

Oct. 19, 1954

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2,692,014

BURNER FOR LIQUID AND GASEOUS FUELS

Filed March 18, 1952

2 Sheets-Sheet 1

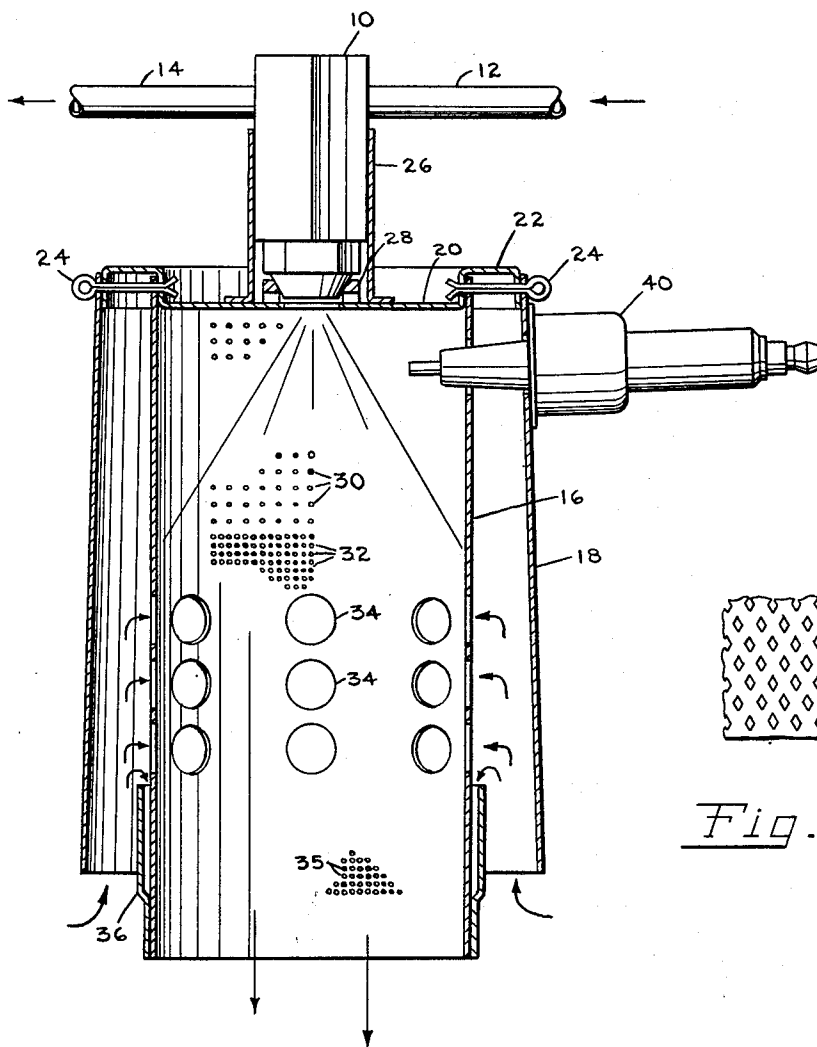


Fig. 2A.

Fig. 1.

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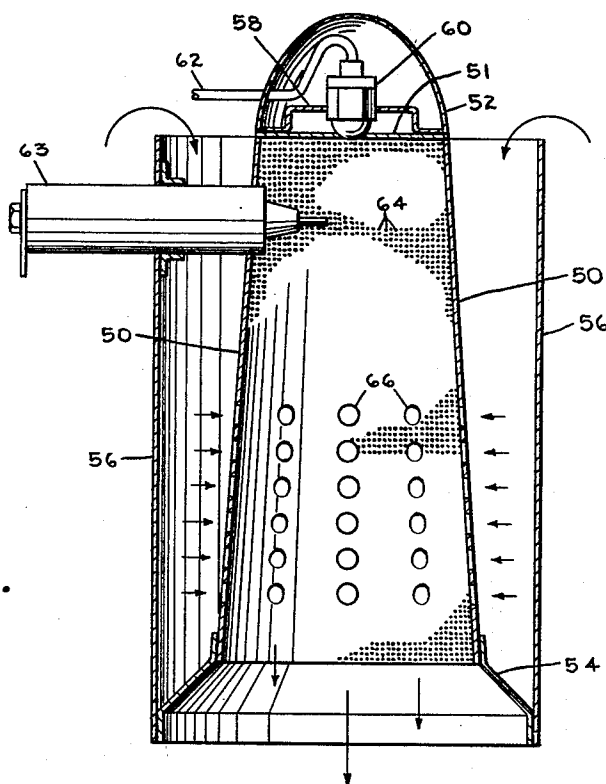


Fig. 3.

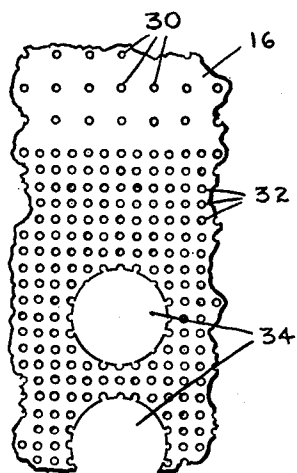


Fig. 2.

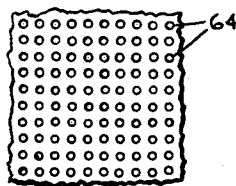


Fig. 4.

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## UNITED STATES PATENT OFFICE

2,692,014

## BURNER FOR LIQUID AND GASEOUS FUELS

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Application March 18, 1952, Serial No. 277,185

10 Claims. (Cl. 158—1)

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This invention relates to burners for liquid and gaseous fuels, to the outside of which the air which supports combustion is supplied under higher than atmospheric pressure.

Fuel burners of the general type to which the present invention relates customarily comprise a sheet metal shell with which cooperates a fuel nozzle supplying a liquid or gaseous fuel to the space within the shell, said shell being provided with holes through which air enters the shell freely in quantity capable of supporting combustion of the fuel within the shell. In designing such fuel burners of the prior art, attempts have been made to make the holes through which the air enters of such sizes and to arrange them in such ways that complete combustion of the fuel is achieved without the formation of a carbonaceous deposit upon the inside of the fuel burners. Nevertheless, in such fuel burners of the prior art, under many conditions of operation, the formation of a carbonaceous deposit upon the inside of the fuel burners does occur, with objectionable results.

The general object of the invention is to provide a fuel burner in which substantially complete combustion of the fuel takes place without the formation of a carbonaceous deposit upon the wall of the fuel burners. To this end, fuel burners embodying the present invention are characterized by the fact that the shell of a sheet material which forms within it the combustion chamber is provided throughout most of its area with many very small and more or less closely-spaced perforations through which air, supplied to the outside of the shell at higher than atmospheric pressure, seeps into the combustion chamber within the shell, thereby providing on the inside surface of the shell a layer or cushion of air which, so I have discovered, serves the highly useful purpose of preventing the formation of a carbonaceous deposit on the inside surface of the shell. The shell is also provided in the perforated portion with the usual comparatively few and much larger holes through which additional air enters the shell freely in quantity capable of supporting substantially complete combustion of the fuel within the shell. Furthermore, I have discovered that the nature of the fuel flame within the shell is advantageously influenced if the sum of the areas of the very small perforations per unit area of the shell is less at some portions of the shell than at others; and this feature of the preferred form of the fuel burners will be hereinafter described.

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This application is a continuation-in-part of my application Serial No. 73,411, filed January 28, 1949, now abandoned, and of my application Serial No. 27,762, filed May 18, 1948, now Patent No. 2,611,599, granted September 23, 1952 in which one of the two forms of the invention hereinafter described is illustrated and described as embodied in a tobacco barn heater.

The invention will be understood from the following description, taken in connection with the accompanying drawings in which Fig. 1 illustrates in cross-sectional elevation a preferred form of fuel burner embodying the invention; Fig. 2 is a fragmentary view, on an enlarged scale, illustrating the perforated sheet material of which the inner shell of said fuel burner is made; Fig. 2A is a similar view of an alternative form of perforated sheet material; Fig. 3 is a cross-sectional elevation, on a smaller scale, of the fuel burner which is shown and described in the aforesaid prior application Serial No. 27,762; and Fig. 4 is a fragmentary view, on an enlarged scale, of the perforated sheet material of which the inner shell of that fuel burner is made.

The preferred form of the invention illustrated in Figs. 1 and 2 will first be described. As will be evident from Fig. 1, the fuel burner there illustrated is provided with a fuel nozzle or atomizer 10 which is illustrated as being of the well-known return-flow type, having a supply pipe 12 and a return pipe 14. The atomizer 10 supplies the fuel-oil to the combustion chamber in the form of a fine cone-shaped spray, as indicated in Fig. 1, in a manner which is well known to those skilled in the art. The fuel burner, which is preferably made of stainless-steel sheet, has an inner cylindrical shell 16 and a slightly tapering outer shell 18, which are retained in concentric relation by a circular dish-shaped member 20 having its outer portion formed into a circular channel 22 which cooperates with the top edges of the shells 16 and 18 and is secured thereto by cotter pins 24, as will be evident from Fig. 1. Thus there is provided between the outer shell 18 and the inner shell 16 an annular space to which air is supplied as indicated by the curved arrows near the bottom of Fig. 1. The member 20, which serves as the end wall of the combustion chamber, is provided at its center with an opening through which the fuel-spray from the atomizer 10 enters the combustion chamber; and said member 20 is provided with a split hexagonal portion 26, which houses the atomizer 10 the tip-end of which engages a

loose centering member 28 slidably mounted on the member 20 and located within the bottom of the hexagonal portion 26. The inner shell 16 of the fuel burner is perforated with a large number of small perforations 30 and 32, and is also provided with several series of circularly-arranged larger holes 34, as will be apparent from Figs. 1 and 2. The primary purpose of the small perforations 30 and 32 is to permit air to seep from the annular space between the shells 16 and 18 through the inner shell 16 enclosing the combustion chamber, thereby providing on its inside surface a layer or cushion of air which I have discovered serves the highly useful purpose of preventing the formation of a carbonaceous deposit on the inside surface of the inner shell 16 of the fuel burner. The larger holes 34 in the inner shell 16 of the fuel burner serve to admit freely into the combustion chamber from the annular space between the shells 16 and 18 the air necessary to support substantially complete combustion of the fuel supplied to the combustion chamber by the atomizer 10; and these larger holes 34 also admit to the combustion chamber additional air which dilutes the gaseous products of combustion. It will be noted that the number of small perforations 30 per unit of area in the upper and approximately one-third part of the inner shell 16 of the fuel burner is less than the number of small perforations 32 and 35 in the lower two-thirds part of said shell 16. This arrangement of the small perforations 30 and 32 results in the seepage into the upper part of the combustion chamber of less air per unit area of the shell 16 than into the central and lower part thereof, which I have found to be advantageous, as hereinafter explained. Of course, the same result may be accomplished by making the upper and approximately one-third portion of the inner shell 16 of two layers of sheet metal each containing perforations arranged as indicated at 32, but partially misaligned, thereby in effect decreasing the total cross-sectional area of the perforations, per unit of area of the shell 16, through which the air seeps into the upper part of the combustion chamber. As shown in Fig. 1, the lower part of the inner shell 16 of the fuel burner is surrounded by a baffle 36, the major portion of which is spaced away a short distance from the perforated inner shell 16. This baffle retards the flow of and increases the heating of the air seeping into the lower portion of the combustion chamber, which I have found to be advantageous, as hereinafter explained. An ignition device 40 of any well-known form, which extends through aligned openings in the shells 18 and 16 into the combustion chamber, is shown in Fig. 1.

The fuel burner which has been described is mounted within a casing (not shown) to which air is supplied under pressure. This compressed air enters the annular space between the shells 16 and 18 as indicated by the curved arrows near the bottom of Fig. 1, and the major portion of the air enters the combustion chamber through the larger openings 34; but some of said air seeps through the perforations 30 and 32 in the inner shell 16 and provides on the inner surface of said shell the layer or cushion of air which, as has been mentioned, serves the highly useful purpose of preventing the formation of a carbonaceous deposit on the inside of the shell 16. The air passing through the annular space between the shells 16 and 18 absorbs heat from

the shell 16 before passing into the combustion chamber, and also serves to moderate the temperature of the outer shell 18.

It will be obvious from Fig. 1 that the small perforations 30 are located in that portion of the inner shell 16 against which little if any fuel spray strikes. Since the sum of the areas of the small perforations 30 per unit area of the shell 16 is less than the sum of the areas of the small perforations 32 per unit area of the shell, less air seeps into the upper part of the combustion chamber which is a more or less stagnant region, than into the middle and lower portions of the combustion chamber where the fuel spray may strike the inner surface of the shell 16. This restriction of the quantity of air which seeps into the upper and approximately one-third part of the combustion chamber has an advantageous effect on the base of the flame, but does not interfere with the prevention of the formation of carbonaceous deposits in that region. The larger quantity of air which seeps through the small perforations 32, throughout the middle and lower regions of the inner shell 16, forms upon the inner surface of the shell 16 a denser layer or cushion of air which I have found effectively prevents the formation of a carbonaceous deposit in these regions where such a deposit is most likely if at all to occur. The baffle 36 serves the useful purposes of impeding and guiding the air on its way to the small perforations 35 which are located near the bottom of the shell; whereby that air is heated and seeps less freely into the bottom of the combustion chamber, which I have found also has an advantageous effect on the flame in that region.

Besides preventing the formation of a carbonaceous deposit upon the inside of the shell 16, the small perforations 30 and 32 also effect a cooling of the shell 16 due to the air seeping through said perforations. To the best of my knowledge and belief it is novel to use such perforated sheet material in this way for the making of a fuel burner; and I believe that I am the discoverer of the highly beneficial results achieved by its use. Furthermore, I have discovered that the size and spacing of the small perforations 30, 32 and 35 have an important bearing upon the results and advantages achieved. For example, in a fuel burner (of the kind illustrated in Fig. 1) having a length of about 5.5 inches and a diameter of about 2.5 inches, the best results seem to be obtained by employing for the making of the inner shell a high-temperature resistant, stainless steel sheet, of about 22 to 26 gauge, in which the perforations 30, 32 and 35 have a diameter of approximately .036 of an inch, the closely spaced perforations 32 and 35 being arranged with approximately 200 holes to the square inch, giving approximately 20% open area, and the less closely spaced perforations 30 being arranged with approximately 50 perforations to the square inch, giving about 5% open area; and if the larger holes 34 have a diameter of about .375 of an inch and are arranged as shown. It will, however, be understood that the gauge of the sheet material, the diameter and arrangement of the holes in the inner shell 16 may vary from the data just given, without departing from the spirit of my invention. The important thing is to make the perforations 30, 32 and 35 of such a size and to arrange them so close to one another that the air seeping through them into the combustion chamber will provide such a cushion or layer of air on the inside of

the shell enclosing the combustion chamber that the formation of a carbonaceous deposit will be prevented. It has been found that this desirable result is achieved if the open area provided by the perforations 32 and 35 is about 16% to 27%, with the diameter of the perforations varying from .025 to .045 of an inch; and if the open area provided by the perforations 30 is about 5% of the area of the shell 16 where those holes are located. As has been mentioned, the larger perforations 34 in the shell 16 serve to admit to the combustion chamber substantially all of the air necessary to support substantially complete combustion of the fuel; but, of course, the air which seeps into the shell through the shell perforations 30 and 32 also helps in a minor way to support combustion of the fuel.

While optimum performance is usually obtained with the hole sizes and relative open areas just stated, one factor already mentioned but not specifically discussed has a special bearing on those factors of hole size and percentage open area. For uniform heat flow and resistance against warpage, it is preferable to use the heaviest (i. e. thickest) sheet material that can be easily worked. In other words, 22 gauge sheet material generally will be more resistant to warpage and have a more uniform temperature during burner operation than, say, 26 gauge material. On the other hand, if the holes 30, 32, 35 are made in sheet material with a metal punch, as is the usual practice, the minimum punch diameter depends on the thickness of the material. Thus, for example, a .040 diameter punch might be suitable for, say, 26 gauge material, and yet might wear out very quickly or even fail immediately if used with, say, 22 gauge material.

Therefore, it is sometimes worthwhile to adopt a hole size and open area percentage slightly greater than optimum in order to be able to use heavier gauge sheet material. For example, it has been found that satisfactory results can be obtained with holes 30, 32, 35 of diameter as great as .055 inch spaced for a corresponding open area of about 30%, where the combustion chamber conditions make it preferable to use heavier gauge sheet materials. In the majority of cases, a good compromise between the optimum configurations from the operational standpoint and from the standpoint of fabricating sheet material of suitable thickness comprises a hole size of about .045 inch with a corresponding open area percentage of about 27%.

It should also be noted that although the combustion chambers I have used most extensively have had generally circular holes or perforations 30, 32, 35 as shown in Figs. 1-3 and 4, this shape hole is not essential to a successful practice of the invention. For example, as shown in Fig. 2A, a pattern of diamond-shaped louvered holes in so-called "expanded metal" material has been tested with satisfactory results. Accordingly, where the diameter of a hole or perforation is referred to herein and in the appended claims, it will be understood that no limitation on hole shape is intended thereby. Rather, it is intended to designate an opening of area corresponding to that of a circle of the stated diameter.

The embodiment of the invention illustrated in Figs. 3 and 4 will now be described. (These figures correspond to Figs. 4 and 5 in my aforesaid application Serial No. 27,762.) Referring to Fig. 3, it will be apparent that the combustion

chamber is within an inner shell 50 which is slightly tapered and at its upper end is closed by an end wall in the form of a circular plate 51 which is covered by a domed-shaped portion 52, and at its lower end is attached to a circular apron 54. Surrounding the inner shell 50 and concentrically arranged with reference thereto is an outer shell 56 which at its bottom edge is connected to the apron 54 and at its top edge is spaced away from the shell 50 so that air may enter the annular space between the upper portions of the shells 50 and 56, as indicated by the curved arrows at the top of Fig. 3. Mounted on a bracket 58 within the domed-shaped portion 52 of the inner shell 50, is a fuel nozzle or atomizer 60 of any well-known form to which a fuel supply pipe 62 is connected. The member 51, which serves as the end wall of the combustion chamber, is provided at its center with an opening through which the fuel spray from the atomizer 60 enters the combustion chamber. This nozzle supplies fuel in the form of a spray to the space within the inner shell 50. An ignition device 63, of any well-known form, which extends through aligned openings in the shells 56 and 50 is shown in Fig. 3.

It will be evident from Fig. 3 that the inner shell 50 enclosing the combustion chamber is made of sheet metal which is perforated throughout substantially its entire area with a large number of small and closely related perforations 64 which are illustrated on a larger scale in Fig. 4. I have found that the best results are obtained by employing for the making of the inner shell 50 enclosing the combustion chamber illustrated in Fig. 3, 22 gauge, type 310 or 446, high-temperature resistant, stainless steel sheet which is perforated with small closely related perforations 64 having a diameter of approximately .036 of an inch and arranged with approximately 270 perforations to the square inch, giving about 27% open area, but it will be understood that the gauge of the metal sheet, the diameter of these perforations and the number of perforations per square inch may vary somewhat from the figures just given, within the limits already stated, without sacrificing the advantages of the fuel burner illustrated in Fig. 3. The important thing is to make these perforations 64 so small and to arrange them so closely to one another that air will seep through them into the combustion chamber within the inner shell 50 so as to provide a cushion or layer of air on the inside of that shell. The much larger holes 66 (shown in Fig. 3) in the cylindrical wall of the inner shell 50, serve to admit to the combustion chamber the air necessary to adequately support combustion of the fuel supplied by the nozzle 60, and additional air to dilute the gaseous products of combustion which is considered desirable in heaters of the kind described in my aforesaid application.

It will be obvious from Fig. 3 that the combustion chamber there illustrated is intended to be supplied with air at a pressure higher than atmospheric pressure; and that said air enters the annular space between the shells 50 and 56. The major portion of this air enters the inner shell 50 freely through the larger holes 66 and supports combustion of the fuel; but some of said air seeps through the small perforations 64 in the shell 50 and provides upon the inner surface of that shell the layer or cushion of air which substantially prevents the formation of a carbonaceous deposit on the inside of the shell 50.

As in the case of the embodiment of the invention illustrated in Figs. 1 and 2, the air seeping through the small perforations 64 in the inner shell 50, is heated by contact with that shell, and serves to cool that shell.

I claim:

1. A burner for liquid and gaseous fuels, having inner and outer spaced metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, an end wall cooperating with one end of said inner shell to close the same, and means cooperating with said end wall for supplying fuel to said combustion space, said inner shell being provided throughout at least about the two-thirds of its portion remote from said end wall with many perforations each having a diameter of between .025 and .055 of an inch and so spaced from one another that the total open area is between 16% and 30% of that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in said perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

2. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, an end wall cooperating with one end of said inner shell to close the same, and means cooperating with said end wall for supplying fuel to said combustion space, said inner shell being provided throughout at least about the two-thirds of its portion remote from said end wall with many perforations each having a diameter of about .045 of an inch and so spaced from one another that the total open area is about 27% of that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in said perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

3. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, a combustion space end wall cooperating with one end of said inner shell to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided throughout about the two-thirds of its

portion remote from said end wall with many perforations each having a diameter of about .045 of an inch and so spaced from one another that the total open area provided by said perforations is about 27% of that portion of said inner shell, whereby to provide air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in said perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

4. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space open at one end through which to supply air to the burner, a combustion space end wall having a marginal portion extending across the other end of said annular space to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided throughout about the two-thirds of its portion remote from said end wall with many perforations each having a diameter of about .045 of an inch and so spaced from one another that the total open area provided by said perforations is about 27% of that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in said perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

5. A burner for liquid and gaseous fuels, having inner and outer spaced metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space open at one end through which to supply air to the burner, a combustion space end wall having a marginal portion extending across the other end of said annular space to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided throughout about the two-thirds of its portion remote from said end wall with many substantially circular perforations each having a diameter of between .025 and .055 of an inch and so spaced from one another that the total open area provided by said perforations is between 16% and 30% of that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in said perforated portion with holes which are much larger in diameter than

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said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

6. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, a combustion space end wall cooperating with one end of said inner shell to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided in about the two-thirds of its portion remote from said end wall with many perforations each having a diameter of about .045 of an inch and so spaced from one another that the total open area provided by said perforations is about 27% of that portion of said inner shell, said inner shell being also provided throughout about the one-third of its portion adjacent said end wall with similar perforations the open area of which is less per unit area in said one-third portion of said inner shell than in said two-thirds portion, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portions of said inner shell, said inner shell being provided in said first-mentioned perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

7. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, a combustion space end wall cooperating with one end of said inner shell to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided in about the two-thirds of its portion remote from said end wall with many perforations each having a diameter of about .045 of an inch and so spaced from one another that the total open area provided by said perforations is about 27% of that portion of said inner shell, said inner shell being also provided throughout about the one-third of its portion adjacent said end wall with similar perforations the open area of which is less per unit area in that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portions of said inner shell, said inner shell being provided in the upper part of said two-thirds of its perforated portion with holes which are about .375 of an inch in diameter and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel, said inner shell being also provided, on the outside of the end remote from

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the end where the fuel enters, with a baffle secured to and concentric with and spaced only a little distance from the outside of said shell, whereby to impede the air passing through the perforations in that portion of said shell and guide the same into engagement with that portion of the outer surface of said inner shell.

8. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, a combustion space end wall cooperating with one end of said inner shell to close the same, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided in about the two-thirds of its portion remote from said end wall with many diamond-shaped perforations each of a size corresponding to a circular hole of diameter between .025 and .055 of an inch and so spaced from one another that the total open area provided by said perforations is between 16% and 30% of that portion of said inner shell, said inner shell being also provided throughout about the one third of its portion adjacent said end wall with similar perforations the open area of which is less per unit area in that portion of said inner shell, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portions of said inner shell, said inner shell being provided in the upper part of said two-thirds of its perforated portion with holes which are about .375 of an inch in diameter and are spaced apart and around said inner shell and have a total area sufficient to permit said air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel, said inner shell being also provided, on the outside of the end remote from the end where the fuel enters, with a baffle secured to and concentric with and spaced only a little distance from the outside of said shell, whereby to impede the air passing through the perforations in that portion of said shell and guide the same into engagement with that portion of the outer surface of said inner shell.

9. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, an end wall cooperating with and closing the end of said inner shell which is adjacent the open end of said annular space, an apron extending between the other ends of said shells and there closing said annular space, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided throughout substantially its entire area with many perforations each having a diameter of about .036 of an inch and arranged with about 270 perforations to the square inch, whereby to provide for air seepage through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in its perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit air to flow

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through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

10. A burner for liquid and gaseous fuels, having inner and outer spaced sheet-metal shells concentrically arranged, thereby providing within the inner shell a combustion space and between said shells an annular space through which to supply air to the burner, an end wall cooperating with and closing the end of said inner shell which is adjacent the open end of said annular space, an apron extending between the other ends of said shells and there closing said annular space, and means for supplying fuel through said end wall to said combustion space, said inner shell being provided throughout substantially its entire area with many perforations each having a diameter of between .025 and .055 of an inch and arranged with between 160 and 300 perforations to the square inch, whereby to provide for air seep-

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age through said perforations from said annular space into said combustion space to form a layer or cushion of air on the inner surface of the perforated portion of said inner shell, said inner shell being also provided in its perforated portion with holes which are much larger in diameter than said perforations and are spaced apart and around said inner shell and have a total area sufficient to permit air to flow through them freely from said annular space into said combustion space in a quantity capable of supporting substantially complete combustion of the fuel.

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