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BURNER FOR FIRING A COMBUSTION CHAMBER

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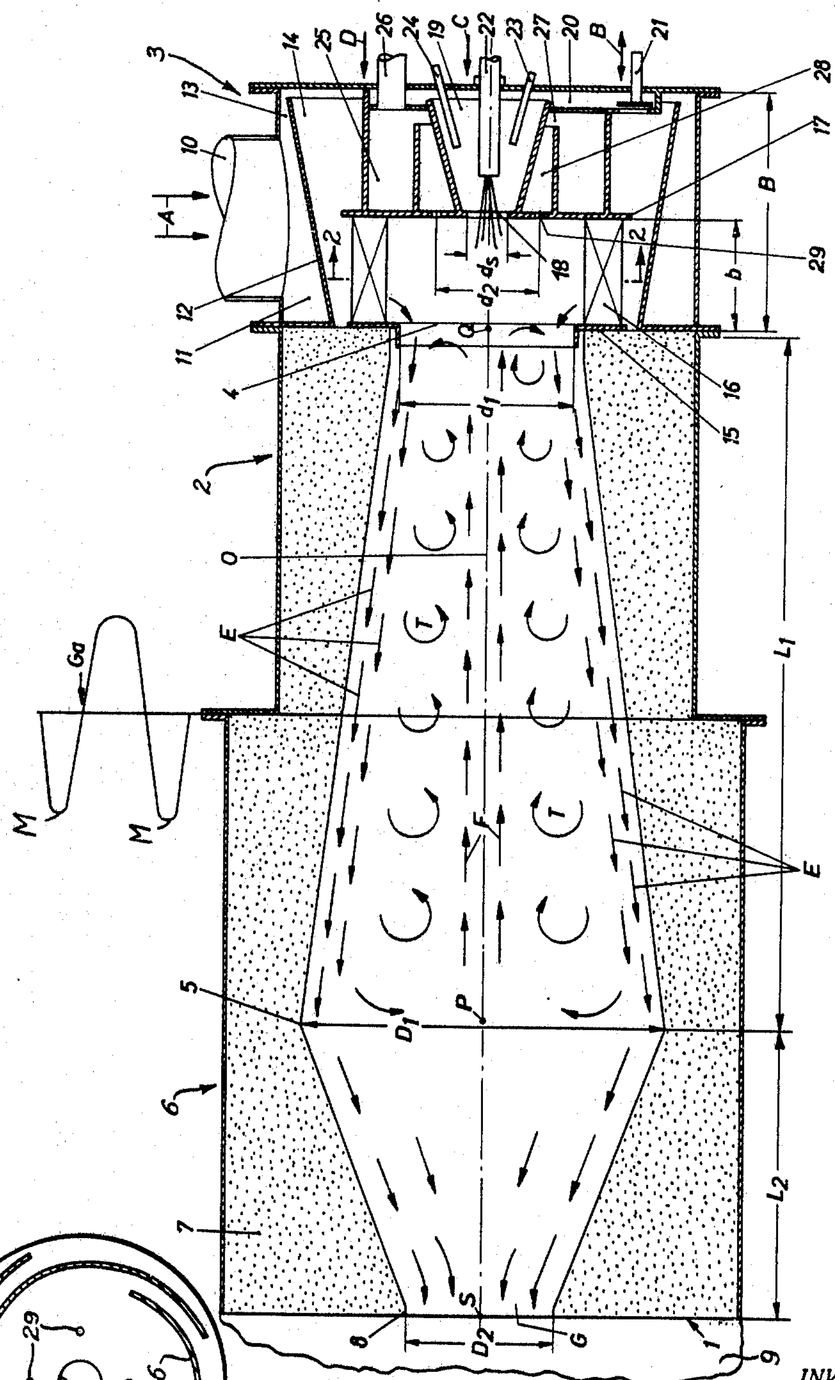

FIG. 1.

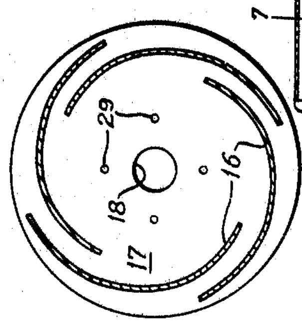

FIG. 2.

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BURNER FOR FIRING A COMBUSTION CHAMBER

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U.S. Cl. 431—158 15 Claims

ABSTRACT OF THE DISCLOSURE

A burner for firing a combustion chamber, having a flame tube which widens conically in the direction of the main flow of the throughput, in which the fuel can be fed in at the intake end where the combustion air is also fed in via an air twisting or swirling device with predominantly radially directed guide vanes and with an accelerating nozzle for the flame gases connected with the outlet end of the flame tube.

BACKGROUND OF THE INVENTION

The combustion and flow process in such a burner proceeds as follows: the combustion air enters at the intake end of the flame tube of the same with a twist. The fuel is introduced coaxially with the flame tube. The combustion air flows spirally along the flame tube wall to its far end. In the area of the axis of the flame tube a negative pressure prevails, which is greater at the intake end than at the outlet end. This is due to the fact that the tangential component of the spiral flow diminishes from the intake end to the outlet end, so that the centrifugal forces acting on the air become smaller. The pressure gradient has the effect that a part of the flow at the outlet end of the flame tube tumbles over and flows back to the intake end. Thus, two opposite flows result. Between these two flows a region of intensive turbulence is formed, in which the combustion air is mixed very intensively with the fuel. A substantial part of the combustion takes place with optimum effect in the interior of the flame tube. The portion of the flow that is not recycled arrives from the outlet end of the flame tube in the accelerating nozzle, is there accelerated, and enters the combustion chamber as a high-velocity flame gas jet.

The long slender flame that arises results in an even distribution of the heat flux density (an expression of the intensity of heat transfer which can be expressed in terms of B.t.u./sq. ft./hr.) over the surfaces that are to be heated. The heat flux-density is the product of the flame jet and the convection. The flame jet diminishes toward the tip of the flame. The high velocity flame jet acts as an injector, however, pulls the gas masses present in its vicinity along with it, and impresses a rapidly circulating motion upon the contents of the chamber to be fired, which is especially pronounced in the area of the tip of the flame. In the majority of all embodiments the heat emission by radiation and convection can be so combined that a uniform heat distribution is obtained. The additional heat emission through convection in the radiation chamber by the object to be heated, furthermore, leads to an increase in the transferable heat output, wherefore burners of the kind initially described almost always are in the position to increase the heat output of the heated objects while at the same time raising the thermal efficiency substantially. Such increase may range from 30 to 100%. The generation of high-velocity flame jets by burners of the kind described, is therefore, from the point of view of energy requirement, economical because in the nozzle connected after the flame tube the static pressure in the flame tube is converted into velocity, and thereby in accordance with the temperature increase through combustion a heat engine process is carried out.

In the practical realization of burners of the kind described, a difficult problem has arisen. According to the above description, an effort must be made to impart to the flame jet as high a velocity as possible. On the other hand, to obtain as economical combustion as possible, a very strong turbulence must prevail in the flame tube. For this reason, the return flow in the area of the tube axis must be very intensive. The first-mentioned requirement can be realized through a sharp pressure drop from the outlet end of the flame tube to the outlet end of the accelerating nozzle. The second requirement, on the other hand, demands a sharp pressure drop from the outlet end of the flame tube to its intake end. These initially contradictory requirements make it extremely difficult to obtain a stable flow pattern. The stability of the flow must, however, be especially high because otherwise the flame will begin to excite the natural acoustic frequency of the furnace-flame tube system and, if occasion arises, of the after-connected smoke gas passage. The pressure amplitudes rising in this way can, according to experience, reach a magnitude corresponding to a water column of several meters.

SUMMARY

The object of the invention is to develop a burner of the type initially described so that it develops a very high velocity flame jet of high stability in an economical manner. This is accomplished according to the invention in that for a layout of the accelerating nozzle for the generation of a flame gas jet, whose velocity at the outlet end of the accelerating nozzle corresponds to a velocity head or dynamic pressure that is at least 5 times the buoyancy force acting on the flame gas jet per unit of area of the flame surface in the combustion chamber, the turbulence producing device and the dimensions of the flame tube are so designed that the negative pressure building in the center of the intake end of the flame tube is at least 10 to 20 times greater, in numerical value, than the average dynamic pressure of the throughput flow, measured at the half-length of the flame tube at the point of the highest velocity of the velocity profile there.

Further novel features and other objects of this invention will become apparent from the following detailed description, discussion and the appended claims taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a longitudinal section through a burner embodiment constructed according to the invention, and

FIGURE 2 is a detail section view of the spiral vanes taken on line 2—2 of FIGURE 1.

It has been found, surprisingly, that by adhering to the characteristics of the flow, aforedescribed in the summary, a very good flame stability can be obtained. The initialy contradictory requirements, that the flame gas jets have a hitherto unattained velocity and that the turbulence in the flame tube must be very high, are also met. Through the invention the pressure drop from the outlet end of the flame tube in both directions is successfully made sufficiently large, and in spite of this, a stable balance is maintained. A special advantage of the burner, according to the invention, consists in that the flow pattern in the burner is not dependent on the Reynolds number. This means that after once establishing the proportions between the characterizing dimensions of the burner, these are independent of the absolute size, the air velocity and the characteristics of the medium of the main flow, thus for example of the temperature or the composition of the combustion air. The burner can be enlarged or reduced as desired or it can be operated at increased velocity as desired. The flow pattern, the mixing process taking place therein, and thereby the flame configurations and the combustion process remain unaffected thereby; the length of the flame depends within narrow limits, not on the throughput of fuel, but only on the ratio of fuel to air.

The above mentioned conditions according to the invention result when for the combustion of 6,000,000 kcal./h. at a preliminary pressure of 600 mm. water column, approximately, the following dimensions prevail:

Intake diameter of flame tube	d_1=455 mm.
Outlet diameter of flame tube and intake diameter of accelerating nozzle	D_1=870 mm.
Outlet diameter of accelerating nozzle	D_2=350 mm.
Length of flame tube	L_1=1,660 mm.
Length of accelerating nozzle	L_2=750 mm.
Axial length of intake guide vanes	b=254 mm.
Angle of spiral of air intake with direction of periphery	7–15° (preferably (12–14).

If a different combustion output is desired, the above noted linear dimensions will be changed. Such changes should be in the same proportions as the ratio between the square root of the throughput or air flow for 6,000,000 kcal./h. and the square root of the throughput for the desired different combustion output. Where changes of the axial intake guide vane length, minimum flame tube diameter and angle of the spiral are desired, the value of such changes are determined in substantially linear proportion relative to each other.

The intake guide vanes are preferably shaped like logarithmic spirals, which form air channels between them. The covering length or overlap between adjacent spiral vanes is at least three times the average unobstructed distance between the vanes. Maintaining the above dimensions will result in the mounting of four intake guide vanes.

As mentioned, a high degree of turbulence must be generated in the flame tube to obtain an economic combustion. This again requires a long and powerful return flow at the flame-tube axis. This return flow strikes the intake end face of the flame tube and then tumbles radially apart. It entrains fuel particles of the liquid or solid fuel used. For example, when operating with heavy fuel oil, half burnt drops of oil containing coke will be transported in the return flow. The danger now exists, that these fuel particles will be deposited at the intake end face and in a short time will form large coke residues there. This is especially objectionable because the fuel must be injected from the center of the intake end face. The danger therefore exists that the injection system in a short time will become fouled. In order to meet this danger in the case of a burner with an injection port for the introduction of liquid or powdered fuels in the area of the axis of the flame tube at whose intake end there is provided, according to a suitable further development of the invention, a partial air flow suitably adjustable in amount, branching off from the main air flow and being introduced through the injection port into the flame tube. By correct metering of the particular flow, this fills the injection port completely and, after flowing through the latter, is forced radially apart by the return flow and distributes itself as a mushroom-shaped cold air veil radially over the intake end face of the flame tube. It protects the latter in that way from contact with the return flow and prevents the formation of deposits. The injection system remains clean and operates without disturbance. The adjustment of this partial air flow is simple. If the partial flow is too small, the return flow will penetrate from the flame tube through the injection port and foul the accessory organs of the burner. This is recognized from the flame tip penetrating through the injection port. If the partial air flow is too great, however, it will push the central return flow, which is flowing through the flame tube, to its smallest diameter back so that it no longer gets near to the intake end face of the flame tube. Since the length of the flame, forming in the area of the intake cross section of the flame tube, is identical with the axial extent of the return flow there, this means that, for example, the jet of the atomized fuel oil which enters the flame tube from the injection port must pass a certain distance through cold, rotating air until it reaches the flame. Drops of oil are thereby thrown out, which deposit themselves on the intake guide vanes and flow along the walls of the flame tube to the zones in which the temperature rises. There these oil residues are carbonized and form coke deposits. One, therefore, has infallible signs if the partial flow is inadequate and can regulate accordingly. As the flow pattern in the flame tube is independent of the Reynolds number, it is sufficient to adjust the partial flow once, whereupon this adjustment fits for all throughputs.

Ahead of the injection port there is suitably arranged a central collecting chamber for the partial flow in which the accessory elements of the burner, such as injection nozzle, ignition device and flame control are arranged, suitably at a distance from the injection port corresponding to one and a half times the diameter of the injection port. The partial flow becomes calm in the collecting chamber and enters the injection port uniformly. The collecting chamber has the additional function of serving as a mounting place for the accessory devices. Of these, the injection nozzle is at such a distance from the injection port that the partial flow can distribute itself uniformly over the cross section of the injection hole. The injection nozzle remains free from influences of the flame while the oil jet itself is accessible to the ignition burner and for inspection.

When the above-mentioned combustion output is maintained, a diameter of 115 mm. has been found suitable for the injection port, which, as in the case of changing the combustion output, is to be changed in proportion to the ratio of the square roots of the throughputs corresponding to the combustion outputs.

The burner according to the invention can also be operated with gas. For this reason, it is provided according to a suitable further development of the invention that around the collecting chamber for the partial air flow there is arranged an annular fuel gas collecting chamber which is connected with the intake end of the flame tube through openings concentric with the injection opening.

The diameter of the circular center line on which the openings of the gas intake are arranged shall be on an average 230 mm. If the cross section is enlarged, the gas outlets will be in the area of too high fresh air velocities, which leads to poor partial load conditions. If the cross section is reduced, the fuel gas collecting chamber can become fouled when the burner is operated with heavy fuel oil and the partial air flow is incorrectly adjusted.

To stabilize the flow of combustion air, it is suitably provided that there is at least one main collecting chamber upstream of the intake guide vanes and one restrictor for the main combustion air flow.

SPECIFIC DESCRIPTION OF DRAWING

The burner **1**, represented in the drawing, shows three main parts, a flame tube **2**, a burner head **3** which adjoins the intake end **4** of flame tube **2**, and an accelerating nozzle **6** adjoining the outlet end **5** of the flame tube. Flame tube **2** and accelerating nozzle **6** are shown contained in masonry **7**. Flame tube **2** expands conically from a diameter d_1 at the intake end **4** to a diameter D_1 at the outlet end **5**. Accelerating nozzle **6** narrows from diameter D_1 to a diameter D_2 at its outlet end **8**. To the outlet end **8** of accelerating nozzle **6** is connected a heating chamber **9** of any desired design, which is to be fired by the burner **1**. The length of flame tube **2** is designated by L_1 while the length of accelerating nozzle **6** is indicated by L_2.

The feed line **10** for combustion air discharges into the burner head **3**, which combustion air flows in the direction of the arrows A. The combustion air flow enters into a main collecting chamber **11**, in which its momentum is broken by an annular wall **12**. An annular restriction **13** calms the main air flow which subsequently arrives in the intermediate collecting chamber **14**. This is connected through an air twisting (swirling) device **15** with the intake end **4** of flame tube **2**. The twisting device **15** consists in the embodiment of the drawing of predominantly radial intake guide vanes **16** whose axial length is designated by *b*. The axial length of the entire burner head is designated by B.

Burner head **3** contains a face wall **17**, which in the area of the central burner axis O, has an injection port **18** with diameter d_s. Behind injection port **18** is partial air collecting chamber **19**, which through channel **20**, is connected with collecting chamber **14**. The cross section of the throughput between intermediate collecting chamber **14** and channel **20** is adjustable by moving a valve **21** in the direction of the double arrow B. Thereby a partial air flow can be introduced into the partial air collecting chamber **19** via channel **20** from intermediate collecting chamber **14**. In the partial air collecting chamber **19** there is a nozzle arrangement **22** for the injection of liquid or powdered fuels in the direction of arrow C, and also an igniting burner **23** and a flame control **24**. These auxiliary burner elements lie with their front ends at a distance behind the injection hole **18**.

The central partial air collecting chamber **19** is surrounded by an annular fuel gas collecting chamber **25**, into which fuel can be introduced through a pipe **26** in the direction of arrow D. Chamber **25** is connected, through an annular restriction **27**, with an intermediate gas collecting chamber **28**, in whose area openings **29** are arranged in face wall **17** having a diameter d_2.

There are a total of four intake guide vanes **16** provided which proceed according to a logarithmic spiral and have air passages between them.

The burner here described has the following dimensions:

	Mm.
D_2	350
D_1	870
L_2	750
L_1	1,660
d_1	455
d_2	230
d_s	115
b	354
B	563

The spiral angle of the air entry, with the direction of the periphery as determined by the intake guide vanes, amounts to 6.52°. The following flow develops in the burner:

The combustion air enters through the twisting device **16** at the intake end **4** into flame tube **2**. It flows along the inner wall of the tube in the direction of arrows E to the outlet end **5** of the flame tube. The flow E has a slight twist whose tangential component, due to the conical widening of the flame tube, decreases from the intake to outlet end. In the area of the burner axis O, there consequently occurs a pressure drop from point P to point Q. This pressure drop has the effect that a part of the flow E in the area of the outlet end **5** of the flame tube tumbles over toward the inside and flows back centrally in the flame tube in the direction of arrows F. Between flows E and F there consequently develops a region of high turbulence T in which an intensive mixing of the fuel introduced in the area of the burner head **3** with the combustion air takes place. The part of the burning fuel air mixture not recycled is brought up to higher speed in accelerating nozzle **6** and enters the heating chamber **9** in the direction of arrows G from the outlet end **8** of accelerating nozzle **6** in the form of a long slender flame gas jet of high velocity. Flow G in accelerating nozzle **6** likewise has a twist which increases in the direction of the nozzle. From this a pressure drop also results at the axis O of the burner from point P to point S.

At the half length of the flame tube a velocity diagram is produced as it is indicated at G above the flame tube in the area of the half tube length in the drawing. At the walls of the flame tubes there is a relatively high flow velocity in the direction of the main flow, while at the axis a return flow has developed. If the dimension of the burner are chosen as indicated above, there will, as a result of the twist, develop a negative pressure in the region of point O or between this and face wall **17** in the area of the axis O, which negative pressure is 10 to 20 times greater in value than the average dynamic pressure of the throughput flow at the half length of the flame tube, measured at the site of the highest velocity of the velocity profile G*d*, at that point. When these flow conditions prevail, a stable flow pattern is produced with high velocity of the flame gas jet. With the indicated combustion of 6,000,000 kcal./h. the flame gases leave the outlet end of the accelerating nozzle **6** at a speed of about 150 m./sec., whereby they have an average temperature of 1,650° C. The thrust or momentum of the burner then amounts to 40 kg. This is a thrust which exceeds the effectiveness of hitherto used burners about ten times. The effect of the burner on the fired object is corresponding.

The invention is not limited to the embodiment shown in the drawing. If another combustion output is to be obtained, a different throughput is required. The linear dimensions of the burner must be changed accordingly and in the proportions of the roots of the throughputs. It is furthermore possible to change the length *b* of the intake guide vanes, the smallest flame tube diameter d_1 and the spiral angle of the air feed. Each such change in one of the said intake magnitudes must, however, be compensated through a change of substantially linear proportion in another of the said intake magnitudes. For example, the spiral angle can be made greater than 6.52° if in compensation the axial extent of the intake guide vanes is reduced. It is important that the desired negative static pressures appears in the intake guide system. The same can be achieved in that, instead of a reduction of the axial dimension of the intake guide vanes, the narrowest cross section of the flame tube is reduced, while thereby, according to the twisting principle, the peripheral velocity and the absolute magnitude of the negative pressure also rise.

The indicated dimensions are optimal. But an especial advantage of the design, according to the invention, consists therein that it is not very sensitive to dimensional variations. These do not result in any serious functional disturbances, but just in results that are not quite the best.

If fuel gas is to be burnt exclusively, then the gas feed **26** and the fuel gas collecting chambers **25**, **28** can be omitted and the gas can instead be introduced directly into the central collecting chamber **19**. Conversely, in the case of exclusive oil operations, the feed line and collecting chambers for gas can be omitted. Furthermore, in case very high air preheating is to be used, the intake guide vanes **16** can be replaced by a logarithmic spiral for the combustion air, which has the same spiral angle. This is also to be recommended if the combustion air is highly polluted. In the case of high demands, a twisting device, which is formed as a logarithmic spiral, is, however, not adequate.

The combustion process is almost not at all dependent, and the impulse of the flame is only insignificantly dependent on whether the walls of the flame tube and, if occasion arises, also the nozzle for acceleration of the hot flame gases, are made of heat-insulating material or whether they are cooled by a medium that is to be heated, or a liquid that is to be evaporated. The first case might occur with the common masonry lining of industrial heating installations, while the second case can replace a part of the heating surface in boilers. Both cases can, therefore, be realized within the framework of the invention.

In transition to smaller size constructions, in addition to the indicated changes of dimensions, which are dependent on the air throughput, a further constriction of the intake width can be useful in order to increase further the negative static pressure in the intake cross section and thus to reduce the cold air screen.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. A burner for firing into a heating zone comprising: a diverging frusto-conical flame tube having a diverging length greater than its maximum diameter; separate inlet passage means at and coaxially disposed with the intake end of said flame tube for feeding fuel and a partial supply of combustion air into said intake end from separate sources; a major combustion air supply inlet device coaxially disposed about and in fluid communication with said flame tube intake end including flow guide vanes having a spiral configuration; and a convergent nozzle device connected and aligned with the large outlet end of said flame tube and having an outlet cross-section area less than the flame tube inlet cross-section area for accelerating the exiting burning gases from said flame tube and generating a flame gas jet with a velocity at the outlet end of the accelerating nozzle having a pressure corresponding to a dynamic pressure which is at least 5 to 10 times the buoyancy force acting on the flame jet in the combustion chamber, per unit of area; said spiral vane inlet device and said flame tube being relatively dimensioned to constitute means for utilizing a high pressure source of combustion air and therewith generating a negative pressure in the center of the intake end of said flame tube which is at least 10 to 20 times greater than the average dynamic pressure of the flame tube throughput flow at the site of the highest velocity of the flame tube velocity profile taken at the half length location in said flame tube.

2. A burner as defined in claim **1**, for enabling a combustion output of 6,000,000 kcal./h. with a combustion air source under a pressure of 600 mm. water column, having the following dimensions:

Intake diameter of said flame tube	$Dd_1=455$ mm
Outlet diameter of flame tube and intake diameter of accelerating nozzle	$D_1=870$ mm.
Outlet diameter of accelerating nozzle	$D_2=350$ mm.
Length of flame tube	$L_1=1{,}660$ mm
Length of accelerating nozzle	$L_2=750$ mm.
Axial length of intake guide vanes	$b=254$ mm.
Angle of spiral of the air intake with direction of periphery	From 7°–15°

3. A burner as defined in claim **2**, wherein the angle of spiral of the air intake with the direction of the periphery is preferably in the range of from 12°–14°.

4. A burner as defined in claim **2**, wherein said inlet passage means for fuel and for partial air includes a fuel introducing injection port, the diameter of which is 115 mm.

5. A burner as defined in claim **4**, wherein said means enabling said partial air flow derives its air from the same source as does said main air flow, said last named means including a device for adjusting the volume of partial air flow.

6. A burner as defined in claim **5**, wherein an annular fuel gas collecting chamber is disposed around said inlet passage means for partial air and is connected with the intake end of the flame tube through openings arranged concentric with said injection port; and wherein the diametral dimension of the circular center line on which the fuel gas chamber openings are arranged, is approximately 230 mm.

7. A burner as defined in claim **1**, wherein said adjacent ones of said inlet guide vanes form air channels between them whose length is at least three times the average unobstructed shortest distance between adjacent vanes.

8. A burner as defined in claim **7**, wherein four of said inlet guide vanes are provided.

9. A burner as defined in claim **1**, wherein said inlet passage means for fuel and for air includes an injection means with a port for the introduction of fuel in the area of the axis of said flame tube adjacent its intake end, and said inlet passage means enabling said partial air flow derives its air from the same source as does said main air flow, said last named means including a device for adjusting the volume of partial air flow.

10. A burner as defined in claim **9**, wherein a preliminary air central collecting chamber for the partial air flow is provided upstream of said injection port and accessory elements for said burner, including an injection nozzle, an ignition device and a flame control, are disposed in said chamber at a distance from said injection port substantially corresponding to one and one half times the diameter of said injection port.

11. A burner as defined in claim **10**, wherein an annular fuel gas collecting chamber is disposed around said partial air collecting chamber and is connected with the intake end of the flame tube through openings arranged concentric with said injection port.

12. A burner as defined in claim **1**, wherein at least one main collecting chamber and one restrictor for the main combustion air flow are disposed upstream of said inlet guide vanes.

13. A burner as defined in claim **1**, wherein said flame tube and said accelerating nozzle are constructed primarily from masonary.

14. A burner based on the dimensional values as defined in claim **2**, for a different combustion output wherein said linear dimensions are changed in proportion to the square root of the ratio of the numerical value of the desired different combustion output over 6,000,000.

15. A burner designed in accord with the conditions as defined in claim **14** and wherein further changes in the values of intake components as obtained in accord with the provisions of claim **14** are made, subject to the condition that said further changes in the inlet guide vane axial length, minimum flame tube inlet end diameter and angle of inlet vane spiral are mutually compensated in substantially linear proportions to retain substantially the desired inlet flow pattern and conditions.

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EDWARD G. FAVORS, Primary Examiner

U.S. Cl. X.R.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,485,566 December 23, 1969

Fritz Schoppe

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 56, "initialy" should read -- initially --. Column 8, line 69, "3,277,202" should read -- 3,227,202 --.

Signed and sealed this 17th day of November 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents