Abstract: A burnpot for a solid particulate stove is disclosed. The burnpot includes a bottom cover (30), a top cover (20), two side plates (42) connecting the top cover and the bottom cover, a bottom grate having a plurality of bottom grate apertures disposed therein and positioned intermediate the bottom cover and the top cover, a top grate (22) having a plurality of top grate apertures disposed therein and positioned intermediate the bottom grate and the top cover and an air passageway configured to direct air to a burn chamber of the burnpot through the bottom grate and the top grate.
BURNPOT FOR SOLID PARTICULATE STOVE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/865,240, filed November 10, 2006, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to a burnpot for stoves that burn solid particulate fuels.

BACKGROUND OF THE INVENTION

[0003] Stoves that burn solid particulate fuels such as wood pellets, shelled corn, and pulverized coal for home heating are very popular. These stoves have a container or burnpot that contains and holds burning fuel, while air is provided through holes in the bottom of the burnpot to provide a flow of oxygen for combustion. Until now, these hole sizes have been 0.125 in. and larger in diameter. This has a tendency to provide too much air at one spot, which can lead to improper combustion and formation of carbon. Also, in some cases, these holes also allow ash and saw dust or other fuel fines to fall through the holes into the air intake passage. This increases the need for maintenance to clean out the air intake passage. By only using standard hole sizes of 0.125 in. and larger in diameter, as seen in conventional burn pots, high volumetric flow of air has a tendency to cool the hot coals as it blows past, reducing the efficiency of the burn. This efficiency is further decreased because these higher volumes of air also tend to sweep volatile components from the fuel, which are carried away in the exhaust, leaving ash and residue that cannot be burnt to completion.

[0004] Furthermore, particulate fuels can clump together in the burnpot, reducing efficiency and increasing the buildup of spent fuel and ash. Accumulated spent fuel and ash must be removed, and so the burnpot requires periodic cleaning to maintain efficiency and performance. Cleaning the burnpot is a time-consuming and difficult chore.

[0005] Inefficient burning of fuel may result in other problems as well. Mechanical problems caused by inefficient burning include hazing of glass windows provided to view the
firebox from outside the stove and the build up of creosote on heat exchangers. Environmental problems include the presence of carbon monoxide and other common pollutants associated with incomplete or inefficient burning, which pollutants continue to be regulated to ever lower emissions standards.

[0006] What is needed is an improved burnpot that conveniently and efficiently burns shelled corn, wood pellets, anthracite coal and other solid particulate fuels for home heating that reduces the frequency for cleaning the burnpot and other areas of the stove and that better diffuses the air to which the fuel is exposed to provide for cleaner burning and lower emissions of pollutants.

SUMMARY OF THE INVENTION

[0007] According to an exemplary embodiment of the invention, a burnpot is disclosed. The burnpot comprises a bottom cover, a top cover, two side plates connecting the top cover and the bottom cover, a bottom grate having a plurality of bottom grate apertures disposed therein and positioned intermediate the bottom cover and the top cover, a top grate having a plurality of top grate apertures disposed therein and positioned intermediate the bottom grate and the top cover and an air passageway configured to direct air to a burn chamber of the burnpot through the bottom grate and the top grate. As a result, air is introduced both below and above the fuel.

[0008] According to another exemplary embodiment of the invention, a solid particulate stove comprises a hopper configured to store particulate fuel, a firebox for burning the particulate fuel and a feed system configured to receive the particulate fuel from the hopper and deliver it to the firebox via an auger. A burnpot connected to the feed system is positioned within the firebox. The burnpot comprising a bottom cover, a top cover, two side plates connecting the top cover and the bottom cover, a bottom grate having a plurality of bottom grate apertures disposed therein and positioned intermediate the bottom cover and the top cover, a top grate having a plurality of top grate apertures disposed therein and positioned intermediate the bottom grate and the top cover and an air delivery passageway configured to direct supply air to a burn chamber of the burnpot through the bottom grate and the top grate and toward particulate fuel resting on the bottom grate.

[0009] According to yet another exemplary embodiment of the invention a burnpot for a solid particulate stove comprises a burn chamber, an air delivery chamber and a grate
separating the burn chamber and the air delivery duct, the grate having apertures disposed therein to direct air from the air delivery chamber toward solid particulate fuel in the burn chamber, wherein a plurality of the apertures are less than about 0.125 inches in width.

[0010] One advantage of the invention is that providing air both over and under the burning fuel promotes cleaner burning, resulting in the reduction of carbon buildup in the burnpot and reducing the need for cleaning the burnpot.

[0011] Another advantage of the invention is that cleaner burning reduces sticky creosote residue build up on heat exchangers, resulting in heat exchangers that operate more efficiently.

[0012] Yet another advantage of the invention is that cleaner burning can additionally be achieved by reducing the size and increasing the number of holes in the grates, reducing emissions levels of noxious pollutants, such as carbon monoxide.

[0013] Still another advantage of the invention is that providing holes in the burnpot smaller than the current 0.125 in. standard promotes a cleaner, more efficient burn and lower carbon monoxide emissions. The burnpot stays cleaner because of reduced carbon build up because more carbon is converted to carbon dioxide instead of soot and carbon monoxide. Smaller grate hole size also reduces the amount of ash and fines that can fall through the holes and into the air intake system.

[0014] Other features and advantages of the present invention will be apparent from the following more detailed description of exemplary embodiments, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 illustrates an isometric view of a burnpot in accordance with an exemplary embodiment of the invention.

[0016] Figure 2 illustrates an elevated front view of a burnpot in accordance with an exemplary embodiment of the invention.
Figure 3 illustrates a bottom view of a burnpot in accordance with an exemplary embodiment of the invention.

Figure 4 illustrates a rear view of a burnpot in accordance with an exemplary embodiment of the invention.

Figure 5 illustrates a cross-sectional isometric view of a burnpot in accordance with an exemplary embodiment of the invention taken across line 5-5 in Figure 2.

Figure 6 illustrates a cross-sectional isometric view of a burnpot in accordance with an exemplary embodiment of the invention taken along line 6-6 in Figure 2.

Figure 7 illustrates a generalized sectional view of a solid particulate stove in accordance with an exemplary embodiment of the invention.

Figure 8 illustrates a burnpot and feed system in accordance with another exemplary embodiment of the invention.

Figure 9 illustrates a cross-sectional view of a burnpot in accordance with another exemplary embodiment of the invention.

Where like parts appear in more than one drawing, it has been attempted to use like reference numerals for clarity.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Figure 7 illustrates a generalized sectional view of a solid particulate stove 100 in accordance with an exemplary embodiment of the invention. The stove 100 includes a hopper 6 in which fuel (not shown), such as wood pellets, wood chips, grains (e.g., shelled corn, barley, wheat, etc.), pelletized biofuels, anthracite coal, walnut shells, peach pits and the like, by way of example, or any other suitable particulate fuel or fuel mixture is stored prior to burning. The stove 100 also includes a feed system 2 that includes an auger 4 to feed fuel from the hopper 6 to a burnpot 10 positioned in a heavily insulated firebox 8. There, the fuel is mixed with oxygen and burned. One or more heat exchangers 5, typically with at least one surface positioned in the firebox 8, are provided to transfer heat from the firebox 8 to air flowing over an opposite surface of the heat exchangers 5 via a fan 7, following which the
heated air is ejected into the environment to heat the surrounding space, all of which occurs in accordance with well-known general principles of basic solid particulate stove operation.

[0026] Turning to Figure 1, in accordance with one exemplary embodiment of the invention, the burnpot 10 has a top cover 20, a bottom cover 30, and two side plates 42. A bottom grate 32 having a plurality of bottom grate apertures 34 is positioned over the bottom cover 30 and provides a surface on which the fuel burns. The bottom grate 32, bottom cover 30 and the portions of the two side plates 42 extending between them define a bottom air chamber 33 (Figure 5). The bottom cover 30 typically includes a maintenance aperture 31 which may have a removable door (not shown) to provide access to the bottom air chamber 33 to remove any ash that settles in it.

[0027] The components of the burnpot 10 can be of any suitable heat- and fire-resistant material and typically are manufactured predominantly from cast iron and/or sheet steel (usually ten to twelve gauge) that are seam welded to produce the final burnpot 10. (For clarity, seam welds are not shown in the Figures).

[0028] The burnpot 10 can be attached to the feed system 2 in any suitable manner, but typically includes a back plate 50 having a plurality of bolt apertures 53 to receive lugs (not shown) extending from the firebox 8 or feed system 2. If a back plate 50 is used, a feed aperture 51 (Figure 2) is also provided in the back plate 50 such that the feed aperture 51 is aligned with the auger 4 when the burnpot 10 is in operation. Fuel is intermittently or continuously fed by the auger 4 or another fuel delivery device into a burn chamber 15 portion of the burnpot 10 where the fuel burns on the bottom grate 32. Oxygen is introduced into the burn chamber 15 by air flowing from the bottom air chamber 33 through the bottom grate apertures 34. The air enters the burnpot 10 from an air intake aperture 55 provided in the back plate 50 (best seen Figures 4 and 5), which may occur in any suitable manner, such as using an intake fan 12 that, along with appropriate ducts, can be used either to push air external to the stove 100 into the air intake aperture 55 or to push combustion exhaust from the firebox 8, creating suction that pulls air external to the stove 100 into the air intake aperture 55. The oxygen in the air burns with the fuel; the combustion reaction products, along with any excess air, is carried out a chimney or other hot gas outlet (not shown) via an exhaust path 9 exiting the stove 100 to an outdoor location. A sufficient volume of gas is introduced into the burn chamber 15 to ensure a suitable excess of oxygen for combustion.
The inventors have determined that by reducing the size of the bottom grate apertures 34 to widths (i.e., diameters in the case of circular holes) less than the 0.125 inch holes currently used, while increasing the number of bottom grate apertures 34, the same volume of air can be introduced into the burn chamber 15. The inventors have also determined that in this manner, the air can be introduced in a more diffuse manner to promote a more efficient and cleaner burn. Thus, while a certain amount of bottom grate apertures 34 of 0.125 inches and larger in diameter are not precluded, at least about 25% of the bottom grate apertures 34 have a diameter of less than about 0.125 inches. In one embodiment at least about 50% of the bottom grate apertures 34 have a diameter of less than about 0.125 inches, while in another embodiment, at least 75% of the bottom grate apertures 34 have a diameter of less than about 0.125 inches. Preferably the bottom grate apertures 34 smaller than 0.125 inches have a diameter in the range of about 0.006 inches to about 0.1 inch. The diameter of the bottom grate apertures 34 may be about 0.11 inches, about 0.1 inch, about 0.062 inches, about 0.045 inches, about 0.03 inches, about 0.006 inches, or any other diameter less than about 0.125 inches. The bottom grate apertures 34 can be produced by any suitable method, such as laser drilling, for example.

Any combination of different hole sizes may be used in the bottom grate 32. Likewise, any pattern of hole placement and any level of hole density may be provided. The bottom grate 32 may include an inclined middle portion 32a, on which most of the burning of the particulate fuel takes place, although the entire bottom grate 32 may include the bottom grate apertures 34 to provide air for combustion. Adjusting hole sizes, placement and density may permit greater control over the size, direction and dispersing of the flame produced by the fuel in the burn chamber 15, which may assist in more even heating of the firebox 8. This in turn results in more even heating of air passing through the heat exchangers 5. For example, it may be desirable to provide a lower hole density in areas of the bottom grate 32 most commonly used with smaller amounts of fuel (e.g. the lower area of middle portion 32a close to the feed aperture 51) and to provide a higher hole density in areas of the bottom grate 32 used when higher amounts of fuel are burned (e.g. the upper area of middle portion 32a), as seen in Figure 5, which shows increasing hole density in the bottom grate 32 as the distance from the feed aperture 51 increases.

Although primarily described and illustrated herein with respect to a burnpot 10 for use in a so-called "under-feed" system, it will be appreciated that exemplary embodiments
of the invention can be implemented with any suitable burnpot and feed system, such as shown in Figure 8 which illustrates a burnpot 10 (shown in combination with a feed system 2) in accordance with another exemplary embodiment of the invention also having a plurality of bottom grate apertures 34 less than 0.125 in. in diameter disposed in the bottom grate 32 of the burn chamber 15 in the manner described above.

[0032] In one embodiment of the invention, the burnpot 10 contains a top grate 22 in addition to the bottom grate 32 to introduce air into the burn chamber 15 from both the top and the bottom of the burnpot 10. In this embodiment, as best seen in Figure 1, the top of the burnpot 10 is bounded by a top cover 20 under which a top grate 22 containing a number of top grate apertures 24 is positioned. Thus, in this embodiment, the burn chamber 15 is defined by the bottom grate 32, the top grate 22 and the portions of the side plates 42 extending between the two grates 32, 22.

[0033] The top cover 20, the top grate 22 and the portions of the side plates 42 extending between the top cover 20 and top grate 22 define a top air chamber 23 (Figure 5) to direct air downward into the burn chamber and on top of the burning fuel. The size of the top grate apertures 24 is typically as described with respect to the bottom grate apertures 34. Likewise, pattern and density may also vary depending on the flame effects desired. It will be appreciated however, that the patterns and density of the top grate apertures 24 and bottom grate apertures 34 do not have to be the same, but may be positioned in combination to achieve a desired overall result. It will further be appreciated that the apertures are generally, but need not necessarily be, circular. For example, the apertures may be slotted, as shown in Figure 5 in which a slotted aperture having reference numeral 24a is illustratively substituted for two circular apertures, or may be a combination of different geometrical shapes, for example a combination of circles and slots.

[0034] Air may be delivered to the top air chamber 23 and forced downward into the burn chamber 15 from the same source as the air delivered to the bottom air chamber 33. After the air enters the burnpot 10 from the air intake aperture 55, a portion of that air is carried to the top air chamber 23 via an air transfer duct 46 that forms an air transfer channel 47 (Figure 6) that connects the top and bottom air chambers 23, 33 and allows the use of a common air source for the two chambers.
[0035] By splitting the air entering the burnpot 10 between top and bottom air chambers 23, 33 to introduce oxygen into the burn chamber 15 both above and below the fuel, increased efficiency of the combustion reaction is achieved without modifying the total volumetric flow of air, reducing the percentage of carbon monoxide produced and thus emitted to the atmosphere. The increased efficiency further results in converting a higher percentage of fuel to heat, reducing carbon buildup in the burnpot 10 and thus the frequency with which it needs to be cleaned. The cleaner burn also has the effect of reducing hazing on any glass windows provided to view the firebox 8 and reduces or eliminates sticky creosote residue that builds up on the heat exchangers 5 and other air passage areas of the stove 100.

[0036] As illustrated in Figure 2, two air transfer ducts 46 are provided, one on each side of the burnpot 10 to promote a more even distribution into the top air chamber 23. A desired percentage of incoming air that is directed to pass through the top air chamber 23 may be achieved by modifying the volume of the air transfer channel(s) 47 and/or the ratio of the area of top grate apertures 24 versus the area of bottom grate apertures 34. In one embodiment, up to about 40% of the air entering the burnpot 10 is directed to pass through the top air chamber 23.

[0037] The top air chamber 23 may be formed as an enclosure so that it is configured to direct all of the air entering the top air chamber 23 into the burn chamber 15 via the top grate apertures 24. Alternatively, the top air chamber 23 may be less than completely enclosed. As shown in Figure 9, a gap 80 may be introduced between the top grate 22 and the top cover 20 to allow a partial by-pass of air entering the top air chamber from passing through the top grate apertures. The gap 80 provides an air curtain that allows combustion air to flow out of the top air chamber 23 and along the heat exchangers 5 positioned above the burnpot 10 (Figure 7). This can improve the quality of burn, by providing additional air to maintain a high BTU burn rate, which in turn promotes cleaner burning by preventing carbon formation from the flame hitting upon the heat exchanger.

[0038] In one embodiment, the bottom grate 32 is s-shaped, as shown in Figure 5, with a curved middle portion 32a that rises toward the top grate 22 as the distance from the feed aperture 51 increases. In another embodiment, shown in Figure 9, the bottom grate 32 is z-shaped, with a flat middle portion 32a. Here, the flat middle portion 32a of the bottom grate 32 is configured and arranged so that the distance between the top grate 22 and the flat middle portion 32a of the bottom grate 32 gradually and constantly increases. The side plates
42 may also be angled at a constantly increasing distance from one another. Where the z-shaped bottom grate 32 is used in combination with outwardly angling side plates 42, the middle section 32a, top grate 22 and side plates define a constantly expanding burn chamber 15. Constant expansion of the burn chamber 15 alleviates pinch points within the burn chamber 15 that may constrict expanding combustion gases during stove operation. As result, a quieter burn can be achieved.

[0039] An embodiment of the invention having top and bottom air chambers in combination with reduced hole sizes has been reduced to practice. Testing showed that a stove having a burnpot in accordance with the exemplary embodiment of the invention passed the EU emissions standard EN14785, becoming what is believed to be the first commercially available under-feed particulate fuel stove to meet this requirement. This emissions standard establishes (1) a carbon monoxide emission level for pellet stoves in which the mean carbon monoxide concentration calculated to 13% oxygen (O₂) content in the flue gas from the mean of at least two results shall not exceed 0.04% (500 mg/m³) at nominal heat output and 0.06% (750 mg/m³) at reduced heat output and (2) that the measured total efficiency from the mean of at least two test results at nominal heat output and at reduced heat output shall be at least 75% at nominal heat output and 70% at reduced heat output.

[0040] Specifically, testing in accordance with EU emissions standard EN14785 was conducted by the Centre Technique Des Industries Aéraliques Et Thermiques in Villeurbanne, France with a particulate fuel stove having a burnpot as illustrated and described with respect to Figures 1-6 in which the top grate had fifty four 0.1 inch and fifteen 0.1 inch holes and the bottom grate had one hundred eighty one 0.1 inch and six 0.125 inch holes. The stove with the inventive burnpot was determined to have passed the standard with a nominal total power of 10.5 kW, a combustion yield (i.e., total efficiency) of 84%, and an average carbon monoxide concentration standardized to 13% oxygen of 0.02%.

[0041] While the foregoing specification illustrates and describes exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular
embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.
CLAIMS

1. A burnpot for a solid particulate stove comprising:
   a bottom cover;
   a top cover;
   two side plates connecting the top cover and the bottom cover;
   a bottom grate having a plurality of bottom grate apertures disposed therein
   and positioned intermediate the bottom cover and the top cover;
   a top grate having a plurality of top grate apertures disposed therein and
   positioned intermediate the bottom grate and the top cover; and
   an air passageway configured to direct air to a burn chamber of the burnpot
   through the bottom grate and the top grate.

2. The burnpot of claim 1,
   wherein the bottom grate, top grate and a portion of each side plate define the
   burn chamber,
   wherein the bottom cover, bottom grate, and a portion of each side plate
   define a bottom air chamber configured to direct air into the burn chamber, and
   wherein the top cover, top grate, and a portion of each side plate define a top
   air chamber configured to direct air into the burn chamber.

3. The burnpot of claim 2, further comprising an air transfer duct connecting the top air
   chamber and the bottom air chamber.

4. The burnpot of claim 2, wherein the top air chamber is sized and configured such that up
   to about 40% of air entering the burnpot is directed to the top air chamber.

5. The burnpot of claim 2, further comprising an air transfer duct connecting the top air
   chamber and the bottom air chamber and wherein a plurality of apertures in the bottom
   grate and the top grate are less than about 0.125 inches in width.

6. The burnpot of claim 2, wherein the bottom air chamber includes an air intake aperture.

7. The burnpot of claim 2, wherein the top air chamber is configured to direct all air entering
   the top air chamber through the top grate apertures.

8. The burnpot of claim 2, wherein the top air chamber is partially enclosed and the top
   cover and the top grate define a gap for air to by-pass the top grate apertures.
9. The burnpot of claim 1, wherein a plurality of bottom grate apertures are less than about 0.125 inches in width.

10. The burnpot of claim 1, wherein a plurality of top grate apertures are less than about 0.125 inches in width.

11. The burnpot of claim 1, wherein the bottom grate apertures are arranged in a pattern different than the top grate apertures.

12. The burnpot of claim 1, wherein the bottom grate apertures have a corresponding density that increases as a distance from a feed aperture increases.

13. The burnpot of claim 1, wherein the bottom grate is z-shaped and wherein the side plates, a middle portion of the bottom grate and the top grate define a constantly expanding burn chamber.

14. A solid particulate stove comprising
   a hopper configured to store particulate fuel;
   a firebox for burning the particulate fuel; and
   a feed system configured to receive the particulate fuel from the hopper and deliver it to the firebox via an auger,
   wherein a burnpot connected to the feed system is positioned within the firebox, the burnpot comprising:
   a bottom cover;
   a top cover;
   two side plates connecting the top cover and the bottom cover;
   a bottom grate having a plurality of bottom grate apertures disposed therein and positioned intermediate the bottom cover and the top cover;
   a top grate having a plurality of top grate apertures disposed therein and positioned intermediate the bottom grate and the top cover; and
   an air delivery passageway configured to direct supply air to a burn chamber of the burnpot through the bottom grate and the top grate and toward particulate fuel resting on the bottom grate.

15. A burnpot for a solid particulate stove comprising:
   a burn chamber;
   an air delivery chamber; and
Attorney Docket No.: 22737-0007-U1

a grate separating the burn chamber and the air delivery duct, the grate having apertures disposed therein to direct air from the air delivery chamber toward solid particulate fuel in the burn chamber, wherein a plurality of the apertures are less than about 0.125 inches in width.

16. The burnpot of claim 15, wherein at least about 25% of the apertures have a width of less than about 0.125 inches in width.

17. The burnpot of claim 15, wherein at least about 50% of the apertures have a width of less than about 0.125 inches in width.

18. The burnpot of claim 15, wherein the plurality of apertures less than 0.125 inches in width have a width in the range of about 0.006 inches to about 0.1 inches.

19. The burnpot of claim 15, wherein the air delivery chamber is disposed under the burn chamber and further comprising:

   a second air delivery chamber disposed above the burn chamber; and
   a second grate separating the burn chamber and the second air delivery chamber, the second grate having apertures disposed therein to direct air from the second air delivery chamber toward solid particulate fuel in the burn chamber.

20. The burnpot of claim 19, wherein at least about 50% of the second grate apertures have a width of less than about 0.125 inches in width.

21. The burnpot of claim 19, wherein at least about 75% of the second grate apertures have a width of less than about 0.125 inches in width.
Figure 1
Figure 8
### A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC.

**INV. F24B1/195**

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24B F23B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Further documents are listed in the continuation of Box C. X See patent family annex

- Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
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### Date of the actual completion of the international search

29 February 2008

### Date of mailing of the international search report

06/03/2008

Name and mailing address of the ISA/

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Authorized officer

Rodriguez, Alexander
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