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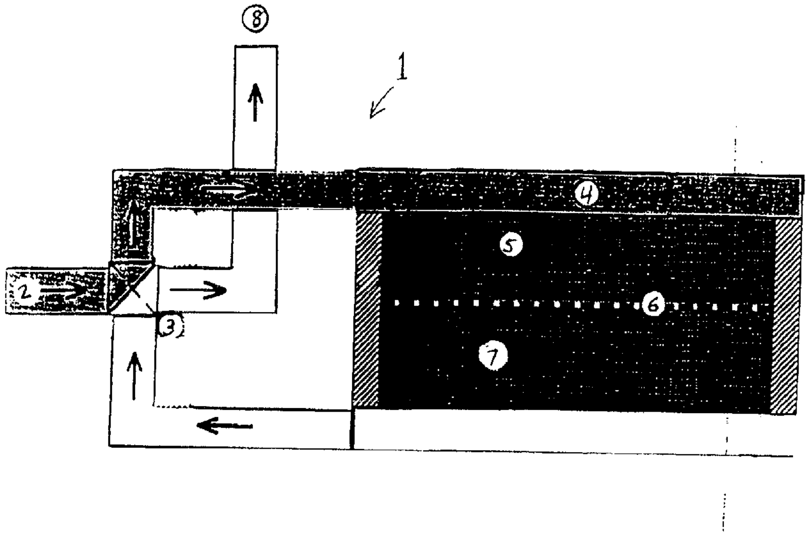
(54) PARTICULES PROFILEES UTILISEES COMME AGENTS CALOPORTEURS DANS DESSYSTEMES D'OXYDATION THERMIQUE A RECUPERATION

(54) HEAT EXCHANGE MEDIA IN REGENERATIVE THERMAL OXIDIZERS



(57) L'invention décrit un échangeur de chaleur pour système d'oxydation thermique (1) à récupération de chaleur incluant au moins une colonne échangeuse de chaleur (5) pourvue d'un lit de matières de remplissage (7) composées de particules spécialement profilées et dimensionnées, dont chacune est formée d'un matériau stable à hautes températures et a de préférence une paroi extérieure cylindrique et des ailettes de renforcement internes s'étendant de la paroi extérieure cylindrique au centre de la particule.

(57) A heat exchanger for a regenerative thermal oxidizer (1) is described which includes at least one heat exchange column (5) provided with a bed of packing material (7) of specially shaped and sized particles, each particle being formed of a high temperature stable material and preferably having a cylindrical outer wall and internal reinforcing vanes extending from the cylindrical outer wall to the center of the particle.

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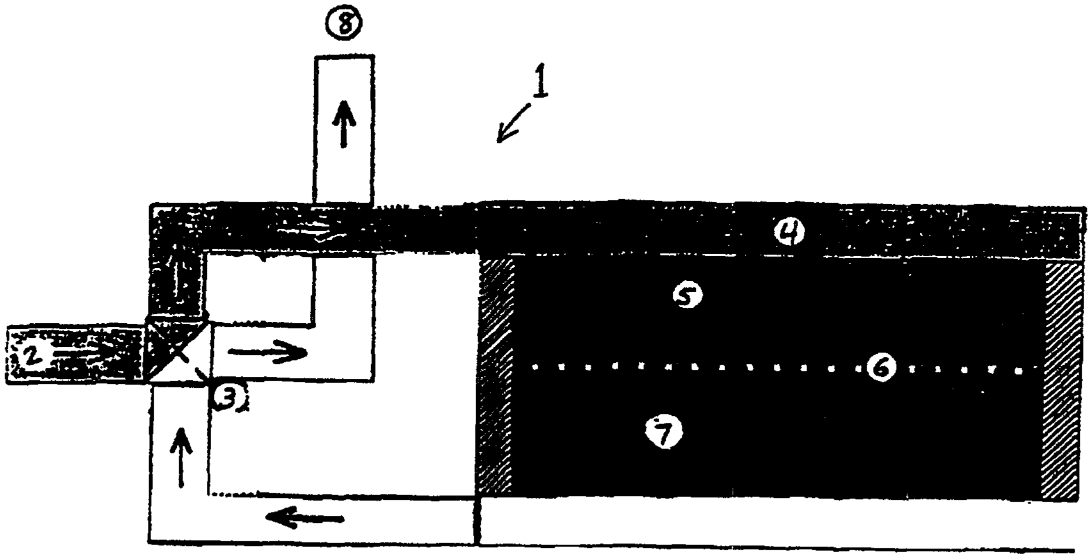


(57) Abstract

A heat exchanger for a regenerative thermal oxidizer (1) is described which includes at least one heat exchange column (5) provided with a bed of packing material (7) of specially shaped and sized particles, each particle being formed of a high temperature stable material and preferably having a cylindrical outer wall and internal reinforcing vanes extending from the cylindrical outer wall to the center of the particle.

HEAT EXCHANGE MEDIA IN REGENERATIVE THERMAL OXIDIZERS

This application is a continuation-in-part of pending U.S. application Serial No. 08/472,218 filed June 7, 1995.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to heat exchange media in regenerative thermal oxidizers. More particularly, the invention relates to heat exchange media for use in heat exchangers in regenerative thermal oxidizers, and the resulting improved thermal oxidizers.

Description of the Related Art

Regenerative thermal oxidizers (RTOs) are used for destroying volatile organic compounds in high flow, low concentration emissions from industrial and power plants. RTOs typically require high oxidation temperatures in order to have high Volatile Organic Compound (VOC) destruction and high heat recovery efficiency.

To more efficiently attain these characteristics, the exhaust which is to be treated is preheated before combustion. A heat exchanger column is typically provided to preheat the exhaust gasses. The column is usually packed with a heat exchange material having good thermal and mechanical stability and high thermal mass. In operation, the exhaust gas is fed through a previously heated heat exchanger column, which, in turn, heats the exhaust gas to a temperature approaching the ideal combustion temperature. This pre-heated exhaust gas is then fed into the combustor.

The treated gas is then directed out of the combustor and back through the heat exchanger column, or, according to a more efficient process, through another heat exchanger column. As the hot combusted gas is fed through the column, the gas transfers its heat to the heat exchange media, cooling the gas and pre-heating the heat exchanger so that another batch of exhaust gas may be preheated prior to the combustion treatment. Usually, a RTO has at least two heat exchanger columns which alternately receive exhaust and treated gasses. This process is continuously carried out, allowing a large volume of exhaust has to be efficiently treated.

The performance of a RTO may be optimized by increasing VOC destruction efficiency and by reducing operating and capital costs. The art of increasing VOC destruction efficiency has been addressed in the literature using, for example, means such as improved combustion systems and purge systems. Operating and capital costs can be reduced by increasing the heat recovery efficiency, by reducing the pressure drop across the oxidizer, and by increasing cycle time (which has an impact on the life of tile equipment). Costs may be reduced by properly designing the RT0 and by selecting appropriate heat transfer packing materials. While design aspects of RTOs have been the subject of prior patent literature, the choice of the heat transfer packing material has not been sufficiently addressed. The object of the present invention is to disclose a shaped packing material which provides a significant increase in the heat recovery and pressure drop performance of an RTO, thereby reducing costs associated with the process.

The properties such as the shape, size, and packing characteristics of a bed of packing material determine the heat recovery, pressure drop, and cycle time of the RTO. For example, heat recovery is proportional to the heat transfer coefficient and the heat capacity per unit bed volume.

Cycle time, like heat recovery, is proportional to the bed heat capacity per bed column. For a given packing material, heat capacity per bed volume is directly proportional to bed void fraction. Pressure drop, on the other hand, is inversely proportional to the bed void fraction. Thus, in conventional bed packing materials, a higher bed void fraction decreases not only pressure drop (which reduces operating cost) but also decreases heat recovery and cycle time (which increases operating cost).

In order to obviate the problems associated with the pressure drop, monolith structures have been proposed (See, e.g., U.S. Patent No. 5,352,115 to Klobucar.) The monoliths, however, suffer from a decreased heat recovery. Further, the continuous structure of the monolith renders it vulnerable to thermal stresses due to a thermal gradient from the inlet portion of the monolith to the outlet portion of the monolith. These stresses may cause cracking and premature failure of the monoliths resulting in costly, unscheduled downtime of the RTO and replacement of the monoliths.

A number of different shapes of packing materials have been disclosed in the prior art. As disclosed below, however, shapes have primarily been used as contacting or mixing devices and as catalyst pellets. The influence of the size and shape of the heat transfer material on the heat transfer, heat storage, and pressure drop in RTOs has not been discussed.

A number of shapes and structures have been disclosed in the prior patent literature. U.S. Patent No. 3,907,710 (Lundsager) discloses a four- and six-ribbed wagon wheel-shaped material. This material has been proposed as a contacting device in a packed tower or column or as an inert support on which catalytic ingredients may be deposited to perform catalytic reactions.

U.S. Patent No. 4,610,263 (Pereira et al.) discloses an extrudate suitable for improved gas-liquid contacting which is made from a solid transitional alumina. This material has a similar shape to the material disclosed in the present invention. The cylindrical extrudate has partially hollow interior and internal reinforcing wings extending from the inner wall to the center of the extrudate particle. The transitional alumina of the reference has a nitrogen surface area of at least 50 m^2g, a diameter of up to about 6.5 mm, an aspect ratio of length to diameter of from .5 to 5, a geometric surface area of at least 25% greater than a hollow tube of the same inside and outside diameter, a porosity of at least .3 cm^3/g, and a surface area per reactor volume of at least 5 cm^2/cm^3.

In light of the foregoing, there is a need for low-cost and simple heat exchange media having excellent thermal and mechanical stability and high thermal mass which will not exhibit a large pressure drop when packed into a RTO column.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a heat exchanger utilizing shaped heat exchange particles, suitably sized, which substantially obviates one or more of the problems associated with the prior art heat exchangers.

Specifically, a heat exchanger column provided with a bed of shaped particles suitably sized according to the present invention addresses the competing considerations of pressure drop across the bed and heat recovery and cycle time associated with the process.

The heat exchange particles of the present invention are made of a high-temperature stable material such a mullite, alpha-alumina, silica-alumina, clay, or the like. The shaped particles of this invention are extrudates called "MINILITHS™" preferably having specially shaped vanes extending from the center. In view of the shape and size of the particles, the heat exchanger column packed therewith will not exhibit a large pressure drop and the heat capacity of these particles is greater than that of conventional extruded monoliths. One embodiment, a cylindrical particle, has a partially hollow interior with internal reinforcing vanes or ribs extending from the inner wall to the center of the extrudate particle. This configuration permits the media to have high strength and a large geometric surface area per heat exchanger volume which is required for efficient heat transfer.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the system, method and particles particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described, the invention is a heat exchanger having a heat exchanger column provided with a bed of heat exchange media particles, each particle being formed of a high temperature stable material and having vanes extending from the center of the particle.

In another aspect, the invention includes a method of exchanging heat by providing a gas through an inlet of a heat exchanger column, then passing gas through a bed of heat exchange media particles, each particle being formed of a high temperature stable material and vanes extending from the center of the particle.

In yet another aspect, the invention includes a heat exchange media particle formed of a high temperature stable material which has vanes extending from the center of the particle; and a geometric surface area of 0.1-50 mm^2/m^3, a cylindrical outer wall diameter of 2-50 mm, and an aspect ratio of 0.1-3.

In a still further aspect, the invention includes a plurality of heat exchange media particles suitably sized so as to avoid large pressure drops while allowing for laminar flow and high heat transfer in the heat exchange column(s).

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory, and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the objects, advantages, and principles of the invention.

In the drawings:

Fig. 1 illustrates a schematic of a typical RTO system having a heat exchange column in which heat exchanger particles are packed.

Fig. 2 is a cross-sectional view of a four-vaned heat exchange media particle according to a first embodiment of the invention.

Fig. 3 is a cross-sectional view of a six-vaned heat exchange media particle according to a second embodiment of the invention.

Fig. 4 illustrates a trilobe heat exchange media particle according to another embodiment of the invention.

Fig. 5 illustrates a quadrilobe heat exchange media particle according to another embodiment of the invention.

Fig. 6 illustrates a modified quadrilobe according to another embodiment of the invention.

Fig. 7 is a side view of one embodiment of a regenerative thermal oxidizer utilizing the heat exchange media of the present invention.

Fig. 8 is a top view of the apparatus of Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a schematic of a typical regenerative thermal oxidizer 1. RTO systems typically comprise a feed delivery system 2 for routing process exhaust containing the VOCs through a valve system 3 and into an oxidizer 4.

The oxidizer comprises one or more heat exchanger columns 5 packed with heat exchange materials. Process exhaust is heated by direct contact with hot heat exchange materials to temperatures (typically in excess of 1400°F) at which the VOCs are completely oxidized to carbon dioxide and water. If such heating is insufficient to increase process exhaust temperature above 1400°F, then supplemental heat may be added by, for example, electric heating elements 6. After the VOCs are oxidized, the process exhaust is cooled by direct contact with cooler heat exchange materials at 7. Then the cleaned exhaust gas exists to the atmosphere at 8. After continuous operation for a given amount of time (referred to as the cycle time), heat recovery efficiency suffers and the columns are switched. i.e., the hotter column is used for heating and the cooler column is used for cooling. In the case of a single column RTO, the direction of flow through the column is reversed by the valve system 3.

The heat exchange media used in such RTO's must be selected so that the RTO meets certain performance criteria. Specifically, excessive pressure drop within the heat exchange columns deleteriously impacts the throughput, and would necessitate large pumps and high energy requirements. In addition, the heat exchange media should be suitably sized to as to allow for laminar flow, i.e., preferably a Reynolds number less than about 3000, most preferably less than about 2100. It is therefore desirable that the heat exchange media be sufficiently large so as to avoid large pressure drops. However, the heat exchange media must not be too large so as to reduce heat capacity and/or heat transfer, thereby resulting in lost efficiency of the RTO. The present inventors have found that by using the heat exchange media shaped and sized in accordance with the present invention, RTO's that are significantly smaller (e.g., 1/3 smaller) than conventional RTO's and that exhibit laminar flow can be made without sacrificing efficiency. More specifically, in view of the shape and size of the heat exchange media particles according to the present invention, the overall height of the regenerative thermal oxidizer can be significantly reduced, since the amount or volume of heat exchange media needed to achieve the same efficiency is significantly reduced. For example, to achieve 95% efficiency, the amount of heat exchange media needed is about 50% of what was previously required. In addition, the regenerative thermal oxidizer is capable of treating effluent gas at a flow rate range of about 0.1M/s to about 1M/s, and has a thermal energy recovery of from about 94 to 99%.

In the preferred embodiment, the heat exchange media in accordance with the present invention includes voids which allow the passage of gas through the media particles. The voids preferably should be larger than the voids existing in the interstices formed amongst the media particles. If the voids are too small, the gas will tend to flow in the interstices rather than through the voids in the particles. The exchange particles according to the present invention are fabricated of a single material and are characterized by protrusions or vanes extending from the center of the particle. Spaces between the protrusions provide an ideal void fraction for the passage of gasses, thereby improving the pressure drop characteristics of the aggregate heat exchanger bed. The voids between vanes also provide a greater surface area for contact between the gas and the particle, thus enhancing heat exchange therebetween. In a most preferred embodiment, the particles are in the form of wagon wheels, i.e., small tubular extruded members having a series of vanes which extend through the center of the axis of rotation of the tubular member. Viewed from the center, they appear as a series of ribs which extend out to the outer tubular element. The outer cylindrical wall provides additional strength (e.g., crush resistance) to the particles and prevents intermeshing of the vanes of neighboring particles. This intermeshing may restrict the flow of gas through the bed due to the filling of voids between the vanes. In the embodiment shown in Fig. 2, there are four vanes or ribs and in the embodiment illustrated in Fig. 3, there are six vanes or ribs. Other embodiments are shown in Figs. 4, 5, and 6. The width of the vanes are preferably smaller than the spacing between the vanes. This spacing creates the desirable void fraction of the aggregate bed packing thereby ensuring an adequate flow through the bed. The particles have substantially constant cross sectional shape, size, and area. Because the particles are used as a discontinuous aggregate bed packing, any thermal variation is localized and will not cause a significant decrease in the service life of the individual particles or the heat exchanger as a unit.

This unique geometry produces a structure having a large geometric surface area and a large void fraction. The geometric surface area is generally in the range of 0.1-50 mm^2/mm^3, and preferably 0.5-5 mm^2/mm^3. Because the particles are made of a high-temperature stable material which can withstand the high temperatures required for efficient destruction of volatile organic compounds, preferred materials of construction include aluminum silicate clays, such as kaolin, aluminum silicate clay mixed with alumina, or aluminum silicate clay and alumina mixed with silica and/or zeolites. Other candidate materials of manufacture include mullite, alumina. silica-alumina, zirconia, and generally any inorganic oxide materials or other materials stable up to about 1000°C. The materials should be dense and have a high heat capacity.

The overall diameter, b, can range in size from about 2 mm to about 50 mm, preferably 6-13mm. In order to achieve optimum heat transfer and heat capacity while minimizing pressure drop, the size of the particles most preferably should be about 10mm (0.375 inches).

In another embodiment in Fig. 3, a six-vaned particle is formed. Again, the overall diameter, d, can range in size from 2 mm up to about 50mm, preferably 6-13 mm. A useful size particle with six vanes is the 0.21 inch size. In order to achieve optimum heat transfer and heat capacity while minimizing pressure drop, the size of the particles most preferably should be about 10mm (0.375 inches). Again, the thickness of the vanes also can be varied.

In another embodiment, illustrated in Fig. 3, the die may be configured so that where the vanes come together they form a circular hub which has a diameter, c, which can be adjusted in size. The hub is an optional structural feature to provide additional crush strength for the particle. It can be used with either the four- or six-vaned embodiments.

The thickness of the wall of the particle, shown as e in Fig. 3, can also be varied. The thicker the wall, the stronger will be the particle in terms of crush strength.

The aspect ratio is the ratio of the length of the particle to its diameter. Aspect ratios can vary from 0.1-3 with generally preferred aspect ratios of 0.4-1.5.

Figures 4-6 show alternative, less preferred embodiments where no outer cylindrical wall is present. Vanes extending from the center of the particle appear as “lobes”; thus Figure 4 shows a trilobe embodiment, and Figures 5 and 6 show quadrilobe embodiments. As compared to the embodiments shown in Figures 2 and 3, the less preferred embodiments of Figures 4-6 are less preferred because when packed in a bed, they present a more tortuous path for gas flow, thereby increasing pressure drop. Being devoid of the outer cylindrical wall, they also provide less surface area for heat transfer.

Turning now to Figure 7 and 8, there is shown a two can regenerative thermal oxidizer utilizing the heat exchange media in accordance with the present invention. Gas to be treated such a process gas inters the inlet of the oxidizer at 10. Heat exchange columns 11 and 12 are positioned below a combustion or oxidation chamber 13, the chamber 13 being heated by one or more burners 14. Pneumatic poppet valves 15 and 15’, preferably “double” poppet valves having a common center section , are associated with the inlet and outlet ducting of the heat exchange columns 11 and 12 are minimize leakage from the unit. An optional flush chamber 26 may be included in the apparatus. Each heat exchange column 11, 12 contains a bed of the heat exchange media in accordance with the present invention. Bed thickness is not a function of gas flow, but only of heat recovery efficiency. With the heat exchange media of the present invention, bed thickness 18 is about 38 inches. The combustion chamber 13 height is a function of flow; the combustion chamber should include 1 inch of height for every 500-600 scfm of process flow, and should be at least 24 inches high regardless of flow. The bed inlet/outlet plenum 19 is 1/2 the combustion chamber 13 height. The overall height of the unit is the sum of the bed height, the plenum height, the combustion chamber height and the insulation thickness (6 inches), and can be represented by the following formula:

$$\text{Height} = [1/370.4][\text{flow}] + 44''$$

where flow is the process flow in scfm, and the minimum height is 80 inches. The diameter of the beds is directly proportional to the $[\text{flow rate}]^{1/2}$.

In operation, solvent laden air is directed into the base of an energy recovery column which is on an inlet mode, by passing through a main exhaust fan (not shown), inlet ductwork, and poppet valve 15 (or 15', as the case may be). The solvent laden air is then directed vertically up into a heat exchange column 11, and through the heat exchange media contained therein. Heat is transferred from the hot heat exchange media to the cooler solvent laden air, so that by the time this air exits the top of the column of media, it has been heated to almost the operating temperature (or set point) of the oxidizer. Burner means associated with the combustion chamber 13 raise the air to the set point temperature and oxidation of the VOC's, which was begun in the heat exchange media, is completed. Hot purified air them passes vertically down through the heat exchange media in the other heat exchange column, and the hot air heats the cooler media therein so that by the time the air exits the base of the column, it has been cooled to an acceptable temperature, such as a temperature only slightly higher than that of the incoming solvent laden air. Flow through the oxidizer is reversed by simultaneously moving both poppet valves 15, 15'. The poppet valves continuously cycle so that one energy recovery column is always in an outlet or gas cooling mode. The frequency of the flow reversals is directly related to the volumetric flow through the oxidizer.

When destruction efficiencies of up to 99% are required, an optional flush control chamber can be used. The flush control chamber includes an associated poppet valve 25, flush chamber 26 and associated duct work. Prior to flow reversal, the flush control poppet valve 25 will change positions to direct the normal exhaust from the oxidizer into the storage chamber 26. When a flow reversal occurs on the oxidizer, the "puff" of VOC laden air that would normally be released to atmosphere is stored in the flush control chamber 26. After a flow reversal is completed, the normal exhaust from the oxidizer continues to flow into the flush control chamber 26 to capture any residual VOC laden air from the base of the energy recovery columns and ductwork. The flush poppet valve 25 then switches position and the normal exhaust is directed to the exhaust stack 27 while the VOC laden air stored in the flush chamber 26 is slowly drawn back into the inlet of the oxidizer.

Example 1

This example illustrates the pilot scale preparation of 0.21" six spoke particle extrudates composed of silica and alumina. Catapal B alumina (27.2 lbs.) was placed in a 50-gallon Sigma mixer followed by addition of 50.0 lbs. water and 4.76 lbs nitric acid and mixed for 60 minutes until a homogeneous gel was formed. While the mixer was running, 130.7 lbs. of Davison non-promoted fluid catalytic cracking catalyst (composed primarily of silica and alumina) was added to the gel, and the resulting mixture was again mixed to homogeneity (about 10 minutes). While mixing, 6.50 lbs. of Methocel K4M was added and mixing was continued for 10 minutes. An additional 25 lbs. of water and 2.08 lbs. of Methocel K4M were added followed by 27 minutes of mixing. The resultant paste was extruded into 0.21" pellets. The pellets were dried at 80°C, and calcined at 1200°C for 6 hours.

Example 2

This example illustrates the lab scale preparation of 0.25" six spoke particle extrudates using mullite. Catapal C alumina (30.0 lbs) was placed in a 50-gallon Sigma mixer followed by the addition of 5.3 lbs nitric acid (70 wt%) in 70.0 lbs. of water and mixed for 40 minutes until a homogeneous gel was formed. While the mixer was running, 300 lbs. of mullite was added to the gel and the mixture was blended for 10 minutes. Methocel K4M (15.0 lbs.) was added and mixing was continued for 5 minutes. An additional 10.0 lbs. of water was added followed by an additional 5 minutes of mixing. A portion of the resultant paste (16.5 Ibs.) was transferred to a 5-gallon Sigma mixer where 3.3 lbs. mullite powder was added and the mixture blended for 15 minutes. The finished paste was extruded into 0.25" six spoke pellets. The pellets were dried at 80°C, and calcined at 600°C for 8 hours followed by further calcination at 1400°C for 6 hours.

A significant advantage of these ribbed particles over conventional spheres is their ability to provide both a large geometric surface area per packed volume of reactor and to provide a lower pressure drop across the bed than is obtained by spheres having a comparable geometric surface area per packed volume. To determine pressure drops 0.2 inch (5.08 mm) samples of the six-vaned extrudate according to the present invention, monoliths and two different sizes of spheres were compared.

Testing Protocol for Heat Exchange Media

The heat exchange media is tested in a small version of a regenerative unit. The unit consists of a vertical reactor 1 m in diameter which can accommodate a bed of heat exchange media up to 1.5 m in height. The chamber is designed to accept gravel and other shaped media as well as ceramic monoliths. The unit is designed to run at gas flow rates between 0.2 and 1 m3/s resulting in superficial gas velocities of 0.3-1 m/s in the heat exchange chamber. The height of the heat exchange media and the gas flow rate are set for each heat exchange media type to obtain a pressure drop around 25 inches of water and a heat recovery around 95%, when possible. The unit was used to test the performance of two different gravel sizes, a 3.3 pitch ceramic monolith and media in accordance with the invention.

The results are shown in Table 1.

TABLE 1

Comparative Performance of Different Packing Materials

	Gravel	Gravel	Monolith	0.2" Particles
Heat Recovery, %	98	95	93	97
ΔT, °C	20	50	70	30
Velocity, m/s	0.3	0.33	0.8	0.45
Bed Depth, m	1	1	1.5	1.2
ΔP,. inches of H_2O	40	23	4.33	20
Packing Composition	44% Alumina 52% Silica 1% Iron Oxide 2% Titania	35% Alumina 55% Silica 2% Iron Oxide 2% Potassium Oxide 2% Titania	Mullite	Silica-alumina
Packing Geometry	Sphere	Sphere	Str. Ch.	6 Spoke

Material Size	2-3 mm	5 mm	3.3 pitch	Diameter: 0.21" w.t.: 0.25"

As can be seen in Table 1, key performance criteria include percent heat recovery, the temperature rise across the bed, the velocity or flow rate of gas for a given cross-section, bed depth, pressure drop, and packing geometry. The performance of 2-3 mm spherical packing is shown to provide 98% heat recovery, 20° temperature increase across the bed for a 1 meter bed at a velocity of .3 m/sec (column 1). Spherical gravel of size 5 mm diameter provides 95% heat recovery at a temperature increase of 50°C (column 2). A monolith of 3.3 pitch provides 93% heat recovery at a higher temperature increase of 70°C (column S). As the shape of the channel or the size of the particle gets larger, the pressure drop across the bed decreases. In contrast with the three prior art materials, particles in accordance with the invention provide a 97% heat recovery with only a 30° temperature increase at a higher linear velocity of .45 m/sec. Additionally, a 1.2 meter deep bed results in only a 20 inch pressure drop. This unexpected result shows that shaped particles of the present invention provide superior performance to gravel and monolith-type substrates commonly used in the industry.

If a catalyst is to be carried by the particles, a washcoat of alumina should be applied to the particle prior to the catalyst. Useful catalysts are generally any VOC oxidation catalyst, such as platinum or palladium.

It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed process and product without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

1. A heat exchanger comprising an enclosure containing a packing of heat-exchange particles, said exchanger being adapted to exchange heat between said particles and a fluid flowing therethrough, each said particle being formed of a high temperature stable material having at least one vane extending from the center of the particle, said at least one vane defining voids on either side thereof, said particles being sufficiently small in diameter and said voids being sufficiently large as to create laminar flow of said fluid through said particles and to reduce pressure drop in said packing as said fluid flows therethrough.

2. The exchanger of claim 1 wherein the particles have a plurality of vanes.

3. The heat exchanger of claim 1, wherein:

said particles are formed essentially of material selected from the group consisting of aluminum-silicate clay, aluminum-silicate clay mixed with alumina, and aluminum-silicate clay mixed with alumina and at least one of silica and zeolite.

4. The heat exchanger of claim 1, wherein the particles have a plurality of vanes and said vanes extend from the center of said particles to an outer cylindrical wall connecting the ends of said vanes..

5. The heat exchanger of claim 1, wherein said particles have at least four vanes.

6. The heat exchanger of claim 1, wherein said particles have at least three vanes.

7. The heat exchanger of claim 1, wherein said particles have at least two vanes.

8. A regenerative thermal oxidizer comprising:

at least one heat exchange column containing heat-exchange media;

a combustion chamber in communication with said at least one heat exchange column;

gas inlet and outlet means in communication with said at least one heat exchange column;

wherein said heat exchange media comprises a plurality of particles, each said particle being formed of a high temperature stable material having at least one vane extending from the center of the particle, said at least one vane defining voids on either side thereof, said particles being sufficiently small in diameter and said voids being sufficiently large as to create laminar flow of said fluid through said particles and to reduce pressure drop in said packing as said fluid flows therethrough.

9. The regenerative thermal oxidizer of claim 8, further comprising at least two heat exchange columns.

10. The regenerative thermal oxidizer of claim 8, wherein each of said particles is from about 6 to about 13 mm in size.

11. The regenerative thermal oxidizer of claim 8, wherein the volume of said particles in said at least one heat exchange column is reduced in size without a sacrifice of heat exchange efficiency and pressure drop as compared to a column containing particles other than as described in claim 8.

12. A heat exchange media particle formed of a high temperature stable material, each said particle having voids larger than the interstices formed when a plurality of said particles are packed together in a heat exchanger column.

13. The particle of claim 12, wherein said voids are formed by at least one vane extending from the center of the particle.

14. A heat exchanger comprising:

a heat exchanger column with a bed of packing material,

said packing material being comprised of heat exchange media particles, each said particle being formed of a high temperature stable material and having voids larger than the interstices formed between said particles.

15. The heat exchanger of claim 14, wherein each of said particles is sufficiently small so as to allow for laminar flow in said heat exchange column.

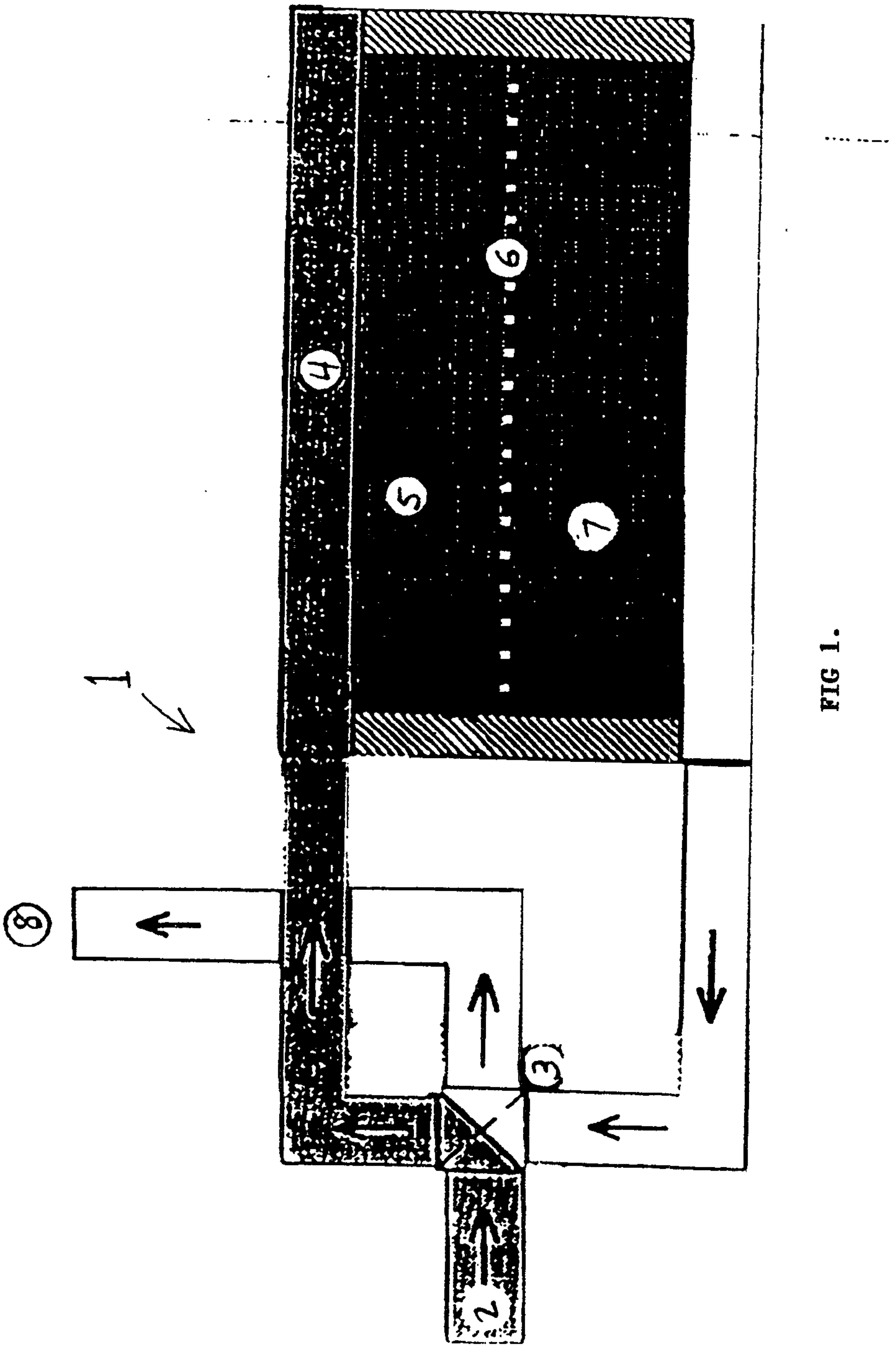


FIG 1.

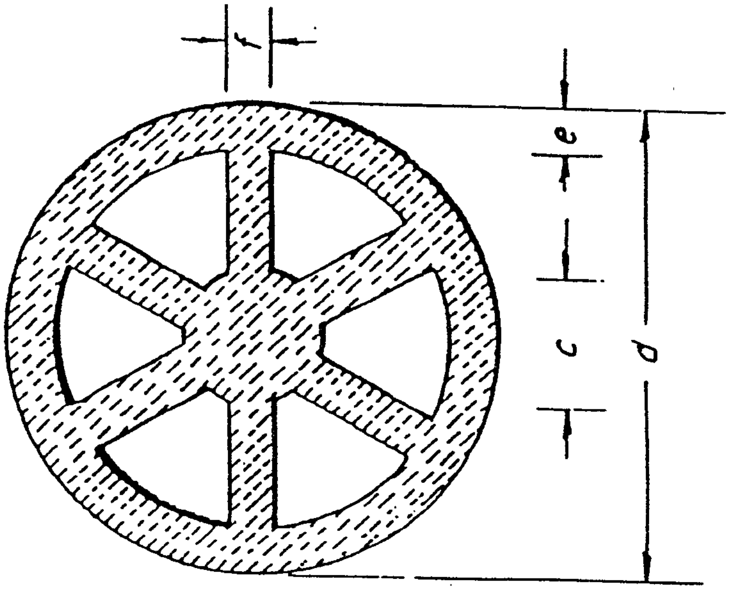


FIG 3.

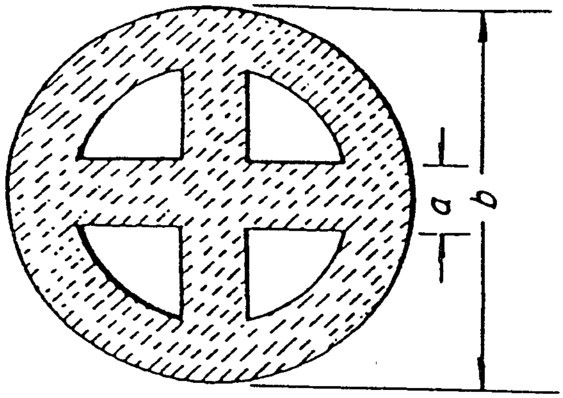


FIG 2.

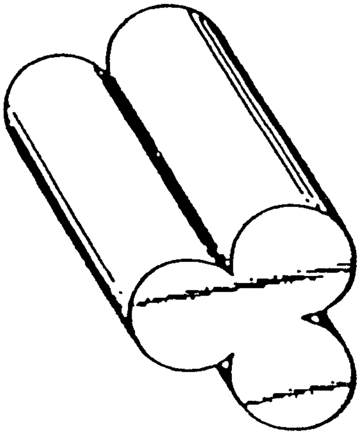


FIG 4.

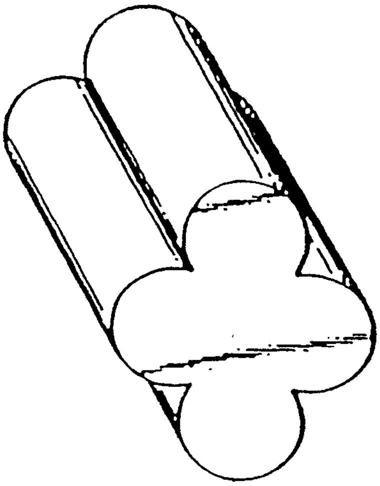


FIG 5.

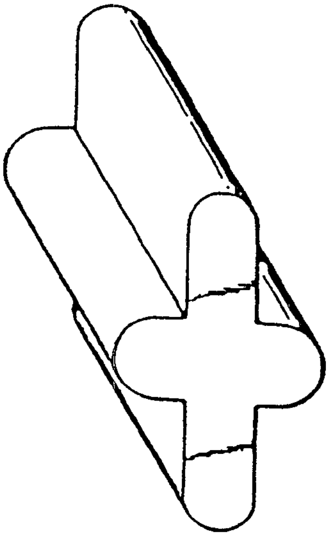


FIG 6.

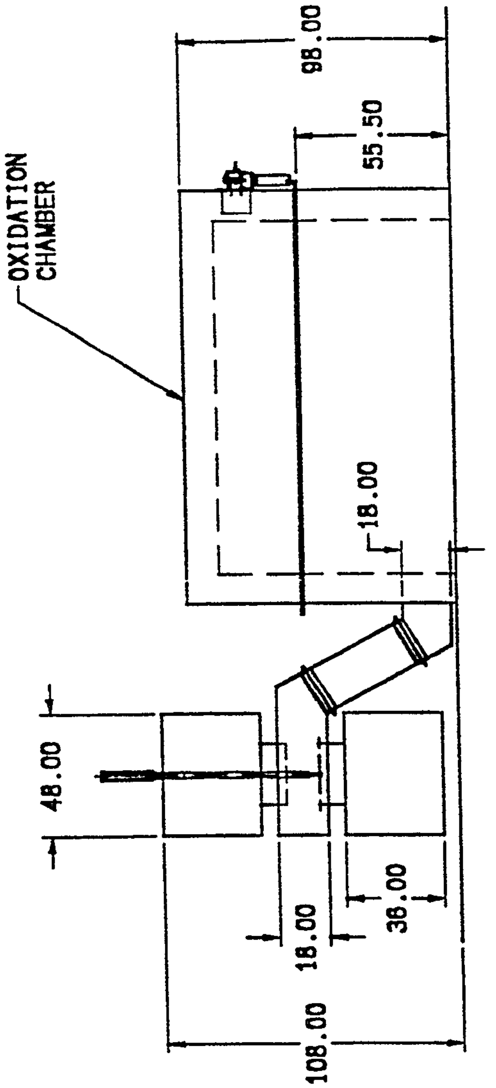


FIG 7.

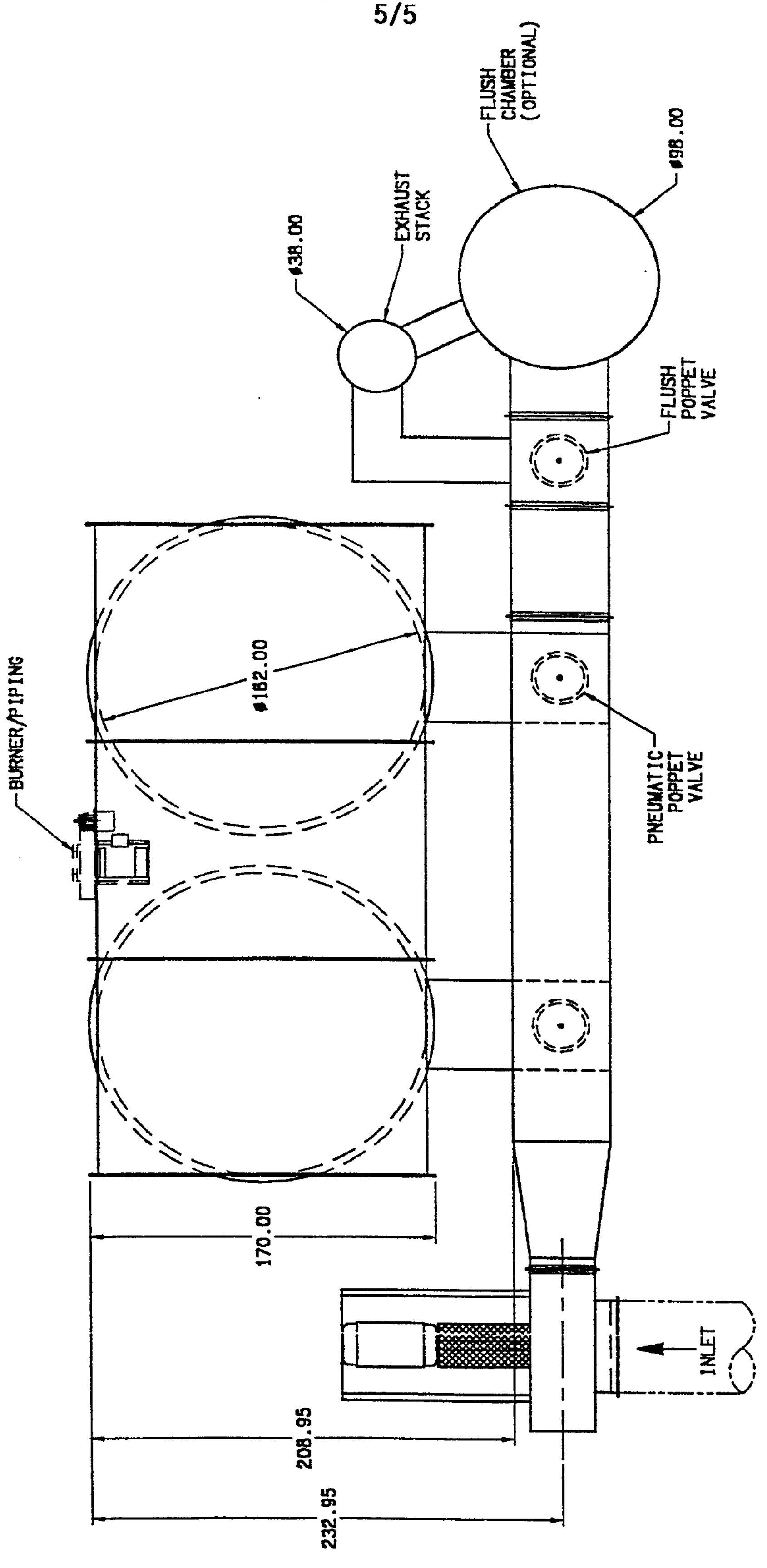
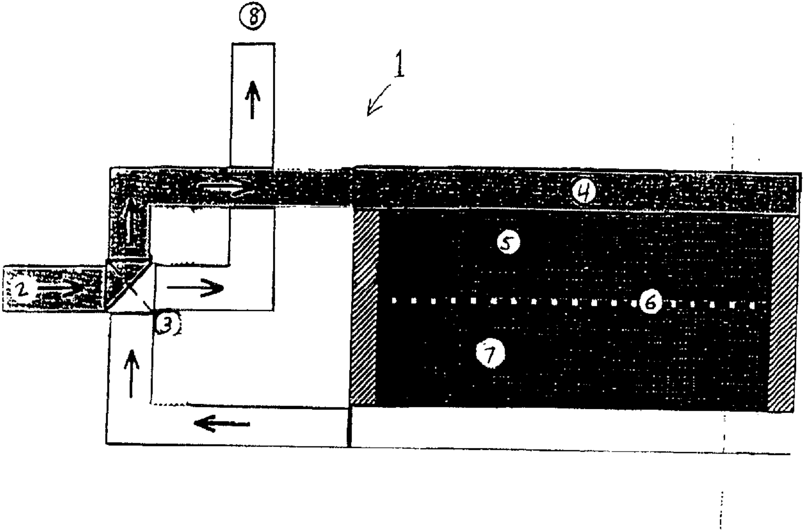


FIG 8.

Drawing Sheet 5/5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