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Muhlrad

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[54] **REGENERATIVE HEAT EXCHANGER AND METHOD FOR PURGING ITS FLOW PASSAGES**

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[51] **Int. Cl.** **F23l 15/02**

[58] **Field of Search** 165/4, 5; 263/15, 263/19

[56] **References Cited**

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710,748 10/1902 Cabot 263/19

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Attorney—Erich M. H. Radde and Charles E. Baxley

[57] **ABSTRACT**

This disclosure teaches a regenerative heat exchanger for recovering heat from a hot dust-laden gas exhausted by a steel converter or the like. In a preferred arrangement this heat exchanger is followed by a dust-removal apparatus of known design. After passage of the hot dust-laden gas through refractory-lined flow passages of the heat exchanger for cooling the dust-laden gas and before countercurrent flow of cooling air through the flow passages for heat extraction from the refractory, the flow passages are purged by circulating purge air up one portion of the flow passages and down another portion exiting to the dust-removal apparatus. Then the circulation through the flow passages is reversed with exit still to the dust-removal apparatus. The purging is achieved by a particularly facile partition and damper arrangement.

6 Claims, 7 Drawing Figures

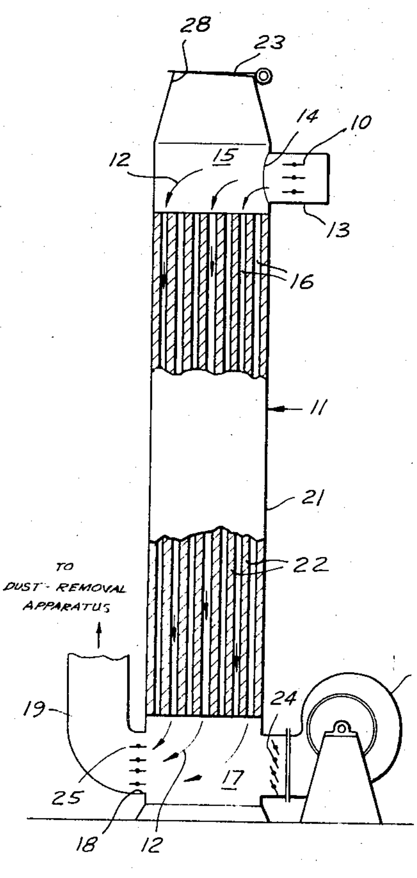

Fig. 1

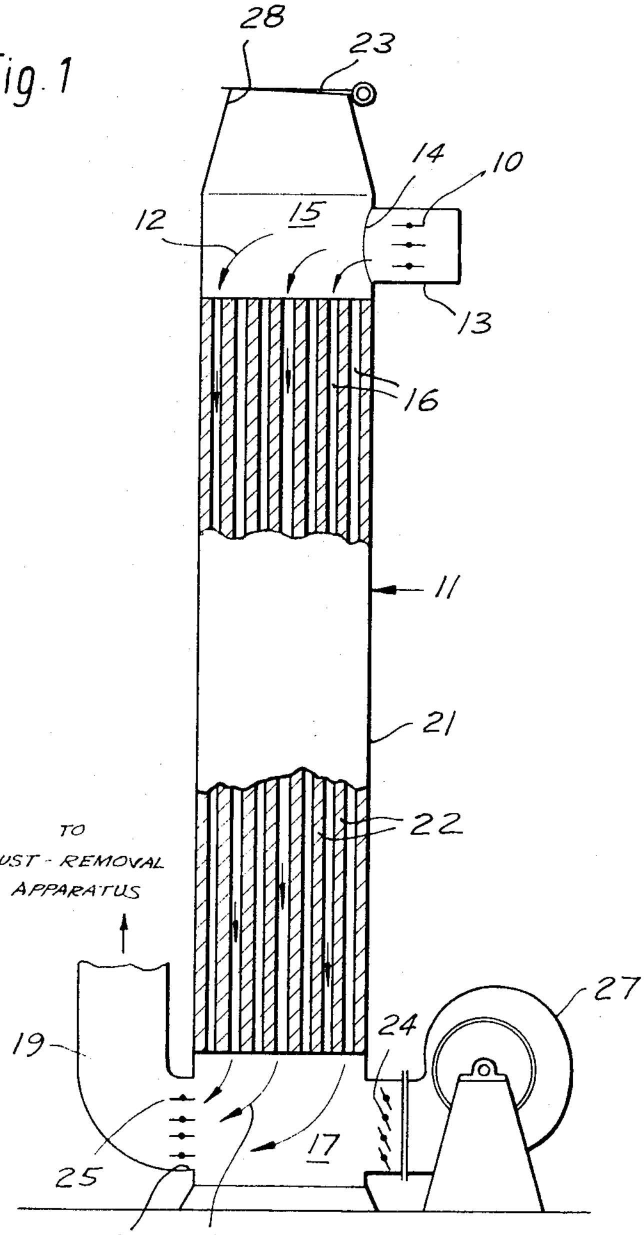

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Fig. 2

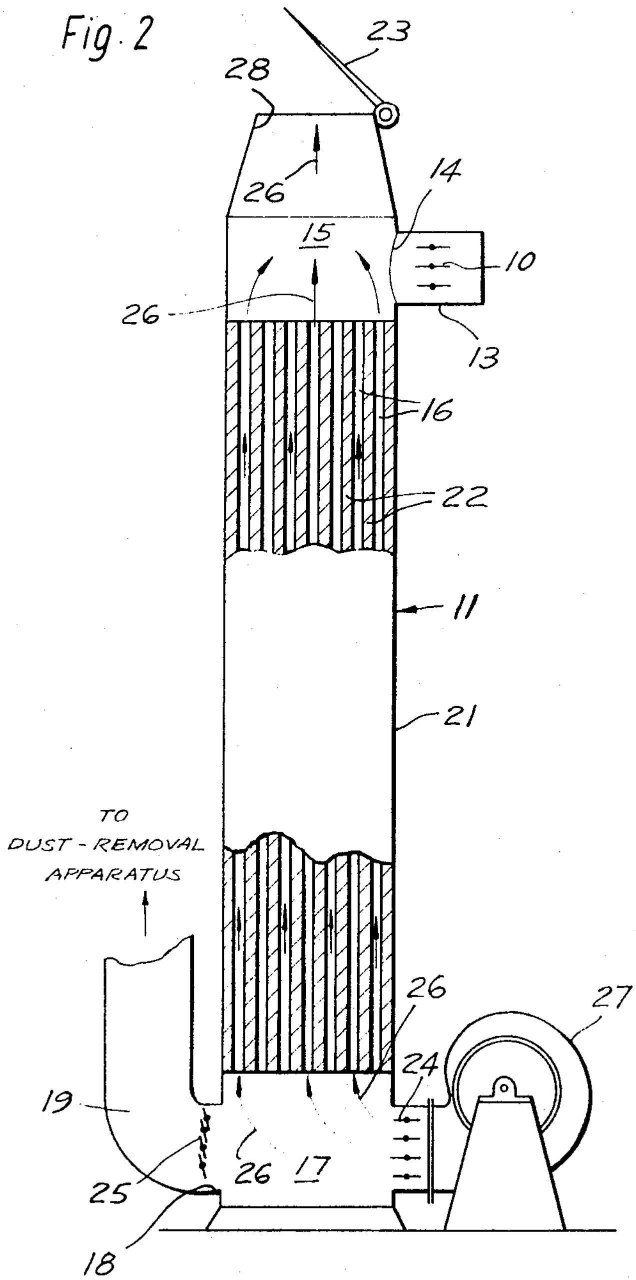

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Fig. 3

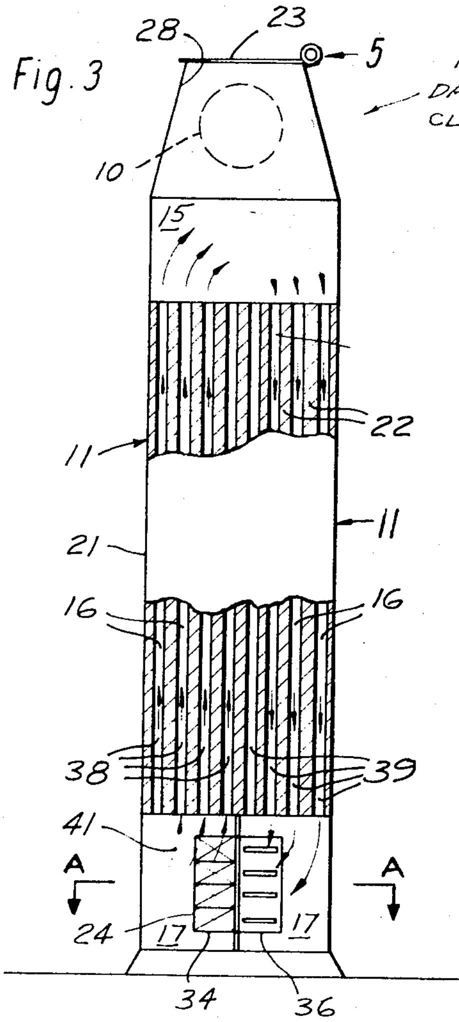
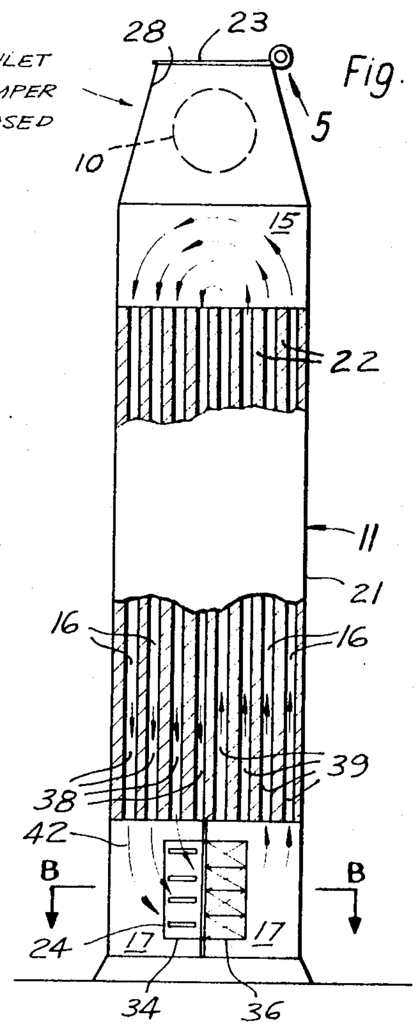


Fig. 4



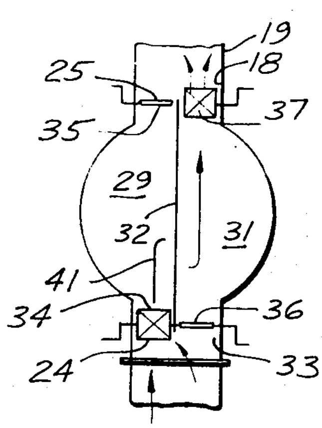


Fig. 5

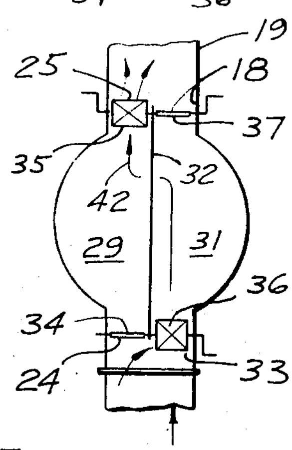


Fig. 6

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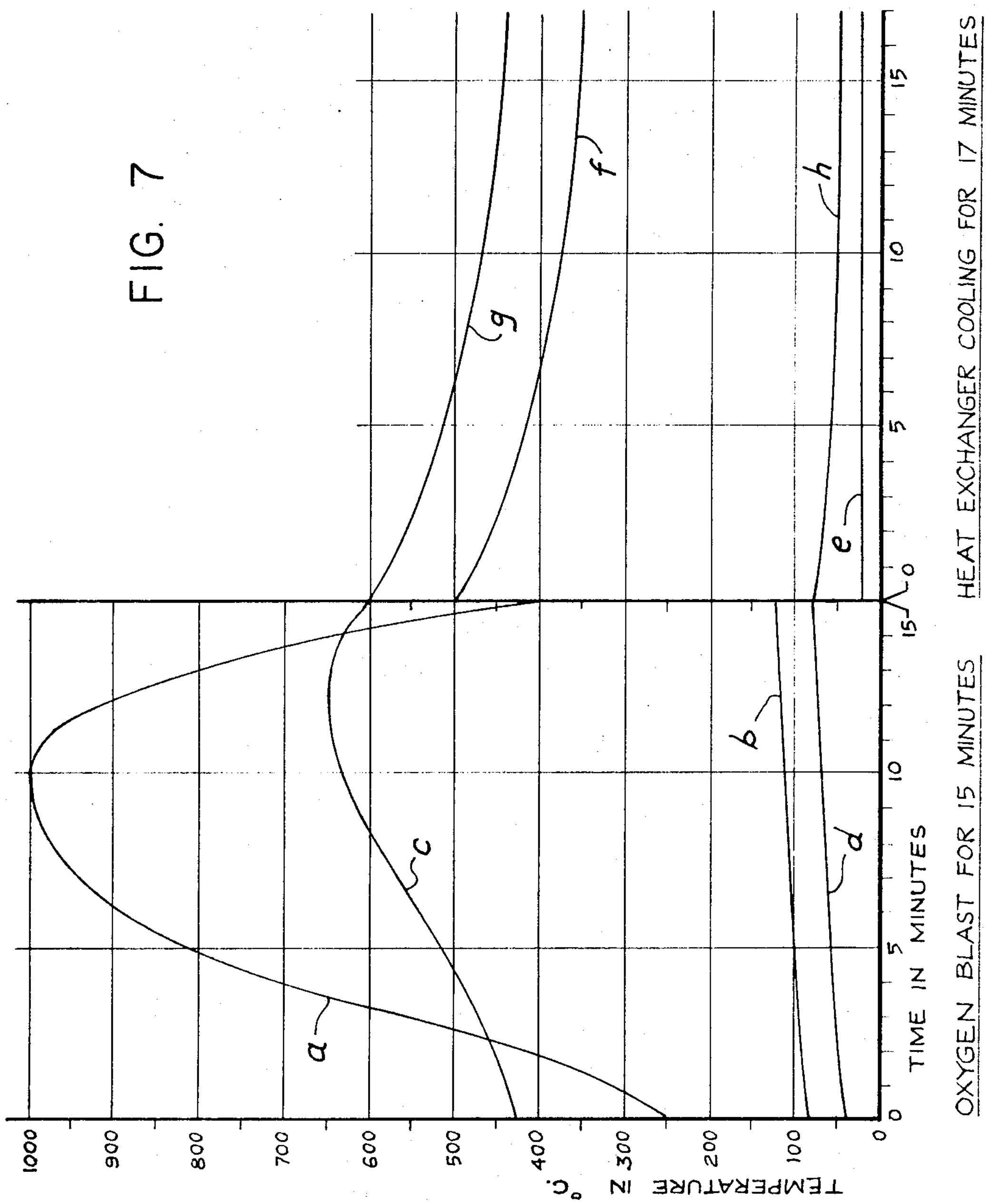
FIG. 7



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REGENERATIVE HEAT EXCHANGER AND METHOD FOR PURGING ITS FLOW PASSAGES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus and related method for cleaning automatically regenerative heat exchangers employed, for example, in cooling hot dust-laden gas exhausted by a steel converter. This heat exchanger is followed by a dust-removal apparatus such as a cloth filter or an electrostatic precipitator so that the gas exhausted ultimately by the steel converter is cooled and free of dust and so that a supply of hot clean air (or other gas) is made available.

2. Description of the Prior Art

Known self-cleansing regenerative heat exchangers, as they are described for instance in French Pat. Nos. 784,141 and 1,477,725, allow a hot gas to flow through refractory-lined flow passages of the heat exchanger. Heat transfer from the hot gas to the refractory causes cooling of the gas. A gas, the temperature of which is about 1000° C. on entering the heat exchanger can be treated advantageously in this manner. The heat exchanger can be designed in economically feasible dimensions so that the gas temperature is reduced to about 100° C. In such a heat exchanger, passage of the gas (which usually flows from the top downwardly) is shut off at regular intervals. Then the heat exchanger is cooled by countercurrently blowing therethrough a cooling air stream which passes through the flow passages from the bottom upward to cool the refractory, thereby heating the air.

Such known regenerative heat exchangers are of a design similar to those of hot-blast recuperators used for preheating air to be delivered to blast furnaces. The regenerative heat exchanger of the present invention is, however, used in a substantially different manner from those of known hot-blast recuperators, because the heat exchanger of the present invention serves a different purpose, namely to cool hot gas to a rather low temperature. Air used in blast furnace operations is preheated to a temperature generally between 700° C. and 900° C. and this air is kept as close as possible to its design temperature. Furthermore, hot gas used for heating refractory of hot-blast recuperators is practically free of dust, usually containing less than 10 mg. of dust per cu.m. By way of contrast thereto the gas used in a heat exchanger according to the present invention may contain up to 50,000 mg. of dust per cu.m. These differences also have a considerable effect upon the design of the heat exchanger according to the present invention which differs essentially from those of conventional hot-blast recuperators.

SUMMARY OF THE INVENTION

It is one object of the present invention to provide a simple and effective apparatus and related method for cooling a hot dust-laden gas, especially waste gas from a Bessemer converter.

Another object of this invention is to provide a simple and effective apparatus and related method for cleaning hot-dust-laden gas.

Still another object of this invention is to provide a simple and effective method for cleaning automatically refractory-lined flow passages of a regenerative heat exchanger used in cooling a hot, dust-laden gas.

Other objects of this invention and advantageous features thereof will become apparent as the description proceeds.

In principle the cooling apparatus and related method according to this invention comprise the following:

a. Refractory-lined flow passages of a regenerative heat exchanger are arranged for being heated by downward passage of a hot dust-laden gas (from a steel converter or the like) therethrough.

b. Thereafter flow of the hot gas is interrupted and cooling air is blown upward in countercurrent direction through the flow passages to cool the refractory. The cooling gas is supplied by a blower.

According to the useful novel and inventive teaching of the present invention, there are interposed between the downward passage of the hot gas and the upward passage of the cooling gas through the flow passages the steps whereby

c. a relatively high-velocity purge gas stream is subdivided successively into two purge streams each of which alternately passes first upward through one half and downward through the other half of the flow passages and then vice versa.

d. After passing through the two halves of the flow passages, the purge streams are delivered to a dust-removal apparatus which is connected to the outlet of the cooling gas.

e. As soon as the dust has been removed substantially from the flow passages, the cooling gas is passed upwardly through both halves of the flow passages and is exhausted from the top of the heat exchanger.

f. Thereupon the cooled regenerative heat exchanger is ready again for use in cooling more of the hot dust-laden gas.

BRIEF DESCRIPTION OF THE DRAWINGS

A heat exchanger according to the present invention is illustrated in the accompanying drawings wherein:

FIG. 1 is a side cross-sectional view of a heat exchanger and shows diagrammatically the phase wherein refractory-lined flow passages are heated by the hot dust-laden gas.

FIG. 2 is a side cross-sectional view similar to FIG. 1 of the heat exchanger and shows diagrammatically the phase wherein the refractory is cooled by upward flow of cooling gas.

FIG. 3 is a rear cross-sectional view of the heat exchanger and shows passage of pure gas upwardly through one half of the flow passages and downwardly through the other half of the flow passages.

FIG. 4 is a rear cross-sectional view similar to FIG. 3 of the heat exchanger and shows passage of the purge gas upward through the other half of the flow passages and downward through the first half of the flow passages.

FIGS. 5 and 6 are plan cross-sectional views of a downstream chamber in the heat exchanger taken along lines A—A and B—B of FIGS. 3 and 4 respectively.

FIG. 7 is a graphical relationship of time with temperature for various locations.

These drawings illustrate the apparatus and its mode of operation. Like numerals indicate like parts throughout the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates heat exchanger 11 during the phase when a hot dust-laden gas travels therethrough as indicated by arrows 12. The hot dust-laden gas from a steel converter or the like (not shown) enters regenerative heat exchanger 11 via duct 13 and courses in turn through inlet port 14 (provided with inlet damper 10), upstream chamber 15, flow passages 16, downstream chamber 17, and outlet port 18 for passage via duct 19 to a dust-removal apparatus (not shown). Flow passages 16 are defined in housing 21 between upstream chamber 15 and downstream chamber 17 and are lined with a suitable heat-storing material such as refractory 22. During this phase lid 23 as well as blower damper 24 are closed. Only outlet damper 25 is open.

FIG. 2 illustrates the same heat exchanger during its cooling operation (carried out in the same manner as the prior art) by means of an upward countercurrently flowing air stream (as indicated by arrows 26) which is blown into flow passages 16 by means of blower 27 with blower damper 24 open while outlet damper 25 is closed. It should be clear that some gas other than air could be employed in this service. In prior art regenerative heat exchangers of this type, by proceeding in the manner heretofore described and reversing the flow of gases very carefully, purging of the heat exchanger was accomplished. For the most part dust was delivered to the dust-removal apparatus which follows downstream of the heat exchanger. However, when outlet damper 25 is closed, blower damper 24 is opened and lid 23 is opened; a clearly visible dust-laden cloud exists via exhaust port 28. This emission of dust usually lasts for several seconds before it disappears. Formation of this dust-laden cloud is due to the fact that, in spite of all counter measures, dust is deposited in the heat exchanger during passage of the hot dust-laden gas therethrough. This dust is raised by and suspended in the cooling air blown upward through the heat exchanger because of turbulence developed by the cooling air which is usually in an amount greater than that of the hot dust-laden gas.

According to the present invention emission of the dust clouds at the beginning of the cooling step is corrected by bringing about a more intense purging of the heat exchanger and by delivering to the dust-removal apparatus the purged dust before opening lid 23, i.e., before expelling the cooling air. For this purpose downstream chamber 17 is subdivided into first and second compartments 29 and 31 as best seen in FIGS. 3–6. Such division is achieved by providing in downstream chamber 17 vertical partition wall 32 which is aligned with a medial bisection of outlet port 18 and blower port 33. Blower damper 24 and outlet damper 25 are now each made of a first and second semidamper which are operated independently from each other. First blower semidamper 34 and first outlet semidamper 35 are on first compartment 29 side of downstream chamber 17. Second blower semidamper 36 side of second outlet semidamper 37 are on second compartment 31 side of downstream chamber 17. FIGS. 3 and 4 illustrate rear cross-sectional views through regenerative heat exchanger 11 and FIGS. 5 and 6 are plan cross-sectional views through downstream chamber 17 as well as blower semidampers 34,36 and outlet semidampers 35, 37. FIGS. 5 and 6 also show subdivision of downstream chamber 17 into first and second compartments 29, 31 separated from each other by partition wall 32.

After the hot dust-laden gas has been passed through the heat exchanger for a suitable time (as per FIG. 1), flow passages 16 and chambers 15, 17 are purged intensively of dust in the manner shown in FIGS. 3, 5, then in the manner shown in FIGS. 4, 6 before the air used for cooling refractory 22 is expelled through exhaust port 28 (as per FIG. 2).

After air preheater 11 has been heated up by the hot dust-laden gas, lid 23 at the top of heat exchanger 11 remains closed. First blower semidamper 34 and second outlet semidamper 37 are opened while second blower semidamper 36 and first outlet semidamper 35 remain closed. Cool air blown countercurrently through open first blower semidamper 34 in blower port 33 into first compartment 29 by means of blower 27 travels upwardly through first flow passages 38 which register with first compartment 29 and after passing through upstream chamber 15 the purge air passes downwardly through second flow passages 39 which register with second compartment 31 of downstream chamber 17 and from there through open second outlet semidamper 37 out outlet port 18 to outlet duct 19 as shown by arrows 41 in FIGS. 3, 5.

The dust purged from heat exchanger 11 is conveyed by duct 19 to a dust-removal apparatus. As shown in FIGS. 3, 5, second blower semidamper 36 and first outlet semidamper 35 remain closed during the foregoing purge operation.

After a predetermined period of time, usually a few seconds, the direction of the purge air stream is changed by closing first blower semidamper 34 and second outlet semidamper 37 and by opening second blower semidamper 36 and first outlet semidamper 35 as shown by arrows 42 in FIGS. 4 and 6. Thus the regenerative heat exchanger is purged by introducing purge air through open second blower semidamper 36 into second compartment 31. The purge air then flows upwardly through second flow passages 39 into upstream chamber 15 and from there the purge air passes downwardly through first flow passages 38 into first compartment 29 so that dust is forced out through open first outlet semidamper 35 in outlet port 18 and via outlet duct 19 to the dust-removal apparatus.

Such a design of a regenerative heat exchanger for cooling hot dust-laden gas achieves more effective purging than was possible in such an apparatus heretofore. This superior purging is due to the fact that during purging both blowers, the one which serves to withdraw gas from the heat exchanger (not shown) which is usually located between the heat exchanger and the dust-removal apparatus (also not shown) and shown blower 27 used for forcing purge air into the heat exchanger (as shown in FIGS. 3, 5 or 4, 6) operate in tandem on the purge air stream. Thereby the amount of energy required to push the purge air is smaller by virtue of the aspirating effect of the other blower (not shown) even though a loss in pressure results on passing both upward and downward through reduced sections of the flow passages. That the amount of energy is smaller than the nominal amount for cooling refractory 22 is due to the fact that, on the one hand, the path of the gas has become longer and narrower while on the other hand, both blowers are working in tandem. Because the cross-sectional area of the flow passages have been reduced by 50 percent, the purge air (per FIGS. 3, 5 or 4, 6) attains twice the speed in purging than for normal cooling of refractory 22 (per FIG. 2). The turbulence produced thereby enables a considerably more effective elimination of dust from the heat exchanger.

Another reason for the high degree of effectiveness of this method for purging a heat exchanger is to be seen in the fact that each of the flow passages is purged successively in ascending and descending directions.

After the flow passages have been purged to remove dust deposited therein, heat exchanger 11 is cooled in the conventional manner (generally as shown in FIG. 2). First 34 and second 36 blower semidampers are closed; first 35 and second 37 outlet dampers are opened; lid 23 is opened; first 34 and second 36 blower semidampers are then opened; and first 35 and second 37 outlet dampers are closed. Thereupon the entire air forced into heat exchanger 11 by means of blower 27 flows from the downstream chamber 17 upwardly through flow passages 16 to upstream chamber 15 and out exhaust port 28. The heat contained in the cooling air is expelled through exhaust port 28 or, if desired, may be supplied to a suitable place for further use.

This type of cooling of the accumulated heat and the manner in which cooling is effected according to the present invention is especially useful in treatment of intermittently produced gases such as are obtained, for instance, on blowing steel converters with oxygen, but may also be used in other plants in which hot gases are produced continuously. In this case an installation is composed of twin regenerative heat exchangers whereby, at a given time, one of the exchangers is used for cooling the gases by heat accumulation in its refractory, while, at the same time, the other member thereof is cooled by blowing air countercurrently into and through that member. Both members of the twin exchanger are reversed automatically in their mode of operation at regular intervals.

The reduction by half of the cross-sectional areas through which the purge gas flows, while otherwise the same conditions are maintained, results in doubling the speed of flow of the dust-laden purge gas and increases wall friction of the gas within the heat exchanger in geometrical progression. Due thereto heat transfer and purging effectiveness are increased many times.

The following example serves to illustrate the present invention without, however, limiting the same thereto.

EXAMPLE

Hot dust-laden converter gas is introduced, as shown in FIG. 1, through inlet port 14 into and passes through regenerative heat exchanger 11 usually for twenty minutes. During this period heat exchanger 11 serves to cool the hot dust-laden converter gas. After passing through flow passages 16 and downstream chamber 17, the cooled gas is discharged through outlet port 18 and duct 19 which leads to a dust-removal apparatus. Lid 23 and blower dampler 24 are closed during the passage of the gas through the heat exchanger while outlet damper 25 is open. The hot gas is cooled thereby to a temperature of about 100° C. The gas velocity is about 15 m./sec. At such a speed most of the dust in the hot gas is removed therefrom. However, some dust remains deposited in the flow passages 16 and downstream chamber 17. This dust is completely removed by proceeding according to the present invention and closing inlet damper 10 so that the flow of hot gases ceases because usually the converter process is completed within 20 minutes. The converter is then discharged and refilled within the next 10 minutes. During said time heat exchanger 11 is purged as shown in FIGS. 3, 4, 5, and 6 by blowing purge gas, usually air, with a gas velocity of 20 m./sec. through open semidamper 34 which is part of blower damper 24 of FIGS. 1 and 2 and closed semidamper 35 which is part of outlet damper 25 of FIGS. 1 and 2 into first compartment 29 of downstream chamber 17 separated by partition wall 32 from second compartment 31 of said downstream chamber 17. The purge gas thus is forced to flow through first compartment 29 upwardly through first air passages 38 upwardly into upstream chamber 15 where the flow of the purge gas is reversed as shown in FIG. 3 and the purge gas flows downwardly through second air passages 39 into and through second compartment 31. From there the gas (which is now laden with dust) is discharged through open semidamper 37 into duct 19 from where it is conducted to the dust-removal apparatus (not shown). After a few seconds, usually not more than five seconds, so that the heat loss is minimal, semidampers 34 and 37 are closed and semidampers 35 and 36 are opened. As a result thereof the purge air is forced through second compartment 31 upwardly into second flow passages 39 and, as is shown in FIG. 4 flows downwardly through first flow passages 38 and through first compartment 29 into outlet dust 19 and from there to the dust-removal apparatus. This passage of the purge air also lasts for only a few seconds, usually not more than five seconds. Thereby, substantially all the dust deposited in downstream chamber 17 and flow passages 16 is rendered airborne due to heavy turbulence created by the high speed of the purge air which amounts to 40 m./sec. because the cross-section of the purge gas inlet and outlet is reduced by half.

After this purging period of short duration not substantially exceeding 10 seconds to minimize the heat loss, semidampers 35 and 37 are closed, semidampers 34 and 36 are opened, and cooling air is blown upwardly through flow passages 16, thereby cooling refractory 22. The cooling air which is substantially free of dust, is heated for about nine minutes or nine and a half minutes, i.e., until the converter is filled. The converter gas is then cooled again as described hereinabove. The heated cooling gas is discharged through open lid 23 to be used as a very pure, dust-free, hot air which is useful in many industrial processes.

The graphical relationships presented in FIG. 7 are for a heat exchanger having square flow passages 16 of 70 mm. width. Refractory 22 was 30 mm. in thickness. Oxygen blasting as per FIG. 1 lasted 15 minutes, cooling as per FIG. 2 lasted 17 minutes. The quantity of cooling air used as per FIG. 2 was 130 percent of that aspirated as per FIG. 1. More particularly the graphical relationships presented in FIG. 7 depict temperature-time relationships as follows:

Curve *a:* Temperature at the gas inlet of the heat exchanger.

Curve *b:* Temperature at the gas outlet of the heat exchanger.

Curve *c:* Temperature of the inner refractory walls at the upper part of the heat exchanger.

Curve *d:* Temperature of the inner refractory walls at the lower part of the heat exchanger.

Curve *e:* Temperature of the countercurrently flowing air at its inlet into the heat exchanger.

Curve *f:* Temperature of the countercurrently flowing air at its outlet from the heat exchanger.

Curve *g:* Temperature of the inner refractory walls at the outlet of the countercurrently flowing air.

Curve *h:* Temperature of the inner refractory walls at the lower part of the heat exchanger before the countercurrent flow of air.

It is understood that the heat exchanger can have any shape, it may be of square, rectangular, or round cross-section.

The outlet duct **19** and the dust collector (not shown) as well as the conduit (not shown) leading from lid **23** may be connected with an apparatus or plant which is continuously operated at the same gas temperature and with the same amount of gas, namely alternatively, for instance, at a temperature of about 150° C. for twenty minutes with purified and cooled converter gas and immediately thereafter for ten minutes with hot cooling gas or air cooled in the heat exchanger.

It will be understood by those familiar with heat transfer, heat exchangers and/or process technology that wide deviations may be made from the foregoing preferred embodiment without department from the main theme of invention defined in the claims which follow.

I claim:

1. A regenerative heat exchanger for removing heat from a relatively hot dust-laden gas exhausted from a steel converter or the like, the heat exchanger comprising in combination:

a. a generally vertical housing provided with an upstream chamber, a downstream chamber and a heat-storage section disposed between said upstream and downstream chambers, said heat-storage section being provided with a plurality of flow passages lined with a heat-storing material, the flow passages connecting said upstream downstream chambers in flow communication each with the other;

b. an inlet port in said housing in flow communication with said upstream chamber and connectable in flow communication with a steel converter or the like to receive the hot dust-laden gas therefrom for passage through the heat-storage section wherein the dust-laden gas is cooled and passed thence to said downstream chamber;

c. an outlet port in said housing in flow communication with said downstream chamber and connectable to a dust-removal apparatus for delivering the cooled dust-laden gas thereto;

d. a blower port in said housing in flow communication with said downstream chamber;

e. a blower associated with said blower port for delivering cooling air to said downstream chamber for passage through the flow passages to said upstream chamber;

f. an exhaust port in said housing in flow communication with said upstream chamber and heaving a lid openable to permit cooling air to exit from said upstream chamber through said exhaust port;

g. a partition wall mounted in said downstream chamber to subdivide that chamber into a first compartment and a second compartment, each connecting the blower port in flow communication with the outlet port;

h. first and second blower semidampers mounted in said blower port in flow communication with said first and second compartments, respectively, to control delivery of the purge air thereto;

i. first and second outlet semidampers mounted in said outlet port in flow communication with said first and second compartments, respectively, to control exit of the purge air therefrom, whereby said first compartment is in flow communication with a first portion of the flow passages and said second compartment is in flow communication with a second portion of the flow passages so that on opening said first blower semidamper, closing said second blower semidamper, closing said first outlet semidamper and opening said second outlet semidamper, purge air from said blower is circulated through said first compartment, the first portion of the flow passages, the upstream chamber, the second portion of the flow passages, the second compartment, and out the outlet port via the second outlet semidamper; alternately, on opening said second blower semidamper, closing said first blower semidamper, closing said second outlet semidamper and opening said first outlet semidamper, purge air from the blower is circulated through the second compartment, the second portion of the flow passages, the upstream chamber, the first portion of the flow portion of the flow passages, the first compartment, and out the outlet port via the first outlet semidamper.

2. In a regenerative heat exchanger as defined in claim **1**, and wherein the hot dust-laden gas is passed first downwardly through the flow passages and alternately the cooling air is passed upwardly through the flow passages, a method for purging the flow passages upon the discontinuance of the passing of hot dus-laden gas and before cooling air is passed upwardly through the flow passages, comprising the steps of:

a. purging the flow passages by circulating the purge air therethrough with the circulation path of the purge air being from the blower via the blower port through the first blower semidamper into the first compartment, the first portion of the flow passages, the upstream chamber, the second portion of the flow passages, the second compartment and out the outlet port through the second outlet semidamper, and

b. thereafter changing the circulation of the air from the blower via the blower port through the second blower semidamper into the second compartment, the second portion of the flow passages, the upstream chamber, the first portion of the flow passages, the first compartment and out the outlet port through the first outlet semidamper.

3. The method of claim **2** further comprising the steps of:

a. substantially simultaneously opening the first blower semidamper, closing the second blower semidamper, closing the first outlet semidamper, and opening the second outlet semidamper, and, subsequently,

b. substantially simultaneously closing the first blower semidamper, opening the second blower semidamper, opening the first outlet semidamper, and closing the second outlet semidamper.

4. The method of claim **3**, wherein the cooling air is passed into the heat exchanger with a speed of at least 20 m./sec.

5. In a method of purging the flow passages of a regenerative heat exchanger in which a partition is provided for dividing the flow passages into first and second compartments, the method comprising the steps of:

a. purging the flow passages by circulating cooling purge air therethrough, with the circulation path of the cooling purge air being into and upwardly through the first compartment of the partitioned heat exchanger and downwardly through and out of the second compartment of the partitioned heat exchanger, thereafter

b. changing the circulation of the cooling purge air to pass into and upwardly through the second compartment of the heat exchanger and downwardly through and out of the first compartment of the heat exchanger, thereby purging the heat exchanger from accumulated dust, and thereafter

c. passing cooling air upwardly through the flow passages and out the heat exchanger.

6. The method of claim 5, wherein the upward and downward passage of the cooling purge air through the first and second compartments of the heat exchanger to purge the heat exchanger from accumulated dust is continued for a period of time which is a fraction of the time required to cool the heat exchanger but sufficient to purge the heat exchanger from accumulated dust.

* * * * *