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TERMINAL REPORT

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TERMINAL REPORT

Prepared by
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for the Government
of Arab Republic of EGYPT

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ABSTRACT

The analysis of production at the Helwan Iron and Steel Works has shown that the BOF shop operates under objectively severe conditions: because of the increased amount of manganese and phosphorus content in hot metal the use of the double-slag process is required. In case of the lack of advanced methods for the process measurement control it leads to recurrent breaks in production rates and breakdown in the developed and applied technology and to violation of technological istruction.

According to statistical data the amount of defective slabs and billets related to their injury because of blow holes, slag inclusions, cracks and so on achieves 20%. Expert assessments carried out within the framework of the present study (famous scientists and practical specialists of the USSR and ARE in the field of steelmaking were involved as experts) made it possible to suggest assumptions on the character of these defects. The analysis of the technology existing at the Helwan works has shown that defects are caused by substantial variations in the composition of initial charge materials, disadvantages of the applied technology for steel melting and continuous steel casting and, in some cases, by its violation. All this is accompanied by marked overheating of the metal at the final stage of oxygen blowing and by intensification of secondary oxidation processes. Formulated conclusions have been proved by means of specially conducted experiments.

A modern concept has been developed at the works for the application of process control computing of BOF in order to improve qu-

ality of manufactured products. However, this concept has not been yet widely introduced into practice.

On the basis of the analysis made with the use of expert assessments two groups of actions are proposed for a reduction in rejects: the first group which allows to reduce the defects without any substantial capital investments, and the second one which involves considerable changes in the process technics and requests essential investment. An improvement in the technology of steelmelting and work out of organizational arrangements for the control of its realization are related to the first group of measures. The second group involves minimization of the number of afterburnings and finally - a transition to the single-slag process due to the introduction of methods for ladle refining of hot metal and steel.

In conclusion, an analysis of opportunities for the production of alloyed steels in the BOF shop at the Helwan works has been made. Thus, it is proposed to produce low-carbon manganese-bearing tube steel, medium-carbon chrome-bearing structural steel and low-carbon aluminium alloyed cold-rolled steel sheets for deep drawing. Possibilities of technological alternatives for the production of these steels have been also considered.

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/UNIDO pub/. /Final report/ on assistance to the Helwan /iron and steel industry/ in /Egypt/ — covers (1) operations at the basic /oxygen/ /furnace/ (BOF) shop (2) problems of /metals/ production quality and its control; methods of improvement (3) technology of /steel/ making and its /quality control/ at the Egyptian Iron and Steel Works (EISCO) (4) methods of improving steel quality in the existing production; use of /computer/s for /process control/. /Recommendations/, /statistics/, /diagram/s, /bibliography/.

/Additional references: /metallurgy/, /alloys/, /computer-aided manufacture/. /Restricted/.

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INTRODUCTION

EISCo is the leading steel company in the country. At present the Plant is the main steel producer for reinforcement and multipurpose tubes. However, industry development in Egypt constantly demands both steel melting increase and its quality increase. In this respect the current situation cannot be acknowledged completely satisfactory. The produced steel quality does not always correspond to the increasing consumer requirements and the continuous casting billets defects are essential.

The problem of the steel quality improvement and defects decrease can be solved in the following ways:

- the existing technology improvement. It does not require considerable capital investments and can be realized within a short time period;
- the reconstruction of the existing units and construction of new ones, it being connected with sizable capital investments;
- carbon steels production substitution for low-carbon steels production.

This will make possible to decrease production metal capacity at the expense of operating properties improvement.

According to the stated above there arises the following problem: to study the conditions of modern steelmaking technology in BOF; to find out high rejection percentage reasons; to determine defects protection measures; to lay down definite measures of steel quality improvement.

This contract was implemented within UNIDO Project N SI/EGY/88/802.

MISA team executing the contract consisted of the following experts:

G. Surguchev - team leader, computer quality control.

A. Vishkarev - quality expert.

A. Timofeev - technician expert.

The contract implementation started on December 9, 1988 and comprised the following stages:

Field work - 3.5 man/month

Home office work - 2.0 man/month

Briefing and debriefing - 11 man/day

The following operations have been done while implementing the contract:

- international literature and publications analysis,
- contract purposes identification and quality improvement methods on the latest publications basis,
- existing technology and quality control methods examination.

Specialists from several organizations rendered support and help in the contract process and during debriefing preparation and discussions:

UNIDO, Viena:

Mr. Ju. Grebtsov - SIDO Metallurgical Branch.

Mr. S. Morozov - Chief Contract Section (DA/PAC).

UNDP office, Cairo:

Mr. Torwat Sabry - programming officer.

EISCo, Cairo:

Mr. Dia El Tantawi - Chairman.

Mr. Kamal Abdel Latif - General Director of Steel Sector.

Mr. Kamal Abdel Geward - Manager of Process Control Centre.

Mr. Yousef Ashour - Quality Control Director.

Mr. Mohamed Shakour - Manager of Steel Quality Control Sector.

Mr. Sabry Abd El-Baky - Director of Steel Production.

Mr. Ahmed Ehson - Manager of BOF.

El Tobin Institute for Metallurgical Study:

Mr. Mahmud Selim - Rector.

Mr. Mohammed Abdalla - Doctor of Science, Head of Steel Department.

MISA:

Mr. Ju. Zheleznov - Rector.

Mr. S. Bakuma - Manager of Research Sector.

We are extremely grateful to all of them and other people we couldn't have mentioned.

2. FINDINGS AND RECOMMENDATIONS

1. It was found by the analysis of steel production that rejects level, (amount of defective slabs) at EISCo's BOF plant is extremely high and reaches 20%.
2. Analysis of the existing technology of steel products shows that technological instability generally produced a large amount of defects (cracks, blow holes, slag inclusions etc.). This is a result of considerable metal overheating in a converter; intensive secondary oxidation processes during metal tapping ladle steelmaking and continuous steel casting. Technological stabilization and protection from secondary oxidation enables to reduce rejects and to enhance steel ingot quality.
3. To determine the nature of any defects that may occur in every practical situations a detailed research should be carried out. This research reveals the influence of different technological factors on defect occurance. As a result it will enable to work out more carefully and to introduce methods and techniques for overcoming these losses.
4. To stabilize the technology of steelmaking and to provide optimum t^o before tapping it is recommended:
   - 4.1. To elaborate and introduce a system of charge calculation of the melt according to input parameters (iron composition and t^o , lime quality etc.). It enables to use an optimal scrap/hot metal proportion to provide the absence of metal overheating and a desired tapping temperature.
   - 4.2. From economic point of view to consider a problem of rea-

sonable increase of the scrap charge in a converter melting. From technological point of view the increase of scrap charge will improve heat balance and will provide the regulation of tapping temperature.

4.3. To provide a modernization of converter with a safe system controlling oxygen expenditure per melt. It will enable to make a heat according to oxygen expenditure but not the time of blow. Thus a number of overheated melts would be reduced.

4.4. The analysis has shown that oxygen pressure fluctuations exceed the admissible limits. It is required to provide stable oxygen pressure not less than 1.5 MPa (in front of the nozzle - not less than 1.0 MPa).

4.5. To ensure normal furnaces operation for lime calcing to provide calcium oxide content not less than 85%. It will enable to make deeper desulphurization and dephosphorization in converter, therefore it will reduce the quantity of heat with reblowing.

4.6. To introduce iron desulphurization that will generally enable to eliminate reblowing as a result of high sulphur content.

5. To prevent secondary steel oxidation it is recommended to change ladle and continuous casting technology a proper way.

5.1. To ensure a complete slag cut-off during metal tapping from a converter with one of the existing techniques (e.g. with the application of a stopper as a lined iron ball). To facilitate and improve a stopper it is reasonable to add lime stone to slag before metal tapping from a converter. Besides the protection from secondary oxidation this operation will enable to eliminate further rephosphorization reaching at present 0.015%.

5.2. Steel casting in continuous casters should be carried out "submerged" using refractory tube that will enable to avoid atmospheric contact with the metal stream.

5.3. To provide protective slag into a mould, the slag will also create garnisage on the slabs surface. In its turn it will result in the reduction of a number of such defects as non-metallic inclusions. It is reasonable to increase tundish capacity.

5.4. To set up and introduce technological instructions of metal oxidation control before deoxidation for determining deoxidation expenditure. To produce final deoxidation only on argon station with inert gases blowing in a ladle.

6. To fulfill the above formulated recommendations it is required:

6.1. To reconsider and specify technological instructions of melting, secondary steelmaking and continuous casting of different grades of steel.

6.2. To ensure complete and absolute implementation of technological instructions.
Quality control of the given technology must be strictly observed at all stages at the steel shop.

6.3. To impose obligations on the quality control services to check strictly the observance of the approved technology at all stages of iron and steel production.

7. The review of advanced approaches for improving the quality shows that the introduction of the computerised process control system into the BOF steelmaking is an important factor contributing to quality improvement. The optimization of pro - cess conditions, in particular metal's temperature during tapping and in subsequent stages, determination of optimal continuous casting and secondary cooling rates promote the production of high-quality billets.

7.1. It was found out that an advanced concept of computer application for solving a wide range of problems has been developed at EISCo.

7.2. Installation of the BOF control system for the realization of a statistical model is an important point in realizing this concept. The system is able to predict the carbon content with an accuracy of 0.3% and the metal temperature with an accuracy of ± 15° C in 93.4% of total melts. Moreover, the system calculates parameters of the melt only up to the moment of the first slagging. The today operating system is unable to provide the calculation of process parameters during second stage at the process after slagging; so its influence on quality improvement of end product is rather restricted.

7.3. It should be assumed that a progress in the development of the process control system in the direction of using a dynamic model will improve the quality inspection and control if the accuracy of temperature predictions will be about ± 10° C.

8. During further development of the computer-aided technology, in particular for metal quality improvement, the following steps are recommended:

   8.1. To design and install a computerized control system for continuous casting, especially for calculating a required metal temperature before steel casting, as well as casting rates and secondary cooling conditions.

   8.2. To design and install a computer-aided system for control of the ladle steel refining process.

   8.3. To design a subsystem for synchronizing operations of converters and continuous casters to minimize time and heat losses between the converter and continuous caster.

9. The analysis of ARE demands in alloy steels and the possibility of their production by the BOF process allows to recommend:

   9.1. Manganese and silicon alloyed low-carbon steels (carbon content below 0.20%) - for the production of tube steels;

   9.2. Chrome alloyed medium-carbon steels (carbon content 0.20-0.40%) - for the production of structural steels;

   9.3. Aluminium alloyed low-carbon steels (carbon content not more than 0.10%) - for the production of cold-rolled steels for deep drawing.

10. To arrange the production of alloyed steels it is necessary to realize the following:

    10.1. To undertake measures which will ensure the metal protection from the secondary oxidation (BOF slag cut-off and casting under the metal level), i.e. to strictly fulfill the recommendations mentioned in clauses 5.1-5.4.

10.2. To make provisions for close control of temperature conditions by the comparison with conventional carbon steel production.

10.3. The process technology of tube and structural steel grades production must provide the following:

- preliminary metal desulphurization,
- converter metal blowing for obtaining low-carbon content ~ 0.08 - 0.10%.
- subsequent metal carbonization (if necessary) in the ladle by additions of coke breeze and graphite,
- homogenizing treatment of the melt with argon on the argon station,
- for improving steel quality and increasing their service performances it is recommended to develop a technology of their melting with vanadium, titanium, niobium microalloying as well as modifying treatment with calcium-containing materials.

10.4. In the production of cold-rolled steels for deep drawing it is recommended:

- to make blowing of ... metal in the converter for obtaining low-carbon content,
- to make provisions for reducing nitrogen content in steel, therefore aluminium additions in the process of metal tapping must be minimum and defined with the account of preventing the metal from the secondary oxidation, and additions of limestone should be introduced onto the ladle bottom before tapping.

- metal alloying with aluminium should be performed on on the stand with the use of argon rate control trying to follow the technology without exposure of the metal surface.

11. For a further development of the technology for melting and steel casting, its quality improvement, reduction in the amount of defects and increase of the production efficiency. The following actions which would require some additional capital investment are recommended:

11.1. To develop and introduce into practice hot metal demanganation before metal pouring into the converter. As an alternative approach for solving this problem it can be offered the following: demanganation on the blast-furnace chute, demanganation during blowing by oxidizing mixtures at the blowing stand, jet refining. The use of hot metal with a reduced manganese content will allow to eliminate the double-slage BOF process.

11.2. To change-over to combined blowing. This will provide for increasing stability of the blowing process, thus to eliminate completely afterblowings connected with metal overheating almost completely.

11.3. To change-over to application of slit lances for metal blowing with argon in the ladle. This will accelerate the melt homogenezation and will rise degassing rates.

11.4. To substitute water cooling systems of continuous casters for mist cooling systems and to apply electro-magnetic stirring. This will allow besides known advantages, to reduce the amount of defected billets associated with cracks of various types.

11.5. To work out and to introduce the control system of continuous steel casting of general parameters.

3. METAL PRODUCTION QUALITY AND ITS CONTROL TECHNIQUES

3.1. Steel Quality Improvement and Quality Stabilization Problems To Be Solved at the Iron and Steel Works.

The main objective of modern steelmaking is to require all the increasing consumer demands towards steel quality. The term steel quality" may be presented in the following way:

- in intrashop defect is one of the quality procuration estimates and it occurs as a result of certain violations of production technology or as a result of faults made during its work out;
- wide fluctuations and a low level of mechanical and other operating properties are also characterized by quality and are connected with the increased and unstable detrimental impurities content, their presence form in a metal etc.

The transformation from carbon grades of steel to alloying grades are also characterised by steel quality.

Based on the abovementioned facts the problem of steel quality improvement should be considered only for concrete conditions. These problems should be solved after a wide-scale analysis taking into account the efficiency of the proposals made and their economic effect to be reached.

A combination of contradictory requirements - metal production quality improvement, energy and raw materials consumption decrease, causes the necessity to develop a thorough technology of metal production as a single process including a blast furnace process, steelmaking and rolling processes. The application of the advanced technology only at one stage, ladle metallurgy introduction demands modernisation of the whole technological line from charge preparation to billets production, besides it is necessary to develop and to introduce a device for a slag cut-off when the metal is tapped, the main ladle refractories and the department for ladle lining heating up to 1100-1200°C, devices and refractories for metal protection from secondary oxidation etc. At the modern level of qualitative metallurgy development it is impossible to specify a certain stage of production making it the most decisive factor in steel quality estimation. Metal quality improvement is connected with a number of problems to be solved at every stage.

3.1.1.Intrashop Defects.

As a rule, defects occuring at a modern BOF may be classified as follows:

- incoincedence of chemical composition and steel properties;
- surface defects of the continuous casting billets (longitudional and transversal cracks, slag inclusions);
- internal billets defects (gas blows, conglomerations of non-metallic inclusions, central porosity).

From the abovementioned it is clear that intrashop defects may be caused by two factors: because of the faults made while developing the technology and because of technological violations made by the works personnel.

Non-correspondence to the stadard of the chemical composition is always explained by gross violations of the steelmaking technology. The personnel operating with steelmaking devices, technological instructions is at good command of getting the required steel composition. Qualified personnel cannot admit this kind of defects. Another situation may happen when the operating cast steel properties do not correspond to the standard (with correspondence to chemical composition standard).

This may occur in two cases:

- when the worked out technology doesn't provide steel production with unvariable properties corresponding to the standard (this problem will be discussed below);
- when the continuous casting billet has got sizable surface and internal defects.

The main defects of continuous casting billets include surface and internal cracks, blow holes, coarse conglomerations of non-metallic inclusions, central porosity, chemical and crystalline heterogenity.

Hot surface cracks are the main ingot defects. When slabs are cast the defects are arranged mainly in the middle part of the face, and in billets they are arranged in the corners. The depth of such cracks may reach 50 - 60mm. The presence of such defects causes rejection and metal scarfing and also the breaks of solidifying billet layer in the mould.

Hot cracks occur as a result of two interaction factors: on the one hand, stress and plastic properties became possible at ingot formation t°, and on the other hand, actual stress and deformation in the billet at that period.

The main types of stresses leading to surface transversal cracks are:

- thermal stress;
- tensile stress caused by ferrostatic pressure;

- shrinkage stress;
- stress caused by the shell bending moment.

The general methods of protection from such types of defects are:

- steel composition optimization and decrease of detrimental impurities content (especially sulphur) to increase metal plasticity at ingot formation t^o;
- optimization of the mould cooling conditions and especially in a secondary cooling zone, providing thermal strength decrease;
- mould construction improvement (mould profile, ribs of waves presence) that provides shrinkage distribution and shrinkage stress level decrease;
- diminishing of the curve radius for decreasing ferrostatic pressure value.

While working out certain methods you should keep in mind that they may cause another type of defects though having a positive influence on crack formation decrease.

The transversal crack formation is mostly connected with the reciprocated mould motion mode. As a result of mould oscillation transversal folds are formed on the billet surface (depth 0.5-1.5 mm). There is no billet shell contact with the mould walls in their hollows and that deteriorates heat removal in these points and thus the solidified shell thickness. During deformation there arises a danger of transversal cracks formation in these sections.

Optimization of the mould oscillations (amplitude and frequency decrease) is a measure undertaken to prevent such a phenomenon.

Casting speed and drawing rolls pressure on the billet render influence on the internal cracks formation.

Swelling and rolling at a complete solidification sector are of utmost importance. Blowholes occurence is connected with a high steel gas saturation and, as a rule, is the result of a considerable steel overoxidation. The following factors influence the degree of reoxidation:

- metal overheat in the course of its production;
- insufficient amount of the introduced deoxidizers;
- secondary oxidation during tapping and continuous steel casting.

It can be concluded that the main methods of blowholes protection should be:

- heat balance control of the converter operation, hot heat even for a short period is not admitted and temperature regulation in proper time should take place;
- metal oxidation control before deoxidation and its data control for determining the quantity of deoxidizers introduced;
- protection from secondary oxidation at all stages of production paying special attention to oxidizing slag cut-off during metal tapping and oxidation prevention of a metal stream during casting and the removal surface (submerged casting).

Non-metallic inclusions conglomerations are the result of folds formation on the billet surface during mould oscillation with the further secondary surface oxidation, losing contact with the mould. Coarse inclusions both on the billet surface and inside the billet may be the result of slag drawing from a tundish and coming as a metal stream. The general protection methods from such defects are casting process control and submerged casting.

Chemical and crystalline heterogenity (including central porosity) is typical of continuous casting billets and is the result of the specific features of steel crystallization processes. In most cases these defects cannot indicate rejections but they render negative influence both on the total properties level and on properties homogenity towards ingot section.

3.1.2. Methods of Operating Properties Improvement

The level of operating properties (first of all mechanical) of a grade of steel depends on detrimental impurities content (sulphur, phosphorus, hydrogen, nitrogen and non-ferrous metals additious), forms of their presence at an operating steel tempereture and on a crystalline structure of metal. The crystalline structure may be changed in those cases when items are subjected to thermal treatment (such cases within the conducted work were not examined). Metallurgical methods of steel quality improve - ment are not only limited by a primary billet structure.

At present the problem of steel production with low detrimental impurities content (the production of the so-called "pure" steel) may be considered to have been solved. Besides in most cases secondary metallurgy methods are used. To yield steel with a low sulphur content (0.003% and lower) ladle iron desulphurization (by means of sodium , lime, magnesium, Ca carbide etc) and ladle steel desulphurization (by means of Perren's method or by powder materials with Ca content ladle blowing with steel). For metal degasing (first of all for hydrogen content decrease) various methods of steel vacuumation and partial blowing with inert gases are widely used.

Vacuumation and blowing are still more widely used for deep refining of non-metallic inclusions. Lately in many industrialized countries ladle iron and steel dephosphorization methods have been worked out and experimentally proved. Thus the results of extremely low detrimental impurities content can be received using secondary metallurgy methods. Moreover the number of ladle iron and steel refining methods and their application is constantly increasing.

The only problem still theoretically unsolved is the removal of non-ferrous additions during steelmaking (such as copper, nickel, tin, antimony etc.). Most of them are in less relationship with oxygen than iron and cannot be removed during oxidized melting. Today some ways of solving this problem are being discovered (e.g. removal of sulphur in a sulphide form), however, there are no stable industrial technologies so far.

When detrimental additions concentration in steel decreases, their presense form while producing items becomes more significant. The development of methods aimed at decreasing negative influence on the remaining content of such additions is on the agenda now. Practically all so-called detrimental impurities possess a limited (extremely low) solubility in a metal at room temperature. They are concentrated at grain boundaries as adsorbed layers at film isolation and more rarely as conglomerations (as non-metallic inclusions). The first problem arising here includes the necessity of grain boundary refining and transformation of such isolations from the grain boundaries to the grain body. That process decreases metal tendency towards brittle disruption and thus it increases the mechanical properties level.

The second objective is to transform plastic isolations into globular, non-deformed inclusions during rolling. Properties anisotropy decreases abruptly in this case (the difference of properties in various sections: along or across deformation direction).

The processes of changing the form of impurities presence are related to modification processes. Various metal additions in microquantities are used as modifiers. Thus to neutralize negative sulphur influence Ca-bearing alloys (silicocalcium, calcium carbide) or rare-earth alloys are used. To neutralize nitrogen first of all aluminium is used. As a rule, modifiers are introduced into a metal in the last refining stages (in a ladle before pouring or even in the process of continuous steel casting). That enables to keep modifiers in a metal as much as possible and it provides their more effective influence.

The reduction of the initial grains size in a solidified ingot can be achieved in two ways: changing the conditions of the billet continuous casting and by steel microalloying. The implementation of the first way may be done by different methods, namely:

- by the degree of steel prerefining;
- decreasing casting t^{o} and its strict control;
- mould construction change and its metal cooling intensity alteration;
- the change of character of the billet secondary cooling;
- various methods of external effect application: electromagnetic

mixing, electroimpulsive effect etc.

In steelmaking practice microalloying methods are widely used to refine the grain and to improve the production quality. Vanadium, niobium, titanium are widely used as microalloying additions (besides those are used as modifiers).

Methods of steel quality improvement discussed in this paragraph enable to solve the raised problem without using difficult and expensive alloying additions.

3.1.3. Alloying as a Method of Improving Operating Steel Properties.

Secondary metallurgy methods application and continuous steel casting improvement enable to stabilize and to a certain extent to enhance steel operating properties. However these properties alteration may be obtained only during alloying steel. Alloying enables:

- to lengthen products durability;
- to lower the metal products capacity, i.e. with the lower metal consumption to obtain the required durability;
- to undertake the production of a new item providing better service properties.

For example, the chromium content increase in structural steels enables practically to double the decrease of reinforcement degree; Mn content increase in tube steels considerably enhances their strength and safety in operation; low carbon steels alloying for deep aluminium drawing ensures ageing absence.

Alloying steels should be produced instead of carbon steels , and in each case it depends on metal requirements and market situation.

The main defects formation behaviour and the reasons of the decreased steel quality are discussed in the review. The given data enable to reveal the main reasons of this or that kind of defect occurence in each particular case and to work out the protection methods. Moreover the conducted analysis enables to develop the real methods of steel quality improvement due to the requirements.

3.2. Standards and Their Importance To Ensure Product Quality.

One of the main objectives of standardization in ferrous metallurgy is to produce a high quality metal homogeneous in its properties from heat to heat, from ingot to ingot by applying efficient steelmaking equipment.

Standards are significant means for determining product quality and establishing technical requirements for raw materials, initial materials, finished products with the cooperation of different branches of industry. Standards determination specify actual metal production characteristics.

Quality, standards and determination techniques are closely connected and the drawbacks of the standardization and computation system are certain to affect the technical level of production, its quality, safety in operation and its durability. Establishing standardization system in ferrous metallurgy with scientifically based classification and terminology on a scientific basis is sure to promote metal quality improvement.

The following aspects of the technical metal classification should be taken into consideration:

1) physical-chemical: chemical composition, structure, properties of metals;

2) technological: nature of metal production and process stage methods, processing methods, technological purpose and metal service purpose.

Imperfection of steel chemical properties allows us to characterise a metal by its nature, assuming that the metal produced from certain raw materials during definite metallurgical processes will contain certain impurities.

Introduction of technological aspects of metal classification according to the processing method enables us to simplify terminology for specifying structural peculiarities of a metal.

Requirements for metallic products are extremely different. Metal classification according to their purposes makes it possible to determine properties, the physical-chemical origin of which are not quite clear.

Metal application with complete correspondence to its quality may guarantee the desired economic and technical effects. Thus quality should be considered as a combination of products properties, making it suitable to meet the requirements according to its purpose.

Due to production development there appear both new and known useful metal production properties and the users find certain methods for their complete application. Therefore by applying the idea of metal production properties, its quality becomes broader. The requirements towards metal production quality are also not constant. They change due to science and engineering development level. Metal production of a considerably high quality corresponds to a more developed level of material production.

Metal production quality is an objective concept. This makes it possible to use a scientific approach towards its estimates selection. If the estimates are selected without regard for objective criteria the efforts of all the personnel may take the wrong direction and may not give the desired effect. Quantitative characteristics of one or several metalproduction properties may serve the metalproduction quality estimate.

In the course of the analysis the given metalproduction quality has to be constantly compared with other analogous production types quality, i.e. to evaluate the quality level which determines the relative characteristics of the production quality based on the comparison of the whole complex of quality estimates with the corresponding basic estimates complex.

When quality is controlled the estimates of the given product are compared with the standards adopted by international, state, branch standards or technical conditions.

Production quality improvement is interpreted by enhancement and development of the useful metal properties.

Nomenclature of quality estimates must be selected with regard for its suitability for a definite quality estimate level purpose. On the one hand, the nomenclature must contain only such estimates which will find practical application. On the other hand they must include all general estimates determining this level.

Metal quality is determined by a number of factors: by a technological process, equipment, charged materials, raw materials, ferroalloys, deoxidizers, personnel qualification. In modern Iron and Steel Works conditions technology quality has acquired great importance. This accounts for the increased intensity of technological processes, the complicated interaction of the former and the further process stage parameters.

The known types of steel quality control can be divided into three groups: steelmaking quality control, slab and ingot quality control, finished metal production quality control.

Every heat, every product possesses specific properties and to a certain extent differs from others in chemical elements contents, impurities, inclusions etc. The change in quantitative characteristics significance is caused by many different factors which in their turn may be subdivided into two groups: systematic and occasional. Systematic factors in Iron and Steel Works may include: metallurgical furnace durability, charging, casting, pouring, technology violations. Under regular observation of a technological process these factors may be revealed and their influence may be either eliminated or decreased in time. The elimination of the systematic factors effect brings the production process to such a state when quantitative characteristics changes are caused exclusively by occasional factors. Such a state of a production process is called steady or stable.

Occasional factors usually produce an effect in various directions and cause inessential, occasional deviations of the measured parameters from the standard. These factors may include occasional fluctuations of a heat mode, occasional errors of personnel while following technological instructions etc. The physical origin of occasional factors is not always known exactly but the general conformity of their actions is studied properly by the theory of probability.

While evaluating metal quality it is important to have standard methods of its control. When national standards are worked out the possibility of their further unification with other countries' standards should be taken into account. Uniform metal quality evaluation, uniform methods and measurements system facilitate the problem of creating international standardization and considerably simplify economic relations between countries.

In standards and technical conditions methods of determining these estimates should be indicated precisely while defining quantitative production characteristics.

It is typical of Iron and Steel Works to have a great number of factors influencing the production quality. Variation of each of these factors, their interdependency and interaction produce a complicated situation in a steelmaking process. Accurate control of those factors determining the results of the production is impossible and moreover, their variation within a definite range has to be admitted.

One of the best methods for the current production control for establishing parameters correlations and determining the influence degree of one of the factors or their total influence on the production result is the statistical method. The primary statistical data of Iron and Steel Works are usually available as technology data. The so-called heat logs have acquired wide application at the Works. The heat logs comprise each heat data from initial raw materials to finished products quality.

It is necessary to work out a complex system of quality production control to meet constant requirements improvement for the quality of various groups and classes of ferrous metals. It is of utmost importance that the system be based on technological parameters of the Iron and Steel Works aimed at quality improvement of the finished metal products with regard for its effect on the consumer.

The main objectives of the quality control system are :

- to determine product quality level during manufacturing;
- to produce a high product quality level during its elaboration;
- to maintain effective product application and to maintain the achieved quality level at handling and operation stages.

During a product quality control process the following procedures are worked out and implemented: organization, technical, economic and other measures aimed at technical improvement, technology and manufacture improvement, better maintenance, control the organization of technological processes and output product quality, raising the skill level of the workers and engineering staff.

The organizational basis of the quality control system consists of the enterprises' standards worked out in accordance with the new higher level standards. For example, USA standards may be divided into three groups:

1. Company standards worked out within separate enterprises, companies or firms and functioning within a given organization.

2. Technical Unions, Trade Association and Company Unions. American Association of Testing Materials (ASTM) oriented at studying technical materials and technical standardization condi tions and testing methods which should be at the centre of attention. ASTM carries out the work in two directions: representation of science and engineering materials in the form of surveys and transactions pulished in reports; the activities of technical committees studying various materials properties. These committees are responsible for specifications development and test methods.

3. National standards worked out by the USA. This organization comprises companies, their associations, technical unions, institutes and also governmental bodies.

The American Standard Association makes use of the following four methods of determining and establishing standards.

1. The "Section Committee" method - the authorities commission, the branch section committee consisting of representatives from interested organizations and consumers working out the given project.

2. "The existing standards" method makes use of these standard projects agreed by competent industrial organizations with regard for their national standards suitability.

3. "National standards" method - standards worked out by the organization dominating in a given branch are considered to be national standards, such standards may be adopted by ASA if they are agreed upon by all the organizations whose interests are not impinged by them.

4. "Common agreement" method is used in simplier cases without requiring technical project test. The standard is adopted at the meeting of the interested organizations.

Most of the adopted ASA standards represent standards of one of the technical unions or Associations. The first among them is the American Association of Testing Materials.

In Great Britain the British Institute for Standards is responsible for working out standard sizes and product size, testing methods, raw materials and finished products quality control.

Technical conditions in British standards make up one of the four standard categories; three other - definitions and measurement units, testing methods and application instructions.

The metallurgical part of British Standards is based on optical metallography research, phase diagrams, measurements, X-ray investigation, electronic metallography and metal physics. The fundamentals of technical calculation determine the standards. Calculations values used by the International Standard Organization are listed.

In the Soviet Union a standard is the production quality criterion. Standardization work is carried out under the guidance of the USSR State Committee for Standards and state, branch, republic and plant standardization taken together. Thus it provides a more effective activity in this field.

Programme elaboration for steel standardization defines the indispensible complex of correlated activities enhancing metal production quality parameters. Standards and technical conditions for casting and rolling initial materials were established as a result. State standards are obligatory for all organizations and enterprises. Due to wide-spread standardization technological processes have been improved and the conditions for new types of production (steel, alloys, rolling sections and other) have appeared. Standards and departmental technical conditions express more completely the advanced experience in various branches of ferrous metallurgy. There is interrelation between State Standards and departmental technical conditions, the latter being the initial standardization stage and precede State Standards elaboration while applying new materials and new types of metal production. Departmental technical conditions are set up in agreement with the supplier and the consumer.

A number of countries are united in the International Standardization Organization (ISO). National Institutes for Standardization are the members of this international organization. The work of establishing international standards is done in ISO technical committees. Each member interested in the problem being discussed has the right to participate in a committee's work. International organizations, governmental and non-governmental organizations maintaining relations with ISO may participate in the work. The adopted international standards are extended among the organization members by the ISO Council.

4. TECHNOLOGY OF STEELMAKING AND ITS QUALITY CONTROL AT EISCO

4.1. Shop Composition.

The Egyptian Iron and Steel Works was built in 1955-58 in cooperation with the West Germany Company "Demag". Since 1959 under technical support of the Soviet Union reconstruction and construction of a number of shops has been carried out. In 1979 BOF was completely put into operation. In 1988 the steelmaking shop produced 842.109 tons with project capacity 1200000 tons.

At present BOF comprises a mixer department, a converter department, a continuous casting department and a number of supplementary departments.

Mixer department has acquired one mixer with the capacity of 1300 t . At present the construction of the second mixer is being carried out. The available equipment in the department enables to weigh hot metal charged into the converter department accurate within 0.1 t . There is no equipment for slag removal from the mixer and that results in its occurence in a charging ladle, then in a converter and thus when the supplied hot metal is weighed considerable faults are observed.

Scrap preparation department due to the use of the scrap produced only at the shop enables to fulfill scrap shortage and sorting according to the grades of steel. At present such procedures are not done and that impede the efficiency of BOF. The equipment available in the shop enables to weigh scrap accurate within 0.1 t .

Converter department comprises three converters with a removable bottom, 80 t each. The converter working capacity is 78 m^3, specific volume - 0.975 m^3/t . The working vessel lining layer consists of tar-magnesite-dolomite compound, the total thickness amounts 800 mm.

Blowing is done through a 4-tuyer lance with 30 mm critical diameter.

The available equipment enables to control oxygen consumption, oxygen pressure before the lance, lance height, slagforming materials consumption.

Metal probes taken from the converter are delivered to the laboratory by means of pneumatic post. Metal analysis is carried out in the quantometer. Time required for receiving analysis results is about 3 min.

Deoxidation addition is charged into a ladle from the bunkers after the preliminary weighing.

After tapping the metal is transported by the transfer cars to a secondary processing sector where top argon blowing through the lance with a 6-9 mm diam. nozzle and argon consumption of 1200 l/min. is done. The available equipment enables to make alloying processes, to make an automatic sampling and temperature measurements.

Continuous casting department consists of vertical casting plant with a water cooling device. Three two-stand slab casting plants with the cross-sections: 150 x 1040, 170 x 1040, 170 x 720 and 170 x 1040 and three six-strand sorted slab casting plants with cross-sections 150 x 150, 160 x 160, 180 x 180, 200 x 200 mm.

The speed of slab drawing makes up from 0.6 to 1 m/sec. (slabs) and from 0.7 to 1.5 m/sec. (blooms).

The oscillating mechanism of the mould provides oscillations with the frequency of 30-35 oscillations per min.

4.2. Grades of the Steel To Be Produced.

At present EISCo's BOF generally performs melting and casting of a number of structural and tube steels. Scheduling and accounting in the shop's operation is carried out according to the grades of steel. Their composition is given in the Table 4.1.

Table 4.1.

Chemical composition of certain grades of steel to be cast.

Grades of steel to be cast	Elements content %						
	C	Si	Mn	P	S	Al	N
			slab	not more than			
C.R.	0.06 - 0.10	0.06 - 0.10	0.25 - 0.50	0.040	0.040	0.005	-
N.P.	0.06 - 0.12	0.06 - 0.12	0.25 - 0.50	0.040	0.040	0.005	-
C.F.	0.12 - 0.17	0.06 - 0.15	0.35 - 0.60	0.050	0.050	0.005	-
37/2	0.12 - 0.17	0.15 - 0.25	0.35 - 0.60	0.050	0.050	0.005	-
44	0.18 - 0.22	0.15 - 0.25	0.55 - 0.70	0.030	0.020	0.005	-
RR-14	0.08	0.05	0.20 0.45	0.030	0.025	0.045 0.085	0.008
08	0.09	0.09	0.20	0.030	0.025	0.020	0.007
		billets					
LS	0.10 0.14	0.15 - 0.25	0.40 - 0.60	0.040	0.040	-	-
MS/44	0.14 - 0.20	0.15 - 0.25	0.40 - 0.60	0.040	0.040	-	-
37	0.12 - 0.17	0.15 - 0.25	0.40 - 0.60	0.040	0.040	-	-
52	0.25 - 0.35	0.15 - 0.25	0.70 - 0.90	0.030	0.020	-	-
52/2	0.18 - 0.25	0.15 - 0.25	0.90 - 1.15	0.040	0.040	0.004	-
52/3	0.16 - 0.20	0.20 - 0.40	1.20 - 1.50	0.030	0.030	0.02 0.09	-
18	0.35 - 0.50	0.15 - 0.25	1.0 - 1.20	0.040	0.040	-	-
60	0.30 - 0.35	0.15 - 0.30	0.60 - 0.90	0.040	0.040	-	-

The main part in the Estimation of the Works capacity (up to 70 %) comprises steels for cold rolling (C.R.) and for tube production (N.P. and steel 37). Steel making of 44 and 52 grades constitutes up to 10 % each from the total Estimation of the Works capacity.

Steel casting is produced at Continuous Casters, the major part of the melted steel being cast into slabs (Table 4.2.).

Steel production and its casting at EISCo.

Table 4.2.

	Total steel making	Slabs	Billets	Mould casting	Losses
t.	84.2,109	504,625	252,874	67,797	16,813
%	100	59.92	30.03	8.05	2.00

It will be indicated below that the general amounts of defects (up to 20-25%) occur during slab casting on CCs. Great attention is given to steelmaking with its further slab casting according to melting and casting technology analysis.

4.3. The Existing Technology of Steelmaking and Steel Casting.

Steel to be produced by BOF technology and CCs adopted by EISCo upholds the use of hot metal, scrap and lime as initial materials. Hot metal is supplied from a blast furnace shop through a mixer department into a converter sector. Weighing is done when hot metal is tapped from a mixer. The amount of hot metal usually makes up about 75 t . Weighing is also done when scrap is prepared for tapping into a converter. Its quantity is usually up to 15 t per heat. After materials charging (scrap, hot metal and slagforming components) oxygen blowing of metal is performed to get a desired composition and steel t°. After the further metal yield its deoxidation and alloying is done. Argon blowing enables to make averaging of metal composition and metal t°. Steel casting is performed at the billet casting plants of the vertical type. The slabs produced undergo examination and surface defects removal may be carried out.

The existing technological instruction for steel melting and casting requires the following demands for the initial materials and certain technological operations.

Hot metal supplied into the converter department must possess the following chemical composition: 0.50-0.80% Si; 1.0-1.8% Mn, not more than 0.045% S and not more than 0.55% P. Before pouring hot metal into a mixer a thorough removal of the blast furnace slag from the ladle should be performed.

Scrap must not contain either Ni or Cu, fine scrap (less than 300 x 300 x 600 mm) must be specially prepared (packed). The use of wastes of unknown chemical composition is not admitted. Scrap preparation must provide the total amount of charge in two scoops maximum.

Lime must be freshly burned, with piece sizes 5-60 mm. CaO content in lime must not be lower than 85% and the quantity of non-conditioned lime - not higher than 15%. Deoxidizers must be dry and their piece sizes should be 10-100 mm.

Converter charge

After the previous heat output, 2-3 t of lime or 1t of dolomite and 1-2 t of lime is charged into a converter. Then scrap charge is performed, its amount is up to 15 t and it is determined by the chemical composition of hot metal, durability and the converter lining t°. The quantity of the poured hot metal is determined by the amount of the converter charge which must constitute 90 t. It should be mentioned that the existing technological instruction is oriented at the converter operation with the overcharge according to its project capacity (80 t).

Oxygen metal blowing and slag modes

According to the instructions oxygen metal blowing should be performed in two stages. The first period duration lasts for 14-15 min. Within the first 5 min. the lance level above the metal level should be kept within 1.6-1.8m and then 1.1-1.3m. During the first period the lime addition is planned providing slag yield with the basicity not lower than 2.5. Metal t° at the end of the first period must not be higher than 1,560°C. When the first period is over it is necessary to remove slag as much as possible.

Before the beginning of the second blowing lined slag additions and other slagforming components are introduced according to the yield of the final slag which must not be less than 4.0. The end of blowing must be determined according to the necessary amount of the consumed oxygen. At the end of blowing the selection of metal tests and t° measurements must depend on grades of steel and a type of continuous casting and must be within the data given in the table 4.3.

Table 4.3

The required metal t° before steel tapping.

Grades of steel to be cast	Casting into	
	slabs	billets
C.R.; N.P.; 37 44; 52/3; Al killed	1,650-1,670	1,660-1,680

In case of one-strand slab casting machine steel t° increases by 10 degrees.

In case of getting unsatisfactory data of temperature, carbon, sulphur and phosphorus, oxygen metal blowing is carried out; in the latter case lime is added. Cooling of overheated melts is performed with lime addition.

Metal tapping and deoxidation

The duration of the heat tapping must be 3-7 min. Steel is deoxidized by ferromanganese, ferrosilicon and aluminium, adding them into a ladle after it has been filled on 1/3.

The quantity of the added materials is determined by the following formula:

$$P = \frac{M \cdot (a-b) \cdot 100}{c \cdot Y}$$

where M - liquid steel mass

a, b, c - elements content in the steel, in a metal before tapping, in ferroalloy

Y - the extent of ferroalloys adoption (80% - for ferro - manganese, 70% - for ferrosilicon.

The quantity of aluminium makes up 400-600 gr/t while casting steel into slabs.

Argon metal processing is performed by blowing through the plunged cylindrical lance. Blowing is done with the intensity of 1.0 -1.3 x 10^{-3} m^3/t per min. Blowing duration is corrected according to the temperature of the yielded metal within 2-7 min.

When the blowing is finished the temperature of the metal is measured and it must correspond to the requirements for the continuous casting.

Continuous steel casting is performed producing slabs and billets. The temperature of a metal in a ladle before casting into slabs must be 1,610-1,630°C, in a tundish 1,540-1,560°C. Casting is done with an open stream and 24 mm nozzle diameter of a tundish. For lubrication of the mould's walls synthetic oil is used. As it was mentioned above the operating casting speed - about 0.65m/min., the frequency of the mould oscillations equals 30-35 osc/min. The secondary slab cooling zone is performed with water, with the total water expenditure 38 m^2/h, it being divided into three sections. When continuous steel casting is made by means of subsequent heat method, first the speed of casting decreases up to 0.2 m/min. and then after ladle replacement it increases up to the operating speed.

According to the grade of the melted steel certain changes and amendments are made in technological instructions of steel melting and casting. Particularly, when steel 52/3 is produced slag pumping-out before metal tapping is supposed to be done, ferroalloys addition is made in the following amounts: ferrosilicon - 100 kg; aluminium - 100-130 kg. per melt. Metal casting should be performed with the protection from secondary oxidation with slag application, casting speed constituting 0.5-0.6 m/sec., metal temperature in a tundish must be 1,520-1,540°C. When 44 steel grade is to be cast its temperature before tapping must be 1,630-1,650°C and in a ladle before casting 1,600-1,620°C. Casting speed is recommended to be 0.6-0.7 m/min., not lower than 0.4 m/min.

4.4. The Existing Control Scheme and Products Quality Indicators

The initial quality control of the melted steel and casting slabs and billets is carried out on the analysis basis of the present technological documentation - "subsequent heat" and steel casting logs.

The steel melting logs should include:

1. Initial materials data:
   - hot metal composition and t°;
   - the quantity of hot metal and scrap;
   - the quantity and time of the addition of definite portions of slagforming materials (lime, bauxite and others).
2. Mode of metal blowing data:
   - lance replacement during melting;
   - oxygen consumption and oxygen pressure in a pipe in front of the lance in the course of melting;
   - data of the blowing situation and slag pumping-out.
3. Melting t° mode.
4. Deoxidation mode.
5. Chemical analysis data of the metal samples.
6. Deviations from technology and in the operation of mechanical equipment.

The steel casting log should include:

1. Casting t^o mode (metal t^o in a ladle and in a tundish during casting).
2. The description of the metal stream behaviour and the change of the metal in a mould in the course of casting.
3. Casting speed alterations data.
4. Water consumption data at a secondary cooling zone.
5. Time, duration and the reasons of casting cessation.
6. Mechanical equipment operation data.

Estimation of the slab quality is made according to:

1. Chemical analysis of steel - no deviations from the given data indicating components in Table 4.1 are admitted.
2. Slabs sizes must correspond to the following requirements:

thickness	120-170 mm
width	500-1,070 mm
length	5,500-600 (reduction of the slab length up to 5,000 mm is admitted).

The estimation of slab quality is made by visual control. The presence of non-metallic inclusions, porosity, axial cracks, longitudinal and transversal cracks, belts and blowholes on the slab surface are registered (fig. 4.1.)

Qualitative slabs must not have (according to visual estimation) exfloitations and their surface must be free from the above-mentioned defects.

In case of defects presence their removal by cleaning is admitted. The depth of the produced cleaning must not exceed 20 mm and 10 mm on the wide and narrow slab face respectively.

Moscow Institute of Steel and Alloys

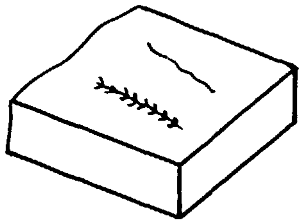
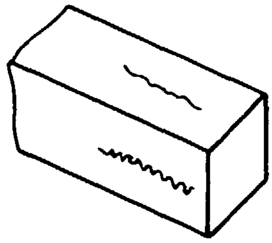
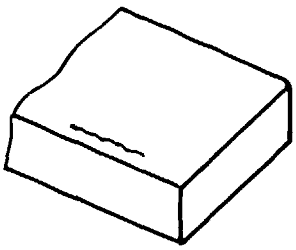
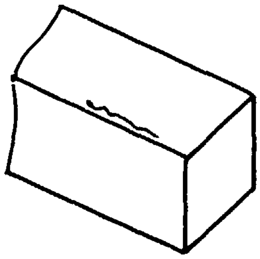
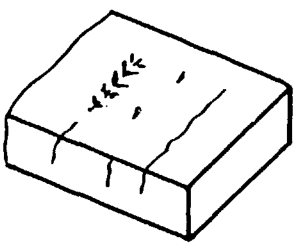
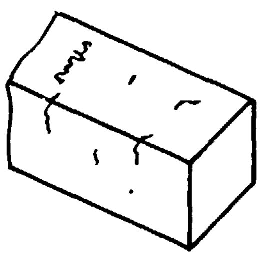
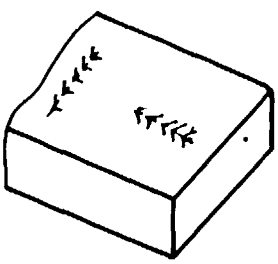
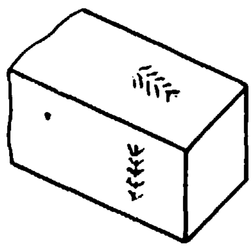
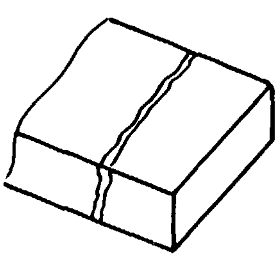
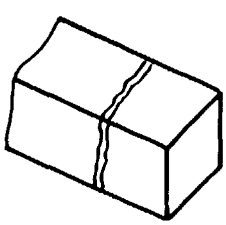
	on slabs	on billets	name of defects
a			Longitudinal cracks on the sides (faces)
b			Longitudinal cracks on the edges
c			Transversal cracks on the sides and edges
d			Transversal and longitudinal cracks on the faces
e			Belts

Fig.4.1. a,b,c,d,e

Some defects of continuous casting metal.

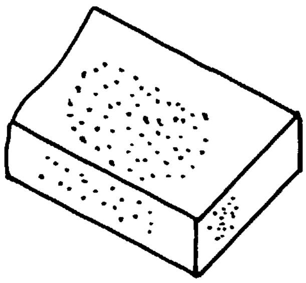
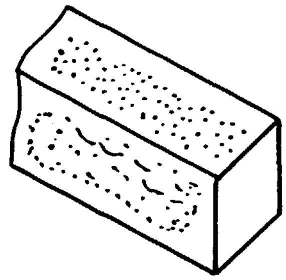
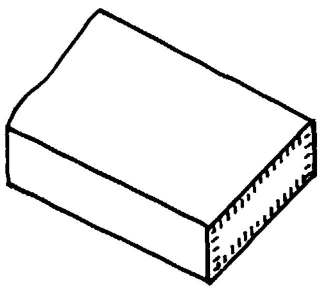
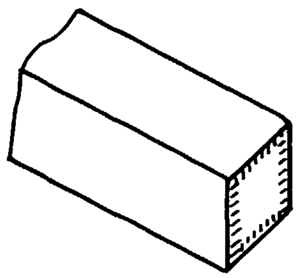
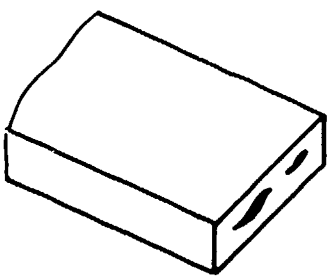
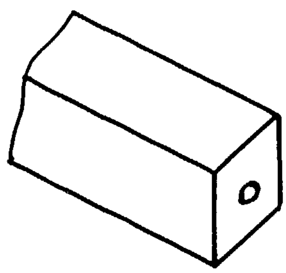
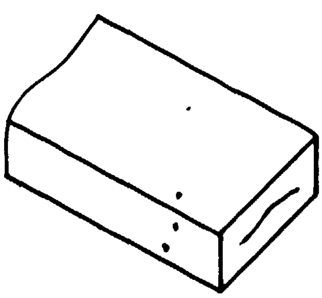
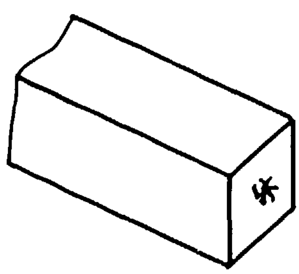
	on slabs	on billets	
f			Slag inclusions
g			Gas blow-holes in the cross-section and blow-holes discovering on cleaning
h			Shrinkage cavitation
j			Axial and central cracks

Fig.4.1. f,g,h,j

Some defects of continuous casting metal.

Depending on the results of the slab quality it may be classified into the following categories: A - qualitative metal without external defects; B - slabs corresponding to the above-mentioned conditions after mechanical scarfing, or C - defected slabs.

The system of the steel casting shop operation analysis comprising a week report of the shop operation results and the received data analysis were worked out at EISCo Works.

The following activities are done weekly:

- analysis of the initial materials quality: iron, lime, oxygen;
- analysis of the materials consumption per heat;
- blowing duration, the amount of blowing periods, the reasons of reblowing, melting t^o mode;
- analysis of yielded metal:

  a) reasons of overheated metal output;

  b) reasons of metal output with the increased P and S content.

The following data are available in the weekly report: Melting according to the grades of steel, distribution of melted metal into continuous casters. Steel pouring mode and the operation of the mechanical equipment shop are described in detail.

A monthly analysis of the shop operation is done according to the same scheme.

For example, the results of the shop operation analysis in December 1988 has shown:

Total amount of heats -		1,021
including poured:	into slabs -	[illegible]
	into billets -	[illegible]
	into moulds -	49

reported into a mixer because of un-
prepared steel pouring department - 6
rejection - 2

Total amount of steelmaking made up 70,400 t (compared with the data in November 1988 - 70,782).

The distribution of the melted steel according to the grades of steel and metal yield (category A + B) when poured into slabs:

Grades of steel	C.R.	N.P.	37	44	Al killed	52/3	Cold stamping	total
Melted, t	15,575	12,230	6,890	6,775	200	53	1,205	42,928
Yield, % (A + B)	82.5	81.5	83.3	76	-	98	74.4	81.19

Due to the above-mentioned data of slab casting and the analysis of the main reasons of the defects in 1986-88 (Table 4.4) it should be stated that the main reasons of unsatisfactory slab production quality are connected with the presence of blowholes and non-metallic inclusions (defective schemes, fig. 4.1. g, h). A considerable defected slabs percent was received due to the belts (4.1. e) and cracks (defective schemes, fig. 4.1. a, b, c).

Analysis of the control scheme and the quality production estimation in BOF enables to state a high level of the observation system, presentation of technological requirements implementation, raw materials quality, declines from technology and deviations in equipment operation. A large amount of the available statistic data of BOF operation, being thoroughly processed, enables to work out valid recommendations both for existing technology improvement and for further development of the future new technological trends in Works steelmaking.

Table 4.4

Slab quality estimates in 1986-88.

Factors	1986	1987	1988
1. Production, t	453,330	402,097	483,614
2. Category A slabs,%	34.6	46.5	41.2
3. Category B slabs,%	41.5	33.0	36.0
4. Category C slabs,% defective	23.5	20.1	22.4
Defects reasons,%			
blowholes	9.7	8.2	8.5
non-metallic inclusions	5.9	4.9	6.7
belts	5.5	5.1	4.7
cracks	1.2	0.9	1.8
other	1.2	1.0	0.7
5. Technological losses,%	0.4	0.4	0.4

5. METHODS OF STEEL QUALITY IMPROVEMENT IN THE EXISTING STEEL PRODUCTION

5.1. Factors Analysis Affecting Steel Quality (due to the Adopted Technological Scheme of Steel Production).

The general feature of the converter secondary processing at EISCo Works is secondary processing of iron with the increased P and Mn content. Wide literature findings and industrial experience of secondary processing of hot metal with the high content of one of the above-mentioned components are available in / 1 - 6 /.

One of the conditions to get positive technological results when hot metal with the high P and Mn undergoes secondary processing and in case of conventional secondary hot metal processing application is charge composition stabilization, hot metal in particular. However, the hot metal composition analysis (Table 5.1) has shown that basic components content may vary in a very wide range. Particularly, in December 1988 (Table 5.1) P content changed from 0.32% to 0.48%, Mn content - from 1.06 to 2.33%, silicon - from 0.30 to 1.07%, carbon - from 3.60 to 4.72% i.e. components content variation makes up 50, 120, 257 and 31 relative percent from the minimum level respectively. Such composition fluctuations lead to changes in input data of the heat balance: working with the minimum impurities content, it is necessary to burn up to 3% iron to provide the desired temperature. If the impurities content in hot metal decreased to the maximum content then metal overheating at the end of blowing may reach 40-50^{o} above the required temperature. Only in some cases hot metal content corresponded to the technical instructions predetermined by the shop construction Project and 13.1-37.7% didn't correspond to the existing technical requirements (Table 5.2). A number of research carried out earlier at the Works contains information of iron composition instability / 7, 8 /.

Negative influence of the mixer slag charged into the converter should be observed. According to the estimation / 8 / the average quantity of the mixer slag charged with hot metal into the converter makes up about 0.5 t. That decreases final slag basicity to about 0.5. Taking into account low lime quality, lime consumption increase by 2-3 kg/t of steel may be observed. Moreover, mixer slag introduces a certain amount of sulphur equivalent to its content increase in iron by 0.010-0.015%. / 8 /.

The quality of the lime used is unsatisfactory (Table 5.3) 5-12.5% of its used quantity corresponds to the technical instructions (CaO content in lime is more than 85%). Analogous data can be found in works /7, 8/.

Scrap consumption per heat (and correspondingly hot metal consumption) according to December 1988 report was changing within wide range (Tables 5.4, 5.5). A considerable amount of heats (16.2-24.10%) was done without scrap and up to 9.3% of heats with the use of so-called liquid scrap (yielded metal which was not supplied for pouring due to organization difficulties or faults in continuous casting department). On the whole in 1988 the scrap portion in metal charge made up only 8.7% which is sure to be a very low indication as compared with the conventional range 23-26% / 3 /.

Table 5.1

Hot metal consumption supplied into the converter department in December 1988 (according to weekly reports).

Week		Component content				
		C	Si	Mn	P	S
I	average	4.07	0.72	2.03	0.39	0.039
	max	4.47	1.04	2.33	0.43	0.065
	min	3.64	0.45	1.69	0.36	0.029
II	average	4.05	0.65	1.97	0.38	0.043
	max	4.44	1.01	2.19	0.43	0.058
	min	3.75	0.34	1.06	0.35	0.033
III	average	4.10	0.66	1.97	0.39	0.039
	max	4.72	0.99	2.32	0.48	0.057
	min	3.60	0.27	1.44	0.34	0.027
IV	average	3.97	0.70	1.75	0.39	0.039
	max	4.25	1.07	2.10	0.42	0.056
	min	3.61	0.30	1.43	0.32	0.025

Table 5.2

Quality of hot metal supplied into BOF in December 1988.

(according to weekly reports)

Week	Amount of hot metal tests analysis, %		
	corresponds to the Project proposals	corresponds to the shop TI	doesn't correspond to TI
I	-	86.9	13.1
II	3.2	62.3	37.7
III	-	74.7	25.3
IV	5.2	77.4	22.6

Table 5.3

Lime quality (according to weekly reports data, December 1988)

Week	Lime quality with CaO content, %				
	16-70	71-35	70-80	80-85	85
I	-	6.2	50.0	31.3	12.5
II	6.2	-	43.7	49.7	6.2
III	5.3	10.5	47.4	31.6	5.2
IV	18.2	18.2	36.4	27.2	-

Table 5.4

Scrap expenditure per melt (according to weekly reports, December 1988)

Week	Scrap consumption, t						
	0	up to 5	5.1-10	10.1-15.0	15.1-20	more than 20	liquid scrap
I	23.2	3.0	61.6	10.1	-	-	2.1
II	16.2	11.7	43.3	19.4	-	-	9.3
III	24.0	3.60	43.5	22.4	0.4	-	6.1
IV	19.5	17.3	56.2	1.7	-	-	5.6

Table 5.5

Hot metal consumption per melt

Week	Hot metal consumption, t					
	less than 70	70-75	76-80	81-85	86-90	more than 90
I	0.4	2.1	57.8	32.5	7.2	-
II	0.8	2.4	49.0	43.3	4.5	-
III	1.2	14.1	35.9	44.7	8.3	0.7
IV	1.6	2.7	53.5	34.1	7.6	0.5

Low and unstable scrap consumption leads to heat balance violation, ensures metal overheating and, as will be shown below, leads to a number of negative consequences. The calculations made enable to consider that during a converter process in EISCo BOF up to 25% scrap may be used for obtaining yielded metal temperature up to 1670°C.

Thus, charge materials quality and converter charging analysis enables to state that the above-mentioned parameters vary in extremely wide ranges and often exceed the ranges established by existing technological instructions. Certainly, it doesn't enable to work out uniform strict technology of the melting process. It ensures deviations from the adopted blowing and further operations modes and affects the yielded metal quality.

The consequences of deviations from initial materials and melting charge requirements to a large extent affect the blowing mode.

The selection of secondary hot metal processing technology is known to be influenced by its sulphur, phosphorus and manganese content. Simultaneously removal of components in a converter causes a number of difficulties so that it ensures steel production either by duplexing or by a double-slag process /1-5/ with the initial slag removal and further semiproduct blowing to yield a desired steel content. According to EISCo's technological instructions a technological scheme with a single slag removal should be implemented. However these data in Table 5.6 show that in most cases a number of blowing periods makes up 3-5 and only in 0.4-4.1% it was possible to follow technological requirements and to perform melts without reblowings.

Practically 100% of heats with reblowing correction affect the converter output because of lengthening the heat cycle duration (Table 5.6) which in 1988 constituted 50 min. in average, a considerable number of heats (896) having the duration more than 60 min. In its turn it decreases converter lining durability (a number of heats during intermaintenance period).

According to the reported 1988 data lining durability made up 166 heats in average with maximum and minimum durability 221 and 125 heats respectively. Converter steel production with reblowing leads to metal overheating - due to the reported 1988 data metal temperature in the converter reached 1,710° C, and that also results in metal overoxidation.

Table 5.6

Amount of blowing periods (due to weekly reports for December 1988).

Week	Amount of blowing periods					
	1	2	3	4	5	more than 5
I	0	0.4	21.1	6.3	17.5	0.8
II	0	2.0	27.5	61.5	8.1	0.8
III	0	4.1	29.7	53.3	11.8	1.2
IV	0	2.7	33.5	55.7	8.1	-

The main factors influencing metal components oxidation speed proportion, slag formation and metal temperature variation during heat are oxygen blowing of the melt mode (lance height variation above the metal level, oxygen consumption and its pressure), slagforming components addition mode.

The reported data analysis towards oxygen blowing of the melt mode have indicated the absence of stable oxygen pressure in piping (Table 5.7) and also considerable fluctuations in oxygen consumption per heat (Table 5.8). It should be stated that the total oxygen consumption considerably fluctuates even during practically equal melting charge. For example, with equal hot metal composition and consumption and also with equal scrap consumption during NN 113,796 and 113,802 heats, the difference of oxygen consumption has made up nearly 30%.

The increased oxygen consumption results in the waste of iron increase, decrease of liquid yield, metal overoxidation and overheating. Literature findings of high-phosphorus hot metal secondary processing /1-3/ and EISCo Works operation experience have shown positive influence on the remaining part of the final slag. In this case 1.5-2 t of lime is charged into the converter before the metallic charge loading. This method in combination with consequent melt blowing with the higher lance level promotes rapid formation of highly-basic slag and relatively low temperature conservation and provides a good degree of metal dephosphorization. High slag basicity conservation during blowing by appropriate lime additions promotes reaching the aim. It has been established by the works trials that during the first period of melting the P oxidation speed is maximum and reaches 0.010 - 0.015 % min.

Table 5.7

Oxygen pressure (atm) December 1988 report.

Week	Oxygen pressure, atm		
	13	14	15
I	0.8	43.5	55.7
II	1.6	66.4	32.0
III	0.8	71.1	28.0
IV	4.8	58.3	36.9

Table 5.8

Oxygen consumption per heat (m^3) December 1988 report.

Week	Oxygen consumption, m^3				
	4000-5000	5001-5500	5501-6000	6001-7000	7000
I	54.3	43.5	1.7	0.4	-
II	84.4	14.8	-	0.4	0.4
III	64.9	35.5	1.7	0.8	0.4
IV	87.8	12.2	-	-	-

When the first period of blowing is over it is important to get a maximum removal of the initial slag. That enables to provide good metal dephosphorization and its chemical composition correlation with the given requirements during the second melting period in case of new highly-basic slag formation.

Noticable deviations in charge materials composition and consumption as well as the absence of a stable mode of the melt blowing in the converter ensure considerable fluctuations in slag composition in the course of blowing. Typical fluctuations of metal composition, slag and melt t^{o} in the course of melting due to data /8/ are given in fig. 5.1-5.4. Slag phase composition and certain components content alteration in the final slag of the converter process are analyzed in detail in the work /7/. As follows from the given data both the final slag composition and other basic technological parameters are characterized by a high degree of instability. For example, CaO content in slag fluctuates within 27.4 - 59.74% range, SiO_2 content - 5.94 - 26.08%, FeO and Fe_2O_3 content within 5.33 - 31.25 and 2.42 - 14.82% respectively. A high degree of slag oxidation (an excessive Fe oxides content in slag) is known to be accompanied by an excess of oxygen content in a metal which in its turn ensures as will be shown below a number of defects in yielded steel after its crystallization. Metal and slag tapping and metal deoxidation during tapping are the final stages of steelmaking. To yield purer steel and to prevent rephosphorization it is necessary to prevent slag occurence in a ladle. Metal tapping must be organized as fast as possible and with a compact stream. Deoxidizers quantity is determined

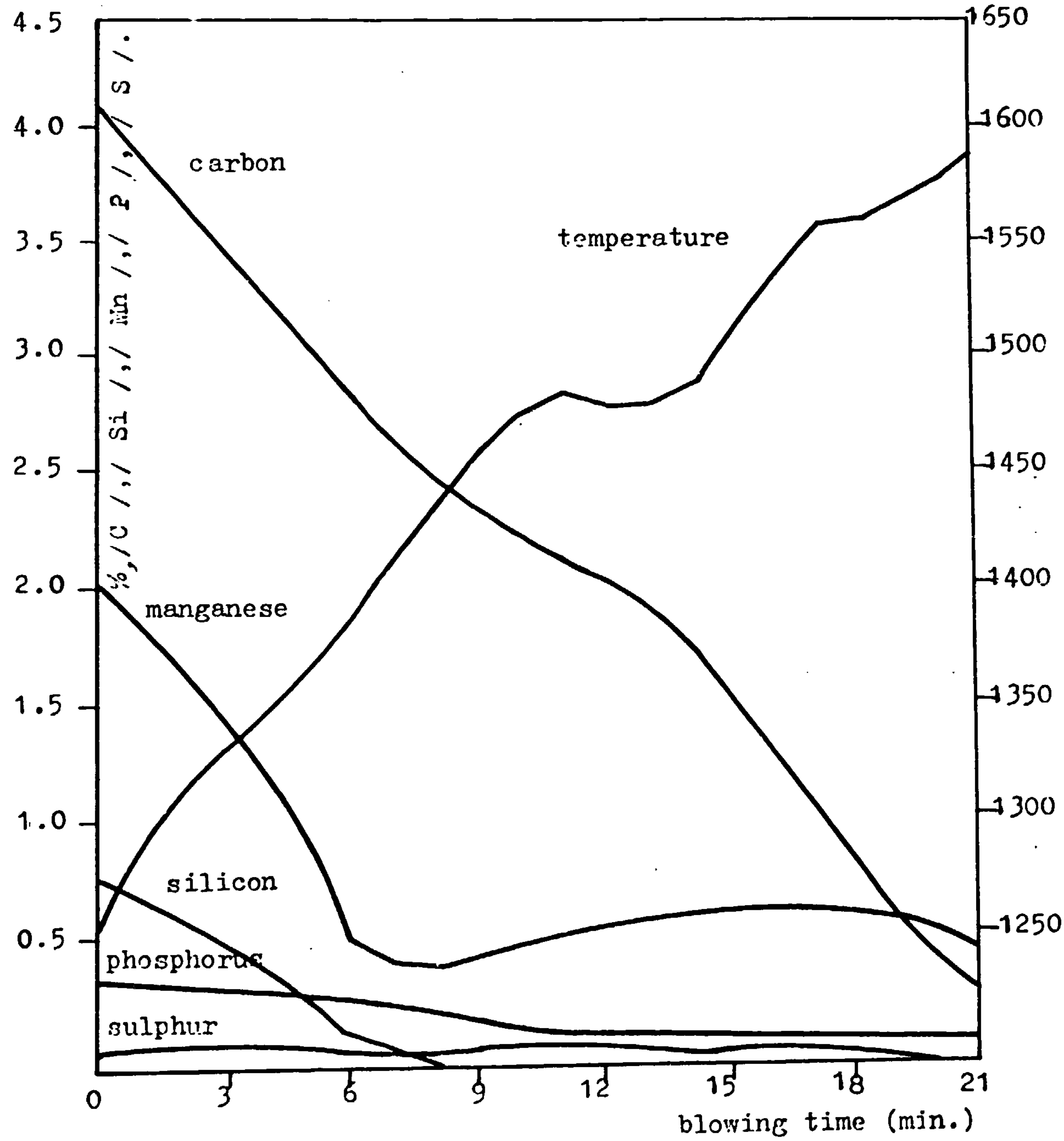


Fig.5.1. Variation of chemical analysis and temperature of the melted metal bath with blowing time.

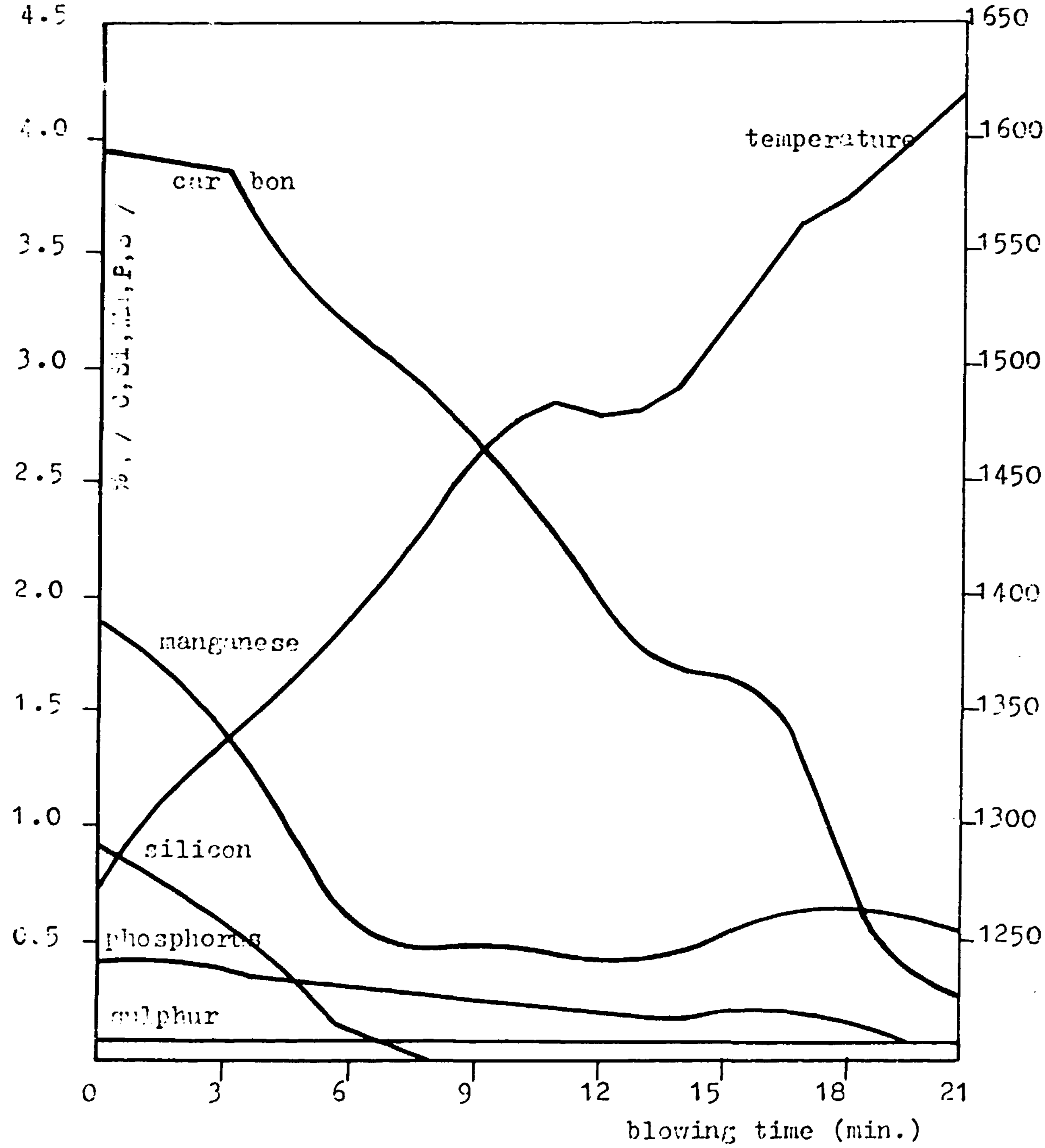


Fig.5.2.Variation of chemical analysis and temperature of the melted metal bath with blowing time.

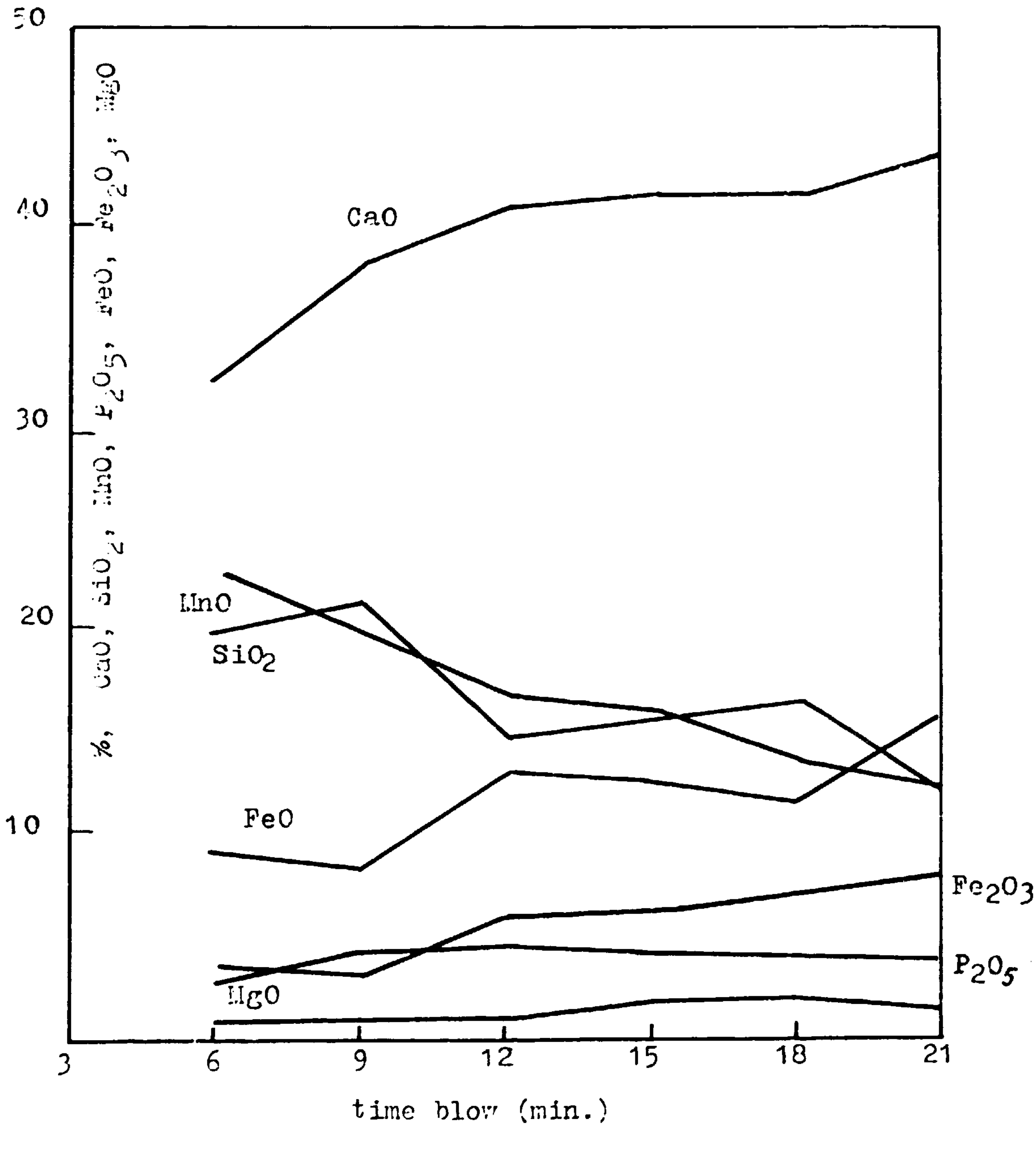


Fig.5.3. Variation of chemical analysis of the slag with blowing time.

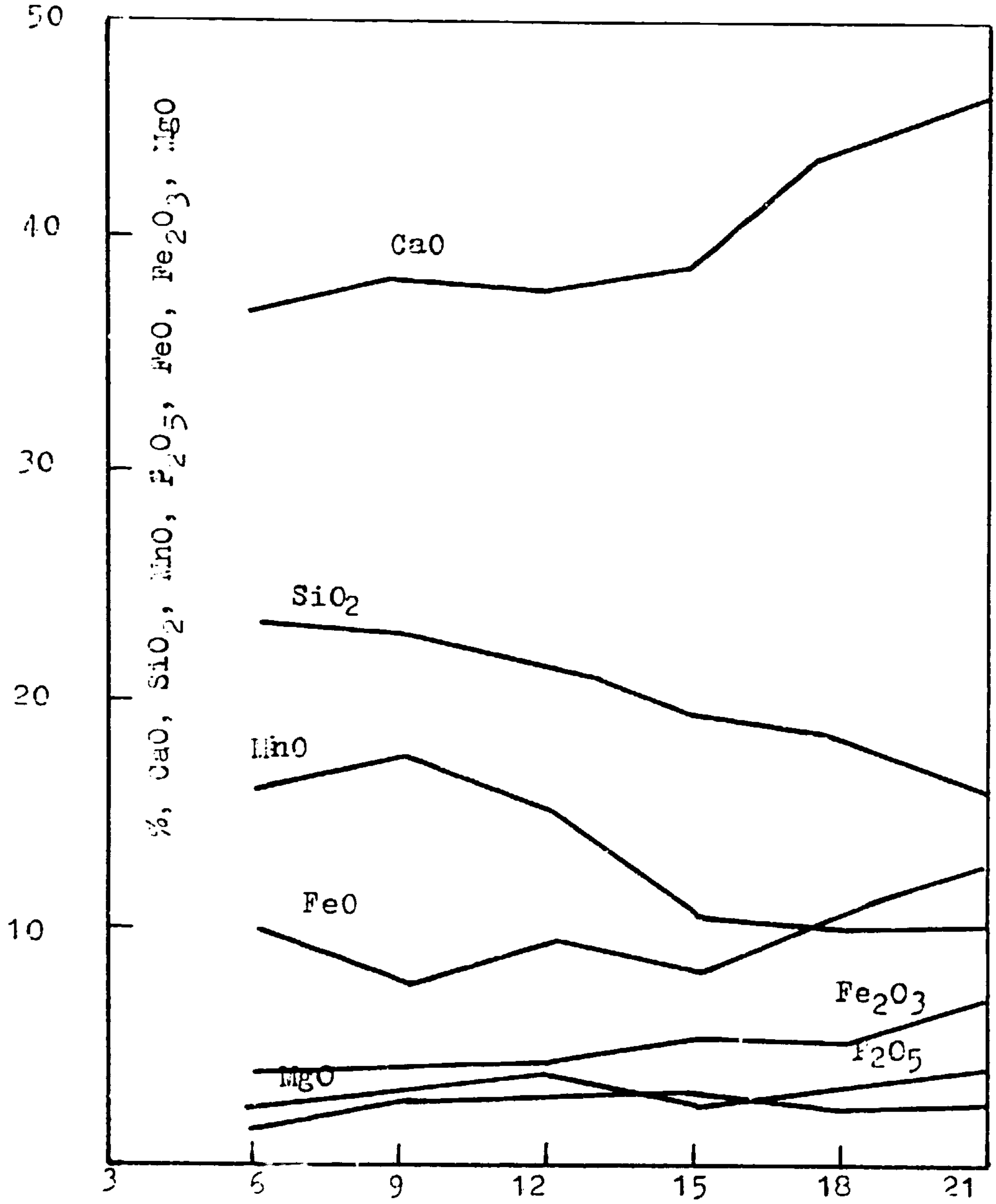


Fig.5.4. Variation of chemical analysis of the slag with blowing time.

by calculations taking into account a remained elements content in the melt and the loss of the element depending on the bath oxidation. At that period, if necessary, steel carburizing with coke is performed.

In the course of argon blowing metal composition and temperature averaging is done on a special equipment with the system of bunkers and dozimeters. It should be noted that a considerable amount of the converter slag in a ladle often leads to rephosphorization and P content increase in a metal up to 0.015%.

After the metal in a ladle has been transported to the CC (continuous caster) the received slabs quality is determined both by the received liquid steel quality and by casting technology and conditions. The research carried out under the guidance of the Works specialists and El-Tabin Institute for Metallurgical Studies / 9 / has enabled to establish the influence of the steel chemical composition (C, P, S, Mn content) on the slab defect presence such as longitudinal crack.

Based on the research results it was stated that the minimum defects percentage is observed when C content equals 0.09-0.11%, defects percentage is reduced with the S and P content decrease and it increases with the Mn/S relation decrease. The mentioned relation is observed to be the minimum defects persentage.

The increased defects with C content less than 0.09% in work / 9 / are connected with the caused increased oxygen concentration in liquid steel and with its corresponding increase of non-metallic inclusions contamination during continuous casting process. Defects quantity increase with C content higher than 0.11% (fig.5.5).

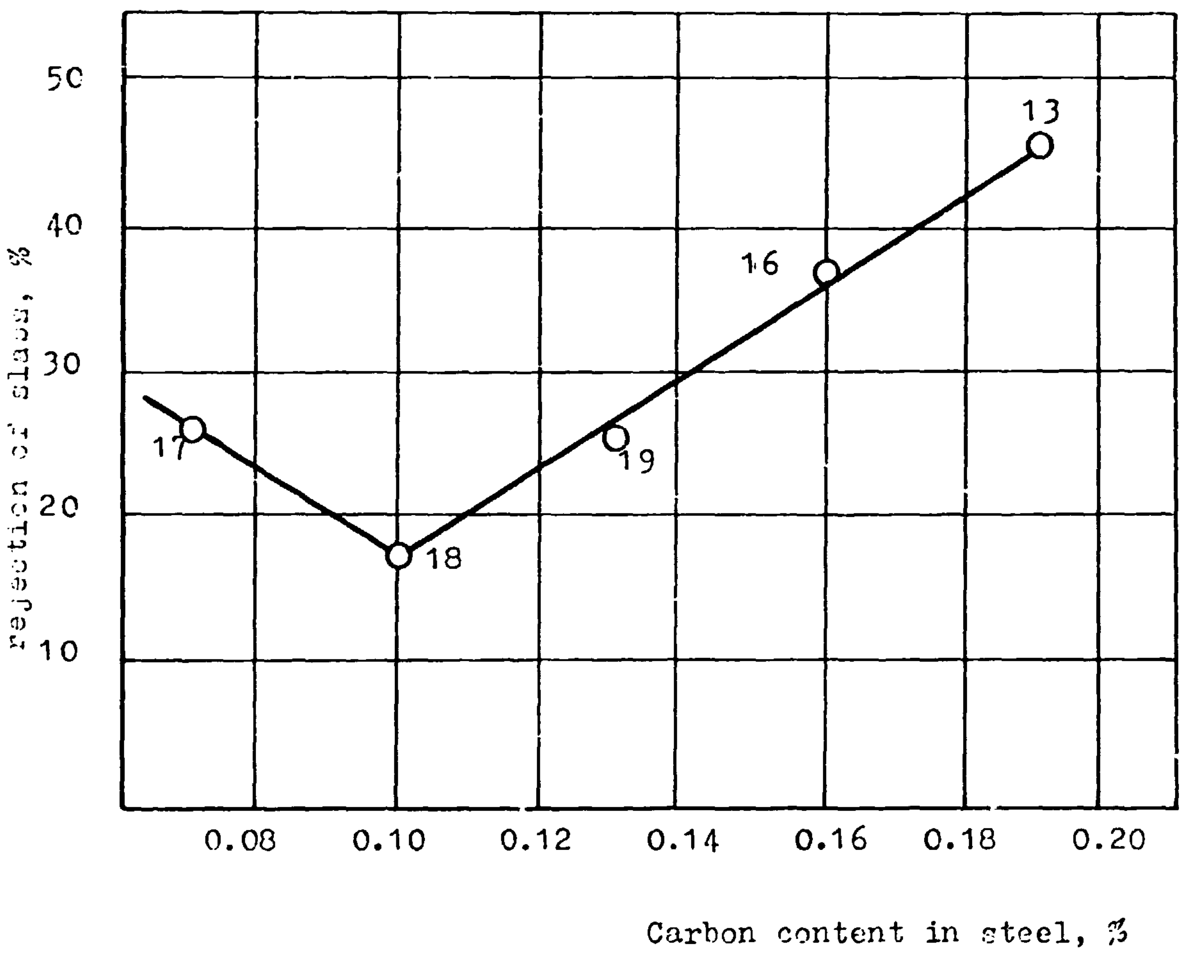


Fig.5.5. The influence of carbon content on rejection of slabs.

In the authors' opinion it may be caused by the $\delta-\gamma$ phase transformation with the corresponding volume decrease and metal shrinkage. The given data (fig.5.6) enable to state that with the total S and P content less than 0.05% C content influence on defects quantity due to longitudional cracking is practically absent. In this connection the authors / 9 / consider it reasonable to limit the total S and P content with 0.05% level when producing steel with C content more than 0.15%.

As steel plastic properties deteriorate with the P concentration increase, defects quantity increase due to longitudinal cracking takes place (fig.5.7). Analogous influence on defects quantity is caused by S content in metal (fig.5.7).

A considerable influence of Mn/S ratio on slab quality (fig.5.8) as the authors / 9 / suggest is the result of the austenite grain -boundary microcracks formation.

The analysis of continuous casting slab quality has enabled to find the presence of a large amount of slabs with belts which result in the interruption of metal feeding in a mould. Metal overheating particularly together with the insufficient tundish preheating (the amount of overheated melts makes up 20-25%) is accompanied by the increased wear of the tundish nozzle which results in incorrect metal stream formation.

The absence of the metal stream protection during casting results in intensive oxidation as mentioned in the work / 9 / on literature data basis / 11, 12 / is followed by a considerable increase of non-metallic inclusions amount / 13, 15, 16 /, and also by the blowholes / 14, 15, 16 /.

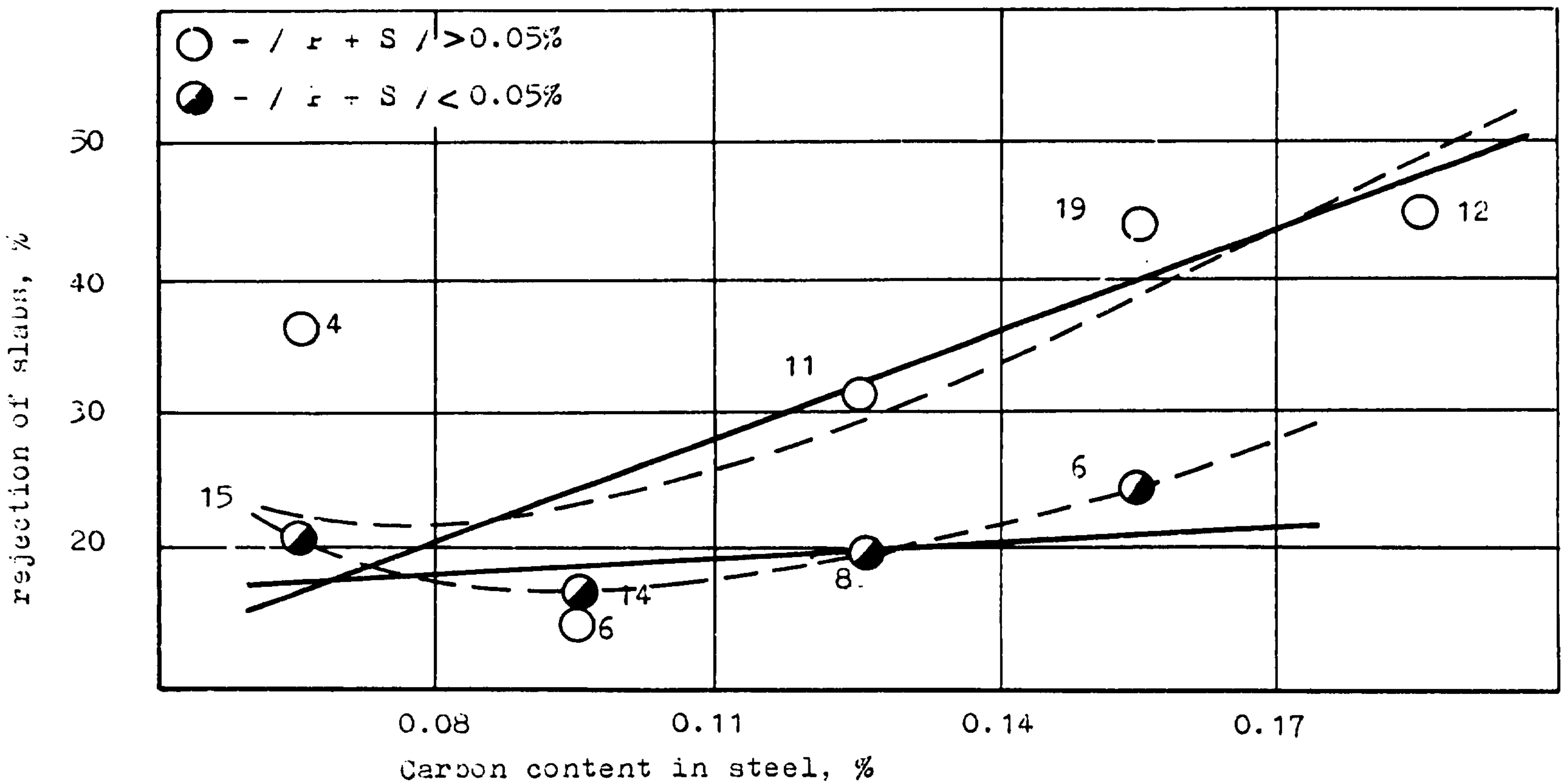


Fig.5.6. The influence of carbon content in steel on rejection of slabs.

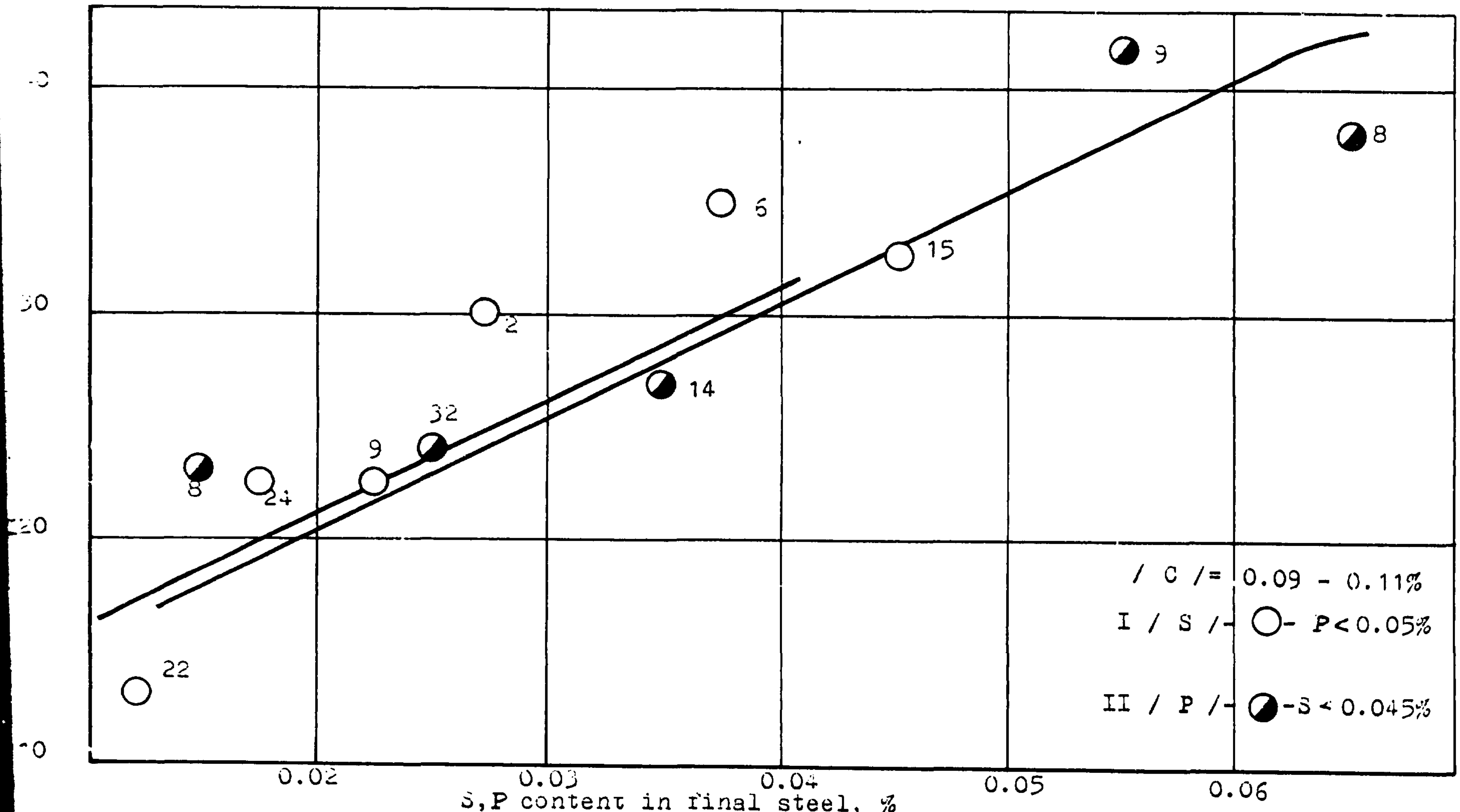


Fig.5.7. The influence of /S/ and /P/ on rejection of slabs.

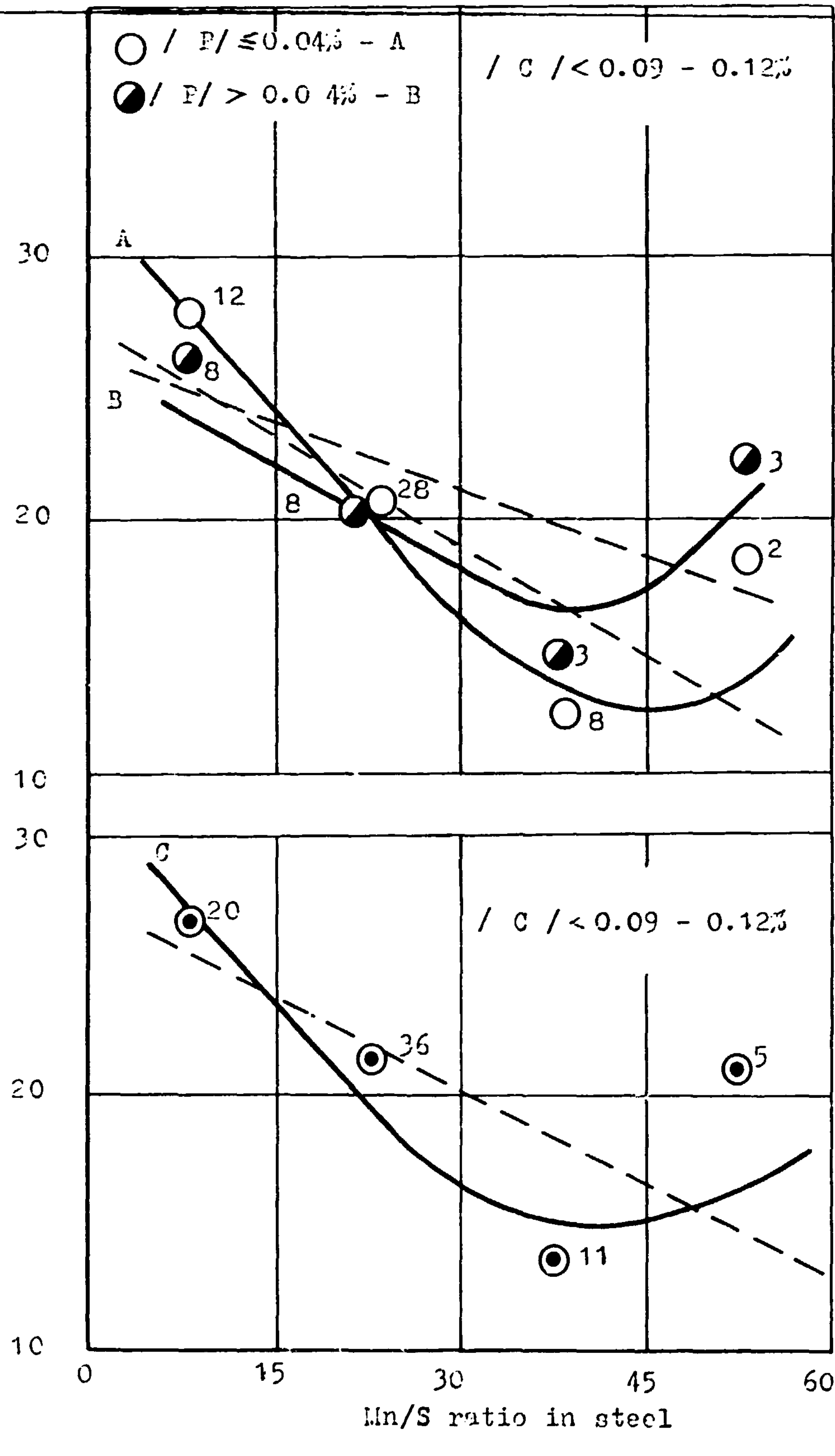


Fig.5.8. The influence of Mn/S ratio on rejection of slabs.
(Figures near points - amount of melts)

The state of the metal in the mould also affects the slab surface quality. When casting with throttled stream metal splashes adhere to the mould walls and cause the formation of the oxidized film on the metal shell. Moreover, a considerable metal temperature overfall in a ladle and in a mould results in further oxidation processes in a mould of the previously introduced deoxidizers and C.

These factors affect unsatisfactory slab surface quality and blowholes formation.

The slab surface quality is to a great extent affected by the processes taking place during melt crystallization: the formation of a solid metal shell, metal shrinkage, its movement during pulling. At the beginning of metal crystallization the shell is formed lower the liquid meniscus as a result of the direct contact with the water-cooled mould wall. When the metal is rapidly cooled the process is followed by the $\delta-\gamma$ phase transformation with the metal shrinkage and gap formation between the mould wall and the slab crust (fig. 5.9, 5.10). At lower levels the skin may adhere to the mould wall due to the ferrostatic pressure increase. The reheating in its turn leads to lowering of the skin and the increased ferrostatic pressure can push the skin in the gap region back toward the mould wall and the skin in the gap region can be thinner.

The conditions of continuous casting slab secondary cooling greatly affect both the surface formation and the inner cracks. Slab water cooling in EISCo Works is followed by drastic thermal stresses and leads to fluctuations of different slab parts cooling.This

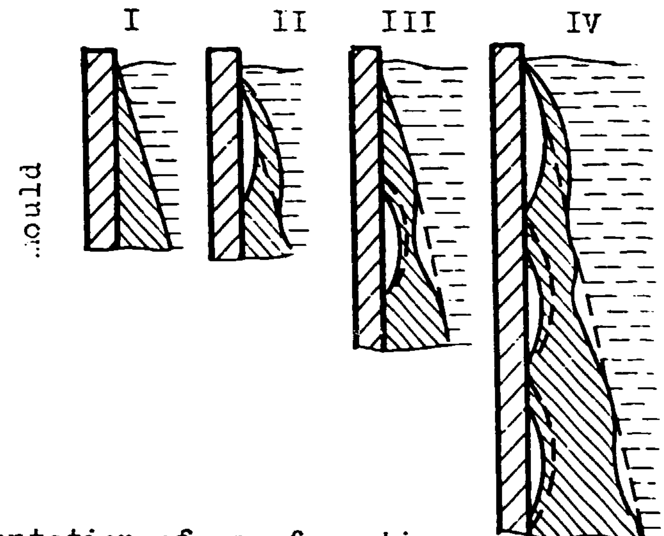


Fig.5.9. Representation of gap formation in the mould as a result of the δ to γ phase transformation.

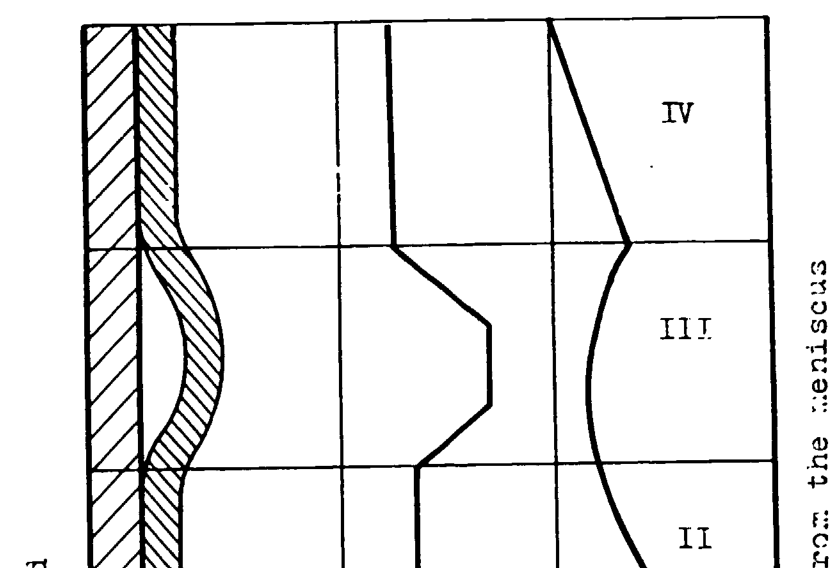


Fig.5.10. The change of the heat flux, temperature of metal skin during casting of slab.

results in sufficient thermal stresses inside the slab followed by crack formation.

5.2. Experts Evaluation of Factors (Experts: EISCo Experts, Soviet Experts).

A questionnaire including the main questions was worked out by a group of the USSR and Egypt specialists in steelmaking to find out the influence of a number of technological factors on oxygen converter steel and continuous casting ingot quality:

1. A number of technological factors influencing detrimental impurities content and their presence form in steel;

2. Technological factors influence on continuous casting ingot defects.

The whole questionnaire list and also some answers of the experts are given in Supplement 1. MISA specialists worked as the USSR experts. These are the leading professors and scientific researcher in Metallurgy of Steel Department and also Lipetsk Iron and Steel Plant specialists working in its research centre, quality control and technology sectors. Technical engineering staff from Egypt Iron and Steel Plant working in BOF and quality control department took part in the research.

Questionnaire results processing makes it possible to state:

1. Relative influence of several factors on detrimental impurities content and the presence form in steel.

1.1. According to experts' opinion final sulphur content in metal melt processing in a ladle is considerably influenced by silicocalcium, lime or artificial slag and basic slag before tapping. A number of experts mentioned a considerable influence of final slag cut-off, metal temperature and oxygen content before tapping.

1.2. Quantity of phosphorus final content in metal the specialists associate first with steel oxidation and final slag basicity degree and the possibility of the latter to be separated from a metal when tapped.

1.3. The required nitrogen, oxygen and hydrogen content in steel may be achieved both by liquid steel vacuum processing and by argon melt blowing and metal protection from secondary oxidation; besides oxygen content is affected by final carbon content and metal temperature.

1.4. Non-metallic inclusions presence form (primarilly oxides) may be influenced by optimum organization of the melt final deoxidation method, by ladle metal processing (artificial slag processing, argon blowing, lime and silicocalcium injection in a ladle) and by protection methods from secondary oxidation.

2. On several factors influence on continuous casting defects.

2.1. Experts consider the following factors to determine continuous casting ingot quality: metal temperature when cast and casting speed. It is these factors that influence greatly longitidinal, transversal and internal cracks presence as well as pores, blow holes presence and the segregation degree.

2.2. Sulphur content in metal considerably influences crack presence and segregation degree. Carbon content influences less its defects presence. But some specialists underlined this factor influence on blow holes presence.

2.3. Experts consider secondary cooling character to influence greatly the possibility to form blow holes. This parameter renders less influence on other defects.

2.4. Secondary cooling character affects considerably such defects presence of CC ingot as longitudinal, transversal and internal cracks.

2.5. Mould oscillation character (frequency and amplitude) affects cracks formation on ingot surface first of all transversal cracks.

2.6. Experts think metal stirring renders weak influence on ingot quality.

Thus, results of experts estimation make it possible to reveal a number of factors influencing considerably metal quality smelted in oxygen converter and cast in CC. In most experts' opinion such factors are: ladle steel processing (its types variations), steel oxidation degree and its temperature as well as final slag basicity, its possibility to be separated from a metal during tapping. These factors render a decisive influence on detrimental impurities content in steel and their presence form.

CC ingot quality (cracks and pores presence, segregation degree) is affected enormously by casting conditions (metal temperature and casting speed) and also secondary cooling character. Experts stress considerable influence of metal secondary cooling on a probability to form blow holes.

5.3. The Ways of Steel Quality Improvement of the Current Production.

5.3.1. The Ways of Defects Decrease.

As it was stated in item 5.1. the adopted EISCo technology, the worked out technology and the applied equipment define a number of factors influencing the quality of the yield production.

The step-by-step operation analysis of the technological scheme makes it possible to determine a number of certain instructions for the produced steel quality improvement without sizable capital investments. The general instructions are based on the necessity to observe strictly the existing technology and its improvement in a number of cases.

Initial materials preparation

Work on chemical hot metal and lime composition standardization and on the quality of the charged hot metal and scrap stabilization should be carried out. The implementation of the work will enable to work out a more rigid technology with narrow limits with regard for lime and oxygen expenditure per melt. Initial materials composition standardization and stringent control at charged materials and oxygen expenditure make it possible to forecast semiproduct composition and the produced steel on the basis of the balance accounts using the available shop equipment.

As stated above the reproduced EISCo hot metal is characterized by the increased Mn and P content. Oxygen converter is not known to be the optimum unit for sulphur removal from the metal. Besides the elaboration of the technological variants of steelmaking from iron being preprocessed - desulphurization, dephosphorization and demanganisation - should be specially examined. At present the installation for iron desulphurization is being at the final stage of construction. This will enable to improve the initial materials quality to a certain degree. However for the essential hot metal quality improvement and for the considerable further steel production technology simplification the possibility of preliminary hot metal demanganization and dephosphorization demands special attention.

The existing trial and industrial trial elaborations / 17, 18, 25 / show the possibility to decrease phosphorus content in hot metal to using as reagents Ba CO_3. It should be stated that in case of predephosphorized hot metal use at the EISCo BOF the technology of converter reproduction receiving naturally Mn alloyed steel (09Г2С, 35ГС and others) may be worked out.

The available literature data applied for the Kremikov Iron and Steel Works (Bulgaria) indicate high efficiency of such a technological variant / 19 /.

Ore deposits introduction with the content higher than the present Mn content will ensure hot metal with 3-5% Mn content production. Besides the possibility of hot metal predemanganization with semiproduct manufacture that more completely corresponds to the oxygen converter reproduction requirements should be underlined.

The above-given technological variants of the preliminary hot metal processing and the optimum variants selection require a more profound techno-economic and experimental elaboration.

The charged materials quality improvement will make it possible to decrease considerably the quantity of slagforming materials and slag that will have positive influence on the yield in the oxygen converter process. Hot metall reprocessing that undergoes predephosphorization or predemanganization will enable to decline a two-slag process that will reduce considerably heat duration and will encrease shop productivity. Lime quality improvement will positively influence the melting heat balance and will enable to increase scrap portion in the metal charge.

Oxygen converter reprocessing and CC

First, the necessity to work with the remaining quantity of the finished slag and its application as a slagforming material in the first period of heat should be mentioned. The available data / 7, 3 / and the examination during the plant period enable to state that a certain portion of heats is performed without the remaining slag.

Oxygen expenditure heat introduction should be specially emphasized. The existing shop equipment and the static balanced model of the oxygen converter process enable to calculate the necessary oxygen expenditure both at the first heat period and while having semifinal metal probe analysis and at the second heat period. The fact that at present heat process is performed without oxygen expenditure account results in unsatisfactory metal quality production at the end of the second metal blowing period and in the necessity to carry out correction reblowing. This leads to a considerable metal quality decrease resulting in metal overoxidation, increased contamination with non-metallic inclusions.

Heat temperature mode is extremely important for the melted metal quality. Metal overheating in a converter results in its increased non-metallic inclusions and gases contamination. Further, during pouring and crystallization it results in a number of slab defects occurrence. Due to the above-mentioned data converter reprocessing technology should be optimized from the point of heat balance, thus rigid, limited metal temperature range both during melt blowing and metal tapping should be determined. This may be achieved, for example, by scrap portion increase. Precise scrap quantity calculation per each definite heat with regard for the yielded iron composition, temperature and quantity is possible due to the existing BOF model.

As stated in item 5.1 rephosphorization is often observed in the process of metal deoxidation and its argon processing. To prevent this phenomena certain measures should be taken to protect slag getting into the ladle. The existing methods / 20, 21 / enable to cut off slag sufficiently and to increase essentially metal quality both at the expense of the final P content decrease and non-metallic inclusions contamination decrease. Slag quantity decrease in a ladle diminishes considerably deoxidizers waste and stabilizes deoxidation process.

The existing metal deoxidation technology is based on the deoxidizers quantity calculation according to the metal chemical analysis without regard for oxidation. However the present elaborations / 15, 22 / make it possible to control metal oxidation before tapping and in a ladle before and in the course of argon processing. In a number of enterprizes these data are successfully applied for precise calculation and deoxidizers correction /23, 16/. Further metal oxidation control and its regulation during continuous steel casting enable to improve cast slabs and billets quality / 26 /, particularly to decrease defects percentage because of blow holes and the increased quantity of non-metallic inclusions presence.

The presence of a great defects percentage received after steel crystallization at continuous casters enables to state the necessity to improve steel casting technology.

5.3.2. Methods of Operating Steel Qualities Improvement.

As stated in chapter 3 operating steel properties level improvement may be achieved by secondary metallurgy. In particular, we think that accoding to the MISCo conditions secondary metallurgy aimed at steel desulphurization should be emphasized. At low sulphur concentration the present sulphide quantity influences greatly the relative decrease of the transversal cross-section during rolling. Such unwanted phenomena as hydrogen cracking and cracking caused by stress corrosion that depends on sulphur presence in steel may usually occur under certain external conditions. Besides sulphur content decrease up to the least possible level for developing less crack-forming tendency it is necessary to transfer Mn sulphides into Ca sulphides or sulphide oxides. As it is shown in various researches such a transformation can be effectively done during Ca processing / 28-30 /.

Oxide inclusions also render negative influence on steel quality. In particular, these inclusions presence leads to contamination of the pouring tube during continuous steel casting deoxidized with aluminium. That is caused by solid alumina inclusions deposition being formed at aluminium deoxidation. The problem may be solved by means of alumina inclusions transformation into liquid Ca Al which doesn't adhere to the internal tube surface.

Such data as desulphurization degree reaching 70-90% when basic slag is added into the ladle and simultaneously melt blowing with inert gases being done is given in a number of works / 31-33 /. The optimum slag composition should include CaO, SiO_2 and Al_2O_3, having the proportion (CaO/SiO_2) : Al_2O_3 = 0.35. The best results were obtained using slag 60% CaO - 15% CaF_2 - 20% Al_2O_3 and performing simultaneous argon melt blowing.

To implement the above-mentioned method of steel quality improvement at EISCo is not a problem. The additions of the appropriate slag mixture should be worked out before argon metal blowing. Additional research should be carried out to select the optimum slag mixture composition and the blowing mode.

To produce qualitative steel with low sulphur content and controlable inclusions quantity the method of powder metal blowing has got a wide application. Such mixtures as CaO - CaF_2 - Al_2O_3 and also Ca alloys (CaCl, CaSi, CaAl, CaSiAl and others) and their mixtures are used as powders. Recently Ca-bearing substances introduction methods have been worked out which used capsule plunging and Ca-bearing wire application. According to the method of capsule plunging Al capsule with CaSi content is plunged into the ladle under the high gas pressure stream. Due to the second method steel wire with Ca content composition is introduced into the ladle by means of the drawing mechanism.

Although a wire drawing method is generally used to regulate the morphology (modification) of the oxide and sulphide steel inclusions it may also improve desulphurization slag activity.

The formation of the detrimental sulphide and lime inclusions may be prevented by Mn and sulphur interaction producing more stable and non-deforming MnCa sulphides when CaSi is introduced.That improves mechanical properties and the ability for shearing processing of the finished product. The detrimental alumina inclusions transfer into less detrimental Ca aluminates which results in the decrease or a complete tundish nozzle contamination removal during continuous casting. Unlike CaSi blowing, Ca-bearing wire introduction does not cause the increase of N and P content in steel.

When processed with CaSi wire in a tundish the oxides in steel possess a finer grain structure than during powder blowing into the ladle.

At EISCo Ca-bearing wire introduction is more applicable during argon metal blowing. The appropriate equipment is available in the shop for this purpose. Some additional research makes it possible to work out the modified steel processing mode.

Continuous casting metal quality improvement.

At present the main trends in continuous steel casting are to raise economic level, to decrease energy consumption, to produce semiproducts with the cross-section close to the finished rolling. To follow the above-stated instructions a number of activities aimed at the improvement of the produced continuous casting billet and at the automatization of the casting process are quite necessary.

Modern continuous steel casting technology includes both actions of forming continuous casting billet surface without defects (high frequency mould oscillation with low amplitude mode, selection of slagforming mixtures optimum composition, soft cooling in secondary cooling zone, cone-shaped mould selection to prevent longitudinal cracks formation) and internal structure formation (electromagnetic mixing, weak squeezing). The technology also envisages measures to protect a metal from secondary oxidation that has a positive influence on the continuous casting slabs and billets quality and its service properties. One of the primary conditions to produce successful casting is the process parameters stability which is achieved due to a high level of modern CCs automatization.

Tundish is the first structural CC element which must provide uniform steel supply into the mould possesses a mixing zone using additions (microalloying) and operates as a unit for the final steel refining from non-metallic inclusions. For metallurgical processes optimization in a tundish it is necessary to decrease air seizure and secondary metal oxidation, to prevent hollows on a metal surface, to maximize liquid steel presence in a tundish, to remove stagnation zones and to provide metal homogeneity coming into a mould.

The indespensable condition for high quality continuous casting slabs and billets production is metal protection from secondary oxidation with oxygen-contained air. Protection makes it possible to extend steel grades which are cast at CCs and to enhance billets quality.

To prevent metal stream between a steel casting ladle and a tundish firebrick tubes in combination with inert gas supply are widely applied and a considerable decrease of the cast steel secondary oxidation and nitrogen absorption is achieved.

At a tundish-mould section the metal stream during a large section ingot casting is protected by the plunged tubes, mostly corund-graphite tubes, sometimes using neutral gas. Casting through the plunged tubes prevents a slagforming mixture drawing by a freely falling stream, the slagforming mixture covering the metal surface in the mould. Heat isolating slagforming mixtures with CaO-SiO_2-Al_2O_3 base and with graphite content materials additions are used to protect metal surface both in a tundish and in a mould.

Mould oscillation with high frequency (about 400 min^{-1}) and low amplitude (on the level of 4mm) makes it possible to reduce considerably the oscillation traces depth where transversal cracks may be developed as a result. The oscillation traces reduction decreases crack formation and increases external billets surface quality. Metal level stabilization in the mould increases effectively external billet surface quality /16, 24 /.

Application of the slide gate with plates which undergo vibrational reciprocated motion enables to decrease a crust formation in the channel gate and to increase the accuracy of the casting process regulation.

In the secondary cooling zone of modern CCs two -component mist cooling instead of water cooling finds a wide application / 25, 26 /. It is connected with a number of advantages of mist cooling: a wide range of cooling intensity regulation, a rather uniform continuous casting billet surface cooling that prevents surface defects propagation, a lower water expenditure, ingot cooling parameters stabilization and a more stable operation of water sprayers. Mist cooling enables to receive better results during crack-sensitive steel casting. At modern CCs cooling along the secondary cooling zone changes smoothly, water supply intensity regulation being implemented by a special computer programme with regard for the grade of steel, casting speed, metal temperature.

Application of the continuous casting billet soft squeezing technology makes it possible to intensify the replenishment of the billet solid-liquid zone and to compensate shrinkage processes that promotes density increase of the billet central zone with the decrease of the central segregation degree.

Electromagnetic mixing application is a highly effective means to improve internal structure quality of the continuous casting billets. It is more expedient to use a combined electromagnetic mixing comprising two or three stages: the first promotes wide and dense equiaxial formation due to mixing in the mould, the second influences a two-phaze crystallization in the central part of the bloom by means of a mixer placed at the end of the liquid zone of the billet. The third mixer may be also used which is placed between the first and the second ones, promoting additional removal of central segregation.

To reduce internal cracks formation and to decrease deformation in a solidified crust it's advisable to undertake measures for swelling limitation making use of a more rigid supporting system.

6. STEEL QUALITY CONTROL ON COMPUTER BASIS

It is known that the high quality of the finished product may be reached only if it is properly and carefully inspected and controlled at all technological stages. Within this work we consider a continuous casting ingot as a finished product. In this case the ingot quality is ensured by the charged materials quality, heat mode, tapping, metal transportation, its ladle processing and casting conditions.

At all technological stages computer application may essentially promote quality improvement.

Let us analyze some international experience of computer application to control BOF processes for quality improvement.

6.1. Computer Application for Process Control.

Some examples of the international experience.

Metallurgy is known to be one of the first industrial sectors where in the mid 50-s computers for process control started to be applied. The first enthusiasm of specialists was changed by great dissapointment. At present a realistic estimation of computer abilities and difficulties of its application has been formulated.Today even in Japan metallurgy is still one of the leading branches applying computer though such branches as electronics, chemistry and others are extremely well-developed there (fig.6.1).

Moreover, process control remains the main branch for computer application.

A lot of positive results of computer application for quality control are quite well known. We shall give only some examples.

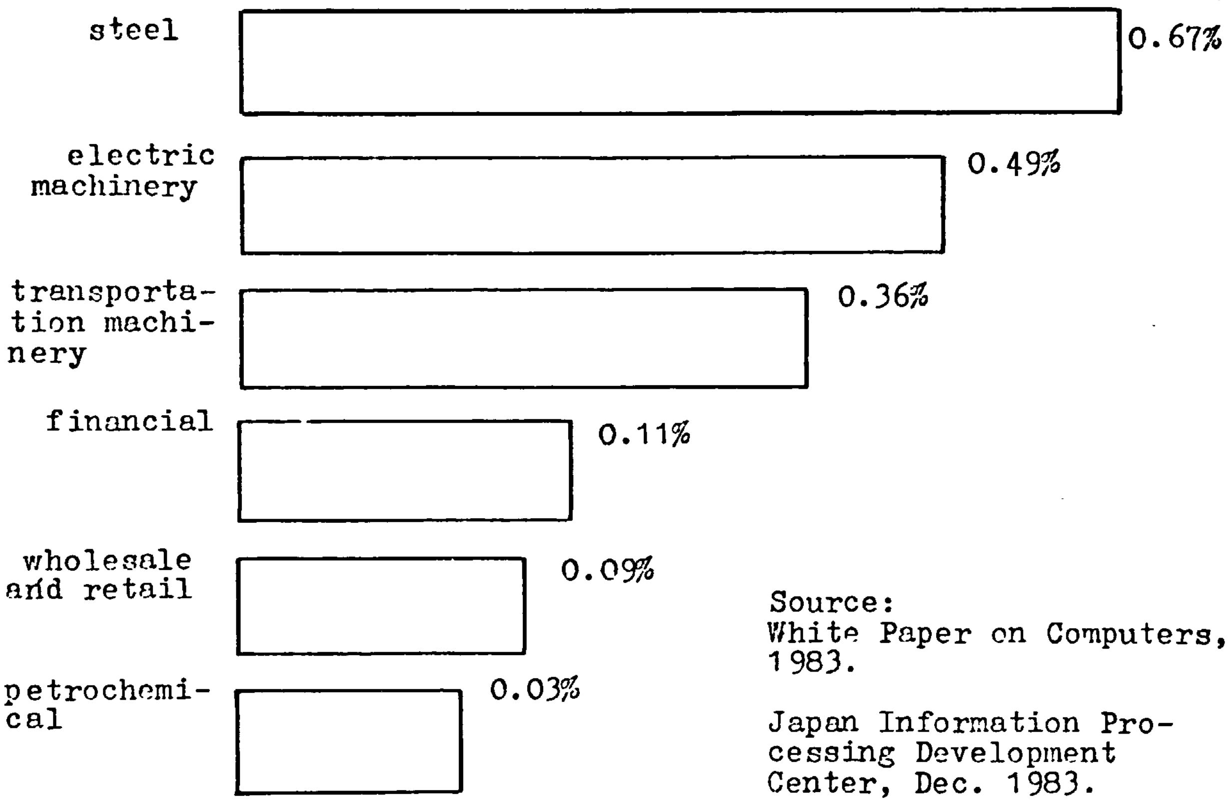
A new computer system has been developed on Bettelchem Steel (USA) enabling to improve considerably continuous casting ingot quality and to lower its cost by about 20%. The system is equipped by modern instrumentation. For example, for safe ingot surface temperature measurement pirometers with light guides are applied. A perfect secondary cooling system that enabled to double the decrease of the number of breaks and to conduct processes when overheat reaches only up to 20°C. Such a low overheat enables to obtain the same influence on quality which is usually received by a liquid metal electromagnetic mixing.

A new integrated control system is installed at the steelmaking shop N 2 at Kawasaky Steel Plant (Japan). The system based on 53500 Fudsi Denki computer includes the processes starting from iron processing in mixers and finally dealing with steelrefining.

The system comprises the following 6 subsystems: control of iron transportation in mixers, iron preprocessing control, charge calculations, refining control, general control problems. The system has been worked out by the company's staff within two years and five months. This development gives the example of the integrated approach towards BOF production quality control.

A branch programme of quality control was elaborated in CSSR. The system is computer-based and comprises 12 main subsystems connected with modern control methods, standardization, the level of skills improvement and personnel responsibility.

These few examples show the possibilities of computer applications for quality inspection and control. "Idealized" computer application scheme can be shown as follows:



Source:
White Paper on Computers, 1983.

Japan Information Processing Development Center, Dec. 1983.

Fig.6.1. Percentage of computer expenses against sales by industries in Japan.

BOF shop receives the order for the finished products - a continuous casting ingot of a certain grade and size which suggests the required mechanical, corrosion-resistant and other properties. BOF order is formed on the basis of rolling or other products fulfilled by the plant order. BOF order may be given as a shift, daily or weekly assignment. To fulfill the assignment in BOF it should be delivered as a shift assignment.

1. One of the first computer functions is to formulate the heat shift schedule according to the selected criteria and the limitations available. As a rule, the heats schedule is oriented at quantitative criteria (output, cost etc.) and at the same time it should take into account quality criteria, ingot layers avoidance, normal metal oxidation etc.

2. The preliminary assignments calculations for casting and melting technology.

The assignments include:

- casting mode (temperature and metal composition during casting etc.),
- casting speed (secondary cooling mode etc.),
- ladle metal processing mode (temperature, processing time, quality and composition of alloying additions etc.),
- heat mode (charge components, weight, blowing mode - intensity, time etc.).

The preliminary assignments calculations may not necessarily be made on computer basis, they may be presented as technological instructions.

3. Assignment recalculation of technological stages according

to real technological variables.

The recalculation is made on the available parameters measurements basis. For example, when there are deviations from the predetermined iron or scrap weight, when iron and scrap are delayed to be fed into the converter, the computer must perform blowing time and blowing intensity recalculations. Such a control should be conducted at all technological stages and according to the obtained results the computer makes corrections of the following technological modes: according to the blending results blowing mode is corrected; according to the analysis and metal temperature - deoxidation, alloying and ladle processing modes are corrected, according to metal conditions before casting - casting speed and secondary cooling mode are corrected.

Generally the main objective of the computer is to optimize the shop operation as a whole; and the influence on the continuous casting ingot is determined by the priority of the optimization criteria selected. If the output and cost are considered to be as criteria then quality estimates may represent limitations or restrictions. Quality estimates may be taken as criteria, to be more exact, some indices characterizing them: metal temperature, its composition, oxygen content and others.

As a rule, the optimization problem is solved not in a formalized but in a quantitative way.

It should be noted that the problem of optimization was set out as a rule in a qualitative way.

6.2. Process Control System at EISCo Works.

EISCo is the leading Iron and Steel Works in Egypt as far as computer application is concerned. Computer application elaborations began in early 70-s and at present there has been developed a concept of computerization and it is consequently being carried out owing to both the Works' efforts and UNIDO projects.

Since November 1987 the process control system on computer base PDP-11/23 and 24 has been operating in BOF and it realizes a static model of heat control. Each converter is equipped with terminals inputing and outputing appropriate information for the operator.

At present the system performs the following functions:

- heat and mass balance calculations and on this basis getting carbon content and metal temperature data (static input-output model),
- various data collection and processing, heats, heat log printing shift, daily and other reports, statistic reports preparation and others.

At present intensive work of the system functions expansion is carried out at the Works - installation of equipment for gas analysis and noise intensity measurements within UNDP/UNIDO project DP/EGY/85/005. This information will serve the basis for the dynamic model which is supposed to be used in the near future.

The system introduction is an advanced step towards works computerization. The results of the system operation are given in Supplement 2.

At present the essential feature of the system operation is that it performs carbon content and metal temperature forecast by the end of the first blowing period for slagging. For the subsequent reblowing stage the system doesn't make calculations.

The reason lies in the difficulty of express analysis of metal and slag and in lack of information on the remaining converter slag quantity. Naturally, it limitates the possibility to apply the system for metal quality inspection and control.

The system shows a rather high accuracy in temperature forecast which is extremely important from the point of metal quality control.

The desired temperature forecast is established within ± 15°C range. In this case, having the possibility to predict rather precisely the temperature on the statical model basis, the aim is to formulate correctly the given optimum temperature during the first blowing period. That is the personnel objective to be engaged in quality control and technology management.

Obviously, the various results of hitting the target are connected with a different variable of admissible temperature and carbon limits: in December 1988 88.6% of all failures are correlated with temperature and 11.4% with chemical composition, i.e. carbon content. The tolerance of carbon content in the first period is established on ± 0.3°C which is more essential in comparison with international standards.

If both permissible limits are kept at the adopted international standard level, i.e. ± 15°C and ± 0.05°C the deviation distribution between them will be more uniform and effectiveness of the whole system will be decreased.

On the whole a sufficiently high degree of the system application in heats should be stated. The calculation is made for all heats, the model is effectively used for 65.7% of process implementation. Non-application of the model is connected with the essential technology violations - considerable violations of the charge or blowing mode.

It should be also stated that at the existing level of the system and static model application it is difficult yet to speak about its essential influence on metal quality. But nevertheless it is necessity and usefulness for process control is obvious.

Getting additional information about the exhausted gases composition and noise level enables to enhance forecast accuracy on the dynamic model basis. Besides there are still express metal and slag analysis problems and problems of their quality evaluation. In this connection it is quite necessary to find an express analyzer on C, Mn, P which would enable to perform a static model forecast correction and to make further reblowing calculation.

Moreover, it is reasonable to evaluate the remained slag quantity influence on C and temperature forecast accuracy, e.g. using the method mentioned in the survey / 7 /.

7. SUBSTANTIATIONS FOR ALLOYING STEEL GRADES SELECTION AT THE EISCO BOF AND THE POSSIBLE MELTING TECHNOLOGIES.

Not only carbon but low carbon steel can be produced in oxygen converters. There are no principle obstacles for their production. Modern secondary metallurgy methods enable to transfer all deoxidation and alloying operations from the converter into a ladle. The converter remains only as a unit for semiproduct melting.

Egyptian steel industry is in great demand for reinforcement steel for construction purposes and for multipurposes tube steel. There exists a deficit in deep drawing steel.

Strength is the main requirement put for structural steel including structural and reinforsement steel. Strength improvement enables to decrease the production metal capacity. When only steel 37 is substituted for 52 it is possible to reduce reinforcement steel diameter, e.g. from 25mm to 18mm without influencing operating characteristics. Alloying enables to decrease metal expenditure to a larger extent.

Chromium is found to be the best suited alloying component used for these purposes. 1% of its addition noticeably increases steel strength. And even in case of the increased carbon content the desirable weldability is observed. International experience has shown that medium carbon chromium steel grades (0.20-0.40 C and 1% Cr)have acquired wide application. As structural alloying steels: 20 - 40Х due to the USSR standards and also 18 - 30ХГТ, 20 - 35ХГСА tube steel should possess strength, plasticity and good weldability. High plasticity is achieved at the expense of low carbon content and to Mn high strength with low carbon content is achieved. Steel grades with carbon not higher than 0.2% and 1-2% Mn content has got wide application for these purposes. Such steel grades comprise 09 2 or 17 2C due to the USSR standards.

Provided high plasticity is needed (absence of brittle distruction), microalloying of these steels (e.g. 09Г2ФБ due to the USSR standards) is additionally used.

Steel grades for deep drawing should possess extremely high plasticity at room temperature. That is achieved at low carbon content. Besides these steels should not be ageing and it may be carried out in two ways: by producing steel with extremely low nitrogen content (not more than 10 ppm) or by combining nitrogen into nitrides. In the latter case the increased aluminium quantity (up to 0.08%) is recommended to be introduced into steel. Thus, steel grades like 08Ю due to the USSR standards are required to be used for deep drawing.

From the technological point of view the simplest and the most universal alloying steel production technology is the one which produces low phosphorus and sulphur content steel with the carbon content lower than the graded steel during the converter reprocessing. Further metal processing receiving the required composition is carried out during ladle processing. According to the mentioned technology the production of the above-mentioned steel grades is possible. Taking into account the specific characteristics of the chemical composition of iron melted in the EISCo blast furnace shop it is reasonable to include stages of iron processing technology necessary for its dephosphorization and demanganization. Therefore, the following technology may be recommended for alloying steel grades produced at the EISCo: hot metal preprocessing for its desulphurization, dephosphorization and demanganization. Hot metal dephosphorization may be done at the installation being under the construction now. Hot metal dephosphorization and demanganization may be performed during hot metal tapping in the blast furnace chute either by means of the appropriate slag mixtures processing or during special iron processing. Industrial trials have shown that special attention should be paid to the stream hot metal refining process in the course of which both hot metal dephosphorization and demanganization producing semiproduct may be performed. And during converter reprocessing the desired composition of steel may be manufactured from the given semiproduct. The subsequent converter reprocessing is performed according to the adopted technology. Metal alloying with chromium, Mn, Al and other elements should be done both during tapping and during argon metal blowing. The available equipment (the system of bunkers, dozemeters, the ability to introduce wire alloying) enables to carry out the operation with high accuracy and to get the required composition of the metal.

According to the specific characteristics of the EISCo iron composition (the increased Mn content) the elaboration of the Mn alloyed steel melting technology (09Г2С, 15Г - 65Г , 17ГС ,35ГС and others) has got special interest.

Among the available technologies the following types should be considered the basic ones:

1. Duplex process producing semiproduct with high Mn content and

its further processing into steel with 1% Mn content. The given technology also enables to process iron with a high Mn content (up to 5-7%).

In this case naturally alloyed Mn steel may be produced and slag with high Mn content to produce ferromanganese is also possible. Oxygen converter reprocessing restoring Mn from slag during intensive decarburizing. To increase the degree of Mn restoration solid reductants with carbon content may be introduced into the converter.

The most difficult problem for the discussed technological methods is metal dephosphorization preserving high Mn concentration. However the available literature data indicate the possibility to optimize slag and temperature mode of the converter heat and to process successfully Mn hot metal with phosphorus content up to 0.11%. However, a considerably high phosphorus content in hot metal requires preliminary dephosphorization. Therefore, there are no difficulties in implementing the above-stated technologies for producing naturally alloyed Mn steels.

The optimum technology selection for the alloying steels production with regard for technological specifications of the processed hot metal, the demands for the steel grades of certain composition and due to the economic factors, it is sure to require detailed analytical elaboration and experimental research work.

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SUPPLEMENT

DATE : 14-JAN-89
TIME : 11:07:42
SHIFT : 1A
NAME : KAMAL

Supplement 2

Deviations from Static Model

*** Started at heat no. : 12486   *** Ended at heat no. : 12497

HEAT-INPUT DATA											MODEL RESULTS		HEAT-OUTPUT DATA																	
						HOT METAL ANALYSIS							ACTUAL 1st ANALYSIS								ACTUAL 2nd ANALYSIS									
HNO	SCO	SNO	SCAO	SC HM	TEMP	C	SI	MN	S	P	SC	LI	FIt	LI	DOL	TEMP	C	MN	S	P	FIt	LI	DOL	TEMP	C	MN	S	P	Remark	
12486A1	11	70	8	82	1290	4.22	0.76	1.49	0.06	0.38	14.	6.5	12.	6.0	0.0	1320	1.80	0.35	0.05	0.12	7.	1.0	0.0	1610	0.23	0.32	0.02	0.02	Model is not applied because of the deviation of Metal-charge ! (Sc. div.)	{ NO }
12487A2	110	70	10	80	1270	4.67	0.77	1.55	0.08	0.40	9.	6.6	20.	6.0	2.0	1670	0.17	0.42	0.02	0.06	2.	2.0	0.0	1690	0.11	0.28	0.01	0.02	Model is applied but there is a deviation of Blowing time !	{ NO }
12488A1	12	70	8	82	1240	3.82	0.62	1.74	0.03	0.42	11.	5.8	12.	5.0	1.5	1480	2.56	0.49	0.04	0.09	8.	1.5	0.0	1620	0.28	0.32	0.02	0.02	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12489A1	13	70	0	90	1230	3.89	0.60	1.48	0.04	0.40	11.	6.2	11.	7.0	2.0	1455	0.00	0.00	0.00	0.00	12.	1.0	0.0	1680	0.22	0.40	0.02	0.02	Model is not applied because of the deviation of Metal-charge ! (Sc. div.)	{ NO }
12490A1	14	70	8	82	1260	3.97	0.70	1.72	0.05	0.38	10.	6.1	12.	6.0	1.5	1500	2.66	0.39	0.06	0.12	7.	1.3	0.0	1640	0.26	0.41	0.04	0.04	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12491A1	15	70	10	80	1270	3.83	0.73	2.01	0.03	0.42	10.	6.4	12.	6.0	2.0	1505	1.59	0.64	0.03	0.10	9.	2.5	0.0	1650	0.19	0.48	0.01	0.03	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12492A2	16	70	10	90	1260	4.17	0.64	2.05	0.04	0.40	13.	5.6	12.	6.0	1.0	1490	2.52	0.52	0.05	0.10	8.	2.5	0.0	1665	0.19	0.48	0.02	0.06	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12493A1	17	70	10	90	1260	3.99	0.91	2.10	0.04	0.41	10.	7.6	12.	6.0	0.0	1470	2.37	0.42	0.03	0.13	8.	0.5	0.0	1640	0.29	0.23	0.03	0.02	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12494A2	57	70	15	75	1270	4.35	0.65	2.10	0.04	0.35	12.	4.9	10.	5.0	2.0	1480	2.74	0.62	0.03	0.15	8.	1.0	0.0	1650	0.40	0.68	0.02	0.03	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12495A2	58	70	15	75	1270	3.70	0.60	1.99	0.04	0.38	12.	4.8	12.	6.0	2.0	1480	2.03	0.54	0.04	0.13	8.	1.5	0.0	1620	0.00	0.00	0.00	0.00	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }
12496A1	18	70	8	82	1240	3.92	0.70	2.19	0.39	0.04	5.	4.0	20.	8.0	0.0	1610	0.00	0.00	0.00	0.00	7.	1.3	0.0	1635	0.14	0.21	0.01	0.02	Model is not applied because of the deviation of Metal-charge ! (Li. div.)	{ NO }
12497A1	19	70	10	90	1270	3.94	0.86	2.08	0.03	0.41	7.	7.3	12.	6.0	2.0	1495	2.21	0.28	0.04	0.09	8.	1.0	0.0	1610	0.21	0.25	0.02	0.02	Model is applied and its result is ! GoodTemp & Good analysis	{ OK }