

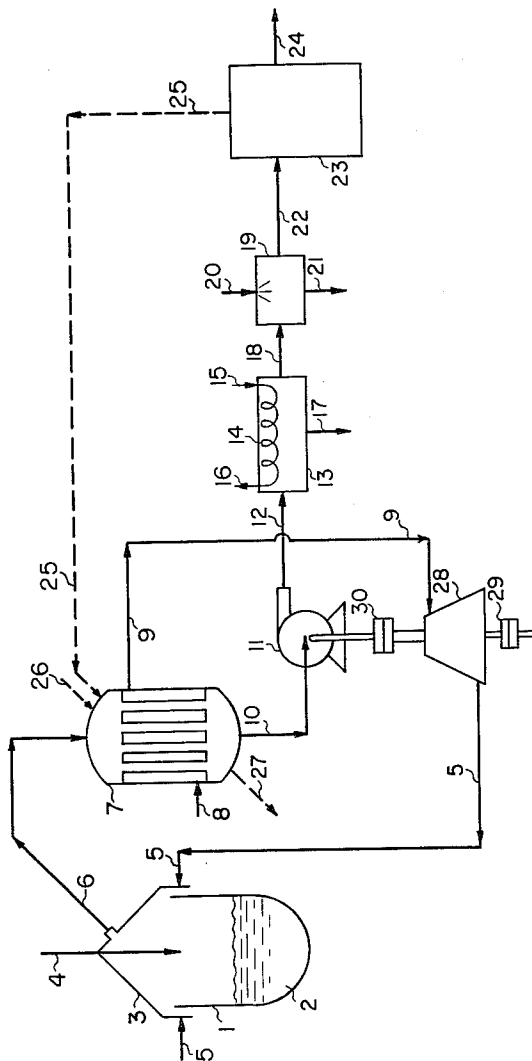
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RECOVERY OF OFF-GAS FROM A STEEL CONVERTER

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RECOVERY OF OFF-GAS FROM A STEEL CONVERTER

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This invention relates to the recovery of off-gas from a steel converter or furnace, such as an iron cupola or top-blown oxygen converter. An improved recovery method is provided, in which a steam curtain is maintained between the converter and top hood. The steam curtain serves to prevent air entry, and the mixed off-gas is subsequently cooled to condense steam and produce a substantially undiluted off-gas which consists mainly of carbon monoxide and has a high heating value. In a preferred embodiment, heating value is also recovered from the off-gas as usable high pressure steam.

Numerous types of iron and steel production facilities operate in such a manner as to generate an off-gas. Typical of these is the top-blow oxygen steel converter, in which a stream of oxygen is directed onto a bath of molten ferrous metal. The oxygen reacts with carbon and other impurities in the molten metal, and as a result a stream of hot off-gas consisting mainly of carbon monoxide is generated. The off-gas also contains a dense fume of red iron oxide and other solid impurities. Thus, the off-gas stream cannot be directly discharged into the atmosphere, due to pollution considerations. In addition, a potential explosion hazard exists. The off-gas stream also has a substantial heating value, and may be employed as fuel. Thus, it is generally necessary to recover the off-gas generated from various types of iron and steel processing units, such as top-blown oxygen converters and iron cupolas.

The off-gas is generally recovered by providing a gas hood above the upper opening of the unit. In some cases, it may be possible to provide a gas-tight mechanical seal between the hood and the converter. This is generally undesirable due to the possibility of leakage and also because of the complex mechanical considerations which are involved. It has been suggested that a seal can be obtained by providing an inert fluid such as nitrogen between the hood and the converter. A system of this nature is described in U.S. Patent No. 3,084,039. This results in considerable dilution of the off-gas. It has also been suggested that a certain amount of in-leakage of air into the hood may be permitted, with removal of a substantial proportion of the off-gas in an undiluted state by means of a gas probe which is inserted into the hood and withdraws off-gas from the central zone of the hood, with simultaneous quench of the off-gas. This procedure is described in U.S. patent application No. 147,505 filed Oct. 25, 1961, now U.S. Patent No. 3,186,831. It is generally undesirable to permit air leakage into the hood, since this results in combustion with the generation of extremely high gas temperatures, the combustion products dilute the off-gas, and heating value of the off-gas is wasted. In addition, a potential explosion hazard exists.

In some cases however, particularly when the off-gas has very low heating value, it has been a practice to dilute the off-gas with air so as to achieve complete combustion or to cool the off-gas stream to a lower temperature prior to further processing such as gas scrubbing. This approach is relatively undesirable since dilution of the off-gas stream takes place necessitating larger gas cleaning equipment, and in addition a water-cooled or refractory-lined enclosure must be provided for combustion.

In the present invention, sealing between the gas hood and the converter unit is attained by providing a curtain

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or blanket of steam, which is discharged into the annular space between the apparatus elements and mixes with the off-gas in the hood. A mixed stream consisting of off-gas plus steam is thus removed from the hood, and entry of air into the hood is effectively prevented. The mixed stream is subsequently cooled to condense the added steam, which is thus removed as a liquid. As a result, substantially undiluted off-gas is produced. The steam for sealing is preferably generated by passing the hot mixed off-gas stream from the head through a waste heat boiler, prior to cooling and steam condensation. The steam generated in the waste heat boiler is thus recycled to provide the steam curtain. In addition, the steam may be generated in the waste heat boiler at an elevated pressure, and expanded through a non-condensing turbine for power recovery prior to recycle as the steam curtain. In this manner, sensible heat in the off-gas stream is converted to usable power. In cases such as the top-blown oxygen converter, a cyclic process is employed, with alternate blow and charge periods. In this case, the off-gas generated during the blow period is burned in the waste heat boiler during the charge period, so as to maintain continuous steam generation.

The method of the present invention possesses numerous advantages. The use of steam as a curtain or blanket for the hood, followed by cooling of the mixed off-gas stream and steam condensation, permits the production of a concentrated off-gas with full heating value and undiluted with inert gas such as nitrogen. In addition, cooling of the gas stream to achieve steam condensation results in substantial cleaning of the gas stream due to the liquid condensation. The sensible heat contained in the off-gas is recovered as usable power, when the steam generated in the waste heat boiler is expanded through the non-condensing turbine. Finally, the use of steam as a curtain and diluent with subsequent condensation results in a considerably smaller volume of off-gas, as compared to prior practice in which air or nitrogen was employed to dilute the off-gas. Thus, the size of gas cleaning equipment for final cleaning of the dirty off-gas is considerably reduced.

It is an object of the present invention to recover off-gas from a steel converter in an improved manner.

Another object is to recover such off-gas by the use of steam as a sealing medium between a converter and associated gas hood.

A further object is to recover such off-gas substantially undiluted with inert components.

An additional object is to recover the sensible heat contained in the off-gas in a usable form so as to generate power.

Still another object is to prevent air entry between the hood and the upper end of a steel converter.

Still a further object is to provide an integrated method for the constant production of by-product steam during the blow and charge periods in the operation of a top-blown oxygen steel converter.

These and other objects and advantages of the present invention will become evident from the description which follows. Referring to the figure, a detailed flowsheet showing a preferred embodiment of the method of the present invention is presented. In the figure, unit 1 is a steel converter, in this case a top-blown oxygen converter. A bath 2 consisting of molten ferrous metal is contained in unit 1. A gas hood 3 is provided above converter 1, and oxygen is passed via 4 into contact with bath 2 during the blow period. A curtain or blanket of steam is disposed via 5 between hood 3 and converter 1, so as to prevent the entry of air into the hood. The oxygen stream 4 reacts with bath 2, so as to convert dissolved carbon into carbon monoxide and also to react with other impurities dissolved in the bath. In addition, a certain pro-

portion of iron itself reacts with the oxygen to form a fume of solid iron oxide particles in the off-gas.

A mixed off-gas stream 6 is withdrawn from hood 3, typically at a temperature in the range of 1000° F. to 3000° F. Stream 6 consists mainly of carbon monoxide and steam, plus entrained solids such as iron oxide fume. The hot gas stream 6 is passed through waste heat boiler 7, and is cooled to a temperature typically in the range of 400° F. to 800° F. by heat exchange with liquid water. The boiler feed water is passed into unit 7 via 8, and generated steam is removed from unit 7 via 9, typically at an elevated pressure in the range of 200 p.s.i.g. to 800 p.s.i.g. Boiler 7 is shown as a fire tube boiler, however a water tube boiler may alternatively be employed.

The partially cooled mixed gas stream is withdrawn via 10 from unit 7, and now passes through fan or blower 11 which serves to circulate the mixed gas stream through the system. The mixed gas stream next passes via 12 to condenser 13, in which the gas stream is cooled to condense steam as liquid water. Condenser 13 is provided with cooling coil 14, through which cooling water is passed via 15 with warmed water discharge via 16. The gas stream is cooled in unit 13 preferably to a temperature below 200° F., and condensed liquid water is removed via 17. The condensation of steam in unit 13 concomitantly serves to remove some of the entrained solid particles from the gas stream, and consequently stream 17 will contain entrained solids.

The cooled and partially cleaned gas stream is now passed via 18 to gas scrubber 19, which is a conventional unit for scrubbing solids from a gas stream. Thus unit 19 may be provided with water stream 20, which is sprayed into contact with the gas stream to remove solids. The scrubbing water stream containing solids is removed from unit 19 via 21. Due to the nature of the entrained solids in the gas stream 18, and the difficulty in fully cleaning the gas stream, unit 19 will preferably consist of a venturi scrubber as described in U.S. Patent No. 2,604,185, although other suitable devices such as a dry cloth filter may be employed instead of a wet scrubber.

The clean gas stream, now consisting essentially of undiluted carbon monoxide, is withdrawn via 22 from unit 19, and is passed to gas holder 23 for storage. The gas stream may be passed via 24 to outside utilization as fuel or for other purposes, however, the gas stream is preferably recycled via 25 for usage within the system of the present invention. Thus, during the converter charge period when oxygen stream 4 is not in use and the purified ferrous melt 2 is withdrawn and replaced with a new charge of ferrous metal, the flow of off-gas stream 6 is small or essentially negligible. In order to maintain continuous steam generation from unit 7 for reasons which will appear infra, during the converter charge period stream 25 is passed into waste heat boiler 7 for combustion with air stream 26. This provides the requisite heating, and flue gas is removed from unit 7 via 27.

In one novel aspect of the present invention, the steam generated via 9 is usefully employed to generate power and is subsequently recycled to provide the steam curtain stream 5. Thus, steam generated via 9 is expanded through non-condensing turbine 28 to a lower pressure, preferably below 50 p.s.i.g., and is recycled as steam curtain stream 5. The turbine 28 may be linked to plant power consumers via mechanical shaft linkage 29, however, turbine 28 is preferably employed to drive blower 11 via shaft linkage 30. In this alternative, the system is self-sustaining with respect to power requirements.

Numerous alternatives within the scope of the present invention will occur to those skilled in the art. Thus, in some cases the magnitude or temperature of stream 6 will not be sufficient to warrant provision of a waste heat boiler for the recovery of sensible heat. In this case, stream 6 would merely be cooled to condense steam from the mixed gas stream and directly produce an undiluted

off-gas. In this case, stream 25 and its function would be omitted and the entire final gas stream would be passed to outside utilization via 24.

Another alternative involves the arrangement of the several gas processing units, in particular the blower 11. With all other factors constant, the power demand for a fan or blower of this nature is roughly proportional to the volume of gas introduced to the fan. Thus, in some cases it may prove economically profitable to pass the gas stream 10 from waste heat boiler 7 directly into condenser 13, and provide blower 11 in the system after condenser 13 so as to act on stream 18, which is of smaller volume than stream 10 due to cooling and steam removal. Blower 11 may also be provided after gas scrubber 19, acting on stream 22. These alternative locations of blower 11 within the process arrangement are intended to be within the scope of the present invention.

In the start-up phase of operation of the present invention, it is a conventional and accepted practice in the steel industry to purge vessels which are to contain an explosive gas by the use of steam to displace oxygen. In this instance, these vessels become rather large. Where nitrogen is available, the train of equipment may be purged with nitrogen instead of steam during start-up. This nitrogen would be wasted to atmosphere.

It will be evident that, in most cases, the total amount of off-gas recycled via 25 to produce steam for driving blower 11 during charge periods will be less than the total amount of off-gas produced via 22. It will generally be more desirable to conserve the balance of excess off-gas for utilization via 24, rather than recycling the total off-gas production via 25, with concomitant production of an excess surge of steam. It is more desirable to have an end product of carbon monoxide rather than steam as a utility in cyclic amounts.

Because of its high carbon monoxide content plus the fact that dilution with inerts such as nitrogen has been prevented, stream 6 is eminently suitable for utilization as a raw material for chemical synthesis such as the production of hydrogen. The production of hydrogen by the reaction of carbon monoxide with water vapor, in the presence of a catalytic bed of promoted iron oxide, is a well-known industrial procedure. Gas stream 6 contains the two components required for this process, namely carbon monoxide and water vapor. Thus, after removal of entrained solids by means of a suitable filter and cooling as in waste heat boiler 7, stream 6 is directly suitable for usage in hydrogen production. In addition, nitrogen is produced in oxygen steel converter facilities as a by-product in the production of oxygen from air. It is evident that the by-product nitrogen may be combined with the hydrogen produced from catalytic conversion of the off-gas, to produce a mixed feed stream for ammonia synthesis.

An example of an industrial application of the method of the present invention will now be described.

Example

The method of the present invention was designed for application to a standard top blown oxygen steel converter, in which iron was converted to steel by the use of a jet of highly purity oxygen. The contaminants in the iron, principally carbon, were utilized as a fuel. The installation was rated as having the capacity of converting 200 tons of material in a normal oxygen blowing time of 20 minutes. The maximum rate of oxygen blown was 16,000 s.c.f.m. (standard cubic feet per minute). On the basis of negligible oxygen demand for the oxidation of the silicon, phosphorous and iron fume, the oxygen was calculated to combine with the carbon in the charge to product 30,000 s.c.f.m. of carbon monoxide with a heating value of over 300 B.t.u. The temperature of the gas in the vessel was usually in the range of 3000° F. At the peak of the blow the gases contained from 10 million to 15 million B.t.u. per minute, divided as one part sensible

heat and 10 parts of potential heat of combustion of carbon monoxide. By application of the method of the present invention, the release of this heat of combustion was prevented and instead the heat of combustion was maintained in a stream of almost pure gas. Due to the inherent cyclic nature of the process, the total heat was available for less than 50% of the operating time, however by application of the method of the present invention a practicable waste heat boiler was provided to recover waste heat as steam. During the blow, the sensible heat of the gas was used for the production of steam with the carbon monoxide going to storage. In the interval between blows, the carbon monoxide was returned to the boiler as fuel for uniform steam production. The gases were very dirty due to entrained iron oxide fume, and the boiler was of special design to allow for a relatively large amount of soot blowing.

I claim:

1. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood, partially cooling said mixed stream in a waste heat boiler whereby steam is generated at elevated pressure, expanding the generated steam through a non-condensing turbine for power generation, recycling the expanded steam as said steam curtain, and further cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas.

2. Method of preventing air entry into a top blown oxygen steel converter containing molten ferrous metal and provided with a hood and oxygen lance, said converter being operated with cyclic blow and charge periods, which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood during a blow period, cooling said mixed stream in a waste heat boiler whereby steam is generated at elevated pressure, expanding the generated steam through a non-condensing turbine for power generation, recycling the expanded steam as said steam curtain, further cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas, and burning said converter off-gas in said waste heat boiler during the charge period, whereby steam is continuously generated by said waste heat boiler during both blow and charge periods.

3. Method of preventing air entry into a top blown oxygen steel converter containing molten ferrous metal and provided with a hood and oxygen lance, said converter being operated with cyclic blow and charge periods, which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood during the blow period, cooling said mixed stream in a waste heat boiler whereby steam is generated at elevated pressure, passing the cooled mixed stream through gas circulation means, expanding the generated steam through a non-condensing turbine connected with said gas circulation means, whereby said turbine provides motive power to drive said gas circulation means, recycling the expanded steam as said steam curtain, further cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas, and burning said converter off-gas in said waste heat boiler during the charge period, whereby steam is continuously generated by said waste heat boiler during both blow and charge periods.

4. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood, cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas, burning said converter

off-gas in a steam boiler whereby steam is generated at elevated pressure, expanding said generated steam through a non-condensing turbine for power generation, and recycling the expanded steam as said steam curtain.

5. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood, cooling said mixed stream through gas circulation means, cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas, burning said converter off-gas in a steam boiler whereby steam is generated at elevated pressure, expanding the generated steam through a noncondensing turbine connected with said gas circulation means, whereby said turbine provides motive power to drive said gas circulation means, and recycling the expanded steam as said steam curtain.

6. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood at a temperature in the range of 1000° F. to 3000° F., cooling said mixed stream to a temperature in the range of 400° F. to 800° F. in a waste heat boiler whereby steam is generated at a pressure in the range of 200 p.s.i.g. to 800 p.s.i.g., expanding said generated steam to a pressure below 50 p.s.i.g. in a non-condensing turbine for power generation, recycling the expanded steam as said steam curtain, and further cooling said mixed stream to a temperature below 200° F. whereby steam is condensed and a substantially undiluted converter off-gas is recovered.

7. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood at a temperature in the range of 1000° F. to 3000° F., cooling said mixed stream to a temperature below 200° F. to condense steam and recover a substantially undiluted converter off-gas, burning said converter off-gas in a steam boiler whereby steam is generated at a pressure in the range of 200 p.s.i.g. to 800 p.s.i.g., expanding said generated steam to a pressure below 50 p.s.i.g. in a non-condensing turbine for power generation, and recycling the expanded steam as said steam curtain.

8. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood at a temperature in the range of 1000° F. to 3000° F., passing said mixed stream through gas circulation means, cooling said mixed stream to a temperature below 200° F. to condense steam and recover a substantially undiluted converter off-gas, burning said converter off-gas in a steam boiler whereby steam is generated at a pressure in the range of 200 p.s.i.g. to 800 p.s.i.g., expanding said generated steam to a pressure below 50 p.s.i.g. in a non-condensing turbine connected with said gas circulation means, whereby said turbine provides motive power to drive said gas circulation means, and recycling the expanded steam as said steam curtain.

9. Method of preventing air entry into a steel converter containing molten ferrous metal and provided with a hood which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood, partially cooling said mixed stream in a waste heat boiler whereby steam is generated at elevated pressure, passing the mixed stream through gas circulation means, expanding the generated steam through a non-condensing turbine connected with said gas circulation means, whereby said tur-

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bine provides motive power to drive said gas circulation means, recycling the expanded steam as said steam curtain, and further cooling said mixed stream to condense steam and recover a substantially undiluted converter off-gas.

10. Method of preventing air entry into a top blow oxygen steel converter containing molten ferrous metal and provided with a hood and oxygen lance, said converter being operated with cyclic blow and charge periods, which comprises passing a steam curtain between said converter and said hood, withdrawing a mixed stream of converter off-gas and steam from said hood during the blow period at a temperature in the range of 1000° F. to 3000° F., cooling said mixed stream to a temperature in the range of 400° F. to 800° F. in a waste heat boiler whereby steam is generated at a pressure in the range of 200 p.s.i.g. to 800 p.s.i.g., expanding said generated steam to a pressure below 50 p.s.i.g. in a non-condensing turbine for

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power generation, recycling the expanded steam as said steam curtain, further cooling said mixed stream to a temperature below 200° F. whereby steam is condensed and a substantially undiluted converter off-gas is recovered, and burning said converter off-gas in said waste heat boiler during the charge period, whereby steam is continuously generated by said waste heat boiler during both blow and charge periods.

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