Abstract:

Title: COMBINED FUEL AND OXIDIZER METERING JETS, SYSTEMS, AND METHODS FOR SIMULTANEOUSLY METERING FUEL AND OXIDIZER

Combined fuel and oxidizer metering jet arrangements, systems and methods for selectively simultaneously metering the flow rate of a liquid and/or LG fuel and an oxidizer for delivery to a single or multi-fuel burner. Through the intelligent selection of specific articles and arrangements, a single type of fuel delivery conduit and mixing tube can be optimized for a variety of fuels without dynamic user modulation of oxidizer flow rates. Invention embodiments include coupled and decoupled jet-mixing tube arrangements as well as fuel jets having intrinsic oxidizer metering abilities and/or fuel jets cooperating with extrinsic structures to establish a desired oxidizer metering arrangement. Features of various embodiments include enhancements to modify the fuel-oxidizer inflow character such as velocity and/or vector as well as modify the fuel-oxidizer ratio through use of spacers for repositioning (as opposed to replacement) of the metering jet relative to a mixing tube.
COMBINED FUEL AND OXIDIZER METERING JETS, SYSTEMS, AND METHODS FOR SIMULTANEOUSLY METERING FUEL AND OXIDIZER

BACKGROUND OF THE INVENTION

Historically, stoves that burn both liquid and liquefied gas ("LG") fuels 5 (hereinafter "multi-fuel stoves") have compromised combustion efficiency and/or performance in favor of fuel flexibility and simplicity. This compromise results from the disparate energy contents and oxidization requirements between fuels: liquid fuels such as white gas, kerosene, or diesel each require differing fuel flow rates but all require a greater volume of oxidizer for a given fuel flow rate than LG fuels such 10 as liquefied butane or propane. Thus, while many multi-fuel stoves provided a user with multiple jets to properly meter or regulate fuel flow rates wherein the user would select a desired jet for a particular type of fuel, similar metering or regulation of air flow rates was often not incorporated in a "one-size-fits-all" approach to fuel-air mixing, primarily due to cost, complexity, safety and/or regulatory constraints.

For instance, the Canadian Standards Association (CSA) regulatory body explicitly disallows stoves burning LP fuels to incorporate user-adjustable air intake louvers or other such devices (ref. CSA 11.2a 2001 § 1.5.4). This regulatory limitation has caused stove manufacturers (1) to build and sell stoves that burn only liquid or only LG fuels, but not both, (2) to build and sell multi-fuel stoves with user-adjustable 20 primary air intakes (e.g. Brunton’s Vapor AF stove) but not sell those products into markets regulated by CSA, or (3) to build and sell stoves that burn both types of fuel, but that sacrifice performance by not providing means for primary air adjustment.

While issues pertaining to cost or complexity can be ignored or mitigated, thus allowing for apparatus that provide means for metering fuel and air flow, regulatory prohibition is absolute, thereby preventing use of user operable means for regulating air flow. The question then becomes how one can have a multi-fuel stove that is optimized for efficiency by metering both fuel and air flow, but that complies with regulatory restrictions pertaining to user operable means for modulating the air flow.
SUMMARY OF THE INVENTION

The invention is directed to combined fuel and oxidizer metering jets for simultaneously metering the flow rate of a liquid and/or LG fuel and an oxidizer for delivery to a single or multi-fuel burner; systems comprising the above-described 5 combined metering jets; and methods for simultaneously metering the flow rate of a fuel and an oxidizer. By combining both fuel and oxidizer metering functions into a single article, a multi-fuel burner having a single type of fuel delivery conduit and mixing tube can be optimized for a variety of fuels without dynamic user modulation of oxidizer flow rate.

Conventional burners, whether for liquid or LG fuels, comprise a tube having an inflow end presenting to a fuel metering article generally referred to herein as a fuel metering jet and an outflow end presenting to a burner. The jet functions to meter, alone or in combination with other components and/or apparatus, the rate of fuel delivered from an upstream fuel source to the downstream burner by causing the fuel to pass through a first end orifice (inlet) to a second end orifice (outlet). An oxidizer, such as ambient air, is entrained into the fuel flow emerging from the jet outlet, usually via a primary oxidizer intake, and there after delivered to the burner via the tube. If oxidizer entrainment via the primary oxidizer intake occurs prior or proximate to the upstream end of the tube, the tube is functionally characterized as a fuel-air mixing tube.

One common form of primary intake comprises a highly mechanically decoupled space between the fuel metering jet outlet and the upstream end of the mixing tube (a decoupled axial arrangement). Another common form of primary intake comprises one or a plurality of orifices or ports defined by the mixing tube proximate to the upstream end, which may or may not have adjustable occlusion members, wherein the fuel metering jet is mechanically linked to the mixing tube, usually at the upstream end thereof (a coupled or radial arrangement). Functionally, a decoupled arrangement is one where oxidizer entrainment usually occurs axially at the upstream end of the mixing tube while a coupled arrangement is one where oxidizer entrainment usually occurs radially downstream of the upstream end of the mixing tube.
All fuel metering jets by definition comprise means for establishing a predetermined fuel flow rate there through. However, combined metering jet embodiments according to the invention further comprise means for establishing a predetermined oxidizer flow rate, wherein the combined metering jet alone (intrinsic) and/or in combination with ancillary structure (extrinsic), such as a mixing tube adapted to receive such jet, comprise(s) the means for establishing a predetermined oxidizer flow rate. Thus, intrinsic combined metering jet embodiments, which are usually but not always found in coupled arrangements, comprise substantially the entire means for establishing a predetermined oxidizer flow rate; extrinsic embodiments, which may found in coupled or decoupled arrangements, comprise one part of the means for establishing a predetermined oxidizer flow rate, with the mixing tube usually comprising another part thereof.

Due in part to the novel aspects of the invention, combined metering jet embodiments according to the invention may also comprise features and aspects of both coupled and decoupled metering jet arrangements. For example, a first hybrid combined metering jet axially entrains oxidizer at the upstream end of the mixing tube (a feature generally associated with a decoupled arrangement) but the metering jet is nevertheless mechanically linked thereto (by definition, a coupled arrangement). As another example, a second hybrid combined metering jet axially entrains oxidizer at the upstream end of the mixing tube (a feature generally associated with a decoupled arrangement) and modifies downstream radial entrainment thereof (a feature generally associated with a coupled arrangement).

To summarize the foregoing, combined metering jets generally can be characterized as either mechanically linked to a mixing tube (a coupled arrangement) or mechanically separate from a mixing tube (a decoupled arrangement), and means for establishing a predetermined oxidizer flow rate can be characterized as intrinsic, wherein the flow rate is substantially exclusively determined only the the combined metering jet, and/or extrinsic, wherein the flow rate is substantially determined by both the combined metering jet and additional structure such as a mixing tube.

Finally, all invention embodiments comprise a fuel metering body having a length "L_B" and defining a fluid passage from an inlet orifice defined by a first end of
the fuel metering body to an outlet orifice defined by a second end of the fuel metering body, and further comprise the aforementioned means for establishing a predetermined oxidizer flow rate, which can be characterized as an oxidizer metering body.

5 Turning then to the various invention embodiments, a first series of combined metering jets for decoupled arrangements comprises extrinsic means for establishing predetermined oxidizer flow rates. Combined metering jets having these extrinsic means comprise an oxidizer metering body, which can be characterized as an oxidizer flow reducing portion, whereby the volumetric flow of the oxidizer through a mixing tube varies as a function of the oxidizer metering body's proximity to the primary intake, which in a decoupled arrangement is at the upstream end of the mixing tube. Because in most burner systems the relative distance between a seat for receiving a metering jet and the upstream end of a mixing tube is fixed, the oxidizer metering body's proximity to the upstream end of the mixing tube can be varied by increasing or decreasing the overall length of the combined metering jet "LOA".

In a first group of invention embodiments within this first series, the oxidizer metering body comprises a hollow, preferably cylindrical or prismatic, shroud, which extends from the fuel metering body second end and terminates at a distal end to establish a length "L₅", and which when added to the length of the fuel metering body "L₆" establishes the overall length of the combined metering jet "LOA". Therefore, by changing the length of "L₅" and/or "L₆", one changes the distance between the shroud's distal end and the upstream end of the mixing tube during operation of the burner system in which the combined metering jet is introduced. Consequently, the volumetric flow rate of an oxidizer entering the mixing tube at the first end of the mixing tube is also changed. The hollow shroud embodiments in this first group may be integral with the fuel metering body or may be attachable thereto, either removably or permanently.

As used herein, the term "hollow cylindrical shroud" or "hollow prismatic shroud" or derivative terms means a generally thin walled tube or pipe of, respectively, elliptical (including circular) or polyhedron cross section. Additionally,
the geometric form may be conical or tapered, for example, a frustum of a hollow cone, and still be considered compliant with these terms. Moreover, the external diameter of the shroud need not be the same as that of the fuel metering body, and in some embodiments described herein, is intentionally not.

A presently preferred arrangement is to have uniformly dimensioned fuel metering bodies of various fuel flow rates and a plurality of hollow shrouds, each having unique lengths \( L_s \), whereby fuel metering bodies and shrouds can be "matched and attached" as needed based upon the nature (e.g., energy content) of the intended fuel. Such an approach permits a given fuel metering body to be used in both oxidizer rich and oxidizer poor environments by attaching, respectively, longer or shorter shrouds, again, either removably or permanently. For more robust and/or lower cost applications, monolithic combined metering jets of varying overall lengths may be preferred.

In a second group of invention embodiments within this first series, the oxidizer metering body comprises an extended portion of the fuel metering body. As such, the extended body portion includes the second or outlet end, which defines the second or outlet orifice of the fuel passage, wherein the overall length "LOA" of the combined metering jet determines the proximity of the jet's second end from the upstream end of the mixing tube during operation of the burner system in which the combined metering jet is introduced. The extended portions of embodiments in this group may be integral with the fuel metering body or may be attachable thereto, either removably or permanently. As with the first group within this series, non-integrated embodiments of this second group embodiments may exploit "match and attach" opportunities. Finally, embodiments wherein the fuel metering body is "extended" through either temporary or permanent attachment of an auxiliary fuel passage member, whether of the same or differing inner diameter, is considered to be within the scope of this second group of embodiments.

Finally, in a third group of invention embodiments within this first series, the oxidizer metering body comprises a hollow shroud extending from the fuel metering body second end the same as or similar to that of the first group, wherein the combined metering jet further comprises at least one hole or port defined by the
shroud such that oxidizer is entrained into the fuel flow there at in addition to the decoupled upstream end of the mixing tube during operation of the burner system in which the combined metering jets according to this third group are introduced.

In each case of the decoupled arrangements described above, changes in the proximity between a combined metering jet and the mixing tube changes the volumetric inflow rate of the oxidizer. However, the quality of the resulting inflow can also be modified by oxidizer metering bodies comprising inflow character modification means. For example, the oxidizer metering body may comprise outer surface features that form, in conjunction with the upstream end of the mixing tube (which may also comprise optimizing or complementary inner surface features), venturi means for increasing the inflow velocity and/or vectoring means for establishing one or more preferred inflow vectors into the mixing tube, e.g., a swirling pattern to increase the dispersion of fuel in the entrained oxidizer during transit in the the mixing tube. Additionally or alternatively, oxidizer metering bodies described above with respect to the third group of invention embodiments within this first series also affect the quality of the oxidizer inflow through the introduction of oxidizer via the at least one port defined by the hollow shroud upstream of the primary intake. Moreover, inner surface features of hollow shrouds may be selected to modify fuel flow characteristics prior to oxidizer entrainment.

Because the combined metering jets of these first series embodiments are decoupled from the mixing tube, non-coaxial orientation there of is possible, which would similarly affect the quantity and quality of an oxidizer inflow. Thus, spatial orientation of these first series embodiments can be intelligently selected to modify the constitution of the oxidizer inflow, alone or in combination with other inflow character modification means.

Turning next to coupled arrangements, a second series of combined metering jets comprises extrinsic and/or intrinsic means for establishing predetermined oxidizer flow rates by functionally and mechanically coupling with a portion of the mixing tube to define the operable area of a primary and/or secondary oxidizer intake. Combined metering jets having these extrinsic means comprise an oxidizer metering body, which can be characterized as an oxidizer flow occluding portion,
while combined metering jets having these intrinsic means comprise an oxidizer metering body, which can be characterized as defining at least one oxidizer intake. As described earlier, extrinsic embodiments functionally cooperate with one or more primary oxidizer intakes defined by the mixing tube to which the metering jet is mechanically linked, while pure intrinsic embodiments do not. As with certain first series embodiments, certain second series embodiments combine features and aspects of both conventional coupled and decoupled metering jet arrangements due to the unique aspects of the present invention, as will be described below.

In a first group of invention embodiments within this second series, the oxidizer metering body comprises an oxidizer flow occluding portion characterized as one of a) a hollow, preferably cylindrical or prismatic, shroud, which extends from the fuel metering body second end and terminates at a distal end to establish a length \(^{\text{LOA}}\); or b) an extended portion of the fuel metering body, including its second or outlet end. In either instance, the overall length of the combined metering jet \(^{\text{LOA}}\) is affected by changes in length \(^{L_s}\) or the extended portion.

When used with mixing tubes having one or more radial primary intakes at or proximate to the first end end thereof, the overall length \(^{\text{LOA}}\) of the combined metering jet determines the extent of primary intake occlusion: the greater the overall length of the oxidizer metering body, the more that the one or more radial primary intakes are occluded, which decreases the oxidizer flow rate, presuming a substantially close fit between the oxidizer metering body and the mixing tube (whether internally or externally thereof). The hollow shroud embodiments in this group may be integral with the fuel metering body or may be attachable thereto, either removably or permanently. Similarly, the extended body portion embodiments may also be integral or attachable to the fuel metering body, although integral embodiments are preferred.

A presently preferred arrangement is to have uniformly dimensioned fuel metering bodies of various fuel flow rates and a plurality of hollow shrouds, each having unique lengths \(^{L_s}\) whereby fuel metering bodies and shrouds can be "matched and attached" as needed based upon the nature \(\text{e.g., energy content}\) of the intended fuel. Such an approach permits a given fuel metering body to be used
in both oxidizer rich and oxidizer poor environments by attaching, respectively, longer or shorter shrouds, again, either removably or permanently. For more robust and/or lower cost applications, monolithic combined metering jets of varying overall lengths may be preferred, whether with respect to fuel metering bodies and shrouds, or extended fuel body portions.

In a second group of invention embodiments within this second series, the oxidizer flow occluding portions of the first group are optimized for use with mixing tubes having an axially oriented intake, which may be a primary intake or created as a supplemental intake. The latter case may be encountered where the one or more radial primary intakes cannot provide sufficient oxidizer entrainment in all environments and/or with all fuel types; an additional intake is necessary but also involves additional costs. By modifying the first group of combined metering jets to accommodate this requirement, a single mixing tube can be used. Alternatively, the additional intake can be considered a means for modifying the character of the oxidizer inflow.

As with the first group embodiments, a maximum outer diameter of the oxidizer flow occluding portion is nominally less than an inner diameter of the mixing tube at the first or upstream end thereof, assuming internal fitment. However, the oxidizer flow occluding portion also comprises at least one outer surface feature such as a groove that, in cooperation with the mixing tube inner surface, creates at least one oxidizer intake.

In a third group of invention embodiments within this second series, the means for establishing predetermined oxidizer flow rates comprise at least one primary oxidizer intake defined by a hollow, preferably cylindrical or prismatic, shroud, which extends from the fuel metering body second end and terminates at a distal end to establish a length "Ls", whereby the volumetric flow of the oxidizer through a mixing tube varies as a function of the combined area of all extension-defined primary oxidizer intakes when coupled arrangement mixing tubes having no primary intakes, i.e., non-ported mixing tubes. It should be noted that these third group embodiments may be used in conjunction with mixing tubes having at least one primary radial intake, i.e., ported mixing tubes. In former case, the constitution of the at least one
primary oxidizer intake defined by the hollow shroud exclusively determines the oxidizer inflow volumetric parameter as well as qualities; in the latter case, the affect is non-exclusive.

Finally, in a fourth group of invention embodiments within this second series, the means for establishing predetermined oxidizer flow rates comprises an oxidizer flow occluding portion the same as or similar to that of the first group, and further comprises at least one hole or port defined by the extension such that oxidizer is entrained into the fuel flow there at in addition to the decoupled upstream end of the mixing tube during operation of the burner system in which the combined metering jets according to this third group are introduced

As with decoupled arrangements, the quality of the oxidizer inflow in coupled arrangements can be modified in these second series combined metering jets. For example, the oxidizer flow occluding portions may comprise surface features that form, in conjunction with the primary intake(s) (which may also comprise optimizing or complementary surface features), venturi means for increasing the inflow velocity and/or vectoring means for establishing one or more preferred inflow vectors into the mixing tube, e.g., a swirling pattern to increase the dispersion of fuel in the entrained oxidizer during transit in the the mixing tube.

In either series of invention embodiments directed to combined metering jets, the means for establishing predetermined oxidizer flow rates is directed to modifying the overall length LOA of the combined metering jet. However as described above, the relative spatial position of the combined metering jet with respect to the mixing tube also affects oxidizer flow rates. Aspects of the present invention provide axial adjustment means for modifying the axial displacement of a fuel metering jet (combined or conventional) without deformation or modification of the metering jet seat and/or the mixing tube spatial location.

Axial adjustment means according to the invention comprise in one case at least one shimming washer sized to sealingly fit between the jet seat and the first end of the combined metering jet, and in another case at least one spacer sized to be sealingly received by the jet seat and sealingly coupled with the combined metering jet. In the former case, such micro axial adjusting means provides an opportunity to
optimize the efficiency and/or performance of a burner arrangement by stacking such shims; in the latter case such macro axial adjusting means, which is preferably a bushing, provides an alternative means for establishing predetermined oxidizer flow rates without replacing an existing fuel metering jet.

Invention embodiments directed to systems comprising combined metering jets according to the article embodiments described herein further comprise a mixing tube according to the various types described herein. In these system embodiments, the mixing tube is preferably matched for the type of combined metering jet used therewith, for example, coupled or decouples, intrinsic or extrinsic, hybrids, etc.

In addition to the foregoing, the present invention lends itself to kit embodiments, which comprise one or a plurality of fuel metering bodies and one or a plurality of oxidizer metering bodies, whether for removable or permanent attachment thereto. Such kit embodiments may further comprise one or a plurality of micro and/or macro axial adjustment means such as shims and/or bushings. In addition, such kit embodiments may further comprise an optimized mixing tube for combined metering jet embodiments having extrinsic means for establishing predetermined oxidizer flow rates.

Invention embodiments directed to methods include all aspects of use concerning the articles and systems described above. By way of example, method embodiments of the invention comprise methods for simultaneously modifying fuel and oxidizer flow rate parameters of a single or multi-fuel burner; and methods for axially adjusting only oxidizer flow rate parameters in a system comprising a mixing tube, a fuel jet seat and a fuel metering jet, whether combined or conventional, through the introduction of axial adjustment means between the jet seat and the mixing tube.

For purposes of this patent, the terms "area", "boundary", "part", "portion", "surface", "zone", and their synonyms, equivalents and plural forms, as may be used herein and by way of example, are intended to provide descriptive references or landmarks with respect to the article and/or process being described. These and similar or equivalent terms are not intended, nor should be inferred, to delimit or define per se elements of the referenced article and/or process, unless specifically
stated as such or facially clear from the several drawings and/or the context in which
the term(s) is/are used.
WHAT IS CLAIMED:

1. A combined fuel and oxidizer metering jet having an overall length “LO_A” for use with a mixing tube in a fossil fuel burner system, the combined metering jet comprising:

   5 a fuel metering body having a length “L_B” and defining a fluid passage from an inlet orifice defined by a first end of the fuel metering body to an outlet orifice defined by a second end of the fuel metering body; and

   means for establishing a predetermined oxidizer flow rate extending from the fuel metering body second end or comprising the fuel metering body second end whereby the “LO_A” of the combined fuel and oxidizer metering jet is selectively increased over the “L_B” of the fuel metering body.

2. The combined metering jet of claim 1 wherein the means for establishing a predetermined oxidizer flow rate comprises an oxidizer metering body.

3. The combined metering jet of claim 1 wherein the means for establishing a predetermined oxidizer flow rate comprises