such that heat and operational consistency can be more reliably managed. It would be further advantageous to provide improved cooling and/or heat management of the injector to prevent the urea from solidifying and to prolong the life of the injector components. It would be advantageous to minimize heat transfer to the injector from the exhaust pipe to minimize or eliminate urea deposit formation internal to the injector. It would also be advantageous to minimize heat transfer from the hot exhaust gas to the injector exit orifice to prevent soot and urea from being attracted to the relatively cool injector exit orifice. It would also be advantageous to provide an injector that does not leak for economical and environmental purposes.

[0009] Methods and apparatus of the present disclosure seek to provide the foregoing and other advantages.

SUMMARY

[0010] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0011] In ~~some embodiments~~accordance with an aspect of the present invention, a method of directing reagent through an injector may involve: receiving a reagent ~~from a reagent tank~~ at a reagent inlet ~~of a reagent injector~~; directing the reagent to a pole piece passage defined between an outside diameter of a pole piece and an inside diameter of an electromagnetic bobbin; directing the reagent from the pole piece passage to a collar passage defined between an outside diameter of a collar of an inner lower body and the inside diameter of the bobbin; directing the reagent from the collar passage to a lower body passage defined between an outside diameter of the inner lower body and an inside diameter of a lower section of the injector; and directing the reagent into a distribution passage defined by the inner lower body~~.~~, ~~T~~the distribution passage ~~may~~ fluidly linking the lower body passage to a distribution chamber defined by the inner lower body and an orifice plate~~.~~; ~~In some embodiments, from the distribution chamber, the method may include~~ directing a first partial volume of the reagent to an orifice in the orifice plate; and directing a second partial volume of the reagent to a reagent outlet ~~of the injector~~.

[0012] In some embodiments, directing a first partial volume of the reagent to an orifice in the orifice plate may include: directing the first partial volume of the

reagent through a plurality of slots in the orifice plate; moving a pintle and unblocking the orifice in the orifice plate; directing the first partial volume of the reagent through a plurality of slots in the orifice plate and through the orifice; and directing the first partial volume of the reagent to a central bore defined by the inner lower body.

[0013] In some embodiments, directing a second partial volume of the reagent to a reagent outlet may include: directing the second partial volume of the reagent through through holes defined in a guide plate through which a pintle passes; directing the second partial volume of the reagent through through holes of a pintle head, the pintle head attaching to and surrounding an end of the pintle; directing the second partial volume of the reagent through an interior of a bobbin of a magnetic coil; directing the second partial volume of the reagent through a central bore of a pole piece; directing the second partial volume of the reagent from the distribution chamber to at least one return passage defined by the inner lower body, wherein the return passage fluidly links the distribution chamber and a central bore defined by the inner lower body. Directing the second partial volume of the reagent around an outside diameter of a solid pintle residing within a central bore defined by the inner lower body.

[0013a] In accordance with another aspect of the present invention, a method of directing reagent through an injector may comprise: pumping a reagent from a tank to an injector reagent inlet; directing the reagent to a pole piece passage defined between an outside diameter of a pole piece and an inside diameter of an upper section of the injector; directing the reagent from the pole piece passage to a bobbin passage located between an outside diameter of the pole piece and an inside diameter of the electromagnetic coil bobbin; directing the reagent from the pole piece passage to a collar passage located between an outside diameter of a collar of an inner lower body and an inside diameter of the electromagnetic coil bobbin; directing the reagent from the collar passage to a lower body passage located between an outside diameter of the inner lower body and an inside diameter of a lower section of the injector; directing the reagent into a distribution passage defined by the inner lower body, the distribution passage fluidly linking the lower body passage and a distribution chamber defined by the inner lower body and an orifice plate; dividing the reagent into a first partial volume and a second partial volume; directing the first partial volume and second partial volume of the reagent into the distribution chamber; directing the first partial volume into curved slots defined in the orifice plate; lifting a pintle from the orifice plate; and directing the first partial volume of the reagent around an orifice in the orifice plate.

[0014] ~~In some embodiments~~As disclosed herein, an injector for injecting reagent may employ an upper injector body, a lower injector body that may be secured to the upper injector body, a retaining plate defining a circular hole such that the retaining plate may be secured around the lower injector body via the circular hole, an insulator defining a circular hole such that the insulator may be secured around the lower injector body, and a mounting flange defining a circular hole such that the mounting flange may be secured around the insulator. The retaining plate may be secured directly against the lower injector body. The insulator may be secured directly against the lower injector body and the retaining plate. The mounting flange may be secured directly against the insulator. The retaining plate may define a plurality of through holes about a retaining plate peripheral edge and the mounting flange may define a plurality of blind holes about a mounting flange peripheral edge. A pin having a first pin end and a second pin end may be employed such that the first pin end resides within

one of the blind holes of the mounting flange and the pin resides completely through one of the plurality of through holes of the retaining plate.

[0015] ~~In some embodiments~~As disclosed herein, a clip having a first clip end and a second clip end may be utilized in such a fashion that the clip may be secured over the retaining plate peripheral edge and the mounting flange peripheral edge. The retaining plate peripheral edge may define a peripheral concavity and the plurality of through holes of the retaining plate may be located within the peripheral concavity. The mounting flange peripheral edge may define a groove. The first clip end may reside within the groove of the mounting flange peripheral edge and the second clip end may reside within the peripheral concavity of the retaining plate peripheral edge. The clip may be C-shaped and the second clip end may reside on the second pin end. The insulator may define a tubular section with an inside diameter and an outside diameter that each have a series of alternating protrusions and recessions.

[0016] ~~In some embodiments~~As disclosed herein, a heat shield may be installed on the mounting flange using a through in the heat shield such that the mounting flange may protrude through the through hole of the heat shield. ~~In some embodiments~~As disclosed herein, the heat shield may be positioned between an injector upper body and an exhaust pipe. A cover may be mounted to the heat shield such that the cover surrounds the upper injector body, the lower injector body, and the mounting flange.

[0017] ~~In some embodiments~~As disclosed herein, an injector for injecting reagent may employ a cylindrical pole piece defining a pole piece first end and a pole piece second end. The pole piece may have a hollow interior from the pole piece first end to the pole piece second end. A spring pre-loader may be located within the hollow interior and against a portion of the first end. A spring may be located within the hollow interior and abut the spring pre-loader. An electromagnetic coil may be secured around a bobbin and the electromagnetic coil may itself surround an outside diameter of the cylindrical pole piece. ~~In some embodiments~~As disclosed herein, the cylindrical pole piece, spring pre-loader, spring and electromagnetic coil reside only within a cavity or chamber of the upper injector body.

[0018] A cylindrical inner lower body may reside within a lower injector body and define a longitudinal central bore. An inner lower body first end may

define a first end first bore with a diameter larger than a diameter of the longitudinal central bore. The inner lower body first end may also define a first end second bore with a diameter larger than the longitudinal central bore and larger than the first end first bore. An inner lower body second end may define a second end bore with a diameter larger than the longitudinal central bore. The injector may further employ a solid pintle residing within the longitudinal central bore. A guide plate may be attached to an intermediate portion of the pintle. The guide plate may reside within the first end first bore. A pintle head may surround an end of the pintle of part of the end of the pintle. The pintle head may reside within the first end second bore; and an orifice plate residing within the second end bore. The cylindrical pole piece, spring pre-loader, spring, electromagnetic coil, cylindrical inner lower body, pintle, guide plate, pintle head and orifice plate may be part of a single cartridge.

[0019] ~~In some embodiments~~As disclosed herein, an injector body upper section may define a chamber within which the single cartridge, or part of the single cartridge, may insert into and reside. The guide plate may define one or more through holes for passage of fluid. Alternatively, the guide plate and the pintle together may define one or more through holes therebetween for passage of fluid. The pintle head may define at least one through hole for passage of fluid. The orifice plate and the inner lower body second end may define a distribution chamber therebetween. The orifice plate may define a plurality of grooves for passage of fluid to an exit orifice for exit from the injector. An interior surface of the injector body lower section and an inner lower body exterior surface may define a fluid pathway. The inner lower body may define a distribution passage fluidly linked to the pathway defined by an interior surface of the injector body lower section and an exterior surface of the inner lower body. The inner lower body may define a return passage that fluidly links the inner lower body central bore and the distribution chamber defined by the orifice plate and the inner lower body second end. The solid pintle may reside within the longitudinal central bore for passage of fluid around the solid pintle and through the longitudinal central bore.

[0020] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this

17. The method of directing reagent through an atomizing injector according to Claim 13, wherein directing the second partial volume of the reagent to a reagent outlet further comprises:

directing the second partial volume of the reagent through through holes of a guide plate through which the solid pintle passes; and

directing the second partial volume of the reagent through through holes of a pintle head to which a pintle is attached.

18. The method of directing reagent through an atomizing injector according to Claim 13, wherein directing a second partial volume of the reagent to a reagent outlet further comprises:

directing the second partial volume of the reagent through the inside diameter of the electromagnetic coil bobbin.

19. The method of directing reagent through an atomizing injector according to Claim 13, wherein directing a second partial volume of the reagent to a reagent outlet further comprises:

directing the second partial volume of the reagent through a central bore of a pole piece, wherein the pole piece is located through inside diameter of the electromagnetic coil bobbin.

20. The method of directing reagent through an atomizing injector according to Claim 13, wherein directing a second partial volume of the reagent to a reagent outlet further comprises:

directing a partial volume of the reagent through a spring residing within a central bore of a pole piece.

~~21. An injector for injecting reagent, the injector comprising:~~

~~an upper injector body;~~

~~a lower injector body that is secured to the upper injector body;~~

~~a retaining plate defining a circular hole, the retaining plate secured around the lower injector body via the circular hole;~~

an insulator defining a circular hole, the insulator secured around the lower injector body; and

a mounting flange defining a circular hole, the mounting flange secured around the insulator.

22. The injector of Claim 21, wherein the retaining plate is secured directly against the lower injector body.

23. The injector of Claim 21, wherein the insulator is secured directly against the lower injector body and the retaining plate.

24. The injector of Claim 21, wherein the mounting flange is secured directly against the insulator.

25. The injector of Claim 21, wherein the retaining plate defines a plurality of through holes about a retaining plate peripheral edge and the mounting flange defines a plurality of blind holes about a mounting flange peripheral edge.

26. The injector of Claim 25, further comprising:

a pin having a first pin end and a second pin end, wherein the first pin end resides within one of the blind holes of the mounting flange and the pin resides completely through one of the plurality of through holes of the retaining plate.

27. The injector of Claim 26, further comprising:

a clip having a first clip end and a second clip end, the clip secured over the retaining plate peripheral edge and the mounting flange peripheral edge.

28. The injector of Claim 27, wherein the retaining plate peripheral edge defines a peripheral concavity and the plurality of through holes of the retaining plate are located within the peripheral concavity.

29. The injector of Claim 28, wherein the mounting flange peripheral edge defines a groove.

30. The injector of Claim 29, wherein the first clip end resides within the groove of the mounting flange peripheral edge and the second clip end resides within the peripheral concavity of the retaining plate peripheral edge.

31. The injector of Claim 21, wherein the clip is a C-shaped and the second clip end resides on the second pin end.

32. The injector of Claim 31, wherein the insulator defines a tubular section with an inside diameter and an outside diameter that each have a series of alternating protrusions and recessions.

33. The injector of Claim 21, further comprising:

a heat shield defining a through hole, the mounting flange protruding through the through hole of the heat shield.

34. The injector of Claim 33, wherein the heat shield is positioned between the injector upper body and an exhaust pipe.

35. The injector of Claim 34, further comprising:

a cover mounted to the heat shield, wherein the cover surrounds the upper injector body, the lower injector body, and the mounting flange.

36. An injector for injecting reagent, the injector comprising:

a cylindrical pole piece defining a pole piece first end, a pole piece second end and a hollow interior from the pole piece first end to the pole piece second end;

a spring pre-loader located within the hollow interior and against a portion of the first end;

a spring located within the hollow interior, the spring the abutting the spring pre-loader; and

an electromagnetic coil secured around a bobbin, the electromagnetic coil surrounding an outside diameter of the cylindrical pole piece, wherein the

cylindrical pole piece, spring pre-loader, spring and electromagnetic coil reside only within the upper injector body.

37. The injector of claim 36, further comprising:

a cylindrical inner lower body defining a longitudinal central bore;

an inner lower body first end defining a first end first bore with a diameter larger than a diameter of the longitudinal central bore, the inner lower body first end also defining a first end second bore with a diameter larger than the longitudinal central bore and larger than the first end first bore; and

an inner lower body second end defining a second end bore with a diameter larger than the longitudinal central bore.

38. The injector of claim 37, further comprising:

a solid pintle residing within the longitudinal central bore;

a guide plate attached to an intermediate portion of the pintle, the guide plate residing within the first end first bore;

a pintle head surrounding an end of the pintle, the pintle head residing within the first end second bore; and

an orifice plate residing within the second end bore.

39. The injector of claim 38, wherein the cylindrical pole piece, spring pre-loader, spring, electromagnetic coil, cylindrical inner lower body, pintle, guide plate, pintle head and orifice plate are part of a single cartridge.

40. The injector of claim 39, further comprising:

an injector body upper section defining a chamber, wherein the single cartridge inserts into and resides within the chamber.

41. The injector of claim 38, wherein the guide plate defines at least one through hole for passage of fluid.

42. The injector of claim 38, wherein the guide plate and the pintle define at least one through hole therebetween for passage of fluid.

~~43. The injector of claim 38, wherein the pintle head defines at least one through hole for passage of fluid.~~

~~44. The injector of claim 38, wherein the orifice plate and the inner lower body second end define a chamber therebetween.~~

~~45. The injector of claim 38, wherein the orifice plate defines a plurality of grooves for passage of fluid.~~

~~46. The injector of claim 42, further comprising:~~

~~an injector body lower section, wherein an interior surface of the injector body lower section and an inner lower body exterior surface define a pathway.~~

~~47. The injector of claim 46, wherein the inner lower body defines a distribution passage fluidly linked to the pathway defined by an interior surface of the injector body lower section and an exterior surface of the inner lower body.~~

~~48. The injector of claim 44, wherein the inner lower body defines a return passage that fluidly links the inner lower body central bore and the chamber defined by the orifice plate and the inner lower body second end.~~

~~49. The injector of claim 48, wherein the solid pintle resides within the longitudinal central bore for passage of fluid around the solid pintle.~~

~~50~~21. The method of directing reagent through an atomizing injector according to Claim 1, wherein directing a first partial volume of the reagent to an orifice in the orifice plate further comprises:

directing the first partial volume of the reagent through a plurality of slots defined in an orifice plate holder.

~~51~~22. The method of directing reagent through an atomizing injector according to Claim ~~50~~21, wherein the orifice plate holder and orifice plate are physically separate pieces.

~~52~~23. The method of directing reagent through an atomizing injector according to Claim 1, wherein directing a second partial volume of the reagent to a reagent outlet further comprises:

directing the second partial volume of the reagent from the distribution chamber to at least one return passage defined by an orifice plate holder, wherein the return passage fluidly links the distribution chamber and a central bore defined by the inner lower body.