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APPARATUS FOR CONTINUOUS STEEL-MAKING

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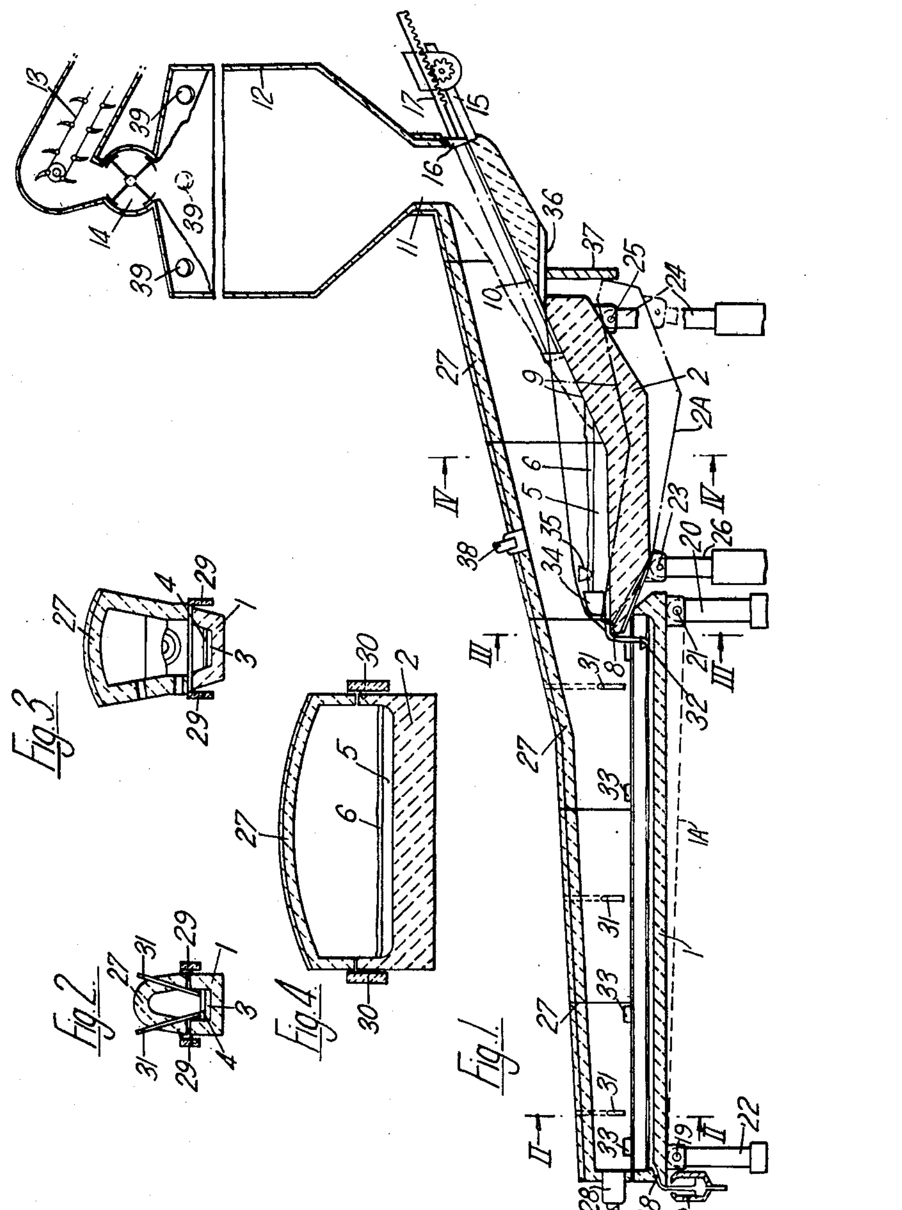

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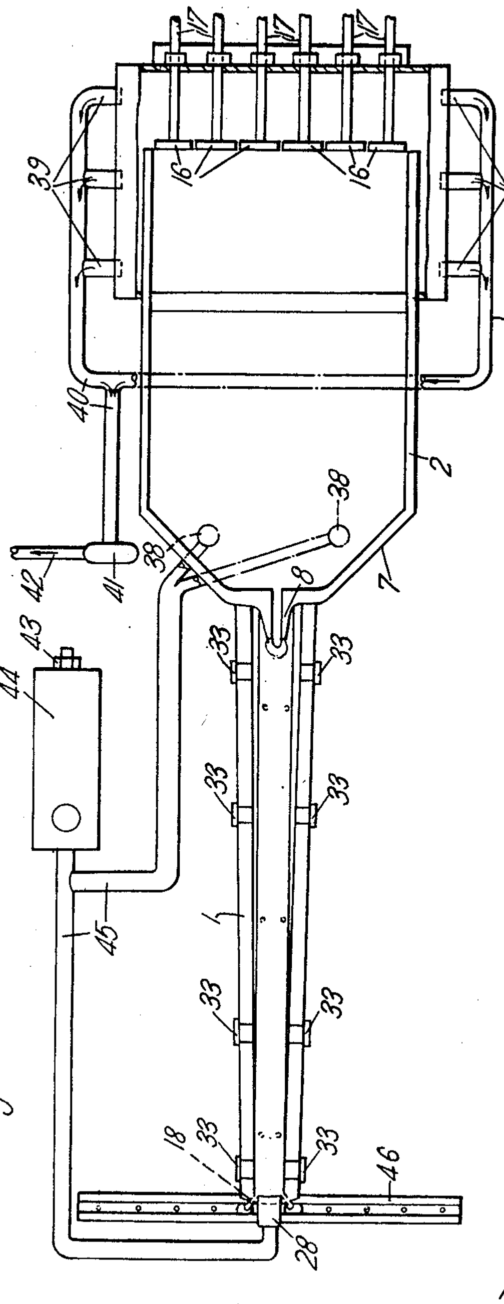

Fig. 5

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APPARATUS FOR CONTINUOUS STEEL-MAKING

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14 Claims. (Cl. 266—11)

This invention relates to continuous steel-making, by the use of a progressively moving refining bath, with the heating gases moving in counterflow and providing waste gases to effect pre-heating of the raw material to be melted and refined, and is concerned with the provision in apparatus for this purpose of hearth apparatus for containing and controlling the flow of molten metal, both the metal initially produced by the melting of the raw ingredients and that metal as then fed to one end of a progressively moving refining bath.

The ideal for absolutely continuous operation of such apparatus is the continuous production of molten metal, followed by its continuous refining, with counterflow of the combustion gases over the refining bath and their subsequent utilisation (with possible augmentation by further combustion gases) to bring the raw ingredients to a molten state and to preheat and prepare them for the actual melting step. In practice, this ideal cannot be achieved, because of the inability of the necessary refractories to remain indefinitely in service under the severe temperature conditions to which they are continually subjected. Thus, continuous tapping from the refining hearth is possible only so long as the tapping hole or holes remain effective, but the time eventually comes when a tapping hole must be fettled, and also the side walls of the hearth, particularly in the vicinity of a tapping hole. Possibly this occurs at a much shorter interval than between fettlings of that bath itself, and could lead to a major shut-down so much earlier than is dictated by the need to fettle the bath.

There is also the question of effecting a change of composition of the ultimate steel. The separation of a run of one composition from a following run of different composition is on the face of it incompatible with truly continuous operation.

One object of the invention is to minimise the effect of these inevitable interruptions, by enabling any of them, when they arise, to be confined to such relatively short interval that, although the ideal of absolute continuity is departed from, the apparatus operates virtually continuously.

Another object is to provide for flexibility of operation as regards change of composition.

Yet another object is to provide for rapid and accurate control over whatever composition is at any time desired.

According to the present invention, apparatus for continuous steel-making comprises an inclined feed channel for the reception of the essential metallic content of the steel to be produced, a refining hearth to which the channel discharges and extending in continuation of the channel, a transverse pivotal mounting for the refining hearth, means for tilting the hearth about its pivotal mounting, at least one tapping hole at the end of the hearth remote from the channel, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch enclosing the hearth and continuing over the channel, at least one burner at the tapping hole end of the hearth and at least one burner near the bottom end of the channel, and an outlet from the top of the feed channel for

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extraction of waste gases from the combustion gases that are thus caused to proceed in counterflow along the hearth and the channel in turn from the burners.

The apparatus provides for the feeding to one end of a progressively moving refining bath in the hearth of the molten metallic content of the steel to be continuously produced, the melting being effected in the channel with the aid of the waste gases leaving the bath serving first to pre-heat the material and then to melt both of them, with supplementary heat from the combustion gases produced over the channel to assist in the melting and the pre-heating.

Advantageously, the axis of the pivotal mounting of the refining hearth is located substantially at the tapping end of the hearth. With the hearth of such a depth that its normal content of metal undergoing refining is retained when the hearth is tilted sufficiently to bare the tapping hole or holes, a tapping hole no longer serviceable can be exposed for repair, as also the sides of the hearth near the tapping hole, before the hearth is returned to working position. Again, if there are two tapping holes, one hole previously in use can be plugged, and an alternative tapping hole can be opened in the same interval during which the hearth is held tilted, after which return of the hearth to working position enables the alternative tapping hole to be brought into use.

The location of the transverse axis at the tapping end of the hearth has the advantage that there is negligible relative movement between the top of the hearth at the tapping end and the bottom of the furnace arch. Since the combustion gases are admitted at the tapping end of the hearth, this negligible movement minmizes the effect of the tilting on the composition of the gases at this final position of the continuous refining, by maintaining substantial isolation of the gases at that end from the outside atmosphere.

The ability of the hearth to be tilted also enables the rate of flow of the tapped steel to be controlled, to counteract enlargement of the tapping hole by erosion. Thus, the tilting may be used to keep the rate of flow constant, as is most usually desirable.

Moreover, by dropping the inlet end of the hearth sufficiently with respect to the tapping end, the content of the bath can be held back when a change of composition is to be made, a return to working position being made when all the conditions for the new composition have been established. Similar holding back may be adopted in accordance with the result of regular analyses performed on the content of the hearth at any point in its length.

The refining hearth is narrow in relation to its length, so as to confine its metal to a steady flow from the end fed by the channel to the tapping end. The channel can be much wider than the refining hearth, since its object is merely to produce and retain a supply of molten metal, and an adequate supply is afforded by a wide channel of relatively short length serving as a fore-hearth. Such a fore-hearth may with advantage be mounted on a transverse pivot near its overflow end, that end overlapping the inlet end of the referring hearth. Such tilting of the fore-hearth can also be used when a change of composition is to be made, by holding back metal entirely from the refining hearth, which could then be completely emptied. At its own inlet end, the fore-hearth is overlapped by the end of an inclined fixed shelf down which pre-heated material passes, the fore-hearth forming a continuation of the shelf and the two together constituting the whole channel along which the essential metallic content of the steel is pre-heated and melted in turn.

The apparatus thus provides for the continuous refining of steel from molten metal continuously produced from material that is pre-heated and melted, with the aid of the waste heat from the refining operation, so that operation is economical in fuel.

The apparatus is flexible both as to the nature of the essential metallic content to be pre-heated, melted, and refined, and as to the composition and quality of the steel produced.

Thus, the channel may be fed with scrap; but if the available scrap includes small material, say less than 4" (100 mm.), the apparatus may also include a vertical shaft for the small scrap, with a waste gas outlet at the top of the shaft. This provides for pre-heating of the small scrap, before it joins the larger scrap, for further pre-heating and eventual melting.

Such a shaft may also be used for pig iron as part of the essential metallic content of the steel, with coke introduced with the pig iron, so that combustion takes place in the shaft.

However, it is most advantageous as regards overall fuel consumption for the shaft to be charged with iron ore or sinter, together with coke (or preferably coal), so that there is at least partial reduction to iron in the shaft, as well as pre-heating. With greatest advantage, the charge to the shaft consists of pellets or briquettes containing finely ground ore and limestone, together with fuel as finely ground coal, or fuel oil, or tar, thus eliminating the cost of metallurgical coke from the continuous steel-making and refining process.

The apparatus is flexible as to the relative proportions of iron ore and scrap for the make-up of the metal to be refined, even to the use of 100% of either. For example, the iron ore may serve to produce 80% of the metal, leaving only 20% to be provided by scrap; and again, the scrap may amount to as much as 95%, leaving only 5% to be provided from iron ore, as more easily melted metal to assist in the melting of the scrap.

It is also possible for the apparatus to be supplied with some molten iron as "hot metal" from a blast furnace; but the most economical operation arises by production of the iron content wholly by reduction of ore in the shaft.

For handling scrap, in any proportion, the apparatus is preferably provided with pushers, movable down the channel. This ensures that, although local melting during preheating may result in some welding together of pieces of the wide range of thickness usually included in larger scrap, the pre-heated scrap is forced to join the highly pre-heated material further down the channel, for its own melting to be completed. Thus, the pushing of one fresh batch of scrap causes previously introduced batches to be pushed progressively onwards, together with material discharging to the channel from the shaft, be that material pre-heated small scrap, pre-heated iron ore that has undergone pre-reduction, or molten iron.

The pre-heating on the channel is performed on the surface of the material lying at its angle of repose in descending from the bottom of the shaft to the floor of the channel leading to the bath, the gases then proceeding up through the charge in the shaft. This surface is extended by the progressive pushing of scrap forming part of the charge, so that pre-heating results from the playing of the waste gases, at substantially their hottest, on an extended surface, immediately after the gases leave the vicinity of the molten mixture produced by them from the pre-heated materials.

The tilting hearth being necessarily independent of the furnace arch above it, and the arch thus not receiving support from the hearth, the arch may be subdivided into sections together making up the length of the hearth, each section being independently supported on the supports provided for the arch as a whole. This enables any section to be relatively quickly replaced by a spare section if localised arch wear takes place, as also for the whole arch to be replaced by a full set of spare sections if the occasion arises. Similarly, the continuation of the arch over a tilting and wider fore-hearth can be formed of further sections, so that by use of the tilting hearths to hold back molten metal temporarily, arch repairs of local character can be carried out with but minor interruptions of the essentially continuous operation of the integrated elements of the entire apparatus.

The tilting of the hearth and its content of metal undergoing refining may be conveniently and accurately effected by gear, such as one or more hydraulic rams, disposed at or near the end remote from the tapping end. Similar gear may be disposed at the tapping end (and possibly intermediately) to enable the whole hearth to be dropped, to be run out transversely and replaced by a spare hearth. Again, only relatively minor interruption arises, and similarly if like provision is made for tilting and running-out of the fore-hearth. Preferably, curtain walls depending from the sides of the arch fit closely to the sides of the refining hearth, to maintain the hearth isolated from the outside atmosphere, when dropped by tilting. There may be similar curtain walls depending from the arch alongside the sides of a tilting fore-hearth.

As will appear in the following description of the accompanying drawings, provision is preferably made for counterflow slag movement along the long and narrow refining bath, with slag removal near the inlet end of the bath. Slag arising from the reduction of the iron ore can be removed just before the molten metal passes from the fore-hearth.

In the drawings:

FIGURE 1 is a longitudinal vertical section of a preferred constructional assembly of tilting refining hearth, fore-hearth (also tilting) and channel, all under a sectionalised arch, ore-reduction shaft, and scrap-charging means;

FIGURES 2, 3, and 4 are transverse arch-and-hearth sections taken respectively on the lines II—II, III—III, and IV—IV of FIGURE 1; and

FIGURE 5 is a plan of FIGURE 1 showing the hearth and fore-hearth with the arch sections removed and the reduction-shaft partly broken away, some ancillary equipment also being shown.

FIGURE 1 shows in operative position both the tilting refining hearth **1** and the tilting fore-hearth **2**, with the dropped positions assumable by each indicated by the broken lines 1A, 2A. In these operative positions, the hearth **1** carries a layer **3** of steel undergoing refining under the influence of a slag layer **4** (see also FIGURES 2 and 3); and the fore-hearth **2** carries a layer **5** of molten metal to be refined, below a layer **6** of slag (see also FIGURE 4). FIGURE 5 shows the hearth **1** to be long and narrow, and the fore-hearth **2** to be much wider than the hearth **1**, but tapering at **7** to a tapping spout **8** that overlies the metal inlet end of the hearth **1**. The fore-hearth **2** holds the metal **5** and slag **6** over only a portion of its length from the spout **8**. Beyond that portion, it slopes at **9** as a continuation of a fixed shelf **10** extending from below the discharge opening **11** at the bottom of a vertical ore-reduction shaft **12**. The shaft **12** is charged with ore, preferably pelletised with limestone and fuel as already described, by a conveyor **13** and a charging device **14** of the rotating pocket type. In continuation of the shelf **10** is a charging platform **15** for steel scrap, across which extend pusher blades **16** operated by rams **17** providing travel for the blades even beyond the lower end of the shelf **10** and on to the fore-hearth slope **9**.

The hearth **1** has two tapping holes **18** for use in alternation, for the continuous discharge of refined steel. Near the holes **18**, the hearth **1** is supported by a transverse horizontal pivot **19**, about which it may be tilted by the operation of a hydraulic ram **20** connected to another transverse pivot **21** at the metal inlet end of the hearth. Dropped to position 1A by the ram **20**, the hearth permits the layer **3**, **4** to run away from the tapping holes **18**, the trough of the hearth being deep enough to contain the greater depth of the layers then formed towards the inlet end by its normal content of metal. In the dropped position of the hearth, both holes **18** are exposed, for the one hole that had up to then been operating and in consequence had become badly cut about by the flow of steel to be plugged, and for the other tap hole to be opened for use. The plugged hole then sinters up on restoraton of the bath to operating level, and can then be opened up for further use later on in the protracted operating run. Repairs to the sides of the hearth 1 can be effected at the same time. The hearth may thus be kept in operation, with but short interruptions for changing from one tap hole to another, until it becomes necessary to run the whole furnace empty for fettling of the hearth, or for replacement of the hearth. Such replacement may be effected by dropping the entire hearth 1 by operation of the ram 20 and a further ram 22 connected to the pivot 19, when the hearth may be run out sideways and a spare hearth run in.

The hearth 2 is similarly tilted about a transverse pivot 23 near the spout 8 by a ram 24 connected to a pivot 25 at the other end, and may be similarly dropped for running out by the additional use of a ram 26 connected to the pivot 23.

Hydraulic tilting and dropping mechanism is only shown by way of example. Motor-driven screw gear can be instanced as one alternative means for these purposes.

The hearth 1, 2 and the shelf 10 are enclosed by arch sections 27 of individual lengths permitting them to be removed from their supports (not shown), they of course having to be supported independently of the hearths because of the freedom the latter must have to tilt. As shown by FIGURES 2 to 4, the sections 27 have a width and height appropriate to the width of hearth below them and the reverberatory functions to be performed on the materials in the hearths.

When in operative position, the hearth 1 has its whole top edge meet the bottom edge of the arch sections 27 at a plane of substantial balance of internal pressure with atmospheric pressure, to minimize filtration of air inwards and of refining gases outwards through the gap between the edges. Curtain walls 29 (FIGURES 2 and 3) depending from the sides of the arch embrace closely the outside of the side walls of the hearth to a depth exceeding the maximum vertical movement of the hearth at the end remote from the tapping end, and serve to isolate the inside of the hearth from the outside atmosphere when the hearth is tilted. Curtain walls 30 (FIGURE 4) serve the like purpose with respect to the fore-hearth 2.

The arch section 27 at the tapping hole end of the hearth 1 has a main burner 28 to produce a flow of combustion gases in counterflow to the movement of the metal layer 3 towards the tapping holes 18.

The refining preferably includes oxygen lancing towards the tapping hole end of the hearth, as by lances 31, with further lances at intervals along the bath. Slag-forming materials are advantageously introduced near the tapping hole end of the hearth, with a slag notch 32 provided near the metal inlet end, so that the slag layer 4 moves in counterflow to the steel layer 3. The slag-forming materials being introduced at the end of the bath where the steel is cleanest, they bring about the highest possible degree of refining of the steel about to be tapped, near the conclusion of the progressive refining resulting from the counterflow movement of the slag towards the other end of the bath from which it is continuously tapped, through the notch 32 and run into a ladle.

The slag-forming materials may be introduced in powder form by the lances 31 for blowing in oxygen or oxygen-enriched gas disposed near the tapping hole. Again, they may be introduced, also in powder form, by a screw-feeder, suitably water-cooled. Yet again, they may be introduced by a shovel or charger that is advanced into the furnace and inverted before being withdrawn, as through one of the inspection doors 33.

From the fore-hearth 2, the molten metal runs from the layer 5 to the spout 8 under a water-cooled slag bridge 34, which holds back the slag layer 6. That layer, formed from materials introduced by way of the shaft 12, moves in the same direction as the layer 6, and is tapped in front of the bridge 34 through a slag notch 35 into a ladle. The notch 35, or an inspection door in the immediate vicinity, may be used for the introduction of a stopper on a water-cooled arm, for interrupting the flow below the bridge 34, as an alternative to dropping the fore-hearth by the ram 24. However, dropping of the fore-hearth is preferred for the interruption of the flow, since the resultant flow backwards along the lowered slope 9 provided for very considerable retention of molten metal over whatever period is required for the interruption of flow to the hearth 1.

When the fore-hearth 2 is raised to operative position, the slope 9 abuts a water-cooled support 36 for the shelf 10. Below the support 36 is a curtain wall 37 to provide a shield when the fore-hearth is dropped.

A slag bridge similar to the bridge 34 may also be positioned near to the tapping holes 18 of the hearth 1.

It is possible for the ram 20 to be used to drop the refining hearth 1 slightly, to hold the charge of molten metal for a longer period of subjection to the refining influences (slag, oxygen, etc.), as may be found necessary as the result of regular analyses performed on the steel at the tapping hole end of the hearth, for example by continuous arc-vacuum spectrometer through which is taken a sample small-diameter continuously cast bar, to enable a change of composition to be noted in a very short time, say 30 seconds.

In general, however, the operation proceeds by way of a steady flow of steel to the tapping hole end, and adjustments found by analysis to be necessary can be made by controlling the rate of oxygen admission at any of the lances 31, and by making appropriate additions of iron oxide or carbonaceous material to the slag layer 4, as also to the steel layer 3, to which additions of other metallic materials, e.g., manganese, silicon, aluminium, or cobalt, may similarly be made. Preferably, all such additions are performed automatically from an analysis of such regular character as to be virtually continuous. Thus, the results of analyses at both ends of the hearth 1 may be fed to a computer, which can serve in turn to control the feed of slag-forming powder, the amount of oxygen, and the oil supply to the burner 28.

Further burners 38 play on to the molten metal in the fore-hearth 2 and on to material approaching melting point on the slope 9. Their combustion gases are added to those from the burner 28, which of course carry with them fume resulting from the operation of the lances 31. After serving to pre-heat material on the slope 9 and the shelf 10 towards melting point, the combined gases progressively pre-heat all the material, including scrap, on the shelf and complete the reduction of the iron ore, before effetcing the major reduction in the shaft 12, with resultant pre-heating of the charge before it issues from the shaft outlet 11. Since the fume in the waste gases is carried through the shaft 12, it is deposited on the material undergoing pre-heating and reduction, with the double advantage of retaining its iron content in the system for return as part of the iron to be melted, and of avoiding air pollution or the need for elaborate precipitation plant.

The shaft 12 converts the CO_2 of the waste gases into CO, and thus producer gas of substantial calorific value is available at the top of the shaft. This is extracted by pipes 39 and led by ducts 40 to a wet cleaner extractor 41, and then by a duct 42 to a gasholder (not shown). This gas, or other gas or fuel oil, may be fed to a burner 43 of an air pre-heater 44 for the supply of high-temperature combustion air, at say 600° C., by ducts 45 to the burners 28, 38.

The continuous production of steel in the above integrated equipment lends itself to further integration with a continuous casting process, the refined steel leaving the bath 1 to pass direct to a continuous casting plant. Thus, a tundish **46** below the tap holes **18** can be mounted to deliver its content of molten steel at the rate required for one or more streams feeding the mould or moulds of the continuous casting plant.

What I claim is:

1. Apparatus for continuous steel-making comprising an inclined feed channel for the reception of the essential metallic content of the steel to be produced, a refining hearth to which the channel discharges, the hearth extending in continuation of the channel, a transverse pivotal mounting for the refining hearth, means for tilting the hearth about its pivotal mounting, at least one tapping hole at the end of the hearth, remote from the channel, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch enclosing the hearth and continuing over the channel, at least one burner at the tapping hole end of the hearth and at least one burner near the bottom end of the channel, and an outlet from the top of the feed channel for extraction of waste gases from the combustion gases that are thus caused to proceed in counterflow along the hearth and the channel in turn from the burners.

2. Apparatus for continuous steel-making, comprising an inclined pre-heating and melting channel, a refining hearth in extension of the channel and much narrower than the channel, a transverse pivot mounting for the hearth at its end remote from the channel, means for tilting the hearth about the pivotal mounting, at least one tapping hole at the pivot end of the hearth, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch over the hearth and continuing over the channel, at least one burner at the pivot end of the hearth and at least one burner in the arch continuing over the channel, and an outlet at the top of the channel for waste gases from the burners.

3. Apparatus for continuous steel-making comprising an elongated refining hearth, a transverse pivotal mounting for the hearth, means for tilting the hearth about the pivotal mounting, a plurality of tapping holes for alternate use at one end of the hearth tilting of the hearth in one direction bringing the holes to exposed position so that one may be opened and the other closed and in the other direction returning the holes to submerged position, a pre-heating and melting channel discharging to the other end of the hearth, an arch over the hearth and continuing over the channel, burners directed over the hearth and the channel, and a waste gas outlet at the end of the channel remote from the hearth of waste gases that have proceeded over the hearth and the channel.

4. Apparatus as in claim 3, comprising curtain walls depending from the sides of the arch and fitting closely to the sides of the refining hearth.

5. Continuous steel-making apparatus comprising an inclined channel consisting of an inclined shelf and a fore-hearth to which the shelf discharges, a refining hearth longer and narrower than the fore-hearth to which the fore-hearth discharges, a transverse pivotal mounting for the refining hearth at its end remote from the fore-hearth, means for tilting the refining hearth about its pivotal mounting, at least one tapping hole at the pivoted end of the refining hearth, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch over the refining hearth and continuing in widened form over the fore-hearth and the shelf, burners directed to the refining hearth and the fore-hearth, and a waste gas outlet at the top of the shelf for gases passing from the burners along the refining hearth and then along the fore-hearth and the shelf.

6. Apparatus as in claim 5, comprising a transverse pivotal mounting for the fore-hearth.

7. Apparatus as in claim 5, comprising a transverse pivotal mounting for the fore-hearth, and curtain walls depending from the sides of the arch and fitting closely to the sides of the fore-hearth.

8. Continuous steel-making apparatus comprising a vertical shaft, an inclined pre-heating and melting channel to which the shaft discharges, a refining hearth in extension of the channel to which the channel discharges, a transverse pivotal mounting for the refining hearth, means for tilting the hearth about its pivotal mounting, at least one tapping hole in the hearth at the end remote from the channel, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch over the hearth and continuing over the channel to the bottom of the vertical shaft, burners directed to the hearth and to the bottom of the channel, and a waste gas outlet from the top of the vertical shaft.

9. Apparatus as in claim 8, comprising means for charging to the top of the vertical shaft steel-making material to be subjected at least to pre-heating in the shaft.

10. Apparatus as in claim 8, comprising pushers, movable down the channel, to force pre-heated material down the channel, including material discharging to the channel from the shaft and scrap charged in front of the pushers.

11. Continuous steel-making apparatus comprising an elongated refining hearth, a transverse pivotal mounting for the hearth, means for tilting the hearth about the pivotal mounting, an arch over the hearth, the arch being formed in removable sections supported independently of the hearth, at least one tapping hole in one end of the hearth, at least one burner at that end of the hearth, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, a pre-heating and melting channel discharging to the other end of the hearth, the arch continuing over the channel and at least one burner directed to the bottom of the channel, and a waste gas outlet from the arch at the top of the channel.

12. Apparatus as in claim 11, wherein the portion of the arch over the channel is formed as removable sections.

13. Apparatus as in claim 11, wherein the channel is formed as a shelf and a fore-hearth to which the shelf discharges, the portion of the arch over the fore-hearth being formed in removable sections supported independently of the fore-hearth.

14. Continuous steel-making apparatus comprising an inclined pre-heating and melting channel, a refining hearth to one end of which the channel discharges, a transverse pivotal mounting for the hearth, means to tilt the hearth about the pivotal mounting, at least one tapping hole at the end of the hearth remote from the channel, tilting of the hearth in one direction or the other bringing such hole to submerged and exposed positions respectively, an arch extending over the hearth and continuing over the channel, at least one burner at the tapping hole end of the hearth and at least one burner at the bottom of the channel, means for introducing slag-forming material near the tapping hole end of the hearth, means for extracting towards the other end of the hearth slag thus constrained to move in counterflow along the hearth, and a waste gas outlet at the top of the channel for gases proceeding from the burners along the hearth and the channel in turn.

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