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longitudinal slitting section (SL) suitable to receive coils from each of said three working sections (CCHR, PCR, CF), a vehicle shredding section (AS) suitable to produce metal scrap fit for use as raw material in the foundry section (SF), a vehicle shredding residue burning section (ASRB) suitable to generate current to supply the plant, and a foundry slag treating section suitable to recycle the slag and recover heat therefrom.



Description

[0001] The present invention relates to an integrated plant with low environmental impact (so-called "green factory") for the production of steel hot-rolled and cold-rolled strip in a wide dimensional range with high productivity and flexibility of the plant and a high quality of the strip.

[0002] It is known that the production cycle for the manufacture of 4 million tons/year of coils of steel strip is based on the so-called "integral cycle", which uses coal for the production of metallurgical coke, lime and flux which, combined with fine iron mineral, generate pellets and sintered after processing in special plants. Pellets and sintered, loaded with the coke in the blast furnace, are turned into liquid cast iron and slag.

[0003] From cast iron then you get the steel in the converter process that dramatically reduces the carbon content. The steel is then refined in a plant for degassing and processed in chemical analysis in special treatment installations. The steel is then cast by continuous casting which produces slabs approximately 200-250 mm thick, 1500-2000 mm wide and 8-12 meters long.

[0004] The slabs leaving the continuous casting are then stored in a deposit and subsequently resumed according to the production program to be heated in a furnace which takes the slabs to the optimum temperature (about 1200°C) for the next stage of hot rolling. This phase normally comprises the passage in a first series of stands that perform the roughing operations and reduce the slab to a thickness of about 35-50 mm and then the finishing rolling is performed in a train that uses up to seven stands. From here the rolled material is sent, after cooling, to the winding on the reels that generate the coils of rolled strip.

[0005] The hot product of this type of plant is normally in the range of thicknesses from 1,8 to 15 mm, with a great prevalence in thicknesses greater than 2,5 mm since this type of plant is unsuitable for the production of coils of thin thickness. Thin thicknesses are usually produced through cold cycles that use large finishing equipment, such as pickling, cold rolling trains with five stands, annealing, galvanizing and painting installations.

[0006] A typical integrated plant of this type, from raw material to finished products, for a capacity of 4 million tons/year occupies very large spaces, usually from 5 to 8 millions of square meters. The typology of these plants is scarcely flexible and involves the need of large amounts of intermediate materials put into storage (slabs, hot-rolled coils, cold-rolled coils, etc.) for a few million tons overall, with a consequent increase in production costs.

[0007] From an energy point of view the costs are quite high both for the material heating costs and for the rolling costs due to a high number of stands. Also the environmental impact is considerable and is mainly due to fine dust, particularly in coking plants and in the blast furnace.

[0008] It is also known that with the thin slab technology it is possible to make plants with reduced energy costs and low environmental impact, by casting thin slabs less than 100 mm thick and in which the liquid steel is produced through by melting iron scrap. With this type of technology it is not possible however to produce more than 1,5 million tons/year with one casting/rolling line and 3 million tons/year with two lines, with profitability problems especially in times, such as the current times, in which the selling price of the coils is low.

[0009] There is therefore the need to realize extremely compact factories that can produce an amount equal to 3-4 million tons/year or more of coils of very high quality and with high production mix, with a single continuous casting line directly connected without solution of continuity to the finishing mill, with low investment and production costs but environmentally responsible.

[0010] The idea underlying the present invention is to realize a factory with very low environmental impact (green factory), with consumption per unit of product reduced by 50% for both energy and water. This result is obtained thanks to the short distance not only between the steel mill and the casting machine but especially between the continuous casting and the winding reel of the hot-rolled strip, using the continuous production technology (so-called endless) that minimizes production time and consumption thereby reducing production costs. The green factory is also characterized by a considerable reduction of raw materials and emissions as well as by a high recycling ratio with recovery even of part of the heat used in the production cycle.

[0011] To this purpose, the green factory according to the present invention comprises a foundry section for the production of liquid steel directly connected to a continuous casting and hot rolling section, which is in turn connected to a cold rolling section that is in connection with a finishing section (galvanic treatment, coating, annealing), a longitudinal slitting section being able to receive coils from each of the three above-mentioned working sections (hot rolling, cold rolling, finishing). Moreover a vehicle shredding section produces metal scrap to be used as raw material for the foundry, a vehicle shredding residue burning section generates current for the plant, and finally a foundry slag treating section is dedicated to the recycling of the slag and to the heat recovery therefrom.

[0012] A first fundamental advantage of the plant according to the present invention is to provide a factory, with a production cycle in line, of extreme compactness in terms of space and production cycle times such that it can be fully realized in spaces of less than 700.000 m². Such a plant allows to produce, with a single continuous casting line directly connected without solution of continuity to the finishing mill, an amount equal to 3-4 million tons/year or more of coils of very high quality and for all applications, including the inner and outer parts of cars, with a high mix of thicknesses and

maximum respect for the environment.

[0013] A second important advantage of the factory realized with the teachings of the present invention lies in the fact that it has very competitive investment and processing costs, it is highly environmentally friendly and has a minimum environmental impact, in particular for the reduction (up to 50%) of the energy and water consumption per unit of product and for the emission of fumes and noise reduced to a minimum, thanks to the fact that the sections are housed in completely closed and soundproofed sheds.

[0014] A further advantage of this factory is the provision of a "human friendly" indoor work environment where the workers, thanks to the integrated automation of all plants, can supervise all production processes in ergonomic and soundproofed pulpits, with no need to be in direct contact with the steel.

[0015] Further advantages and characteristics of the plant according to the present invention will become apparent to those skilled in the art from the following detailed and non-limiting description of an embodiment thereof with reference to the accompanying drawings in which:

Fig.1 is a schematic view of the different sections that make up the plant and of their connections, with the exception of the foundry slag treating section which is omitted;

Fig.2 is a schematic view in longitudinal section of the beam of the foundry slag treating section;

Fig.3 is a schematic view in cross section of the collection basin of said slag;

Fig.4 is a perspective view partly broken away of the structure of the panels used to make the coverage sheds of the sections;

Fig.5 is a perspective view of a continuous casting machine, in the version with the electromagnetic brake external to the cooling circuit of the mould and depicted in the inoperative position;

Fig.6 is a perspective view of the casting machine of Fig.5 with the electromagnetic brake depicted in the operative position;

Fig.7 is a perspective view of a continuous casting machine, in the version with the electromagnetic brake internal to the cooling circuit of the mould;

Fig.8 is a schematic front view that shows the magnitude of the wave generated by the turbulence of the liquid steel introduced into the mould;

Fig.9 is a schematic top plan view showing the profile of the terminals of the magnetic cores of the electromagnetic brake;

Fig.10 is a schematic side view showing the profile of the terminals of the magnetic cores of the electromagnetic brake; and

Fig.11 is a diagram of the cooling circuit of the mould.

[0016] Referring to Fig.1, there is seen that a plant according to the present invention comprises a foundry section SF for the production of liquid steel which is fed directly to an adjacent section CCHR for the continuous casting and hot rolling to a thickness between 0,8 and 25 mm. More specifically this section CCHR comprises a device for the continuous casting in thin slab with liquid core reduction (LCR) followed by a finishing mill capable of reducing the thin slab to a strip of the desired final thickness, in addition to a device for cooling the strip thus obtained and to a final winding station provided with relative shears for obtaining coils HRC.

[0017] The coils HRC of hot-rolled steel strip obtained in the section CCHR can be passed for possible additional processing to an adjacent pickling and cold rolling section PCR comprising lines with different rolling trains, for example a line with three rolling stands to obtain a thickness between 0,2 and 1 mm.

[0018] Similarly, the coils CRC of cold rolled steel strip obtained in the section PCR can then be passed for possible additional processing to a longitudinal slitting section SL or to an adjacent coil finishing section CF which may comprise lines HDGL for hot dip galvanizing treatment (typically zinc coating), lines HDGCL for hot dip galvanizing treatment combined with an additional coating (typically paint) and lines AL for annealing.

[0019] The wide range of finished products that can be obtained with the present plant thus comprises coils HRC of hot rolled steel strip with a thickness comprised between 0,8 and 25 mm, the maximum width being equal to the width of the mould, and coils CRC of cold rolled steel strip with a thickness comprised between 0,2 and 2 mm that can later be zinc coated (HDGC) or zinc coated and painted (HDGCC). A typical mix of finished products for a production of 4 million tons/year includes 1 million of HRC and 3 millions of CRC divided in half between lower and higher thicknesses.

[0020] In section SF the present invention adopts the most advanced melting technologies of raw materials such as metal scrap, DRI (Direct Reduced Iron), HBI (Hot Briquetted Iron) and cast iron to obtain the liquid steel which is then refined, processed and loaded with the appropriate ferroalloys in order to be ready for casting in section CCHR. These melting and refining phases of the liquid steel are carried out within sheds that are closed and kept in depression, so as to prevent the escape of fumes which are sucked by a special plant and filtered prior to the emission in the atmosphere in suitable installations for reducing pollutants that use the most advanced technologies available.

[0021] By way of example, the section SF schematized here comprises two melting electric arc furnaces EAF, three

ladle furnaces LF, two vacuum decarburization furnaces VOD and a vacuum degassing system RH (Ruhrstahl-Heraeus).

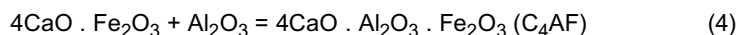
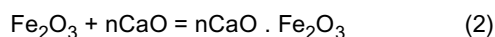
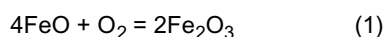
[0022] For manufacturers of steel from electric oven the availability of scrap of good quality in adequate quantities is critical, and for this purpose there is provided a section AS where a mill is employed for crushing and shredding "packs" of vehicle bodies and a procedure is used for the recovery of waste elements (metals such as lead, copper, zinc and tin) whose presence in the steel can affect the production of high quality steels.

[0023] In the present plant there is also provided a section ASRB where there is implemented a process for the energy recovery of the residual consisting of a mix of various types of materials such as plastics, rubbers, textiles, glass (so-called ASR = Automobile Shredder Residue or "fluff"), rather than disposing of it almost entirely in a landfill as is currently done according to the state of the art. For this purpose there is used, as described in the Italian patent n. 1416512 herein incorporated by reference, a compact reactor and a process of pyro-gasification of fluff optimized in terms of thermo-chemical and thermo-fluidodynamical efficiency, thus maximizing the extraction of the energy content of the fed material.

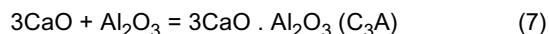
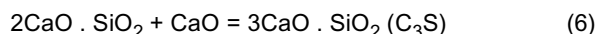
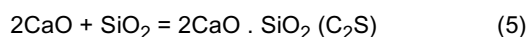
[0024] The electricity generated from the thermal energy obtained from the fluff in section ASRB is fed into the plant network, thus contributing to the reduction of kWh needed to produce 1 ton of steel. In this way the calculated value, fulfilling the criteria of PAS 2050:2011, of the carbon footprint of the finished product is less than 1300 kg CO₂/ton, in relation to 1 ton of hot-rolled carbon steel type S235 JR (low alloy) 2 mm thick and 1500 mm wide, with an hourly production of 330 tons/h. This value includes the raw material (mainly steel scrap), the melting process in the EAF furnace and the endless process of continuous casting and rolling of the strip, including the water cooling system (so-called "cradle-to-gate" value).

[0025] In the steel production process, a substantial portion of the production waste is represented by the slag that originates in the melting processes. In particular, in the processes based on electric melting furnaces EAF of the Siemens-Martin type the percentage of slag produced for each unit of liquid steel is about 16% by weight. This slag is usually discharged into areas of cooling/treatment outdoors for later disposal, which involves emissions of steam and the remote possibility of throwing of materials in the case of direct contact of the liquid slag with significant quantities of water.

[0026] The basic chemistry that occurs during the slag cooling process consists of some modifications for which the iron oxide FeO is oxidized to ferric oxide Fe₂O₃, which reacts with the oxides of lime and aluminum forming minerals after the cementation process:



[0027] The silicon and alumina present in the slag also react with the portion of unbound lime present forming minerals after the cementation process:



[0028] The continuous monitoring of the completion of these processes allows the reuse of the slag thus modified both as conglomerate for roadbeds and as an inert in the production of concrete.

[0029] Referring to Fig.2, there is seen that in the green factory object of the present invention all activities of cooling/treatment of the slag are carried out indoors. The section ST for treating slag FS is in fact contained in a shed built with soundproof panels suitable to limit the propagation of noise and contain any throwing of materials. Also the whole shed is at a slight depression to convey any emission to a centralized fumes treatment plant through a special system ECS for capturing emissions released from the slag FS being treated. The same kind of protection of the working environment and of limitation of the emissions is preferably applied also to the other sections.

[0030] The slag cooling basin, shown in Fig.3, comprises a system HRS for heat recovery from the slag which is discharged in the basin at each completion of the melting cycle of a batch of steel, at intervals comprised between 35 and 60 minutes. The basin accumulates a number of discharges in proportion to its size, then the basin is allowed to cool and in the meantime there is used a twin basin to continue operations and the plant proceeds so alternately.

[0031] The structure of the basin comprises an internal tank 1, a waterproofed external tank 2 and a layer of thermal insulation material 3 arranged between said two tanks. The internal tank 1 has a bottom wear layer 4 suitable to protect

the structure of the tank itself inside which pass pipes of the heat recovery system HRS.

[0032] The residence time of the cooling slag in the basin allows the transmission of heat to the underlying structure of the internal tank 1 and, thanks to its size, there is established a temperature regime such that the piping network of the HRS system manages to remove the additional heat resulting from each new discharge. A control system automatically switches the individual cooling circuits in series/parallel configuration to adapt the flow rates/temperatures to the needs of the heat users, both inside and outside of the factory (e.g. remote heating).

[0033] The shed of section ST, as well as the sheds of the other sections, is preferably made with metal panels insulated with high-density mineral wool, of the type illustrated in Fig.4. More specifically, a panel consists of an external sheet 5 with a C-shaped cross-section suitable to support an internal sheet 6, exposed to the noise, that has a micro-perforated surface behind which there is a sound-muffling floating lamina 7 elastically suspended between two layers 8, 8' of high-density (80-100 kg/m³) mineral wool insulation. Furthermore, a protective foil 9 is arranged between the micro-perforated sheet 6 and the internal layer 8 of mineral wool.

[0034] By varying the type of the intermediate sound-muffling lamina 7 and modulating the thickness and density of the mineral wool layers 8, 8' diversified levels of sound attenuation can be reached in relation to the presence and different sound spectrum of the internal noise sources. Typically a panel with only the inner layer 8 of mineral wool 80 mm thick has an attenuation of $28 \div 32$ dB in the spectrum $f > 250$ Hz.

[0035] The factory realized with the teachings of the present invention consists of plants for the production of hot-/cold-rolled steel strips, galvanized and coated, that are characterized by being as compact as possible while respecting all the phases of transformation of steel. More specifically, the plant for the production of hot-rolled strip is based on the "endless" technological concept which involves casting and rolling directly connected in line without solution of continuity for the maximum exploitation of the enthalpy of the liquid steel. Such a plant is extremely compact (length about 180 meters) and allows the production of high quality steel strips wound in coils that cannot be obtained with other conventional plants or through other thin slab technologies at a competitive cost, with more than 70% of the hot-rolled coils that may have a thickness in the range from 0,8 to 1,6 mm and a width in the range from 1560 to 1800 mm.

[0036] The endless configuration, described for example in European patent EP 1868748 and represented in Fig.1 in section CCHR, is characterized by the important aspect consisting of the direct connection without solution of continuity of the continuous casting and rolling stages, with a single set of stands that implements the roughing and finishing steps. This solution, in addition to reducing the energy request practically to that regarding only the finishing, since it eliminates the wasteful heating of the slab replaced by a single temperature recovery between casting and the rolling mill, is particularly favorable in terms of yield of the steel because the losses due to oxide rather than for other wastes are minimized.

[0037] Thanks to the endless technology it is possible to obtain hot-rolled strip with a minimum thickness up to 0,8 mm with dimensional features, internal structure and quality typical of cold-rolled strips, in particular as regards planarity and very tight thickness tolerances, also on the head/tail of the strip. These properties of the hot-rolled coils HRC allow to obtain, with a subsequent step of cold rolling in section PCR, strips having a minimum thickness of 0,2 mm with excellent geometric characteristics.

[0038] The tremendous technical progress in the field of continuous casting plants allowed to reach higher and higher flow rates, i.e. to increase more and more the quantity of steel per unit time output from the continuous casting. With the teachings of the present invention it is possible to obtain a very high productivity of the continuous casting machine capable of casting up to 10 tons/min of steel thanks to the particular technological system composed of the plunger, the mould and the electromagnetic brake (so-called "mould system"), as shown in figures 5 to 7.

[0039] The electromagnetic brake (EMB) is an essential component in the achievement of a high flow rate in continuous casting and to achieve a flow rate of 10 tons/min it was necessary to design an innovative geometry of the terminals of the magnetic cores of the EMB, as illustrated in more detail below.

[0040] It is known, in fact, that the objectives of the introduction of an electromagnetic brake in a continuous casting machine are primarily the stabilization of the meniscus M in the mould, where the solidification of the steel begins with the formation of the first solid "skin" of the product, and the reduction of the penetration depth of the inclusions, both solid and gaseous. The molten metal passes through the static magnetic field generated by the EMB and by virtue of the relative motion between the metal and the field induced currents are generated within the metal that create an induced magnetic field. The interaction of this induced field with the magnetic field of the EMB results into a mechanical force (Lorentz force) opposite to the direction of motion of the metal, from which results the braking action which is proportional to the square of the magnetic field of the EMB.

[0041] In this way the speed of the molten metal is decreased and the kinetic energy lost is converted into heat energy, in accordance with the principle of conservation of energy. Therefore there is a redistribution of the flow of metal in the mould, which allows to retain the inclusions in the zone of the meniscus M which, moreover, is hotter due to the reduced turbulence.

[0042] There are two different construction types of the electromagnetic brake, which have the same operating principle but depending of the casting machine you can have the external arrangement or the internal one. The former is preferred

in case of new machines, the second is usually used in case of retrofit where the space available is smaller. In both cases, the moulds must be suitable for use with the EMB, mainly as regards the cooling water chambers which must be shaped to accommodate the cores of the brake and be made of nonmagnetic stainless steel, so as not to affect the passage of the magnetic field towards the mould and not decrease the effectiveness of the device.

[0043] Taking into consideration the external arrangement, shown in figures 5 and 6, the components of the EMB are mounted externally to the mould, formed by four copper plates CP that delimit the space in which there is poured the liquid steel fed through the submerged nozzle SN. These components are:

- a magnetic yoke MY that allows the "magnetic closure" of the circuit and is normally integrated in the support structure of the casting machine;
- two electric coils EC connected in series and formed from copper windings consisting of tubes of rectangular section directly cooled with de-ionized water; coils EC are supplied with direct current from a converter and said current flowing in the windings creates the magnetic field and allows to obtain the braking effect on the molten metal;
- two magnetic cores MC, on which coils EC are wound, which are equipped with a supporting and handling system to enter and exit from the water chambers WC of the mould; in the operative position of Fig.6 the two cores MC are inserted in the water chambers WC to take them closer to the mould so as to pass the magnetic field generated by coils EC through the mould itself, whereas when it is necessary to replace the mould the two cores MC are retracted by means of the handling system (preferably hydraulic) to the inoperative position of Fig.5, so that the mould can be removed freely.

[0044] In the internal arrangement illustrated in Fig.7, all the aforesaid components of the EMB are mounted directly on the mould which is equipped with cores MC, complete with coils EC, that "live in symbiosis" with the mould itself, therefore one must provide as many pairs of magnetic cores MC as are the moulds in use.

[0045] The solution object of this invention can be applied to both arrangement, external and internal, and consists of a particular geometry of the front surface of the terminals of the magnetic cores that are no longer made as the usual steel parallelepipeds normally used. This geometry has been designed to have a magnetic field inside of the mould able to guarantee optimal casting conditions even with the high flow rates typical of the continuous process used in the present plant (so-called technology ESP = Endless Strip Production).

[0046] The applicant has performed tests to evaluate the effectiveness of the geometry chosen for the terminals of the EMB by analyzing the stability of the meniscus M of the molten metal through the so-called "sheet test" (dip test) which consists in dipping in the mould, parallel to the wide plates CP, a sheet of stainless steel having a thickness equal to 0,2 mm. From the analysis of the sheets it is possible to obtain an indication of the magnitude of the wave generated by the turbulence of the liquid steel introduced into the mould through the submerged nozzle SN, measuring both the difference W_1 between the points of maximum and minimum and the difference W_2 between the maximum point and the average height of the wave, as shown in Fig.8.

[0047] For the test to be effective it is important that the time of immersion in the mould is sufficient to allow the melting of the sheet but without being too long, so as to obtain a realistic image of the wave that is present in the moment in which the sheet is dipped, i.e. an instantaneous representation of the meniscus. Through the tests performed it was verified that while with the traditional flat terminals the statistical average of W_1 and W_2 was respectively 26 and 15 mm, with the terminals having the geometry developed by the applicant the average of W_1 and W_2 is reduced respectively to 7 and 3 mm. It is therefore evident how the turbulence in the mould decreases dramatically by using the geometry object of the present invention.

[0048] The studies carried out by the applicant have allowed therefore to define a geometry of the front surface of the terminals close to the mould that is illustrated in figures 9 and 10. By indicating with L the width of each terminal and with H the difference between the point of the terminal profile closest to the mould and that farthest from the same, the plan view of Fig.9 shows the significant points of passage of the profile in the horizontal plane that are then interpolated by a polynomial curve of the sixth order $a*x^6+b*x^5+c*x^4+d*x^3+e*x^2+f*x+g$.

[0049] The values of L, H and of the coefficients of the interpolating curve are comprised within the following ranges:

$$\begin{aligned} L &= 400 \text{ mm} \div 600 \text{ mm}; \\ H &= 300 \text{ mm} \div 450 \text{ mm}; \\ a &= -3,6*10^{-12} \div -2,7*10^{-13}, \\ b &= 95*10^{-10} \div 8*10^{-9}, \\ c &= -4,3*10^{-6} \div -48*10^{-7}, \\ d &= 1,6*10^{-4} \div 1*10^{-3}, \\ e &= -9,2*10^{-2} \div -2*10^{-2}, \\ f &= -1,2*10^{-1} \div 8,7*10^{-1}, \\ g &= 0. \end{aligned}$$

[0050] The side view of Fig.10 similarly shows the profile of the terminals in the vertical plane, where S indicates the thickness of the terminals and the significant points of passage of the profile are again interpolated by a polynomial curve of the sixth order $\underline{a} \cdot x^6 + \underline{b} \cdot x^5 + \underline{c} \cdot x^4 + \underline{d} \cdot x^3 + \underline{e} \cdot x^2 + \underline{f} \cdot x + \underline{g}$.

[0051] The values of S and of the coefficients of the interpolating curve are comprised within the following ranges:

$$\begin{aligned} S &= 300 \text{ mm} \div 400 \text{ mm}; \\ \underline{a} &= 3,1 \cdot 10^{-12} \div 2,3 \cdot 10^{11}, \\ \underline{b} &= -2,0 \cdot 10^{-8} \div -3,8 \cdot 10^{-9}, \\ \underline{c} &= 1,5 \cdot 10^{-6} \div 5,7 \cdot 10^{-6}, \\ \underline{d} &= -3,7 \cdot 10^{-4} \div -1,8 \cdot 10^{-4}, \\ \underline{e} &= -3,8 \cdot 10^{-2} \div -1,8 \cdot 10^{-3}, \\ \underline{f} &= -7,8 \cdot 10^{-1} \div 2,6 \cdot 10^{-1}, \\ \underline{g} &= 0. \end{aligned}$$

[0052] Also for the achievement of the aforementioned flow rate value, it was also necessary to design an innovative mould cooling system of the dynamic type (DMC = Dynamic Mould Cooling) shown schematically in Fig.11.

[0053] In fact, unlike the current state of the art which provides for constant flow rates of cooling water regardless of the operating conditions, the DMC is a management system for the cooling water of the copper plates of mould 10 which consists in the variation of the cooling water flow rate as a function of the casting speed and of the thickness of the plates themselves. This is done through the use of variable-speed pumps 11 inserted in the cooling circuit, in addition to a conventional heat exchanger 12 and a bypass valve 13.

[0054] This management of the cooling water can make constant the heat transfer in the mould despite considerable changes in the operating conditions, with important beneficial effects both on the formation in the mould of the first skin of the blank and on the life of the copper plates. On the ESP line of the Arvedi steelworks in Cremona it was possible to obtain, with the help of the DMC, a thickness of the first skin between 10 and 15 mm at the exit of the mould and a life of the plates of over 1400 castings. This is the result of the reduction in the formation of cracks in the copper, which is positively reflected not only on the reduction of the defectiveness of the product but also on the decrease in the stops of the line due to breaking of the first skin of the blank with the consequent leakage of liquid steel (so-called break-out).

[0055] Experimental tests conducted at the plant of the Arvedi steelworks in Cremona have shown that it is possible to cast, thanks to the innovative geometry of the terminals of the magnetic cores of the electromagnetic brake and to the innovative system of dynamic mould cooling, thin slabs with a thickness of 100 mm at a speed of 6 m/min with a flow rate greater than 7,1 tons/min thus making it possible to produce, with a single integrated line of continuous casting and rolling, an amount of hot-rolled coils greater than 4 million tons/year with an average specific energy consumption lower than 135 kWh/t. This has made it possible to compact the factory object of the present invention in such a manner as to be entirely realized in spaces of 500.000-700.000 m².

[0056] The present invention can also be applied by replacing the endless process according to the teachings of patent EP 1868748 with that of patent EP 1558408, which comprises a roughing and finishing step with an intermediate heating between the roughing mill and the finishing mill, rather than a single rolling plant. In addition it can also be applied to integral cycle plants, i.e. with the melting of mineral and coal in a blast furnace, applying the best available technologies to minimize the environmental impact.

Claims

1. Integrated plant with very low environmental impact for producing coils of hot-rolled and cold-rolled steel strip, comprising a foundry section (SF) for producing liquid steel directly connected to a continuous casting and hot rolling section (CCHR) with final winding of the strip into coils, this latter section (CCHR) being in turn connected to a cold rolling section (PCR) that is in connection with a finishing section (CF), said plant further comprising a longitudinal slitting section (SL) suitable to receive coils from each of said three working sections (CCHR, PCR, CF), a vehicle shredding section (AS) suitable to produce metal scrap fit for use as raw material in said foundry section (SF), a vehicle shredding residue burning section (ASRB) suitable to generate current to supply the plant, and a foundry slag (FS) treating section (ST) suitable to recycle the slag and recover heat therefrom.
2. Plant according to claim 1, **characterized in that** the foundry section (SF) includes electric arc melting furnaces (EAF), ladle furnaces (LF), vacuum oxygen decarburization furnaces (VOD) and a vacuum degassing system (RH).
3. Plant according to claim 1 or 2, **characterized in that** the continuous casting and hot rolling section (CCHR) includes a device for the continuous casting of thin slabs with liquid core reduction (LCR) that directly feeds a rolling mill with

a single series of stands suitable to carry out the roughing and finishing of the thin slab until it is reduced to a strip with a thickness comprised between 0,8 and 25 mm.

4. Plant according to any of the preceding claims, **characterized in that** the cold rolling section (PCR) includes pickling and cold rolling lines with different rolling mills suitable to reduce the hot-rolled steel strip to a cold-rolled strip with a thickness comprised between 0,2 and 2 mm.
5. Plant according to any of the preceding claims, **characterized in that** the finishing section (CF) includes hot dip galvanizing lines (HDGL), hot dip galvanizing and coating lines (HDGCL) and annealing lines (AL).
6. Plant according to any of the preceding claims, **characterized in that** the foundry slag (FS) treating section (ST) includes a slag (FS) cooling basin made up of an internal tank (1), a waterproofed external tank (2) and a layer of thermal insulation material (3) arranged between said two tanks (1, 2), the internal tank (1) having a bottom wear layer (4) suitable to protect the structure of the tank itself inside which pass pipes of a heat recovery system (HRS) comprising means for switching single cooling circuits in series/parallel configuration in order to adapt the flow rates/temperatures to the needs of the heat users on the basis of commands from an automatic control system.
7. Plant according to any of the preceding claims, **characterized in that** at least the foundry section (SF) and the foundry slag (FS) treating section (ST), preferably also other sections, are contained in sheds built with soundproof panels suitable to limit the propagation of noise and to restrain possible throwing of material, said sheds being at a slight depression so as to convey any emission to a centralized fumes treatment system through an emission capture system (ECS).
8. Plant according to the preceding claim, **characterized in that** the soundproof panels are metal panels insulated with high-density mineral wool at 80-100 kg/m³, each panel consisting preferably of an external sheet (5) with a C-shaped cross-section suitable to support an internal sheet (6) that has a micro-perforated surface behind which there is a sound-muffling floating lamina (7) elastically suspended between two layers (8, 8') of said high-density mineral wool insulation, a protective foil (9) being also preferably arranged between said micro-perforated sheet (6) and the internal layer (8) of mineral wool.
9. Plant according to any of the preceding claims, **characterized in that** the sections include ergonomic and sound-proofed pulpits connected to the plant devices so as to allow the operators to supervise all the production processes without being in direct contact with the steel being worked.
10. Plant according to any of claims 3 to 9, wherein the continuous casting device includes an electromagnetic brake (EMB) arranged along two opposite long sides of a mould, said electromagnetic brake (EMB) being **characterized by** the geometry of the front surface of terminals of magnetic cores (MC) on which there are wound electric coils (EC) that generate the magnetic field, said geometry providing a profile in the horizontal plane defined by a length (L) of the terminal, by a difference (H) between the point of said profile closest to the mould and the point farthest from the mould and by significant passage points interpolated by a polynomial curve of sixth order $a*x^6+b*x^5+c*x^4+d*x^3+e*x^2+f*x+g$, the values of length (L), of difference (H) in distance from the mould and of the coefficients of said polynomial curve being comprised within the following ranges: L = 400 mm ÷ 600 mm; H = 300 mm ÷ 450 mm; a = $-3,6*10^{-12}$ ÷ $-2,7*10^{-13}$; b = $9,5*10^{-10}$ ÷ $8*10^{-9}$; c = $-4,3*10^{-6}$ ÷ $-4,8*10^{-7}$; d = $1,6*10^{-4}$ ÷ $1*10^{-3}$; e = $-9,2*10^{-2}$ ÷ $-2*10^{-2}$; f = $-1,2*10^{-1}$ ÷ $8,7*10^{-1}$; g = 0.
11. Plant according to the preceding claim, **characterized in that** the terminals of the magnetic cores (MC) have a geometry of their front surface providing a profile in the vertical plane defined by a thickness (S) of the terminal, by a difference (H) between the point of said profile closest to the mould and the point farthest from the mould and by significant passage points interpolated by a polynomial curve of sixth order $\underline{a}*x^6+\underline{b}*x^5+\underline{c}*x^4+\underline{d}*x^3+\underline{e}*x^2+\underline{f}*x+\underline{g}$, the values of thickness (S), of difference (H) in distance from the mould and of the coefficients of said polynomial curve being comprised within the following ranges: S = 300 mm ÷ 400 mm; H = 300 mm ÷ 450 mm; $\underline{a}$ = $3,1*10^{-12}$ ÷ $2,3*10^{-11}$; $\underline{b}$ = $-2,0*10^{-8}$ ÷ $-3,8*10^{-9}$; $\underline{c}$ = $1,5*10^{-6}$ ÷ $5,7*10^{-6}$; $\underline{d}$ = $-3,7*10^{-4}$ ÷ $-1,8*10^{-4}$; $\underline{e}$ = $-3,8*10^{-2}$ ÷ $-1,8*10^{-3}$; $\underline{f}$ = $-78*10^{-1}$ ÷ $2,6*10^{-1}$; $\underline{g}$ = 0.
12. Plant according to any of claims 3 to 11, wherein the continuous casting device includes a system for managing the cooling water of wide and narrow copper plates (CP) that make up a mould (10), **characterized in that** said system, through the use of variable-speed pumps (11) located in the cooling circuit, is suitable to perform a variation of the flow rate (P) of the cooling water depending on the steel casting speed in said mould (10) and on the thickness of

said copper plates (CP).

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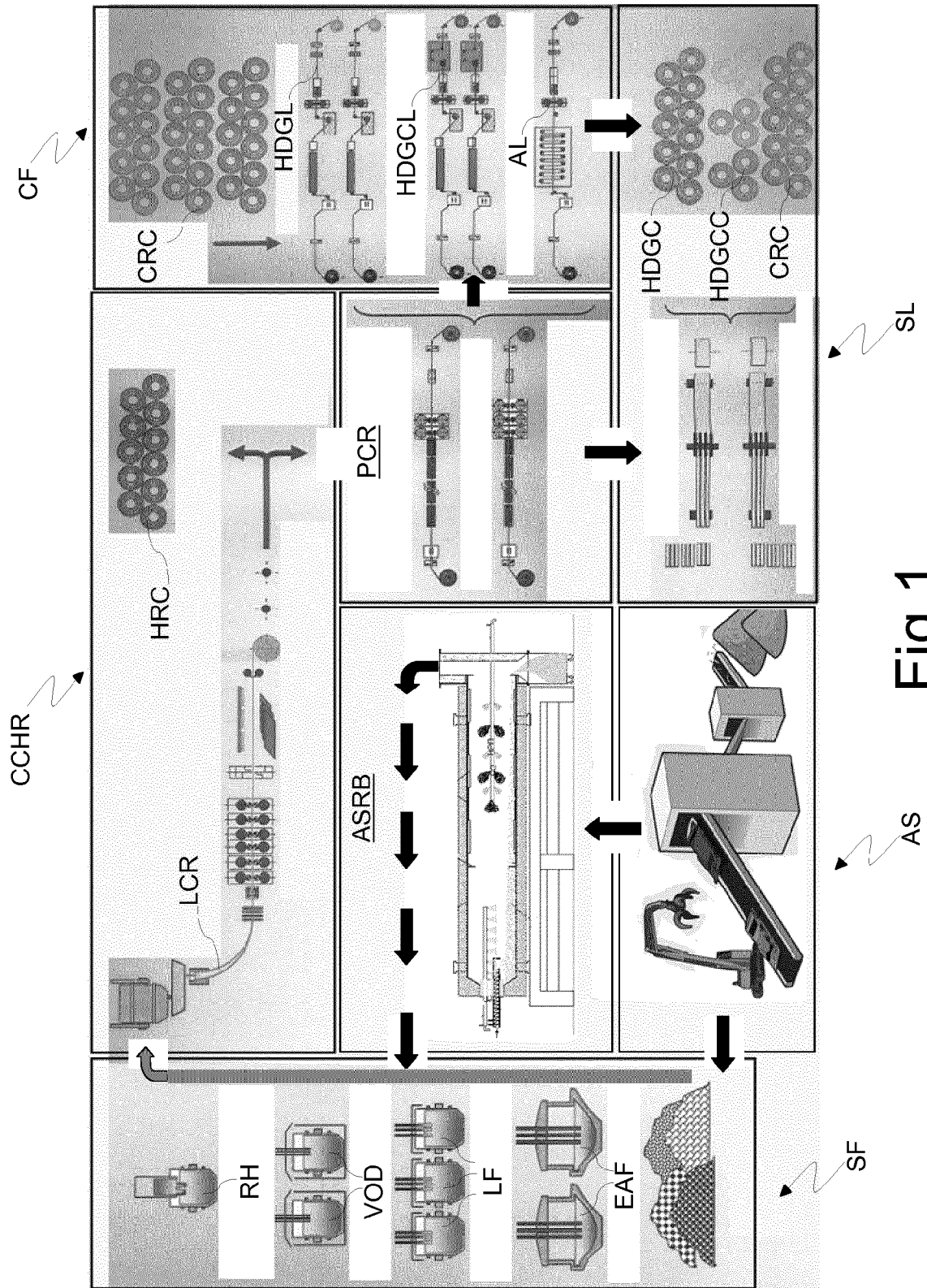


Fig. 1

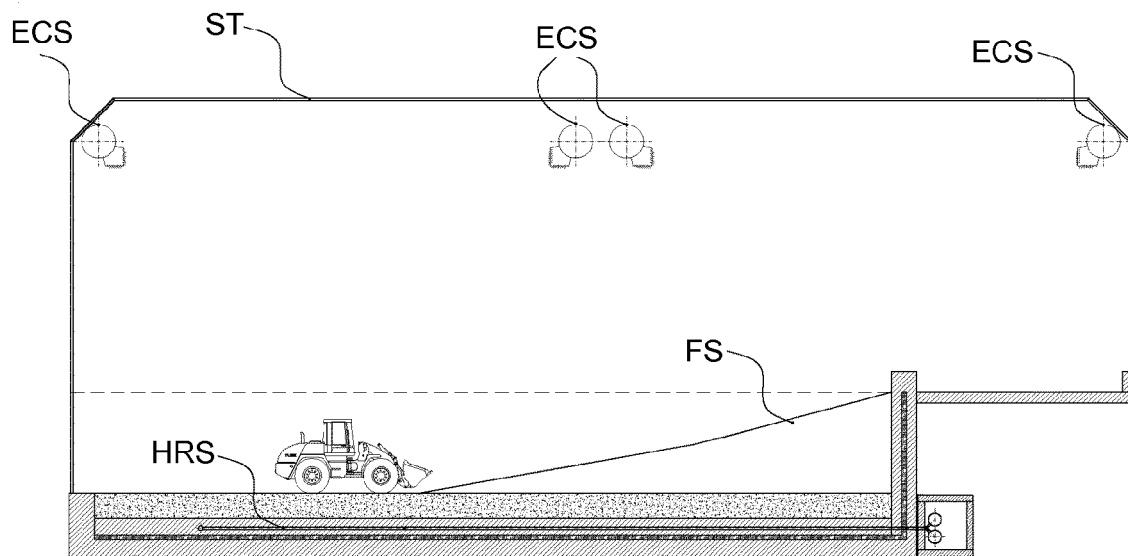


Fig.2

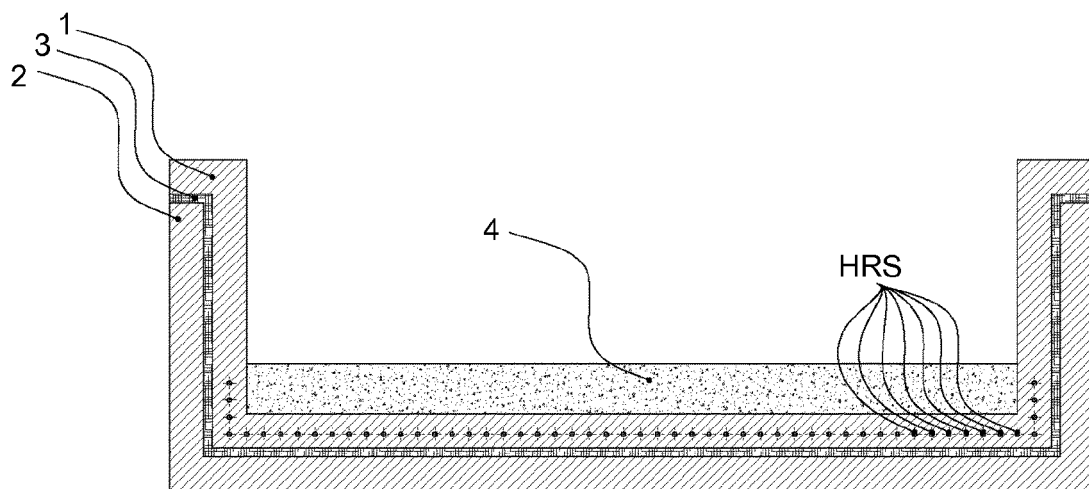


Fig.3

Fig.4

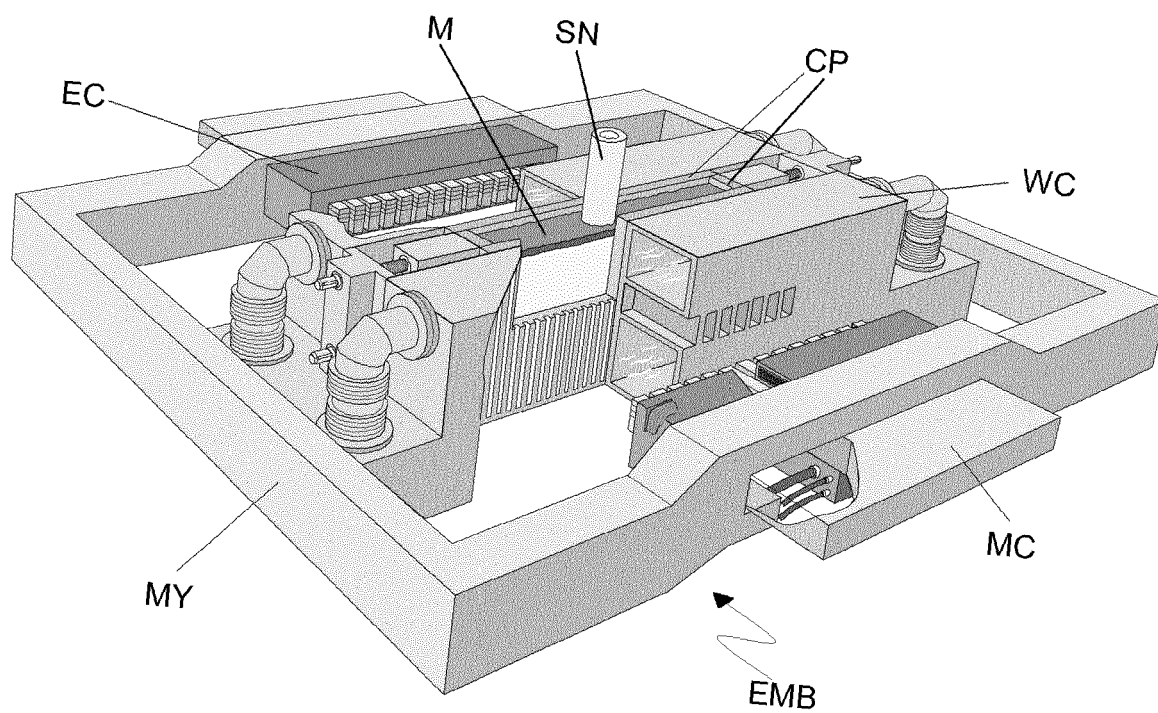
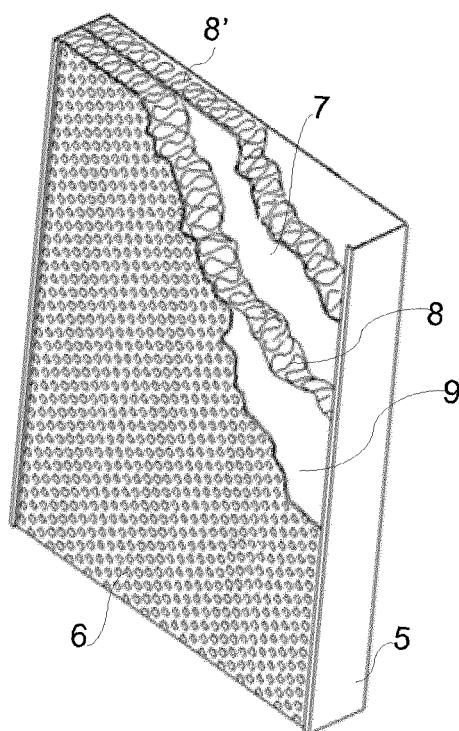


Fig.5

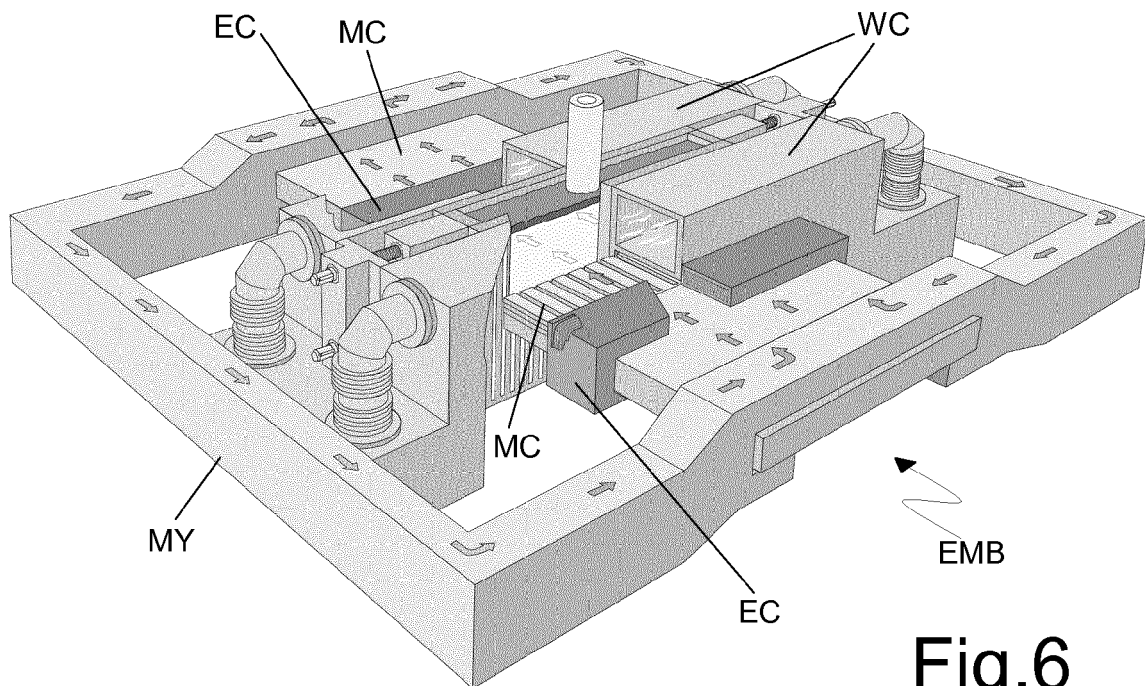


Fig.6

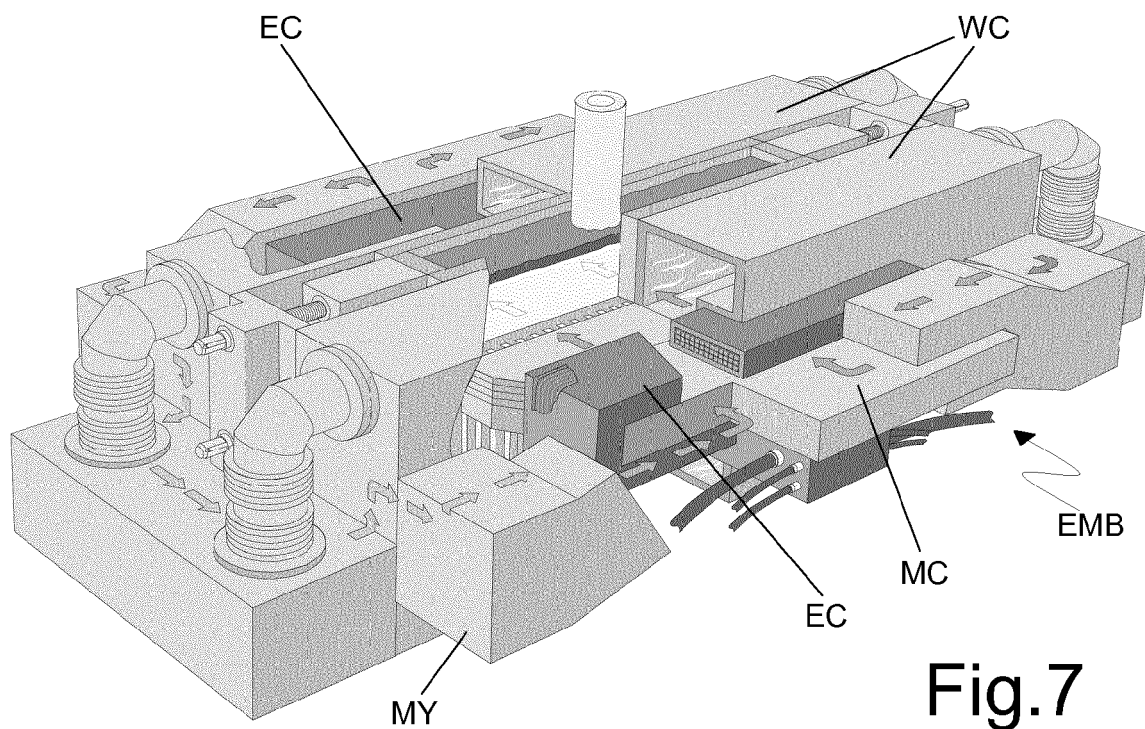


Fig.7

Fig.8

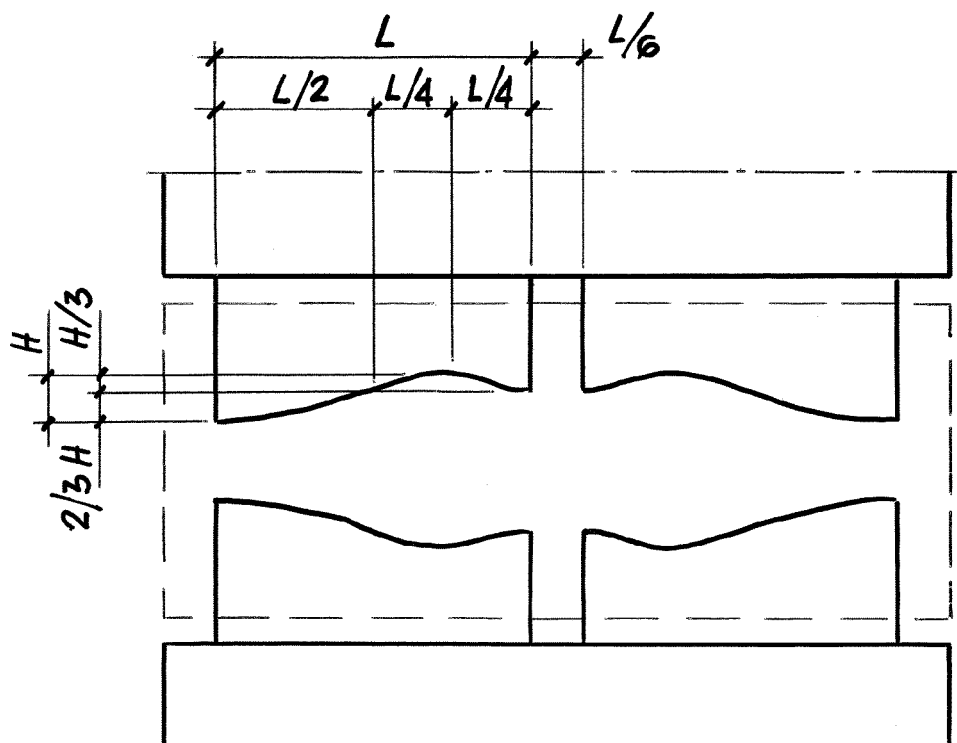
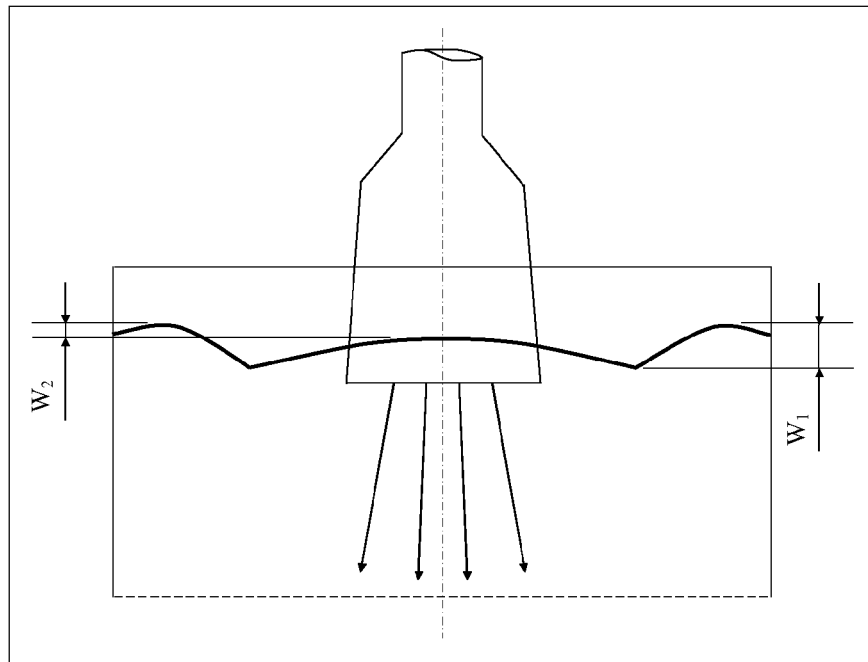


Fig.9

Fig.10

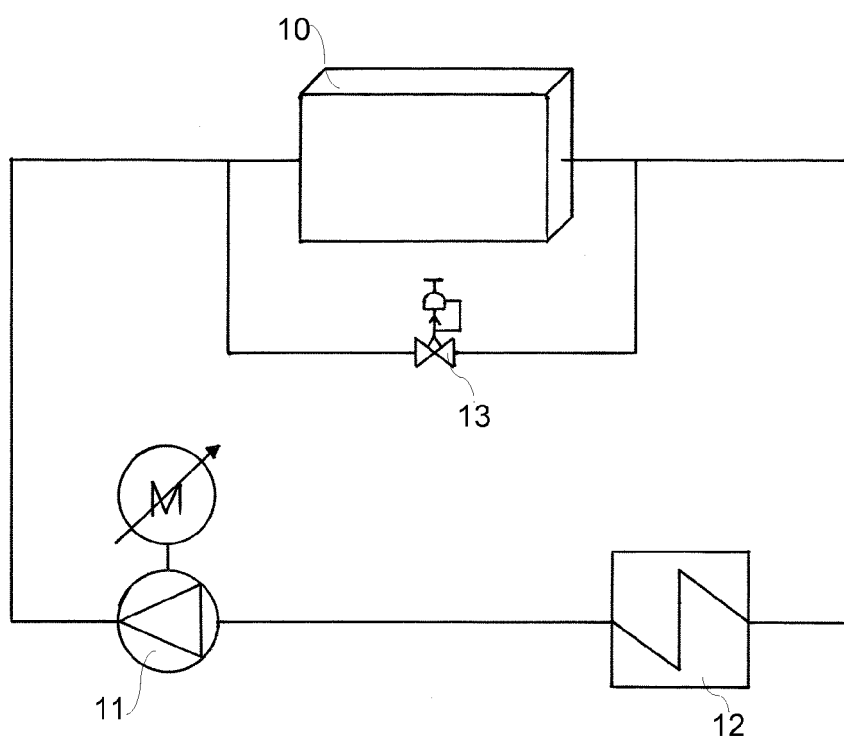
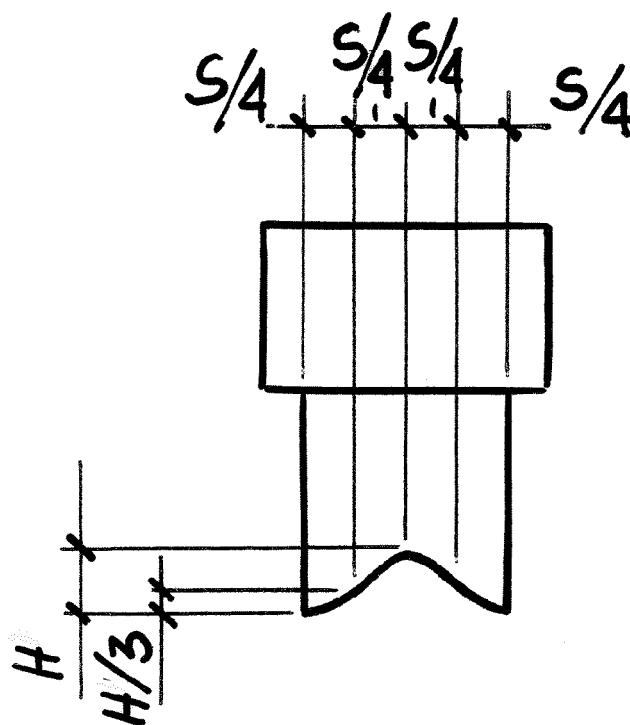


Fig.11



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Place of search Munich		Date of completion of the search 4 February 2016	Examiner Zimmermann, Frank
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