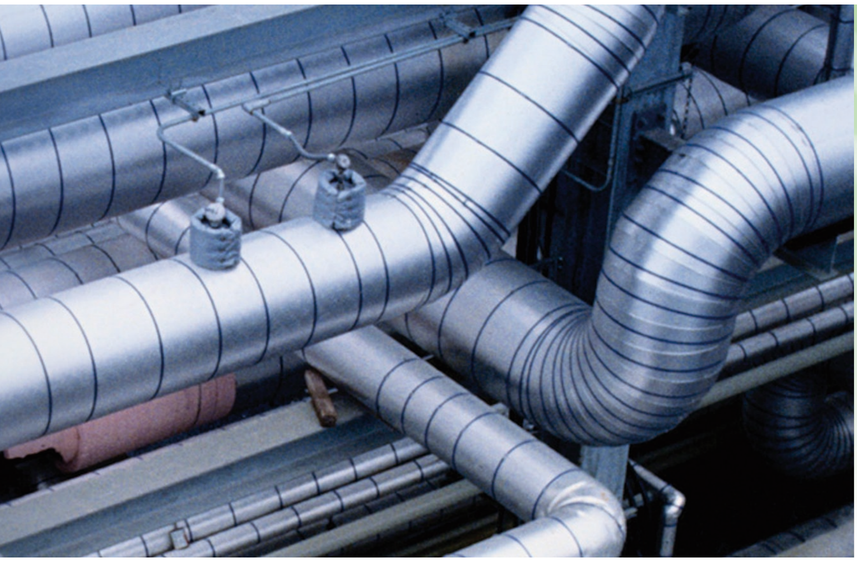
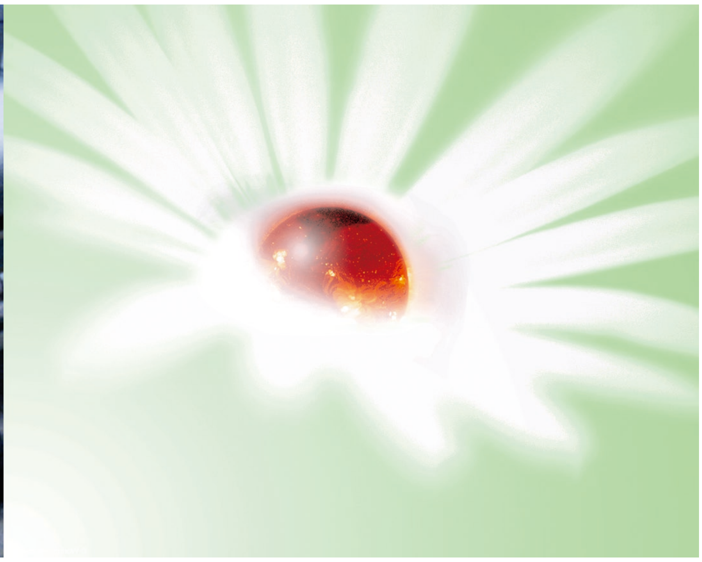
TECHNOLOGIYA METALLOV | INDUSTRIAL COMPANY

PROJECT

MAGMA

MULTIPURPOSE
MELTING UNIT
AND ITS APPLICATION





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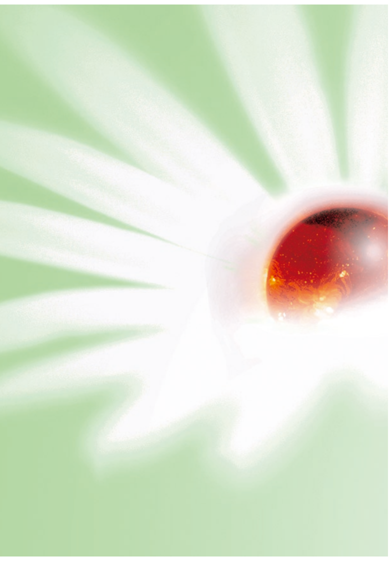

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MULTIPURPOSE MELTING UNIT «MAGMA»

DESIGN DEVELOPMENT OF MELTING UNITS AND CREATION OF «MAGMA» UNIT

First melting units for the production of ferrous metals were based on the fuel-air design. They heated and melted metals using the heat evolving from the oxidation of fuel by air. Such melting units had a refractory lining of the entire working space and were operated non-continuously. As low-calorie fuel (generator gas) was normally used and air was cold, temperature in the working space of such melting units was rather low and did not allow producing liquid steel. Until the end of the nineteenth century puddling furnaces were used that produced low-carbon steel in the pasty condition in the form of a puddling ball that actually was a mixture of iron and high-iron acidic slag. Production rate of such melting unit was very low and a huge quantity of heat was carried away from the furnace working space with flue gases with a high content of atmospheric nitrogen.

In the middle of the nineteenth century Siemens in Germany invented a regenerative melting furnace and used it for the production of glass. Several years later the Martin brothers in France started using such furnace for the production of liquid steel from solid furnace-charge (scrap metal). Regenerative furnaces had special devices in which air and later gaseous fuel were heated by the heat of flue gases thus increasing thermal efficiency of the furnace and increasing temperature of the working space. This allowed production of liquid metal and a significant increase in the production rate of the furnaces that acquired the name of Siemens-Martin furnaces or open hearth furnaces. Open hearth furnaces confidently ranked first among steelmaking units until the middle of the twentieth century, but an increase of temperature in the working space (flame temperature 1900-2000°C) inevitably caused reduction of resistance and quick wear of the unit's refractory lining and limited the possibility of further enhancement of the melting. The use of more expensive and more qualitative refractories did not give any significant increase in resistance of lining of open hearth furnaces and melting duration in such furnaces remained long (several hours). Loading solid furnace-charge (scrap metal, fluxing materials and solid oxidizing agents) by charging boxes of relatively small volume did not facilitate reduction of melting duration or increase of open hearth furnace production rate either.

In late nineteenth century, the electric arc furnace appeared, which became a competitor of the open hearth furnace for solid furnace-charge melting. The arc furnace had a very important advantage: a very high temperature of the heat source, i.e. the electric arc burning between the furnace-charge and graphite electrodes that delivered electric current. Arc temperature was 4000-4500°C, whereas burning fuel flame in blast furnace was 1900-2100°C. This allowed faster furnace-charge melting even in the presence of refractory lining and reaching shorter durations of steel melting. As long as electric power generation remained relatively limited and the design of electric furnaces was unsophisticated, they could not provide a serious competition to open hearth furnaces. The situation changed in the middle of the twentieth century. Superpower arc furnaces appeared in 1960s and their specific power was much higher than power of open hearth furnaces. As a result, production rate of the arc furnace exceeded production rate of the open hearth furnace of the same volume in several times and electric furnaces virtually ousted open hearth furnaces from metallurgical practices by the end of the twentieth century. In order to reach such results in a relatively short period of time, designers and process engineers had to invent and implement a number of novelties that were fundamental for metallurgical melting units.

1. As refractory brick lining of the work space did not withstand exposure to superpower arcs, such lining was rejected. Water-cooled panels would be installed in the walls and the ceiling of the arc furnace. Skull formed on the internal working surface of water-cooled panels and this skull substituted the expensive brick lining. As a result, specific power of electric furnaces increased still further.
2. As electric power is an expensive heat carrier due to a high consumption of primary heat carriers used for electric power generation (average efficiency of a thermal power plant is 0.35),

primary heat carriers, such as natural gas burned in fuel-oxygen burners and coal oxidized by oxygen supplied to the furnace working space by water-cooled lances, started to be widely used. This allowed a significand decrease in electric power consumption and a decrease in the total consumption of primary heat carriers.

3. In order to reduce heat losses with flue gases, designs with furnace-charge preheating by these flue gases were successfully implemented in shaft preheaters or conveyor preheaters of scrap, heat regeneration being similar to the open hearth furnace. This resulted in further reduction of consumption of electric power and primary heat carriers for steel melting.
4. Furnace-charge melting in liquid bath of molten metal (Consteel process) was suggested and implemented for the acceleration of furnace-charge melting and reduction of electric power generation consumption. The Consteel process virtually opened a way to the organization of a semi-continuous process of furnace-charge melting.

At the same time, attempts were made at organizing the melting processes with formation of skull on water-cooled panels in the slag zone of a melting unit operated without electric arcs but with fuel-oxygen heating of the working space. Organization of such process was only successful in non-ferrous metallurgy where melting is performed at relatively low temperatures of slag, metal and free space of the furnace (Vanyukov furnace in Russia). Attempts at the operation with skull on water-cooled parts at high temperatures characteristic of ferrous metallurgy had no success because of low resistance of water-cooled panels and a very high consumption of water for their cooling.

Water as a primary coolant for the parts of melting unit structures has a number of significant drawbacks:

- temperature of water in water-cooled parts should not be higher than 50-55°C because with higher temperatures the process of rust formation on the internal surfaces of the structure runs intensely, which eventually results in the burn-through of parts and extremely undesirable entry of water into the working space of a melting unit;
- water boiling point is 100°C; in the event of overheating of a water-cooled part of the structure, formation of vapor locks is possible that prevent normal water passing and result in the destruction (burn-through) of the part.

Achievements and design trends of melting units described above were taken into account during the design of the melting unit «MAGMA» and during development of its process flow charts. In order to eliminate the limitations of water cooling, liquid sodium was chosen as primary coolant. Liquid sodium is a liquid metal coolant that is successfully used in the nuclear industry (reactor BN-800 of Beloyarsk Nuclear Power Plant). The sodium boiling point is 900°C, which almost rules out the formation of vapor locks and allows for operation with skull at higher temperatures, organization of a continuous process of furnace-charge melting and improvement of the unit's technical and economic performance.

As a result, a continuous fuel-oxygen skull melting unit was created with a body cooled by a liquid-metal coolant. This melting unit can be used for multiple purposes including metal melting, ore-thermal processes, and industrial and municipal waste processing.

The «MAGMA» unit normally is equipped with a furnace-charge preheater where furnace-charge is preheated by the heat of flue gases of the melting chamber, i.e. heat is partially regenerated, which results in the reduction of consumption of heat carriers.

MULTIPURPOSE MELTING UNIT «MAGMA»

APPLICATION CONCEPT

Mankind has accumulated and dumped on the Earth an enormous amount of industrial and household waste generated by human activities.

Waste has been and continues to be disposed of in dumps, storage sites, deposits and special landfills that cover vast areas.

Waste exerts an adverse effect on the environment and people themselves. Intensive economic development and the concept of «a consumer society» speed up the accumulation of such waste in the 21st century.

At the same time, there is a continuing increase in the extraction of resources necessary for accelerated economic growth and for meeting the demands of «the consumer society»: ore, energy carriers and mineral components required for growing production.

As a consequence, the surface of our planet continues to be covered with new metallurgical waste dumps, slag heaps, tailing ponds, abandoned pits, etc.

The problem of efficient processing most of the above-mentioned wastes is solved with the help of «MAGMA» unit. «MAGMA» is a cost-effective continuous skull melting unit that can process and convert wastes into useful products (metals, construction materials, thermal power and electricity) by waste-free and environmentally clean technologies.

«MAGMA» UNIT AND ITS APPLICATION

The multipurpose melting unit «MAGMA» is primarily intended for efficient processing of industrial and municipal wastes, ores and energy carriers by waste-free and environmentally clean technologies

A model type of «MAGMA» unit depends on the specific purpose of its application.

The main modules of the unit are the melting chamber and its original cooling system.

The other components of the unit (driers, heaters, charge feeders, the heating system, molten metal mixers and feeders of reducing agents to molten metal, the release system of melting products, i.e. slag and metal, the process automated control system, the system for use of the thermal power of off-gases and their purification) are all selected depending on the application purpose of multipurpose melting unit «MAGMA».

Natural gas or thermal coal are used as fuels; they are burned in oxygen. This engineering solution has allowed reaching high temperatures: up to 1900°C in the working space of the melting chamber of the unit and up to 1650°C in the molten slag zone.

An original cooling system design of the melting chamber uses a liquid-metal coolant to maintain temperature of the body of the melting chamber not higher than 500^{0}C.

Under such conditions, skull is formed in the molten slag zone on the working surface of the melting chamber and this skull is used instead of the slag zone lining of conventional refractories. The molten metal zone (bottom of the melting chamber) is lined with refractories.

As a result, «MAGMA» unit can operate for a long time without interruption for maintenance.

The multipurpose melting unit «MAGMA» is heated by fuel-oxygen burners. Heating of the unit with thermal coal is possible, where the coal is fed onto the surface of the molten slag.

If necessary, a solid reducing agent can be fed to the molten ore and slag by using injectors. Nitrogen is transport gas that is heated in heat exchangers to cool down the liquid-metal coolant.

Metal and slag are released from the melting chamber of the «MAGMA» unit continuously or non-continuously depending on the design of further processing stages for production of final products.

The heat of the off-gases from the melting chamber can be used in a boiler unit and for generation of electric power or for preliminary heating up of the charge fed to the unit. Process gases are treated by modern gas purification systems.

Principal specifications of multipurpose melting unit «MAGMA» are given in Table 1.

Principal specifications of multipurpose melting unit «MAGMA»

Table 1

Thermal power, MW	up to 100
Fuel types	natural gas, thermal coal
Oxidising agent	technical oxygen (95% O_2)
Metal temperature in liquid lower bath, °C	1350-1550
Temperature of molten slag, °C	1400-1650
Temperature of gas phase in free space (above molten slag), °C	1800-1900
Melting chamber dimensions:	
outside diameter, m	4
length, m	9
Melting chamber steel	boiler alloy steel
Cooling of melting chamber body	liquid-metal coolant (sodium)
Bath lining	periclase-carbonaceous or high alumina bricks
Lining in slag zone of melting chamber	slag skull

«MAGMA» UNIT APPLICATIONS

HIGH–TEMPERATURE PROCESSING OF MUNICIPAL SOLID WASTE WITH COMMERCIAL ELECTRIC POWER GENERATION

The multipurpose melting unit «MAGMA» provides autogenous technology of processing (incineration) of unsorted municipal waste on a layer of molten over-heated slag that forms from mineral components of waste and fluxes specifically added in the process of incineration.

Temperature of the working space of the melting chamber over the layer of molten slag is 1800-1900°C and temperature of slag is 1400-1650°C.

Toxic compounds (dioxins and furans) formed during incineration of unsorted municipal waste are completely destructed under the influence of high temperatures (over 1350^0C)

A number of principally new technological solutions are used in processing municipal waste:

1) preliminary drying of waste to moisture content 10-15%;
2) incineration of waste in oxygen allows to decrease the volume of the off-gases and reach concentrations NOx < 80 mg/m^3, CO < 7 mg/m^3.

The multipurpose melting unit «MAGMA» is equipped with highly efficient cooling systems of the unit body, afterburning of CO and recovery of heat from process gases in heat-recovery power boiler.

Off-gases are treated by a multistage processing route:

1) «quenching» of gases for exclusion of secondary formation of dioxins and furans;
2) cleaning of gases from hazardous substances.

The waste drying and feeding system, as well as the melting unit, is hermetically sealed, which creates a small underpressure in the working space of the melting chamber. This rules out the possibility of non-organised emissions of process gases from multipurpose melting unit «MAGMA» to the environment.

Waste is incinerated in oxygen fed to the working space of the melting chamber by water-cooled combined burner-lances.

The metal component of waste, when molten and accumulated at the bottom zone of the melting chamber, as well as excessive amount of slag, is released from the unit non-continuously for subsequent processing into finished products.

In the process of incineration of unsorted municipal waste, chemical composition of molten slag is adjusted by adding fluxes for the purpose of further production of cast-slag saleable products not containing toxic compounds.

The dust captured in gas treatment facilities is injected back to molten slag where it is assimilated by slag (Fig. 1).

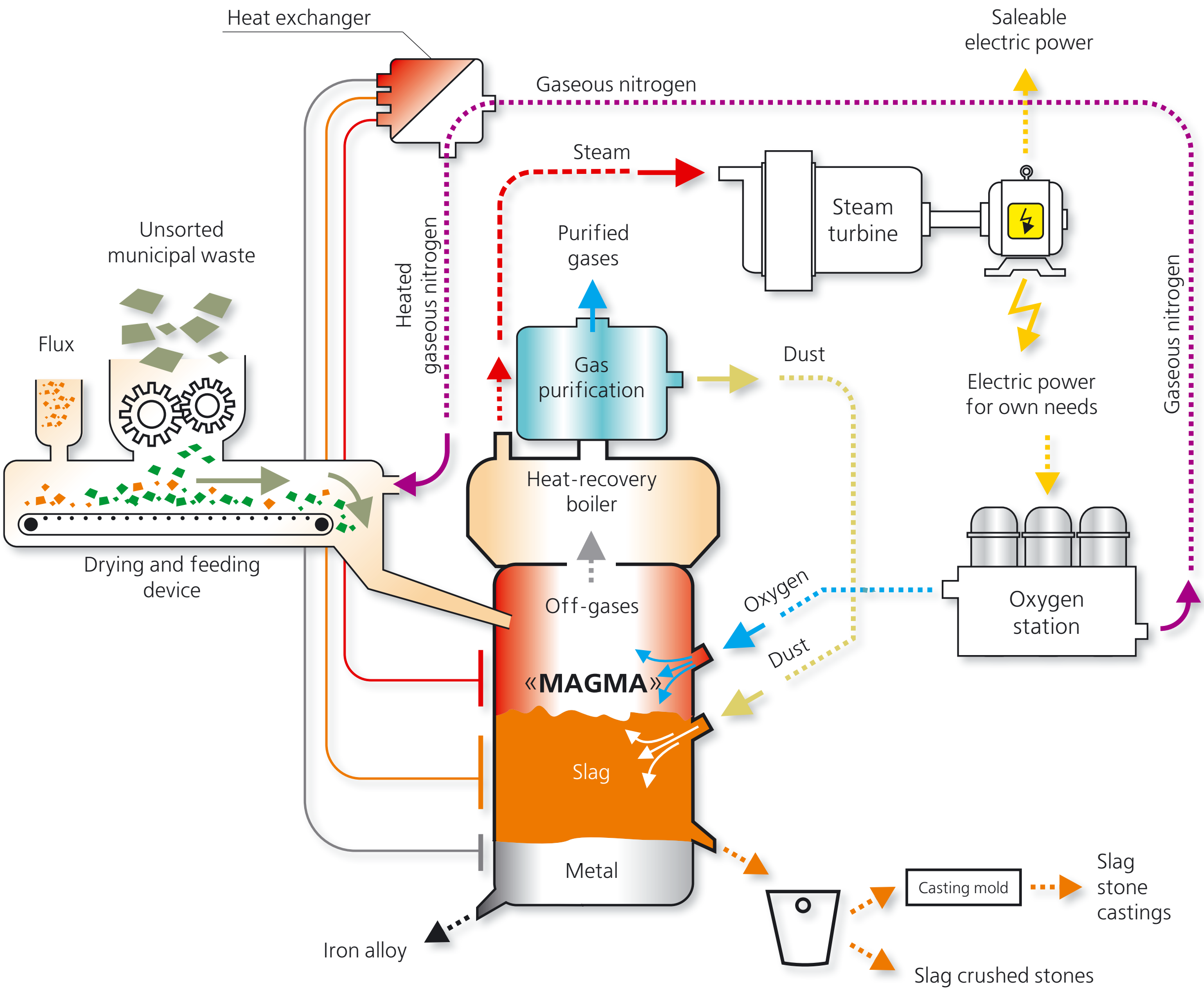

Fig. 1. Waste-free processing of municipal waste

Comparative performance of waste incineration plants

Table 2

Parameter	«MAGMA» unit plant (Russia)	MVA Weisweiler GmbH (Germany)
Maximum production capacity for wet unsorted municipal waste, thousand tons per year (000 tpy)	300	360
Waste incineration method	on surface of molten slag	on burning grate of power boiler
Waste from incineration process	no waste	toxic ash, toxic dust of gas treatment
Heat recovery	heat-recovery power boiler	heat-recovery power boiler
Oxygen consumption, m^3/ton of waste	340	—
Temperature of molten slag, ^0C	1400-1650	—
Temperature of gas phase, ^0C	1800-1900	1100
Construction period, years	2	4

«MAGMA» unit can be used for remediation of existing municipal landfills.

Figures of municipal solid waste (MSW) incineration in the «MAGMA» unit

Table 3

Output products	Unit per tonne of wet waste	Amount
Electric power	MWh/t	0.26-0.35
Iron alloy	kg/t	7
Construction materials	kg/t	266

Production figures are given per ton of municipal waste with initial moisture content 30% and can change depending on morphological composition of waste.

Processing of unsorted municipal waste by «MAGMA» unit gives the following benefits:

1) environmentally clean process in accordance with European Union requirements;
2) profitable production;
3) waste-free technology.
4) possibility of constructing thermal power plants using solid municipal waste as fuel.

PROCESSING OF STEEL SLAGS OF FERROUS METALLURGY

Production of cement can be increased by increase of extraction of natural resources and construction of new plants for processing these natural resources. However, this is a costly and environmentally detrimental method.

At the same time, wastes of ferrous metallurgy contain an enormous amount of oxidised steel slags with a high basicity.

After meltdown of such slags in the melting unit «MAGMA» and partial reduction by carbon of oxides contained in them by process route shown below (Fig. 2), we get molten slag (molten clinker) similar by its chemical composition to cement clinker manufactured by conventional methods at existing cement plants (Table 4).

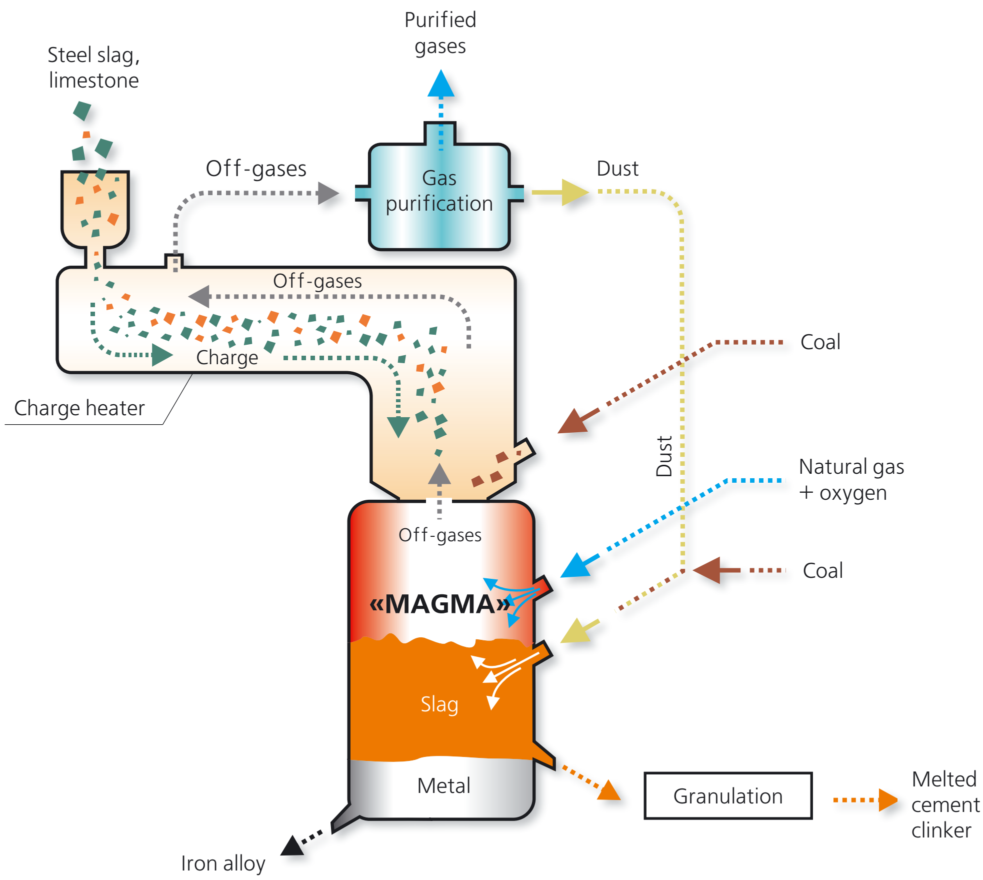

Fig. 2. Flow diagram of melted cement clinker production

Chemical composition of oxidised steel slag, cement clinker and Portland cement type CEM 1

Table 4

Material	Content, %							
	CaO	Al_2O_3	SiO_2	MgO	Fe_2O_3	MnO	Fe, prills	SO_3
Oxidised steel slag	40-55	1.5-3	15-19	1.5-2.5	18-25	4-7	4-6	–
Slag smelted and partially reduced in «MAGMA»	61.7-63	1.8-3.7	18-24	1.8-3.1	4.5-5.2	2.5-4	0	–
Conventional cement clinker	60-67	3-8	17-25	2,5-5	4-5	–	0	–
Typical Portland cement type CEM 1	62-64	5.5	21.5	1.5	3-4	–	0	1.9

Production capacity of multipurpose melting unit «MAGMA» for clinker is 250,000-300,000 tpy and depends on chemical composition of the slag being processed.

Up to 800 kg of melted cement clinker and up 250 kg of iron alloy can be produced out of 1 ton of re-smelted steel slag.

This allows to significantly reduce the costs of production of the melted clinker.

Production of melted cement clinker out of ferrous metallurgy waste allows to decrease the environmental impact due to refusal from the use of natural resources, reduce energy intensity of production and CO_2 emissions per ton of products, i.e. achieve a significant environmental improvement (Table 5).

Comparative figures of cement clinker production methods

Table 5

Production method	Raw materials	Saleable products	Energy carriers used	Specific units per 1 ton of product				
				Limestone consumption	Natural gas consumption	Coal consumption	Off-gases volume	CO_2 emissions
				kg	m^3	kg	kg	kg
Conventional method	natural resources (clay, limestone)	cement clinker	natural gas, electric power	1150-1850	82-96	–	1500-1700	720-840
«MAGMA» method (range of given figures depends on slag composition)	ferrous metallurgy wastes (oxidised steel slags, scales, gas treatment dust)	cement clinker, iron alloy	natural gas, electric power, coal	50-570	60-70	70-110	520-930	290-615

PROCESSING OF RED MUD FROM ALUMINA PRODUCTION

In the Bayer production of alumina, red bauxite sludge is produced as a by-product, which is a fine substance of the following composition, %

Fe_2O_3	CaO	SiO_2	Al_2O_3	MgO	TiO_2	S	P_2O_5	Na_2O
40-55	8-11	5-15	14-16	0.5-1.4	2-5	up to 2	0.2-0.5	up to 2

Moisture content in such product is 40-60%.

For absence of efficient processing technologies, the main mass of red mud is not used and is stockpiled in special sludge storages that affect the environment badly. More than 100 million tons of red mud has been accumulated in Russia to date.

The melting unit «MAGMA» is applicable for pyrometallurgical processing of red mud by the method of liquid-phase reduction of iron oxides by carbon in one-stage process (Fig. 3), or by two-stage process in combination with electrical arc furnace.

The heat recovered from the body of the unit by the liquid-metal coolant is used for dewatering (drying) of initial red mud.

Partially dried mud fed to the unit is smelted in a liquid slag bath. Iron oxides contained in red mud are reduced by carbon (coal) fed to the surface of the molten mass. Reduced iron in the form of cast iron settles down to the bottom of the unit. Composition of the re-smelted and reduced slag is adjusted by adding fluxes according to the type of its further use.

Cast iron, raw material for additional recovery of alumina or clinker for production of alumina cement are the products produced in the one-stage route of red mud processing.

In the two-stage process, ferrosilicon can be produced in addition to the above-mentioned products.

Processing of red mud by multipurpose melting unit «MAGMA» is a completely waste-free technology because the dust captured in the gas treatment system is recuperated (injected) by injectors to the melting chamber of the unit to the molten slag.

Production capacity of the standard model of «MAGMA» unit for processing red mud dried to moisture content 15% is 350,000–380,000 tpy.

Up to 0.35 tons of cast iron and up to 0.5 tons of alumina clinker can be produced out of 1 ton of processed red mud.

Specific consumption of energy carriers for processing of 1 ton of red mud:

- thermal coal up to 200 kg;
- natural gas up to 50 Nm^3;
- technical oxygen up to 100 Nm^3.

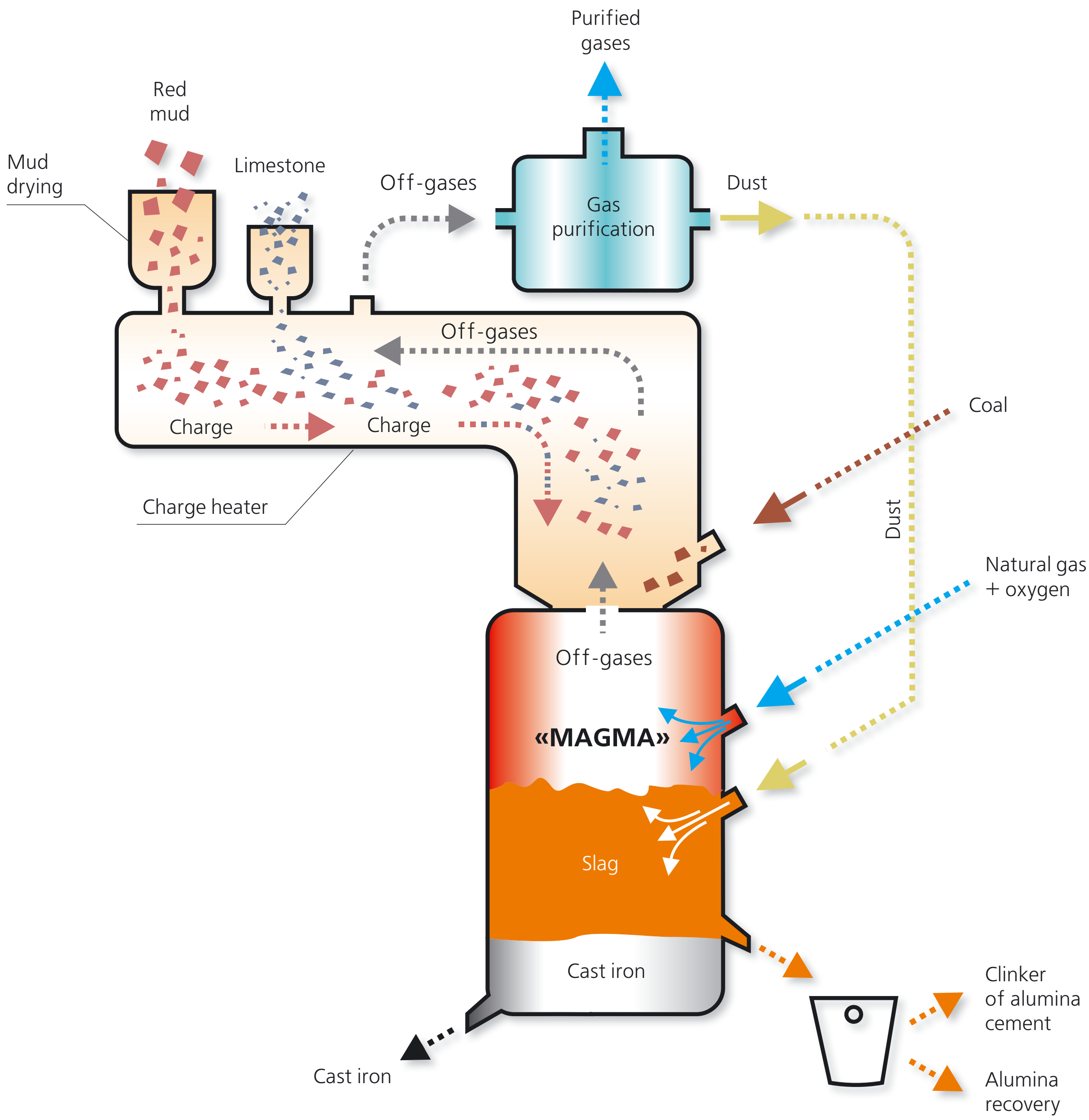

Fig. 3. Flow diagram of one-stage processing of red mud

PROCESSING OF SLAGS OF NON-FERROUS METALLURGY

Leading scientific centres of Russia conducted researches that showed efficiency of use of liquid slags for production of cast slag products: parts of tunnel lining, weighting material for pipe-lines, products for chemical, metallurgical and construction industries.

Best quality is achieved in slag castings made out of low basicity (acidic slags) with high content of iron oxides (Table 6).

Such chemical compositions are characteristic of the slags from non-ferrous metallurgical plants that produce nickel and copper and for the slags of thermal power stations that work on thermal brown coal (Table 7).

Properties of cast slag products

Table 6

Parameter	Unit	Value
Volume weight	kg/m^3	2900 - 3000
Ultimate compression strength	MPa	200 - 500
Ultimate bending strength	MPa	15 - 50
Impact strength	kJ/m^2	1.06 - 1.25
Elasticity modulus	MPa	(0.43-1.01) · 10^5
Poisson number	–	0.25
Thermal resistance	^{0}C	200 - 600
Thermal conductivity at 20 ^{0}C	W/ (m · ^{0}C)	1.07 - 1.52
Specific heat capacity at 20 ^{0}C	kJ/(kg · ^{0}C)	0.67- 0.85
Temperature coefficient of linear expansion within interval 20-600 ^{0}C	1/^{0}C	(0.6-0.83) · 10^{-5}
Abrasion coefficient	kg/m^2	0.1 - 0.2
Water absorption	%	0.03 - 0.1
Freeze resistance	cycles	over 300
Acid resistance in 20% hydrochloric acid	%	up to 97.8
Acid resistance in concentrated sulphuric acid	%	up to 99.7
Alkali resistance in 35% alkali	%	up to 98.6
Diffusion coefficient of Sr and Cs ions: - at t=25 ^{0}C - at t=600 ^{0}C	cm^2/s	 ~10^{-18} ~10^{-14}

Average compositions of slags from non-ferrous metallurgy and thermal power plants

Table 7

Type of slag	Content, %											Melting temperature, ^0C
	SiO_2	FeO	CaO	Al_2O_3	MgO	Cu	Co	Ni	Zn	Pb	S	
Copper smelter slags	32-45	25-45	12	3.2-9.7	2-11	0.3-0.9	–	–	0.5-1	0.22-0.8	0.4-1.2	1100-1150
Nickel shaft furnace slags	39-45	16-24	12-21	4.5-7.5	9-17	–	0.010-0.024	0.1-0.17	–	–	0.43-0.5	1100-1200
Nickel basic oxygen furnace slags	25-35	40-60	2-3	3-10	2-4	0.1-0.2	0.01-0.02	0.3-0.7	–	–	2-3	1100-1200
Ash of thermal power plants working on brown coale	54-55	2.5-10	1.6-2.5	24.7-25.2	2.5-2.6	–	–	–	–	–	0.1-0.3	1400
Average composition of slag castings	44-49	7-20	6-16	9-20	5-13	–	–	–	–	–	–	1300-1350

These wastes, which have relatively low melting temperature, are annually produced in large amounts and are accumulated in dumps.

The «MAGMA» unit allows to economically smelt slags of non-ferrous metallurgy and thermal power plants with adjustment of chemical composition and temperature of molten mass in the process of re-melting.

Furthermore, the metal component present in slags of non-ferrous metallurgy is extracted from it and is used as additional saleable product.

The gas treatment system of the unit can capture zinc and lead contained in the slags being re-smelted.

As a result, production costs of slag castings can be significantly reduced through sale of additionally produced metal.

The «MAGMA» unit has better technical performance than slag-melting units conventionally operated in industry (Table 8).

The multipurpose melting unit «MAGMA» has still more effective performance in case of using hot liquid slags fed into the melting chamber of the unit directly from metallurgical furnaces.

In this case the unit will be also used for leaning of slags of non-ferrous metallurgy.

Comparison of performance of slag-melting units

Table 8

Type of slag-melting unit	Production capacity for smelted charge	Fuel consumption per 1 ton of charge		Consumption of blowing per 1 ton of charge	Temperature of slag
	ton per hour	absolute units	MJ	m^3	^0C
Melting unit «MAGMA»	up to 50	natural gas 70-82 m^3	2600-3000	oxygen 157-182	1400-1650
Arc stationary furnace with water cooling of the unit body (limestone-alumina slag)	2.5 - 3	electric power 1500 kWh	5400	–	1650-1700
Regenerative tank furnace for production of mineral molten mass	3	natural gas 200 m^3	7340	air 3700	1380

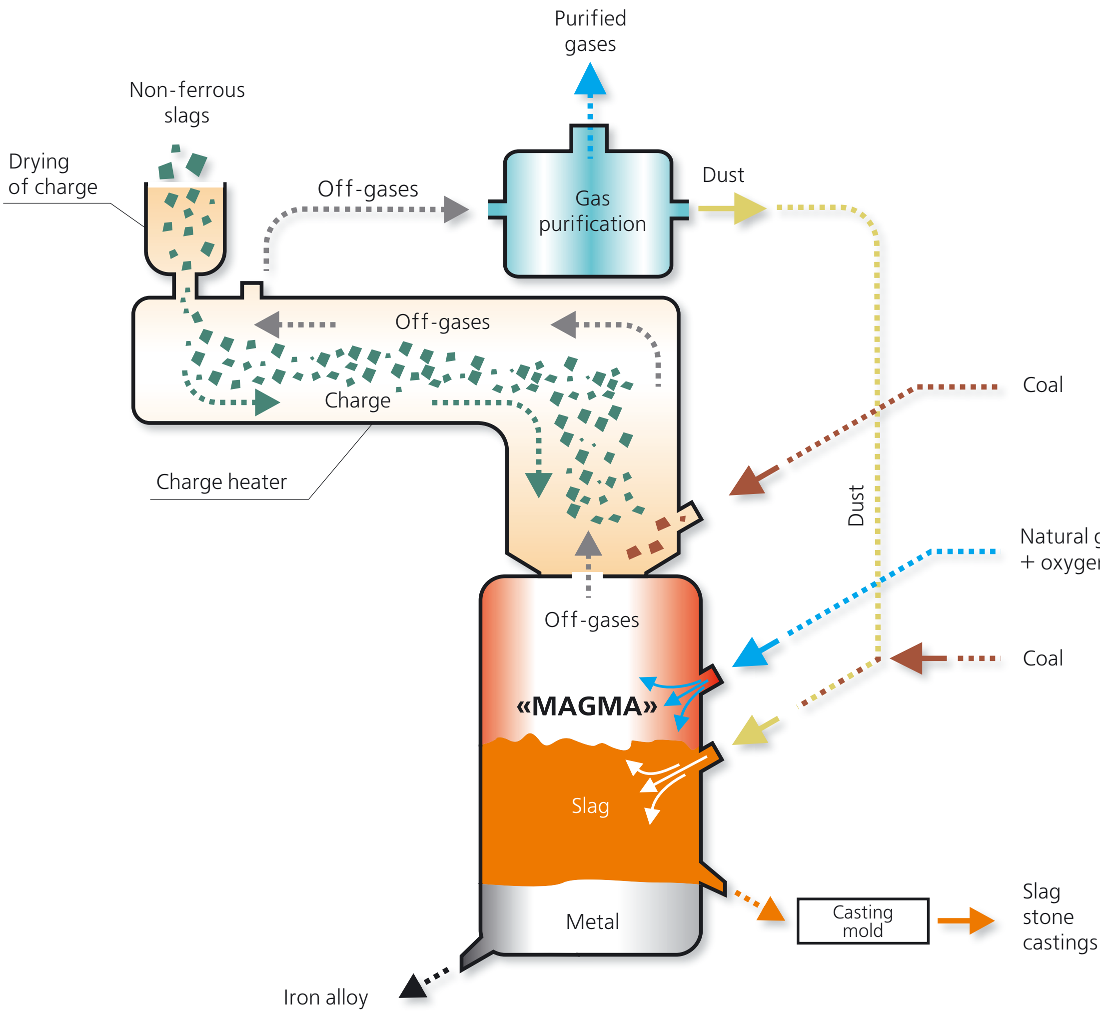

Fig. 4. Flow diagram of processing of non-ferrous metallurgy slags

COKE–FREE PRODUCTION OF CAST IRON

Significant capital and operating costs for preparation of iron ore (concentration and agglomeration of ore) and coke production in many cases do not allow to organise efficient cast iron production on a small scale (up to 1 million tpy).

Organisation of iron production by the method of direct reduction does not require same high expenses for preparation of iron ore.

With relatively small capital costs, «MAGMA» unit can be used for efficient coke-free production of small amounts of cast iron from non-agglomerated iron ore by continuous process (Fig. 5).

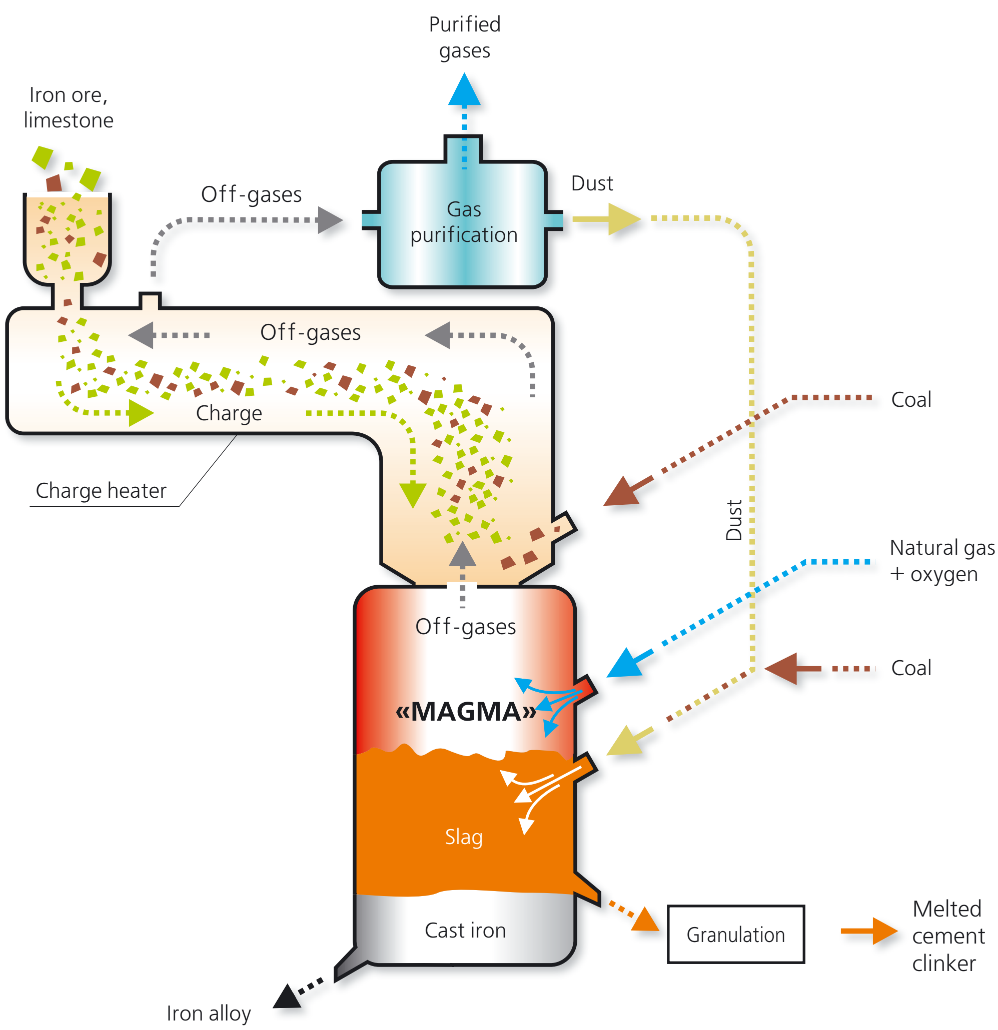

Fig. 5. Flow diagram of coke-free production of cast iron from non-agglomerated iron ore

Charge (iron ore, limestone), before feeding to the unit, is preliminary heated up by off-gases of the melting chamber in a rotating cylindrical heater to temperature 900-1000°C. At such temperatures, process of partial decarbonisation of limestone proceeds with formation of lime and partial reduction of iron oxides.

Charge heated in the heater is fed to the surface of the molten mass, charge melting and reduction of iron oxides occurs in the liquid bath.

Coal required for reduction of iron oxides and adjustment of carbon content in cast iron is fed into the melting chamber onto the surface of the ore and lime molten mass and additionally injected inside by injectors.

The dust captured by the gas treatment system is recuperated by injectors to the melting chamber into the molten slag.

Heat, which is necessary for melting the charge, heating the molten mass, endothermic reactions of reduction of metal oxides and compensation of thermal losses of the unit, is fed into the working space of the melting chamber by gas-oxygen burners.

Cast iron and slag are released from the unit non-continuously.

Chemical composition of slag is close to the composition of blast furnace slag .

Production capacity of the standard model of «MAGMA» unit for cast iron is 200,000-250,000 tpy and depends on composition of the iron ore being used.

Specific consumption of energy carriers for production of 1 tonne of cast iron:

- natural gas 110-115 Nm^3;
- thermal coal 250-320 kg;
- oxygen 220-230 Nm^3.

PROCESSING OF TITANIUM MAGNETITE ORES

The Urals region (Russia) experiences an acute deficit of iron ore for blast furnaces of metallurgical plants. Iron ore has to be brought in from remote regions (Karelia, Central Russia, East Siberia, etc.). At the same time, Chelyabinsk Province (Urals, Russia) has large deposits of titanium-magnetite ore with high contents of TiO_2 and Vn.

Complex processing of such ores by blast furnaces is practically impossible because of formation of high-melting-point slag with a high TiO_2 content.

The task of efficient and complex processing of titanium magnetite ores is solved by using highly efficient cooling system of the melting unit «MAGMA» that allows to use high temperatures in the working space of the melting chamber (Fig. 6).

The result of primary separation of titanium magnetite ores is vanadium cast iron and titanian slag, from which the following products can be produced at later stages of complex processing: vanadium slag (raw material for production of vanadium alloys), steel, ferrotitanium, highly titanian slag (raw material for a TiO_2-based colouring pigment, titanium sponge, etc.).

Processing of titanium magnetite ore by the proposed technology is completely waste free.

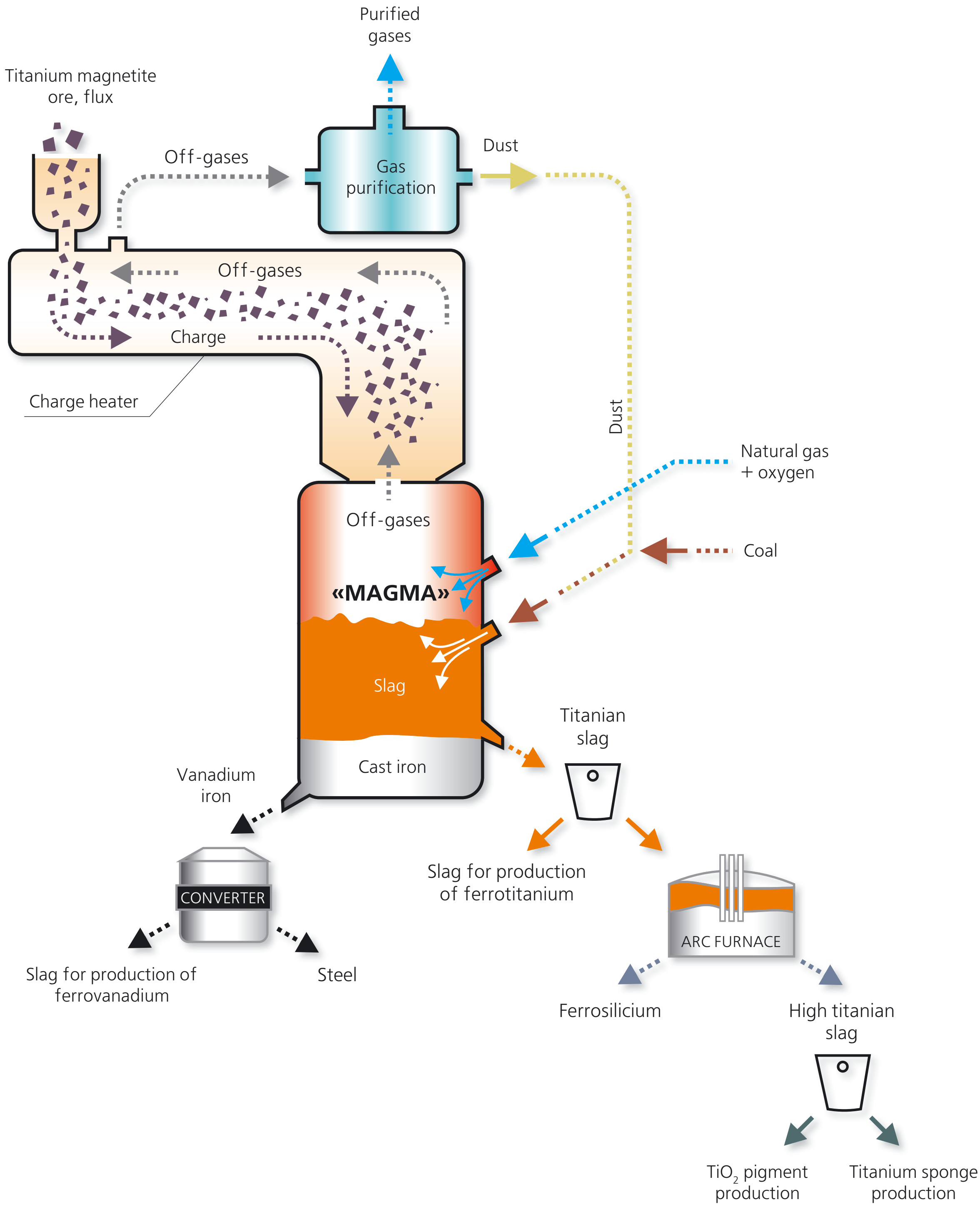

Fig. 6. Flow diagram of processing of titanium magnetite ores

FERROUS SCRAP MELTING

Scrap and slag-forming materials are smelted in a liquid bath of molten metal formed upon starting the melting unit «MAGMA».

For refining of the molten metal from phosphorus and partially from sulphur, oxidised basic slag (slag ratio 0.04-0.06) is put over the molten metal which is from time to time renewed.

The heat required for metal heating and melting is fed into the working space of the melting chamber by fuel-oxygen burner and by oxidation of coal by gaseous oxygen fed into the bath by special lances.

Temperature of molten slag is 1600-1650°C and temperature of metal is 1500-1580°C.

The generated metal semi-product is non-continuously released from the melting chamber into the ladle transported further to the heating facility of the ladle-furnace unit.

Processed slag is released from the melting chamber non-continuously. At a later stage it can be used for production of Portland cement clinker.

Production capacity of the standard model of multipurpose melting unit «MAGMA» for scrap reaches 60-65 tons per hour.

The melting unit can also operate with extra-furnace heating of scrap by off-gases. Above the melting chamber, a hermetically sealed shaft heater of scrap in this case is installed, the shaft heater being equipped with holding and dozing devices and lances for afterburning of CO in the off-gases.

Production capacity standart model of «MAGMA» unit in this case increases up to 80 tonnes per hour.

Use of the melting unit «MAGMA» for continuous melting of ferrous scrap and production of metal semi-product allows to significantly reduce the aggregate consumption of fuel as compared with conventional arc steel furnaces due to more rational use of the energy of primary fuel.

The proposed technology of scrap processing has a number of technical and economic advantages over the conventional combination used in electric-melting of steel: steel electric arc furnace - ladle-furnace unit.

First of all, this means an increase of output of proper liquid metal in melting. Whereas conventional melting of scrap in an arc furnace with the use of melting intensifiers provides an output of proper product in the range of 91-92%, the proposed technology provides an output of proper product after scrap melting in the range of 94-95%.

Increase of output of the proper product is achieved through:

- lesser oxidation of iron when melting in a liquid bath (immersion of a piece of scrap into the molten mass);
- lesser development of iron oxidation in the presence of coal carbon;
- recuperation of iron-containing dust captured by the gas treatment system by injectors to the molten slag;
- small losses of iron in the form of prills in cast slag due to the use of small volume of slag in the process of re-melting of scrap and application of original siphon design of release of slag from «MAGMA» unit;
- exclusion of slag pumping from «MAGMA» unit.

The proposed technology of melting of ferrous scrap, as compared with the technology conventionally used, decreases capital costs because of absence of heavy-duty electric arc furnace and respective costly power infrastructure for its operation.

PROCESSING OF SOLID RADIOACTIVE WASTE

Solid radioactive waste (SRW) is accumulated in the process of operation, maintenance and decommissioning of nuclear power plants and other nuclear installations. Such waste includes: filters, sorbents, ion-exchange tars, products of liquid radioactive waste solidification, items of process equipment, biological protection, pipelines, tools, building structures, special workwear, thermal insulation, etc. Radioactive waste, according to the processing method, is divided into the following groups:

- incenirable waste (wood waste, cloth, paper);
- compressible waste (metal waste, plastics);
- decontaminated or remelted waste with preliminary decontamination (metal waste);
- packed without processing (high radioactivity waste).

More often, however, various methods of decontamination and remelting of metal radioactive waste are used in practice.

The amount of metal radioactive wastes of low and average contamination accumulated in Russia exceeds 1 million tonnes.

Due to the forthcoming closure and dismantling of out-dated equipment of atomic power stations and nuclear fuel cycle enterprises and disposal of ships with nuclear power units, accumulation of significant amount of metal radioactive wastes is also expected in the future.

Similar situation builds up in a number of industrially developed countries.

Insignificant amount of metal radioactive wastes in Russia and other countries is decontaminated by pyrometallurgical method in induction and electrical arc furnaces of low capacity. These melting aggregates operate non-continuously and due to their design peculiarities do not provide a sufficient purification of metal. Therefore metal radioactive wastes are preliminary purified mechanically, hydraulically or otherwise, which is a reason for high cost and small amounts of processing of metal radioactive wastes.

The melting unit «MAGMA» allows to carry on pyrometallurgical decontamination of metal radioactive wastes continuously at considerably lower costs of processing.

The process of metal radioactive wastes fed into the unit is carried on continuously. Before feeding to the unit, metal radioactive wastes are heated in a shaft heater to temperature 700-800°C. This allows to decrease energy consumption and increase production capacity of the unit.

Metal radioactive wastes are smelted in a liquid metal bath under oxidising conditions, which speeds up melting, improves decontamination of metal radioactive wastes and reduces dust formation.

For assimilation of radionuclides oxidised and removed from the molten metal, a layer of oxidised slag of low basicity with temperature 1600-1650°C is formed and permanently maintained over the metal. Amount of slag is not high (2-3% of the metal weight).

Decontaminated metal is non-continuously or continuously released to the ladle, ladle out to form ingots that are further used as charge in steel production.

Slag contaminated with radionuclides is non-continuously released from the melting unit into containers for disposal of radioactive wastes.

The generated oxidised slag of low basicity does not fall to pieces with time and is an ideal substance for absorption and storage of radionuclides.

The dust captured by the gas treatment system that contains radionuclides disposed with the slag.

Production capacity of multipurpose mellting unit «MAGMA» for processing of radioactive solid waste is up to 10,000 m^3 per year.

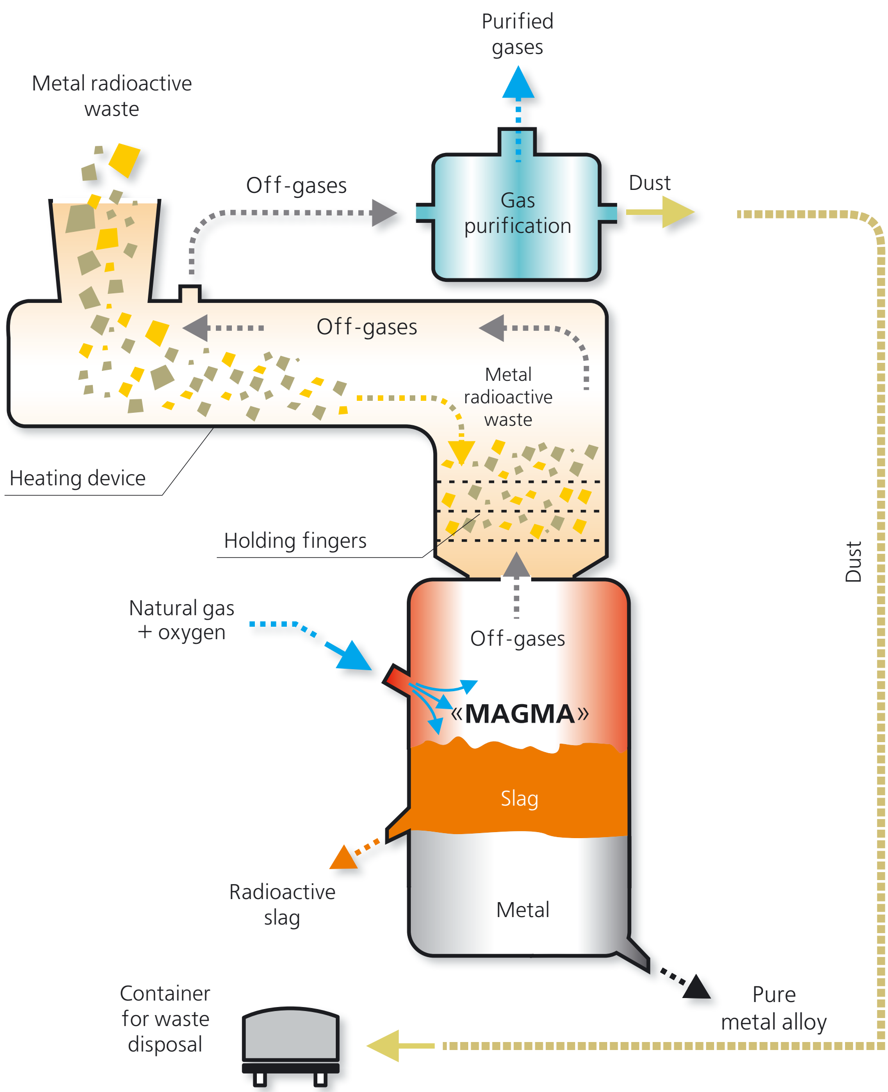

Fig. 7. Flow diagram of decontamination process of metal radioactive wastes

Comparative performance of radioactive metal wastes disposal

Table 9

Parameter	«MAGMA» project	Existing companies
Decontamination	pyrometallurgical	mechanical, chemical, pyrometallurgical
Contamination level of the metal radioactive wastes being disposed	low, average	low
Melting unit type	hermetically sealed, fuel-oxygen, skull, body cooling by liquid-metal coolant	electrical induction and arc furnaces with refractory lining
Volume in terms of metal, tons	up to 20	up to 5
Slag ratio	0.04-0.06	0.04-0.06
Production capacity, ooo tpy	up to 7	up to 3
Consumption for melting of 1 ton of metal radioactive wastes: natural gas, m^3 oxygen, m^3 electric power, kWh	 163 261 65.5	 – – 600-800
Secondary radioactive wastes produced, relation to the weight of metal radioactive wastes	slag 6% dust 1%	slag 4-5%, refractories 2-5%, dust 1-2%
Limitation in use of decontaminated metal	without limitations	10-65% without limitations
Costs of disposal of 1 m^3 of metal radioactive wastes	2500 EURO	2000-8000 EURO

APPLICATION IN NON-FERROUS METALLURGY

The multipurpose melting unit «MAGMA» can be efficiently used in non-ferrous metallurgy instead of conventional units: shaft furnace, Vanyukov furnace, Ausmelt unit, unit for fuming in production of Ni, Cu, Pb, Sn, etc.

Thanks to design peculiarities and high cumulative thermal efficiency, melting unit «MAGMA» provides better technical and economic performance.

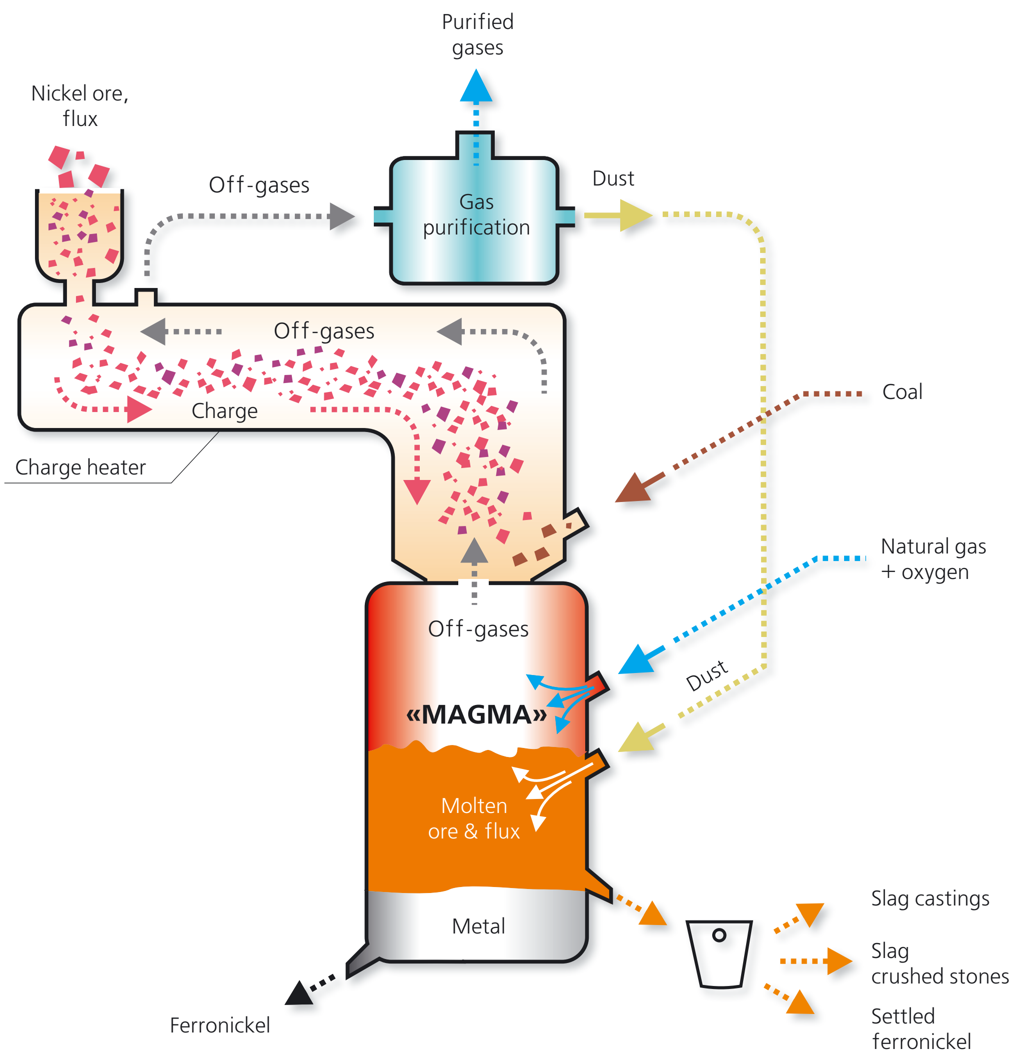

Fig. 8. Flow diagram of production of ferronickel from oxidised nickel ore

Continuous melting of ferronickel with the use of the melting unit «MAGMA» envisages preliminary heating of nickel ore and flux by process gases from the melting chamber of the unit.

Fed materials are melted in a liquid bath of ore-flux molten mass.

For liquid-phase reduction of nickel, cobalt and some part of iron, carbon reducer is used that is fed to the surface of the molten mass.

The melting chamber of «MAGMA» unit is heated by fuel-oxygen burners located on the perimeter of the body of the melting chamber.

The dust captured by the gas treatment system is injected in the flow of heated nitrogen into the ore-flux molten mass, where nickel and cobalt are additionally reduced from the dust.

The produced ferronickel is also released from the melting chamber non-continuously.

The depleted reduced slag not containing oxides of nickel and cobalt is continuously released from the melting unit.

Further, after settlement and sedimentation of ferronickel prills, the slag is used for production of cast-slag products or slag crushed stones and fibrous slag insulating materials.

Production capacity of multipurpose melting unit «MAGMA» for melted charge material is 400,000 tpy.

The unit can be used for matte production by processing of sulfide nickel and copper nickel ores.

PROCESSING OF HIGH-ASH THERMAL COAL

The multipurpose melting unit «MAGMA» can be used for waste-free processing of high-ash (ash content up to 35%) thermal coals for generation of electric power.

Production capacity of the «MAGMA» unit for incineration of high-ash thermal coal is 50-100 tons per hour.

Production of saleable electric power is up to 90 MWh.

Principally, two routes of processing of high-ash coal can be implemented.

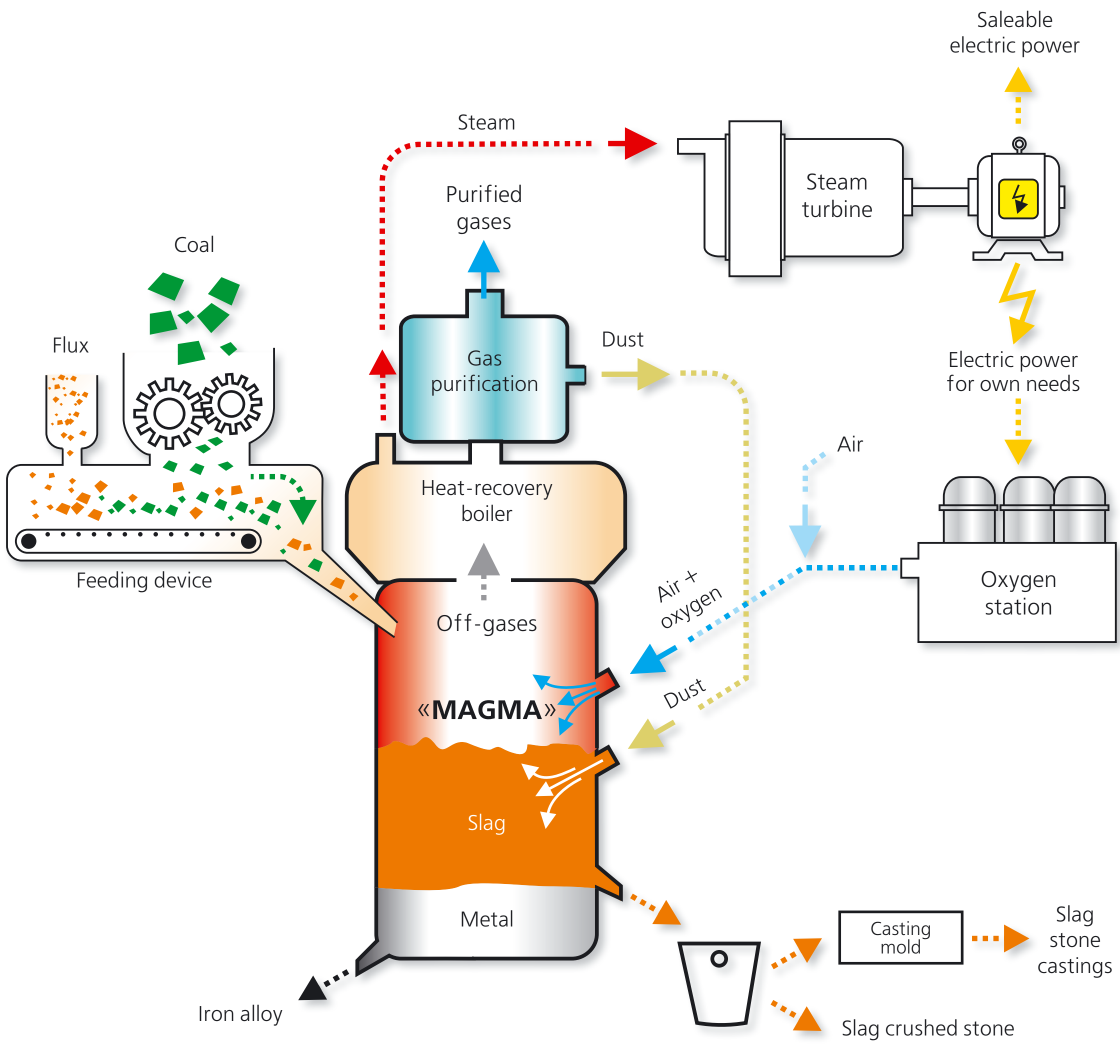

Fig. 9. Flow diagram of processing of high-ash thermal coal (Diagram 1)

Processing Route 1

1) incineration of coal in the melting chamber of the unit in air enriched with oxygen on the layer of the molten slag;
2) afterburning of the formed flue process gases in a heat-recovery power boiler installed over or near the melting chamber of «MAGMA»;
3) production of electric power by traditional processing route used in thermal power industry.

When burning high-ash thermal coal in multipurpose melting unit «MAGMA», ash contained in it is smelted and dissolved in the slag bath.

Temperature of molten slag in the melting chamber is 1500-1600°C. This allows to adjust the composition of the slag being smelted by adding fluxes.

Slag is used for production of cast-slag products or cast-slag crushed stones that by their quality are not inferior to natural granite crushed stones (Table 10).

The dust captured by the gas treatment system is injected by injectors into the smelting chamber, to the molten slag where it is assimilated by slag.

Principal physical and mechanical properties of cast-slag crushed stones

Table 10

Properties	Cast-slag crushed stones	Granite crushed stones
Density, kg/m^3	2800-3000	2500
Strength limit, MPa compression bending	 200-500 20-30	 100-300 5
Abrasivity, kg/m^2	0.5-0.7	1-5
Water absorption, %	0.1-0.2	0.1-1
Frost resistance, cycles	over 300	300

Processing Route 2

1) gasification (incomplete burning) of high-ash thermal coal in the melting chamber of the unit on the layer of the molten slag. The produced gas is mainly composed of CO and H_2 and some quantity of water vapour;
2) cooling of gas in a special heat exchanger. Cleaning of gases from dust and dewatering;
3) generation of electric power from dried gases in a gas turbine.

Chemical composition of molten slag is also adjusted by adding flux and it is used at a later stage for production of saleable cast-slag products.

The dust captured by the gas treatment system is injected into the molten slag.

Thus environmentally clean and waste-free processing of high-ash thermal coal is achieved.

When incinerating high-ash coal, partial reduction is possible of iron from oxides contained in the ash.

The additional saleable product thus produced is used in production of steel at a later stage.

The multipurpose melting unit «MAGMA» can be used for processing of wastes from concentration of thermal coal.

CONCLUSION

Application of multipurpose melting unit «MAGMA» is based on environmentally clean waste-free technologies.

Capital costs for implementation of technologies with using of multipurpose melting unit «MAGMA» are lower than the capital costs of existing plants that produce similar products.

Period of construction - 2 years.

Payback period for capital costs does not exceed 3-5 years depending on the purpose of application of multipurpose melting unit «MAGMA» and availability of relevant infrastructure at the construction site.

TECHNOLOGIYA METALLOV
INDUSTRIAL COMPANY

COMPANY PROFILE

Industrial company «Technologiya Metallov»(Chelyabinsk, Russia) is an engineering company that develops and implements innovative technologies of environmentally clean and waste-free processing and disposal of industrial and municipal waste, efficient processing of ore and energy carriers, creation of principally new designs of melting units for implementation of created technologies.

The company brings its know-hows to the Russian and international markets.

Industrial Company «Technologiya Metallov» cooperates with leading scientific research and design bureaus of Russia for creation of innovative technologies and modern designs of melting units.

Assembly design of melting unit «MAGMA» and created technologies of its application are protected by Russian and international patents.

TECHNOLOGIYA METALLOV

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