MINISTRY OF EDUCATION AND SCIENCE,
YOUTH AND SPORTS OF UKRAINE
STATE HIGHER EDUCATION INSTITUTION
“PRYAZOVSKYI STATE TECHNICAL UNIVERSITY”

TECHNICAL PROPOSALS

Catalogue

Mariupol

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TECHNICAL PROPOSALS

TECHNICAL PROPOSAL 1

1. Name.

"Iron smelting practice of injecting into the blast furnace the hot blast with subatmospheric oxygen content under the conditions of shrinkage or lack of natural gas".

2. Key words.

ENERGY-SAVING, BLAST-FURNACE AIR, AIR-BLAST TEMPERATURE, OXYGEN CONTENT IN THE BF AIR, INDUSTRIAL NITROGEN, BLAST ENGINE, COKE CONSUMPTION.

3. Purpose.

The reduction of the coke overconsumption and the decrease of the pig iron production costs.

4. Application field.

Ferrous metallurgy**,** BF production.

5. Description and basic technical and economic characteristics.

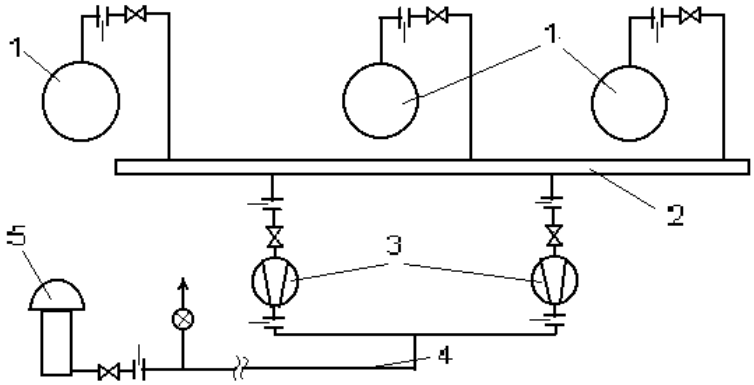
The largest natural gas consuming industry in Ukraine is ferrous metallurgy. A single iron and steel plant consumes 4-5 mln m^3 of natural gas per day. From 1/3 to 1/2 of the overall consumption is the share of the BF plants. The main consumption of natural gas in the BF plant is determined by the injection of the 100-120 m^3 of gas per each ton of pig iron produced. When the supply shortage of the gas occurs, the natural gas consumption is reduced in the BF plant in the first place, as the other energy consumers of the iron and steel works find natural gas their single energy source. Moreover, the gas is injected into the blast furnace under the pressure of 3 ATG and above. The reduction of the gas pressures makes its injection into the BF impossible. With no natural gas the BF smelting characteristics are to decrease: the air-blast temperature falls from 1000-1200 ^{0}C, the coke consumption increases from 480-500 to 700-760 kg/t of pig iron, the productivity decreases by 20%. This causes the pig iron cost price to increase by 20-25%. The sudden air-blast temperature drop results in the early breakdown of the stove, causing additional multi-million losses.

The best replacement of natural gas in the BF production is pulverized coal fuel that is widely used in European countries. However, the application of this fuel in Ukraine requires great capital costs and much time (3-4 years) for introduction and development.

Before the introduction of the pulverized coal fuel on the iron-and-steel works, iron smelting with injecting into the BF the hot blast with subatmospheric oxygen content turns out to be a temporary energy-saving method of iron smelting that provides an essential cost reduction. Due to the constant fuel combustion temperature in the tuyeres the method allows maintaining the air-blast temperature of 1,000 ^{0}C in case of lack of the natural gas, reducing the coke overconsumption by 60-80 kg/t iron without decreasing the BF productivity.

The reduction of the oxygen content below 21% is achieved through injecting industrial nitrogen into the blast, nitrogen being an unused by-product of the oxygen production that is emitted into the atmosphere. The nitrogen consumption necessary for one BF with the pressure of 500 mm of water is 30-35 thousand m^3/hr. The nitrogen supply system includes (see the illustration) two standard air propellers and a pipeline that delivers nitrogen to the air inlets of the blast engine. The BF nitrogen supply system is assembled within three months on any ironwork having an oxygen plant. The daily cost saving due to the implementation of the suggested method in the BF shop with the capacity of 10,000 t pig iron/day amounts to UAH 500-800 thousand. The construction costs of the BF nitrogen supply system are repaid within a month.

6. Illustrations.



The scheme of delivering low-pressure nitrogen to the BF blast engines:

1 – scrubbers of the oxygen plant separation units; 2 – collector; 3 – air propeller; 4 – nitrogen pipeline; 5 – air inlet of the blast engine.

7. Comparison with analogues, advantages.

The conventional method to reduce BF-smelting costs with no natural gas available is blast humidification. Due to retaining the high air-blast temperature the coke overconsumption with no natural gas available is reduced by 30-35 kg/t of pig iron. Decreasing the oxygen content in the blast below 21% is more efficient, as it ensures reducing coke overconsumption by 60-89 kg/t of pig iron.

8. Consumers.

BF plants of iron and steel works, which have an oxygen plant.

9. Expectant market geography.

Iron and steel works of Ukraine.

10. Proposal validity period.

Unlimited.

11. Suggested conditions of the implementation of the technical proposal.

Compilation of the technological task for designing and technical and economic assessment, scientific supervision of the design and construction works, adopting technologies, design study and key ready construction of the system. Contractors – Pryazovskyi State Technical University and “Azov-Engineering” Ltd (Mariupol). R&D costs – UAH 300,000; the costs of the design, construction and installation works amount to UAH 8-16 mln.

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Appendix: the list of main scientific publications:

1. Тарасов В.П., Томаш А.А., Семакова В.Б. Изменение расхода кокса и производительности доменной печи при содержании кислорода в дутье менее 21 % // Труды международной научно-технической конференции «Теория и технология аглодоменного производства». – Днепропетровск, 1995. – С. 37 – 39.
2. Новые аспекты снижения содержания кислорода в дутье доменных печей в современных экономических условиях / А.А. Томаш, В.П. Русских, В.П. Тарасов, В.Б. Семакова, И.М. Пефтиев, Е.И. Хрущёв, А.А. Малимон, В.С. Чумаченко // Труды V международного конгресса доменщиков «Производство чугуна на рубеже столетий». Днепропетровск – Кривой Рог, 7 – 12 июня 1999 г. – Днепропетровск: Пороги, 1999. – С. 238 – 242.
3. Снижение энергетических затрат на выплавку чугуна в современных условиях Украины / В.П. Тарасов, В.П. Русских, А.А. Томаш, В.Б. Семакова // Металл и литьё Украины, 2000. - № 3 – 4. – С. 5 – 7.

TECHNICAL PROPOSAL 2

1. **Name.**
   “Blast-furnace air humidification through water-spraying in the tuyere region”.

2. **Key words.**
   TUYERE STOCK, THERMAL STATE OF THE HEARTH, WATER-SPRAYING, INDIRECT REDUCTION, AIR-BLAST TEMPERATURE, REDUCTANT CONCENTRA-TION.

3. **Purpose.**
   Ensuring the high air-blast temperature under the conditions of shortage of natural gas and BF air humidification vapour, decreasing the specific coke consumption for iron smelting under the given conditions.

4. **Application field.**
   BF iron making.

5. **Description and basic technical and economic characteristics.**

The system makes it feasible to simultaneously feed several agents into the BF air: natural gas, fuel oil, vapour etc. Therewith, the theoretical combustion temperature in the hearth with the modified concentration of the listed blast elements. The suggested BF technology is supported by the specific air tuyere design that allows modifying the additive ration in the BF air.

The improvement of the BF smelting technical-and-economic performance after the development introduction is ensured by:

- maintaining the maximum hot-blast temperature under any changes of the parameters (oxygen enrichment, moisture alterations, changes of the hydrocarbon additives consumption etc.);
- increasing the concentration of the gaseous reductants in the hearth gases;
- improving the gas permeability of charge column through decreasing the furnace gases viscosity together with increasing the hydrogen concentration in the gases;
- employing the BF smelting thermal state automatic control system.

The production-scale implementation of the given technical proposal requires the following: agents supply and delivery control system for each air tuyere of the BF, tuyere region thermal state control system and thermal state regulation system. The introduction costs of the system at one BF amount to UAH 80-90 thousand, the economic effect from the coke saving depends upon its price and amount to several millions hryvnas.

6. **Illustrations.**
   No.

7. **Comparison with analogues, advantages.**

No steam production costs are required; no negative influence of the air blast humidification on the blast-furnace brickwork is present, as distinct from the developments of the Japanese metallurgists.

8. **Consumers.**
   Ironworks, which have a BF plant.

9. **Expectant market geography.**
   Pryazovya, Donetsk region, Ukraine, CIS.

10. Legal Protection.

Patent of Ukraine № 74297 A, IPC C21B5/00
"Спосіб доменної плавки" ("Blast-furnace smelting method").

Patent of Ukraine № 47026 A, IPC C21B7/16
"Дуттьова фурма доменної печі" ("Blast-furnace tuyere").

11. Proposal validity period.

Unlimited.

12. Suggested conditions of the implementation of the technical proposal.

On the terms of the agreement.

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TECHNICAL PROPOSAL 3

1. **Name.**
   "Control method of the charge and gases distribution in the blast furnace".

2. **Key words.**
   ORE MATERIAL, COKE, GAS FLOW, FURNACE TOP, BLAST FURNACE.

3. **Purpose.**
   The method is for introduction in BFs equipped with bell-type charging devices.

4. **Application field.**
   Ferrous metallurgy, iron-making.

5. **Description and basic technical and economic characteristics.**

The method includes feeding ore material and coke. In this regard increasing the ore burden and reducing the gas flow intensity at the walls of the top are conducted through charging ore materials at a higher burden level than that of the coke.

The gas flow distribution control is performed using different gas permeability degrees of the two BF burden components: ore materials and coke. The mechanically more stable coke possesses the higher gas permeability degree, and the fraction of 25 mm is screened from the coke before charging. The less solid ore materials are fractured in the BF, and only the 5 mm fracture is screed from them. The ore materials add the increased resistance to the gas flow. In the areas of the top, which are charged the larger quantity of ore materials and the lesser quantity of the coke, i.e. which have the higher ore burden, the intensity of the gas flow is reduced. In the areas of the top, which are charged with the larger quantity of the coke and the lesser quantity of the ore materials, i.e. which have the lower ore burden, the intensity of the gas flow is increased.

The control method of the charge and gases radial distribution in the BF is employed as follows. The initial charging system $\begin{cases} CCCC\downarrow \\ AAAA\downarrow \end{cases}$ – 1.50 m with the constant burden level of 1.50 m both for coke and agglomerate. The control of the CO_2 content in the top gas and the gas temperature at the walls is held. When the CO_2 content in the boundary area is decreasing lower that 10% or the top gas temperature at the wall is increasing more than 180 ^{0}C, the boundary area is to be charged with additional ore materials.

The next charging system is $\begin{cases} CCC\downarrow -1.50\,m \\ AAAA\downarrow -1.75\,m \end{cases}$ with the burden level of 1.50 m for coke and 1.75 m for the ore material – agglomerate. After four skips of coke are taken to the large bell, the charging control system is in the stand-by mode till the burden surface is descending by 1.50 m from the edge of the large bell in the descended state. When the target burden level is reached, the large bell is opened letting the coke dump on the top, thus making the column of coke. The large bell is then closed. The four skips of agglomerate are charged on its surface. The charging control system is in the stand-by mode till the load descends by the target level of 1.75 m. Afterwards the large bell moves down and the agglomerate is dumped on the top making the agglomerate column. Subsequently the cycles of charging four skips of coke and four skips of agglomerate is repeated. If the CO_2 concentration at the top walls exceeds 16% or the top gas temperature in the boundary are is lower that 140 ^{0}C with the hard burden yield, the core zone is to be discharged and the charging system $\begin{cases} CCC\downarrow = 1.75\,m \\ AAAA\downarrow = 1.50\,m \end{cases}$ is applied.

The production-scale test of the control method of the charge and gas radial distribution was conducted at the BF № 4 (with the working volume of 2,002 m^3) of a metallurgical iron and steel works of Mariupol. The BF was not equipped with the facilities for the top gas sampling and the gas temperature measurement at the top radius. The development of the peripheral gas flow was controlled according to its temperature under the stockline-wearing plates. After the initial charging system $\begin{cases} CCCC\downarrow \\ AAAA\downarrow \end{cases}$ – 1.50 m was changed by the system $\begin{cases} CCC\downarrow -1.50\ m \\ AAAA\downarrow -1.75\ m \end{cases}$, the average temperature under the stockline-wearing plates dropped from 566 to 474 ^{0}C, which testifies the substantial reduction of the gas flow at the walls. After changing to the charging system $\begin{cases} CCC\downarrow = 1.75\ m \\ AAAA\downarrow = 1.50\ m \end{cases}$, the average temperature under the stockline-wearing plates once more increased from 474 to 563 ^{0}C, i.e. the intensity of the peripheral gas flow has increased.

The BF operation experience demonstrates that improving the control of the charge and gas radial distribution ensures addition reduction of the coke consumption by 1.05-2.0 kg for 1 ton of cast iron and the productivity improvement at the same time. Due to the reduction of the specific coke consumption in the BF with the working volume of 2,002 m^3 the annual economic effect makes:

$$0.001 \times 1.5 \times 350 \times 1{,}200 = \text{UAH } 630{,}000$$

where 350 is the price of 1 ton of coke, UAH; 1,200 – the annual production, thousand ton, of the BF with the working volume of 2,002 m^3.

6. Illustrations.

No.

7. Comparison with analogues, advantages.

Among the similar methods of BF charging is the well-known method that includes separate charging of coke and ore materials *AA*↓ *CC*↓, *CC*↓ *AA*↓, including increased loads *CCCC*↓ *AAAA*↓ (Patent of Ukraine №51584A, IPC C21B7/00//Промышленная собственность (Industrial Property). – 2002. – №11).

The given method of the separate BF charging with the increased loads ensures more balanced ore materials distribution in the radius of the work space; the redistribution of the gas flow in the cross-section of the furnace in the coke columns and elimination of the gas flow alteration caused by the inefficient ore mixture distribution; improvement of the gas permeability of the softening area due to the more efficient shaping of the coke holes. This ensures the reduction of the specific coke consumption by 25-35 kg/t pig iron together with the improvement of the BF productivity. However, this method does not make it feasible to regulate the distribution of ore materials and coke in the BF.

The suggested control method of the radial distribution of charge and gases in the BF through modifying the ore materials charging conditions with the separate discharge ensures the targeted redistribution of the gas, thus increasing the reducing power degree of the gases and reducing the specific coke consumption for 1 ton of cast iron.

8. Consumers.

Ironworks.

9. Expectant market geography.

Ukraine, CIS, Germany, UK, Brazil etc.

10. Legal Protection.

Patent of Ukraine № 69655A, 11/11/2003.

11. Suggested conditions of the implementation of the technical proposal.
On the terms of the agreement.

12. Proposal validity period.
Unlimited.

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TECHNICAL PROPOSAL 4

1. **Name.**
   "The development and introduction of the natural gas supply method that ensures maintaining the high gas pressure at the BF tuyeres in wintertime".

2. **Key words.**
   NATURAL GAS (NG), TUYERE, BLAST FURNACE, THROTTLING, PILOT PLANT.

3. **Purpose.**
   Creating the technological circuit of NG supply to the BF tuyeres that excludes the influence of the seasonal reduction of the NG consumption for the gas pressure at the tuyeres.

4. **Application field.**
   BF plants of Iron and Steel Works in Ukraine.

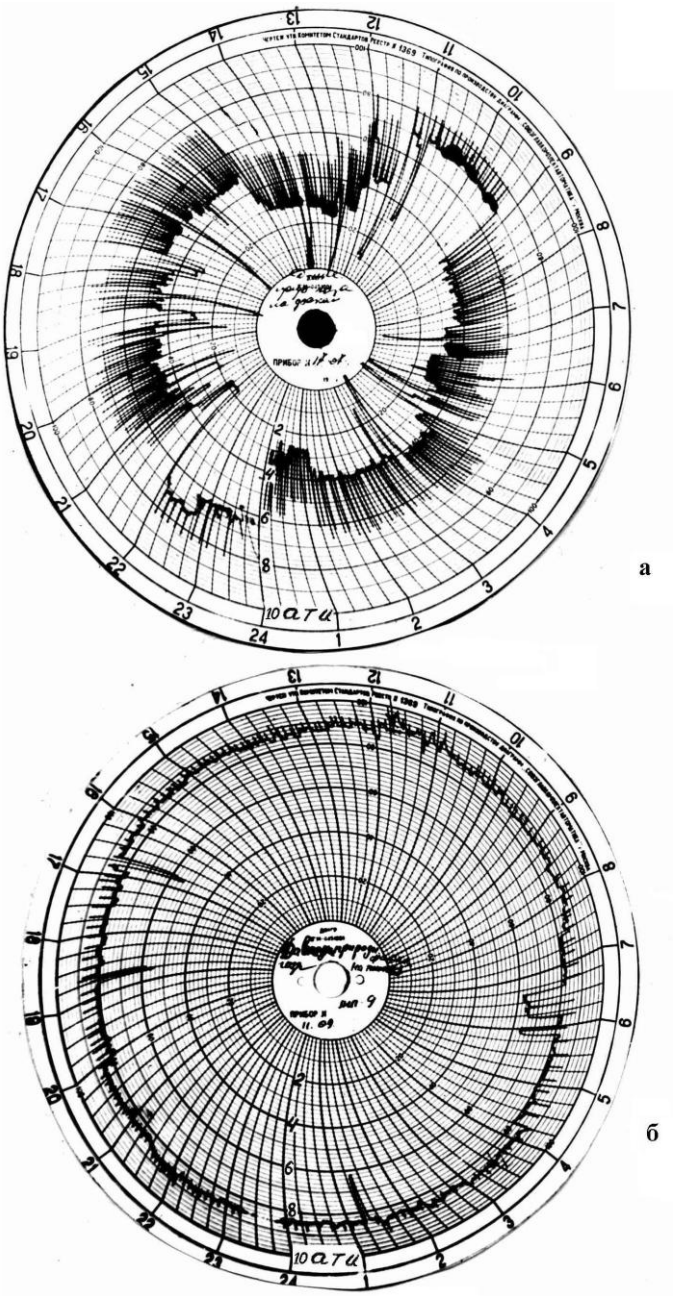
5. **Description and basic technical and economic characteristics.**

Annually in wintertime the ironworks in Ukraine suffer from the limitation of the gas supply. Among the ironworks is the OSC AZOVSTAL Iron and Steel Works. For the last few years the reduction of the NG consumption for this enterprise caused the gas pressure drop below (~ 2.5 ATG) the level of the injected air pressure (~ 2.7 ATG). Therewith, injecting the NG into the BF through the tuyeres is technologically impossible. The cast-iron production at the BF plant of the OSC AZOVSTAL Iron and Steel Works is substantially decreased during 5-10 day each year. Still, longer periods of the NG consumption limitation are possible to occur in the future. Unfortunately, the operating personnel got used to the present situation considering it inevitable. However, the reduction of the gas pressure due to the decrease of its consumption directly results from the inefficient consumption control rather than from the low network gas pressure. For example, during the complete cutting-off the NG feed to the BFs (January 19, 2006) the supply network pressure amounted to 17 ATG.

The present proposal is aimed at the creation of the technological circuit of the NG supply that ensures that the decrease of the NG consumption does not result in the reduction, but in the increase and stabilization of the NG pressure at the BF tuyeres.

6. **Comparison with analogues, advantages.**

The research work has been made at the open-hearth plants of the OSC AZOVSTAL Iron and Steel Works (picture 1) and the OSC ILYICH Iron and Steel Works of Mariupol on the methods of the wintertime increase of the gas pressure at the burner.



Picture 1. The diagram of the daily changing of the NG pressure at the burner of the open-heath furnace №9 of the OSC AZOVSTAL Iron and Steel Works as to the present (a) and suggested (b) circuits of the NG supply control

The burners with the new circuit of the NG supply control have effectively functioned for a long period of time.

The introduction of the suggested proposal at the BF plant of the OSC AZOVSTAL Iron and Steel Works will give the annual economic effect of ~ UAH 10 mln.

7. **Consumers.**
   BF plants of Iron and Steel Works in Ukraine (including the six BFs of the OSC AZOVSTAL Iron and Steel Works).

8. **Expectant market geography.**
   Near and far abroad countries.

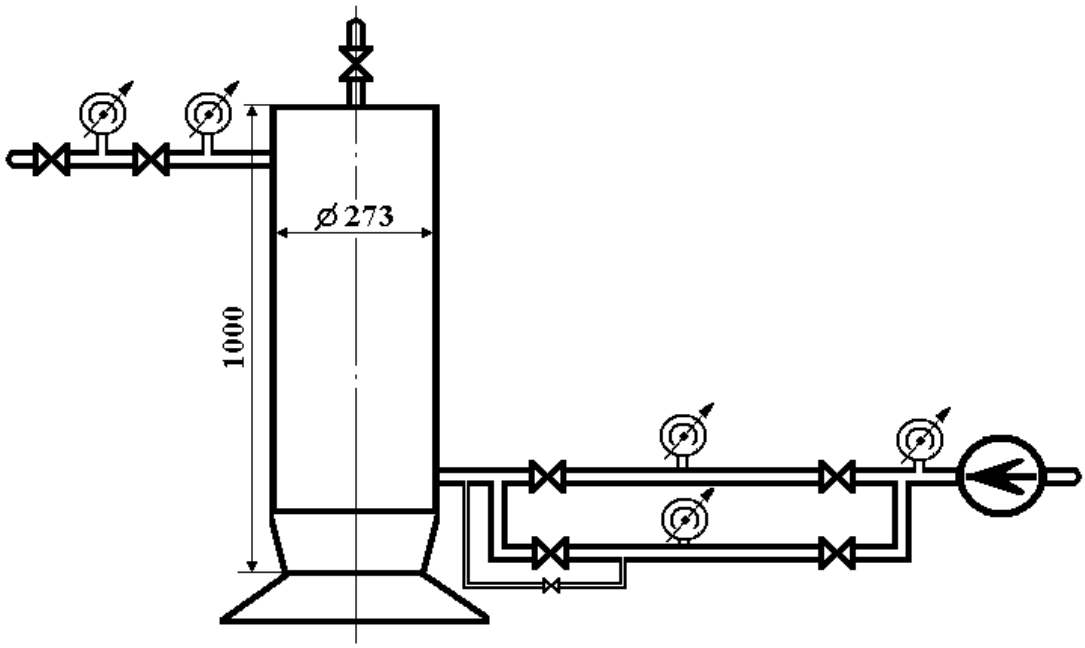
9. Legal Protection.

The technical proposal is patentable.

10. Suggested conditions of the implementation of the technical proposal.

The introduction of the technical proposal, on the OSC AZOVSTAL Iron and Steel Works in particular, requires the realization of the complex of research, design and implementation work:

1. Analysis study on the recount of the supply pipelines, the NG consumption for each tuyere (about 100 tuyeres) being reduced (contractor – Pryazovskyi state Technical University).
2. Manufacturing, assembling and conducting tests on the laboratory physical model (picture 2) with installation of the supply pipelines according to the new control circuit. The delivery pressure amounts to 10-12 ATG.
3. Carrying out the project (contractor – the Project Designing Department of the OSC AZOVSTAL Iron and Steel Works) of the installation of the additional (in wintertime) pipelines for each tuyere, preliminary calculations of the NG supply system included.
4. Designing the new circuit of the NG supply distribution on the enterprise from the gas-distribution station (contractor – UKRGIPROMEZ). The assembling of the new regulation system at the GDS (control equipment and flowmeter). Assembling the wintertime variant of the NG supply system on the each tuyere of the six BFs.



Picture 2. Trial plant pattern.

5. Signing the NG supply agreement to the OSC AZOVSTAL Iron and Steel Works. According to the agreement the gas consumption control is entrusted to the BF plant (not to the GDS).
6. Registration of the patent documentation for invention.
7. Tests and start-up of the new control system of NG supply to the six BFs.

The costs for the proposal introduction work amount to UAH 200,000; including UAH 90,000 for the R&D work. The term of the work performance is one year. Desired is the wider distribution of the new technological circuit of the NG supply to the BF tuyeres in the system of the PA “Metallurgprom”.

11. Proposal validity period.

Unlimited.

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TECHNICAL PROPOSAL 5

1. **Name.**
   “Acoustic automation system of the basic-oxygen and arc-furnace steelmaking processes”.

2. **Key words.**
   CONTROL, ACOUSTICS, BASIC-OXYGEN FURNACE, ELECTRIC ARC FURNACE, MELTING, HIGH-TEMPERATURE MEASUREMENTS, REAL-TIME, TEMPERATURE, CHEMICAL COMPOSITION, RECOURSE AND ENERGY SAVING.

3. **Purpose.**
   The system is designed for the real-time regulation and control of the BOF and arc-furnace steelmaking processes.

4. **Application field.**
   Ferrous metallurgy, steelmaking.

5. **Description and basic technical and economic characteristics.**

The acoustic system is assembled from the reliable technical components and based on the stable and robust algorithm. The visual indication ensures the real-time control of the basic melting parameters, including the melting-stop signal.

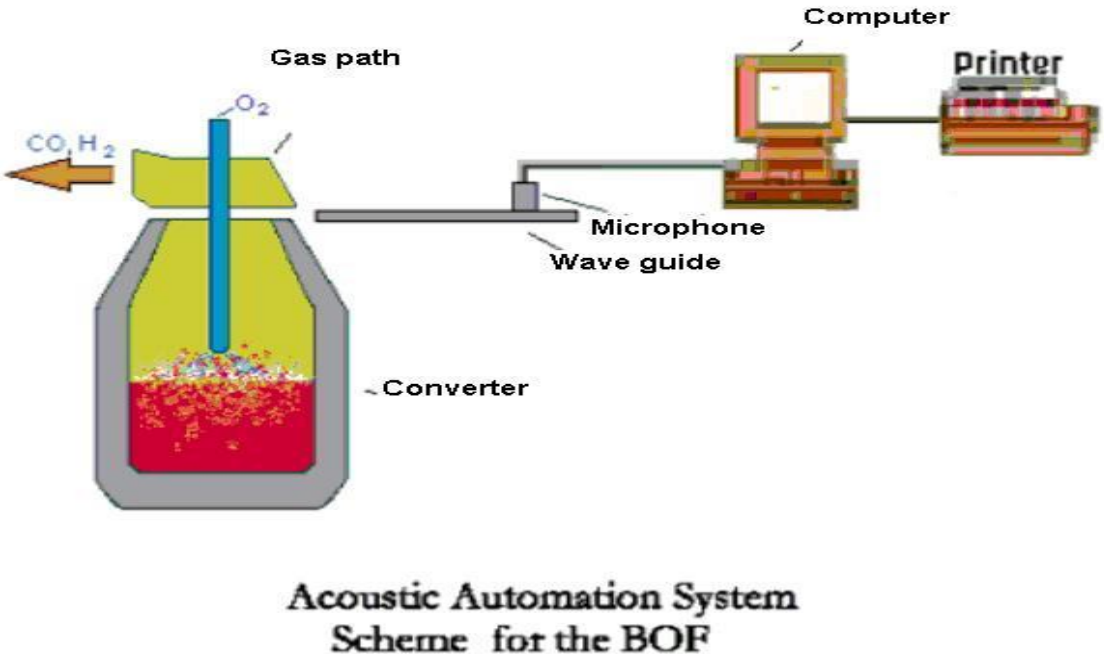
The components of the system are:

- initial acoustic data registration unit;
- acoustic data filtrating and processing unit. On the real-time basis the following parameters are defined: mass-averaged melt temperature, mass-averaged concentration of chemical elements in the melt, scrap melting pattern, pattern of the melt liquid slag phase formation;
- unit for the instrumentation complex and melting technological parameters control.

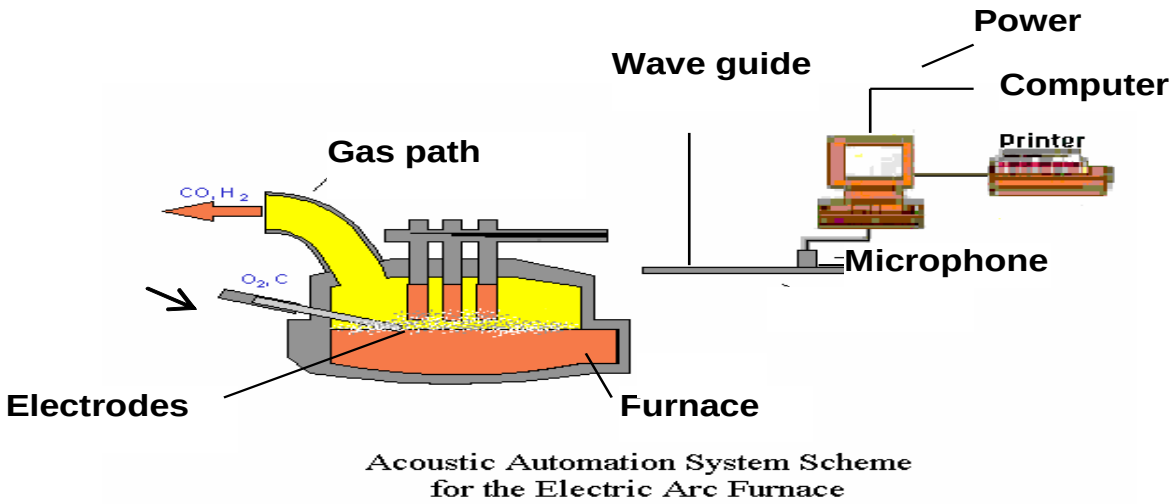
The acoustic system was tested on the BOFs with the capacity of 25, 180 and 400 t in Ukraine and China (1986-1995), on the alternating and direct current electric arc furnaces with the capacity of 15, 30, 50, 100, 150 and 250 t in Israel, Japan, Italy, Spain, and USA (1997-2005). The tests confirmed the high reliability and accuracy of the parameters defined by the system. The correlation coefficient of the parameter values, which are controlled by the system and are measured conventionally, reaches 0.95-0.97. The employment of the acoustic system made it feasible to observe the technological process, consequently ensuring the improvement of the steel made, reduction of the aluminum and ferroalloy consumption. Among the major results are: facilitation of the technological process, decrease of the mistakes of the operation personnel, finding the unpresentable samples and measurements.

The received operation data testify that the energy recourses saving reaches 5-30%, the furnace productivity is enhanced by 10-25% and the metal loss is reduced by 1.5-5%. The high reliability of the technological parameters ensures creating control systems of the basic-oxygen and arc-furnace steelmaking processes.

6. Illustrations.



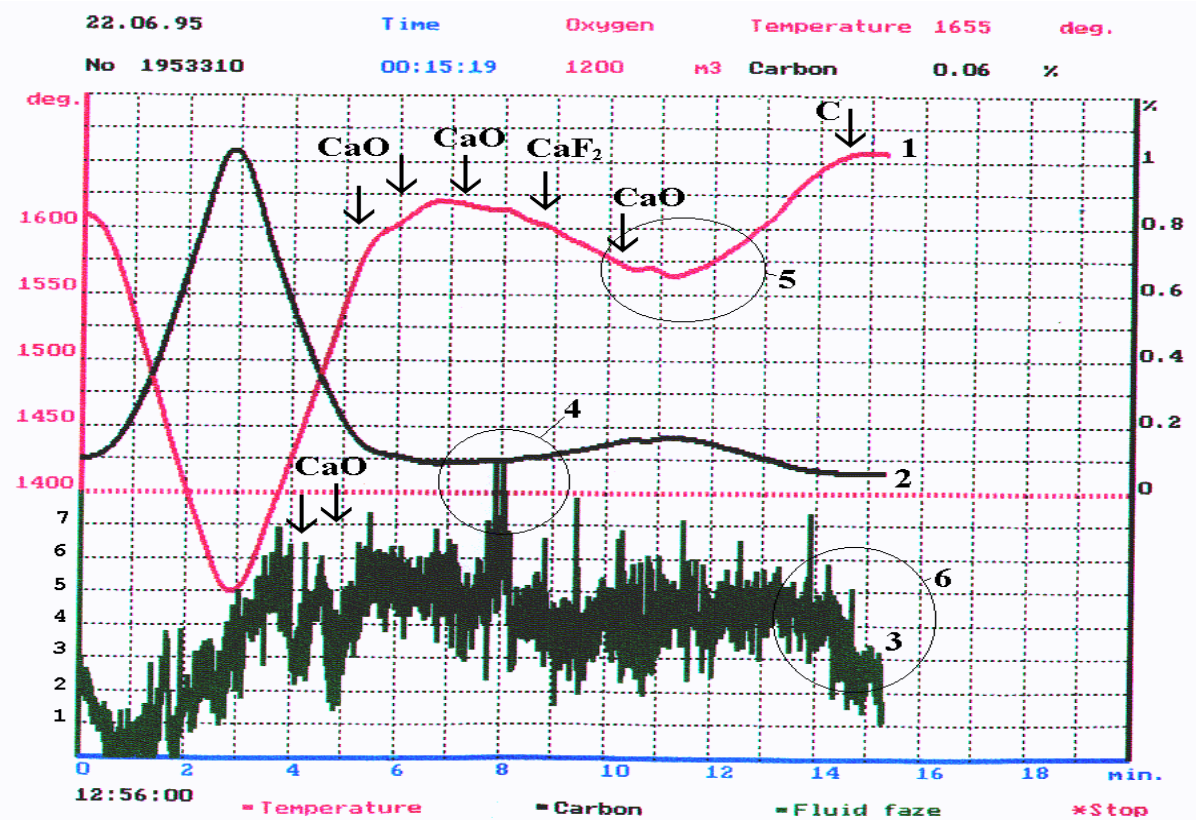
Picture 1. Acoustic Automation System Scheme for the BOF



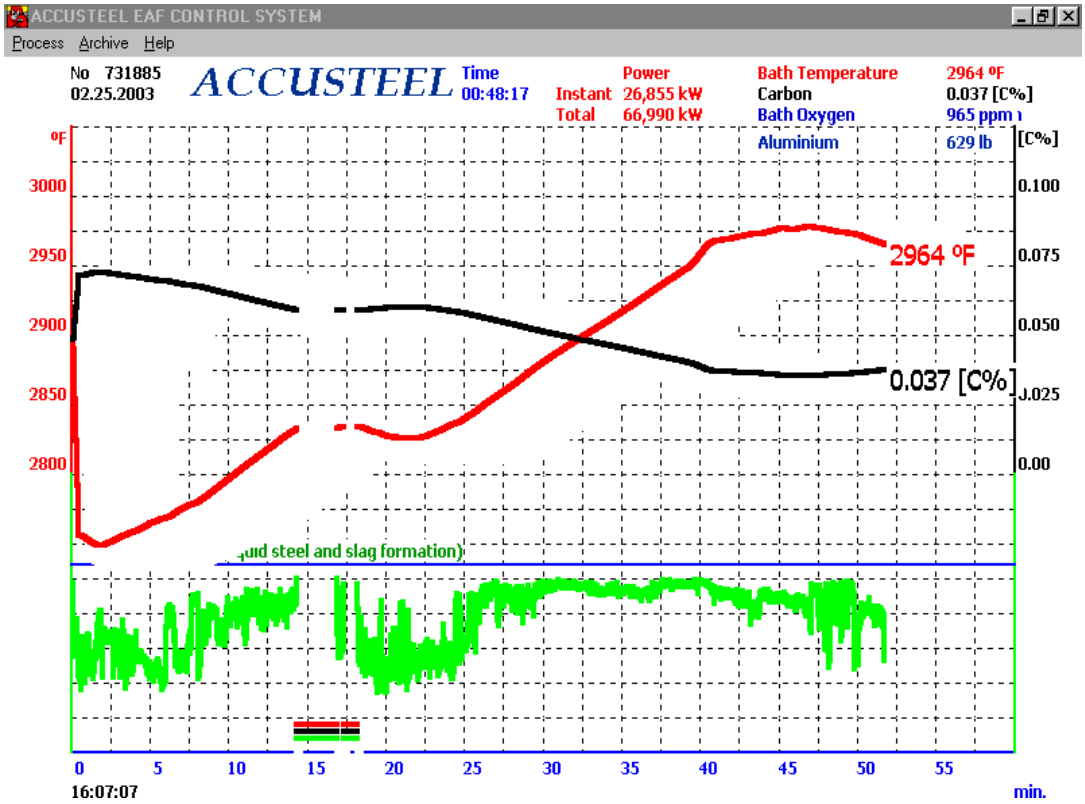
Picture 2. Acoustic Automation System Scheme for the Electric Arc Furnace

The pictures demonstrate the acoustic automation system schemes for the basic-oxygen and electric arc furnaces. The initial data source for the system is the operation melting noise that emerges BOF due to the interaction of the oxygen jet and the melt; in the electric arc furnace the noise is results from the interaction of the plasma jet and the melt. The noise traced by the microphone that is installed in the wave guide, is transformed into the electrical signal. The signal is then transferred to the analog-digital converter in the computer. The converted acoustic signal is then put into calculation. As the result, the following operation process data are received: 1) mass-average temperature; 2) chemical composition; 3) real-time statistics of the melt liquid slag phase formation. The received data appears in the computer display in digitalized and graphical forms.

Here are some of the examples of the system-controlled operation parameters visualization.



Picture 3. Basic-oxygen Conversion.



Picture 4. Electric Arc Conversion.

7. **Comparison with analogues, advantages.**

The analogues are presented by the computer systems designed for the regulation and control of the BOF and EAF steelmaking. The algorithm of the systems is based on the physical representation of the material and thermal balance of the melt. In order to make the calculations more dynamic, the following parameters are taken into account: the acoustic noise signal of melt or the off-gas gas composition data with the calculations corrected according to the results of the melt temperature measurements with the thermocouple in the end of the melt. The results of the calculation are the real-time data of the temperature and the chemical composition of the melt. However, among the disadvantages of the conventional algorithms are: a) the survey of the dynamics of the material component of the melt is impossible (in the calculation the statistical information is used); b) the low, within 0.2-0.5, correlation of the temperatures, which were calculated by the computer system and measured by the thermocouple in the end of the melt; c) the dissimilarity of the analysis results of the off gases, which were sampled in the gas path, and the in0operation gas composition in the steelmaking unit.

The nearest analogue of the developed system is the acoustic system of the slag0making process control in BOFs and EAFs.

The performance capabilities of the conventional systems are limited by their inability to convert the steelmaking process dynamics data into the reliable operation parameters.

The suggested acoustic computer system makes it feasible to trace the mass-average temperature of the melt, carbon content in the metal, and the dynamics of the melt liquid slag phase formation in real time.

8. **Consumers (present and prospective).**

Ironworks.

The modified acoustic system can be employed for the monitor and control of the:

- fuel combustion processes in the aircraft jet engines, electric plant burners, reheat furnaces;
- technological processes of cement, quicklime, copper, aluminum, nickel, magnesium production, oil cracking, production and sterilization of food;
- thermal control of nuclear and thermonuclear reactors.

The enterprises of the named fields are sure to be considered the consumers of the suggested acoustic system.

9. **Expectant market geography.**

Ukraine, CIS, Spain, China, Brazil, USA, Austria, Italy, Germany, France, UK, Japan etc.

10. **Legal Protection.**

Patent of the Russian Federation № 2006007 “Способ определения температуры жидкости” (“Method for measuring the temperature of the fluid”), 15.01.1992.

Patent of the USA № 6039472 “Method for measuring the temperature of a metallurgical furnace using an acoustic noise parameter and rate of electrical power”, 21.03.2000.

11. **Suggested conditions of the implementation of the technical proposal.**

On the terms of the agreement.

12. **Proposal validity period.**

Unlimited.

13. **Contact information:** tel.: +38 0 629 44 64 98; fax +38 0 629 34 52 94;
e-mail: omid@pstu.edu

TECHNICAL PROPOSAL 6

1. **Name.**
   “Process engineering of the automatic vacuum metal (AVM) ingot casting technique”.

2. **Key words.**
   INGOT CASTING, AUTOMATIC VACUUM METAL, ELIMINATION OF THE CHEMICAL INHOMOGENEITY, CROP REDUCTION, ENERGY SAVING.

3. **Purpose.**
   Production of the high-quality steel ingots for rolling and forging production, ensuring the substantial increase of the metal yield and the enhancement of the metal homogeneity.

4. **Application field.**
   Ferrous metallurgy, mechanical engineering.

5. **Description and basic technical and economic characteristics.**

Nowadays a great number of ironworks introduce method of metal casting on the continuous-casting machine (CCM), which is not always efficient due to the great capital costs on the building of the CCM. The conventional ingots casting techniques from killed and alloyed steel grades inevitably cause the creation of the hot top of the ingot, in which the melt hardens the last. The top results from the development of liquation processes in the ingot causing its axial and extra-axial inhomogeneity to increase. The similar problems, though in a less degree, occur in the continuous cast billets. However, due to the less time needed for the metal freezing during the continuous casting, the liquation in such metal is less developed than in the ingots.

When casting the AVM ingots their upper parts are exposed to cooling, which decreases the freezing time of the melt and reduces the liquation. The employed methods make it feasible to get inside the ingot a hermetic shrinkage hole that is formed in vacuum (with no outer gases getting inside). During the following plastic strain the hole is completely melted, with no lamination occurred. The reduction of the liquation makes it feasible to enhance the metal quality, and the melting of the shrinkage hole walls ensures efficient ingot casting from killed and alloyed steel grades. During the plastic strain the top scrap of the produced billets lies within 0.5-8% depending on the requirements of the metal.

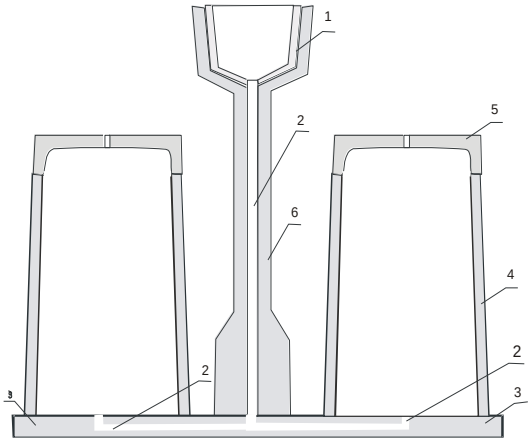
The stable and solid top of the ingot makes it possible to move the ingot to the soaking pit (or thermostat) till its complete freezing and at the same time without breaking the safety standards. This ensures substantial cost saving for the ingots heating for the plastic strain, and even further rejecting such heating method in favour of the temperature control for the temperature equalization in the cross-section of the ingot.

The basic technical and economic characteristics of the AVM ingots casting method:

- reduction of the top scrap of plate ingots from 18-20% to 3-3.5%;
- reduction of the top scrap of bar ingots by 5-15%;
- 0.5% reduction of the top scrap of semikilled steel ingots (the recovery amounts to 95%);
- reduction of the steel-casting train preparation costs by 10-15% due to the removal of the tuyere hot top manufacturing, service, and repair operations;
- 14-17% reduction of the energy carriers consumption for ingots heating in the soaking pit;
- reduction of the pollutant emission into the atmosphere by 15-29%;
- the economic effect of $ 20 mln for one ton of metal due to the recovery increase only.

6. Illustrations.

The structural scheme of the AVM ingots production method introduction device.



фиг. 1

Picture 1.

1 – sectional top, 2 – gates, 3 – bottom plate, 4 – ingot mold, 5 – refrigerating cover, 6 - runner

7. Comparison with analogues, advantages.

The shrinkage hole hermetization method was suggested in France in 1967. The method is based on the plugging of the ingot head, cure of the melt fro a certain period of time, and turning the ingot mold around 180^0 on the horizontal axis. Thereafter the ingot is placed into the slow heat cell and hold there till the full crystallization across the section. Afterwards, the ingot is in its initial position taken to the flash heat cell. During the following 1971-1974 years a great number of similar shrinkage hole hermetization methods were put forward. Those methods differed only in the scheme of the ingot horizontal axial rotation. However, the desired degree of the metal homogeneity in non-metallic inclusions was not reached.

The suggested ingots casting method differs in the optimization of the thermo time control of the ingot solidification process. Due to the casting process of the ingots they were called pressurized or AVM (automatic vacuum metal); during the crystallization process the shrinkage hole inside the ingot undergoes hermetization, thus preventing the outer gases from penetrating the shrinkage hole and averting the oxidative processes in the freezing melt. The production-scale tests proved that the rolled products manufactured of the ingots (both plate and bar), which were cast according to the suggested method, had the top scrape of the killed steel ingot pieces of 3-8% instead of the usual 13-18%. The analysis of the results testified that the AVM ingots bloom possesses the higher quality of the metal and the lesser top scrape.

Among the most prominent advantages of the suggested method is the almost complete absence of the axial heterogeneity (both chemical and physical). In the top end of the piece the degree of the liquation square is substantially reduced or it is completely absent. This way the transfer of such products as rails to the lower quality degree is excluded.

On top of that, the introduction of the new technology does not require high capital costs. The present cost for the AVM ingots facilities do not surpass the present costs for the common ingots facilities.

The method allows rolling ingots with the increased enthalpy, which makes it feasible to considerably reduce the energy consumption and to increase the recovery and the quality of the metal.

8. Consumers.

Ironworks and mechanical engineering plants.

9. Expectant market geography.

Ukraine, near and far abroad countries.

10. Legal Protection.

The technical proposal is patentable. On the basis of the results of the preliminary work an application for the supposed invention was given and the patent of Ukraine was received. The process of the technical proposal introduction involves the development and commercial tests of the new technical solution that in a great measure differs from the conventional methods, which is supported by the appropriate legal protection.

11. Suggested conditions of the implementation of the technical proposal.

The TP introduction working costs (research and design work, tools production, experimental adjustment of the method under the present production conditions; contractors – Pryazovskyi State Technical University, "KAMIT" Ltd, Mariupol Branch of Urkgipromez) amount to UAH 500,000. The execution period is two years. The TP is allowed for replication, whereupon for each type of ingots the specific parameters of the freezing process are developed.

12. Proposal validity period.

Unlimited.

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TECHNICAL PROPOSAL 7

1. **Name.**
   "The theory and development of the energy and resource saving methods of injecting powder materials into the metallurgical melts and melting facilities".

2. **Key words.**
   DISPERSED FLOWS, POLYDISPERSE GAS SUSPENSIONS, PARTICLE ATTRITION, TWO-PHASE JETS, ADDED MASS.

3. **Purpose.**
   Improving the theory of the complex dispersed flows streams, the use of the theory for the creation and introduction of the competitive iron and steel production technologies.

4. **Application field.**
   Top-blown, side-blown, bottom-blown converters, electric furnaces, blast furnaces equipped with the pulverized coal fuel transfer and injection systems.

5. **Description and basic technical and economic characteristics.**

The systems of powder materials injection into the metallurgical melts and melting facilities are concerned with numerous theoretical and practical problems, which hinder the large-scale implementation of the advanced technologies. The introduction of the technical proposal (TP) gives the possibility to receive new information on the nature of the complex dispersed flows. On the basis of this information new calculation methods and technical solutions can be created in conformity to the following class of issues:

5.1 The high-density flow streams in the pneumatic conveying system:

- monodispersed uni- and multicomponent two-speed gas suspensions of constant composition; isothermal stream;
- monodispersed multicomponent gas suspensions with regard to the form of particles and their attrition;
- polydispersed multicomponent, multispeed gas suspensions of constant composition and with regard to the Magnus force;
- polydispersed multi-fraction gas suspensions with regard to the particle attrition, numerous resists and diversions;
- monodispersed multicomponent oil-fuel emulsion flows with regard to the particle attrition.

5.2 Streams in BOF and ladle tuyeres:

- monodispersed high-density gas suspensions of constant composition and intensive heat input; collisionless mixtures;
- monodispersed multicomponent gas suspensions with regard to the particle attrition and nonpermanent heat input;
- polydispersed multicomponent multispeed gas suspensions with intensive heat input, speed and temperature lag;
- polydispersed multicomponent gas suspensions with regard to the particle attrition and intensive unbalanced heat input;
- monodispersed multicomponent oil-fuel emulsion flows with regard to the alteration of the particles size and intensive heat input;
- design of the gun tuyere with the variable consumption of the gas suspension longwise (monodispersed stream, polydispersed flows, but with the heat input).

5.3 Stream in nozzles:

- monodispersed uni- and multicomponent gas suspensions of constant composition;
- monodispersed многокомпонентные gas suspensions with regard to the alteration of the particles size;
- polydispersed multicomponent gas suspensions of constant composition and with regard to the particle attrition;
- monodispersed multicomponent gas suspensions with regard to the particle attrition in the nozzle scarf;
- influence of the powder concentration on the diversion of the two-phase jet in the nozzle scarf.

5.4 Polydispersed flows in off-gas cleaning systems:

- isothermal stream;
- stream with heat input;
- dispersed flow with the absorption of foul gases.

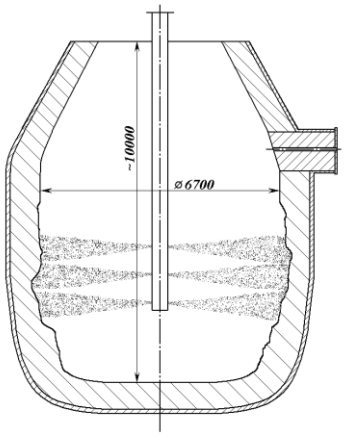
5.5 One- and two-phase stream in the high-power turbulent jets (~ 5 MW):

- structure of the supersonic non-design jet in the high-temperature cavity of the converter;
- structure of the supersonic non-design jet in the high-temperature cavity of the converter with regard to the carbon oxide (CO) combustion in oxygen (turbulent boundary layer);
- influence of the CO combustion in the oxygen jet on the added mass of the surrounding converter gas;
- supersonic one- and two-phase flows in the nozzle scarf;
- examination of the structure of the supersonic non-design jet in the high-temperature cavity of the converter with regard to the inclusion of slag-metallic emulsion the by the jet;
- structure of the polydispersed gas-dynamic flame during the spraying of the alloys with regard to the crystalline transformation and fluctuating velocities;
- lining gunning systems with regard to the dispersion of the powder particles in the converter cavity (as well as regarding the coke particle combustion in oxygen, heating and softening of the refractory particles);
- turbulent subsonic air jet in the BF combustion zone with regard to the inclusion of the gas-dispersion environment;
- turbulent subsonic two-phase jet in the BF combustion zone with regard to the inclusion of the high-temperature reactive gas-dispersion environment.

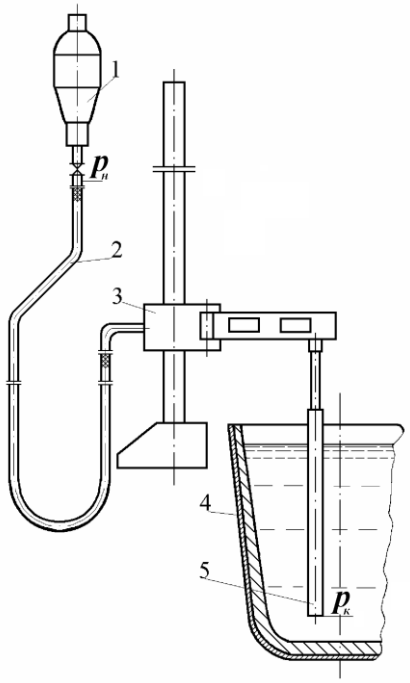
5.6 Method for slag skull spraying on the BOF hot lining:

- analysis of the motion of the various viscosity melted slag dripping during the direct and diagonal blows of the supersonic non-design unreactive jet.

6. Illustrations.

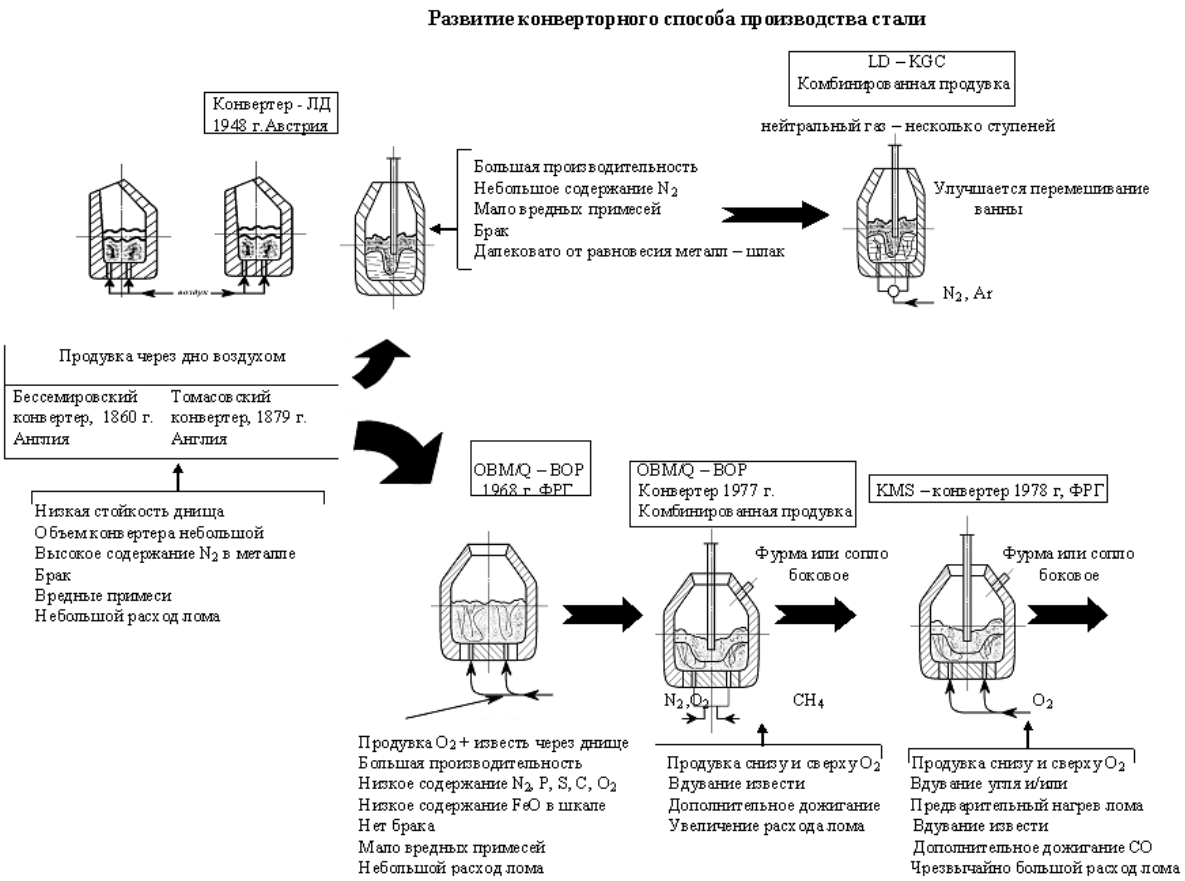


Examples of injecting dispersed flows into the melts and melting facilities.



Picture 1.
1 – ground bunker
2 – pneumatic transport system
3 – regulation gear
4 – ladle
5 – gas powder tuyere

Picture 2



Picture 3. The Development of the Basic-Oxygen Steelmaking Method

7. Comparison with analogues, advantages.

The existing analytical models commonly show the calculation of monodispersed streams only. Besides, the number of physical impacts on the stream is not more than 5-7. The number of physical impacts on the complex stream in the models created within the present technical proposal reaches 15. The new models are expected to fit more the actual stream of the dispersed structures. New methods of