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ROTATING ATOMIZING CUP BURNER

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FIG. 1

FIG. 2

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ROTATING ATOMIZING CUP BURNER

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1. This invention relates to the combustion of liquid fuel which is atomized by being discharged from the tip of a rotating atomizing cup into a surrounding stream of advancing air, and is concerned particularly with an improved atomizing cup burner construction for burning the fuel. More specifically, the improved burner is of the type in which the air advances in a stream or series of streams surrounding the rotating atomizing cup in a direction of which at least a considerable component is directed parallel to the axis of the atomizing cup; the liquid fuel which leaves the edge of the atomizing cup is caught and atomized by this air stream. A burner, of this general type is described in U. S. Patent No. 2,214,568.

In the known burners of the type described above, i. e., in which the air has a substantial velocity component parallel to the cup axis, the inner surface of the cup is weakly conical over the entire length or at least near the forward edge, i. e., the cone has a small apex angle, as a result of which the fuel leaving the cup near the forward edge has, in addition to the velocity in a plane perpendicular to the cup axis caused by centrifugal action, a substantial forward velocity, parallel to the cup axis, which was acquired within the cup; this has the advantage that the fuel mist leaving the cup displays to a greater or lesser extent the conical shape generally desired.

A drawback of such known burners is, however, that it is not possible to reduce the capacity below a certain level without encountering unsatisfactory atomization and, consequently, uneconomical combustion. It is frequently desirable to construct burners which will operate efficiently at low capacity.

There is also a second type of atomizing cup burner wherein the fuel-air mixture is discharged essentially in a plane perpendicular to the cup axis, the rotating cup being strongly flared and, sometimes, calyx-shaped. With burners of this type the air stream is deflected so as to move also essentially transversely to the cup axis; atomization is usually far less sufficient for efficient combustion and the droplets are hurled against hot refractory walls for vaporization.

According to the present invention it was found that fine atomization and efficient combustion of liquid fuel even at small flow rates can be effected by flowing the liquid fuel in the form of a film along the inner surface of a rapidly rotating cup, said surface being calyx-shaped, whereby the liquid film becomes progressively thinner as it moves toward the edge of the calyx, and discharging the liquid substantially in a plane transverse to the cup axis into a surrounding current of air moving at high velocity essentially parallel to the cup axis. In the preferred embodiment of the invention this current of air has a rotational component in a direction opposite to the direction of rotation of the cup and advances out of contact with the cup until it reaches the edge of the cup. The resulting reaction causes the liquid to be caught by the air and broken up into a fine mist, which is ignited by any suitable means, known per se, such as electrodes, and forms a flame which advances forwardly while flaring radially outwardly.

As used in the present specification and claims, the expression "discharging the liquid substantially in a plane transverse to the cup axis" means to discharge it in a direction such that the ratio of the component parallel to the cup axis to the resultant velocity is less than about one to four. The liquid discharged from the edge of the cup partakes of three distinct velocity components: First, a forward component caused by the forward movement of the film along the cup surface, this component becoming smaller as the surface is more strongly flared outwardly, and falling to zero when the edge is turned outwardly at an angle of 90° to the cup axis; second, a radially outward component, which becomes greater as the surface is more strongly flared outwardly and reaches a maximum when the edge is turned outwardly at an angle of 90° to the cup axis; and, third, a tangential component, essentially in the plane of the radial component, but directed tangentially to the edge of the cup. The resultant velocity is the resultant of these three components. While I may flare the calyx to make an angle of between 60° and 90° with the cup axis, it is also possible to practice the invention by using cups which are somewhat less flared, e. g., in which the edge is flared out to only 30°. Although the ratio of the forward component to the radial component with a 30° cup is about 0.58, the third (tangential) component increases the resultant velocity so that the ratio of the forward component to the resultant velocity can still be made to be less than 0.25.

As used in the present specification and claims, the expression "surrounding current of air moving essentially parallel to the cup axis" means that the air is moving predominantly in a direction perpendicular to a radius to the cup
axis, having only a minor component, if any, toward or away from the cup axis. Thus, if the surrounding air current flows in an annular channel which is directed inwardly or outwardly from the cup axis at an angle less than 30°, the vehicular component substantially parallel to the cup axis is less than half and this component is minor. This definition does not exclude rotational motion of the air in the annular channel; for example, in an annular channel of uniform cross-section, when the air is rotated in a sense toward the cup axis, the direction of movement at any point on the helix is perpendicular to a radius to the cup axis, so that there is neither an inward nor an outward component.

It was found that by discharging the liquid substantially in a plane transverse to the cup axis into a surrounding current of air moving essentially parallel to the cup axis good atomization is attained, and that the atomization can be still further improved by imparting to the air a rotational component in a direction opposite to that of the cup and by using a calyx-shaped surface for the cup to reduce the liquid to a thin film even better results can be attained.

A burner suitable for carrying out the foregoing method comprises a calyx-shaped cup mounted on a rotating shaft driven by any suitable means. By "calyx-shaped" is meant a cup the inner surface of which widens toward the edge at a progressively increasing slope from the cup axis. It may also be described as a cup having an inner surface of revolution the generatrix of which is curved outwardly from the cup axis. It is desirable that a line in the plane of the cup axis tangent to the surface at the edge form an angle not less than about 30° with the cup axis. This calyx-shaped widening permits fuel, even though flowing at low rates, to be evenly thinned by causing the component of the centrifugal force which is directed parallel to the wall of the cup to increase gradually towards the edge of the cup; in other words, the fuel film moving on the inner surface of the cup toward the edge is accelerated gradually but within a short time, being drawn out and thinned so as to be able to leave the cup as a uniformly thin film.

In order to have the oil atomized into fine droplets, it is necessary that it leave the rotating cup as a very thin film. In tests leading up to the present invention it was found that in the known rotating cup atomizers and burners wherein the air moves essentially parallel to the cup burner the film of oil leaving the cup is much too thick and stable; the oil, upon reaching the cup edge, appeared to break and form streaks of oil along the edge and these streaks contracted to form torus-shaped columns of liquid. These columns, which extend from the cup edge at regular intervals, are unstable and break up into droplets at a short distance from the cup. Since the size of these droplets should, for good atomization, be as small as possible from the start, it is absolutely essential to keep the torus-shaped columns small. It has now been found that the diameter of the columns is dependent upon the thickness of the film of oil on the inside of the cup, and that a calyx-shaped cup as described in this specification is necessary to attain such a thin film.

The outer surface of the cup wall is then shaped to extend inwardly from the edge toward the cup axis, so that the fuel will not have a tendency to creep over the cup edge along the outer surface. By applying the foregoing measures it has been found that a small amount of efficient atomization and combustion of much smaller quantities of fuel per unit time than can be done with known similar burners.

To give the resulting flame a conical shape, such as is desired in many instances, the air must be introduced at a greater velocity than when the fuel mist leaving the cup already assumes the conical shape of itself; moreover, a high air velocity is favorable to obtaining a fine atomization. The air velocity in the axial direction is determined by the width of the surrounding air nozzle and the rate at which air is flowed through the nozzle. The air velocity may, however, also be increased by imparting to the air, apart from its velocity in the direction of the cup axis, an additional velocity component perpendicular to said axis, as by causing the air to rotate. According to the preferred embodiment of this invention this increased air velocity is attained by providing a whirl chamber in the air passage immediately ahead of the air nozzle, this chamber being constructed as a body of revolution with the wall tangentially directed air inlet ports, although whirlier inserts or other types of baffles for causing whirling may be used. In order to obtain the most effective atomization the direction of rotation of the air in the whirl chamber should be opposite to the direction of rotation of the atomizing cup.

By making the size and/or the direction of the tangentially directed air inlet ports to the whirl chamber adjustable it is possible to modify the velocity of rotation of the air and, consequently, the resulting velocity of the air flowing from the air nozzle, both as to direction and magnitude, and to adapt this velocity to the circumstances. If the air flowing toward the cup edge were in contact with the rapidly rotating atomizing cup it could be safely given a whirling motion; but this would result in a loss of effective velocity because it would be in the same direction as the rotating cup. In order to prevent this the cup is, preferably, surrounded by a stationary jacket which bounds the air channel on the inner side, keeping the air current separated from the flame. The jacket could, if desired, be rotatably mounted and rotated in a direction opposite to the direction of rotation of the cup, but this construction is usually not necessary. The calyx shape of the cup facilitates the mounting of this jacket around the cup.

For the proper functioning of the burner according to the present invention it is essential that the circumferential distribution of the liquid fuel be effected evenly before the oil reaches the region of high conicity. One method of insuring such even distribution is to provide an extension rearwardly of the calyx-shaped part, said extension having a comparatively small diameter and, preferably, a small conical angle, and to feed the fuel into the interior of this extension. This extension may be a part of the cup itself or a hollow shaft with a tapered base or, as in the embodiment the thin film in the cup and both. The fuel is thereby given an opportunity to spread evenly over the circumference of the extension and, from there, over the inner surface of the calyx. The point of introduction of the liquid fuel to the extension is located preferably a dis-
tance back along the cup axis from the forward edge mounting up to three times the diameter of the edge of the cup.

An example of a burner according to this invention is shown in the accompanying drawing, Fig. 1, which is a vertical, longitudinal cross-sectional view of one preferred embodiment of the burner; and Fig. 2 is a transverse section taken on line 2-2 of Fig. 1.

The burner comprises a supporting housing 3 having bearings 4 and 5 for rotatably mounting a hollow shaft 6. The hollow shaft is generally cylin-
drical throughout most of its length, but its bore may be tapered slightly beginning at a point between the bearings 4 and 5. A pulley 1, mounted on shaft 6, may be driven by a belt, not shown, from any source of power for imparting a high rotational velocity to the shaft.

The atomizer cup 8 is rigidly mounted at the forward end of the shaft 6, as by screw threads. The inner surface of the cup is partly conical and partly calyx-shaped; the rear part of the cup is conical, having a conical high speed weakly conical taper of the shaft 6; the forward part joins smoothly with the conical part and increases progressively toward the sharp edge 9, forming a calyx. In the embodiment shown, only the forward quarter length of the cup is calyx-shaped, and the tangent to the inner surface of the plane of the axis makes an angle of about 73½° with the axis. It is preferred to construct the cup to cause this angle to be between about 30° and 90°. Liquid fuel, such as oil, is introduced into the air nozzle 11 through a supply pipe 10, mounted concentrically therein and connected to a source of fuel oil by flow control means, not shown. Oil flows from the supply pipe through an orifice 11 directed laterally against the inner surface of the shaft 6.

The outer surface of the cup 8 is generally cylindrical but is curved outwardly at the forward end to end in the knife edge 9, whereby the external diameter of the cup in back of the edge 9 is less than the edge diameter. The cup is surrounded by a stationary part 12, formed as a part of the housing 3, and extending almost to the cup edge 9. The outer diameter of this jacket is substantially the same as that of the cup edge, or slightly larger, as shown. While the jacket 12 may in certain cases be omitted, it is desirable to provide it to avoid imparting to the advancing air a rotational velocity component in the same direction as the cup.

The air nozzle and whirl chamber housing may be formed integrally. The latter comprises a hollow cylindrical housing 13 adapted to be attached to the supporting housing 3 by being screwed against flange plate 14. The annular space 15 between the housings 3 and 13 is the whirl chamber. A plurality of tangential air inlet ports 16, 16' are formed in the housing 13, through which air may be supplied under pressure from any suitable source, such as a blower, not shown. The air enters 17 at the outer edge of the liquid housing 13 and is slightly convergent, but may also be truly cylindrical or even slightly divergent.

In the operation of the burner, oil is supplied to the supply pipe 10 at the desired rate of burning and the hollow shaft 6, together with the liquid oil impinges against the inner wall of shaft 6 and is evenly distributed thereon; it advances toward the atomizing cup as a result of the centrifugal force, brought into play by the conical shape of the inner wall. Due to the great distance between the orifice 11 and the cup edge 9 the advancing layer of the oil has ample opportunity to become evenly distributed circumferentially over the interior surface of the hollow shaft and atomizing cup, so that an extremely fine oil film reaches the calyx-shaped portion of the cup. In this widening portion the film is gradually curved outwardly, approaching a direction transverse to the cup axis, and accelerated by centrifugal force. After the even circumferential distribution in the conical part, the film is more rapidly thrown to the calyx-shaped part in a relatively short time and issues from the sharp knife edge as a fine mist. This mist is caught and atomized by the advancing current of air flowing out of the nozzle 11 at a high velocity, which is moving forward, especially parallel to the cup axis, and directs the forming flame forward, the atomized mixture being ignited just beyond the nozzle 11 by means known per se.

The advancing air in nozzle 11 is given a rotary motion by being introduced into the whirl chamber 15 via tangential ports 16, 16'. The angular velocity of the rotating air is greater in nozzle 17 than in the whirl chamber 15 because the diameter of the flow passage is less than that of the whirl chamber. Also, the angular velocity tends to increase while advancing through the nozzle 17 by virtue of the constriction of the nozzle near its forward end, and the jacket 12, which prevents dissipation of angular momentum by brushing against the outside of the rotating cup. The tendency toward angular acceleration is, however, somewhat opposed by friction. The velocity at which the air leaves the nozzle is the resultant of the forward and rotational velocities and is, consequently, greater than the forward velocity; this resultant velocity, which determines the fineness of atomization, may, while retaining a given forward velocity, be modified by altering the rotational velocity. This may be effected by altering the inlet ports 16, 16' as to direction or size, for instance by providing adjustable constrictions (not shown) or by providing a plurality of interchangeable housings 13 with inlet ports 16, 16' of different sizes.

It is seen that the direction of rotation of the air in the nozzle 11 is opposite to that of the atomizing cup, whereby the sectoral difference in velocity between the fuel droplets and the air is greatest and the reaction of the air with the fuel is most effective. The rotation of the air in such a direction is made possible by providing the jacket 12 which, owing to the recessed shape of the outer surface of the cup, can be easily located without interfering with the flow of air so as to catch the fuel droplets hurled from the cup edge immediately upon leaving the nozzle 11.

It was found that with a burner according to the present invention, when proper dimensions and a suitable speed of rotation for the atomizing cup, etc., are selected, small quantities of fuel may be effectively atomized and burned with a high efficiency of combustion. Such a burner constructed according to the design described above, in which the edge 9 of the cup had a diameter of 20 mm., and the cup was rotated at a speed of 11,000 revolutions per minute, the consumption of fuel was 3 kg. per hour; the width of the annular air passage in the nozzle 11 was 3.5 mm., and the air issuing had a forward velocity of about 35 meters per second and a total velocity of about 50 meters per second, and was supplied at a rate slightly
in excess of that necessary for theoretically complete combustion. The flame burned steadily and efficient combustion with no smoke or deposition of soot resulted. As the rotational speed of the cup is increased, fine atomization results, but higher air speeds are desirable at higher rotational speeds.

I claim as my invention:

1. A burner for liquid fuel comprising a supporting housing, a shaft rotatably mounted in said housing carrying an atomizing cup at the forward end thereof, at least the forward portion of the inner surface of the cup being calyx-shaped, widening toward the front, means for rotating said shaft in a given direction, means for supplying liquid fuel into the atomizing cup, a tubular air nozzle surrounding the atomizing cup, a jacket between the atomizing cup and the air nozzle providing an annular air channel between the air nozzle and the said jacket, said cup being rotatable in the said given direction relatively to the jacket, said air nozzle and jacket having their axes directed forwardly for the forward passage of an annular current of air in a direction essentially parallel to the cup axis, and means for supplying air to the rear of said air channel to form said air current and for imparting thereto near said rear end a rotary motion in a direction opposite to the said given direction.

2. A burner for liquid fuel comprising a supporting housing, a shaft rotatably mounted in said housing carrying an atomizing cup at the forward end thereof, at least the forward portion of the inner surface of the cup being calyx-shaped, widening toward the front, means for supplying the liquid fuel into the atomizing cup, a tubular air nozzle surrounding the atomizing cup and spaced from the cup but closely adjacent thereto to provide a relatively narrow annular channel having its forward outlet in the proximity of the forward edge of the cup and having its axis directed forwardly and said outlet having a diameter substantially equal to that of said cup edge for the forward passage of air essentially parallel to the cup axis, an annular whirl chamber in communication with the rear end of said tubular nozzle and disposed coaxially with respect to said nozzle, said chamber having a circumferential wall of substantially greater diameter than the diameter of said forward outlet, and means for feeding air into said whirl chamber tangentially near said circumferential wall, whereby the angular velocity of air fed tangentially into said whirl chamber is increased in passage from said circumferential wall to said outlet.

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