Oct. 22, 1963 M. O. SEM ET AL 3,108,150

SEMI-ENCLOSED SMELTING FURNACE AND METHOD OF OPERATING SAME

Filed Oct. 11, 1960 3 Sheets-Sheet 1

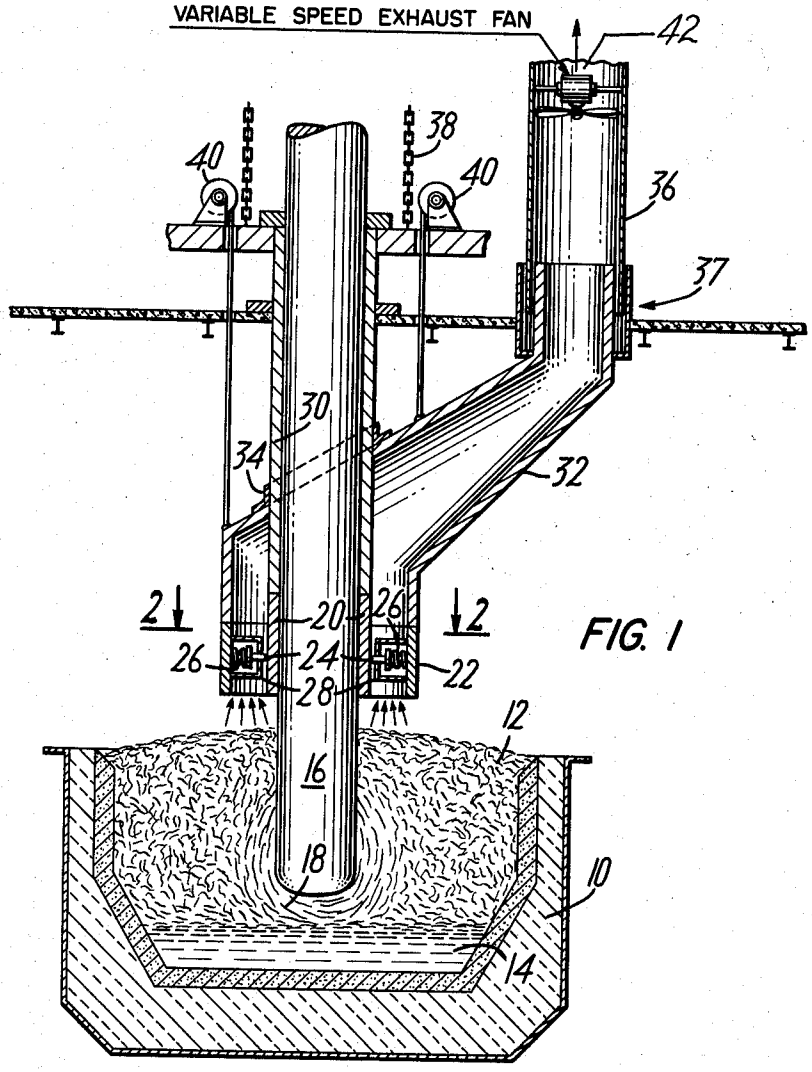


FIG. 1

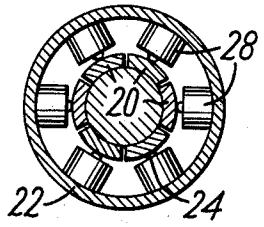


FIG. 2

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Filed Oct. 11, 1960 3 Sheets-Sheet 2

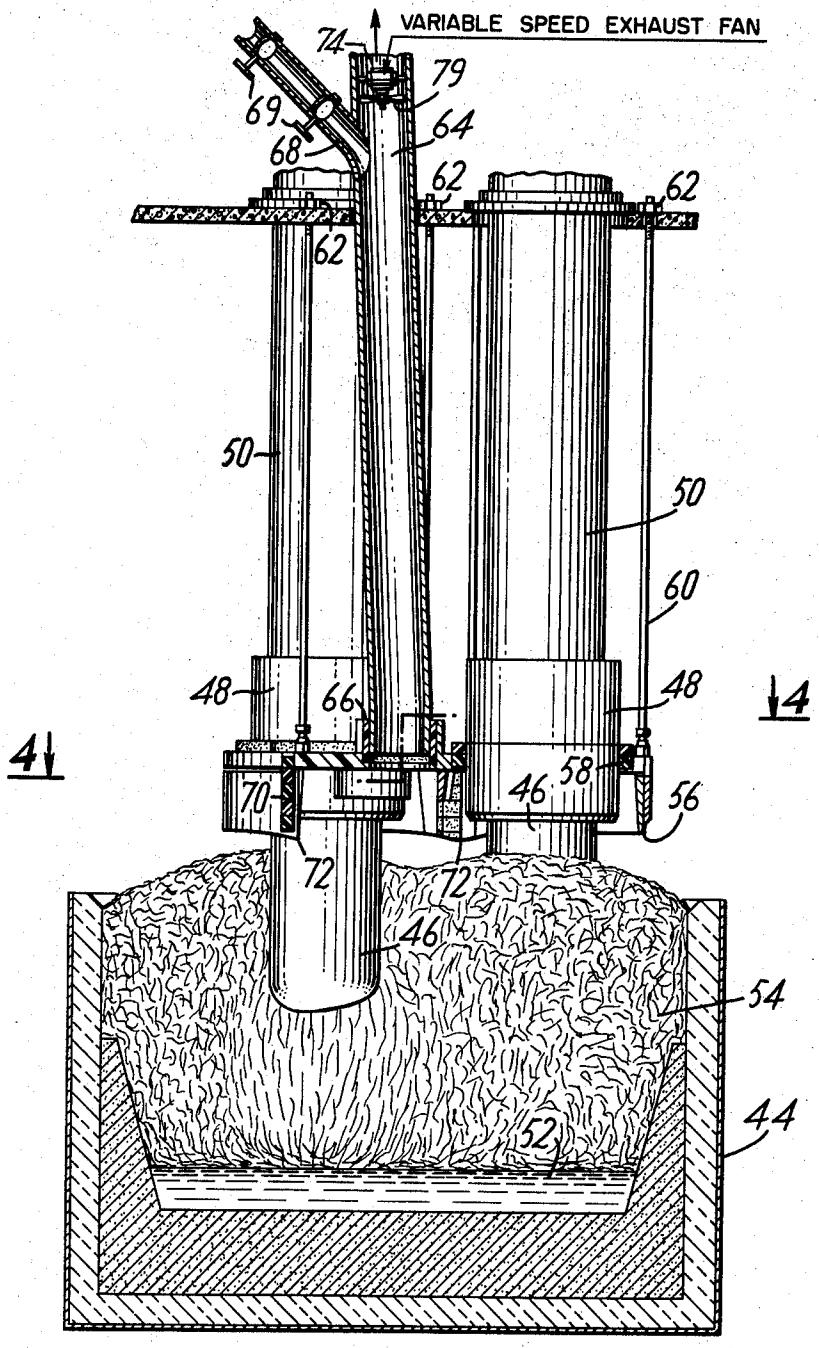


FIG. 3

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SEMI-ENCLOSED SMELTING FURNACE AND METHOD OF OPERATING SAME

Filed Oct. 11, 1960 3 Sheets-Sheet 3

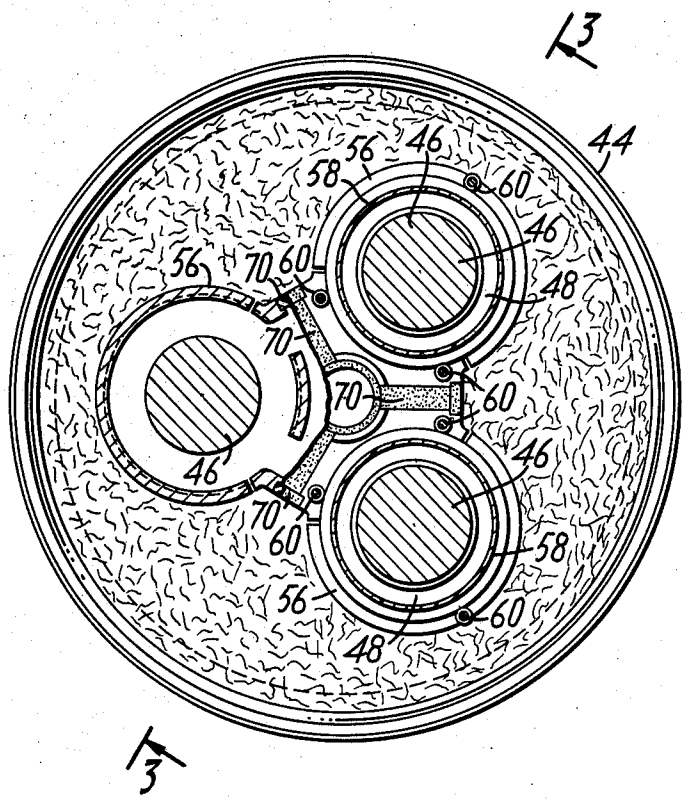


FIG. 4

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United States Patent Office 3,108,150 Patented Oct. 22, 1963

3,108,150

SEMI-ENCLOSED SMELTING FURNACE AND METHOD OF OPERATING SAME

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Filed Oct. 11, 1960, Ser. No. 61,965
Claims priority, application Norway Oct. 15, 1959
5 Claims. (Cl. 13—9)

This invention relates to open electric smelting furnaces of the type in which one or more (usually three) electrodes go down into a furnace pot and the charge is deep enough to surround such electrodes for a substantial part of their length. The particular feature of novelty of this application is the arrangement made for collecting gas and dust from such furnaces, without having the furnaces fully enclosed. To accomplish this end we provide the furnace with a tool member which surrounds each electrode and through which the electrode may move, the hood member extending out a substantial distance from the electrode. It may for example have an internal diameter which ordinarily should not be less than about one and one-half times the diameter of the electrode and may be substantially greater, though it should not be large enough to cover the entire furnace pot and interfere with the charging and stoking. Only in rare cases will it be necessary to have the hood member extend out from the electrode a distance greater than the radius of the electrode. The hood member preferably is made movable relative to the electrode and suspension mechanism is provided so that the hood member ordinarily will be held above the charge but the exact position of the hood member should be capable of being varied according to the desires of the operator. For example it may be adjusted so that it may just contact the charge if the operator wishes, though ordinarily this not desirable. In cases, as in the production of ferrous alloys, where coarse scrap iron is used as a raw material there is danger that the chamber wall will be damaged if it contacts the charge and forms a short circuit between the electrode and the chamber wall.

With the hood member thus arranged above the charge and covering an area appreciably less than the entire surface of the charge it might be assumed that one would either lose considerable quantities of gas or risk introduction of air so that a part of the valuable CO gas generated in the furnace would be burned and the valuable gases unduly diluted. We have discovered however, that by suspending the hood member so that it is movable vertically relative to the charge, and by adjusting the suction on the hood member as later described, one can adjust the distance between its lower rim and the charge surface proportionately to the evolution of gas so that only a negligible part of the furnace gas will be burned by air which is sucked in below the rim of the hood member.

It is known that gas from electric smelting furnaces carries with it large amounts of dust. If this dust is released into the atmosphere it may be injurious and usually the dust also represents substantial values and this recovery may be of importance to the economy of the process. We have found that as much as 80% of the gas is evolved immediately around the electrode and that using a hood member of the dimensions specified, substantially all this portion of the gas can be captured. We have also found that this 80% of the gas carries between 90 and 95% of all the dust escaping from the furnace. The dust particles are appreciably larger than those released from a furnace where the gas burns on the surface. In fact, the dust particles may be from 10 to 12 times larger in an unburned gas than in a burned

gas. This means that it is considerably simpler to remove the dust from the gas which is collected by our arrangement.

The reason why the gas escaping around the electrode carries so much dust is that practically all eruptive escape of furnace gas (known as blowing) takes place near the electrode. During blowing open channels are formed in the charge through which the dust is carried off by the violent gas currents whereas in the marginal portions of the furnace the gas escapes with relative even distribution and without much pressure and the dust will be filtered out as the gas passes through the charge layer. This marginal gas will therefore burn at the charge surface with small flames which usually have a blue or dark yellow color. The temperature of the flame is low and the dust content of this gas is relatively insignificant. The gas escaping near the electrode has, as mentioned above, relatively high pressure and also is under such a high temperature that if it is allowed to burn it will burn with an almost white flame and, as stated, it also carries the greater part of the dust. Thus, even if the hood member is of such size or so adjusted that a reasonable peripheral portion of the furnace is not protected so that part of the gas is burned at the charge surface, this ordinarily will not cause any appreciable dust trouble in the furnace room or in the surrounding atmosphere.

With a device of this kind, particularly where the hood member is hung above the charge so that there is an open space below the edges of the hood member through which gases can pass either in or out, adjustment of the gas quantity sucked through hood member is an important feature of our invention. If the exit pipe becomes clogged or if the frictional resistance of this pipe is enough to create any appreciable back pressure a large proportion of the gases will otherwise simply flow out from under the sides of the hood and in this respect our invention differs substantially from devices where the edges of the hood member are largely or partially sealed as by being packed in the charge so that virtually no gas can escape under such edges. If the gas quantity exhausted through the hood member is too high an undue suction will be created around the sides of the hood and substantial quantities of air may be drawn in which will burn and defeat the purpose of the invention. It is therefore important that mechanism be supplied for controlling the gas quantity in the exhaust pipe from the hood member. The precise nature of this mechanism is unimportant and may simply consist of an exhaust fan preferably with variable speed control. The fan may be located anywhere in the exhaust system though we have found that it is often advantageous to maintain the desired amount of gas through the gas scrubbing equipment and in that case the exhaust fan is applied to the gases after the solids have been removed and the gas cooled so that substantial constant measuring conditions are maintained.

With a furnace of this type the quantity of gas developed will vary with the furnace load and we have found it important to adjust the gas quantity exhausted from the hood member so that an amount of gas will be drawn off which ordinarily will be about equal to or slightly less than the theoretical amount of gas generated according to the furnace load. For example we have found that smelting furnaces of the type referred to, which may be termed semi-enclosed furnaces, in which the hood member has a diameter such that it is spaced about 20 cm. from the electrode and by adjusting this hood member at a level where its lower rim is about 15 cm. above the charge, by adjusting the exhaust fan so that approximately 80% to 90% of the total gas production is drawn off through the hood member, a reduc-

ing gas can be collected which has a composition comprising from 50% to 80% CO and which contains some 95% of the total dust escaping from the furnace. The factor of setting the fan to draw off from about 80% to 90% of the theoretical gas generated is desirable but is not in itself critical. Conditions should be adjusted according to the porosity of the charge and the type of production. However, the setting should be such as to draw off between 70% and 100% of the theoretical amount of gas. By controlling the amount of gas sucked off within these limits the furnace can be operated with virtually no air sucked into the system under the edges of the hood member and relatively little gas will escape out from under the edges of the hood member, though, of course, gas may escape from the portion of the charge not covered by the hood member.

In computing the amount of gas to be exhausted from the hood member it will ordinarliy be found advisable to compute the exhaust volume of gas at constant temperature and this ordinarily can be done most advantageously after cooling the gas, that is in the clean gas pipe where there will be virtually constant measuring conditions.

It would be natural to assume that control of the gas exhaust with regard to constant quantity would not present any advantages, as the gas production in a smelting furnace is not even. However, experiments have shown that the gas production is much more constant than generally believed. The variations are found in the temperature of the gas collected inside the hood whereas there is little variation in the actual amount of gas. If the furnace blows the gas temperature will increase very much which will increase the actual volume of the gas at that temperature. However, the volume at constant temperature will remain unchanged. In order to collect the same amount of gas at the same temperature the gas velocity in the hot part of the hood and the exhaust gas pipe will increase automatically. Therefore, the system is automatically adjusted to conditions. The kw.-load on the furnace has however an important influence on the quantity of gas developed and the amount of gas exhausted should therefore be adjusted according to the actual furnace load. Ordinarily this will not necessitate frequent adjustments as the furnace is usually operated with a constant load for long periods, but of course adjustments in the amount of gas drawn off can be made where the load varies to any great extent.

In a semi-enclosed furnace of the type to which this invention relates, a possible increase or reduction in the development of gas will not have as important consequences as one might imagine. If the gas quantity increases above the values to which the instruments are adjusted some gas will have to escape the hood and burn with steady flames at the open surface of the charge. This gas will carry little or no dust and metallurgical fumes since most of the solid constituents will be filtered out as explained above. Also, as already pointed out, it has been proved that most of the dust is carried off by the gases escaping through the smelting crater around the electrode where the actual reduction takes place and where consequently the gas quantity and gas pressure are highest. An increase of the gas quantity resulting in some gas escaping from the collecting arrangement will therefore not cause difficulties for the furnace crew or the surroundings.

On the other hand, if the gas quantity should decrease below what is stipulated some false air will be drawn into the gas chamber and some of the gas will be burned. The combustion gas will however, itself, increase the volume of the gas to be exhausted so that virtually an automatic adjustment and self-compensation will be attained. It will also require a considerable deficiency of gas to cause the development of sufficient heat from the combustion of gas to have a detrimental effect on the equipment. The gas production may decrease to from 75% to 80% of the normal without detrimental effects other than reduction in gas quality due to partial combustion.

From the above it follows that the constant exhaust amount may be adjusted somewhat lower than what corresponds to the gas quantity produced at the actual furnace load, and applicants have found, as stated above, that good results can be obtained by adjusting the gas suction at from 70% to 100% of the average gas production with preferably from 80% to 90% being taken off.

This invention of exhausting a constant amount of gas per time unit is particularly useful in connection with semi-enclosed furnaces and may be used in furnaces where the hoods are located above the charge as well as in furnaces where the edge of the hood is embedded in the charge. In many cases it can even be used advantageously with fully enclosed furnaces instead of following the usual practice of operating at a slight plus pressure. The amount of gas may be controlled by volume as well as by weight.

By thus drawing off the major portion of the gas and by adjusting the suction so that normally little or no air is drawn into the system to cause combustion, it is possible to obtain a reducing gas with a CO content of from 50% to 80% which may be burned in order to utilize its combustion value. It will also be found that the amount of gas collected amounts to only from 5% to 15% of the volume of gas that escapes from an ordinary open furnace where the gas is burned and thereby is enormously diluted. The expense for gas cleaning is greatly reduced by keeping the gas in concentrated form and at the same time the gas may be used for other valuable purposes as for example the gas may be burned under a waste heat boiler for production of steam.

It is further advantageous that the hood member be movable vertically as this may become important during charging or stoking operations or for the removal of electrode fragments or the like. It will be noted that since the hood member is associated with the electrodes and may be held above the charge sufficiently so that the edge is not embedded in the charge this device may permit the use of rotatable furnaces where the furnace pot and charge are rotated in relation to the electrodes and the gas collection equipment.

The hood member may be so mounted that it will permit free vertical movement of the electrode and electrode holder through it or it may be caused to move with the electrode holder to follow the movements of the electrode during normal operation. Such electrode movements ordinarily are of such limited scope as not to have much influence on the spacing between the lower rim of the hood member and the charge. Even if the hood member moves with the electrode it is desirable to arrange so that relative movement can be had for charging the electrode, making repairs or the like.

An advantage of arranging the hood member so that it moves with the electrode is that it may serve as a pressure ring for usual contact clamps. In such case the pressure is transferred to the contact clamps by means of pressure members inserted through the gas chamber found within the hood member. This has the advantage that the gas can rise freely within the gas chamber with relatively little obstruction to cause combustive dust and clogging.

It is not necessary that the hood member be arranged symmetrically around the electrode and since the pipe for exhausting the gas from the hood member ordinarily must come off from one side it may be advantageous to have the spacing between the electrode and hood member wall smaller in that area adjacent which the gas is exhausted. For a similar result it is possible to make the lower wall of the hood member slope slightly so that the hood member may approach closer to the charge (or may even penetrate the charge slightly) in the area below the gas exhaust pipe.

As mentioned hereinabove, the diameter of the hood member should be at least about 1½ times the diameter of the electrode. This means that the open gas withdrawal area which is circumscribed by the hood member immediately around the electrode and above the charge in the pot should have a minimum open area of at least about 1¼ times the cross-sectional area of the electrode, so that combustible gas generated in the furnace may be exhausted or withdrawn through such open area in accordance with the method of our invention.

For the purpose of simplicity the foregoing discussion of our invention has been directed primarily to a furnace with a single electrode. In three-phase electric smelting furnaces with electrodes in triangular position it is known that one more or less continuous furnace crater is formed shaped as a clover-leaf. In such case the main quantity of gas is known to be developed near the electrodes. Considerable quantities of gas are also developed in the central part of the furnace between the electrodes. With this type of furnace it is advantageous to have a single hood member which itself may be of clover-leaf shape which will surround all three electrodes and cover the continuous smelting crater as completely as possible. In such case it is advisable to have the pipe from which the gas is exhausted in the central part of the furnace and it has also been found advisable to have one or more charging tubes for introducing the charge into the furnace pass through the hood member. It has been found that by having a single chamber for all three electrodes the regularity of production of gas is equalized among the three and by mixing the gas developed from the three electrodes under a common hood member with common exhaust, large variations in gas temperature will be avoided and the gas exhaust can be adjusted so that it will more closely approximate 100% of the gas evolution than can be done with three separate gas chambers.

Our invention can readily be understood by reference to the accompanying drawings in which

FIG. 1 is a vertical section through a single phase furnace with one electrode, one hood member and one exhaust pipe.

FIG. 2 shows a horizontal section along the line 2—2 of FIG. 1.

FIG. 3 shows a vertical section through a three-phase furnace with a single hood member for all three electrodes.

FIG. 4 shows a horizontal section along the line 4—4 of FIG. 3.

In the form of furnace shown in FIGS. 1 and 2, **10** is the smelting furnace, **12** is the solid charge and **14** is the molten bath. **16** is the electrode and ordinarily below the electrode a hollow space or crater is formed as indicated at **18**. It is known that if the charge is not sufficiently porous the gas pressure in a crater such as shown at **18** can become high enough so that it will burst through the charge causing the furnace to "blow" as described above, carrying with it substantial amounts of dust.

The numeral **20** indicates contact clamps for holding the electrode and **22** designates the hood member which in this case serves as a pressure ring. Pressure can be transmitted from the pressure ring to the contact clamps by bolts **24** operated by springs **26**. The spring pressure is, for example, adjusted by means of a screw device which can be inserted through an opening in the chamber wall. This opening may be covered by a lid or the like to prevent dust from reaching the spring housing **28**. While details of this construction are not illustrated they may follow closely the form of construction illustrated in U.S. Patent 2,949,496 though in this case it will ordinarily be found advantageous to use coil springs which that patent suggests may be used. The contact clamps **20** are connected with the suspension casing **30** which should be water cooled. The supply of current to the clamps is made in usual manner as by usual water cooled copper pipes not here shown.

The hood member **22** merges into the gas pipe **32** which is sealed against the suspension casing as indicated at **34**. In the illustrated embodiment the hood member **22** and exhaust pipe **32** ordinarily will move with the electrode and the movable pipe **32** is therefore connected with a stationary pipe **36** in any desired way as by the water seal indicated at **37**. The hood member **22** and pipe **32** are here shown as suspended from the electrode suspension mechanism indicated at **38** but separate winches indicated at **40** may be supplied so that the pipe **32** and hood member **22** may be raised or lowered relative to the electrode.

As previously pointed out the gas is preferably exhausted through pipe **32** by a fan. Such a fan which is intended to have variable speed control is indicated at **42**. For the purpose of convenience this is shown in the pipe **36** though it may be positioned much further along in the apparatus and even be arranged beyond the gas scrubbing equipment, not shown. For practical reasons the fan may be arranged beyond the scrubbing equipment so that it works on a gas which is cooled to a substantially constant temperature.

In FIGS. 3 and 4 the smelting furnace is indicated at **44** and the electrodes at **46**. This is a three-phase furnace and the electrodes are in the usual triangular arrangement as shown in FIG. 4. The electrodes **46** are suspended from the current carrying holders **48** which in turn are suspended by means of the suspension casings **50**. **52** is the melt collecting on the bottom of the furnace and **54** is the solid charge covering the molten bath. A clover-leaf shaped hood member **56** surrounds all three electrodes and covers the central part of the furnace. This hood member **56** is electrically insulated from the electrode holders and sealed against these by means of the insulating packings **58**. The electrodes **46** can be moved up and down in relation to the hood member by means of usual electrode winches which are not shown in the drawings. The hood member **56** is movably suspended by means of the rods **60** which may be supplied with threaded members **62** or other device for raising and lowering the rods in order that the distance of the hood member from the charge surface can be varied during operation. It is understood that this is merely intended to be illustrative of the possibility of making the height of the hood members adjustable as any desired form of mechanism for doing so may be employed.

The gas is led away from the central part of the hood member through the pipe **64** which is located in the central position between the electrodes. As shown at **66** a slip joint is provided between the pipe **64** and the hood member so that the hood member may be moved vertically.

Preferably a branch pipe **68** is provided, equipped with appropriate locks or other means for preventing escape of gas indicated at **69** through which a portion of the charge may be introduced. Such charge is desirably introduced into the central part of the furnace and it has the added advantage that coarse material on falling freely down the pipe **64** will tend to carry along precipitated dust and the like and clean the pipe.

Preferably the hood member **56** is divided into three sections as shown, one for each electrode. These sections preferably are electrically insulated from each other as indicated at **70** so as to prevent the flow of current from one electrode to another in case of short circuiting between the electrode and the hood member. As indicated at **72** the portions of the hood member which are near the central part of the furnace may be made to extend down slightly further than the portions further out. This will result in a better suction in the parts of the hood member further away from the gas exhaust pipe. In

this example the exhaust means is indicated by the fan 74 which also should have a variable speed control.

Summing the matter up, in accordance with the present invention, we provide an electric smelting furnace having a furnace pot into which one or preferably three electrodes penetrate and which is adapted to hold a charge in which the electrodes are embedded. Above the charge we hang a hood member which preferably is held above the charge but in any event is not sufficiently embedded in the charge to prevent air or gas passing under its edge. This hood member is provided with variable means for exhausting gas from the hood member and in normal operation so long as the load on the furnace remains substantially fixed, the amount of gas exhausted is kept substantially constant at constant temperature. In such case even if temporarily the gas volume is increased due to blowings of hot gas or there is produced less gas, such excess or deficiency will be compensated by gas or air passing one way or the other under the edge of the hood member. If there is an excess of gas such gas will burn outside the hood member and if there is a deficiency the air drawn in will burn and the combustion gases will make up the deficiency.

Operating in this manner gas of high concentration and value can be collected from the furnace and at the same time the release of substantial quantities of gas and dust into the furnace room or into the atmosphere is largely prevented. In this way many of the advantages of a closed furnace are obtained but since the edge of the hood member should not extend out to cover the entire furnace pot ready access is had to the furnace for stoking and charging. In the case of a three phase furnace having three electrodes, it is desirable that the principal amount of gas be exhausted from a middle point and it is also advisable that means be provided for introducing charge into the area between the electrodes.

It is to be understood that the examples given are intended only by way of illustration and our invention may be modified in many particulars and with the use of various specific types of apparatus.

What we claim is:

1. The method of operating a semi-enclosed smelting furnace of the type having a pot adapted to receive a charge and an electrode adapted to enter and smelt such charge which comprises suspending above the charge only a single hood member which immediately circumscribes around the electrode and above the charge an open gas withdrawal area, the open area of which is at least about 1¼ times the cross-sectional area of the electrode but less than the entire area of the charge in the furnace pot, adjusting the height of such hood member above the charge so that air and combustible gas generated in the furnace pot can pass under the edge of said hood member, withdrawing through said hood member between about 70% to 100% of the average amount of gas generated in the furnace pot, and changing the height of the edge of said hood member and the rate of gas withdrawal in proportion to a change in the amount of gas generated in the furnace to establish a substantially constant rate of withdrawal of gas whereby only negligible combustion of such gas by small amounts of air which may be sucked in under the edge of said hood member can take place during furnace operation.

2. A method as specified in claim 1 in which charge is dropped through said hood member into the furnace pot.

3. A method as specified in claim 1 in which the amount of gas sucked off is between 80% and 90% of the average amount of gas generated.

4. In a semi-enclosed furnace of the type having a furnace pot adapted to receive a charge, and an electrode adapted to extend down into the furnace pot and smelt the charge, the improvement which comprises only a single hood member circumscribing immediately around the electrode and above the charge in the pot an open gas withdrawal area, the open area of which is at least about 1¼ times the cross-sectional area of the electrode but less than the entire area of the charge in the furnace pot, means for withdrawing through said hood member combustible gas generated in the furnace pot during smelting operations, first adjustment means for varying the height of the edge of said hood member above the charge and second adjustment means for varying the rate of withdrawal of gas through said hood member, said two adjustment means permitting change of height of the edge of said hood member and change of the rate of gas withdrawal in proportion to a change in the amount of gas generated in the furnace pot to establish a substantially constant rate of withdrawal of gas in amounts ranging from between about 70% to 100% of the average amount of combustible gas generated in the furnace pot whereby only negligible combustion of such gas by small amounts of air which may be sucked in under the edge of said hood member can take place during furnace operation.

5. A structure as specified in claim 4 in which the outer wall of the hood member is arranged to slope down more closely to the charge in the areas most close to the exhaust means.

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