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(54) **MULTI-PURPOSE, MULTI-OXY-FUEL,  
POWER BURNER/INJECTOR/OXYGEN  
LANCE DEVICE**

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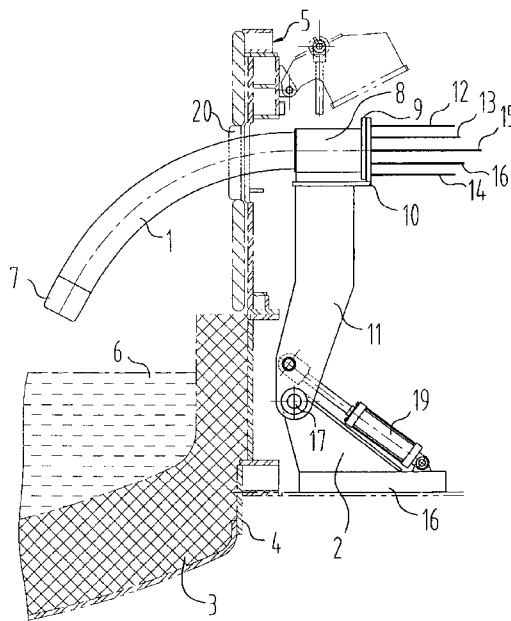
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266/268**

(57) **ABSTRACT**

A multi-purpose, multi-oxy-fuel High Temperature Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, for steelmaking from recycled scrap and/or virgin ferrous charge, which can be employed in multi-oxy-fuel (natural gas; pulverized carbonaceous matter; heavy oil), especially by Oxygen Combusted mixture of Natural Gas/Pulverized Carbonaceous Matter in High Temperature Power Burner Mode, for efficient and rapid melting of solid

ferrous charge (cold or preheated) in a special steelmaking Metallurgical Furnace or Open Hearth Furnace, Tandem Furnace, BOF, EAF, as its augmenting or only source of thermal energy; more than one Device in Oxygen-Natural Gas/Pulverized Carbonaceous Matter Power Burner Mode, can be employed as the only source of thermal energy in a modified, originally Electric Arc Furnace, as total replacement of Graphite Electrodes and Electric Arc System, the replacement being noticeably more primary energy efficient than the thermal energy provided by Graphite Electrode/Arc System; it also can be employed in an Solid Particles Injector Mode, for injecting of adequately granulated carbonaceous materials or lime into the molten steel for its carburizing or for foamy slag control; further it can be employed in a natural gas shrouded, pulsating oxygen stream, for vertically to the charge oriented soft blow supersonic Oxygen Injection Lance Mode, for decarburization of the molten metal contained in the hearth of the metallurgical furnace and foamy slag control; in one of the embodiments—generally arcuate—pivotally mounted, liquid media cooled composite body, is pivoted into and out of a furnace vessel through a small opening in the shell wall for auto-regulated constant optimal positioning of the Composite Body Tip against solid or molten charge, in each and all multi-purpose modes; furthermore, when inserted into the furnace vessel, the arcuate composite body can be rotated about its longitudinal axis for directing the oxy-fuel high temperature flame towards unmolten charge in the furnace; in an other—generally linear—embodiment, the liquid cooled composite body is attached to the mast type carrier allowing vertical movement of the composite body which enters the furnace vessel through a small opening in the furnace roof; the bimetallic, liquid cooled special tip assembly of both—arcuate and linear embodiments—of the composite body includes easy replaceable, independent, multi-opening nozzles, mounted in a protective, retracted position inside of the liquid cooled special tip assembly.



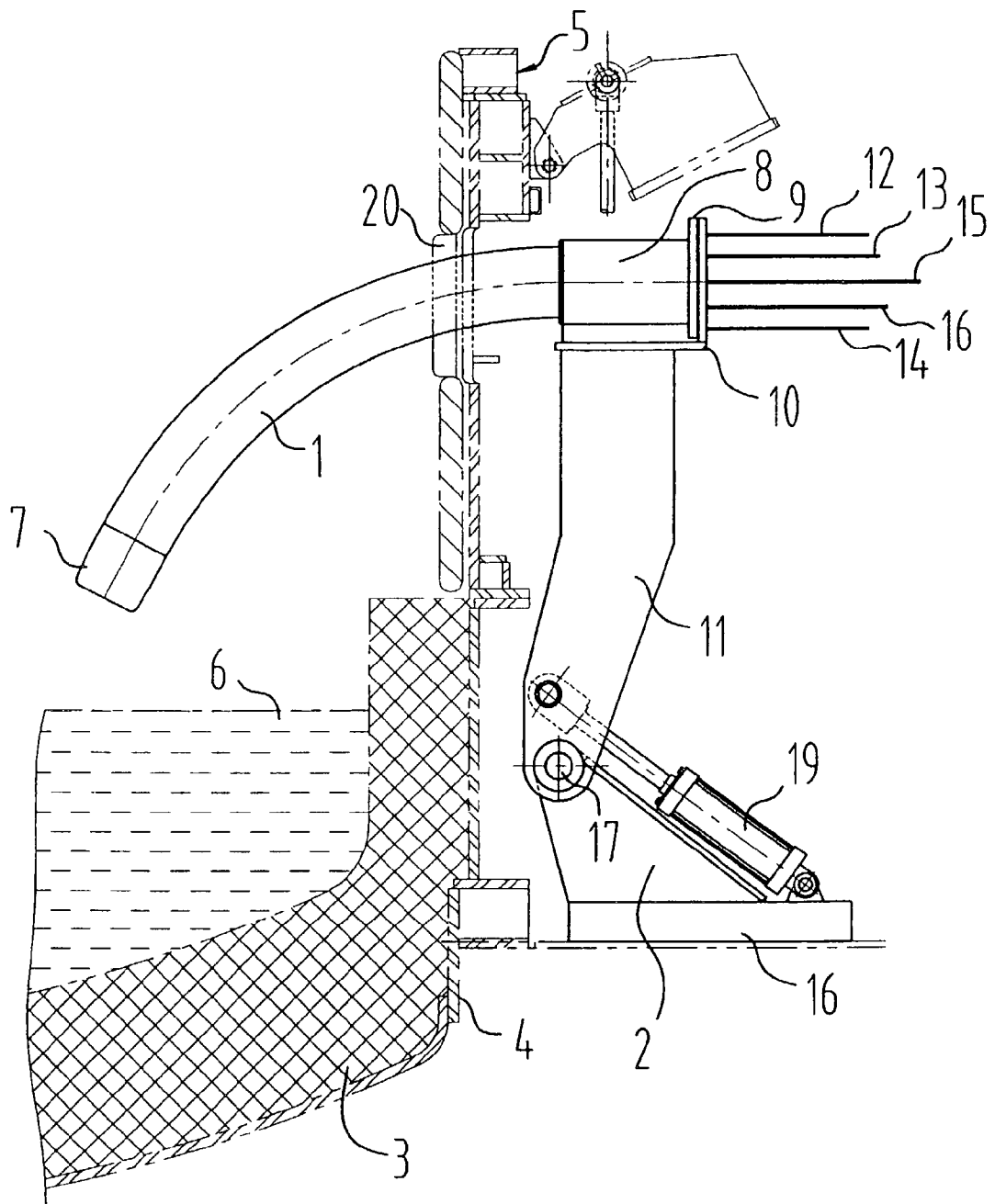


FIG. 1.

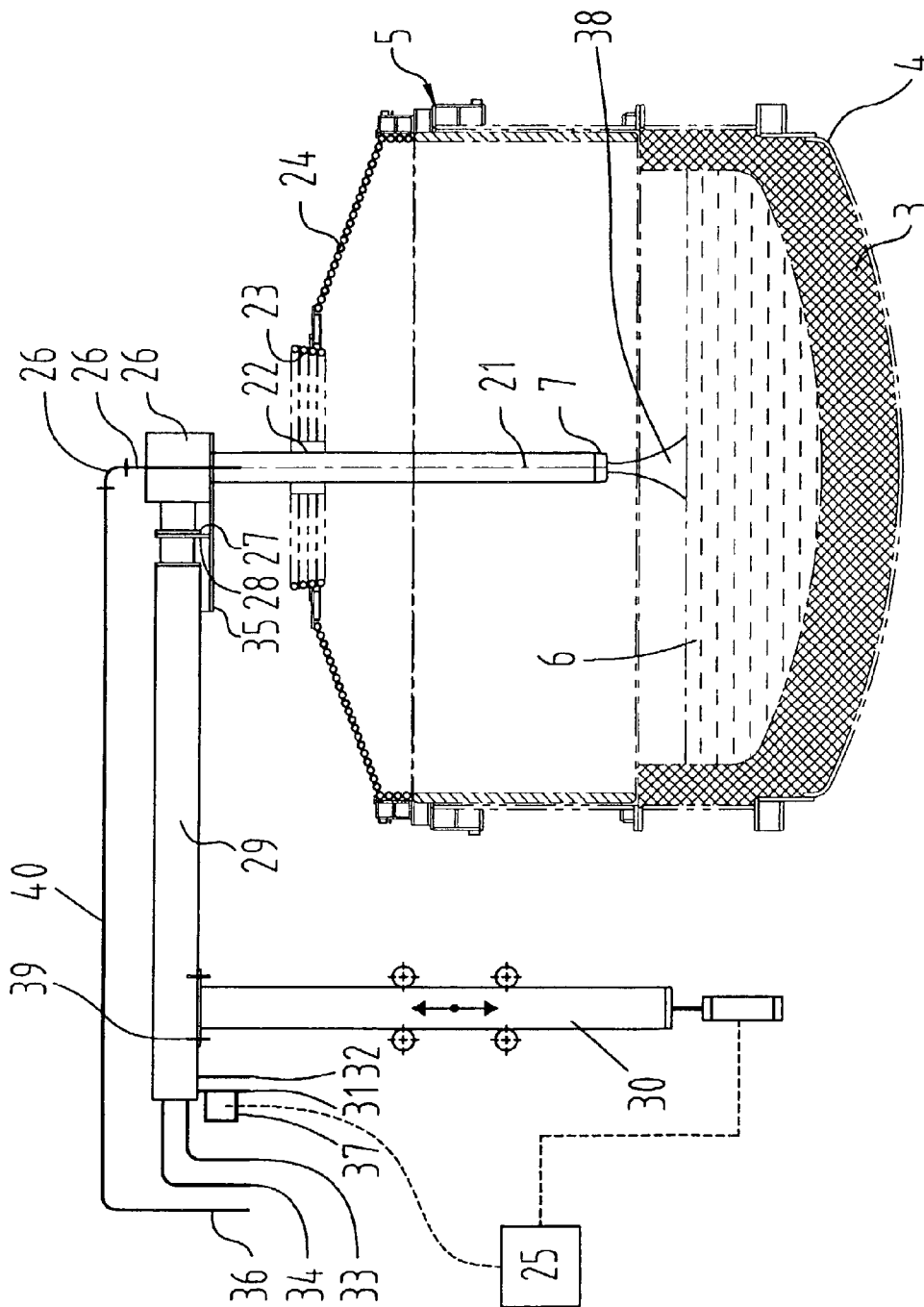


FIG. 2

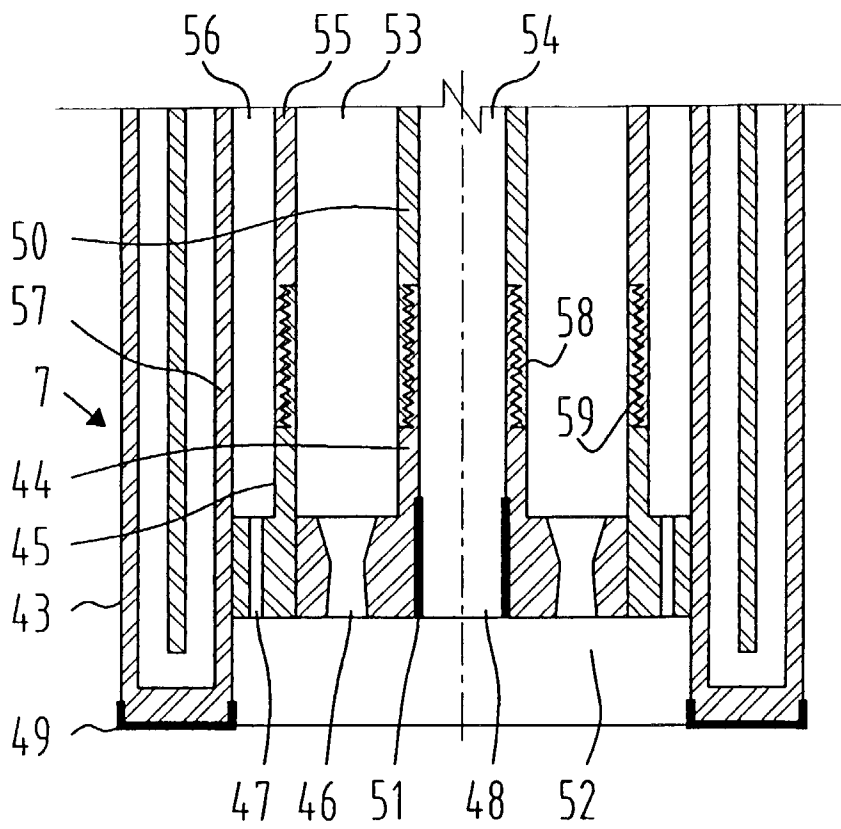


FIG. 3

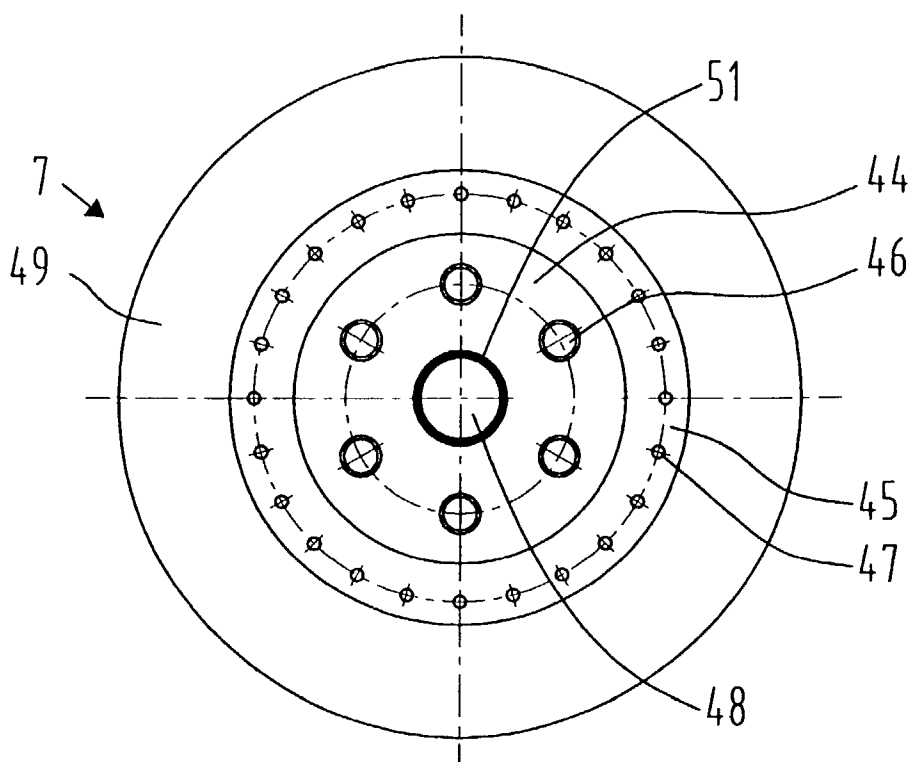


FIG. 4

TABLE I

## NON-ELECTRIC SCRAP MELTING PROCESSES

| PROCESS                                      | DATA & CHARACTERISTICS FOR 100% SCRAP CHARGE                                                                                                                 |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SHAFT FURNACES WITH COKE / COAL</b>       |                                                                                                                                                              |
| Cupola Furnace                               | 150 Kg / tonne coke; 650 m <sup>3</sup> / tonne hot wind; productivity up to 100 tonne / hour                                                                |
| Blast furnace<br>( SIFF Process )            | 222 Kg / tonne coke with 83% Fe in scrap and hot wind temperature of 1062 °C; productivity 60 tonne / hour                                                   |
| PRISM Process                                | 400 Kg / tonne coke; 80 Kg / tonne coal fines; 150 Kg / tonne plastic granules; rich gas generation; productivity 1.2 tonne / hour                           |
| <b>SHAFT FURNACES WITH NATURAL GAS / OIL</b> |                                                                                                                                                              |
| KYS Process                                  | 2.0 GJ / tonne of natural gas; 105 m <sup>3</sup> / tonne O <sub>2</sub> ; 105 kWh / tonne for super heating; productivity 24 tonne / hour                   |
| KVA Process                                  | 1.6 GJ / tonne natural gas (42 m <sup>3</sup> ); 76 m <sup>3</sup> / tonne O <sub>2</sub> ; 11.25 Kg / tonne Si ( in FeSi ); productivity 60 tonne / hour    |
| <b>CONVERTER PROCESSES</b>                   |                                                                                                                                                              |
| KS-Process                                   | 247 Kg/tonne of fine granulated brown coal coke; 280 m <sup>3</sup> /tonne O <sub>2</sub> ; 31 m <sup>3</sup> /tonne natural gas; productivity 68 tonne/hour |
| TULA Process                                 | 80 Kg/tonne piece coal; 25 m <sup>3</sup> /tonne natural gas<br>150 m <sup>3</sup> /tonne O <sub>2</sub> ; productivity 105 tonne/hour                       |
| Z-BOP-Process                                | 68 Kg/tonne piece coal; 125 m <sup>3</sup> /tonne O <sub>2</sub> ;<br>productivity 117 tonne/hour; yield < 80%                                               |
| C-FFOX-Process                               | 112 Kg/tonne coke; 30 Kg/tonne coal; 71 m <sup>3</sup> / tonne O <sub>2</sub>                                                                                |
| ASLUC-Process                                | 130 Kg coke/tonne; 130 m <sup>3</sup> /tonne O <sub>2</sub> (at 60% postcombustion)                                                                          |
| SMP-Process                                  | 195 Kg of coal fines/tonne; 160 m <sup>3</sup> /tonne O <sub>2</sub> ; productivity 140 tonne/hour                                                           |
| DAIDO-Process                                | 97 Kg/tonne carbon; 150 m <sup>3</sup> /tonne O <sub>2</sub> ; productivity 0.5 tonne/hour                                                                   |
| EOF-Process                                  | 95 Kg/tonne coal; 5 Kg/tonne oil; 125 m <sup>3</sup> /tonne O <sub>2</sub> ; prod'y: 25 tonne/hour                                                           |
| <b>ENERGY OPTIMIZING PROCESSES</b>           |                                                                                                                                                              |
| UNIMELT™-Cold Scrap                          | 10.5 Kg / tonne pulverized coal; 47 m <sup>3</sup> / tonne natural gas; 118 m <sup>3</sup> / tonne O <sub>2</sub> ; productivity 150 tonne/ hour             |
| UNIMELT™-Preheated Scrap                     | 18.5 Kg / tonne pulverized coal; 27 m <sup>3</sup> / tonne natural gas; 106 m <sup>3</sup> / tonne O <sub>2</sub> ; productivity 167 tonne/ hour             |
| COMBIMELT™-Cold Scrap                        | 65 Kg/ tonne pulverized coal; 13 m <sup>3</sup> / tonne natural gas; 128 m <sup>3</sup> / tonne O <sub>2</sub> ; productivity 150 tonne/ hour                |
| COMBIMELT™-Preheated Scrap                   | 52.5 Kg/ tonne pulverized coal; 5 m <sup>3</sup> / tonne natural gas; 106 m <sup>3</sup> / tonne O <sub>2</sub> ; productivity 167 tonne/ hour               |

FIG. 5

TABLE II

PROJECTED REPRESENTATIVE DATA AND PARAMETERS

Calculated Cost of Electricity and Off-Gas Generation for Melting and Superheating of 1 ton of Steel from Cold Scrap in Electric Arc Furnace<sup>1</sup> when Electricity is Generated with Fuels Combusted by air at Standard Power Station

1 ton = 2000 lbs

| Primary energy Fuel | Energy req'd to produce 1t of steel from cold steel scrap (kWh/t) | Primary energy efficiency (%) | Total Primary Energy req'd to produce 1t of steel from cold steel scrap (kWh/t) | Fuel unit Cost per unit (\$/unit) | Fuel heat content |           | Primary fuel req'd to produce 1t of steel from cold steel scrap (units) | Cost of Primary fuel req'd to produce 1t of steel from cold steel scrap (\$/ton) | Air required for total combustion of fuel (per unit of fuel) (ft³) | Cost of air for combustion (fan supplied) at \$0.2100004 (\$/1000 ft³) | Total cost with addition of combustion air (\$/t) | Exhaust gas composition |       |       |       |                   |      |       |
|---------------------|-------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------|-----------------------------------|-------------------|-----------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------|-------------------------|-------|-------|-------|-------------------|------|-------|
|                     |                                                                   |                               |                                                                                 |                                   | Btu/unit          | kWh/ unit |                                                                         |                                                                                  |                                                                    |                                                                        |                                                   | CO₂                     |       | CO²   |       | NO <sub>x</sub> ² | SO₂  |       |
|                     |                                                                   |                               |                                                                                 |                                   |                   |           |                                                                         |                                                                                  |                                                                    |                                                                        |                                                   | scf/t                   | lbs/t | scf/t | lbs/t | g/t               | acft | lbs/t |
| Natural gas         | 400                                                               | 32                            | 1250                                                                            | 1000 ft³ \$5.00                   | 1000,000          | 293       | 4.3                                                                     | \$21.33                                                                          | 40471                                                              | \$8.09                                                                 | \$29.42                                           | 4227                    | 486   | 25    | 2     | 476               | 0    | 0     |
| Pulverized coal⁴    | 400                                                               | 34                            | 1250                                                                            | 1 lb \$0.02                       | 10,000            | 2.9       | 426.5                                                                   | \$5.53                                                                           | 45511                                                              | \$9.10                                                                 | \$17.63                                           | 9440                    | 1084  | 57    | 4     | 667               | 58   | 11    |

<sup>1</sup> Conventional Electric Arc Furnace,

<sup>2</sup> CO/CO2 volumetric ratio (average): 0.006

<sup>3</sup> Based on Lakeview's (Mississauga, Ontario) Power Station Energy Production and Air Emissions report

<sup>4</sup> Lignite and subbituminous coal containing 1.3% sulfur

FIG. 6

TABLE III

PROJECTED REPRESENTATIVE DATA AND PARAMETERS

Calculated Cost of Thermal Energy and Off-Gas Generation for Melting and Superheating of 1 ton of Steel from Cold Scrap in Metallurgical Furnace<sup>1</sup> when Thermal Energy is Generated Directly in Furnace with Fuels Combusted by Oxygen

1 ton = 2000 lbs

| Primary energy Fuel       | Energy req'd to produce 1t of steel from cold steel scrap (kWh/t) | Primary energy efficiency (%) | Total Primary Energy req'd to produce 1t of steel from cold steel scrap (kWh/t) | Fuel unit Cost per unit (\$/unit) | Fuel heat content |           | Primary fuel req'd to produce 1t of steel from cold steel scrap (units) | Cost of Primary fuel req'd to produce 1t of steel from cold steel scrap (\$/ton) | Oxygen required for total combustion of fuel (per unit of fuel) (ft³) | Cost of oxygen for combustion at \$21/1000ft³ (\$/1000 ft³) | Total cost with addition of combustion oxygen (\$/t) | Exhaust gas composition (fuel combustion only) |       |       |       |     |       |       |  |
|---------------------------|-------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------|-----------------------------------|-------------------|-----------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------|------------------------------------------------|-------|-------|-------|-----|-------|-------|--|
|                           |                                                                   |                               |                                                                                 |                                   | Btu/unit          | kWh/ unit |                                                                         |                                                                                  |                                                                       |                                                             |                                                      | CO₂                                            |       | CO¹   |       | NOₓ | SO₂   |       |  |
|                           |                                                                   |                               |                                                                                 |                                   |                   |           |                                                                         |                                                                                  |                                                                       |                                                             |                                                      | scf/t                                          | lbs/t | scf/t | lbs/t | g/t | scf/t | lbs/t |  |
| 100% from Natural gas     | 400                                                               | 100                           | 400                                                                             | 1000 ft³ \$5.00                   | 1000,000          | 293       | 1.36                                                                    | \$6.82                                                                           | 2732                                                                  | \$5.46                                                      | \$12.29                                              | 1353                                           | 155   | 8     | 0.6   | 48  | 0     | 0     |  |
| 20% from Natural gas      | 80                                                                | 100                           | 80                                                                              | 1000 ft³ \$5.00                   | 1000,000          | 293       | 0.27                                                                    | \$1.36                                                                           | 546                                                                   | \$1.09                                                      | \$2.46                                               | 271                                            | 31    | 2     | 0.1   | 10  | 0     | 0     |  |
| 80% from Pulverized coal³ | 320                                                               | 100                           | 320                                                                             | 1 lb \$0.02                       | 10,000            | 2.9       | 109.2                                                                   | \$2.19                                                                           | 2462                                                                  | \$4.93                                                      | \$7.11                                               | 2425                                           | 279   | 14    | 1.1   | 53  | 15    | 3     |  |
| Total                     | 400                                                               | 100                           | 400                                                                             |                                   |                   |           |                                                                         | \$3.55                                                                           | 3008                                                                  | \$6.02                                                      | \$9.57                                               | 2696                                           | 310   | 16    | 1.2   | 63  | 15    | 3     |  |

<sup>1</sup> Metallurgical Furnace = Modified Electric Arc Furnace; Standard electric energy supplying components (Furnace Transformer, High Current Network, Cables, Electrode Arms, Graphite Electrodes) are replaced with UNILANCE™ (100% Natural Gas) or CGO-COMBILANCE™ (20% Natural Gas plus 80% Pulverized Coal) Units

<sup>2</sup> CO/CO2 volumetric ratio (average): 0.006

<sup>3</sup> Lignite and subbituminous coal containing 1.3% sulfur

FIG. 7

## MULTI-PURPOSE, MULTI-OXY-FUEL, POWER BURNER/INJECTOR/OXYGEN LANCE DEVICE

### BACKGROUND OF THE INVENTION

#### [0001] I. Field of the Invention

[0002] This invention relates to a multi-purpose, multi-oxy-fuel (natural gas; pulverized carbonaceous matter—hereinafter “coal”; heavy oil) High Temperature Power Burner/solid materials (coal; lime) Injector/supersonic Oxygen Lance shrouded with combustible gas umbrella, with versatile positioning ability Device, for metallurgical furnaces making steel from solid recycled and/or virgin ferrous charge, for delivering into the interior of a metallurgical furnace high temperature thermal energy for efficient and rapid melting of solid recycled or virgin ferrous charge, when in oxy-fuel burner mode and when burning mixture of natural gas/pulverized coal with gaseous oxygen; furthermore, and in particular more than one Device, in multi-oxy-fuel, when burning mixture Natural Gas/Pulverized Coal in High Temperature Burner mode, can be employed for providing modified Electric Arc Furnace (EAF) with thermal energy as its singular and only source and acting as a more efficient total replacement of thermal energy provided by the graphite electrodes and Electric Arc system of an Electric Arc Furnace; when in Oxygen Lance mode for delivering by natural gas shrouded strong, soft blow, bundled, not-splashing decarburizing stream of oxygen; when in Injector mode for delivering into or on the surface of the molten steel pulverized coal or adequately fragmented calcined lime.

#### [0003] II. Description of the Prior Art

[0004] Electric arc furnaces are world wide dominating the manufacture of regular quality steels from recycled steel scrap and other iron containing materials such as Direct reduced iron (DRI), Hot briquetted iron (HBI), hot or cold pig iron etc. The use of oxy-fuel burners to provide a source of additional auxiliary thermal energy into the electric arc furnace is becoming a standard, with the power of the augmenting oxy-fuel burners being rapidly and constantly increased. As a rule, the fuel for this burners is almost exclusively natural gas, with few exceptions using light (diesel) and heavy oils. The originally used high purity oxygen is now days replaced with less expensive PSA and VPSA oxygen with its purity is in the range of 92-95%. The typical Mini-mill size of PSA oxygen producing unit, primarily for melting, is currently in the range of 1,000 to 1,600 SCF ton<sup>-1</sup> of produced steel. Hence, natural gas and lower purity oxygen powered oxy-fuel burners are employed in electric arc furnaces to increase the total heat input to a low powered furnace; to heat up the cold spots, particularly in a high powered electric arc furnace so as to promote uniform melting; and to offset the effects of maximum demand control on electric energy supply.

[0005] From the view point of primary energy equivalents, steelmakers involved with steelmaking from recycled scrap could consider themselves very fortunate. The reason for it is, that each ton of steel scrap, initially produced from primary raw materials (iron ore, coal) contains—by conservative assessment—approximately 17 million Btu of primary energy. However, as recycled feed material, steel scrap is assigned energy value of zero. Therefore, steelmaking using primarily steel scrap as raw material is one of the most actual energy efficient and economical industrial recycling

processes. In that respect, Electric Arc Furnace steelmaking from recycled scrap has had and still has a supreme bona fide status. Moreover, from the economical and ecological view points, the steel as extremely versatile material, used in practically all known human activities, and because of its perpetual recyclability, steel is the most ecologically friendly material. Steel scrap is therefore very precious “green” material.

[0006] Be that as it may, Electric Arc Furnace steelmaking process is an pyrometallurgical process, which with sizeable air infiltration generates complex and harmful emissions through its inherited operating combustion characteristics. Furthermore, Electric Arc Furnaces using only electric arc as the only source of thermal energy, are with respect to the utilization of the primary energy, very inefficient.

[0007] Current state of the art of the conventional Electric Arc Furnace apparatus and operating practices generate substantial emissions in the form of dust and hot fumes. These contain large quantity of nitrogen oxides NO<sub>x</sub>, very small quantities of sulphur oxides SO<sub>x</sub>, carbon dioxide CO<sub>2</sub>, carbon monoxide CO, and also VOC's, Dioxins and Furans.

[0008] Carbon monoxide CO, resulting from incomplete oxidation of carbon is a poisonous gas. The NO<sub>x</sub> produces smog, which contributes to respiratory diseases. It is also believed, it supports depletion of ozone layer around our planet, causing increased occurrence of skin carcinoma. Carbon dioxide—CO<sub>2</sub> is targeted as the main reason for destruction of our planets ozone layer and therefore responsible for predicted warming up of the Earth's climate.

[0009] The obvious solution to the problem of excessive emissions, in our case the smoke and dust from Electric Arc Furnace steelmaking is to reduce the quantity of the toxic emissions by introducing into the production process additional equipment and apparatus for decontamination and purification of the emissions.

[0010] Such ambitious goals for reduction of excessive emissions, promoted by the environmentalist are in principle correct. However, compliance with such demands would result in large investment costs with consequent increase of the cost of produced steel. Currently, the conflict between ideals of environmentalists and industry in developed countries is growing rapidly. Furthermore, air pollution originating by the virtue from metallurgical processes of iron and steelmaking, and increased by energy inefficient processes may have very grave consequences which at present are even hard to foretell. Distress signals have already appeared of dangers that await mankind if urgent measures are not taken to protect the environment against pollution and energy inefficient processes.

[0011] With Worlds economic disproportions, the justifiable question of the steel industry is:

[0012] “How to reduce pollution and at the same time reduce cost of steel production?”

[0013] To attempt to answer above question, we must first consider the two main direct consequences of the continuous world wide development of the industry:

[0014] pollution of the environment in general and air pollution specifically. Waste smokes and gases formed by industrial processes have become a problem of vital importance;

[0015] overall prime energy inefficiency of currently operated processes and systems. Energy cost crisis which began not so long ago in North America is making existing situation even worse, threatening to spread world wide.

[0016] From the viewpoint of environment pollution reduction related to the steelmaking industry, of great concern is the fact that on our planet about 2 billion tons of coal and 1 billion tons of petroleum products are burnt and approximately 2 billion tons of metallic and non-metallic minerals are processed every year (source UN Statistic 1998). Since iron and steelmaking metallurgical processes are strongly involved in high emissions of air polluting toxic gases and as well as production of toxic wastes, it is only logical that they are also more and more in the spotlight of attention.

[0017] When considering energy utilization efficiency, noticeably aggravating is the fact, that more than 50% of the currently operating ferro-metallurgical industrial processes, consuming massive quantities of electric energy—of which at least a half is generated by burning large quantities of fossil fuel—are extremely inefficient in relation to the primary energy. In that respect, conventional Electric Arc Furnace steelmaking from cold scrap is exceptionally inefficient: Cumulative thermal efficiency of the thermal energy produced in an Electric Arc Furnace represents only 16-18% of the 100% of primary energy contained in the fossil fuel, burned in the steam producing boiler to propel the turbine and electricity generating electric alternator.

[0018] There are many other also vitally important questions related to the current conventional Electric Arc Furnaces and their steelmaking process systems. However, one of the questions which is outstanding above all the others is:

[0019] “Taking in consideration extremely low conversion efficiency of the electric energy brought into an Electric Arc Furnace, when the electric energy is generated from the primary energy fossil fuel via the classic way: steam boiler—steam turbine—electric alternator, is the electric energy, from the economic and ecological points of view the only and the best and optimally suitable to be the main source of thermal energy used for melting of cold recycled scrap and or virgin metallic charge?”

[0020] In principle, there are three answers to this question.

[0021] The first, partially positive answer to the above question—from the purely prime energy utilisation efficiency viewpoint is: The utilisation efficiency of the Electric Arc Furnace process with respect to the primary energy is inefficient and is not to be considered acceptable as continuing standard, nevertheless, it could be as a temporary measure substantially improved by using the sensible and chemical energy of the hot of gases for scrap preheating. This is already done, regretfully it is not yet exploited to its full potential.

[0022] The second answer, also on the positive side and with the respect to the pollution problems caused by current operating practices of the Electric Arc Furnaces steelmaking process is: Sealing of the inner space of the Electric Arc Furnace shell from the surrounding ambient in the most practically efficient way (slag door, roof against shell, elec-

trode ports et c.), will eliminate at least 50% of the sourcing of harmful gases and at the same time improve the energy utilization.

[0023] Ultimately, it must be clearly understood, that the above two partial answers could be taken into account only as short term, temporary solution.

[0024] The third answer, which is to be recognized as the only lasting solution, is:

[0025] Electric energy used for creating high heat source of thermal energy via electric arc is not the best or only form or type of energy to be used for melting recycled steel scrap and producing new steel. Electric energy used via electric arc for creating high temperature heat source for melting in Electric Arc Furnace is extremely inefficient with respect to the primary energy; this is valid especially when electricity is generated via burning of the coal in the boiler, producing the steam for the turbine. This fact has been recognized more than 20 years ago when the first attempts for replacing electric energy with an other type of energy took place. Nuclear electric energy generation slowed down the desirable direction of energy replacement.

[0026] Oeters and Steffen (Elektrostahl Erzeugung—Stahl & Eisen, 1997; pp.793-831) have in appropriate detail discussed replacement of electric energy with fossil fuel and oxygen powered processes. Table No.I. is based on their summarization of non-electric scrap melting processes with the addition of the Energy Optimizing Furnace. All listed melting processes are dedicated to melting 100% scrap charge. Some of them have incorporated, desirable and energy saving, integral or pre-charging scrap preheating. Several of the processes listed in the Table No. I. are involved in day by day operation and production of steel.

[0027] In spite of all efforts to replace electric energy used by the Electric Arc Furnaces in Mini-Mills for steelmaking from scrap or other iron containing materials, by other type of energy, Electric Arc Furnaces so far still dominate unchallenged in the area of steelmaking from recycled scrap.

[0028] In the past, the main reason for such extended use of Electric Arc Furnaces was primarily low cost of electric energy and relatively low installation capital cost, simple design and operation of the Electric Arc Furnace. Electric Arc Furnace steelmaking from scrap made also possible the formation of very efficient and profitable regional Mini-Mills. However, present day situation in availability and cost of electric energy has drastically changed, not ever to return back. In majority of developed countries, the electric energy is not available and with price deregulation it is too expensive to be used for profitable steelmaking. Another reason threatening continuation of Electric Arc Furnace steelmaking from scrap are already discussed ecological problems.

[0029] On the other hand, the main obstacle to the introduction of the more primary energy efficient high temperature sources for steelmaking from scrap is the fact, that all so far known steelmaking processes using primarily fossil fuel such as natural gas and oil as substitute, required a completely new or substantial and costly modification of the furnace design and reconstruction of the surrounding auxiliaries. That means, that so far known, more primary energy efficient metallurgical furnace design could not simply and directly replace the Electric Arc Furnace. Nevertheless, steelmakers recognized the significant improvement coming

forth even from the stationary fossil oxy-fuel burners installed in the shell-walls of the Electric Arc Furnace. The power input of so called “auxiliary” natural gas/oxygen burners is reaching in some cases over 50% of the electric arc power input. Be that as it may, the eventual advantages of oxy-fuel burners are lost by their stationary non-mobile type; the heat transfer efficiency drops of as soon as the scrap is melted in front of the burner. Further continuation of firing of the burner is extremely inefficient and wasteful (after being fired over 20% of the melting time the efficiency of the stationary burners usually drop from about 75-80% in the begin of the melting process, to about 20-30%).

**[0030]** Except the only satisfactory operating “Multi-purpose pyrometallurgical process enhancing Device” (U.S. Pat. No. 4,653,730 “Unilance”), very significant omission of any other type of augmenting burners available on the market is—in addition being almost exclusively of stationary design—that none of them—including “Unilance” is offering any burner design using the cheapest and most applicable source of the thermal energy available—coal. This is the actual situation, although there have been during last 20 years, “simple” but more or less successful burners using coal combusted by air; recently performed practical tests have shown insufficient temperature of coal-air flame.

**[0031]** An other problem which has not yet been solved to the satisfaction of the steelmakers, is the—as much as mechanized as possible—introduction-injection system and apparatus for carbonaceous (coal, coke, anthracite) and slag forming (CaO) materials into the steelmaking Electric Arc Furnace. It appears, that the main reason why none of the several available systems has not emerged as a leader is the fact that none of them has functioned properly at all of time. The systems using calorized, consumable pipes have one pipe for each additive material (C and CaO), each of these pipes being controlled separately by an remotely controlled manipulator. Since each of the consumable pipes moves independently, they are introduced into the vessel of the Electric Arc Furnace through its slag door opening. For that purpose, most of the time the slag door is wide open. It is however, very well known that open slag door means higher electric energy consumption and increased production of  $\text{NO}_x$ . Similar situation exist for water cooled pipe systems. Slag door is open all the time, because slag door opening is the only window in the vessel shell big enough to accommodate two water cooled pipes: one for granulated coal and the other for oxygen.

**[0032]** Another, functionally inadequate characteristics, common to almost all of the state of the art lance systems, is that most of them have coal and oxygen introduced through two independent pipes. This arrangement is not capable of mixing properly pulverized coal and oxygen before entering the slag-steel interface. From practical operation experience it is known, that this feature is critically important for optimal development and controlling of foamy slag, in particular its basicity and consistency. Finally, except the “Unilance”, none of the known stationary systems was or is capable introducing-injecting carbonaceous material and granulated lime through the same pipe, which is very desirable for foamy slag control.

**[0033]** Summarized, except “Unilance”, none of the known carbonaceous materials and/or lime introducing—injecting systems of any kind, with consumable pipes or

watercooled lance bodies are fully capable of developing and controlling of the optimum dept and consistency of the Foamy Slag, which is vitally important for successful and economical steelmaking from recycled steel scrap.

**[0034]** However, new energy and ecology reasons and conditions dictated that a totally different approach for function and operation of the lance tip—for an adequate multipurpose, multi-oxy-fuel metallurgical processes enhancing device—must be introduced in order to comply with the new, much more demanding operating conditions of economic steelmaking. These conditions resulted in substantial, fundamentally inventive changes of the tip of the existing “UNILANCE”.

**[0035]** Resulting from the invention, the new tip assembly, for the Multi-Purpose, Multi Oxy-Fuel Power Burner/Injector/Oxygen Lance Device, complying with the new economically improved steelmaking process, came to existence. As it will be documented further, the new invention commanded functional re-engineering and redesign of the tip of the “UNILANCE” to comply with the requirement and capability of burning simultaneously or independently natural gas and pulverized coal. The invention actually brought into the being a new metallurgical combination tool with almost non-imaginable benefits to steelmaking from recycled steel scrap and/or other ferrous charge materials.

**[0036]** Contents of Tables II. and III. are with all necessary, strictly authentical details, and using actual numbers demonstrating different cases of electricity generation.

**[0037]** Table II. is illustrating the most unfavourable case, when the electric energy for the Electric Arc Furnace employed for steelmaking from recycled scrap is being supplied with electricity generated by a Standard Thermal Power Plant (Boiler-Steam Turbine-Alternator et c.), combusting coal or natural gas with air. Due to losses of the electricity supplying system the cumulative efficiency of electric energy brought to the secondary terminals of the furnace transformer from the Thermal Power Plant is only  $\eta_{cum}=34\%$ . In other words, the Table II., is attesting beyond any reasonable doubt, that any Electric Arc Furnace using electricity generated at a Power Plant burning coal or natural gas is extremely inefficient with respect to primary energy contained in natural gas or coal.

**[0038]** That means, that for the electric energy, necessary for melting and superheating of one (1) ton of 2000 lbs of recycled steel scrap or other ferrous charge material, requiring actually 400 kWh at the secondary terminals of the furnace transformer by the conventional Electric Arc Furnace, a quantity of natural gas or coal containing energy (called “primary energy”) equal to 1,250 kWh must be combusted at the Thermal Power Plant!!!

**[0039]** In the case of the natural gas costing currently about \$5.00/1,000 SCF, and adding only cost for the combustion air blower the calculated cost for energies for melting and overheating of one (1) ton of steel scrap would be \$29.42, or \$0.073 (7.3 cents)/kWh.

**[0040]** In the case of using coal at the Thermal Power Plant for generation of electricity, and at the cost for the coal of \$40.0/ton the cost for melting and overheating of one (1) ton of recycled steel scrap would be \$17.63 or \$0.008 (0.8 cents)/kWh. However, cost of producing the electricity from

coal is increased by several additional charges depending on location and resulting in its higher a commercial price.

[0041] Unfortunately, the lower price of electricity generated by using the coal instead of natural gas, is many times overcome by the fact that combustion of the coal with air, produces about 2.2 times more  $\text{CO}_2$  and CO in addition to 1.4 times more of  $\text{NO}_x$  and about 38 scf/ton of  $\text{SO}_2$  (natural gas does not produce  $\text{SO}_2$ ).

[0042] Table III. is showing the avantgarde case of exploitation of primary energy contained in natural gas and properly prepared—pulverized coal. In this case both, natural gas and pulverized coal are combusted by oxygen in a special design multi-oxy-fuel High Temperature Burner/Lance which is an other object of this invention and which is involved directly in melting recycled steel scrap in the working space inside of the Furnace vessel. The Furnace is actually a modified conventional Electric Arc Furnace. The modification is simple and can be done in a very short period of time. In principle, the modification consists in removing from the Electric Arc Furnace the Standard Electric energy supplying components such as: Furnace Transformer, Secondary High Current Network, Secondary flexible Electric Cables, Electrode Arms including Graphite Electrodes. This components are replaced with the main object of this invention which is providing a multi-purpose, multi-oxy-fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, in curved or linear embodiment.

[0043] The exceptional improvement in utilization of primary energy of natural gas and pulverized coal originates from the fact, that both, natural gas and pulverized coal are brought to the Furnace without losing any of their primary energy and therefore the cumulative efficiency of natural gas and pulverized coal when brought to the Furnace is  $\eta_{\text{cum}} = 100\%$ .

[0044] That means again, that thermal energy, necessary for melting and super heating of one (1) ton or 2000 lbs of steel from recycled steel scrap or other ferrous charge material requiring 400 kWh at the entrance into the Furnace is the only energy needed.

[0045] However, because of drastic reduction of quantities of primary energy of natural gas and pulverized coal, there is also drastic reduction in quantities of exhaust gases, as it could be seen when comparing Tables II. and III. Total cost of the pulverized coal version for direct combustion in the furnace (table III.) is only \$7.11 compared to the \$9.30 (Table II.) for the case when coal is used for primary energy.

[0046] Total cost of natural gas calculated version for quantity of nat. gas as prime energy combusted for generation of electricity is \$29.42/ton. When natural gas is brought to the modified Furnace and combusted via oxygen directly in the Furnace vessel, the cost drops to \$12.29/ton or 41.77%. Even more important is that the volume of  $\text{CO}_2$  and CO drop down from 4227 SCF/t to 1353 SCF/ton or only 32.00% of the original value.

#### OBJECTS OF THE INVENTION

[0047] This invention has been developed to obviate previously discussed problems of the prior art. Accordingly, the invention has as its object of greatest importance to provide a Mechanical System Apparatus Device comprising a complete assembly of the multi-oxy-fuel High Temperature

Power Burner/Injector/Oxygen Lance including all ancillaries and which is fully capable to replace Electric Arc Furnace electric energy supplying system and components these being the furnace transformer, secondary high current network, flexible water cooled high current cables, electrode arms including graphite electrodes and thus creating in one embodiment a new entity to be known as Metallurgical Furnace having the same or better functioning, production and operation characteristic than the original Electric Arc Furnace. The inventive character of the Metallurgical Furnace, originating and created by and from the objects of this invention, is a subject of another Patent Application.

[0048] It is another object of this invention to provide a Metallurgical Furnace with a Mechanical System Apparatus device comprising a multi-oxy-fuel High Temperature Power Burner/Injector/Oxygen Lance as replacement of the electric energy supplying system and components and at the same time drastically improve efficiency of utilization of the primary energy contained in fossil fuels, and—for example—by being capable of burning a mixture of pulverized coal (approx. 80%) and natural gas (approx. 20%) with oxidant being VPSA oxygen, which will have approximately three (3) times better utilization of energy contained in natural gas or pulverized coal and approximately three (3) times less generation of harmful gases in particular  $\text{CO}_2$  and CO.

[0049] It is another object of this invention to provide a Mechanical System Apparatus Device which can be, in one of the multi-purpose modes, employed as High Temperature Power Burner, of the design as per this invention, and combusting by Oxygen a mixture of Natural Gas/Pulverized Coal for efficient and rapid melting of solid ferrous charge in a metallurgical furnace (Open Hearth; Tandem Furnace; BOF; EAF) for steelmaking from recycled steel scrap and other ferrous charge, as its augmenting or only source of thermal energy.

[0050] It is another object of this invention to provide, on acoustics principle based and operating, a control system for accurate positioning of the by fluid cooled discharge Tip of the arcuate and/or linear Device in optimal position of predetermined distance from the solid or liquid charge in the hearth of the vessel of the Metallurgical Furnace, powered by arcuate or linear Devices.

[0051] It is also another object of this invention to provide a multi-purpose, multi-oxy-fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, which can be employed in an Injector mode for injecting via suitable gaseous carrying medium adequate size granulated solid materials such as coal or lime into the metallurgical furnace vessel inner space, in particular into the molten steel contained in the hearth of the vessel, for its carburizing, or into the molten steel—slag interface for developing and controlling of optimal volume and consistency of the foamy slag.

[0052] It is also another object of this invention to provide the important feature of coaxial pre-mixing of pulverized coal or lime with the oxygen prior to introduction—injection of the mixture into the slag—steel interface. This feature being critically important for optimal development and lasting control of foamy slag, in particular its dept, basicity and consistency.

[0053] It is also another object of this invention to provide a multi-purpose, multi-oxy-fuel Power Burner/Injector/Oxy-

gen Lance, Mechanical System Apparatus Device with its discharging end Tip, which is because of its extra ordinary multi-purpose functioning of an un-orthodox composite design subassembly, this subassembly encompassing three sub-sub-assemblies, first sub-sub-assembly being the outside protective, fluid cooled Tip Cover, made from high thermally conductive material and permanently attached to the Devices arcuate or linear fluid cooled body, and in the critical zone covered with high temperature withstanding material coating, the second sub-sub-assembly being of easy removable-replaceable insert, made of high thermal conductive material, is a natural gas directing functional part of the Composite Nozzle System, the third sub-sub-assembly is also of easy removable-replaceable design and it is the oxygen and solid material directing portion of the Composite Nozzle System and as such it consists of the two parts, from high thermal conductive material made Oxygen Directing Part via at least two De Larval nozzles and solid materials, with coaxial feature, through the oxygen directing part installed high abrasion material tubular insert, for injecting of pulverized coal and other solid materials.

**[0054]** It is also an object of this invention to provide a multi-purpose, multi-oxy-fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, which can be employed as a Supersonic Oxygen Lance, with its bundled streams enveloped with the natural gas peripheral coaxial shroud for expedient and efficient decarburization of the hot metal contained in the hearth of the furnace vessel with reduced metal oxidation, and as an Subsonic Oxygen Lance also with its streams enveloped with the natural gas coaxial shroud for accurate control of development and optimal volume and consistency of the foamy slag.

**[0055]** It is also an object of this invention to provide a multi-purpose, multi-oxy-fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, which can be employed as a Supersonic Oxygen Lance, with its bundled streams of oxygen enveloped with the natural gas peripheral and coaxial shroud for expedient decarburization of the molten metal contained in the hearth of the furnace vessel and with the Device Tip submerged into foamy slag and therefore improving metallurgical process efficiency and reducing the operating noise of the Device.

**[0056]** It is also an object of this invention to provide mechanical system apparatus Device which in one specific embodiment has strictly linear form of the round, by fluid cooled composite main body of the Device, the said linear body being attached to one end of the horizontal arm, supported at the other end by a vertical mast type, extendable repositioning mechanism, allowing the: situated strictly linear composite body of the Device to be inserted or withdrawn from the interior of the furnace through a small opening in the furnace roof originally intended for graphite electrodes of the electrical supply system.

**[0057]** It is also an object of this invention to provide mechanical system apparatus Device which in one specific embodiment has an arcuate form of the round, by fluid cooled composite main body of the Device, the said arcuate composite body being attached to a pivoted combination type arm, allowing the arcuate form of the round composite main body to be inserted and withdrawn from the interior of the furnace through a small opening in the furnace shell wall.

**[0058]** It is yet another object of this invention to provide a method of decarburizing or refining of molten metal contained in the hearth of the Metallurgical furnace.

**[0059]** It is yet another object of this invention to provide combustion regulating system, to control combustion of the fuels in the hearth of the Metallurgical Furnace and by that control the quantity of CO (carbon monoxide) in the hot exhaust gases, which are to be used for charge preheating purposes.

**[0060]** Other objects and features of the present invention will become apparent from the following Disclosure of the Invention and summary of the preferred embodiments of the invention and detailed description considered in conjunction with the accompanying drawings. It is to be understood, that the drawings are introduced solely for the purpose of illustration and not as definition of the limits of the invention, for which references should be made to the appended claims.

#### DISCLOSURE OF THE INVENTION

**[0061]** The cardinal and prime purpose and object of this invention is to provide System and Mechanical Apparatus Device encompassing a multi-purpose, multi-oxy-fuel High Temperature Power Burner/Injector/Oxygen Lance which have the capability to replace primary energy inefficient and ecologically imperfect electric energy which is via electric arc converted into thermal energy for melting of solid metallic charge introduced into the furnace vessel hearth. The capability of the Device as per objects of invention fully complies with the task of energy replacement, by making it possible to involve the replacement energy into the physical/chemical process of generating high temperature source of thermal energy directly in the hearth of the Furnace vessel, by using more readily available fossil fuels such as natural gas, pulverized coal or preferably mixture of both of these fuels combusted by oxygen.

**[0062]** Therefore, for the reason of replacement of inefficient electric energy as a fuel, with more appropriate fuels, the objects of the Invention provide a new and improved multi-purpose, multi-oxy-fuel High Temperature Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device, capable of providing in multi-oxy-fuel High Temperature Power Burner mode, which by using oxygen for burning the mixture of pulverized coal and natural gas, and thus creating a high temperature burner flame, is capable of rapid and efficient melting of cold or warm recycled steel scrap or other ferrous charge, with the main purpose of the Device being is to replace, in relation to the primary energy utilization efficiency, the inefficient Electric Arc Furnace electric energy supply system.

**[0063]** The functional components of the inefficient electric energy supply system to be removed from the original Electric Arc Furnace are: Furnace transformer—including HV auxiliaries, secondary high current network, flexible water cooled high electric current cables, electrode arms including graphite electrodes; the removed components are replaced with adequate number of arcuate and linear embodiments of the Device, with all ancillaries. The described replacement-exchange of electric system components with components of the Devices, (Mechanical supporting and repositioning apparatus systems for Devices, valve trains, Hoppers for pulverized coal, dosing systems for pulverized coal, piping and hoses for technological materials

and fluidic cooling, including PLC controls et c.) is converting in the most economical way, with minimum costs, the primary energy inefficient and ecologically delinquent and offensive Electric Arc Furnace for steelmaking from recycled cold or preheated scrap and/or other ferrous charge into a Metallurgical Furnace, having substantially improved primary energy efficiency utilization and radical ecological advances and gains, while performing the same, but ameliorated function of steelmaking.

**[0064]** With the present state of environmental pollution in general and air pollution in particular:

**[0065]** A project is suggesting and documenting, that replacing one type of fuel or energy with another type of fuel or energy of a certain production process will result in lowering of overall emissions of harmful gases from the production process and at the same time it will improve energy utilisation efficiency with regards to the primary energy content. It is obvious that such project is to be strongly recommended; the only obstacle which stop it, would be excessive cost because of substantial production equipment replacement.

**[0066]** A project is documenting, that replacing one type of fuel or energy with another type of fuel or energy of a certain production process, with benefits as above and it is possible to be done with minimal change or modification of the existing production equipment and with time for return of cost involved—due to reduction of production costs—is six (6) to eight (8) month. This project is more than desirable and must be realized.

**[0067]** A third project is suggesting and documenting, that replacing one type of fuel or energy with another type of fuel or energy of a certain production process and by adding complimentary equipment to the already made minimal change and modification of the original production equipment with all benefits of the first two projects, but with the following end results:

**[0068]** reduction of overall energy consumption by more than 30%;

**[0069]** reduction of CO<sub>2</sub> and CO emissions by minimum of 35-40%;

**[0070]** reduction of production costs by minimum of 25-30%;

**[0071]** return on investment, including cost for additional equipment five (5) to seven (7) month.

**[0072]** It is more than obvious, that project #3 will be embraced and procured as soon as possible by any Management.

**[0073]** Above triple example projects are more than sufficient illustration how beneficial the realization of change over from Electric Arc Furnace to Metallurgical Furnace is any measurable aspect.

**[0074]** Summarized, the Multi-Purpose, Multi-Ox-Fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device is at the present time of great importance,

**[0075]** because of its ability to improve the steelmaking from recycled cold scrap in so substantially and in so many ways. Existing Electric Arc Furnace, modified to a Metallurgical Furnace fully exploiting all benefits offered by the Device in arcuate and linear embodiments will actually experience most desirable renaissance. The modification of the existing original Electric Arc Furnace using the Device with implementation of all objects of the invention and multi-functioning of the Device will result in multitude of major and minor functional process system improved operating characteristics and parameters encompassed in the System Mechanical Apparatus assembly as per specific furnace requirements, assuring the:

**[0076]** Capability of the Mechanical System Apparatus of the Device to be added to almost all existing Electric Arc Furnaces, in existing Melt Shops;

**[0077]** Capability of the Mechanical System Apparatus of the Device, encompassing a Multi-Purpose, Multi-Ox-Fuel Power Burner/Injector/Oxygen Lance, to replace as an unit the primary energy inefficient electric energy supply system of the existing Electric Arc Furnace (Furnace transformer, including HV auxiliaries, secondary high current network, flexible water cooled high electric current cables, electrode arms including graphite electrodes) and with minimal changes and modifications to the existing Electric Arc Furnace, with components of the Device (Mechanical supporting and repositioning apparatus systems—arcuate and linear—Arcuate and Linear composite bodies of the Devices, valve trains, hoppers for pulverized coal and granulated lime, dosing systems for pulverized coal and granulated lime, piping and hoses for technological materials and fluid cooling, including PLC controls etc.).

**[0078]** Capability of the Metallurgical Furnace (modified original Electric Arc Furnace) newly equipped with components of several units—arcuate and linear—of the Device, to out-perform in each and all aspects of operating characteristics and basic parameters, the original Electric Arc Furnace;

**[0079]** Capability to supply most efficiently all necessary thermal energy for melting and superheating of cold recycled steel scrap or other ferrous charge, when several Devices, linear or arcuate, are operating in High Temperature Power Burner mode, with pulverized coal and natural gas mixture combusted by oxygen;

**[0080]** Capability, when in the C-Injector mode, and when using inert gaseous high velocity propelling—carrying media for pipe transportation of carbonaceous materials to efficiently inject, the exact, pre-programmed quantities of properly granulated carbonaceous materials as per requirements of the metallurgical process into the molten steel for its carburizing;

**[0081]** Capability, when in the C-Injector mode, and when using inert gaseous, medium velocity propelling—carrying media for pipe transportation of carbonaceous materials to efficiently inject into the steel-slag interface, the exact, pre-programmed quantities of pulverized carbonaceous materials

strictly as per requirements of the metallurgical process, for development and control of proper depth, basicity and consistency of the foamy slag;

[0082] Capability, when in the Injector-Combi mode and when using inert gaseous, medium velocity propelling-carrying media for pipe transportation of carbonaceous materials and when using subsonic oxygen and natural gas to efficiently inject into the steel-slag interface the exact, pre-programmed quantities of pulverized carbonaceous materials by oxygen supported and by natural gas shrouded rapid development of CO for foamy slag control;

[0083] Capability, when in the CaO-Injector mode, and when using inert gaseous, medium velocity propelling-carrying media for pipe transportation of lime materials to efficiently inject into the steel-slag interface, the exact, pre-programmed quantities of granulated lime materials strictly as per requirements of the metallurgical process, for development and control of proper dept, basicity and consistency of the foamy slag;

[0084] Capability, when in the C-Injector or CaO-Injector mode to blow holding gaseous purging media through the oxygen and natural gas passages;

[0085] Capability, when in the Oxygen Lance mode to blow holding gaseous purging media through the carbonaceous materials passage;

[0086] Capability to substitute with one only multi-purpose, multi function Device several auxiliary apparatus and mechanisms, previously required for functioning of an Electric Arc Furnace, in particular graphite electrodes for converting electric energy into thermal energy in extremely high temperature furnace interior, water cooled or non-cooled lances and pipes for injecting of carbonaceous materials into the furnace, water cooled or non-cooled lances and pipes for injecting of decarburizing or foamy slag controlling oxygen;

[0087] Capability to eliminate need for stationary auxiliary ox-fuel burners, which have become a standardized addition to Electric Arc Furnaces, in some cases reaching equal power input as from electric arcs, because although less in numbers and smaller in size, the multi-ox-fuel High Temperature Power Burners of the Device provide all necessary power input;

[0088] Capability to eliminate complicated manipulators for all non-cooled and water cooled pipes and lances required by the former Electric Arc Furnace and replace them with simple, rugged and reliable repositioning mechanism of linear and arcuate bodies of the Devices;

[0089] Capability to improve sealing of the furnace interior from the surrounding atmosphere, because Devices are replacing several previously independent apparatus and mechanisms, and therefore there are not so many openings to be sealed;

[0090] Capability to reduce oxidation of the ferrous charge during melting period, by being able to con-

trol composition of the combustion gases of the Multi-Ox-Fuel High Temperature Power Burners of the Devices;

[0091] Capability to provide improved heat transfer from the torches of the mobile Multi-Ox-Fuel High Temperature Power Burners of the Devices in comparison with the heat transfer from the torches of the stationary ox-fuel burners;

[0092] In comparison with original, not modified Electric Arc Furnace used to produce steel from recycled steel scrap or other ferrous charge, the above listed capabilities of the System and Mechanical Apparatus Device encompassing a Multi-Purpose, Multi-Ox-Fuel, High Temperature Power Burner/Injector/Oxygen Lance in accordance with the objects of the invention are credited for substantial improvements of further listed technical parameter and economic factors:

[0093] Complete elimination of primary energy inefficient electric energy;

[0094] Complete elimination of graphite electrodes;

[0095] Complete elimination of electric energy supplying system;

[0096] Reduction of primary energy by utilizing pulverized coal/natural gas burners combusted by oxygen by 65%;

[0097] Reduction of CO<sub>2</sub> by 65%;

[0098] Reduction of CO by 35%;

[0099] Reduction of the Tap-to-Tap time by 10-15%;

[0100] Reduction of VOC, dioxins and furans to below currently permitted limits;

[0101] Reduced maintenance requirements, because of simplicity and ruggedness of the entire apparatus mechanism;

[0102] Reduction of the noise pollution to 85 db;

[0103] Reduction of converting and operating costs by approx. \$20.0;

[0104] Overall improved safety and working conditions;

[0105] Additional details of the invention and all of its advantages will be apparent and will come forward from the detailed description with the reference to the drawings and tables included.

#### BRIEF DESCRIPTION OF THE DRAWINGS AND TABLES

[0106] For the purpose that the invention may be readily understood, applicable preferred embodiments of the invention will be described by way of example, with reference to the accompanying drawings wherein, with the numbers in the drawings are the same for the common components:

[0107] FIG. 1 is a schematic side view of one of the possible embodiments of the invention, the arcuate composite body of the Device in conjunction with a metallurgical furnace;

[0108] FIG. 2 is a schematic side view of another possible embodiments of the invention, the linear composite body of the Device in conjunction with another type of top blown metallurgical furnaces such as OH, Tandem Furnace, BOF and preferably modified Electric Arc Furnace;

[0109] FIG. 3 is a cross sectional view of one embodiment of the tip section of the composite body of the Device;

[0110] FIG. 4 is a coaxial front view of the tip of the composite body of the Device;

[0111] FIG. 5 Table I. NON-ELECTRIC SCRAP MELTING PROCESSES. The table is listing the comparable parameters of major known non-electric scrap melting process;

[0112] FIG. 6 Table II. CALCULATED COST OF ELECTRICITY AND OFF-GAS GENERATION AT . . . STANDARD THERMAL POWER STATION. The Table is depicting inefficiency of electric energy when used for melting and superheating of a charge in an conventional Electric Arc Furnace;

[0113] FIG. 7 Table III. CALCULATED COST OF THERMAL ENERGY AND OFF-GAS GENERATION . . . WHEN THERMAL ENERGY IS GENERATED DIRECTLY IN FURNACE WITH FUELS COMBUSTED WITH OXYGEN. The Table is depicting drastic improvement of the primary energy utilization efficiency when fuel combusted with oxygen directly in the hearth of the furnace vessel.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0114] The detailed description of the invention is demonstrating and proving that its multi-purpose, multi-function and multi ox-fuel novel features of the Device are facilitating enactment of:

[0115] sub- or super-sonic bundled gas flow of oxygen combusting stoichiometrically the shrouding gaseous fuel envelope for controlled, high heat producing flame torch of purposefully controlled dept of penetration, functioning as highly efficient source of highest temperature of thermal energy from gaseous fuel exploited for high temperature preheating of solid metallic bodies, melting of the said solid metallic bodies and finally superheating of the pool of molten metal forthcoming from the preceding melting of the said metallic bodies;

[0116] sub- or super-sonic bundled gas flow of oxygen combusting stoichiometrically the mixture of centrally injected pulverized coal and shrouding gaseous fuel envelope for controlled, adequately high heat producing flame torch of purposefully controlled dept of penetration, functioning as highly efficient source of adequately high temperature of thermal energy from the mixture of pulverized coal and gaseous fuel exploited economically for adequately high temperature preheating of solid metallic bodies, melting of the said metallic bodies and finally superheating of the pool of molten metal forthcoming from the preceding melting of the solid metallic bodies;

[0117] subsonic, high density, high velocity injection, with purposefully controlled dept of penetration of carbonaceous or calcium (dolomitic lime) materials or their mixtures of proper granulation, with deeper penetration of carbonaceous materials for carburization of molten metal or shallower penetration of carbonaceous or calcium (dolomitic lime) materials into the molten metal—slag interface, for most efficient foamy slag creation and controlling of the proper dept of the created foamy slag;

[0118] sub- or super-sonic bundled gas flow of oxygen shrouded with reduced quantity combustion of the gaseous fuel envelope for controlled, deep penetrating action of the oxygen stream, functioning as highly efficient decarburizing feature of the Device;

[0119] The liquid cooled composite arcuate body 1. of one of the preferred embodiments of the Multi-Purpose, Multi-Ox-Fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device 2. is shown in FIG. 1., in conjunction with a Metallurgical Furnace vessel 5. with its shell 4., lined with refractory 3. and containing molten steel 6.; as per requirements of the Optimal Steelmaking Process, there could be more than one Mechanical System Apparatus device 2. per Metallurgical Furnace Vessel 5. The composite arcuate body 1. is having at one end the special tip assembly 7., while at the other end it is equipped with the manifold 8. with special subplate 9. serving as quick connecting transition between special subplate 9. of the composite arcuate body 1. and matching subplate 10., permanently connected to the lever arm 11. The subplate 10. functions also as battery limit terminal of flexible hoses supplying the liquid cooled composite arcuate body 1. with cooling medium, preferably cooling water—hoses 12. and 13., natural gas hose 14. pulverized coal hose 15. and oxygen hose 16. Lever arm 11. is connected to the main supporting base 16. via pivot 17. The position of the lever arm 11. is controlled by the hydraulic cylinder 19. Extension and contraction of the cylinder 19. causes that the composite arcuate body 1. follows a predetermined arcuate path while being inserted or withdrawn from the shell 4. Of the furnace vessel 5. through a relatively small opening 20.

[0120] With reference to FIG. 2., it illustrates, as per the object of invention, an other, generally linear embodiment of the liquid cooled composite body 21. of the Multi-Purpose, Multi-Ox-Fuel Power Burner/Injector/Oxygen Lance, Mechanical System Apparatus Device 22., partially inserted into the furnace working space via small and sealed opening 23. in the liquid cooled metallic roof delta 24. For safe and accurate holding of the generally linear liquid cooled composite body 21. during operation, the horizontal light weight arm 29. is equipped with holding base plate 35. for holding of the composite body 21. and for functional conversion of the permanently vertical only portion of the generally linear liquid cooled composite body 21. into vertically oriented manifold 26. terminated with special subplate 27. which also serves as a bolted quick connecting transition between special subplate 27. of the composite body 21. and matching subplate 28. of the horizontal, light weight supporting arm 29. At its other end the light weight horizontal supporting arm 29. is attached via a sliding bolted connection 39. to the top end of the vertically oriented, by a hydraulic cylinder 60. actuated Mast-type repositioning mechanism 30. The Mast-type repositioning mechanism 30. regulates the dis-

tance of the special tip 7. of the generally linear liquid cooled composite body 21., against the solid or liquid charge 6. so that multi-fuel oxygen torch flame 38. is always in proper and optimal position for maximum heat transfer from the torch flame 38. The control of the Mast-type repositioning mechanism 30. originates from the acoustic sensor 37. attached to the sound sensitive portion of the generally linear liquid cooled composite body 21. and which permanently monitors sound of the multi-fuel oxygen torch flame 38., and transferring each and all changes in the torch flame combustion procedure via PLC 39. to the Mast-type repositioning mechanism for corrective moves, if necessary. The liquid cooling media, preferably treated cooling water is brought to the light weight horizontal arm 29. is brought and removed via flexible hoses 31. and 32. at the rear end of the light weight arm 29. Flexible hoses 33. and 34 serve for supply of natural gas and oxygen. Pulverized coal is supplied via flexible hose 36. to the solid pipe 40. positioned externally on the top of the light weight horizontal arm 29. and ending with a special abrasion resisting elbow 41. connected to the internal pipe 42. located coaxially in the centre of the generally linear, liquid cooled composite body 21.

[0121] FIG. 3. is showing the detail of the cross sectional view of one of the embodiment of the special tip assembly 7. of the liquid cooled, arcuate 1. or generally linear 21. embodiments of the liquid cooled composite bodies 1. or 21. of the Device 2.

[0122] The purpose of the special, liquid cooled tip assembly 7. shown in FIG. 3. as per pertinent object of invention and consisting of several independent and highly functional parts such as liquid cooled housing 43. made of highly thermally conductive material and for its protection against abuse furnished with low thermally conductive high strength material layer 49. Another independent part is the coaxially arranged and highly functional nozzle 44., made of highly thermally conductive material and protected against excessive abrasion via high abrasion resistant material insert 51., is interconnected, in protective recessed position in the well 52. of the housing 43., with the conduit 50. via mutually threaded ends 58., of pulverized coal supplying conduit 50. and nozzle 44. The opening 48., connected to the passage 54. of the conduit 50 of the composite arcuate 1., or generally linear 21., liquid cooled composite bodies of the Device 2. serves for introduction of carbonaceous materials and/or slag creating additions such as calcined lime, exploiting for that purpose carrying gaseous medium such as air, argon, nitrogen or another gas. Further function of the nozzle 44. is to direct oxygen through one or more converging/diverging opening/openings 46. which is/are connected to the source of pressurized oxygen supply passage 53.

[0123] Another independent and highly functional part of the special, liquid cooled tip assembly 7. is the intermediate nozzle 45., positioned coaxially between the body of the main nozzle 44. and inner wall 57. of the liquid cooled housing 43. Function of the independent intermediate nozzle 45. is to direct the gaseous fuel, preferably natural gas from the passage 56., via straight, tubular nozzle openings 47. into desired coaxial, umbrella type shrouding contact with oxygen emanating from the converging/diverging openings 46. of the nozzle 44. at supersonic speeds and together to interact coaxially with the stream of pulverized coal dis-

charged at subsonic or supersonic speed from opening 48. when the Device 2. is in the Multi-Ox-Fuel Power Burner mode.

[0124] Independent design character of the two main components of the liquid cooled special tip assembly 7. in particular the oxygen and pulverized coal administering main nozzle 44. and preferably natural gas administering intermediate nozzle 45. is of paramount importance, since they are exposed to the high operational wear by abrasion.

[0125] The first independent, threaded screw-on design character and thread 58. creates a temporary but safe and sound connection of the body of the main nozzle 44. and pulverized coal or calcined lime supplying conduit 50.; and the second independent, threaded screw-on design character and thread 59., creating an other temporary but safe and sound connection of the intermediate nozzle 45. and tubular member 55., forming toroidal conduit 56., for delivering natural gas to the nozzle openings 47. The threaded connections 58. and 59., are extremely important, because they are making possible and allowing easy replacement of these two parts—main nozzle body 44. and intermediate nozzle body 45.—when worn out, without necessity of cutting off the entire special tip assembly 7. of the Device 2. This unique feature of the special liquid cooled tip assembly 7. is drastically reducing maintenance of the entire apparatus.

[0126] FIG. 4. is showing the front head view of the special tip assembly 7. with its outer housing permanently attached to the several layers of pipe of the liquid cooled composite arcuate body 1. in one of the preferred embodiments and in the other preferred embodiment case, to the linear liquid cooled composite body 21. of the Device 2., as per FIG. 1. and FIG. 2. The front head view of the special tip assembly 7. is clearly showing functionally compulsory coaxial and symetrized arrangement of pulverized coal administering opening 48. of the main nozzle 44. with oxygen jets openings 46. and the intermediate nozzle 45. with openings 47. for shrouding and flame bundling natural gas.

[0127] TABLE I. of the FIG. 5. is introduced as a comparative self-explanatory proof of the improvements achieved with the present invention, in comparison with all other known processes, with special attention to be drawn to the consumption of fossil fuels—solid and/or gaseous as well as quantity of oxygen required to produce 1 tonne of liquid steel. The four processes, using the objects of present invention, are introduced as ENERGY OPTIMIZING PROCESSES.

[0128] TABLE II., of the FIG. 6. and TABLE III., of the FIG. 7. are also introduced as comparative self-explanatory proof of the improvements to be achieved with the objects of the present invention, especially when considering energy losses and cost of electricity when it is produced via standard Thermal Power Plant.

[0129] TABLE II. of the FIG. 6. is providing detailed information concerning "CALCULATED COST OF ELECTRICITY AND OFF GAS GENERATION . . . WHEN ELECTRICITY IS GENERATED WITH FUELS COMBUSTED BY AIR AT STANDARD THERMAL POWER STATION".

[0130] TABLE III. of the FIG. 7 is providing detailed information concerning "CALCULATED COST OF THER-

**MAL ENERGY AND OFF-GAS GENERATION . . . WHEN THERMAL ENERGY IS GENERATED DIRECTLY IN FURNACE WITH THE FUELS COMBUSTED BY OXYGEN”.**

[0131] While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art, that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system and method of operating a steelmaking metallurgical furnace for melting solid metallic charge and super heating already molten metallic charge, by efficiently combusting with oxygen a mixture of—or each separately—natural gas, pulverized coal or heavy oil, decarburizing of molten metallic charge by soft blow supersonic velocity of the oxygen rich gas via one or more converging/diverging nozzles coaxially shrouded with combustible gas via coaxially to converging/diverging oxygen nozzles arranged soft blow supersonic or subsonic velocity nozzles, and also injecting solid carbonaceous materials and other metallurgical additives via gaseous transporting medium:

- (I) providing a metallurgical furnace having a furnace shell wall a furnace refractory bottom and a furnace roof, with a metallurgical charge housed therein,
- (II) providing a multi-purpose, multi-ox-fuel apparatus combination of power burner/oxygen lance/solid materials injector device comprising:

In one preferred embodiments, a liquid cooled, arcuate composite body, having an inlet end and an outlet end;

a rotating supporting arm member, said arcuate composite body being supported by the said arm member adjacent to the said inlet end;

a base frame, said supporting arm member being connected to the said base frame via rotating pivot arrangement;

a hydraulic cylinder connected between the said rotating supporting arm member and said base frame, construing means for rotation of the said supporting arm member with supported arcuate composite body around rotating pivotal arrangement, relative to the said base frame in an arcuate path between a lowered and raised position of the supporting arm member;

said liquid cooled, arcuate composite body having therein, coaxially to the arcuate centre line arranged several passages created by pipes of appropriate diameter and wall thickness for conveying from said inlet end to the said outlet end with special tip assembly of the composite arcuate body pulverized coal, natural gas, oxygen, cooling liquid inn passage and cooling liquid out passages;

said generally most central passage of the composite arcuate body for flow and conveying of pulverized carbonaceous material and/or calcined dolomitic lime via flow of pressurized gaseous media, said

generally most central passage extending from said inlet end of the composite arcuate body to the said outlet end in the main nozzle of the special tip assembly;

said generally second passage from the centre of the composite arcuate body for sole flow of combustion oxygen, said generally second passage from the centre extending from the said oxygen inlet end of the composite arcuate body to the said outlet end into the entrance of the converging side of the converging/diverging nozzles of the main nozzle body of the special tip assembly;

said generally third passage from the centre of the composite arcuate body for sole flow of combustible gas, preferably natural gas, said generally third passage from the centre extending from the said natural gas inlet end of the composite arcuate body to the said outlet end into the entrance of the more than one tubular nozzles of the intermediate nozzle of the special tip assembly;

said liquid coolant in-flow passage and a liquid coolant out-flow passage extending from said inlet end to said outlet end in spaced apart concentric side-by-side relationship and surrounding all other passages, closer to the centre of the composite arcuate body;

said by liquid cooled special tip assembly, its outer body connected permanently to the outlets end of the composite arcuate body, its assembly being of simple, highly functional design and allowing simple, easy and expedient replacement of the eventually worn out main and intermediate nozzle bodies, by only screwing out the particular worn out nozzle body and screwing in a new appropriate nozzle body, made to specification;

said both easy to replace nozzle bodies arranged in recessed position in relation to the liquid cooled tip of the outer body;

said lower edge of the by liquid cooled special tip assembly outer body, made of high thermally conductive material being protected by adequate thickness layer of hard material/s;

- (III) providing a multi-purpose, multi-ox-fuel apparatus combination of power burner/oxygen lance/solid materials injector device comprising:

in another preferred embodiment, this being a liquid cooled, generally vertically oriented straight linear composite body, having an inlet end and an outlet end, the outlet end of the linear composite body being oriented downwards, toward the solid or molten charge in the refractory lined bottom of the furnace vessel shell;

a straight, generally horizontally extended and positioned composite tubular the special type arm, connected by a sliding screwed connection at the inlet end of the arm to the vertical repositioning extension—mast;

a vertical repositioning extension—mast, of rugged steel structure, in the preferred embodiment being vertically repositioned by a hydraulic cylinder while

accurately guided up and down via special adjustable guide rollers, the rollers attached to the stationary superstructure base frame located in close proximity of the furnace vessel shell;

said liquid cooled generally vertically oriented and straight linear composite body having therein, coaxially to the straight and linear centre line arranged several passages created by pipes of appropriate diameter and wall thickness for conveying from said inlet end to the said outlet end with special tip assembly of the composite straight and linear body the pulverized coal, natural gas, oxygen, cooling liquid inn passage and cooling liquid out passages;

said generally most central passage of the composite straight linear body for flow and conveying of pulverized carbonaceous material and/or calcined dolomitic lime via flow of pressurized gaseous media, said generally most central passage extending from said inlet end of the composite straight linear body to the said outlet end in the main nozzle of the special tip assembly;

said generally second passage from the centre of the composite straight linear body for sole flow of combustion oxygen, said generally second passage from the centre extending from the said oxygen inlet end of the composite straight linear body to the said outlet end into the entrance of the converging side of the converging/diverging nozzles of the main nozzle body of the special tip assembly;

said generally third passage from the centre of the composite straight linear body for sole flow of com-

bustible gas, preferably natural gas, said generally third passage from the centre extending from the said natural gas inlet end of the composite straight linear body to the said outlet end into the entrance of the more than one tubular nozzles of the intermediate nozzle of the special tip assembly;

said liquid coolant in-flow passage and a liquid coolant out-flow passage extending from said inlet end to said outlet end in spaced apart concentric side-by-side relationship and surrounding all other passages, closer to the centre of the composite straight linear body;

said by liquid cooled special tip assembly, its outer body connected permanently to the outlets end of the composite straight linear body, its assembly being of simple, highly functional design and allowing simple, easy and expedient replacement of the eventually worn out main and intermediate nozzle bodies, by only screwing out the particular worn out nozzle body and screwing in a new appropriate nozzle body, made to specification;

said both easy to replace nozzle bodies arranged in recessed position in relation to the liquid cooled tip of the outer body;

said lower edge of the by liquid cooled special tip assembly outer body, made of high thermally conductive material being protected by adequate thickness layer of hard material/s;

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