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## (54) Nozzle.

(57) A two-fluid nozzle for atomizing a liquid-solid slurry which provides a plurality of atomizing gas streams which intersect the discharged liquid-solid slurry centripetally to effect high fidelity atomization of the liquid-solid slurry. The nozzle comprises an elongate central conduit (16) for the flow of the liquid-solid slurry and an elongate annular conduit (12) the cocurrent flow of the atomizing gas. The annular conduit (12) is coaxial with and surrounds at least a portion of the central conduit (16). In gas communication with the annular conduit is a plurality of discharge conduits (22b, 24b) each of which has an intermediate portion and an angled portion. The angled portion extends from the intermediate portion at an angle within the range of from 10° to 80° with respect to an outward extension of the longitudinal axis of the central conduit (16). The cross-sectional area for flow of each of the angled conduit is less than that of the intermediate portion and the total cross-sectional area for flow of the discharge conduits measured at their intermediate portions is less than that of the annular conduit. By this decrease in the total cross-sectional area for flow from the annular conduit to the angled portions of the discharged conduits, the velocity of the gas being discharged from the nozzle is higher than the velocity of the gas as it passes through the annular conduit. This increase in gas velocity results in better atomization of the liquid-solid slurry.

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## Description

# NOZZLE

This invention relates to a two-fluid nozzle for atomizing a liquid-solid slurry.

Synthesis gas produced by the partial oxidation of a carbonaceous material, e.g., coal, can have its heating value upgraded by feeding the gas to a vertical upflow reactor for further reaction with an atomized carbonaceous slurry. The most significant reactions to occur are between the fixed carbon provided by the carbonaceous slurry and the $CO_2$ and water vapor content of the synthesis gas. These reactions yield CO and $H_2$ which add to the heating value of the synthesis gas. The reactions are endothermic and avail themselves of the heat contained in the synthesis gas feed which is at a temperature in the range of from 1090°C to 1650°C and typically 1370°C.

The synthesis gas is usually obtained as the direct outflow from an entrained flow gasifier and fed to a vertical flow reactor. Vertical flow reactors can be either of the upflow or downflow type. Most commonly, the carbonaceous slurry is comprised of water and particulate coal and generally contains approximately 50 weight percent water. The carbonaceous slurry is fed to the vertical flow reactor in an atomized state and is preferably directed into the synthesis gas so as to effect a uniform dispersion of the carbonaceous slurry and the synthesis gas.

The nozzle of this invention is particularly suitable for use in atomizing a water-coal slurry fed to a vertical flow reactor. Generally speaking, the coal is provided to the slurry in a finely ground state so that substantially all of it passes through an ASTM E 11-70C Sieve Designation Standard 1.40mm (U.S. Series No. 14) and at least 80 percent passes through an ASTM E 11-70C Sieve Designation Standard 425µm (U.S. Series No. 40). The atomizing gas fed to the nozzle is preferably steam; however, other gases such as, for example, nitrogen and synthesis gas may be utilized.

The two-fluid mixing nozzle of this invention comprises an elongate central conduit for the flow of the liquid-solid slurry through the nozzle. The liquid-solid slurry is introduced into or adjacent the distal end of the central conduit and is discharged from its discharge, i.e., proximate, end. For ease in construction, the central conduit can be provided by the interior wall of an elongate pipe. Surrounding at least a portion of the length of the central conduit is an elongate annular conduit. The annular conduit is used for the cocurrent flow of the atomizing gas through the nozzle. The gas is introduced into or adjacent the distal end of the annular conduit and is communicated from its discharge, i.e., proximate, end of the annular conduit to a plurality of discharge conduits, hereinafter described. The annular conduit is coaxial with the longitudinal axis of the central conduit. When the central conduit is formed by a tube, the annular conduit is conveniently defined by the outside wall of the tube and inside wall of a larger diameter tube which is coaxial with the first.

In gas communication with the annular conduit are the hereinbefore-mentioned plurality of discharge conduits (ports). These discharge conduits each discharge the gas communicated to them at an angle "a" within the range of from 10° to 80° with respect to an outward extension of the longitudinal axis of the central conduit. The discharge conduits are also peripherally located with respect to the discharge end of the central conduit. By so angling and locating the discharge ports, the gas passing through them will intersect and impact, in a uniform manner, the liquid-solid slurry stream discharging from the central conduit. This intersecting and impacting results in disintegration of the slurry stream to effect its atomization. It has been found that by having the gas discharged from the discharge conduits at the hereinbefore described angles, high atomization of the slurry is achieved. When the nozzle of this invention is to be utilized for atomizing, say, a water-coal slurry feed, it is preferred that the angle "a" at which each discharge conduit directs the gas communicated to it be within the range of from 55° to 65° with respect to the outward extension of the longitudinal axis of the central conduit. The selection of any particular angle "a" for other types of feeds will be dependent upon the velocities of the liquid-solid slurry and the gas as they leave their respective conduits, the physical characteristics of the liquid-solid slurry and the degree of atomization sought. Considering the interdependence between these three factors, angle selection is by empirical methods.

It is preferred that the discharged conduits be substantially equidistantly spaced from one another and substantially equidistantly displaced from the longitudinal axis of the central conduit. By so locating the discharged conduits, uniformity in distribution of the disintegrating force on the discharged liquid-solid slurry is achieved, thus resulting in high fidelity atomization.

If desired, the discharge conduits can be dimensioned to have a total cross-sectional area for flow which is less than the cross-sectional area for flow provided by the annular conduit. By providing this disparity in the cross-sectional areas for flow, the velocity of the gas leaving the discharge conduits is increased over its velocity in the annular conduit, which increase can be beneficial in effecting better atomization than would be possible if the gas was discharged at its velocity in the annular conduit.

These and other features of this invention will be more fully understood from the following description and drawings in which identical numerals refer to identical parts and in which:

Figure 1 is a cross-sectional view of an embodiment of this invention taken along its longitudinal axis; and

Figure 2 is a front view of the mixing nozzle shown in Figure 1.

Referring now to Figures 1 and 2, there can be seen a two-fluid nozzle of this invention, generally designated by the numeral 10. Nozzle 10 includes an elongate outer tube which has an inside wall 14. Coaxially located within outer tube 12 is central tube 16. Central tube 16 is maintained in this coaxial position by means of two sets of spacers. One set of spacers comprises spacers 30, 31 and a third spacer, not shown, while the other set of spacers comprises spacers 32, 33 and a third spacer, not shown. The spacers are preferably of a narrow width and, in each set, are located 120° from one another.

Nozzle 10 provides an annular conduit 35 for gaseous flow through the nozzle by means of inside wall 14 of outside tube 12 and outside wall 18 of central tube 16. Also provided by nozzle 10 is central conduit 36 which is defined by inside wall 20 of central tube 16.

The liquid-solid slurry is fed into the distal end or portion 19 of central pipe 16 and is discharged therefrom at its discharge end 21. The gas, which will be utilized to atomize the liquid-solid slurry, is introduced via feed conduit 13 to annular conduit 35 at the distal end or portion 15 of outer tube 12 and is discharged through a plurality of discharge conduits 22, 23, 24 and 25 located at the discharge end 17 of annular conduit 35. The number of discharge conduits can vary over a wide range, say, from 3 to 500 conduits. Generally, 3 to 20 conduits are preferred. As can be seen in Figure 2, the discharge conduit open onto nozzle tip face 29 and are equidistantly spaced from one another and from the longitudinal axis of central tube 16. Nozzle tip face 29 is substantially coplanar with the discharge end 21 of central tube 16. By substantially coplanar, it is meant that nozzle tip face 29 and discharge end 21 are within 0 to 2.54 cm of being in a true coplanar relationship.

The discharge conduits each have two portions, an intermediate portion and an angled portion. The angled portion extends from the intermediate portion at an angle "a" within the range of from 10° to 80° with respect to an outward extension of the longitudinal axis of the central tube 16. When atomizing a water-coal slurry feed, angle "a" is preferably from 55° to 65°. For discharge conduits 22 and 24 shown in Figure 1, the intermediate portions are designated by the numerals 22a and 24a, respectively, and the angled portions are designated by the numerals 22b and 24b, respectively. Discharge conduits 23 and 25 are similarly configured. The total cross-sectional area for flow of the three discharge conduits measured at their intermediate portions is less than that for annular conduit 35. Further, the cross-sectional area for flow of each of the angled portions of the discharge conduits is less than that provided by each intermediate portion associated with its angled portion partner. By having this decrease in the total cross-sectional area for flow from annular conduit 35 to the angled portions of the discharge conduits, the velocity of the gas being discharged from nozzle 10 is much higher than the velocity of the gas as it passes through annular conduit 35. This increase in gas velocity results in better atomization of the slurry by shearing and disintegration of the liquid-solid slurry being discharged from central conduit 36.

Sizing of the various conduits and the selection of the angles for the discharge conduits are dependent upon the gas reactant feed rate to the reactor, the liquid-solid slurry composition and feed rate, the atomizing gas feed rate and its velocity of discharge from the discharge conduits and the degree of atomization sought. As mentioned previously, such determination is made empirically. For example, after empirical study, it was found that nozzle 10 could be specified as follows:

outside tube 12 3/4" (19 mm) diameter 310 SS SCH. 40

central tube 16 1/8" (3.175 mm) diameter 310 SS SCH. 40

intermediate portions of discharge conduits 22, 23, 24 and 25 3/16" (4.76 mm) diameter

angled portions of discharge conduits 22, 23, 24 and 25 3/32" (2.38 mm) diameter at an angle of 70° with longitudinal axis of pipe 16.

Such a nozzle provides a good atomized water-coal feed to a vertical flow reactor which has fed, to its bottom, synthesis gas flowing at the rate of 380 actual cubic ft/hour (0.003 $m^3/s$). The water-coal slurry is fed to the nozzle at a rate of 42 gallons/hour (0.0441 l/s) while the atomizing gas, i.e., steam, is fed to the nozzle at a rate of 50 lbs/hour (22.68 kg/hr).

While certain representative embodiments and details have been shown for the purpose of illustrating the present invention, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the invention.

## Claims

1. A two-fluid mixing nozzle which comprises: (a) an elongate central conduit (18) for the flow of a liquid-solid slurry through said nozzle, the conduit having a distal end for introduction of the slurry and a discharge end for the discharge of the slurry; (b) an elongate annular conduit (12) for the flow concurrently with said flow of the slurry, of a gas through the nozzle, the annular conduit having a distal end (15) for the introduction of the gas and a discharge end provided with a plurality of discharge conduits (22b), wherein the elongate annular conduit is substantially coaxial with the longitudinal axis of the central conduit and circumscribes at least a portion of the length of the central conduit; and wherein the discharge conduits (22b) are peripherally located adjacent the discharge end of said central conduit, and wherein each of the said discharge conduits is arranged to discharge the gas communicated to it at an angle of from 10° to 80° with respect to the outward extension of said longitudinal axis whereby the discharged liquid-solid slurry is impacted by the discharged gas to effect the atomization of said liquid-solid slurry.

2. A nozzle as claimed in Claim 1 wherein the discharge conduits (22b) each have an angled portion from which said gas is discharged and

an intermediate portion which is between the annular conduit and the said angled portion, the angled portion extending from the intermediate portion at an angle "a" within the range of from 10° to 80° with respect to an outward extension of the longitudinal axis of the central conduit.

3. A nozzle as claimed in Claim 2 wherein the cross-sectional area for flow of each of the said angled portion is less than the cross-sectional area for flow of the said intermediate portion associated with the angled portion.

4. A nozzle as claimed in Claim 2 or Claim 3 wherein the total cross-sectional area for flow for said intermediate portion is less than the cross-sectional area for flow of said annular conduit.

5. A nozzle as claimed in any one of the preceding claims wherein the discharge conduits open onto a nozzle tip face and are substantially equidistantly spaced from one another and substantially equidistantly displaced from the longitudinal axis of the central conduit.

6. A nozzle as claimed in any one of the preceding claims wherein the discharge conduits open onto a nozzle face, the nozzle face being substantially coplanar with the discharge end of the elongate central conduit.

7. A nozzle as claimed in any one of the preceding claims wherein there are from 3 to 500 discharge conduits.

8. A nozzle as claimed in any one of the preceding claims wherein said angle is from 55° to 65°.

9. A vertical flow reactor for carbonaceous slurries, comprising a nozzle as claimed in any one of the preceding claims.

10. A method of atomizing a carbonaceous slurry, which method comprises passing the slurry through the first conduit of a nozzle as claimed in any one of Claims 1 to 8, and passing a gas through the second conduit to effect atomisation of the slurry.

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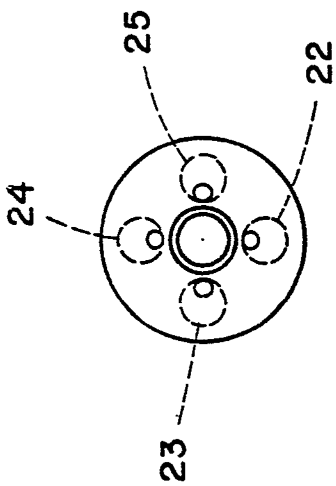


FIG.2

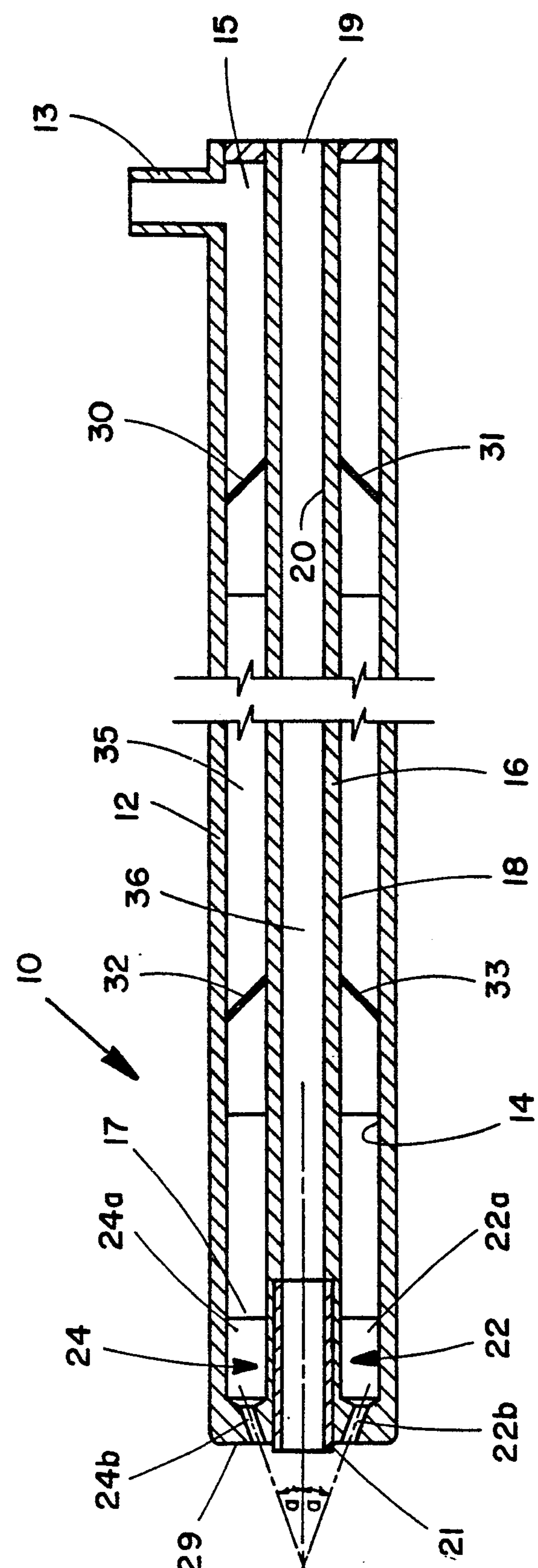


FIG.1