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GAS HEATER

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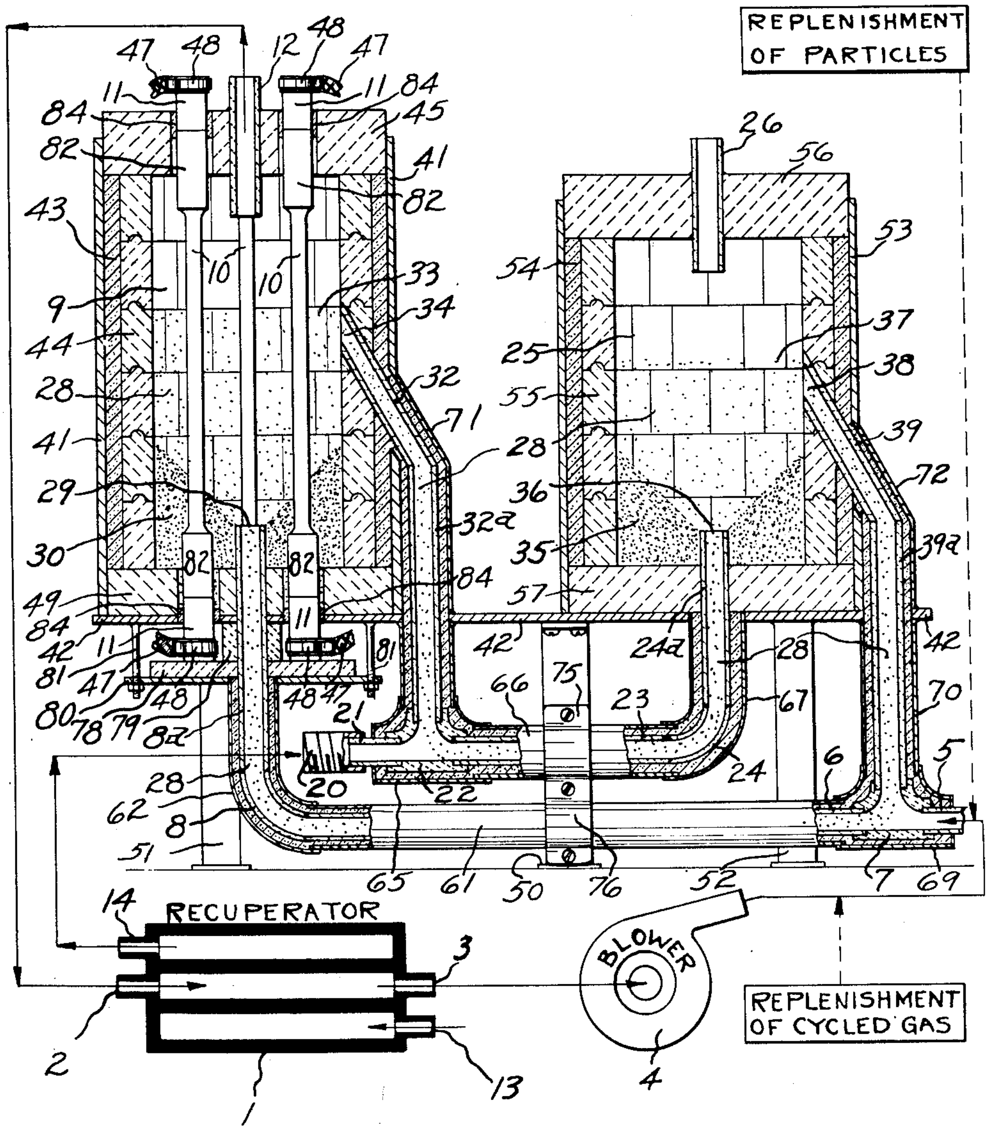

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GAS HEATER

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The invention relates to gas heaters.

One object of the invention is to provide gas heating apparatus which can be embodied in a small compact unit. Another object of the invention is to provide apparatus for rapidly heating gas by means of electric resistance heating units. Another object of the invention is to extract larger quantities of heat units per unit volume of heater equipment, thus attaining high output of thermal energy from such resistors. Another object is to achieve a high heat transfer coefficient from a resistance unit to gas. Another object is to provide an electric heater to heat gases that deleteriously affect the resistances used, without subjecting the resistances to such gases, while at the same time heating a large volume of gas to a high temperature by means of a relatively small heater, and as an example I can use silicon carbide heater bars which can be operated at high temperatures for a long time if located in a protective atmosphere and heat a gas such as steam without deteriorating the heater bars, whereas such silicon carbide bars have only short lives in a steam atmosphere. Another object of the invention is to provide a heater with electrical resistance heater units, preferably silicon carbide bars, and to provide an inert or non-oxidizing atmosphere in the chamber where the bars are located, to recycle the inert gas and to transfer the heat units to another chamber or passage through which the gas to be heated passes.

Other objects will be in part obvious or in part pointed out hereinafter.

The accompanying drawing illustrates an embodiment of the invention in which most of the heater is shown in vertical section, with certain associated apparatus and piping being illustrated diagrammatically.

Referring now to the drawing, it will facilitate a quick understanding of the invention first to trace the path of the inert or non-oxidizing gas and then to trace the path of the gas to be heated. The inert or non-oxidizing gas enters a recuperator **1** at entrance port **2**. The recuperator **1** may be of any desired construction and as recuperators are well known I have simply given the diagram found in the current Rules of Practice of the United States Patent Office. It will, however, preferably be a large recuperator or a series of recuperators greatly to lower the temperature of the gas. The gas which is now cooled leaves the recuperator **1** through port **3** and goes to a blower **4** which is also diagrammatically illustrated. The gas is taken from the

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blower **4** to a pipe **5** which is connected to a pipe **6** by a T-union **7**. The pipe **6**, shown as a straight pipe, is coupled to a bent pipe **8** which is coupled to a straight pipe *8a* which extends into a fluidizing chamber **9** having therein resistor rods or bars **10**, for example the well known silicon carbide resistor bars having cold ends **11**. The gas which is heated in the fluidizing chamber **9** to a high temperature is taken by a refractory pipe **12** back to the entrance port **2** of the recuperator **1**. In the drawing, which is diagrammatic, the entrance port **2** is shown as located at some distance from the refractory pipe **12** but in reality the port **2** may be only a short distance from the top of the chamber **9** and thus the pipe **12** can be a short straight pipe.

The gas to be heated, which is under pressure so that it will move through the heater, enters the recuperator **1** at an entrance port **13** and leaves the recuperator **1** at an exhaust port **14**, having been heated to an intermediate temperature. The partially heated gas then enters the heater at a pipe coupling **20** and the gas then enters a refractory pipe **21** leading to a refractory T-union **22** which is connected to a refractory pipe **23** connected to a curved refractory pipe **24** connected to a straight refractory pipe *24a* which leads to a fluidizing chamber **25**, and the fully heated gas then exhausts through a refractory pipe **26** to any apparatus for any process of conversion with which this invention is not concerned. In accordance with my invention gas can be heated to high temperatures economically in a small apparatus, and in industry and chemical engineering there are many reasons for heating gas to high temperatures and so there will be many uses for my apparatus but it is unnecessary for me to describe these or any of them as they relate to other arts.

The chambers **9** and **25** contain a quantity of fine particles **28** of refractory material in "fluidized" condition. The refractory material may be an oxide, carbide, silicide, nitride, boride, or a mixture of compounds. Just what refractory material to select depends upon which are poisonous to whatever reaction is to take place and it also depends upon availability and cost. Furthermore, at the temperatures involved, the nature of the gas entering the pipe **21** and present in the chamber **25** has to be considered. If this is reducing it might be desirable to avoid some of the oxides if the temperature is too high; if the gas is oxidizing it might be desirable to avoid some of the carbides. Readily available refractory oxides are alumina, silica and magnesia; the most readily available and inexpensive carbide which is sufficiently refractory for most applications is silicon carbide which will probably be preferred in most instances. The borides, silicides and nitrides are less available and more expensive but some thereof may be preferred for particular applications.

The particle size of the refractory material is a matter for careful consideration. In general the finer the particle size of the "fluidized" material, the more efficient is the transfer of heat from the chamber 9 to the chamber 25 and therefore, for a given temperature of the gas exhausting from the refractory pipe 26, the higher can be the rate of flow of the gas being heated. However for several reasons it is undesirable to lose particles in great quantities; it is expensive, it requires cleaning of any apparatus coupled to the heater, and it may interfere with some reactions. Accordingly since particles of the finer sizes will be carried away through the pipe 26 and lost to the heater, I find it is in general desirable to use particles not finer than 100 grit size. On the other hand for efficient use of the heater the particles in general should be no coarser than 60 grit size. So therefore the best specification is that the particles be through No. 60 screen onto No. 100 screen. However this is no hard and fast rule because for some applications loss of particles would be unimportant but rate of heat transfer might be very important hence there is no real limit to the fineness of the particles which can be employed although for practical purposes I can say that particles finer than 600 grit size, U. S. Bureau of Standards, probably would not be used. At the other end of the scale particles coarser than 24 grit size would not appear to be useful in this invention.

The "fluidized" condition is really a state of gaseous-solid emulsion. The gas entering the chamber 9 from the pipe 8*a* sustains the particles 28 of refractory material in the chamber which cannot choke the entrance port 29 because the velocity of the gas stream prevents them from doing so. Stagnant particles 30 settle in the bottom of the chamber 9 where the velocity of the gas stream is inadequate to support them and form a funnel shaped bottom for the chamber 9.

Fine particles stay in this gaseous-solid emulsion condition known as the "fluidized" condition wherever the velocity of the gas stream is high enough to keep them sustained or in motion. A fluidized emulsion in a chamber such as the chamber 9 where the gas stream is mainly upwardly will reach a level analogous to a liquid level. I provide refractory overflow pipes 32 and 32*a* and provide a great enough quantity of refractory particles to create a fluidized level 33 above the level of the overflow port 34 which is the entrance to the pipe 32. The pipes 32 and 32*a* extend downwardly and the latter is connected to the refractory T-union 22. Particles will therefore flow downwardly through the pipes 32 and 32*a* to the T-union 22 where they will be picked up by the gas which is moving in a fast stream to the right in the pipes 21 and 23 and through the T-union 22. The particles 28 will therefore be carried into the fluidizing chamber 25 which has stagnant particles 35 forming a funnel shaped bottom at the lowest point of which is the entrance port 36 for the gas and the fluidized particles. Again I provide enough particles 28 and so adjust the sizes of the chambers 9 and 25 and the rates of flow of the two gas streams that the fluidized level 37 in the chamber 25 will be above an overflow port 38 of a refractory pipe 39 extending downwardly. Particles 28 will therefore descend through the pipe 39 and a pipe 39*a* connected to it to be picked up by the gas incoming through the pipe 5 and going through the T-union 7, through pipe 6 and through the pipes 8 and 8*a* into the chamber 9. Thus the cycle is completed and the particles 28 travel continuously through chamber 9, pipes 32 and 32*a*, union 22, pipe 23, pipes 24 and 24*a*, chamber 25, pipes 39 and 39*a*, union 7, pipe 6, pipes 8 and 8*a* back again to chamber 9. During the operation of the heater both chambers 9 and 25 should have fluidized particles 28 of refractory material therein up to just above the overflow ports.

The fluidized particles 28 in the chamber 9 are heated by the resistor rods 10. The illustrative embodiment is of four rods 10, two having axes in the plane of the section, the middle one being near the far side of the chamber 9, and there being a fourth one, not shown, in front of the plane of the section; thus the rods 10 are symmetrically located in the chamber 9. One or more resistor rods 10 deliver more heat units per minute to the fluidized particles than they would to the walls of the chamber 9 and thus the introduction of the bed of fluidized solids makes it possible to extract much more heat from the resistor rods in a gas heater of a given size than could be extracted in the absence of the fluidized particles. This can best be illustrated by these examples:

Example I

A vertical tube has several vertical resistor rods distributed within it and a non-radiating gas is passed upward through the tube in order to pick up heat from the resistor rods. The heat transfer mechanisms are convection and conduction and the areas of transfer simply the surface areas of the rods and the tube which absorbs radiant energy from the rods and passes it on to the gas by convection and conduction. The heat transfer coefficient is controlled by the gas velocity and because of practical limitations the velocity is confined to a range of values which provides extremely low heat transfer coefficients. This is primarily due to the existence of slow moving gas films along the heating surface wherein the heat transfer is purely by conduction and gases have low heat conductivities.

Example II

This case is the same as Example I except that a static bed of granular solids is introduced into the tube. The mechanism of transfer is somewhat changed. Those solids in contact with the heating surface pick up heat by solid to solid conduction and those solids in view of the rods absorb radiant energy. However, since the bed is static a temperature gradient is set up such that those particles close to the rods are extremely hot and those at some distance very cool. The main reason for this extreme gradient is the fact that for this temperature region refractory solids with low heat conductivities must be used. True the gas to solid contact area has been greatly increased but a large portion of the solid surfaces will be at far too low a temperature.

Example III

This case is the same as Example II except that the gas velocity is increased to the point where fluidization is obtained. The mechanism of heat transfer is the same as in Example II but now the mechanical turbulence brings about a uniform temperature throughout the bed. The heat transfer area is greatly increased and though the overall gas velocity may be low, the localized gas velocity between the particles is high, and so the slow moving gas films are reduced to a minimum. This results in an overall heat transfer coefficient many times larger than that available in either Example I or II.

Regardless of how carefully the grit was screened to eliminate fines some fines will necessarily be found among the particles 28 when the apparatus is first charged therewith. Most of these will soon pass out through the pipe 26. Thus after the apparatus has been in use for a short time there is very little loss of fluidized particles but occasionally a particle will gain the velocity of escape and be lost. Therefore if calculation is made for the initial loss the heater will operate for a long time without replenishment of particles but eventually replenishment has to be made. Any closable opening in the pipe 5 will serve as an entrance for replenishment of particles. Replenishment has been indicated diagrammatically in the drawing and preferably is done through a pipe which opens at a level above the level 37 as indicated, as in such case the blower 4 does not have to be stopped during replenishment.

The constructional details can be widely varied but as conducive to a fuller understanding of the invention the further features of the apparatus herein illustrated will be briefly described. The chamber 9 comprises a cylindrical steel casing 41 having a steel bottom 42 and having a refractory lining 43 which can be simply packed refractory grain and for heat insulation zirconia is preferred. Inside of the lining 43 is a cylindrical lining 44 made out of shaped refractory bricks, such as sintered alumina bricks. A removable refractory cap 45 is made out of any suitable refractory material such as a single piece of sintered alumina. Braided wire conductor ribbons 47 are wrapped around the cold ends 11 and held in place by spring metal clips 48 and are connected in circuit with electric power. The cylindrical lining 44 is supported by a refractory bottom plate 49 which can be made of sintered alumina and which has holes therethrough receiving the cold ends 11 and the pipe 8*a*.

The bottom 42 is part of a horizontal frame piece 42 supported by legs 50, 51 and 52. This piece also forms a bottom to a cylindrical steel casing 53 forming the supporting structure for the chamber 25. A refractory lining 54 similar to the lining 43 and a cylindrical refractory lining 55 similar to the lining 44 complete the chamber 25 which has a removable refractory cap 56. The refractory pipe 12 passes through the cap 45 and the refractory pipe 26 passes through the cap 56 as shown and a little cement on top of the caps 45 and 56 can be used to hold the pipes in place. A refractory bottom plate 57 supported by the steel bottom 42 supports the cylindrical refractory lining 55 and the stagnant particles 35.

A steel pipe 61 surrounds the refractory pipe 6, a steel pipe 62 surrounds the refractory pipes 8 and 8*a*; a steel T-union 65 encompasses the pipe 21 and the T-union 22; a steel pipe 66 and a curved steel pipe 67 surround the pipes 23, 24 and 24*a* and in every case refractory grain is rammed between the refractory pipe or union and the steel pipe or union. Similarly a steel T-union 69 surrounds the T-union 7 and this is connected to a steel pipe 70 surrounding the pipe 39*a* below the bottom 42. Steel casings 71 and 72 welded to the sides of the casings 41 and 53 respectively encompass the upper parts of the pipes 32*a* and 39*a* respectively and also parts of the pipes 32 and 39. Refractory grain is rammed inside the union 69, the pipe 70 and the casings 71 and 72. The pipes 61 and 66 are secured to the leg 50 by brackets 75 and 76. The resistors 10 should not fit tightly in each of the cap 45 and bottom plate 49 as they would be fractured due to elongation and contraction if they did fit tightly in each of these parts; they are shown as located in oversized holes in the cap 45 and bottom plate 49 and hence I provide a refractory plate 78 to support the rods 10 which also supports a refractory sleeve 79 surrounding and providing thermal insulation for the pipe 8*a* which is held in place by the plate 78 through which it passes. The plate 78 is in turn supported by a steel plate 80 which is supported by bolts 81 extending downwardly from the steel bottom 42.

The gas to be cycled through the recuperator 1, blower 4, pipe 5 etc. fluidizing chamber 9 and back to the recuperator can be any of the inert gases of which helium and argon are the most readily available. Argon has distinct advantages in that its specific gravity is greater and helium diffuses rather readily but is fairly inexpensive at the present time. Nitrogen can be used in some applications as it is inert towards silicon carbide or metals at the lower range of temperatures.

The resistor rod 10 is made of recrystallized silicon carbide according to a general process invented by Francis A. J. Fitzgerald, see for example U. S. Patent No. 650,234, dated May 22, 1900. This process was developed in Switzerland for the manufacture of resistors about thirty years ago and such resistors are now well known. The cold ends 11 are made by impregnation with silicon as described in U. S. patent to Henry Noel Potter No. 1,030,327 of June 25, 1912. The silicon impregnated silicon carbide has far lower resistivity than the remainder which is simply recrystallized silicon carbide and so therefore the voltage drop occurs between the cold ends and the heat is liberated between the cold ends. The central portions of these resistors, i. e. the portions between the cold ends, are necessarily porous and are readily attacked, at the usual temperatures of operation, by such gases as oxygen, steam and to a lesser extent by air. At such usual temperatures oxygen quickly oxidizes silicon carbide and steam appears to have a strong oxidizing effect thereon also. While these resistors can be and have been operated for long lengths of time in an air atmosphere it has usually been considered that they shouldn't be run at temperatures much over 1400° C. if they are going to have reasonable life expectancy. By operating them in an inert atmosphere such as A or He, they can be heated to temperatures greater than 1400° C. even up to 1600° C. and will usually last longer than the same resistors in air at 1400° C. Nitrogen will nitride the silicon carbide resistors at very high temperatures, but they can be operated at 1400° C. in nitrogen for a much longer time than they can be operated in air and will have useful lives in nitrogen at 1500° C. or even higher. To keep the cold ends 11 from being burned out I may further form them on enlarged end portions 82 providing temperature gradients between the ends 11 and the central hot portions of the resistors.

There are many reasons for wanting to heat air, steam and oxygen (and nitrogen at the higher temperatures) and in this heater they can be heated without affecting the life of the resistors. Even at 1000° C. silicon carbide resistors would quickly burn out in oxygen. In steam at even 1200° C. the silicon carbide resistors would have very short lives. Oxygen, steam and air are deleterious to metallic resistors at high temperatures so the same reason exists for this apparatus using metallic resistors. In fact molybdenum, which has a melting point of 2620° C., cannot be heated to anywhere near that temperature in air; in this apparatus, protected by argon or helium, it could be heated nearly to the melting point, and it could be heated to reasonably high temperatures in nitrogen.

But the enumeration of certain gases which the heater can heat to particular advantage is not meant to exclude others. Any gas can be introduced through the port 13 into recuperator 1 into the pipes 21 and 23 and through the fluidizing chamber 25. For example the gas may be a hydrocarbon to be cracked and it would be undesirable to pass the hydrocarbon through a chamber containing silicon carbide resistance elements because of the deposit of carbon thereon. Furthermore there may be other gases which could be cycled through the blower 4 etc. For replenishment of the cycle gas as it is lost through diffusion or in any other manner, it will suffice to have on hand a bottle full of the gas under pressure with suitable valves and a pipe connected to the line between the blower 4 and the pipe 5, as clearly indicated in the drawing.

In describing the invention I have necessarily described a complete heating system but the heater proper is the unit which is shown in detail (minus the pipes 12 and 26) as it is such heater which is an article of commerce to be sold without the recuperator or the blower or the outside piping (indicated by lines and arrows) which are other articles of commerce. The particles of refractory material to be fluidized to wit: refractory grain is likewise a separate article of commerce. I desire therefore particularly to claim the heater proper shown in detail as this is a manufacturing unit and a "manufacture" for sale.

The reason for using the recuperator 1 with the apparatus of this invention is that, if the heater is operated at high temperatures, as contemplated, the ordinary blower (made of metal) would be quickly oxidized or even melted. By using the system illustrated and described the blower 4 receives only moderately hot gas but the heat units in the gas exhausting from the chamber 9 are not entirely lost. In some applications, where the temperatures are somewhat lower or if the blower including its impeller and shaft are made of refractory materials, the recuperator 1 can be dispensed with entirely or be of diminished size and capacity for exchanging heat units.

The selection of materials is important but depends upon the gas being cycled, the gas being heated, and the temperature of the resistors 10. Sintered alumina is a good material from which to make the various refractory pipes, the cylindrical linings, the refractory caps and the refractory bottom plates. This material is resistant to abrasion, it is not a conductor of electricity and it will not react excessively with the fluidized particles 28 even if they are carbide particles at the lower range of temperatures, say up to about 1450° C. For operating the apparatus at resistor temperatures of 1450° C. and lower, I therefore recommend that the refractory pipes, refractory T-unions, refractory caps and refractory bottom plates be made of sintered alumina and this can be so whether the cycled gas is argon, helium or nitrogen and assuming that the fluidized particles are silicon carbide particles and the resistors 10 are silicon carbide resistors. Sintered alumina has another good characteristic in that it is relatively impervious to gases although if helium is used there will be some gas lost through diffusion. To prevent gas loss through the cap 45 and the bottom plate 49 asbestos packing 84 is provided around the cold ends 11 of the resistors 10. Sintered alumina cannot be classed as a thermal insulator but it is a poor conductor of heat but the provision of the refractory linings 43 and 54 of zirconia particles provides good heat insulation for the apparatus. The refractory grain rammed between the refractory pipes and unions and the steel pipes and unions should likewise preferably be zirconia for the best results. I do not recommend zirconia bricks for the cylindrical linings 44 and 55 because at high temperatures zirconia becomes conductive.

Another selection of materials useful for resistor temperatures up to 1600° C. comprises zirconia grain linings throughout, as in the previous embodiment, silicon carbide fluidized particles 28 and refractory pipes, T-unions, caps and bottoms of bonded silicon carbide with a highly refractory bond. While recrystallized silicon carbide is electrically conductive, bonded silicon carbide is not. In this embodiment the material everywhere is silicon carbide, only the solid pieces have a minor proportion of refractory bond of a nature known to those skilled in the ceramic arts. Thus there will be no reaction between the fluidized particles and the walls of any of the pipes or chambers or between the particles and the resistor rods. For many practical applications this is probably the best selection of materials.

In the claims the fluidizing chamber 9 is referred to as a first chamber, the fluidizing chamber 25 is referred to as a second chamber, the T-union 7 is referred to as a first T-union, the T-union 22 is referred to as a second T-union, the pipes 32 and 32a are referred to as a first pipe, the pipes 39 and 39a are referred to as a second pipe, the pipes 6, 8 and 8a are collectively referred to as a third pipe and the pipes 23, 24 and 24a are referred to as a fourth pipe. This is believed to be necessary for identification without confusing circumlocution since there are pluralities of chambers, T-unions and pipes. The expression "T-union" is to be taken to include any gas connection having three branches and "pipe" means any conduit capable of functioning to convey gas as indicated herein.

It will thus be seen that there has been provided by this invention a heater in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments might be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A gas heating apparatus comprising a first

refractory lined fluidizing chamber, electrical resistance heating means in said chamber, a first refractory pipe having an opening into said chamber well above the bottom thereof and extending downwardly from said opening, said chamber having an upper opening well above the level of the opening into said chamber of the first refractory pipe, said chamber also having an opening in the bottom thereof, a second refractory lined fluidizing chamber, a second refractory pipe having an opening into said second chamber well above the bottom thereof and extending downwardly from said opening, said second chamber having an upper opening well above the level of the opening into said second chamber of the second refractory pipe, said second chamber also having an opening in the bottom thereof, a third refractory pipe connected to the opening in the bottom of the first chamber, a fourth refractory pipe connected to the opening in the bottom of the second chamber, a first refractory T-union two of the branches of which are connected respectively to the second refractory pipe and to the third refractory pipe, and a second refractory T-union two of the branches of which are connected respectively to the first refractory pipe and to the fourth refractory pipe, whereby when the upper opening of the first chamber is connected to a blower, the blower is connected to the first T-union, the second T-union is connected to a supply of gas to be heated and the chambers are partially filled with particles of refractory material, the apparatus will function as a gas heater and the gas to be heated will not come in contact with the electrical resistance heating means.

2. A gas heating apparatus comprising a first refractory lined fluidizing chamber, electrical resistance heating means in said chamber, a first refractory pipe having an opening into said chamber well above the bottom thereof and extending downwardly from said opening, said chamber having an upper opening well above the level of the opening into said chamber of the first refractory pipe, said chamber also having an opening in the bottom thereof, a second refractory lined fluidizing chamber, a second refractory pipe having an opening into said second chamber well above the bottom thereof and extending downwardly from said opening, said second chamber having an upper opening well above the level of the opening into said second chamber of the second refractory pipe, said second chamber also having an opening in the bottom thereof, a third refractory pipe connected to the opening in the bottom of the first chamber, a fourth refractory pipe connected to the opening in the bottom of the second chamber, a first refractory T-union two of the branches of which are connected respectively to the second refractory pipe and to the third refractory pipe, a second refractory T-union two of the branches of which are connected respectively to the first refractory pipe and to the fourth refractory pipe, and a quantity of refractory particles in each of said fluidizing chambers, said particles being between 24 grit size and 600 grit size, whereby when the upper opening of the first chamber is connected to a blower, the blower is connected to the first T-union and the second

T-union is connected to a supply of gas to be heated, the apparatus will function as a gas heater and the gas to be heated will not come in contact with the electrical resistance heating means.

3. A gas heating apparatus as claimed in claim 2 in which the refractory particles are silicon carbide particles.

4. A gas heating apparatus as claimed in claim 3 in which the electrical resistance heating means comprises silicon carbide resistors.

5. A gas heating apparatus as claimed in claim 4 in which the refractory lining of one of the chambers is a silicon carbide lining.

6. A gas heating apparatus as claimed in claim 2 in which the electrical resistance heating means comprises silicon carbide resistors.

7. A gas heating apparatus as claimed in claim 6 in which the refractory lining of one of the chambers is a silicon carbide lining.

8. A gas heating apparatus as claimed in claim 2 in which the refractory lining of one of the chambers is a silicon carbide lining.

9. A gas heating apparatus as claimed in claim 8 in which the refractory particles are silicon carbide particles.

10. A gas heating apparatus as claimed in claim 2 in which the refractory lining of one of the fluidizing chambers is an alumina lining.

11. A gas heating apparatus as claimed in claim 10 in which the refractory particles are alumina particles.

12. A gas heating apparatus as claimed in claim 11 in which the electrical resistance heating means comprises silicon carbide resistors.

13. A gas heating apparatus as claimed in claim 2 in which the refractory particles are alumina particles.

14. A gas heating apparatus as claimed in claim 13 in which the electrical resistance heating means comprises silicon carbide resistors.

15. A gas heating apparatus as claimed in claim 2 in which the electrical resistance heating means comprises silicon carbide resistors and the refractory lining of one of the fluidizing chambers is an alumina lining.

16. A gas heating apparatus as claimed in claim 1 in which the electrical resistance heating means comprises silicon carbide resistors.

17. A gas heating apparatus as claimed in claim 16 in which the refractory lining of one of the chambers is a silicon carbide lining.

18. A gas heating apparatus as claimed in claim 1 in which the refractory lining of one of the chambers is a silicon carbide lining.

19. A gas heating apparatus as claimed in claim 1 in which the refractory lining of one of the chambers is an alumina lining.

20. A gas heating apparatus as claimed in claim 19 in which the electrical resistance heating means comprises silicon carbide resistors.

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