Dec. 17, 1968 J. HUEBLER ETAL 3,416,509

SELF-CLEANING GAS OVEN

Filed Nov. 23, 1966 4 Sheets-Sheet 1

FIG. 1.

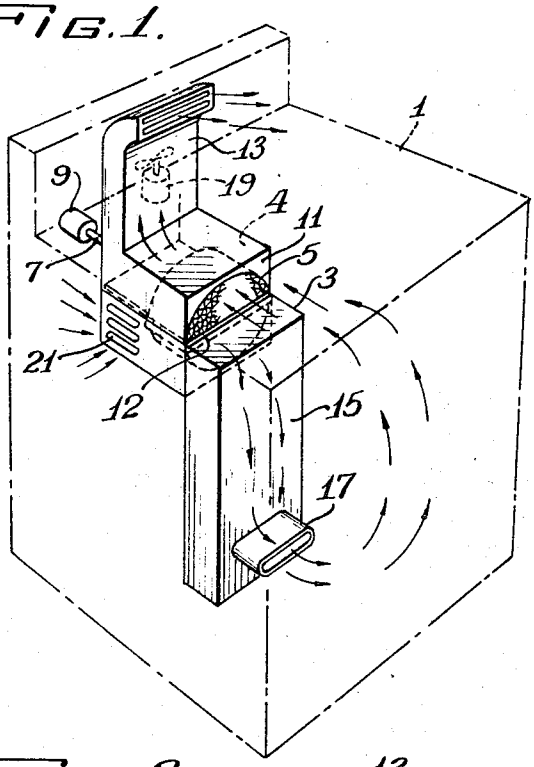


FIG. 2.

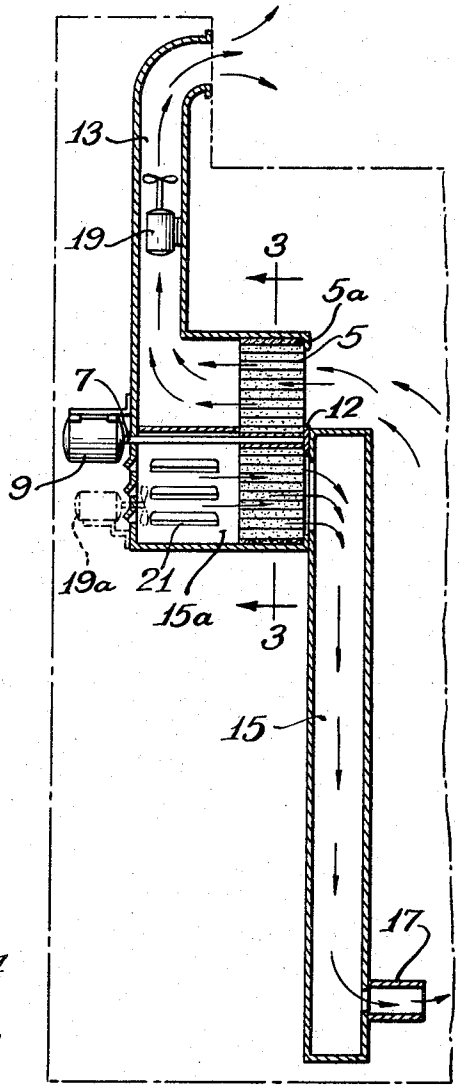


FIG. 3.

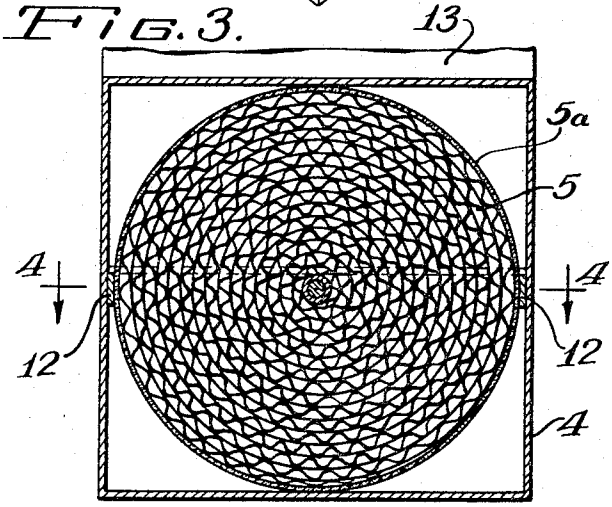
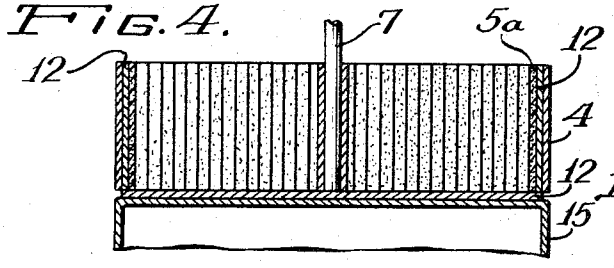


FIG. 4.



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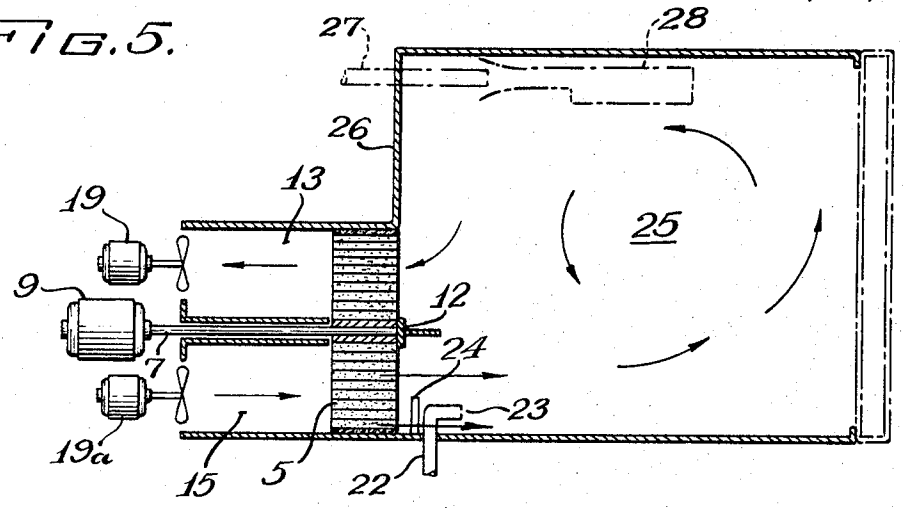
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SELF-CLEANING GAS OVEN

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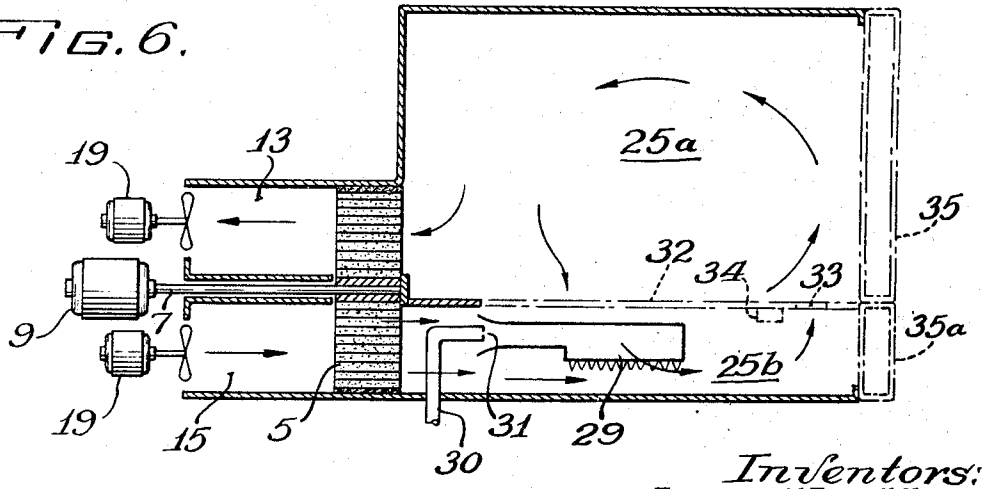
NON-AERATED BURNER SYSTEM (R2)

Fig. 5.



PARTIALLY AERATED BURNER SYSTEM (R1)

Fig. 6.



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TOTALLY AERATED BURNER SYSTEM

FIG. 7.

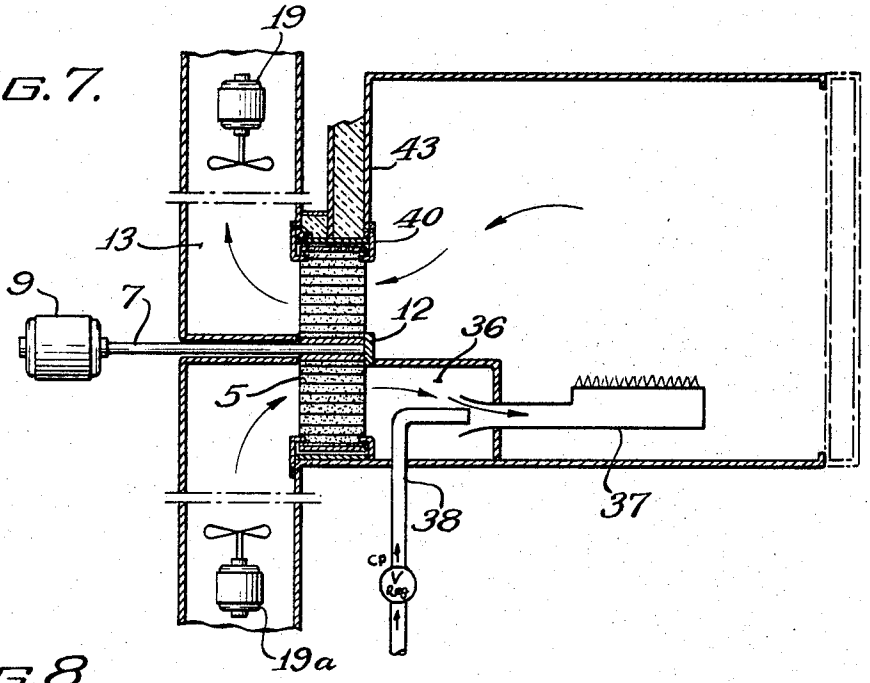
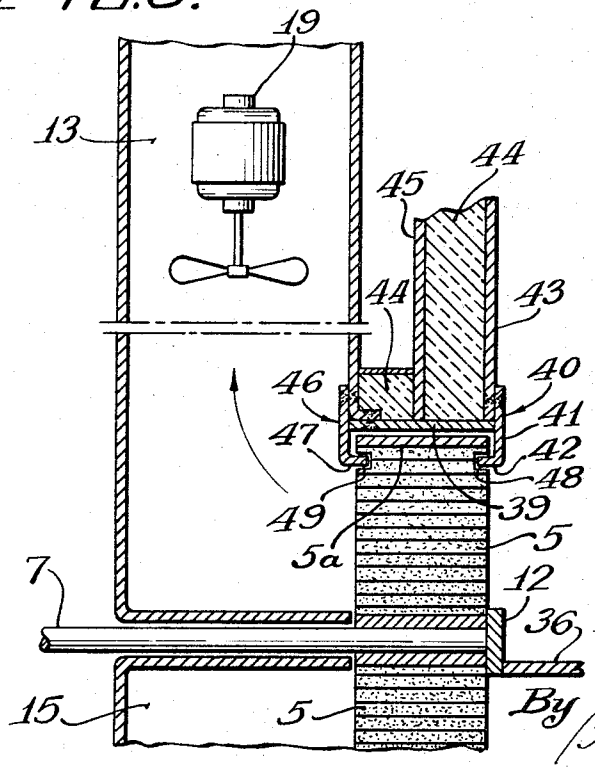


FIG. 8.



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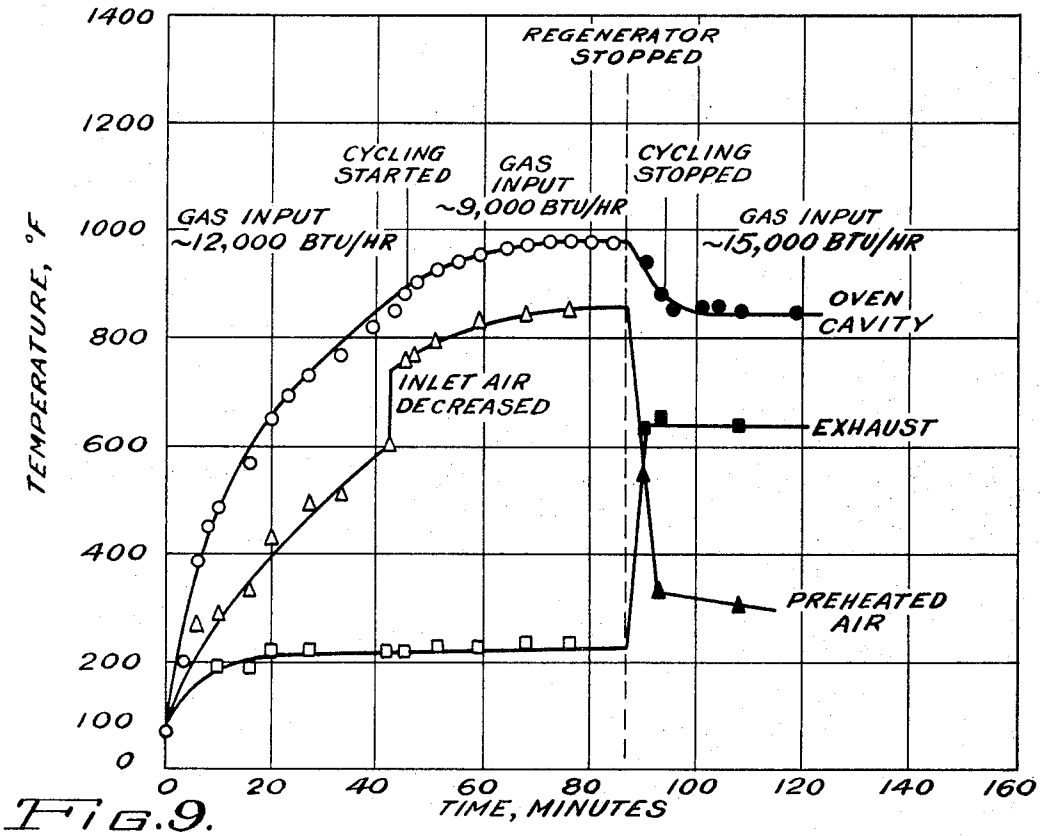


FIG. 9.

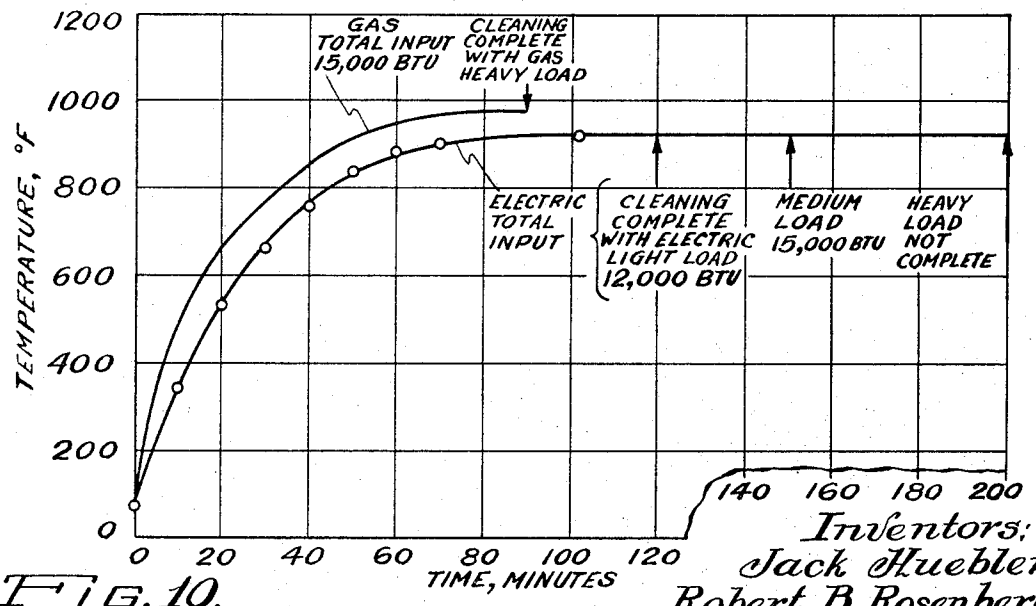


FIG. 10.

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3,416,509

SELF-CLEANING GAS OVEN

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Continuation-in-part of application Ser. No. 583,291, Sept. 30, 1966. This application Nov. 23, 1966, Ser. No. 596,521

41 Claims. (Cl. 126—21)

ABSTRACT OF THE DISCLOSURE

The specification discloses gas-fired self-cleaning ovens for commercial or domestic use and methods of self-cleaning that are made possible by the use of heat exchangers in conjunction with conventional gas ovens. Hot flue gases drawn from the oven are cooled by heat exchange with incoming air in a recuperator or, preferably in a rotating wheel type regenerator, to sufficiently low temperature that such gases may be exhausted directly into the room, thus obviating outdoor venting of hot flue gases. The incoming air is preheated by the exchanger and the efficiency of utilization of the heating value of the gas is increased. The cleaning time for a heavy food soil load is typically one hour. The method of cleaning involves incineration of food soil vapors by the flame to completely oxidized products of CO_2 and H_2O, and substantially no smoke and potentially hazardous vapors are exhausted into the room. Careful control of all air is taught, and the use of air in excess of stoichiometric is disclosed. Conventional burners may be used, and range from the totally aerated to nonaerated type, with the method being equally applicable to single or double cavity type of gas ovens. Improved performance as compared to electric self-cleaning ovens, and to gas ovens having venting means is disclosed.

The application is a continuation-in-part of application Ser. No. 583,291, filled Sept. 30, 1966, now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

The field of art to which this invention relates is that of gas-fired cooking ovens, both commercial and domestic, and more particularly to the provision of means permitting such ovens to be unvented, self-cleaning ovens.

Description of the prior art

Typical of prior art gas-fired stoves is that shown in Hennessy No. 2,336,988 wherein an exhaust vent giving a combined stack effect and "ejector effect" is disclosed. Hot flue gas is continuously exhausted during cooking via ducting into a vertical flue at the back of the gas range. The bottom end of the flue is open and extends below the point at which the exhaust duct enters. By this arrangement, ambient air is drawn upwardly by the parallel discharge of the hot flue gases to provide an "ejector effect," thus cooling the eventually exhausted flue gases. No self-cleaning apparatus or method is disclosed, and the exhaust venting arrangement is not concerned with combustible input gases. Although the Hennessy device has a comparatively cooler exhaust gas than an oven having no mixing of ambient air with the exhaust, there is no change in the total B.t.u. output to the room.

Unlike gas ovens, no air for combustion is required

in electrical ovens, and therefore no problem of disposal of large quantities of hot flue products is presented. However, a comparison and contrast with that electrical art is relevant since self-cleaning is known in electrical household cooking ovens.

An early design for a self-cleaning electrical oven is disclosed in Ames No. 2,224,945 wherein the "self-cleaning" concept for an electrical oven is set forth. A glowing radiant heat is provided of such intensity and so emitted and directed as to consume and dissipate or reduce to the form of an impalpable ash any materials as are deposited on the metal surfaces during cooking, thereby cleaning all crevices in or between the parts and leaving the metal surfaces bright, clean, thoroughly sterile, and freed from odor. Although that first design was for a cooker oval in plan view, a more modern oven of the type that has a hinge door on a side wall is disclosed in Ames No. 2,247,626.

In Ames No. 2,300,837, a further modification is disclosed in which a cup formed of mesh wire or screen of Monel metal or other suitable material is placed above and adjacent to the electrical heating element in the path that vapors evolved would follow in exiting out an exhaust duct. It is disclosed that the screen mesh cup, being near the heating element, quickly becomes very hot so that any odors or smoke passing through or in contact with the screen are broken down into colorless and odorless products.

A recent design for an electrical self-cleaning oven is disclosed in Hurko No. 3,121,158. A contact device having a screen formed of platinum or platinum-coated wire for oxidizing the smoke and cooking odors produced in an electrical oven during self-cleaning is disclosed in Welch No. 2,900,483.

In the above described prior art patents involving direct heat electrical self-cleaning ovens, it is fundamental that no air is required in the self-cleaning operation beyond a small amount that is permitted to leak into, or is passed into the cavity, which air may assist in entraining the vapors past a Monel metal screen cup or a catalytic unit that promotes partial oxidation or degradation of food soils. Thus, with such a reduced quantity of entering air, electric self-cleaning ovens such as Hurko No. 3,121,158 operate on the principle of only partial oxidation of food soils. However, such cleaning method has a serious disadvantage in that objectionable gases are produced, particularly if there is a rapid heat-up from ambient to the cleaning temperature range of 750–950° F. In the electrical ovens, the hot walls promote boiling-off of more smoke-causing vapors of the soils than can be completely oxidized at the prevailing cavity temperature, or than can be oxidized by the catalytic or Monel metal screen vapor degrading units. As a result, such vapors and smoke are exhausted into the kitchen. To obviate such objectionable smoke, flammable vapors, and vapors hazardous if breathed, present-day electric self-cleaning ovens have a relatively lengthy cleaning cycle, particularly during the heat-up to cleaning temperature. To make the cleaning operation reasonably safe for domestic use, the electric oven cleaning cycle is on the order of 2½ hours for a light load, about 40 minutes of that being for heat-up to the cleaning temperature range of 750–950° F. In our tests we have found that a heavily soiled electric oven (100 g. of food soils thereon) does not completely clean within 3 hours and 20 minutes. Even with that relatively long cycle time, however, the exhaust gas temperature is above about 450° F.

The electric self-cleaning ovens are also prone to an additional problem of redeposition of the vapors and partially degraded food soils. This is caused in part by the fact that in the electrical process, the food soils are

only partly oxidized or degraded, and thus some form of redepositable flue products are present. A second factor is the condensation in cold spots, such as in exhaust ducting or around any gaps between the oven cavity door and the walls. Because partial oxidation is inherent in the electrical method, condensation of partially degraded soils around the door is alleviated by provision of a third heating element, in addition to the normal broil and bake units, near the cavity mouth in the form of an auxiliary mullion heater.

Fundamentally different problems are presented by gas-fired ovens, wherein the consumption of natural gas or the like and air lead to the production of hot combustion exhaust products, termed herein flue gases. At normal cooking temperatures, these gases are ordinarily vented to the room. However, at a temperature adequate to clean the interior surfaces of the oven cavity, the incoming air flow in one of our tests was about 315 standard cubic feet per hour (s.c.f./hr.) and the gas flow is about 22 s.c.f./hr. The flue gas temperature during a cleaning cycle using those gas and air inputs could be as high as 1000° F, and exhausting flue gas of that temperature to the kitchen is self-evidently impractical and unsafe, the heat gain by the kitchen from the flue products alone under those conditions being about 6300 B.t.u./hr. The 1000° F. gases could be vented to the outdoors, but the amount of construction necessary is uneconomical, particularly in frame dwellings or apartments, where heavy insulation and a class A flue would be required. Thus, direct gas-fired self-cleaning without venting flue products is entirely impractical, and the vented self-cleaning is uneconomical.

PRINCIPAL OBJECTS OF THE INVENTION

It is an object of this invention to provide a method and apparatus for transforming food soils deposited on the interior of oven cavities to substantially oxidized form, as CO_2 and H_2O, which are not redepositable, flammable or hazardous if breathed.

It is another object of this invention to provide a gas-fired oven that is self-cleaning yet requires no venting to the outside of the room in which the oven is located.

It is another object of this invention to provide a method and means whereby hot flue gases produced during self-cleaning of a gas-fired cooking oven can be used to preheat incoming air to be used in combustion in the self-cleaning process, and the hot flue gases are reduced in temperature to a level tolerable for exhausting directly into the room in which the oven is located, to thereby reduce the total fuel required for the self-cleaning operation as compared to a vented gas-fired oven.

It is another object to provide a self-cleaning gas-fired oven and method for its operation by which food soils are removed from the oven cavity without creating objectionable smoke, flammable vapors, or vapors hazardous if breathed.

It is a further object to provide a self-cleaning gas-fired oven that (1) is efficient in operation, both for cooking and for self-cleaning (2) has a relatively short self-cleaning cycle, and (3) can be constructed simply and with a minimum of change in conventional production techniques by using, for instance, conventional oven burners, cavities, insulation, doors, outer panels, hardware etc., and be substantially within the dimensions and cost of present gas-fired ovens.

Other objects of the invention will become apparent as the invention is more fully described hereinafter.

PRESENT INVENTION

The objects of our invention are in part achieved by using in conjunction with a gas-fired, self-cleaning oven a heat exchange device, such as a heat regenerator, so arranged such that (1) the hot exhaust gases issuing from the oven during the cooking or self-cleaning cycle are cooled so that such gases may be exhausted directly into the room, thus obviating venting of such gases, (2) the incoming air which is to be combusted with gas in the oven cavity is preheated, and (3) the circulation of gases within the cavity brings the food soil vapors into intimate contact with at least one burner flame where the soil vapors are incinerated to complete oxidation products CO_2 and H_2O. When using a regenerator device, the regenerator contacts the flue gases, thereby removing substantial amounts of heat energy from these gases. At a later time the heat energy accumulated in part of the regenerator is released to the incoming combustion air, thereby cooling the regenerator back to a temperature where it can continue to cool the exhausting hot gases. A conventional gas-fired oven will exhaust 6300 B.t.u./hr. to the kitchen when the oven cavity is 1000° F., whether or not an exhaust device of the type shown in Hennessy No. 2,336,988 is used. In the device of the present invention, only 1000 B.t.u./hr. is exhausted to the kitchen, and by our method the total heat produced is less since less fuel gas is necessary to maintain the cavity at optimum cleaning temperature.

In the drawings:

FIG. 1 is an isometric diagrammatic view of a conventional gas-fired oven having a heat regeneration device incorporated therewith;

FIG. 2 is a side view partially in section showing the device of FIG. 1;

FIG. 3 is a view along the line **3—3** of FIG. 2; and

FIG. 4 is a view along the line **4—4** of FIG. 3.

FIGS. 5–7 are schematic representations of embodiments of the invention, and illustrate modes of placement within an oven cavity of, respectively, a nonaerated burner arrangement (FIG. 5), a partially aerated burner arrangement (FIG. 6), and a totally aerated burner arrangement (FIG. 7).

FIG. 8 is a schematic representation of one embodiment of the sealing arrangement of the regenerator wheel.

FIG. 9 is a graphical representation of temperatures during the operation of the cleaning cycle, and includes a test wherein the regenerator of the present invention is stopped.

FIG. 10 is a graphical representation of the comparative cleaning times of electric self-cleaning ovens and the ovens of the present invention.

With reference to FIGS. 1–4, one embodiment of a heat exchanger of our invention is a heat regenerator shown secured, for example, to the back of a conventional oven or stove cabinet **1**. The oven or stove per se may be any conventional gas-fired oven or stove, whether free-standing or built-in, single or double oven cavity, and has appropriate controls, insulation and heat-resistant materials of construction.

The heat regenerator of this embodiment comprises a housing, shown generally at **3**, in which is positioned a wheel **5** which serves as a heat sink as described in detail hereinafter. Wheel **5** is mounted on a shaft **7** which is adapted to rotate by means of a small electric motor **9**. Alternatively, shaft **7** can be driven by suitable linkage with the motor of fan **19** as described hereinafter. Wheel **5** is isolated in a portion of housing **3** indicated by numeral **4** by means of seals or baffle plates **11** which are arranged so as to direct the flow of gases through the wheel as hereniafter described and prevent flow of gas around the outside periphery of the wheel. Alternatively, the housing portion **4** may be tubular, with suitable end seals as will be described below with reference to FIG. 8, thus eliminating the need for baffle plates **11**. Along each face of the wheel there is also provided a wiper **12** of tubular or flat configuration, for example, a roll of glass fiber material, which serves to prevent flow of gas between the upper and lower section of wheel **5** across the face of the wheel.

The upper part of housing **3** is an exhaust vent **13** containing electric fan **19** adapted to draw air from the

cavity as shown by the small arrows indicating air flow. The lower portion of housing **3** comprises air flow ducts **15***a* and **15**. Incoming air, preheated by heat exchange in the regenerator wheel **5**, flows through duct **15** to be supplied as primary, secondary, or both primary and secondary air to burners in the appropriate oven cavity.

The gas burners may be located at any convenient place within the oven cavity. They may be placed as is conventionally done, for example, along the top and bottom of the oven cavity in the single cavity type of oven (FIG. 5), or along the upper portion of the lower cavity in a double cavity type of oven (FIG. 6). To the bottom of duct **15** may be secured an optional short extension tube **17** which serves as a conduit to direct incoming air toward the center of the oven cavity or alternatively to provide primary air, as is described in greater detail below. Located within duct **15***a* may be an electric fan **19***a* adapted to blow air into duct **15**. Alternatively, the fan or fans may be located anywhere in association with housing **3**, such as are schematically shown in FIGS. 5–7, so long as the proper circulation of gases into and out of the oven cavity is effected. Along the sides and back of housing **3** adjacent wheel **5** are vents **21** through which incoming air is drawn first into the housing and thence through the lower portion of wheel **5** and into duct **15** as shown by the arrows indicating air flow.

Regenerator wheel **5** is cylindrical, and is preferably a material of corrugated (as shown in front view in FIG. 3), or honeycomb or similar surface design, and has a plurality of small axial passages through which the input and flue gases may pass. It may be made of any heat-resistant material, preferably one that has a high heat capacity such as asbestos impregnated with sodium silicate or a ceramic or refractory material, such as Corning's "Cercor." A typical wheel construction suitable for use herein is shown in Pennington U.S. Patent No. 2,700,537.

A particularly useful embodiment for a regenerator wheel is an asbestos wheel made by rolling into cylindrical configuration a sheet of corrugated asbestos, having the usual sinusoidal configuration of material with a backing layer on one or both sides as shown best in FIGS. 3 and 4. An outer band of asbestos material **5***a* may be used to retain the corrugated asbestos sheet in the rolled-up configuration. The "period" of the corrugations is on the order of ⅛ inch, and the thickness between adjacent layers in the rolled-up configuration is on the order of 1/16 inch. The wheel need not be formed in a spiral configuration, but may be a circular core cut from layers of corrugated asbestos laid together in straight or arcuate rows, as when the wheel would be cut from a segment of a larger roll. Such a wheel is similar to that used in commercially available open cycle air drying devices.

For an oven cavity of about 2 cubic feet capacity, the wheel is preferably about six inches in diameter and three inches thick and rotates at about 5 r.p.m. The hot exiting flue gases pass through the upper half of the wheel as shown in FIGS. 1, 2 and 5–7 giving up heat to the wheel. The wheel rotates continuously so the hot half of the wheel is then exposed at its lower half to incoming combustion air which cools the wheel.

It will be understood that the dimensions of the regenerator wheel and its rate of rotation are not critical and are functions of oven cavity size and temperature requirements. Those skilled in the art will recognize that the parameters can be adjusted within the skill of the art to provide the cooling effect desired for any particular oven design.

In operating the heat regenerator of FIGS. 1 and 2 in conjunction with self-cleaning of the oven cavity, start-up is accomplished by turning on the gas, fans and motor **9**. Air from outside the device is then drawn in through vents **21** and down through duct **15** to the oven cavity. At the same time wheel **5** begins to rotate. Hot products of combustion with excess air enter the front upper half of wheel **5** and are drawn therethrough by the circulation of gases caused by fan **19**. The location of baffle **11** and wiper **12** directs the hot gases through the upper portion of the wheel and prevents mixing of the exhaust gases with incoming air in the lower portion of the wheel. Flue products transfer heat to the wheel **5** and are then discharged through flue outlet **13**, which communicates with the room.

With wheel **5** rotating, the hot section of the wheel rotates out of the flue box into the lower portion of housing **3**. Room air then enters through vents **21** and passes through the lower portion of the wheel and is thereby heated and directed down through duct **15** into the oven chamber. Baffle **11** and wiper **12** ensures that all incoming air passes through the lower portion of the wheel.

Referring now to the placement of the burners in the cavity, FIG. 5 shows a nonaerated burner arrangement (designated in our tests as R–2), in which the preheated air exits from the wheel **5** into the area near a gas inlet tube or burner **22** having a small orifice **23**. This air exits directly from the wheel or is so baffled, as by baffle **24**, as to be directed as secondary air. There is no primary air supply to the burner **22**, and thus the flame is of the secondary type. As described above, the wiper **12** prevents short circuiting across the wheel face of the preheated input air into the flue gas stream exiting out the upper half of the wheel.

Referring still to FIG. 5, the wheel **5** may be seen extending rearwardly from the cavity wall **26**, and the wheel is rotated by suitably supported shaft **7** by motor **9**. Air is blown through the lower half of wheel **5** into the oven cavity **25** by fan **19***a* via ducting **15**. On the exhaust side, flue gases are drawn out through ducting **13** by fan **19**. As shown in phantom lines at the top of cavity **25**, a conventional broil burner **28** having gas inlet tube **27** can be provided. The broil burner is not restricted to a partially aerated type as shown, but may be totally aerated or nonaerated. In this embodiment, the flame of the broil burner is turned on during the self-cleaning cycle to provide a source or zone, in addition to the flame of burner **22**, of secondary flame in which the food soils vapors are incinerated to a state of complete oxidation.

FIG. 6 illustrates schematically still another embodiment, a partially aerated burner, designated in our tests as R–1, and shown as a conventional drilled-port burner in a single cavity. Input fan **19***a* blows ambient air through duct **15** and thence through the preheated side of the regenerator wheel **5**, to be dumped as preheated air to the rear of the burner **29**. As is seen from the arrows illustrating air flow, the air is delivered as both primary and secondary air. Fuel gas enters via tube **30**, and issues into the burner throat through orifice **31**. Both primary and secondary flame cones are propagated in this embodiment, with gas inspirating the preheated air. As is noted from the air pattern in the cavity, food soil vapors are brought into contact with the flame where they are completely oxidized principally in a second flame cone zone (not shown) to CO_2 and H_2O. The flue gas products are drawn by fan **19** through the exhaust side of the wheel **5** via duct **13**.

This embodiment is particularly adaptable to the double-cavity single-burner type of oven as well as the single cavity oven as shown. Baffling **32**, shown in phantom lines, may be so arranged as to divide the oven into two cavities, a bake zone **25***a* and a plenum or broil zone **25***b*, as is the case in conventional single-burner double-cavity ovens. The baffle is provided with convection or circulation holes, for example, around the sides and along the forward edge as at **33**. The baffle may be supported by a downwardly depending skirt along the front edge or by legs (not shown). Alternatively, the baffle may be supported by projections **34** along the interior side walls of the cavity, or secured thereto. Conventional doors **35**, **35***a*

for the double-cavity type of oven are shown in phantom lines to the right in FIG. 6. It is to be understood that the wheel need not be placed so that the upper half extends only into the upper cavity and the lower half only into the lower. The wheel dividing baffle and wiper **12** are so arranged and are of such configuration that short circuiting across the cavity side or inner face of the wheel is substantially avoided. Thus, the wheel may be placed where convenient with suitable ducting for the input air and flue gases. It is also to be understood that conventional burners of the non-aerated and totally aerated type may be used, in conjunction with suitable ducting, in the double-cavity type of oven.

FIG. 7 shows another embodiment in which a totally aerated burner is employed in the oven cavity. Fan **19***a* blows air through wheel **5**, and the thus preheated air passes via suitable ducting **36** to burner **37**. The gas inlet tube **38** in this example may have an orifice, and the air is so ducted to the burner as to be all primary. The flue gases are drawn through wheel **5** and duct **3** by fan **19**.

FIG. 8 shows a detail of one embodiment of means for sealing the regenerator wheel to insure passage of gases through the axial passages therein, and to prevent leakage of gases between the outer asbestos covering **5***a* of the wheel **5**, and housing **39**. The sealing means consists of a flanged ring **40** having an annular portion **41** and flange portion **42** fastened, as by spot welding or screws, to the interior of the oven cavity wall **43**. Insulation **44** is provided between the inner cavity wall **43** and the outer oven wall **45**, and over such part of the housing **39** as extends beyond the outer oven wall **45**. A similar flanged ring **46** is secured to the wall of duct **13**. The flange portions **42**, **47** of rings **40**, **46** fit into annular grooves **48**, **49** provided in wheel **5**. These grooves may be formed simply by pressing the flange of a ring into the relatively soft asbestos material of the wheel and rotating the wheel or ring about a central axis until a suitable clearance is obtained. Alternatively, the flange of the ring may be fastened to the wheel with the annular portion **41** rotating against a seal (not shown) at the oven cavity wall. Where the wiper **12** extends along the width of the wheel, as best seen in FIG. 4, the above sealing arrangement may be unnecessary since short circuiting along the wheel side is prevented and the gap that exists between the hot asbestos **5***a* and the housing **39** (FIG. 8) around the remainder of the wheel is not too great to prevent suitable operation.

As a cleaning temperature range, we have found an operable minimum to be about 750° F. This minimum is inherent in the fact that this is the temperature at which the food soils will eventually completely vaporize from the oven cavity walls. We are limited to a maximum temperature only by materials failure, production quality steel failing around 950° F., and enamel failure occurring at about 1050–1100° F. Better materials would permit higher temperature and therefore a faster cycle. The temperature of the exhaust gases is not an appreciable problem since the size of the regenerator wheel may be varied to assist in the control of that temperature. In runs with the regenerator device above described as used in conjunction with a conventional oven, the ambient input air was 70° F., the oven cavity registered 975° F. and the exhaust gas 230° F. With the cavity temperature reduced to clean at between about 885–907° F., the exhaust temperature could be maintained at about 220° F. The optimum cavity temperature is about 925° F.

It is to be noted that the heat-up time is considerably shorter than an electric self-cleaning oven, 16–20 minutes being an easily achievable minimum time in which to reach the 750° F. cleaning temperature for a standard oven burner of 23,000 B.t.u./hr. input. The self-cleaning period is typically less than 1 hour at a maximum temperature of 1000° F. As shown in FIG. 10, with an input of only 12,000 B.t.u./hr. during the heat-up period, 750° F. was achieved for a gas-fired self-cleaning oven of this invention in about 30 minutes and the cleaning of a heavy load of typical soils (100 g. cherry pie filling) was completed in 1½ hours with a total output of 15,000 B.t.u. (FIG. 10, upper curve). The lower curve of FIG. 10 shows the cleaning times of a conventional electric oven having light (25 g.), medium (50 g.) and heavy (100 g.) loads, and the corresponding total B.t.u. output. The shorter cycle time for the gas-fired oven of the present invention means that the time during which heat is dumped into the room is reduced. It is to be understood that the gas oven self-cleaning cycle can be lengthened by reducing the cleaning temperatures, if desired, but that reduced cleaning temperatures are not necessitated by an initial production of quantities of volatiles and smoke. However, there appears to be some types of soils which are not easily removable if at all below cavity temperatures of 850° F. There is also no speed of cleaning limitation necessitated by a limited capacity catalytic oxidizing element as in the case of electric self-cleaning ovens.

An additional benefit accruing from short cleaning cycles is the reduced consumption of fuel. As compared to a gas-fired oven without a heat exchanger, the oven of the present invention uses about 40% less fuel. Further, the regenerator and fans may be programmed to remain on after the gas is turned off to permit a forced air cooling of the interior and thus make the oven available for normal cooking use in a shorter period.

Burner inputs for the cleaning cycle may be any that are available, and conventional burners range from 10,000 to 35,000 B.t.u./hr. for a domestic range, with 10–25,000 B.t.u./hr. being preferred. The system is normally run fuel lean, with a minimum amount of air being stoichiometric with respect to the gas plus the small amount needed to oxidize the food solids. Self-cleaning ovens of the present invention use substantial excess air and thus can be described as having forced convection heat transfer. In tests run with the system of this invention, the amount of air used has been from stoichiometric, as defined above, to 1000% in excess of stoichiometric, with 30–60% in excess being preferred. The air has been put in from between 22 to 2200 s.c.f./hr. and the gas from 12 to 23 s.c.f./hr.

The conventional burners useful in the invention may be of the drilled-port type, and they may range from non-aerated to completely aerated. Since an excess of air is supplied to the oven, the preheated air is preferably split so that 0–60% of the total goes to the burner as primary air and the rest is secondary air. The fan or fans and gas are coupled as a single interlocked system, that is, the fans must be on when gas is supplied, but the reverse is not true. While a velocity head is not necessary, it can be provided to prevent short-circuiting of the input air by its passing directly out the regenerator rather than circulating in the cavity to carry the food solid vapors to the flame combustion zone where the vapors are completely incinerated.

As a safety device, the doors may be provided with means to secure them from opening during the self-cleaning cycle. Similarly, means to turn off the gas and the input fan, but not the exhaust fan and the wheel, may be provided as a safety device to prevent a hot blast of air from exiting when the door is opened.

It is fundamental to the method of our invention that the food soils are substantially completely oxidized to harmless combustion products CO_2 and H_2O within the oven cavities. The final oxidation products contain substantially no carbon monoxide, that is, much less than 100 p.p.m. as shown by typical test data, which value is well within the "no CO" standard of the American Gas Association. There may be an initial stage of degradation in which the food solids are partially oxidized to whatever stage they naturally will go at the given temperature. However, a key feature of our method is the careful control of all air so that there is circulation within the cavity so that the initially vaporized and partially oxidized food solids are returned to the flame where they are

completely combusted and incinerated in the outer flame cone so that the flue products are the products of a complete oxidation. Since complete ignition, combustion, and oxidation to the entirely colorless, low molecular weight products, CO_2 and H_2O occur in our method, there is no concern with redeposition of vaporized products on oven walls, flue walls, or around the door mullions.

Further, the flow or circulation patterns within the cavities are such that the doors are more evenly heated, and the need for mullion heaters for self-cleaning is obviated.

The oven may be run at cavity pressures ranging from positive to negative. The cavity pressure may be controlled by sealing and by adjustment of the size of the orifice or speed of the exhaust fan. When the cavity pressure is negative, some air will be drawn into the cavity through any small gaps that exist. While this is an additional load on the system, controlled gaps can be provided by appropriate sealing structure so that the slight inward draw of air prevents exit of vapors during the initial heating to cleaning temperature. It should be understood that such gaps are small and are part of the complete control over the total gases balance, input and output, of the oven that is involved in our method. Unlike convenional gas ovens which may rely on large openings in the bottom or the back to supply combustion air, the ovens of our invention use substantially completely sealed cavities having forced or induced combustion air supply, depending on whether both exhaust and input fans, or input fan alone, is used.

Further, because of the complete combustion afforded by the control of air circulation at all times during the entire cleaning cycle, there is little or no smoke output, paricularly during the initial heating.

The operative conditions and advantages of the heat regeneration system of our invention is best illustrated by considering the following examples. In these examples, the food soils applied in test cleanings were of three types, cherry pie filling, apple sauce, and cooking oil. There appeared to be no significant difference in cleaning time between tests where fresh applications of the soils were followed by an immediate cleaning cycle, and tests where cleaning followed an initial bake-on of food soils at about 400° F. The freshly applied soils charred during the heat-up to the cleaning temperature, and thus conditions during the cleaning portion of the self-cleaning cycle were substantially equivalent. A light load is defined as 25 g. of food soils, a medium load as 50 g. and a heavy load as 100 g.

Example 1.—No regenerator, direct heating

A conventional oven is fitted with a conventional gas burner of the drilled-port type of 23,000 B.t.u./hr. output. The interior walls of the oven cavity are coated with 25 grams of food soils (one wall each of cherry pie filling, apple sauce, and cooking oil) to represent a light accumulation of cooking deposits. The burner is ignited, and the gas is adjusted to bring the temperature to above 750° F., a value chosen to accomplish cleaning in a reasonable length of time. The oven achieved a cleaning temperature of about 850° F. in 20–25 minutes. The cleaning temperature was then maintained in the steady state cleaning condition. Since the flue gas exhaust temperature was not appreciably below 850° F., the room containnig the oven became unbearably hot and unsafe so that the test was shut down before cleaning was completed.

Example 2.—Regenerator method of this invention (R–1)

A conventional oven is fitted with a burner of 12,000 B.t.u./hr. input and a regenerator wheel having an effective cross section of 6 inches in diameter and a thickness of 3 inches. The wheel is made of asbestos impregnated with sodium silicate. After coating with 100 g. of food soils the fan and regenerator are turned on and the fuel gas is ignited. The input ambient air passes through the wheel and is dumped near the input air orifice of the burner for normal inspiration. The fan speed is adjusted so that the air is about 100% in excess of stoichiometric, and about 60% of a stoichiometric amount of air is inspirated as primary air. The remainder of the total air, 140% of stoichiometric, is directed as a secondary stream forwardly past the burners to circulate upwardly in the oven cavity. This air and the hot rising gas forms a convection stream that circulates around to bring the vapors into contact with the secondary combustion zone in the outer flame cone of the burner, prior to exiting out the upper, or output, half of the regenerator wheel. The oven achieves the minimum cleaning temperature of 750° F. in under 20 minutes. Thereafter, the cavity temperature gradually rises to achieve a steady state value of between 970 to 980° F. No smoke is observed during the heat-up or cleaning stages of the self-cleaning cycle. A thermocouple, placed in the path of the input air exiting from the lower half of the regenerator, measures the temperature of the preheated input air. This preheated air thermocouple stabilizes at about 850° F. during cleaning, while an exhaust flue gas thermocouple stabilizes at about 230° F. Cleaning is completed in about 1½ hours. The fuel gas and fans were linked together and to a regulator device (thermostat) to maintain the steady state cleaning temperature. It was found that the fuel gas was off 25% of the time, an input of 9,000 B.t.u./hr., yet the desired cleaning temperature was maintained. After shut-off of the gas upon completion of cleaning, the fan and regenerator were programmed to continue operation.

Example 2*a*.—Exhaust gas analysis

The oven of Example 2 was coated with 50 g. cherry pie filling and 10 g. cooking oil, and then put through the self-cleaning cycle. Fuel gas input was 20 s.c.f./hr. with about 100% excess air. The analysis of samples of the exhaust flue gas taken at the mid point of the steady state cleaning portion of the self-cleaning cycle are shown below in Table 1.

TABLE 1

Flue product:	Amount (p.p.m.)
CO	40–50
CH_4	19.8
Ethane	0.2
Ethylene	1.4
Propane	0.2
Propylene	0.1
Acetylene	<0.1
Butanes	<0.1

The CO value of 40–50 p.p.m. in the flue gas is an equivalent value of 10 p.p.m. for the room, and is well within the American Gas Association "no CO" specification of 100 p.p.m.

Example 2*b*.—Regenerator method (300 g. load)

Example 2 was repeated to clean a 300 g. load of food soils, the fuel gas input being 23,000 B.t.u./hr., with the cavity temperature during cleaning being thermostatically set at 1000° F. The oven cavity was clean within one hour of start-up.

Example 3.—Regenerator shutoff during run

With the same apparatus as in Example 2, the steady-state conditions were achieved, and the regenerator was shut off. The fans remained under the control of the regulatory device. Shortly thereafter, the cavity temperature dropped to 850° F., the exhaust flue gas temperature rose to 655° F. and the preheated air thermocouple indicated a fall-off to about 300° F. A graph showing the results of the test is shown as FIG. 9, with the thermocouple temperature values after shutoff of the regenerator being indicated in solid data points to the right of a vertical dashed line labeled "Regenerator Stopped."

With a gas input rate of only 12,000 B.t.u./hr., the oven reached the cleaning temperature of 750° F. within about 30 minutes. At about the 43rd minute after start-

up from the ambient 75° F. when the cavity temperature had reached about 850° F., the amount of inlet air was decreased. The temperature of both the cavity and the preheated air increased, while that of the exhaust remained steady at about 230° F. Under thermostatic control the oven burners started cycling, alternately on and off, at about the 47th minute after start-up. The cavity temperature increased to a steady state value of between 970–980° F. with the burners off 25% of the time, a fuel gas input of only 9,000 B.t.u./hr. At about the 86th minute, the regenerator was shut off, and the cross-over of the temperature values is evident.

It is also observed that after the regenerator was shut off, the burner was unable to maintain the original cleaning temperature, falling to about 850° F. as shown. This drop in cavity temperature occurred even though the burner was on continuously, at a fuel input of 15,000 B.t.u./hr. This is a marked contrast to the regenerator steady-state conditions wherein the gas is off 25% of the time, at a fuel gas input of 9,000 B.t.u./hr. That is a 66% increase in rate of fuel gas consumption while the temperature dropped 120–130° F., to a value at which some food soils are not completely removed. That lower cleaning temperature also would necessitate a longer cleaning cycle, assuming 655° F. flue gas temperatures could be tolerated in a room.

Although it is not meant to be binding, it is thought that the conditions occurring during the time when the regenerator is stopped may approximate those of a recuperator type of heat exchanger. The performance characteristics of the recuperator could be improved by having an exchanger material of higher thermal conductivity, but the regenerative type heat exchanger is the preferred embodiment for domestic uses. With a relatively larger recuperator, and the usual recuperator materials, the exhaust temperature can be lowered to a reasonable value, particularly for commercial purposes.

Example 4.—Cleaning temperature

Example 2 was repeated twice with the fuel conditions set to achieve a cleaning temperature of about 975–1000° F. and 850° F., respectively. The cleaning times were less than one hour and more than two hours, respectively.

Example 5.—Smoke test

A standard electric self-cleaning oven such as shown in Hurko No. 3,121,158 is put through self-cleaning cycles after coating with various amounts of food soils. A test of the gas-fired self-cleaning oven was run for comparative purposes, with the test results tabulated below:

VISIBLE SMOKE, TEST RESULTS

Type of Soil	Amount of Soil	Smoke Density (Exhaust)	Smoking Time	Time to Clean
		Electric Oven		
Pie filling	25 gm	None	None	2 hr.
Do	50 gm	Very light	3 min	2½ hr.
Do	100 gm	Similar to heavy cigarette smoke.	7 min	Not completely clean after 4 hrs. Black soil remains intact after wiping with damp rag.
Clear cooking oil	50 gm	Sudden smoke (moderate) at oven temperature of 830° F. after 43 min. on.	1 min	Door opened after 68 min. No oil remained. Oven clean.
In the above test with cherry pie filling—entire cavity including oven bottom was dirtied. When no soil was placed on oven bottom less smoking was noticed.				
		Gas Oven		
Pie filling	More than 100 gm. Less than 300 gm.	None	None	About 1 hr.

The values for time to clean is graphically represented in FIG. 10.

With an ideal heat exchanger utilized in our method, the flue gases could be cooled by the entering air to a temperature of about 150° F., when the gas input is 22 s.c.f./hr., the air input is 315 s.c.f./hr., the cavity is maintained at 1000° F. during the self-cleaning cycle, and the temperature of entering air is 75° F. The heat gain by the ambient from the flue gases would thereby be reduced to about 400 B.t.u.'s per hour. With the heat regenerator of our invention which, e.g., operates at about 90% efficiency with wheel dimensions and rotation rate as previously described, the flue gases leave the regenerator at about 230° F. with a heat gain of about 1000 B.t.u.'s per hour by the ambient. Compared to a gas-fired oven without a heat exchanger in which 6300 B.t.u./hr. is gained by the room, the heat gain by the room from the flue gases is decreased by abont 5300 B.t.u.'s per hour by the use of a heat exchanger of our invention.

In one embodiment of our invention, the heat regenerator device above described is modified to use part of the flue gases, about 10%, to preheat the incoming fuel gas, thereby further decreasing the heat losses in the flue gas. A heat exchanger of, e.g., 90% efficiency on the gas side further decreases heat losses by about 430 B.t.u. per hour from the above indicated figure, and thus the gain by the ambient is less than 600 B.t.u./hr. Exhaust flue gas temperatures for such modified system would be, for an ideal heat exchanger, about 145° F., and for a heat exchanger of, e.g., 90% efficiency as used in the specific embodiment of our invention, about 215° F.

Although our invention has been specifically described preferably employing a heat regenerative device as heat exchanger, we also contemplate using a heat recuperative device such as a tube-and-shell or finned heat exchanger. Those skilled in the art will recognize that the only limitation to the particular heat exchanger used is that the size must be proper to effect the desired cooling function and still be practical for incorporation within the stove unit, whether used for domestic or commercial purposes.

Having described our invention, those skilled in the art will recognize that various modifications can be made to such appliances within the spirit of the invention, which we intend to be limited solely by the following claims.

What is claimed is:

1. A self-cleaning gas-fired cooking oven comprising a cooking cavity, a fuel gas burner disposed within said cavity, means for supplying fuel gas to said burner, an inlet duct and an exhaust duct connected to said cavity, means for circulating gases through said cavity via said inlet and exhaust ducts, heat exchange means in communication with said inlet duct and said exhaust duct, whereby cool gases entering said cavity through said inlet duct are brought into heat exchange relationship with hot exhaust gases, produced by combustion of said fuel gas, exiting through said exhaust duct, thus cooling said exhaust gases for release to the space surrounding said oven.

2. An oven of claim **1** which includes a baffle dividing said cooking cavity into a broil zone and a bake zone said baffle being provided with apertures to permit circulation of gases between said zones.

3. An oven of claim 1 in which said cooking cavity is substantially completely sealed against gases leakage.

4. An oven of claim 2 in which said burner is disposed below said baffle in said broil zone.

5. An oven of claim 1 in which said burner ranges in type from completely aerated through partially aerated to non-aerated.

6. An oven of claim 1 in which a plurality of burners are disposed within a single cavity.

7. An oven as in claim 1 in which said heat exchange means includes heat recuperative means comprising thermally conductive material for passing heat from said hot exhaust gases into heat exchange relationship with said cool entering gases.

8. An oven as in claim 1 which said heat exchange means includes means for passing said hot exhaust gases in heat exchange relationship with both said fuel gas and ambient air entering through said inlet duct.

9. An oven of claim 1 in which said heat exchange means includes a heat regenerator comprising means acting as a heat sink adapted to be moved continuously between streams of said exhaust gases and entering gases.

10. An oven of claim 3 in which said heat sink means is a rotatable wheel comprised of heat-resistant and substantially non-thermal-conductive material having axially disposed apertures therethrough.

11. An oven of claim 10 in which said wheel consists of asbestos, asbestos impregnated with sodium silicate or a refractory material.

12. An oven of claim 11 in which said wheel is a cylindrical structure comprising corrugated asbestos or sodium silicate impregnated asbestos, said corrugation providing said axially disposed apertures.

13. An oven of claim 1 in which said gases circulating means includes a fan, means defining an orifice adjacent said fan, and means for controlling the orifice size or speed of said fan, whereby the cavity pressure may be maintained at a pressure ranging from positive to negative with respect to the external pressure.

14. An oven of claim 1 in which said gases circulating means is a fan, and said heat exchanger means is a rotatable heat sink means, and including means linking said fan and said rotatable heat sink means to a common source of rotatory power.

15. An oven of claim 1 which includes means responsive to the temperature in said cavity, means for controlling the flow of fuel gas to said burner, and means linking said temperature responsive means to said control means, whereby said temperature in said cavity is maintained above a predetermined minimum.

16. An oven of claim 1 which includes means responsive to the temperature in said exhaust duct, means for controlling flow of fuel gas to said burner and means linking said temperature-responsive means to said control means, whereby said temperature in said exhaust duct is maintained below a predetermined maximum.

17. An oven of claim 1 including timer means for stopping the flow of fuel gas to said burner after a time period sufficient to clean said oven.

18. An oven of claim 1 in which said gases circulating means is a fan and said heat exchange means is a regenerator wheel, a timer effective for selectively stopping rotation of said fan and said wheel while simultaneously stopping said gas flow.

19. A method for cleaning the interior food-soiled surfaces of a cooking cavity in a gas-fired oven comprising, (1) supplying as input gases external air and fuel gas to said oven, the quantity of said external air being in excess of stoichiometric for combination with said gas, (2) burning said fuel gas to produce hot combustion gases and hot excess air, (3) circulating said hot combustion gases and said hot excess air within said cavity in contact with said food-soiled surfaces to raise the temperature of said cavity and said surfaces above 750° F., thereby converting said food soil to hot vapors and partly oxidized degradation products, (4) incinerating said hot vapors and products to form substantially completely oxidized hot gaseous products, and (5) passing said completely oxidized hot gaseous incineration products and said hot excess air into heat exchange relation with said input air to cool said completely oxidized hot gaseous incineration products and said hot excess external air for release as relatively cool exhaust flue gases to the space surrounding the oven.

20. A method of claim 19 in which said excess external air is supplied only as primary air.

21. A method of claim 19 in which said excess external air is supplied only as secondary air.

22. A method of claim 19 in which said excess external air is supplied as both primary and secondary air.

23. A method of claim 19 in which said hot, substantially completely oxidized vapors and said excess air is brought into heat exchange relation with said external air.

24. A method of claim 19 in which said circulating step is controlled to maintain the cavity at a positive pressure.

25. A method of claim 19 in which said circulating step is controlled to maintain the cavity at a negative pressure.

26. A method of claim 19 including the step (6) of maintaining the temperature of said cavity surfaces above 750° F. for a period of less than one hour while circulating said gases and said air within said cavity.

27. A method of claim 26 including the added step of (7) shutting off said fuel gas, while maintaining a circulation of external air into said cavity whereby said air is heated by contact with the heated interior surfaces of said oven, (8) passing said heated external air into heat exchange relation with said input external air, and (9) exhausting said heat exchanged external air to the space surrounding the oven.

28. A method of claim 19 including the step (6) of regulating the input of fuel gas to said oven after the oven temperature is above 750° F. to maintain said temperature between 850–1100° F. for a period of less than 1 hour.

29. A method of claim 19 in which said hot vapors and partly oxidized degradation products are brought into contact with a plurality of vertically spaced apart sources of said burning fuel gas.

30. A method of claim 19 in which the rate of input of external air and rate of heat exchange of said input air with heated excess air and oxidized hot gaseous incineration products is controlled so that the rate of heat output in said exhaust flue gases, while maintaining the oven at a cavity cleaning temperature of between 750–1100° F., is about 1000 B.t.u./hr.

31. A method as in claim 19 wherein said incineration is maintained completely within said cooking cavity.

32. A gas-fired domestic or commercial-type appliance having a cavity to which heat is applied and a fuel gas burner disposed in association therewith, comprising in unitary combination means for circulating gases through said cavity, said gases including hot exhaust gases formed in said cavity and preheated air, means defining a heat exchanger mounted on said appliance for cooling said exhaust gases exiting from said cavity during a heating period and for preheating ambient air entering said cavity, said heat exchange means being adapted to withdraw heat from said exhaust gases and transfer it to said ambient entering air, whereby said ambient air is preheated and said exhaust gases are cooled to below about 230° F., and means for discharging said cooled gases directly into the space surrounding said appliance.

33. An appliance as in claim 32 wherein said heat exchange means includes a heat regenerator comprising means acting as a heat sink adapted to be moved continuously between streams of said exhaust gases and entering air.

34. In combination with a self-cleaning, gas-fired oven having a cooking cavity therein, a heat exchanger for cooling exhaust gas exiting from said cavity during the self-cleaning cycle and for preheating air entering said cavity during said cycle, said exchanger adapted to con-

tact streams of said exhaust gas and entering air, whereby said exhaust gas heats said exchanger and said entering air cools said exchanger; means for drawing ambient air into said cavity during said self-cleaning cycle; and means for discharging exhaust gas from said cavity.

35. Device of claim **34** wherein said heat exchanger is a heat regenerator comprising heat sink means adapted to be rotated selectively between streams of said exhaust gas and entering air whereby said exhaust gas intermittently heats said means and said entering air intermittently cools said means.

36. The device of claim **35** wherein said heat sink means is a wheel consisting of substantially nonthermal-conductive material.

37. Device of claim **35** wherein said wheel consists of asbestos or ceramic and said means for drawing air is an electrically-operated fan.

38. Device of claim **37** wherein said wheel is a cylindrical structure of corrugated asbestos.

39. Device of claim **35** wherein said means for drawing ambient air into said cavity includes an electrically operated fan.

40. Method for cleaning the interior food-soiled surfaces of the cooking cavity in a gas-fired oven wherein air for burning with fuel gas is supplied to said cavity and hot flue gas is exhausted from said cavity, comprising (1) heating said surfaces to temperatures in the range 750° F. to 950° F. by burning fuel gas within said cavity to vaporize and oxidize said food soils, thereby creating hot flue gas, (2) contacting said hot flue gas, prior to exhaustion from said oven, with heat exchange means at a temperature lower than said flue gas, thereby increasing the temperature of said heat exchange means and decreasing the temperature of said flue gas, and (3) contacting said air, prior to entry into said cavity for burning, with said heat exchange means at a temperature higher than said air, thereby decreasing the temperature of said heat exchange means and increasing the temperature of said air, whereby the heat losses in the cleaning operation are minimized and whereby said hot flue gas is cooled sufficiently to permit exhaustion to the surrounding area.

41. Method of claim **40** wherein said fuel gas is heated prior to burning in said cavity by heat exchange with part of said hot flue gas.

References Cited

UNITED STATES PATENTS

3,251,402	5/1966	Glav	165—7
3,327,094	6/1967	Martin et al.	126—21

FOREIGN PATENTS

662,210	12/1951	Great Britain.

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