapping hole in the furnace, which guarantees constant slag layer, by intensive walls and arc cooling. The process suggests the production of an item which is subjected to ladle processing.

DH (Dortmund-Horder, Western Germany) - a unit where vacuum chamber has a refractory pipe lowered through the top into the ladle: vacuum chamber (or ladle) is periodically lowered and raised then by portions metal is charged and teemed back into a ladle. In the USSR the unit is usually called cycling degassing unit.

ESR (Electro Slag Remelting)

FERROCAL - wire, containing calcium or silicocalcium or Ca + Al, covered with the shell or special coating, preventing oxidation when stored for a long period. Wire is introduced into a liquid metal with a definite speed and deoxidizes it.

GAZAL (Gas, French company L'Air Liquide) - a method worked out and licenced in 1948 in France. It is a refining method by liquid metal gas blowing through gas pemeable refractory, mounted in the bottom of the refining vessel (ladle, crucible, etc.). The definition can be usually found in literature in French.

Finkl, sometimes Finkl-Mohr (Fink and Sons Plant, USA) - unit, including a ladle with a porous stopper for bottom inert gas metal blowing (and stirring). A ladle with a metal is placed into a vacuum chamber, where vacuum processing of a metal being stirred with inert gas going from the bottom. Method variety: a ladle with a metal is covered with a lid (arc), through which electrodes for metal heating are introduced onto which surface slag of the required composition is deposited. A metal (with a slag) is stirred by the inert gas supplied from the bottom (in this variant the process is often called Finkl-VAD-process).

Injection Metallurgy, Injection (Ij) Treatment - a method of powdered materials injection into metal.

KAT-Ca (Kobe Argon Treatment - powdered calcium-bearing materials CaC_2) injection in the argon stream into a ladle with basic lining. While injecting Ca consumption is increased from 1.5 to 3.5 kg/t and makes up 2.5 kg/t in average; on the metal surface in a ladle slag with CaO + CaF_2 or CaO + Al_2O_3 + CaF_2 mixtures additions are deposited (material consumption 4.5-11 kg/t).

LD-RH-OB (Oxygen Blowing) - vacuum converter steel processing in RH unit (circulation degassing) with a simultaneous oxygen supply into a vacuum-chamber, providing decarburization intensity and also partial CO to CO_2 and metal heating during processing.

LF (Ladle Furnace) - a unit, designed for metal blowing during bottom argon (or nitrogen) blowing; a ladle is covered with a refractory lid (arc) through which electrodes are lowered for reheating. High basicity low oxidation refining slag is deposited on the metal surface in a ladle.

LF-Ij (LFIj) - metal processing in a unit of a ladle-furnace type with powdered reagents blowing into a metal.

LRF (Ladle Refining Furnace) - a process worked out by a Japanese company "Nippon Seikodze" for nuclear reactors steel production. The process includes metal smelting with a low phosphorus content (0.003% P) in a steelmelting arc furnace, metal tapping into a ladle, reteeming (with furnace slag separation) from a ladle into a unit like a ladle with a lid through which three electrodes are inserted into slag for bath reheating. By means of lime and fluospar addition (total consumption 30-35 kg/t) high basicity slag is deposited, a metal is argon bottom blown and is reheated simultaneously. Then lid-arc with electrodes is taken away and then is covered by a lid with vacuum-pump, after that it is vacuum processed when intensively argon stirred simultaneously. Metal is tapped into a tundish and is poured into ingot moulds located in a vacuum chamber. In a teeming process a metal is argon blown in a tundish.

MA-RK (Molten Al-Rimmed Killed) - a process of liquid Al supply (by means of a pump) through the pipe into an ingot mould for steel oxidation regulation during its teeming. It is worked out by US Steel Corp. (USA).

MA-RK (Molten Al-Rimmed Semikilled) - liquid Al supply through the pipe into the ingot mould to produce semikilled steel. It is worked out by US Steel Corp. (USA).

NRIM -(National Research Institute for Metals, Japan) -processes worked out by NRIM.

Perren method (worked by a french engineer Perren) - metal processing by liquid basic slags for desulphurization. In the USSR this method is called a method of metal processing with artificial slags. This metal processing method with slag tapping was first proposed in 1925 by a soviet engineer A.S.Tochinsky.

PMA (Pacific Metals Co,Ltd; Hot Alloy) technological schemes of stainless steels production on the basis of liquid initial high carbon melts of ferronickel (13-15% Ni; 2-2,5 % C) and ferrochrome (44-46% Cr; 6-7% C). Cheaper semiproducts with the increased carbon and sulphur content are usually used. Refining is done in the arc steelmaking furnace or in LD-converter, final refining - in a AOD-converter (in some cases in ASEA-SKF type unit). A finished metal is cast at CC with electromagnetic stirring unit.

PM (Pulsation and Mixing method) - refractory pipes are plunged into a metal, provided with a materials charge system in its upper part and connected (in the upper part) with gases pumping-off systems and inert gas pouring; connecting consequently a pipe cavity with the mentioned systems, change pressure and correspondingly a metal level (and its quantity) which is absorbed into a pipe, providing intensive metal stirring in a ladle.

Rapid Al Feeder (Rapid Feed) - a method of affecting a metal in a ladle by submerging an aluminium ingot into a liquid metal (the definition is suggested by Kawasaki Steel Corp.,Japan.

RH (Ruhrstahl Heraeus, Western Germany) - a unit where vacuum chamber has 2 refractory pipes, plunged into a ladle through one of which metal is raised from a ladle into a vacuum chamber, through the other flows back into a ladle (as if "circulating"). "Circulation" intensity is regulated by inert gas supply into an ascent refractory pipe. In the USSR it is called circulation degassing unit.

RH-OB process (RH, Oxygen Blowing) - metal blowing in a vacuum chamber RH - units with oxygen; sometimes is called RHO-process.

SAB (Sealed Ar Bubbling) - bottom argon metal blowing in a ladle, a refractory chamber is lowered from the top into the ladle the wall of the chamber protect ("cover") artificial slag from the contact with final furnace oxidised slag, the former being on the metal surface directly above the blowing zone. As a result a metal stirred by the bottom supplied argon intensively contacts with artificial slag of a desired composition.

SCAT (System of Calcium Adding Technique) - metal processing method in a ladle by "shooting" metal bullets from calcium-bearing (usually silicocalcium) materials deep into a metal.

Scandinavian Laucers - system or SL-process (Lance Scandinavian system) - metal blowing in a ladle through a lance lowered nearly to the ladle bottom with powdered mixtures (usually CaO + CaF_2). Gas-powder mixture passes through a lance tip into horizontally located holes.

SS-VOD (Strong Stirring VOD) - vacuum oxygen decarburization with intensive metal bottom argon blowing in a ladle (usually through a porous stopper).

TN (Thyssen Niederrhein AG plant) - calcium-bearing materials in a powdered state injection into a metal by means of a lance descended from the top.

UDDACON (Swedish Corp. Uddeholm and ASEA Converter) - gas-powdered spray injection into a metal in a unit of a converter type, equipped with a channel high frequency inductor for reheating and stirring; steel tapping is done through the hole located in the unit wall directly into the centre of the ingot mould plate (for excluding contact with the atmosphere).

VAD (Vacuum Arc Degassing) - a unit including a chamber on a self-movable carriage and a vacuum wire in a stationary arc. A ladle is transported into a chamber, metal is argon blown in a ladle (without vacuum), probes are selected, slag is pumped off, a chamber with a ladle is covered with an arc and a metal is vacuum processed. Electrodes performing a metal heating are lowered through the arc. High basicity non-oxidized slag is simultaneously deposited and argon blowing is done. Sometimes they are called Finkl-VAD units, as they resemble Finkl unit types.

VAKUVIT (Vakuum Vitkovice vacuum unit in Vitkovice plant in CSSR) - oxygen blowing of the steel surface in a ladle placed into a vacuum chamber metal is bottom argon blown; to protect a ladle from metal splashes a shell is fixed.

VAR (Vacuum Arc Remelting).

VCD (Vacuum Carbon Deoxidation) - correspondingly VCD-Praxis, VCD-processing, etc.

VID (Vacuum Induction Melting). In the USSR it is defined as VIR - vacuum induction remelting.

VOD (Vacuum Oxygen Decarburization) - oxygen metal blowing (or top blowing), a metal being under vacuum in a ladle (in a vacuum chamber).

VODK (Vacuum Oxygen Decarburization Converter) - a unit for oxygen metal blowing in a converter, covered with a vacuum lid with a to vacuum pumps, providing an opportunity to make vacuum in a converter space above metal (during simultaneous oxygen blowing).

WF (Wirefuder process, Wire Feed) - deoxidizing mixtures injection into a metal, their being located into a shell as a wire.

Appendix 2

Ladle Steelmaking Units

country, firm	unit type	put into operation year	contruction cost mln. dol.	notes	source
1	2	3	4	5	6
Great Britain	ladle-furnace	1988	-	24.000 t/week	Metal Bulletin Monthly. 1987.N194. P. 96
	ladle steel blowing	1987	-	ladle capacity 200 t	Stahl und Eisen. 1987. Bd 107.N25.26 S.16 Metallurgical Plant and Technology. 1988.N1.V.11 P.85
	Steel Refining	1988	-	24.000 t/week	Steel Times 1986.N12.P642 Metals Materials.V.4. N4.P.210
India SAIL	vacuum-oxygen decarburisation	1985	-	ladle capacity 60 t	Stainless Steel Metal Bulletin Stainless Survey.1985 P.59,61,63,64
Spain ANSIDESA	CaS unit	1987	-	output 310.000 t/yr	Fachberichte Huttenpraxis Metallweiterverarbeitung 1986.Bd 24. N5.S.426
Italy "Nova Italsider"	RH-OB unit (two)	-	16,8	-	SteelTimes. 1985.N8. P.366-384
	ASEA	1987	-	treatment time 90-95min	Fachberichte Huttenpraxis Metallweiterverarbeitung. 1987.Bd 25. N8.S.647
Canada "Algoma Steel"	ladle steelmaking unit N 1	1988	36		American Metal Market 1988. V.96 N74. P.1
	N 2	1988	20		

continuation

1	2	3	4	5	6
DOFASCO	refining in a ladle	1987	11,5 (15 mln canad.dol)	melt weight 300 t., output 2,5 mln t/yr	Metallurgia 1986.V.53. N5.P.162
STELCO	RH-OB/PB unit	1989	41,5 (54 mln canad.dol)		Steel Times Internat. 1988.V.2 n2.P.2
KNR Uhan Metallurgical Works	RH unit	1988	-	output 1mln t/yr	Metal Bulletin Monthly 1988. N201 P.97
Holand "Hoogovens"	RH-OB unit type	-	-	capacity 310 t	Review Metallurgie.1986 V.83 N4. P.323-331
USA "Betlihem Steel"	vacuum decarburization unit	1989	-	315.000 t/yr	Stahl und Eisen.1988 Bd108.N5. S.34. Metal Bulletin Monthly 1987.N203 P.111 33 Metal Producing.1985 V.23.N10 P.40-43
"National Steel"	ladle steelmaking complex	1986	16	2 mln t/yr	33 Metal Producing.1988 N2.P.22
Taiwan "China Steel"	RH vacuumator type		-	ladle capacity 250 t, output 2,4 mln t/yr	Stahl und Eisen.1985 Bd105.N22. S.12
FRG "Krupp Stahl"	RH vaccumator type	1986	-		Fachberichte Huttenpraxis Metallweiterverarbeitung 1986.Bd24. N5.S.423
"Kind und Ko Edelstahlwerke"	vacuum-inductor degassing unit		-	capacity 5t for secondary refining	Metal Bulletin Monthly 1987.N198 P.83

continuation

1	2	3	4	5	6
South Korea POSCO	furnace-ladle 20	1988	-	ladle capacity 110 t	Fachberichte Huttenpraxis Metallweiterverarbeitung 1987. Bd 25 N8 S.738

Appendix 3

Continuous Steel Casting Installations

country firm	number units	number shrouds	type of install. firm	steel-teeming ladle capacity, t.	total output, thous t./yr	constr. starts / put into operat. yr.	construct cost mln. dol.	notes	source
1	2	3	4	5	6	7	8	9	10
Australia	1	4	Bloom, "Kobe Seikosc"	-	2000	1985 / mid.1987	64	-	Steel Times, 1988.v.213, N5.P.234
	2	1	Slab, "Shleman-Ziman"	300	2500	1985 / 1987	104	200-300x 1250-2200 mm	Metal Bulletin, 1985 N6962.P.29 Steel Times International. 1987.v.11 N3.P.4
Austria "Eisenwerk Breitenfeld"	1	4	Billet, low height "Fest-Alphine"	-	80	- / 1986	-	billet 140x 180, 100x 100, 120x 120mm	Express-data/In-t Chermetinf, 1987.Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.5
Argentina, "Asindar"	1	2	Slab,	-	-	- / 1988	-	thin slab prod. 150x 150, 220x 290, 2200mm	Metal Bulletin, 1987 N202, P.115
	1	2	Bloom	-	-	- / 1987	-		Metal Bulletin. 1987 N7153, P.19
Bangladesh "Rahim Steel Mills"	1	1	Billet-bloom "Contact"	6	-	- / 1986	-	Carbon steel casting	Catalogue N10184, P.6

continuation

1	2	3	4	5	6	7	8	9	10
Belgium "Usines Gustave Boel"	1	1	Curve-line "Shleman-Ziman"	-	600	1985/1986	-		Metal Industry News. 1985. v.2, N3.
Brazil "Mannesmann"	1	3	Radial bloom "Mannesman-Demag"	-	400	–/1986	-	bloom squard 170, 194, 230	Express-data/In-t Chermetinform." 1987. Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23. P.5
"Kosipa"	1	1	Slab "Contact"	130	600	–/1987, august	250 3inst	slab 260x 1900	Concast Technology News. 1988. N1. v.27. p.2
	2	1	the same	130	1200	–/1988		slab 180x 1000 300x 1990mm from carbon and low alloy steels	
"Company Siderurgica di Tubaran"	1	2	slab	-	2000	–/1989	150-170		Metal Bulletin. 1986. N7127. P.23
"Kofavi"	1	4	billet bloom "Contact"	80	300	–/1987 february	-	sorted billet 100x 100; 160x 160mm from carbon steels	"Ferrous Metals". N11. P.44 Catalogue N10184. P.8
"Siderurgica I.L. Aliperti"	1	4	billet bloom "Contact"	50	-	–/1988	-	carbon and low alloy steel	Catalogue N10184. P.8

continuation

1	2	3	4	5	6	7	8	9	10
"Company Siderurdgica Belgu-Minera"	1	-	-	-	400	1987 / -	350-400 (total capital investment progr		Ferrous Metals, 1987. N24.P.38
Great Britain BSC	1	3	radial	80	300	- / 1986	-	round billet diam. 310, 380, 430mm	Express-data /In-t Chermetinform. 1987. Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.5
"Llanyarn"	1	2	slab BSC	130	-	- / 1988 april	-	254x 1550mm from carbon steel	Ferrous Metals.1986 N12.P.46 Stahl und Eisen.1988 N11.P.12
"Hanteg"	1	3	billet "Engineering contracting"	19	40	1985 / 1988	7,5 (£4)	round and square billet	Ferrous Metals.1987 N5.P.41 Steel Times.1986 N12.P.642
Venezuela "Sidetur"	1	4	billet "Contact"	75	-	- / 1988	-	square 100-150mm from carbon steel	Catalogue N10184.P.8
Egypt "Alecsandria national Steel"	3	4	billet	-	800	1983 / 1986	-		Steel Times Internat. 1986.v.10 N3.P.38
"Egyptian Copper Workes"	1	4	billet bloom "Contact"	50	-	- / 1986	-	carbon steel	Catalogue N10184.P.8
"Egyptian Iron and Steel"	1	-	slab "Fest-Alpine"	-	500	- / 1990	-		Stahl und Eisen.1988 Bd 108,N9 P.18

continuation

1	2	3	4	5	6	7	8	9	10
India "Steel Strips"	1	2	billet bloom "Contact"	17	–	– / 1986	–	carbon and low alloy steel	Catalogue N10184.P.6
"Surrendra"	1	2	billet bloom "Contact"	10	–	– / 1987	–	carbon steel	Catalogue N10184.P.6
"Somani Ferro Alloys"	1	2	billet bloom "Contact"	15	–	– / 1987	–	carbon and low alloy steel	Catalogue N10184.P.6
"Indian Steel Rolling Mills"	1	1	billet bloom "Contact"	7	–	– / 1987	–	carbon steel	Catalogue N10184.P.6
"Chundiwala Steels"	1	2	billet bloom "Contact"	17	–	– / 1987	–	carbon and low alloy steel	Catalogue N10184.P.6
"Shri Jahar Alloy Steels"	1	3	billet "Contact"	40	–	– / 1989	–	square 150-200, carbon alloy corrosion-resistant steels	Steel Times Int. 1988.v.12 N1.P.11
"Partar Ragasthan Special Steels"	1	2	billet "Contact"	25	–	– / 1986	–	carbon low-alloy steels	Catalogue N10184.P.6
"Bhushan Industrial	1	2	billet "Contact"	23	–	– / 1986	–	square 80-130mm carbon steels	Catalogue N10184.P.6
	1	1	billet "Contact"	25	–	– / 1989	–	billet 130x140mm carbon steels	Concast Technology News.1988. v.27.N2. P.8
"Allied Steels"	1	2	billet "Contact"	24	–	– / 1986	–	carbon low-alloy steels	Catalogue N10184.P.6

Continuation

1	2	3	4	5	6	7	8	9	10
"Bhatria Electric Steel"	1	2	billet bloom "Contact"	14	–	–/1986	–	carbon low-alloy steels	Catalogue N10184.P.6
Indonesia "P.T. Master Steel"	1	4	billet "Contact"	36	–	–/1988	–	square billet with side 80,140mm mass up to 36 t.	the same
Spain "Marcia Usin"	1	6	slab-bloom "Contact"	80	–	–/1986	–		Catalogue N10184.P.10
"Echevarria"	1	6	billet bloom "Contact"	100	–	–/1986	–	alloy steel	Catalogue N10184.P.10
"Olsa"	1	1	horizon. billet "Nippon Kokan"	–	120	–/1986	–	billet from corrosion-resistant steel square 145, 125mm	Express-data. /In-t Cher metinform. 1987.Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.6
"Ensidesa"	2	2	billet "Demag"	250	2400	1986/1988	128		Stahl und Eisen.1988 Bd 108.N1. P.14
Sestao	1	–	slab	–	750	–/1986	62		Metal Bulletin Monthly.1986. N181.P.7-19
"Altos Hornos de Vizcaya"	3	1	slab	110	2600	–/1985-86	162		Metal Bulletin Monthly.1986 N181.P.7-19
"Pedro Orbegoso"	1	4	billet bloom "Contact"	75	–	–/1986	–	alloy steel billet 220x 180mm	Catalogue N10184.P.8

continuation

1	2	3	4	5	6	7	8	9	10
"Patricic Echevarria"	1	2	bloom "Krupp"	-	110	1986/1988 (has been built for 18 mo.)	22 (35 mln m.)	bloom 240x 310mm from special steels	Metal Bulletin.1988 N7263.P.25
Italy "Lucchini Siderurgica"	1	5	sorted billet	100	-	-/1988	-	billet 140x 140mm 160x 300mm from carbon steels	Ferrous Metals.1987 N11.P.45
Breshia	1	4	sorted bloom "Contact"	80	-	-/1988	-	160x 160- 160x 300mm from alloy steels	Ferrous Metals.1987 N11.P.45
"Cogea"	1	8	billet bloom "Contact"	-	-	-/1986	-	billet with square side 127, 140, 160mm	Stahl und Eisen.1986 Bd.106.N19 P.26
"Italsider"	1	-	slab	-	-	1985/1986	126	slab thickness up to 240mm	Stahl und Eisen. 1986.Bd.106 N21.P.14
SETA	1	5	bloom "Fest-Alpine"	-	500	1984/1986	-		Express-data./In-t Chermetinf. 1987. Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.5
"Terni"	1	1	slab "Fest-Alpine"	150	450	-/1987	15	slab width 700-1600mm 165-250mm	Ferrous Metals.1987. N24.P.35-40

continuation

1	2	3	4	5	6	7	8	9	10
"Delta-sider"	1	6	radial "Fest-Alpine"	-	500	-/1986	-	round billet diam. 120mm	Express-data./In-t Chermetinf. 1987. Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.6
Canada "Atlas Steels"	1	3	billet "Darieli"	80	270-360	-/1987	9,2 (12 mln canad. dol.)	square billet with side 100, 200mm	Steel Times Int. 1987.v.7. N2.P.18
DOFASCO	1	2	slab vertical "Demag" "Hitati Josen"	272-325	2000	1985/1987 december	150		Stahl und Eisen.1988 Bd.108.N8 P.12 Iron and Steel Eng. 1986.v.63 N8.P.17-23
STELKO	2	2	bloom -slab	-	1900-2200	-/1988	350		
IPSCO	1	1	slab	-	800	1984/1987	25		Iron and Steel Eng. 1988.v.65 N2.P.D-14
KITE	1	4	billet "Rocop"	-	400	-/1986	-		Metal Bulletin.1985 N7002.P.27
"Sydney Steel"	1	3	"Contact"	125	-	-/1989	-	square 292, 381, 432mm	Concast Technology News.1988. v.27.N1.P.7
Colombia "Fundente"	1	2	billet "Contact"	15	-	-/1989	-	square 100-130mm carbon steels	Concast Technology News.1988. v.27.N2 P.8
KHR	1	1	slab "Demag"	-	280	-/1986	-	slab width 700-1200mm 180mm thickness	the same

Continuation

1	2	3	4	5	6	7	8	9	10
Handan	1	1	slab "Demag"	-	240	– / 1986	-	slab 650-1200x150mm 700-1200x180mm	Express-data./In-t Chermetinf. 1987.Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.7-8
Works Shoudu	2	8	sorted billet "Contact"	210-235	1500	1985 / 1987	18	square billet with side 100-120mm length 12-14m	Tool and Alloy Steel.1986 v.20. N 3. P.23 Met.Bullet. 1988. N7246.P.23
Works Shanhai	1	2	slab radial "Fest-Alpine"	20-30	400	– / 1986	-		Express-data./In-t Chermetinf. 1987. Ser. Steel and Ferroalloy Production Refractory Production and Ferrous Metal Scrap Preparation N23.P.7
Works Yok	1	3	billet "Sumitomo"	-	80	– / 1987 November	-	billet 140x140; 140x180; 150x200mm	Sumitomo Metals.1988 N18.P.7
Works Chanda	1	4	billet "Contact"	40	-	– / 1988	-	square billet with side 100-120 from carbon low alloy steels	Steel Times Int.1988. v.12.N1.P11

continuation

1	2	3	4	5	6	7	8	9	10
Mexico "Siderurgica Lazaro 3 Cardenas"	3	2	slab "Demag" "Hitati Josen"	-	2000	1984/1986	-		Metal Bulletin. 1985 N6984. P.23
Tamsa"	1	5	billet "Demag"	-	600	1985/1987	140 (with elect. furnace)	round billet for	Metal Bulletin. 1985 N6998. P.27 Fachberichte Huttentechnik, Metalleiterverarbeitung. 1987 N7. P.609
Netherlands "Hoogovens"	1	2	slab "Demag"	100	2400	1985/1986	169	slab thickn 250mm width 1950-2100mm	Steel Times 1987. v.215 N1. P.2
	2	6	billet "Contact"	110	1000	1985/1987	-	carbon alloy steels	Catalogue N10184. P.11 Concast Technology News. 1987 v.26. N3. P.1
Aimaden	2	2	sorted "Demag"	-	2600	-/1987	27,4		Stahl und Eisen. 1987 Bd.107. N1 P.115
New Zealand "New Zealand Development"	1	6	billet "Contact"	70	-	-/1986	-	carbon low-alloy steels	Catalogue N10184. P.11
Pakistan "Itterfag Foundries"	1	3	billet "Contact"	40	-	-/1986	-	carbon steels square billet with side 150mm	Catalogue N10184. P.8
"Pakistan Steel Mills"	1	6	billet "Fest-Alpine"	-	500	-/1989	-		Stahl und Eisen. 1988 Bd.108. N9 P.20.
Paraguay "ACEPAR"	2	2	billet	-	240	-/1986	-		Metal Bulletin. 1986 N7055. P.22

continuation

1	2	3	4	5	6	7	8	9	10
Portugal "Siderurgica National"	3	6	billet-bloom "Contact"	130	1100	– / 1988	–	carbon steels	Catalogue N10184 P.11
USA "Birmingham Steel"	1	3	–	18	–	– / 1986	–	carbon steels	33Metal Producing 1987.v.25 P.38-42
"Betlechem Steel"	2	1	slab-bloom "Fest-Alpine"	250	2600	– / 1986	250	personnel 100	Iron and Steel Eng. 1985.v.62. N4.P.62
"Burns-Harbor"	1	2	slab	270	2000	– / 1986	–	personnel 100	33Metal Producing. 1987.v.25 P.38-42
"Connecticut Steel"	1	2	radial "Contact"	27-30	225	– / 1988	–	carbon low-alloy steels	Metal Producing.1987 v.25.N.2 39-42 Metal Prod. 1987.v.25 N5 P.38-42
"North Star Steel"	1	3	billet	81	360	– / 1986	–		33Metal Producing 1987.v.25 N5.P.38-42
"Inland Steel"	1	1	slab	220	1290	– / 1986	–	carbon low-alloy steels	Amerikan Metal Market.1986. v.94.N2P.1 33Metal Pro 1987.v.25 N5.P.38-42
"Chapparral Steel"	1	2	horizontal	135	180	– / 1987 December	–		Iron and Steel Eng. 1988.v.65 N2.P.D-21
"Milton Manufacturing"	1	3	billet	20	180	– / 1986	–	carbon steels	33Metal Producing 1987.v.25. N5.P.38-42

continuation

1	2	3	4	5	6	7	8	9	10
"National Steel"	1	2	slab "Contact" "Sumitomo"	–	2200	– / 1987	–	slab thickn 240mm width over 1880 mm length 5,9-9,0m pouring rate 1,8m/min	Concast Technology News.1988 v.27.N1.P.3
	1	2	slab	163,213	2000	– / 1987	–		Iron and Steel Eng. 1988.v.65 N2.P.D2-4
"Newcor Steel"	1	3	billet	100	594	– / 1988	–		33Metal Pr. 1987.N.5 P.38-42
Norfolk	1	3	billet -bloom	45	270-360	– / 1988	–	carbon steels	Iron and Steel Eng. 1988.v.65 N2.P.D-21
Krofor-dovill	1	1	"Mannes-mann"	–	820	1986 / 1989	–	width 1350mm	Ferrous Metals. 1987.N1. P.47 Ironmaking and Steel-making.1988 v.15 N3. P.119.
"Rouge Steel"	1	2	slab "Demag" "Hitati Joden"	232	1600	1984 / 1986	130		Metal Prod. 1987.N5. P.38-41
USX	1	–	slab	–	2800	1986 / –	200		Ferrous Me. 1987 N24. P.40-41
Ferfild	1	2	slab	–	1700	– / 1989	200		Iron and Steel Eng. 1988.v.65 N2.P.D-4
Gary	2	2	slab curve-line "Contact"	–	2970	1984 / 1986	300	personnel 156 with ladle steel process. person.	Sumitomo Metals News 1986. N15. P.2 Iron and Steel Eng. 1986.v.63 N8.P.D24-29

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1	2	3	4	5	6	7	8	9	10
i. Taiwan "China Steel"	1	2	slab radial "Contact"	250	2400	1985 / 1987	34	pouring rate 2,0 m/min	Concast Technology News. 1988 v.27. N1. P.4 Stahl und Eisen. 1988 B 108 N11 S15
Thailand "GS Steel"	1	2	billet -bloom "Contact"	20	-	- / 1987	-	carbon steels	Catalogue N10184 P.6 Ferrous Me. 1987. N2 P. 25-26
Turkey "Izmir Demir Chelik"	1	4/5	radial billet "Contact"	75	450	- / 1987	90 whole complex	billet with side 100-140mm	Ferrous Me 1987. N18 P.40
"Chebi-tas"	1		billet	-	310	1987 / -	-		Metal Bulletin. 1988 N7265. P.26
"Kukurova Chelik Idastrisi"	2	6	billet -bloom "Contact"	90	-	- / 1986	-	carbon steel	Catalogue N10184. P.1
"Akinsiler"	1	-	sorted	-	400	- / 1988	30 (with elect. furnace	100x 120mm	Metal Bulletin. 1987 N7174. P.21
"Habas Industrisi"	2	5/6	billet -bloom "Contact"	80	600	- / 1987	-	100x 100, 120x 120mm carbon steel	Catalogue N10184. P.11 Ferrous Me. 1987. N6-7 P.80
"Sivas Demir Chelik"	1	5/6	billet "Contact"	90	450	- / 1989	-	square billet with side 100-160mm	Concast Technology News. 1988 N1. P.4
Philippine "Armstrong Industries"	1	2	billet -bloom	12	-	- / 1987	-	carbon steels	Catalogue N10184. P6

continuation

1	2	3	4	5	6	7	8	9	10
"SKK Steel"	1	2	billet "Contact"	25	–	–/1988	–	square billet with side 130mm from carbon steels	Steel Times Int. 1988.v.12 N1. P711
Finland "Ovako Steel"	1	2	bloom curve-line "Demag"	-	350	–/1989	120 (600 mln fin.m.	280x 350mm	Fachberichte Huttentechnik, 1987.v.25 N8.S.744
France "Societe Metallurgique de l'Escaut"	1	4/5	billet-bloom "Contact"	80	–	–/1986	–	carbon alloy steels	Catalogue N10184.P.8
FRG "Klockner Stahl"	1	6	slab-bloom "Contact"	125	720	–/1987	–	165x 165; 200x 240mm	Stahl und Eisen.1987 Bd.107.N9. P.12 Concast Technology News.1987 v.26.N3.P.3
"Hesh Stahl"	1	1	slab curve-line "Shleman-Ziman"	175	2000	1984/1986	29		Fachberichte Huttentechnik Metallwaiter 1987.N7. S.611
Sweden SSAB	1	1	slab "Demag"	-	800	–/1989	95 (150 mln m)	slab width 1700mm	Ronstoff Rundschau. 1987.N 27 S.738
RSA ISCOP	1	2	slab curve-line "Fest-Alpine"	155	1700	1985/1987	62 (120 mln		Metal Bulletin.1987 N7187.P29
S.Korea POSCO	2	2	slab curve-line "Demag" "Hitati Josen"	250	2700	1984/1987	119	slab 230x 820mm	Steel Times Int.1987. N2.P.20-21 Ferrous Me 1987.N11. P.45

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1	2	3	4	5	6	7	8	9	10
Pohang	1	2	slab curve-line "Fest-Alpine"	330	2000	1984/1986	29		Stahl und Eisen.1987 Bd.107.H8. S.12,14
"Sammi Steel of Seul"	1	1	billet-bloom "Krupp"	30	150	1987/1988	-		Steel Times Int.1986 v.10.H3.P.7
"Kang Won Industrial	1	5	billet "Krupp"	-	450	-/1988	13 (20 mln.m)	square billet with side 120-200mm	Metal Bulletin.Monthly.1987 H12.P.11
Japan "Kobe Seikose"	1	1	slab curve-line H4	80	1200	1987/1989	138 (17 mlrd	slab width 600-800mm thickn. 230mm	Steel times Int.v.12 H1.P.4

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