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Metallothermal power plants

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Abstract. Metallothermal power plants represent a proposal to obtain less polluting and cheaper thermoelectric energy, simultaneously with obtaining complementary metallurgical products (alloys, laminates, refractory/abrasive materials, powders, etc.). The thermal power plant uses a single primary energy source, namely the chemical energy potentially existing in a new type of fuel „metallothermal fuel”. This is a thermitic fuel that, by reacting thermally, drastically reduces the production of residues and more than 100 times the release of polluting gases (CO₂, NO_x, H₂S, SO₂, SO₃ etc.).

Keywords: thermal power plants, steel mills, metal-thermal fuels, metallothermic electro-metallurgical converters, circular economy, renewable energy.

Introduction

Metal-thermal power plants are a proposal to obtain cleaner and cheaper electricity. The thermal power plant is a customization of the process and the device presented in the Patent Application no. PCT /RO2023/00010 "ELECTROMETALLURGICAL METALLOTHERMIC PROCES AND INSTALLATION

Currently, many classical thermal power plants use fossil fuels (coal, fuel oil, natural gas, etc.) as a primary source of energy, which are relatively expensive and polluting. This reality led to the shutdown of some of the functional thermal power plants, which created a minus of energy availability, which also led to an increase in the price of electricity supply.

Of course, if there were furnaces (boilers) capable of "burning" less polluting fuels, those power plants could be restarted.

In addition, if the furnaces used (boilers of classical thermal power plants) would significantly reduce the production of waste materials / polluting waste (polluting

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gases, slags, ashes, etc.), the benefits could be all the more important as, instead of polluting residues / waste, useful materials would be obtained.

In this regard, it is proposed to use "metal-thermal fuels" burned in "converters" metallothermic electro-metallurgy", i.e. in metallothermic thermal power plants.

In order to materialize the proposal, it starts from the efficiency and greening of a "coal-fired power plant"

According to Nikos Nikolaidi. ENERGY OBTAINED IN THERMAL POWER PLANTS, the block operating diagram of a classic coal-fired power plant is reproduced in figure 1 and its components (modules) are marked in Table 1.

Table 1

Item.	MODULE	Item.	MODULE
1	Cooling tower	15	Coal hopper, possibly with drying tower
2	Condenser cooling circuit pump	16	Coal mill
3	High voltage power line	17	Boiler drum
4	Step-up transformer	18	Ash evacuation
5	AC electric generator	19	Superheater
6	Turbine	20	Air fan
7	Low pressure pump	21	Intermediate superheater
8	Capacitor	22	Air intake required for combustion
9	Medium pressure steam turbine	23	Low pressure steam saver
10	Turbine regulating valves	24	Air preheater
11	High pressure steam turbine	25	Electrofilter for ash
12	Degasser	26	Exhauster (flue gas fan)
13	Low pressure preheater (PJP)	27	Chimney
14	Coal feed tape		

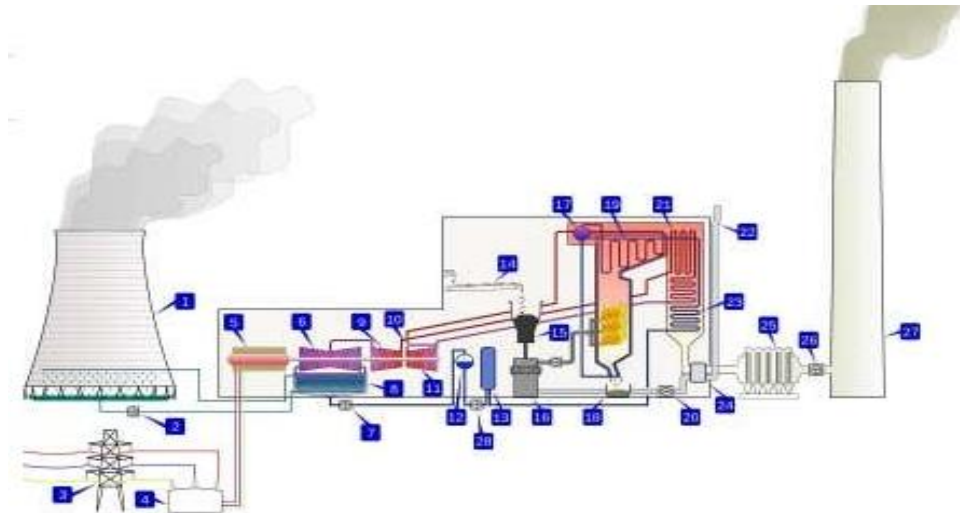


Fig. 1. Block diagram of a classic coal-fired power plant, in which the components are shown in Table 1.

From figure 1 it can be seen that the operation of modules 14. Article 27 contributes to the 'polluting footprint' of the power plant and that replacing them with functionally similar but less polluting modules may pave the way for a significant greening of the power plant.

In this regard, it is proposed to use metallothermic electro-metallurgical converters [1] which, "burning metallothermic fuels", produce thermoelectric energy, metal alloys, slags and reaction gases through aluminothermic oxidation-reduction reactions [2]. All redeemable.

"Metallothermal fuels" are actually termites,[3] i.e. homogenized powdered mixtures resulting from the transformation of tinting (e.g. steel) and/or iron ores (as far as possible pyrite-free) into oxide reactants, plus reducing reactants (aluminium powders), reaction inhibitors, fondants and alloying materials

Metallothermic fuels (homogenized powdered termitic mixtures) introduced into refractory crucibles, when a triggering energy occurs,[4] generate exothermic and exergonic oxidation-reduction reactions that are self-stimulating, being able to run sequentially, continuously or multisequentially serially with continuous scrolling.

The reaction of metal-thermal / aluminothermic mixtures [5] represents the "combustion" of metal-thermal fuels, which leads to the production of metals, slags, reaction gases and heat energy that can be converted into electricity.

The assembly formed by the refracting crucible, metallothermic fuels and their oxidation-reduction reactions outlines a "metallothermic electro-metallurgical converter" which, by releasing the potential chemical energy existing at atomic level into metallothermic fuels, can simultaneously lead both to obtaining thermoelectric energy and to obtaining finished steel products, corundum slags and reaction gases.

This assembly suggests a thermal power plant that simultaneously and complementarily produces electricity and useful metallurgical materials (not waste).

If the current state of knowledge related to the operation of classical coal-fired power plants is well defined,[6] the same situation is not found regarding the composition and operation of the "electro-metallurgical metallurgical metallurgical converter".

The "electro-metallurgical metallothermic converter" was proposed in 2023 [1] by the author of this article. It is additionally defined as a process and as an installation

This thermal power plant proposal recommends the use of metal oxides (e.g. FeO, Fe₂O₃, Fe₃O₄) from metal ores (pyrite-free) and/or from some metal oxide waste (tinning). In addition, it is proposed to use metal reducers (eg aluminum) [7] along with alloying materials (eg FeMn, FeNi, Cu etc.), reaction inhibitors (eg nail flower, steel chips, etc.) and fondants (eg CaCO₃).

In this situation, it is obvious that, in order to obtain metallurgical products (alloys, slags, powders, etc.), traditional coke ovens, blast furnaces and steel mills become useless [8], which can also reduce the release of polluting gases such as CO, CO₂, H₂S, NO_x, SO₂ and SO₃ that today accompany the obtaining of such processes.

Currently, according to POSCO Newroom worldwide, there are three metallurgical technologies, used to produce steels. These are shown schematically in figure 2.

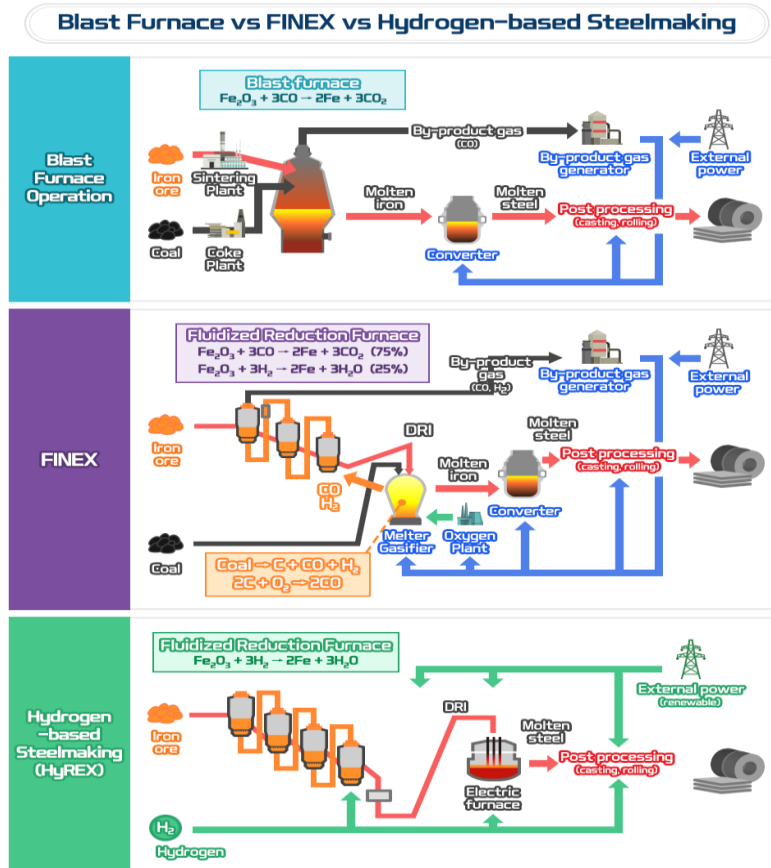


Fig. 2. Diagram of the three classical steelmaking technologies.

The classical technology of producing cast iron and then steel uses, as reducers of oxides in iron ore, carbon or carbon monoxide, which leads to the production of carbon dioxide (greenhouse gas).

The classical technology uses ore preparation plants, coke ovens, blast furnaces, cast iron-steel converters, casting plants, rolling mills, etc.

The QUARK solution proposes to eliminate coke ovens, blast furnaces and cast iron to steel converters.

Critical study of the current situation reveals that among The known metallurgical technologies for producing metal alloys the "cleanest" is the H-IRON technology, to reduce iron ore oxides with hydrogen, using 100% H₂, but this is expensive and relatively dangerous [1]

Known metallothermic technologies are discontinuous or continuous [9]. They use oxide reactants derived only from tinning (e.g. steel tinting).

Known metal-thermal technologies [10] produce metals/alloys, ferroalloys, slags, reaction gases and unused heat to obtain thermoelectric energy

The metal-thermal power plant efficiently transforms some raw materials into "metal-thermal fuels" used to release the potential chemical energy existing at atomic level in them and use it to generate thermal and/or thermoelectric energy, complementary to the production and recovery of metals/alloys, slags and reaction gases, while also aiming at significantly reducing the generation of waste products, including pollutant gases such as CO₂, NO_x, H₂S, SO₂, SO₃, etc.

The consignments of raw materials used to obtain metallothermic fuels consist of:

1. Oxide precursors consisting of: metal ores (e.g. pyrite-free iron ores) and/or oxide waste (e.g. steel cutting).
2. Metal reducer precursors consisting of: bulk powders of atomised aluminium, magnesium or processed waste of such products;
3. Precursors of reaction moderators consisting of: reaction inhibitors (nail flower, metal chips - eg steel) and fondants (eg CaCO₃).
4. Precursors of alloying materials (e.g. bulk ferroalloys).

Through processing, batches of raw materials become batches of:

- a. Termitic reactants consisting of: metal oxides (eg FeO, Fe₂O₃, Fe₃O₄, CuO, Cu₂O etc.) and metal reducers (eg aluminum powders, magnesium powders or shredded waste, with controlled grains, of such materials);
- b. Reaction moderators consisting of: reaction inhibitors (e.g. steel chips) and fondants (e.g. dry CaCO₃ powders).
- c. Alloying materials (e.g. ferroalloys, chips or powders of pure metals) with controlled grains

Batches of processed raw materials (reducers, oxides and/or reaction moderators) are characterized by chemical and particle size compositions that together define the "assortments" of the respective materials (eg., $Fe_{70\%}^{0,2-0,3}Mn_{3-5}^{3-5}$, etc).

The assembly consisting of assortments of reactants, reaction moderators and alloying materials dosed as a percentage, mixed and homogenized, according to "termitic recipes", constitutes the aluminothermic mixtures representing the "metal-thermal fuels" used.

The serial/parallel processing of different batches of raw materials are sequences of processes that lead to the release of caloric energy and to the production of complementary metallurgical products.

For the unitary processing of raw materials (including ores and/or oxide waste), it is proposed to build termite factories [11], capable of transforming useful raw materials into components of termite mixtures, thus implicitly into metal-thermal fuels.

In view of this situation, it is proposed:

- a.- Study the implications of obtaining similar oxide reactants using historical targeting heaps and/or iron ores (pyrite and siderite free).
- b.- Obtaining aluminum reducing powders and aluminum scrap (eg aluminum oily slurry, shredding aluminum sheets, etc.).
- c.- Diminishing the presence of atmospheric air in the aluminothermic reaction

- d. – Use of excess thermal energy to convert it into electricity
- e.- Cooling of the reaction crucible.
- g.- Research of technical solutions for obtaining different brands of steels
- h.- Study of technical solutions for obtaining the same brand of steel when the chemical composition of raw materials varies.
- i. – Study of the possibilities of selecting highly refractory materials (eg high-density graphite) for the production of crucibles in which "metallothermal fuels burn".

The main advantages that can differentiate this proposal from the state of the art are:

1. Avoiding the use of traditional energy resources (hydraulic, wind, fossil fuels, nuclear, photovoltaics, etc.), proposing a new type of fuel. METALLOTHERMAL FUEL
2. "Cleaner" production of metals/alloys and abrasive and/or heat-resistant materials, complementary to the particularly cheap availability of heat energy that can be converted into thermoelectric energy.
3. The production prices of all metallic materials/alloys or non-metallic materials resulting after recovery, simultaneously with obtaining "caloric and/or "electric" energy, are much lower than the known values, because only one primary energy source (potential chemical energy existing in metal-thermal mixtures) is used to obtain simultaneously two types of useful products – heat and metallurgical products.
4. The proposed technology contains sequential or multisequential technological solutions with continuous serial flow, capable of processing, with the same process and installation, various metal oxides and reducers, whether they come from some ores or from certain wastes. Examples: iron ores (pyrite and siderite free) or steel oxide scrap (steel plating) and aluminium powders produced industrially or recovered through recycling (e.g. shredding aluminium sheet scrap or processing aluminium oily slurry).
5. The proposed technology offers the possibility of flexible use of a multitude of thermic recipes for civil use (solutions for obtaining metal-thermal fuels) which, do not lead to explosions and which, not complying with the provisions of Law 126/1995, lead to the generation, within the metal-thermal reaction, of temperatures between 2200 and 23000C.
6. The possibility of making more flexible, in real time, the use of different metallothermic fuels (different thermic recipes [11]), capable of continuously leading to different metallurgical sequences, by switching without pauses, from one recipe to another, while obtaining certain reaction products, even when the composition of raw materials varies in real time.
7. The possibility of obtaining the same brand of steel even when sequentially using different metallothermic fuels.
8. Simplifying known steel technologies by eliminating traditional coke ovens, blast furnaces and steel mills in order to produce a multitude of steel brands or just one in a multisequential manner.

9. Significant reduction of the generation of polluting gases (CO_2 , SO_2 , SO_3 , H_2S or NO_x), by eliminating carbon reducers and by eliminating pyrite and/or siderite ores.

10. It is proposed to reduce the initial presence of atmospheric air in the reaction crucible by promoting aluminothermic reactions in vacuum, which can reduce the generation of NO_x gases.

11. Use of some of the already existing technological equipment. Examples: continuous foundry, rolling mills, steam turbines, electric generators, transformers, etc.

12. The proposed technology allows the recycling / recovery of historical steel cutting heaps (in Romania about 100 million tons) - Circular economy.

13. The proposed technology allowing the energy recovery of the targets, as they appear, constitutes a renewable energy source.

The objective technical problem solved by the metal-thermal power plant is the cleaner and cheaper production of thermoelectric energy, simultaneously with the serial multisequential production with continuous development of metallurgical products, by using a single renewable primary energy source, obtained by recycling historical landfills (waste). The energy used is represented by the potential chemical energy existing at the atomic level in metallothermic fuels "burned" in a single heat-resistant crucible.

The conceptual block diagram of the thermal power plant is shown in figure 3, and the technological block diagram in figure 6.

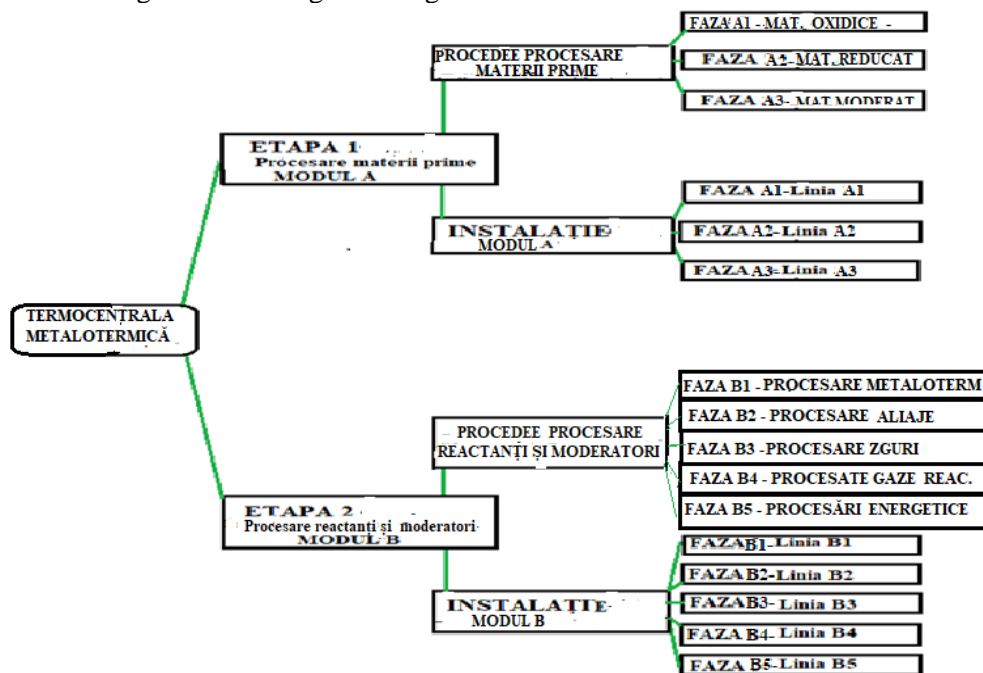


Fig. 3. Block diagram of the metal-thermal power plant.

The critical study undertaken leads to the conclusions:

The metal-thermal power plant can represent a new possibility of cleaner production of thermal energy and/or thermal energy, while producing useful metallurgical materials and significantly reducing the production of waste, including polluting gases.

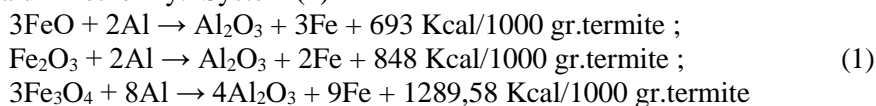
The great diversity of chemical compositions of oxide raw materials leads to the production of a diversity of oxide termitic reactants, which requires the proportional generation of a diversity of termitic recipes, capable of leading to certain reaction products.

The research methods used were both theoretical methods and experimental methods of laboratory or demonstration model.

The theoretical research started from the fact that the operation of classical thermal power plants is well known and that the metal-thermal power plant aims to streamline and green it by using "metal-thermal fuels", processed in an aggregate dedicated to them. Electro-metallurgical metallicular converter.

For this reason, theoretical research had to provide theoretical support related to the development of processes releasing the necessary thermal energy.

The identification of the theoretical solution started from the system of equations defining aluminothermy. System (1)



The problems related to the efficiency of the aluminothermic production of electricity have been treated distinctly but complementarily both as a process and as an installation.

Thus, through bibliographic research [12] it has become evident that the potential chemical energy released by metallothermal fuels is due to the electrical forces arising from the rearrangement of electric charges of electrons and protons in the process of forming new chemical bonds leading to reaction products.

It was also noted that any chemical or metallurgical process proceeds in the sense of diminishing the internal energy of the system, which causes the released energy to be transferred to the environment in the form of heat (usable energy).

The amount of calorific energy available through the considered metallothermic / aluminothermic reactions depends on the type of oxides and reducers used, but for quick estimates an average of about 850 Kcal / Kg termite reacted can be allowed, which can generate temperatures in the crucible of over 26000C. For this reason, it is necessary to cool the crucible, since its operating temperature should not exceed 23000C.

The CBI process treats the specific reactions of metallothermy (e.g. – aluminothermy) as theoretically having two complementary components: an exergonic energy component and a predominantly endergonic component [13].

Oxide components in tinning and/or ores, together with reducing metals, are used for their potentially exergonic properties.

The other materials that are inserted into the metallothermic crucible may be endergonic (Ex. reaction inhibitors, etc.) and others can be exergonic (e.g. Mg, Ti, Zr, etc.), which makes the operation of the crucible correspond to an excess energy balance from an energy point of view.

The specificity of the process used ensures continuously, in the metallothermic converter, a molar equilibration of the flow rate of reactants with the flow rate of reaction products. This simultaneously leads to an equilibration of the speed at which the reactants are consumed, compared to the speed at which the reaction products are formed.

The exergonic component manifests itself after passing the transient stage of priming the metallothermic reaction, which is initially endergonic.

The exergonic component can occur when the reaction-free enthalpy is negative ($\Delta G_0 < 0$).

The exergonic component is dependent both on the temperature/speed of the aluminothermic oxidation-reduction reactions, expressed in kilograms of aluminothermic mixture (thermite) consumed in one second, and on the chosen production capacity.

Production capacity estimation starts from molar evaluation of type (1) reactions,

The exergonic component causes the controlled flow of type (1) reactions to evolve to reduce oxides if enthalpy free of negative reaction is generated.

The reducing component of metallothermic reactants must be as cheap and sufficient as possible to support a continuous, efficient and carried out process at the chosen production capacity.

The moderating component can start only if it has the necessary energy, provided by the exergonic component, and because of this there is initially a time lag between the two components.

The graphical representation of the conditioning revealed by the system of type equations (1) leads to obtaining "termitic diagrams" specific to each batch of processed raw materials[14].

"Termitic diagrams" show the direct/linear/biunivocal links between reaction parameters, which allows the choice of one parameter to identify others. This facility transforms 'termitic diagrams' of the type shown in figure 3b into a command and control tool for the process adopted.

Thus, the temperature of the metallothermic process is identified as the necessary and sufficient parameter for the molar/parametric definition of metallothermic recipes leading to a certain metallothermic fuel, processed at a given time.

And vice versa, reaction temperatures can be estimated starting from a certain chemical composition of metallothermic fuel.

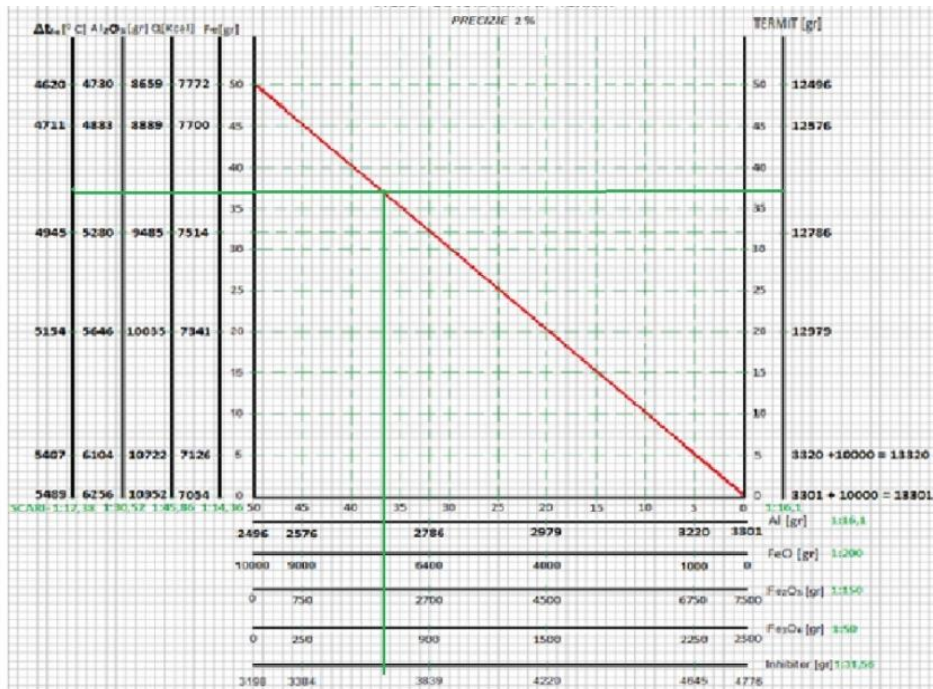


Fig. 3b. Termite diagram.

Research has revealed that for each batch of raw materials must be compiled a "Process Moment Sheet" capable of characterizing the ongoing sequence,

For this purpose, sequentially, for each batch of processed raw materials, an information program (Program P) compiles a comparison sheet of the defining characteristics of the exergonic component of the process and the resulting reaction products. Thus, through Program P, a "thermitic module" of 10 kg of oxide reactants is chosen in real time, as a theoretical reference, to which the necessary reducers are added and based on the outputs from the reactions, the "Aluminothermal Process Moment Sheet" is drawn up.

The "Aluminothermal Process Time Sheet" is of the type shown in Table 2. It highlights parametrically (quantitatively and percentage) the sequential, momentary situation of the inputs and outputs of the respective reactions (aluminothermal) [15].

In this way, for each batch of processed raw materials, the way is opened for the realization, in real time, of metal-thermal fuels with flexible properties, directed to obtaining reaction products (energetic or / and metallurgical) that satisfy the chosen target.

Table 2

Material Parameter	FeO [kg /%]	Fe ₂ O ₃ [kg/%]	Fe ₃ O ₄ [kg /%]	Of [kg/%]	Fe [kg/%]	Al ₂ O ₃ [kg/%]	SLAG [kg/%]
CP[Kcal/Kg ⁰ C]	0,200	0,180	0,207	0,114	O,157	0,329	0,280
THERMITIC MODULE REACTANTS							
OXIDES [kg]	1,100/8,3	2,500/19	6,400/48,8		-	-	-
Al [kg]	0,2754/8,8	0,8488/27,2	1,9888/63,88	3,113/23,7%		-	-
Al/oxides ratio [%]	25	33,9	31	31	-	-	-
TERMITES [kg]	1,3754/10,5	3,349/25,5	8,389/63,9	-	-	-	-
ΔQtermite [Kcal]	952,8	2840	10818,4	-	-	-	-
Total termites [Kg]	13,113						
REACTION PRODUCTS CORRESPONDING TO THE THERMITIC MODULE							
Fe [kg]/%	0,6838/12,6	1,1931/22	3,5329/65,24	-	5,409 / 41,2	-	-
ΔQiron[Kcal]	297,8	468,1	1593,8				
Al ₂ O ₃ [kg]	0,4162/9	1,3069/29	2,8671/62	-	-	4,590/ 35	-
Slag [kg]	0,578	1,815	3,982	-	-	-	6,375/ 48,6
ΔQ slag [Kcal]	239,5	752,1	1650,1	-	-	-	-
Fe / Al ₂ O ₃ [%]	1,643	0,913	1,231	-	-	-	-
ΔQ [Kcal]	953,15/6,52	2.839,95/19,43	10.818,2/74,03	-	-	-	-
Total iron + slag [Kg/%]	11,784 / 89,8%						
ΔQiron + ΔQslag [Kcal]	2359.7 + 2641.7 = 5001.4						
Total ΔQ [Kcal]	14.611,2						-
Fe/Al ₂ O ₃ ratio	1,18						
FEEDBACK LOSSES							
Reaction gases [Kg]/[%]	WEIGHT [kg/%]			HEAT [Kcal/%]			
	1,429 / 10,9			1611,45/ 10,9			-
Total heat lost [Kcal]	9609,7						
YIELDS / RATIOS							
Total mass yield [%]	76,3						-
Iron yield [%]	41						-
Slag yield [%]	48,6						-
Thermal ratio [Kg/Kcal]	0,89745						-
Calorific yield [%]	34,2						

Metallothermal fuels with controlled/directed properties may occur if oxide reactants are separated according to predominant chemical compositions and if the recipes of the selected oxides combine to generate predominantly certain reaction products.

Thus, for example, if it is aimed at maximizing the obtaining of iron alloys and the release of thermal energy, oxides containing mainly magnetite are used, and if it is aimed at minimizing the obtaining of such products, ferrous oxides can be used predominantly.

The separation of oxides by predominant compositions is done with differential magnetic separators that use magnetic fields with controllable/adjustable intensities.

Such a separator is shown in figure 4



Fig. 4. Differential magnetic separator with controllable magnetic fields.

Such theoretical considerations show that metallothermic fuels can be induced with the necessary properties from the design stage. For example, by using certain assortments of metallothermal fuel components (reactants or reaction moderators) it is possible to predetermine both the temperature released and the speed at which they are consumed, as well as the characteristics of the resulting metallurgical products (chemical compositions, metallographic structures, mechanical properties).

The design of fuels with controlled properties must be done, in real time, according to the characteristics of the batch of raw materials processed at a given time. This can be done using an information program that processes the defining data of the raw materials and components of the manufactured fuels.

The information program (Program P) monitors the operation of the entire thermoelectric center. Program P is loaded into a contraler (Ctrl) that monitors all stages and phases through which raw materials pass to become metalthermal fuels with properties dependent on the characteristics of the batch of raw materials processed at a given time and which are capable of generating the tracked reaction products (energy and metallurgical products).

The block diagram of operation of the controller (Ctrl) is shown in figure 5.

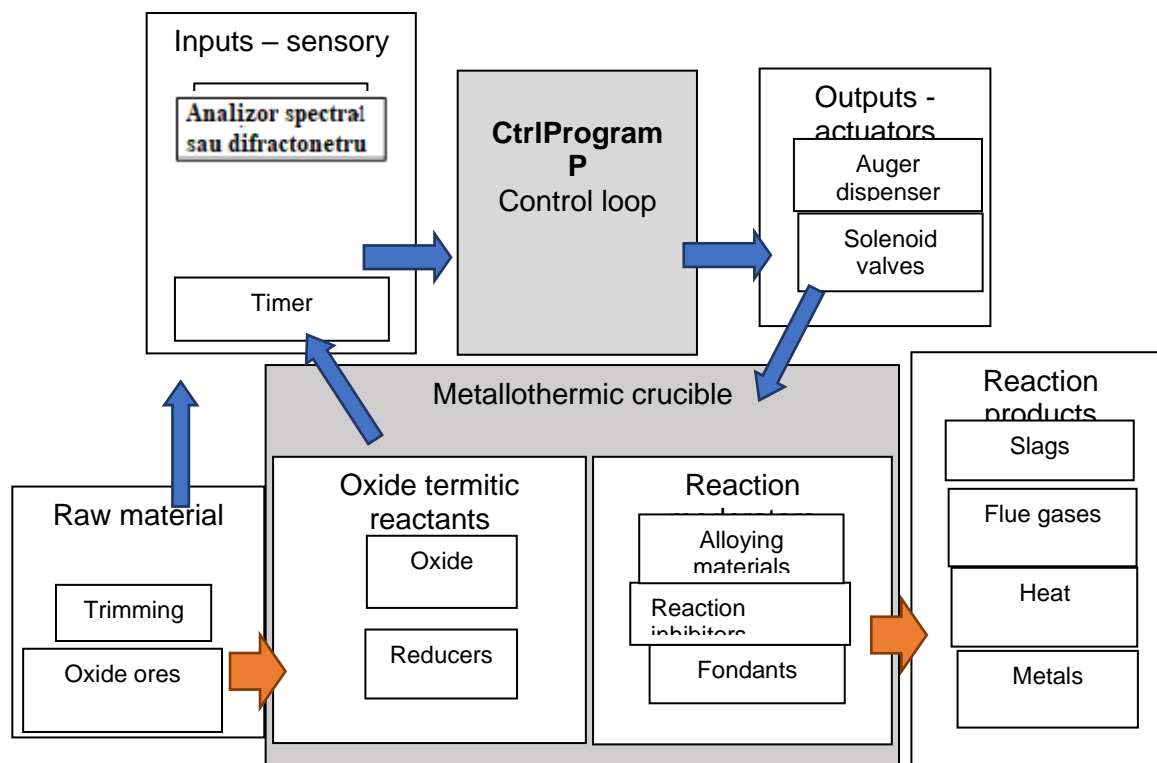


Fig. 5. Functional block diagram of the controller (Ctrl).

The experimental research was oriented towards highlighting the possibilities of sequential conduction of heat-generating aluminothermic processes and useful metallurgical products.

The experimental research was done on a demonstration model.

They revealed that in order to obtain electricity, simultaneously with obtaining metallurgical products, it is necessary:

- Use of highly refractory crucibles (e.g. graphite), with double walls, among which coolant fluids must be recirculated and excess heat transfer from the crucible outside it.
- Use as cooling and heat transfer fluid copper smelters at temperatures of about 11500C because accidental direct contact of copper and steel does not produce large amounts of vapour.
- Initial reduction of the presence of atmospheric air in the aluminothermic reaction enclosure, as this makes it possible to significantly reduce the production of NO_x gases.
- Use of reaction inhibitors both to control the reaction rate and to stop the process in case of failure.

- Use the existing diversity of oxide raw materials (tinting and/or ores) and reaction moderator precursors to obtain the required quantities of oxide and moderating components of metallothermic fuels.
- Generation of a recipe package of metallothermic fuels capable of leading to the obtaining of programmed reaction products.
- Sequential use of metallothermal fuel recipes capable of allowing the operation of the thermal power plant within the programmed parameters.

Notes: 1. The transition from one metallothermic fuel recipe to another represents a new sequence of operation of the thermal power plant.

2. Metallothermal fuels do not use carbon, carbon monoxide or hydrogen as reducers, but aluminium, which reduces CO_2 production.

The description of the composition and operation of the metallothermal power plant is made modularly, according to figure 6.

This allows the processes, sub-assemblies and installations used to be presented in groups.

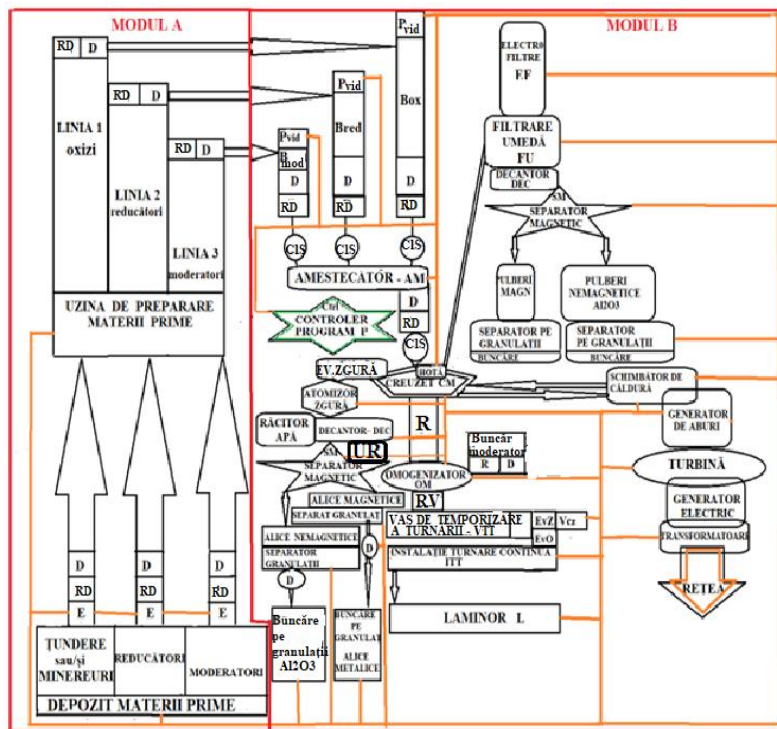


Fig. 6. Functional block diagram of the thermal power plant in which (except for the explicitly nominated subassemblies): E-elevator, D-dispenser, RD- diffractometer, Bmod- set of alloying mat. bunkers, inhibitors and fondants, Bred- set of reducing hoppers, Box- set of oxide hoppers, Cls- directional damper, R- XRF analyzer, RV- spectral analyzer, UR- shot dryer, EvZ- secondary slag evacuator, Vcz- secondary slag collection vessel, Evo- set steel evacuators.

The presentation of the operation of the thermal power plant follows the intercorrelations of the constituent modules, A and B.

Module A – Brings together the process and plant for processing raw materials and transforming them into metallothermic reactants and reaction moderators.

The process related to Module A is organized on 3 subprocesses / phases leading to 3 processing lines, dedicated to the three types of raw materials used (oxidizing, reducing and reaction moderators).

Module B – Brings together the process and installation for transforming termitic reactants and reaction moderators into metal-thermal mixtures (metal-thermal fuels) and for their recovery through the resulting reaction products. There are five sub-processes/phases leading to the 5 product processing lines resulting from Module A.

The operation of the two modules is controlled, through the P program, with the help of the controller (Ctrl).

From a technological point of view, the transformation of raw materials into useful reaction products, goes through 2 stages:

Step 1 – Presents process technological operations and related installations that allow raw materials to be transformed into metallothermic fuel components, i.e. termitic reactants and usable reaction moderators (including fondants).

Step 1 is controlled through the controller (Ctrl) containing the information program used. Program P.

Stage 1 is carried out on 3 process phases (subprocesses) that suggest and justify the composition of the 3 complementary technological lines: A1, A2 and A3 respectively.

Phase A1 – represents the sub-process and complementary processing plant (Line A1) of oxide precursors, shown in figure 7.

Phase A1 aims to produce, on line A1, oxide termitic reactants.

Technological line A1, the block diagram of which is shown in figure 7 (complementary to figures 3 and 6), consists in its first part of two separate circuits which initially allow sequential processing of the two main types of raw materials (ores or tinding).

After going through the specific circuits, the two types of raw materials come together technologically on a common route.

The two specific circuits are:

Circuit1 – for processing ores, until they are taken over on the elevator circuit (e);

Circuit 2 – for processing the tuning, until they are taken over on the elevator circuit(s).

On circuit 1, the primary elevator (E), pos. (1) - fig. 11, takes the ores from the dump and after characterization with diffractometer (RD), pos. (2) - fig. 11, climbs them into the Raw Materials Preparation Plant.

Here the ores are crushed, separated particle size and transferred to the primary magnetic separation system (3).

The magnetic separator has the possibility of separating magnetic components (metal oxides) from non-magnetic ones (sterile).

The tailings are gravitationally directed to the tailings dump (8) and the useful materials are sent, also gravitationally, to the jaw crusher (5) and then to the rotary crusher (6). Both crushers are mass-produced, electrically driven. They have the operational elements made of manganese steel (Mn 14-16%).

SCHEMĂ BLOC - LINIA A1-MODUL A

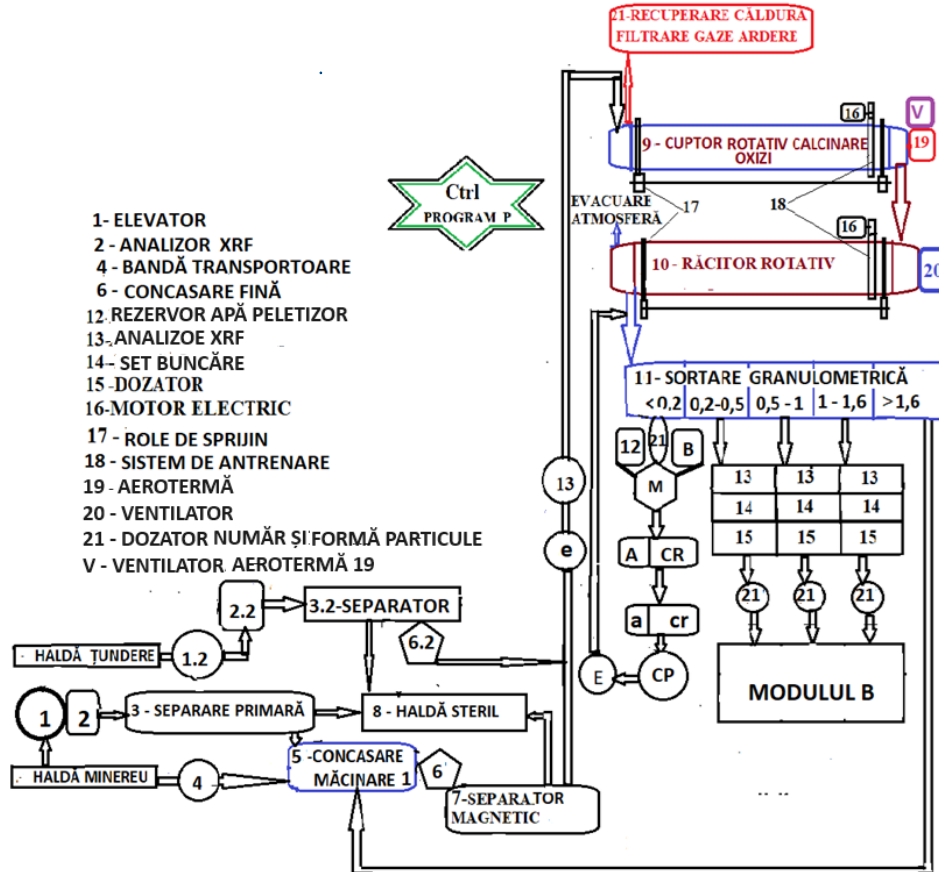


Fig. 7. The block diagram of Phase / Line A1 - consists (apart from the subassemblies explicitly indicated) of: e-elevator 2, 3 and 3.2 - magnetic separators, 1.2 - elevator, 2.2 - XRF analyzer, 6.2 - fine crushing, M - mixer with continuous operation, CR - pelletizing furnace, B - bentonite hopper, A - heater, cr - rotary cooler, a - cooling fan, E- elevator, CP- rotary crusher.

- Phase A2 – represents the sub-process and complementary processing plant for reducer precursors (Line A2), shown in figure 8.

The precursors used are: Industrial powders of atomised aluminium or aluminium powders resulting from the shredding of aluminium scrap or powders obtained from oily aluminium slurries.

The 3 types of precursors are processed on specialized production lines, schematically shown in figure 8.

The particle size classes of interest are: 100-200 μ , 200-300 μ , 300-500 μ .

- Phase A3 - presents the subprocess and complementary processing plant for reaction moderator precursors and alloying materials. Line A3 - figure 9.

The precursors of alloying materials are represented by ferroalloys, and of reaction moderators are represented by precursors of reaction inhibitors (chips of OL 37 - eg nail flower) and fondants (eg CaF₂ or CaCO₃).

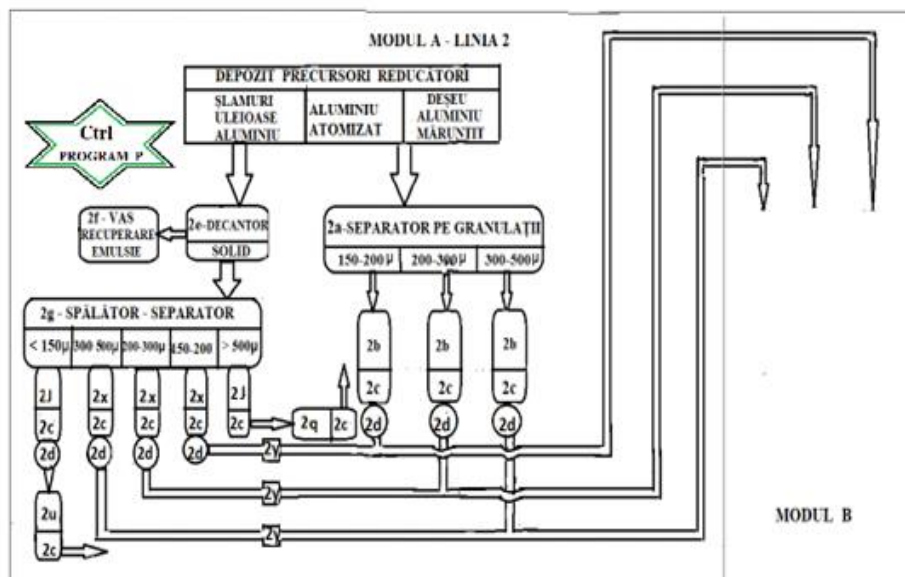


Fig. 8. Block diagram of phase / line A2, where: 2e - clarifier, 2f - emulsion recovery vessel, 2j - storage hoppers for granules not directly usable, 2g - washer - separator, 2c - dispensers, 2d - elevators, 2u and 2q - reprocessable grain storage hoppers, 2x - useful grain storage bunkers, 2y - sense valves, 2b - storage bunkers useful granules of aluminum powders.

Step 2 – Presents the technological process operations and related installations that termitic reactants, alloying materials and reaction moderators go through (made in Step 1) to be transformed into metalthermal fuels and then into recoverable reaction products (thermoelectric energy, metals / alloys, metal or corundum slags and powders).

Step 2 – includes 5 subprocesses/phases that take place on 5 technological lines, corresponding to the 5 types of processes that aluminothermic capitalize on the results of Stage 1.

The schematic intercorrelation of the 5 technological lines, of stage 2, is shown in figure 10.

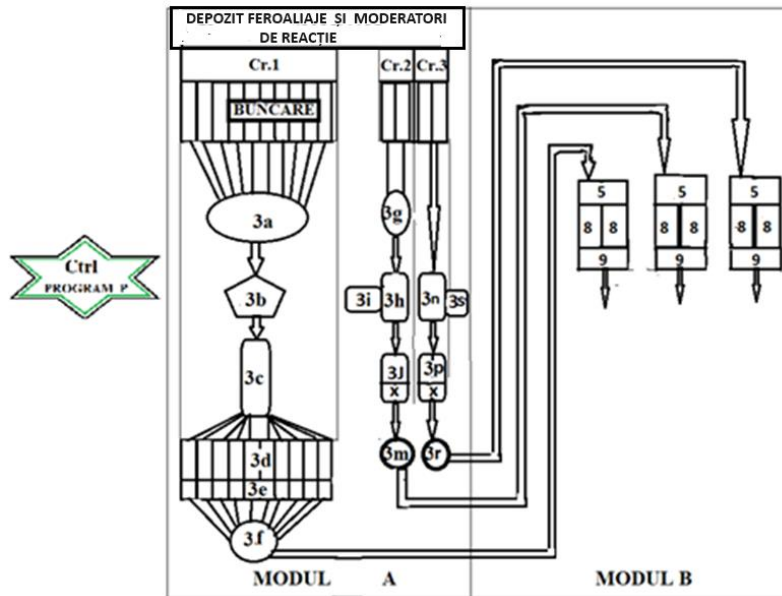


Fig. 9. Block diagram of phase/line A3, where:

- Cr.1- represents the processing circuit of the precursors of alloying materials, composed of: 3a - jaw crusher, 3b - rotary crusher, 3c - bunker header dedicated to each alloying element, 3d – auger dispensers, 3e – XRF analyzers, 3f – elevators.
- Cr2 – represents the processing circuit of reaction inhibitors, composed of: 3g – rotary crusher, 3h – rotary dryer, 3i – hot air heater, 3j – refractive inhibitor collection bunkers, X- spectral analyzers
- Cr. 1- represent the fondant processing circuit which consists of: 3n – rotary dryer with continuous operation, 3s – heater, 3p – fondant collection bunkers, X spectral analyzers, 3r elevators

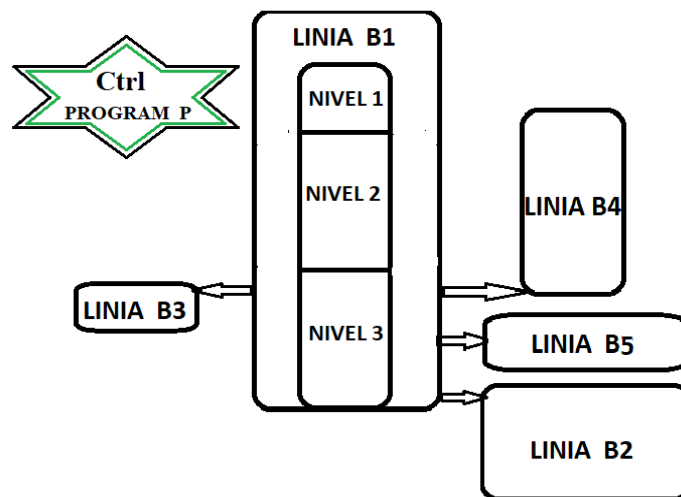


Fig. 10. Block scheme of intercorrelation of the 5 technological lines of Stage 2
Stage 2 is controlled by the controller (Ctrl) containing the information program used.
Program P.

The 5 phases of Stage 2 are:

Phase B1 – presents the complementary process and installation for aluminothermic processing of termitic components processed in Stage 1, to become termites/metal-thermal fuels and recoverable reaction products, respectively. Line B1.

The block diagram of phase/line B1 is shown in figure 11, in which for level 1 there are: PV – vacuum pump, Am – mixer homogenizer, RD – XRF analyzers, Box – oxide hopper set, B red. Set of reducing hoppers, Bmod – set of moderator hoppers, D - auger flow meters, Cls direction damper.

At level 2 there are: AM – mixer (rotary drum type) with direction end Cls., D – dispenser, R – XRF analyzer.

At level 3 there are: CM double-walled crucible, among which molten copper MT is recirculated, Hood H, direction dampers Cls, Ezg slag evacuator, Di – spacers graphite enclosures.

Phase B2 - presents the process and line that allows the processing of metallic materials resulting in phase B1 and which leads to obtaining finished metals / alloys, using the complementary installation, respectively Line B2.

The block diagram of phase B2 is shown in figure 12, where: CM – double-walled metalothermic crucible, R- XRF analyzer, BOM MOD- Alloying material hoppers, BOM PULB- Termite powder bunkers, R- XRF analyzer, D- dispensers, OM – rotary homogenizer for molten steels, RV – spectrometer, VTT- inclinable casting timing vessel that allows natural cooling of steel to a temperature of about 16000C, directing and discharging secondary slag on the EZ circuit and collecting it in the OZ vessel. From the VTT on two distinct circuits (one bottom circuit and another below the secondary slag level) the steel reached continuous casting temperature is discharged. ITT stands for continuous casting plant and L stands for rolling mill for superior valorisation of produced steel.

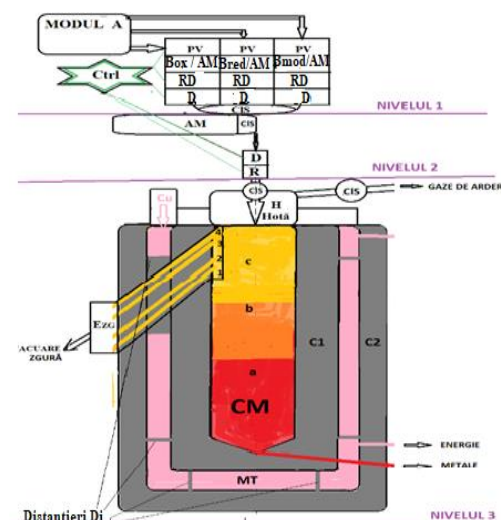


Fig. 11. Phase block diagram/line B1.

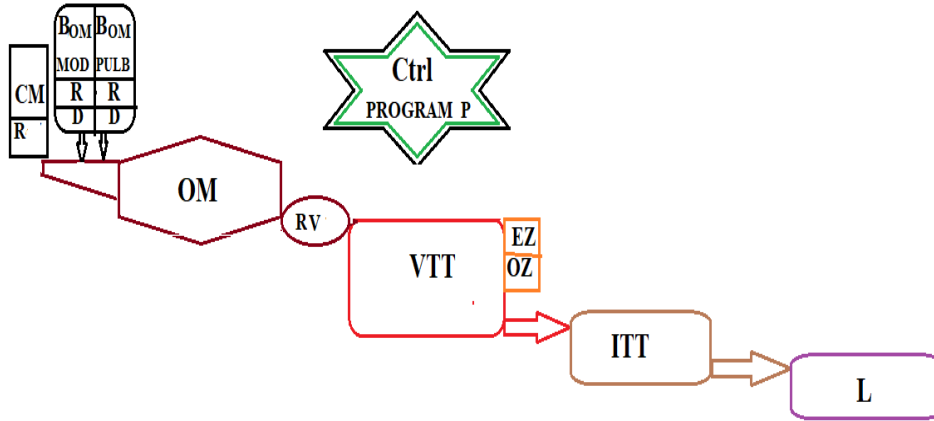


Fig. 12. Phase block diagram/line B2.

Phase B3 - refers to the process of processing metallothermic slags resulting in the crucible (CM) and leading to the complementary processing plant of these slags (Line B3).

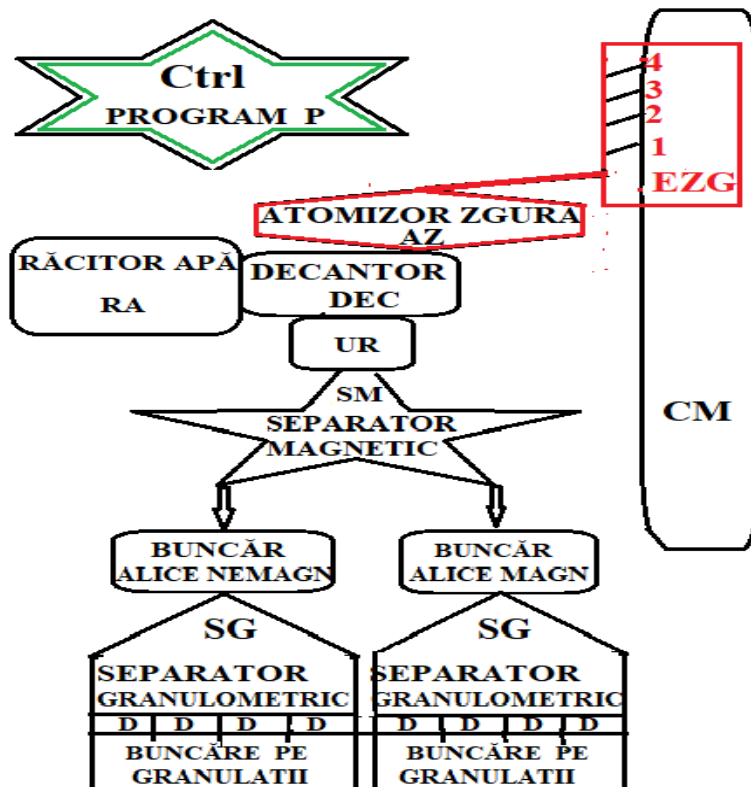


Fig. 13. Phase block diagram/line B3.

Line B3 consists of the sub-assemblies explicitly indicated in figure 13 together with: UR shot dryer and EZG slag evacuator.

Phase B4 - presents the process used to process the reaction gases resulting from the metallothermal processes in the crucible (CM) and which leads to the complementary installation for processing these gases, respectively to Line B4.

The block diagram of phase B4 is shown in figure 14, where: CM- double-walled aluminothermic crucible, H- heat-resistant hood (e.g. graphite), CG- reaction gas exhaust stack, RCP - heat recovery, NB- nebulizer for wet filtration, EF- electrofilters, AG- gas analyzer, VP- fan, RAP- water cooler, DP- set of decanters with alternating operation, TRU- tilting rotary dryer, SMP- magnetic separator, SGP- grain separator.

Magnetic powders represent metal powders and non-magnetic powders represent corundum powders.

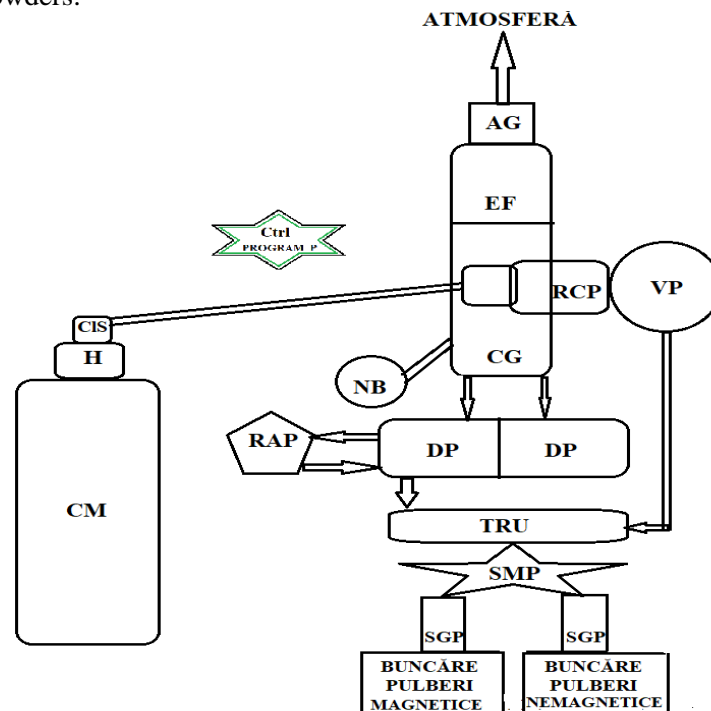


Fig. 14. Phase block diagram / line B4

Phase B5 - presents the process used for controlled cooling of the crucible (CM) and for harnessing the caloric energy released aluminothermic in it, by transforming caloric energy into thermoelectric energy usable both to meet the energy needs of the thermal power plant and to create a deliverable available in the national electricity distribution network. At the same time, the process carried out in Phase B5 suggests and justifies the composition of the complementary installation that materializes this phase, namely Line B5.

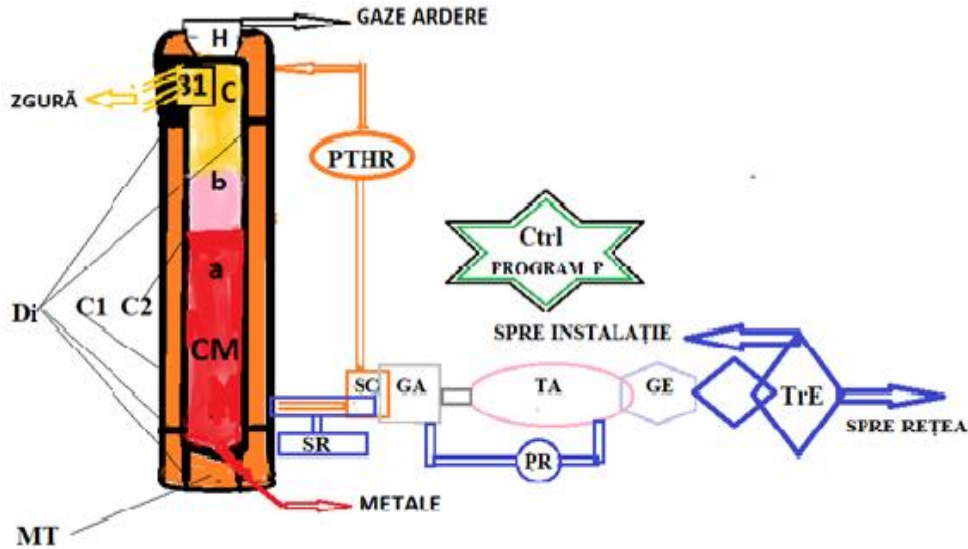


Fig. 15. Block diagram of phase/line B5.

The block diagram of the Feeze/Line B5 is shown in figure 15, where: CM - aluminothermic crucible with double walls among which the cooling and heat transfer fluid MT is recirculated, C1 and C2 - thermosetting chambers of the CM crucible, separated by spacers Di, H - thermosetting hood, landmark 31 - slag evacuator, PTHR - MT recirculation pump (cooling and heat transfer fluid), SR - MT fluid controlled cooling system, SC - heat exchanger, GA - steam generator, TA - steam turbine, PR - condensate recirculation pump, GE - electric generator, TrE - electrical transformer system capable of ensuring both the energy needs of the thermal power plant and the delivery to the national grid of the existing energy available.

Starting experimental research and creating the test base. Preliminary results.

Preliminary experimental research - was oriented towards highlighting the possibilities of sequential/multisequential conduction of aluminothermic processes generating heat and useful metallurgical products.

Currently, on the space of SC QUARK IMPEX SRL, a demonstrator has been built that has proven that using (COMB) it is possible to obtain sequentially or multisequentially, in continuous serial mode, steels, corundum slags, reaction gases/and caloric energy, without the use of coke ovens, furnaces and cast iron-steel converters. Figures 16, 17 and 18.

The existing demonstrator is to be developed to facilitate the realization (CE-MM) capable of leading to the simultaneous and complementary production of electricity

and metallurgical products using a single source of unconventional primary energy, namely the potential chemical energy existing at the atomic level in (COMB).

Using the experimental set-up in Figure 19, it was demonstrated that the use of metallothermal fuels can produce more than 100 times less polluting gases such as CO₂, NO_x, H₂S, SO₂, SO₃, etc., which showed that the emptying of the reaction crucible is justified only in special situations. Figure 20.

3. A portable gas analyzer type was used. Si-CA 230 Kit 4NS/2700, produced by SAUERMANN GROUP, accompanied by the METROCERT UMITERP Calibration Certificate no. 06.501.20.12.23 - Figure 21.

3 experiments were carried out that gave results dependent on the chemical composition of the strands and respectively on the chemical composition of the steels that generated them. The average value is shown in Figure 20.

For the analysis of the reaction gases, 14 kg of metallothermal fuel were used, which "burned" in about 80 s.

The crucible used was a crucible protected with stamped magnesite

The temperature gradient on the surface of the reaction gas exhaust chimney is shown in Figure 14.

The preliminary results obtained were reduced to values indicated in the literature. Example: In the Metallurgical Engineer's Manual-vol.1,1978- The composition of blast furnace gas (p.481) in relation to m³/t cast iron is: 15.66% CO₂; 24.21% CO; 54.38% N₂; 5.54% H₂; 0.21% CH₄.



Fig. 16. Aluminothermic steel mill demonstrator assembly.



Fig. 17. Equipment placement in the aluminothermic steel mill demonstrator.



Fig. 18. Ready-to-work equipment.



Fig. 19. Experimental montaj

S1Ca-230 v1.15 1D2211000041	
11:53:54 - 25/05/2024 Gaz cocserie	
O2	20.90 %
CO	0 PPM
NO	97 PPM
NOx	45 PPM
SO2	0 PPM
CO2	0.08 %
Eff. (eta)	---
T gaz	627.4 °C
T aer	30.7 °C
deltaT	586.5 °C
Tiraj	-0.07 mb
X Aer	---
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Fig. 20. Measurement report.



Fig. 21. Gas analyzer.

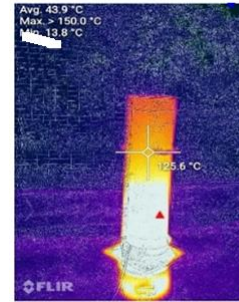


Fig. 22. Temperature gradient in the gas chimney.

At the same time, the aim was to demonstrate the possibility of sequential production of alloys, slags, powders and heat, without the use of traditional primary energy sources and without the use of traditional coke ovens, furnaces and steel mills.

For the demonstration, about 90 kg of metallothermal fuel were used, which, in about a minute, generated about 35 kg of steel and about 35 kg of slag, at a temperature of about 2300C and heat

Preliminary theoretical researches have revealed that in order to obtain electricity, simultaneously with obtaining metallurgical products, it is necessary:

Use of highly refractory crucibles (e.g. graphite), with double walls, between which cooling fluids must be recirculated and transfer of excess thermal energy from the crucible outside it.

The use of metal melts (copper ex.de) at temperatures of about 11500C as a cooling and heat transfer fluid because the accidental direct contact of copper and steel does not generate large amounts of vapor.

makes it possible to significantly reduce the production of NOx gases.

-The use of reaction inhibitors both to control the reaction speed and to stop the process, in case of failure.

- There is the possibility of using oxidic raw materials (shaving and/or ores without pyrite or siderite), precursors of alloy materials and reaction moderators to obtain the necessary quantities and qualities of components of metallothermal fuels.

- It is possible to flexibly generate recipes for metallothermal fuels capable of leading to the production of the programmed products.

Conclusions. The metal-thermal power plant technologically brings together the production of thermoelectric energy and metallurgical materials.

1. The metal-thermal power plant can represent a less polluting alternative both to current technologies for producing thermal energy and to current technologies for obtaining metallurgical products (alloys, laminates, powders etc.)

2. The metal-thermal power plant materializes a form of circular economy that allows the use of renewable energy in order to streamline the production of thermoelectric energy, and much with the efficiency of obtaining metallurgical products (alloys, rolls, slags, powders).
 3. The efficiency of obtaining thermoelectric energy simultaneously with the efficient obtaining of metallurgical products is due both to the use of a single primary energy source (potential chemical energy existing in metallothermal fuels) and to the elimination of important subassemblies both from the composition of classical thermal power plants (all components producing thermal energy) and from the composition of metallurgical / steel production capacities (coke ovens, blast furnaces and even classic steel mills).
 4. The metal-thermal power plant uses less polluting fuels. Metal-thermal fuels.
 5. The metal-thermal thermocentral allows the recycling of historical shredding dumps and constitutes a renewable energy release (metals oxidize and the resulting oxides release the accumulated potential energy).
 6. The capacities for producing thermoelectric power and metallurgical products are interdependent and complementary. For example, burning about 14Kg/s of metallothermal fuels results in about 11,900 Kcal/s or 49,742 KJ/s. The electricity corresponding to these powers has a value of about 10 MWh. This energy also corresponds to the simultaneous production of about 5.5 Kg alloys / s and about 4.5 Kg slags / slags, which represents a production of about 174,449 t / year of alloys / laminates and about 141,912 t / year of slags.
- NOTE - Electricity production is affected by specific efficiencies (about 20%).

Proposals

- a. – Identification and study of the applicability of highly refractory materials more resistant to thermal wear than graphite.
- b. – Development and experimentation of command and control equipment, capable of guaranteeing the safe operation of the thermal power plant
- c. – Studying the cheapening of metal-thermal fuels
- d. – Construction of metal-thermal fuels factories (termite) capable of unitary processing of ores and/or tinding.
- e. – Efficient use of metal-thermal fuels (termite) in the steel industry, with the recovery of the available energy.
- f. – Refurbishment of coal-fired power plants so that they become "cleaner" and more economically efficient, simultaneously producing energy, metallurgical products and putties for aluminothermic welding of railway tracks.

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