

## **ADJUSTABLE FLOW NOZZLE SYSTEM**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This is a PCT application that claims benefit to U.S. provisional application serial number 62/797,815 filed on January 28, 2019, which is herein incorporated by reference in its entirety.

### **FIELD**

**[0002]** The present disclosure relates to an adjustable flow nozzle system; and in particular, to an adjustable flow nozzle system that adjusts the cross-sectional area of a collective opening formed by each adjustable flow nozzle by selective rotation of one component relative to another component with each component having a respective opening in overlapping arrangement with respect to one other to form the collective opening for controlling the flow rate of each individual adjustable flow nozzle.

### **BACKGROUND**

**[0003]** Semiconductor processing involves selective removal of semiconducting materials, polymers or metals from the surface of base wafers including silicon. This is accomplished through spraying various chemicals – corrosive agents or solvents – on a batch of wafers. One of the many factors that influences the removal rate is the flow rate (or volume) of liquid moving through the spray nozzles. Currently, the adjustment of flow through each spray nozzle is done at the “macro” level by adjusting the total flow to all of the spray nozzles in the manifold at once. Individual spray nozzles can also be changed within the manifold, but this individual adjustment of each spray nozzle is both time consuming and may not precisely adjust the flow of liquid through each respective spray nozzle.

**[0004]** It is with these observations in mind, among others, that various aspects of the present disclosure were conceived and developed.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0005]** FIG. 1 is a perspective view of an adjustable flow nozzle system showing an adjustable flow manifold.

**[0006]** FIG. 2 is a side view of the adjustable flow manifold of FIG. 1.

**[0007]** FIG. 3 is a top view of the adjustable flow manifold of FIG. 1.

**[0008]** FIG. 4 is a bottom view of the adjustable flow manifold of FIG. 1.

**[0009]** FIG. 5 is a cross-sectional end view of the adjustable flow manifold along line 5-5 of FIG. 2 showing one of a plurality of adjustable flow nozzles disposed within the adjustable flow manifold.

**[0010]** FIG. 6 is a perspective view of a manifold body for the adjustable flow manifold of FIG. 1.

**[0011]** FIG. 7 is a bottom view of the manifold body of FIG. 6;

**[0012]** FIG. 8 is a top view of the manifold body of FIG. 6 showing the channel in broken line.

**[0013]** FIG. 9 is an end view of the manifold body of FIG. 6 showing the channel in broken line.

**[0014]** FIG. 10 is a cross-sectional view of the manifold body taken along line 10-10 of FIG. 9.

**[0015]** FIG. 11 is an enlarged cross-sectional view taken along line 11-11 of FIG. 10.

**[0016]** FIG. 12 is a perspective view of a top cover shown in FIG. 1.

**[0017]** FIG. 13 is a top view of the top cover of FIG. 12.

**[0018]** FIG. 14 is a cross-sectional view of the top cover taken along line 14-14 of FIG. 13.

**[0019]** FIG. 15 is an enlarged cross-sectional view of the top cover of FIG. 14 showing one of a plurality of apertures defined along the top cover.

**[0020]** FIG. 16 is a side view of the adjustable flow nozzle.

**[0021]** FIG. 17 is a bottom view of the adjustable flow nozzle of FIG. 16.

**[0022]** FIG. 18 is a perspective view of the adjustable flow nozzle of FIG. 16.

**[0023]** FIG. 19 is a partial cut-away perspective view of the adjustable flow nozzle of FIG. 16.

**[0024]** FIG. 20 is an exploded view of the adjustable flow nozzle of FIG. 16.

- [0025] FIG. 21 is a cross-sectional view of the adjustable flow nozzle taken along line 21-21 of FIG. 16.
- [0026] FIG. 22 is a perspective view of the spray nozzle.
- [0027] FIG. 23 is a bottom view of the spray nozzle of FIG. 22.
- [0028] FIG. 24 is a cross-sectional view of the spray nozzle taken along line 24-24 of FIG. 23.
- [0029] FIG. 25 is a perspective view of a stem retainer.
- [0030] FIG. 26 is a side view of the stem retainer of FIG. 25 showing the interior chamber and slot in broken line.
- [0031] FIG. 27 is a bottom view of the stem retainer of FIG. 25.
- [0032] FIG. 28 is a cross-sectional view of the stem retainer taken along line 28-28 of FIG. 27.
- [0033] FIG. 29 is a perspective view of the nozzle retainer.
- [0034] FIG. 30 is a side view of the nozzle retainer of FIG. 29 showing the upper and lower chambers in broken line.
- [0035] FIG. 31 is a top view of the nozzle retainer of FIG. 29.
- [0036] FIG. 32 is a bottom view of the nozzle retainer of FIG. 29.
- [0037] FIG. 33 is a cross-sectional view of the nozzle retainer taken along line 33-33 of FIG. 30.
- [0038] FIG. 34 is a perspective view of a restrictor adjuster.
- [0039] FIG. 35 is a top view of the restrictor adjuster of FIG. 34.
- [0040] FIG. 36 is a side view of the restrictor adjuster of FIG. 34.
- [0041] FIG. 37 is a bottom view of the restrictor adjuster of FIG. 34.
- [0042] FIG. 38 is an end view of the restrictor adjuster of FIG. 34.
- [0043] FIG. 39 is a perspective view of an adjustment key used to hold the nozzle retainer in a stationary position while turning the stem retainer and restrictor adjuster together.
- [0044] FIG. 40 is a bottom view of the adjustment key of FIG. 39.
- [0045] FIG. 41 is a side view of the adjustment key of FIG. 39.
- [0046] FIG. 42 is an end view of the adjustment key of FIG. 39.
- [0047] FIG. 43 is a top view of the adjustment key of FIG. 39 showing the protrusions in a flat configuration.

**[0048]** FIGS. **44A-44D** are perspective sequence views showing the adjustable flow nozzle in a fully open position (FIG. **44A**), partially open position (FIG. **44B**), partially closed position (FIG. **44C**), and fully closed position (FIG. **44D**).

**[0049]** FIG. **45** is a side view of the first adjustment key coupled to the nozzle retainer and the second adjustment key prior to engagement with the restrictor adjuster.

**[0050]** FIG. **46** is a top view of the first adjustment key coupled to hold the nozzle retainer in a stationary position and the second adjustment key coupled to concurrently rotate the restrictor adjuster and stem retainer.

**[0051]** FIG. **47** is a graphical representation showing mass collected as a function of nozzle opening for the adjustable flow nozzle system.

**[0052]** FIG. **48** is a graphical representation showing the nozzle mass collected across the manifold for the adjustable flow nozzle system.

**[0053]** Corresponding reference characters indicate corresponding elements among the view of the drawings. The headings used in the figures do not limit the scope of the claims.

## DETAILED DESCRIPTION

**[0054]** Various embodiments for an adjustable flow nozzle system having one or more manifolds with each manifold having a plurality of adjustable flow nozzles in an array along a manifold body of each manifold in which the flow rate of each adjustable flow nozzle may be individually adjusted are described herein. In some embodiments, the adjustable flow nozzle system may be used for semiconductor processing through the spraying of various solvents or corrosive agents through a plurality of individually adjustable flow nozzles on a batch of silicon wafers at various flow rates within a process spray chamber. In some embodiments, each adjustable flow rate nozzle includes a stationary nozzle retainer defining an inlet opening in overlapping relation with a rotatable stem retainer that defines an inlet opening in which the overlapping inlet openings are rotated relative to each other along a common axis of rotation for defining an adjustable collective opening that controls the flow rate of fluid through the adjustable fluid nozzle. In some embodiments, adjusting the cross-sectional area of the collective opening as the stem retainer is rotated relative to the stationary nozzle retainer adjusts the flow rate through the adjustable flow nozzle. In some embodiments, the flow rate of each adjustable flow nozzle is adjusted through the selective overlap of the inlet openings such that each adjustable flow nozzle is adjustable between a no flow rate when no overlap occurs between the overlapped openings and a maximum flow rate when maximum overlap between the overlapped inlet openings occurs. In some embodiments, the flow rate of each adjustable flow nozzles along the manifold may be individually adjusted by engaging and rotating a restrictor adjuster coupled to the stem retainer that rotates the stem retainer and adjusts the cross-sectional area of the collective opening for each individual adjustable flow rate nozzle. Referring to the drawings, various embodiments of an adjustable flow nozzle system are illustrated and generally indicated as **100** in FIGS. **1-48**.

**[0055]** Referring to FIGS. **1-5**, the adjustable flow nozzle system **100** includes an adjustable flow manifold **102** having a plurality of adjustable flow nozzles **104** positioned in an array along a manifold body **106**. In some embodiments, each of the adjustable flow nozzles **104** may be manually adjusted to a particular flow rate. In some embodiments, each adjustable flow nozzle **104** may be manually adjusted to adjust the flow rate of each adjustable flow nozzle **104** without requiring each adjustable flow nozzle **104** to be disassembled or require disengagement of the

adjustable flow nozzle **104** from the manifold body **106** to adjust the flow rate as shall be discussed in greater detail below.

**[0056]** As shown in FIGS. **1-11**, the manifold body **106** of manifold **102** is collectively defined by a top side **122**, a bottom side **124**, a front side **126** and rear side **128** forming a distal end portion **130** and an opposite proximal end portion **132** that collectively define the elongated rectangular-shaped manifold body **106**. As shown in FIGS. **7-11**, the manifold body **106** defines a plurality of access openings **134** arranged in series along the top side **122** of the manifold body **106** in communication with a channel **129** that extends the length of the manifold body **106**. In some embodiments, each of the (FIGS. **8-10**) plurality of access openings **134** is configured to allow a portion of a respective spray nozzle **110** of the adjustable spray nozzle **104** to extend outwardly from the manifold body **106** as illustrated in FIGS. **4** and **5**.

**[0057]** As shown in FIGS. **6** and **8-10**, the manifold body **106** further defines a plurality of apertures **135** arranged in series along the bottom side **124** of the manifold body **106** and configured to be engaged to a respective adjustable flow nozzle **104**. In one arrangement, each aperture **135** is aligned along the bottom side **124** of the manifold body **106** with a respective access opening **134** aligned along the bottom side **124** so that an upper portion of the adjustable flow nozzle **104** extends outwardly from a respective aperture **135** and a lower portion of the adjustable flow nozzle **104** extends outwardly from a respective access opening **134** as illustrated in FIG. **9**. As shown in FIG. **11**, each access opening **134** communicates with a respective access cavity **139** and each aperture **135** communicates with a respective nozzle cavity **138**. The nozzle cavity **138** is configured to receive a portion of the adjustable flow nozzle **104**. In some embodiments, each respective access opening **134** is located directly opposite a respective aperture **135** such that the adjustable flow nozzle **104** may be accessed through the aperture **135** to manually adjust the flow rate of the adjustable flow nozzle **104**. As shown in FIGS. **29** and **31**, in some embodiments a plurality of adjustment markers **183** may be engraved or placed around the circumference of each respective nozzle retainer **112** to provide a visual indicator of flow rate for a user when manually adjusting the flow rate desired for each respective adjustable flow nozzle **104** as shall be described in greater detail below. In some embodiments, the adjustment markers **183** may be preset numbers, lines, visual indicators,

structural markers, or a combination thereof which provide the user with a visual indication of flow rate being set for each respective adjustable flow nozzle **104**.

**[0058]** As further shown in FIG. **10**, the proximal end portion **132** of the manifold body **106** defines a proximal opening **141** and the distal end portion **130** of the manifold body **106** defines a distal opening **140**. As noted above, the manifold body **106** further defines an axial channel **129** in communication with the distal opening **140** at one end and proximal opening **141** at the opposite end of the axial channel **129**. As further noted above, each access opening **134** is configured to allow passage of the spray nozzle **110** of each adjustable flow nozzle **104** to extend outwardly from the manifold body **106**, as shown in FIG. **5**.

**[0059]** Referring to FIGS. **12-15**, in some embodiments the manifold **102** may include a top cover **103** secured to the bottom side **124** of the manifold body **106** (FIG. **3**). As shown, the top cover **103** defines a plurality of apertures **135A** that are configured to align with a respective plurality of apertures **135** formed through the manifold body **106** when the top cover **103** is secured to the manifold body **106**. Similarly, the top cover **103** defines a plurality of apertures **189A** that are configured to align with a respective plurality of apertures **189** formed through the manifold body **106** when the top cover **103** is secured to the manifold body **106**. As shown in FIG. **3**, the plurality of aligned apertures **189** and **189A** are each configured to receive a respective securing member **136**, such as a screw, to secure the top cover **103** to the manifold body **106**.

**[0060]** Referring back to FIGS. **1-5**, one possible fluid pathway through the adjustable flow manifold **102** is illustrated. As shown, inlet flow **A** enters the axial channel **129** (FIG. **8**) through the distal opening **140** formed by inlet **194** of the manifold body **106** and outlet flow **B** exits the opposite end of the axial channel **129** through the proximal opening **141** formed by the outlet **195** of the manifold body **106**. In one aspect, each adjustable flow nozzle **104** may be manually adjusted to allow a respective outlet flow having the same or different flow rates.

**[0061]** As shown in FIGS. **16-21**, in some embodiments each adjustable flow nozzle **104** includes a stem retainer **114** that is manually and individually adjusted to modify the cross-sectional area of a collective opening **133** (FIG. **21**) defined by the overlapping cross-section formed by the inlet opening **153** of the stem retainer **114** and the inlet opening **171** (FIG. **16**) of the stationary nozzle retainer **112** such that the current flow rate for that particular adjustable flow nozzle

**104** may be changed to a desired flow rate by changing the overlapping cross-section between the inlet openings **153**, **171** that define the collective opening **133**. As such, each adjustable flow nozzle **104** can be individually adjusted to provide a flow rate that is either the same or different than the other adjustable flow nozzles **104** of the adjustable flow manifold **102** by the rotating the stem retainer **114** relative to the stationary nozzle retainer **112** to adjust the overlapping arrangement between the inlet openings **153**, **171** as shall be discussed in greater detail below.

[0062] Referring to FIGS. 29-33, when the adjustable flow nozzle **104** is assembled the nozzle retainer **112** is fixed in position and engaged to the stem retainer **114** which is disposed within the nozzle retainer **112** and rotatable relative to the stationary nozzle retainer **112**. In operation, the stem retainer **114** may be manually rotated using second adjustment key **166B** (FIG. 45) to rotate the restrictor adjuster **116** to adjust flow rate of each respective adjustable flow nozzle **104**, while first adjustment key **166A** (FIG. 45) is engaged to the stationary nozzle retainer **112** for holding the nozzle retainer **112** in a stationary position as the restrictor adjuster **116** and stem retainer **114** are rotated together. As shown, each adjustable flow nozzle **104** includes a spray nozzle **110** which is engaged to the stem retainer **114** and functions as a nozzle arrangement for the release of fluid at a predetermined flow rate in a spraying action.

[0063] As shown in FIGS. 22-24, in some embodiments the spray nozzle **110** includes a nozzle body **143** defining a nozzle head **148** forming a nozzle opening **144** configured to provide a spraying action. As shown in FIG. 21, the spray nozzle **110** also defines a nozzle conduit **146** defined through the nozzle body **143** and is in fluid flow communication with a nozzle channel **145** formed through the nozzle head **148** for establishing fluid flow communication with the nozzle opening **144** during the spraying action. In some embodiments, the nozzle body **143** forms an annular groove **147** configured to receive O-ring **191** to provide a fluid tight seal. As further shown in FIGS. 22 and 24, in some embodiments the nozzle body **143** may form a slot **149** between opposite flat portions **150A** and **150B** which are configured to engage the spray nozzle **110** to the nozzle retainer **112** when the adjustable flow nozzle **104** is assembled.

[0064] As noted above, the stem retainer **114** is operable to gradually open or close fluid flow communication through an individual adjustable flow nozzle **104** when rotated by a second adjustment key **166B** such that rotation of the

restrictor adjuster **116** concurrently rotates the stem retainer **114** to adjust fluid flow as the stem retainer **114** is rotated relative to the stationary nozzle retainer **112**. Referring to FIGS. **25-28**, the stem retainer **114** includes a stem retainer body **120** defining a stem portion **151** and a body portion **152** with an annular groove **154** formed between the stem portion **151** and body portion **152** and is configured to receive an O-ring **192** (FIG. **20**) to provide a fluid tight seal. As shown, the body portion **152** defines inlet opening **153** that communicates with an interior chamber **157** (FIG. **28**) formed through the interior portion **152**. As shown in FIG. **28**, the internal chamber **157** communicates with an axial opening **159** to establish a fluid pathway through the stem retainer **114** between the nozzle retainer **112** and the spray nozzle **110** when fluid flow communication is established at a predetermined flow rate. As further shown in FIGS. **25** and **26**, the stem portion **151** of the stem retainer **114** defines a mounting portion **155** having a first abutment shoulder **158A** formed opposite a second abutment shoulder **158B** with a slot **156** defined laterally between the first and second abutment shoulders **158A** and **158B**. In one arrangement, the slot **156**, the first abutment shoulder **158A**, and the second abutment shoulder **158B** collectively define a mounting structure for engaging restrictor adjuster **116**. The restrictor adjuster **116** is operable to adjust fluid flow rate through the adjustable flow nozzle **104** when rotated by second adjustment key **166B** such that rotation of the restrictor adjuster **116** (FIGS. **18-21**) concurrently rotates the stem retainer **114** for changing the overlapping arrangement of the first inlet opening **153** of the stem retainer **114** relative to the second inlet opening **171** that forms the collective opening **133**.

[0065] Referring to FIGS. **29-33**, in some embodiments the nozzle retainer **112** has a generally cylindrically-shaped nozzle retainer body **170** forming a main body portion **173** having a scalloped surface **178** and a cap portion **172** forming an annular groove **174** between the cap portion **172** and main body portion **173** configured to receive an O-ring **193** (FIG. **20**) that provides a fluid tight seal. As shown, the main body portion **173** defines inlet opening **171** formed through the main body portion **173** that communicates with lower chamber **179** formed through the nozzle retainer body **170**. As shown in FIG. **30**, lower chamber **179** also communicates with an upper chamber **180** adjacent an upper axial opening **175** formed through cap portion **172**. In some embodiments, a lower axial opening **176** (FIG. **33**) is formed through the lower portion of the nozzle retainer body **170** and

communicates with the lower chamber **179**. As shown in FIGS. **29-31**, the main body portion **173** defines a plurality of legs **177** and in some embodiments a plurality of adjustment markers **183** (FIG. **31**) are aligned circumferentially around the cap portion **172** to indicate desired flow rate. As shown in FIGS. **30** and **33**, the upper and lower chambers **179**, **180** are collectively configured to receive the stem retainer **114** within the nozzle retainer **112** when the adjustable flow nozzle **104** is assembled. In some embodiments, the cap portion **172** forms opposing first and second slots **181** and **182** formed across the upper axial opening **175** with slot **182** formed adjacent one end of the plurality of markers **183**.

[0066] Referring to FIGS. **34-38**, **45** and **46**, as noted above the flow rate of the adjustable flow nozzle **104** may be adjusted by rotating the restrictor adjuster **116** coupled to the stem retainer **114** using a second adjustment key **166B** in the rotational direction indicated by the adjustment markers **183** (FIG. **29**) as the first adjustment key **166A** engaged to the nozzle retainer **112** to maintain the nozzle retainer **112** in a stationary position as the stem retainer **114** and restrictor adjuster **116** are rotated together by the second adjustment key **166B**. In some embodiments, the restrictor adjuster **116** defines a generally circular-shaped restrictor body **160** defining a cavity **161** (FIGS. **34** and **35**) in communication with opposing first and second slots **164** and **165** formed on opposite sides of cavity **161**. As shown in FIGS. **34** and **35**, the restrictor body **160** forms a lateral extension **162** having an indicator line **163** that may point to any one of the adjustment markers **183** for indicating the desired flow rate of a respective adjustable flow nozzle **104**.

[0067] Referring to FIGS. **39-43**, **45** and **46** in some embodiments, first adjustment key **166A** may be used to maintain the nozzle retainer **112** in a stationary position and includes an elongated key body **167** defining a distal portion **168** and a proximal portion **169** that is of sufficient length to allow the distal portion **168** to access the adjustable flow nozzle **104**. In some embodiments, first and second key elements **185** and **186** extend from the distal portion **168** of the elongated key body **167** of the first adjustment key **166A** which are configured to engage and maintain the nozzle retainer **112** in a stationary position as the stem retainer **114** and adjuster **116** are rotated together by second adjustment key **166B** (FIGS. **45** and **46**). In some embodiments, the second adjustment key **166B** may be a screw driver, although the second adjustment key **166B** is not limited to a screw driver and may be any adjustment tool configured to engage and rotate the restrictor adjuster **116**.

As shown, the proximal portion **169** of the first adjustment key **166A** may be configured to define an opening **187**.

**[0068]** FIGS. **44A-44D** illustrate a sequence of operation for the adjustable flow nozzle **104** as the stem retainer **114** is rotated relative to the stationary nozzle retainer **112** as the first key element **166A** (FIG. **46**) engages the nozzle retainer **112**, while the second key **166B**, for example a screw driver, is engaged to turn the adjuster **116** and rotate the stem retainer **114** to individually change the flow rate of each of the respective adjustable flow nozzles **104** along the adjustable flow manifold **102**. Referring to FIG. **44A**, the adjustable flow nozzle **104** is shown in the fully open position wherein the stem retainer **114** is rotated such that the inlet opening **153** of the stem retainer **114** is fully or substantially overlapped with the inlet opening **171** of the stationary nozzle retainer **112** to collectively form a fully open collective opening **133** having maximum flow rate capacity. Referring to FIG. **44B**, the adjustable flow nozzle **104** is shown in the partially open position wherein the stem retainer **114** has been rotated such that the inlet opening **153** of the stem retainer **114** rotates slightly out of position relative to the inlet opening **171** of the stationary nozzle retainer **112** to collectively form a partially open collective opening **133** having a lower than maximum flow rate. Referring to FIG. **44C**, the adjustable flow nozzle **104** is shown in the partially closed position wherein the stem retainer **114** has been further rotated in the same direction such that the inlet opening **153** of the stem retainer **114** has been rotated even more out of position relative to the inlet opening **171** of the stationary nozzle retainer **112** to collectively form a partially closed collective opening **133** having a lower flow rate than the collective opening **133** shown in FIG. **44B**. Referring to FIG. **44D**, the adjustable flow nozzle is shown in the fully closed position wherein the stem retainer **114** has been rotated to the maximum rotational position such that the inlet opening **153** of the stem retainer **114** has been rotated fully out of position relative to the inlet opening **171** of the stationary nozzle retainer **112** to form a fully closed collective opening **133** having a zero minimum flow rate.

**[0069]** In some embodiments, the overlapping inlet openings **153** and **171** that form the collective opening **133** may be slotted elongated openings; however, in other embodiments the overlapping inlet openings **153** and **171** of the stem retainer **114** and nozzle retainer **112**, respectively, may be other shapes and sizes, such as a circular-shaped opening, an oval-shaped opening, a square-shaped

opening, a rectangular-shaped opening, a symmetrically-shaped opening, and/or an asymmetrically-shaped opening. In one aspect, the overlapping inlet openings **153** and **171** may be designed to effectuate whatever granularity or flow response is required to achieve flow performance through the spray nozzles **110**.

**[0070]** In some embodiments, the components of the adjustable flow nozzles **104** are selected to have the proper chemical compatibility for the semiconductor processing operation such that these components will not corrode or become brittle including seals which will not corrode, swell or become brittle. In addition, the components of the adjustable flow nozzles **104** are selected from material(s) that are thermally stable throughout the operating range of the adjustable flow manifold **102** and provide proper mechanical integrity to retain their respective shape/function while withstanding the relevant operational and process demands of the adjustable flow nozzle system **100**. In some embodiments, materials that may be used for manufacturing components of the adjustable flow nozzles **104** may include stainless steel (or other metal alloys) for use with solvents as well as PFA, PTFE, ECTFE, PVDF, PP, HADPE, etc. for use with corrosives and potentially solvents. In some embodiments, common materials and elastomers for manufacturing of the seals **191**, **192** and **193** may include Kalrez, silicone, Viton, and PTFE.

#### *Test Results*

**[0071]** Referring to FIGS. **47** and **48**, test results for the adjustable flow nozzle system **100** are shown. The test was conducted on a single adjustable flow nozzle manifold **102** with five adjustable flow nozzles **104**. FIG. **47** shows a graph that illustrates how fluid flow is reduced as a function of the percentage of scale, parametrized for all five adjustable flow nozzles **104**. FIG. **48** shows the same data from FIG. **47**, but now as a non-tuned distribution of fluid flow collected across the adjustable flow manifold **102** using the same percentage of scale on each adjustable flow nozzle **104**, and then parameterized by the percentage of scale. The data illustrated in these graphs shows the ability of the adjustable flow nozzles **104** to decrease the fluid flow as the overlap between the inlet openings **153/171** is reduced from a maximum flow rate to essentially zero flow rate. As such, the data clearly demonstrate significant granularity for adjustment (e.g., a broad operating range) and hence implies that a plurality of nozzles (as would be incorporated into a manifold) can be individually adjusted to achieve matching flow rates through each

adjustable flow rate nozzle **104**. As shown, a variation exists in the data (particularly at the 0 percentage setting) due to the precision of this adjustment and the manufacturing tolerances of the prototype nozzles **104** used in this test.

**[0072]** It should be understood from the foregoing that, while particular embodiments have been illustrated and described, various modifications can be made thereto without departing from the spirit and scope of the invention as will be apparent to those skilled in the art. Such changes and modifications are within the scope and teachings of this invention as defined in the claims appended hereto.

## CLAIMS

What is claimed is:

1. An adjustable flow nozzle system **100** comprising:
  - an adjustable flow manifold **102** comprising:
    - a manifold body **106** defining an axial channel **129** that extends between a distal end portion **130** defining a distal opening **140** and a proximal end portion **132** defining a proximal opening **141**;
    - a plurality of access openings **134** formed along a first side **122** of the manifold body **106**; and
    - a plurality of apertures **135** formed on an opposite second side **124** of the manifold body **106**;
    - wherein the plurality of access openings **134** and the plurality of apertures **135** communicate with the axial channel **129**;
    - and
  - a plurality of adjustable flow nozzles **104** coupled to a respective one of the plurality of apertures **135**, each of the plurality of adjustable flow nozzles **104** comprising:
    - a spray nozzle **110** configured for providing a fluid pathway for a fluid exiting the adjustable flow nozzle **104**;
    - a stem retainer **114** engaged to the spray nozzle **110**, the stem retainer **114** defining a first inlet opening **153** and an axial opening **159** in fluid flow communication with a first chamber **157**; and
    - a nozzle retainer **112** engaged to the spray nozzle **110**, wherein the nozzle retainer **112** defines a second inlet opening **171** in communication with a second chamber **179** and wherein the stem retainer **114** is configured to be rotatably disposed within the second chamber **179** of the nozzle retainer **112** such that the first inlet opening **153** of the stem retainer **114** is in an overlapping arrangement with the second inlet opening **171** of the nozzle retainer

**112** such that a collective opening **133** is formed between the first inlet opening **153** of the stem retainer **114** and the second inlet opening **171** of the nozzle retainer **112** as the stem retainer **114** is rotated;

an adjuster **116** in operative engagement with the stem retainer **114** for causing rotation of the stem retainer **114** relative to the nozzle retainer **112** such that the cross-sectional area of the collective opening **133** is adjusted as the stem retainer **114** is rotated.

2. The adjustable flow nozzle system **100** of claim 1, wherein adjusting the cross-sectional area of the collective opening **133** adjusts the flow rate through each of the plurality of adjustable flow nozzles **104**.
3. The adjustable flow nozzle system **100** of claim 1, wherein the flow rate exiting each of the plurality of adjustable flow nozzles **104** is within a range between a minimum flow rate and a maximum flow rate.
4. The adjustable flow nozzle system **100** of claim 1, wherein the flow rate of the fluid exiting each adjustable flow nozzle **104** is adjusted through the selective overlap of the first inlet opening **153** of the stem retainer **114** with the second inlet opening **171** of the nozzle retainer **112** such that each adjustable flow nozzle **104** is adjustable between a minimum flow rate when minimum overlap between the first inlet opening **153** and the second inlet opening **171** occurs and a maximum flow rate when maximum overlap between the first inlet opening **153** and the second inlet opening **171** occurs.
5. The adjustable flow nozzle system **100** of claim 1, further comprising:
  - a first key **166A** having an elongated key body **167** defining a proximal portion **169** and a distal portion **168** and having at least one key element **185** extending from the proximal portion **169** of the elongated key body **167**, the at least one key element **185** being

configured to engage the nozzle retainer **112** to maintain the nozzle retainer **112** in a stationary position; and  
a second key **166B** configured to engage the adjuster **116** for rotating the adjuster **116** and the stem retainer **114** together relative to the nozzle retainer **112**.

6. The adjustable flow nozzle system **100** of claim 1, wherein the fluid enters the axial channel **129** of the adjustable flow nozzle system **100** through the proximal opening **141**, wherein the axial channel **129** is in fluid flow communication with each of the plurality of adjustable flow nozzles **104** such that the fluid enters the collective opening **133** of one or more of the adjustable flow nozzles **104** and wherein the fluid exits the one or more adjustable flow nozzles **104** through the spray nozzle **110** of the adjustable flow nozzle **104**.
7. The adjustable flow nozzle system **100** of claim 1, wherein the manifold **102** further comprises a plurality of nozzle cavities **138** in communication with the axial channel **129** and wherein each of the plurality of adjustable flow nozzles **104** is disposed within a respective one of the plurality of nozzle cavities **138**.
8. A method for adjusting the flow rate for an adjustable flow nozzle system **100** comprising:
  - providing an adjustable flow manifold **102** comprising:
    - a manifold body **106** defining an axial channel **129** that extends between a distal end portion **130** defining a distal opening **140** and a proximal end portion **132** defining a proximal opening **141**;
    - a plurality of access openings **134** formed along a first side **122** of the manifold body **106**;
    - a plurality of apertures **135** formed on an opposite second side **124** of the manifold body **106**, wherein the plurality of access openings **134** and the plurality of apertures **135** communicate with the axial channel **129**; and

a plurality of adjustable flow nozzles **104** coupled to a respective one of the plurality of apertures **135**, each of the plurality of adjustable flow nozzles **104** comprising:

- a spray nozzle **110** configured for providing a fluid pathway for a fluid exiting the adjustable flow nozzle **104**;

- a stem retainer **114** engaged to the spray nozzle **110**, the stem retainer **114** defining a first inlet opening **153** and an axial opening **159** in fluid flow communication with a first chamber **157**;

- a nozzle retainer **112** engaged to the spray nozzle **110**, wherein the nozzle retainer **112** defines a second inlet opening **171** in communication with a second chamber **179** and wherein the stem retainer **114** is configured to be rotatably disposed within the second chamber **179** of the nozzle retainer **112** such that the first inlet opening **153** of the stem retainer **114** is in an overlapping arrangement with the second inlet opening **171** of the nozzle retainer **112** such that a collective opening **133** is formed between the first inlet opening **153** of the stem retainer **114** and the second inlet opening **171** of the nozzle retainer **112** as the stem retainer **114** is rotated; and

- an adjuster **116** in operative engagement with the stem retainer **114** for causing rotation of the stem retainer **114** relative to the nozzle retainer **112** such that the cross-sectional area of collective opening **133** is adjusted as the stem retainer **114** is rotated;

inserting a first key **166A** having an elongated key body **167** defining a proximal portion **169** and a distal portion **168** through one of the plurality of apertures **135**, the first key **166A** further comprising at least one key element **185** extending from the proximal portion **169** of the elongated key body **167**;

engaging the at least one key element **185** of the first key **166A** with the nozzle retainer **112** to maintain the nozzle retainer **112** in a stationary position;

engaging a second key **166B** with the adjuster **116**; and

rotating the second key **166B** such that the stem retainer **114** is rotated relative to the stationary nozzle retainer **112** for adjusting the cross-sectional area and flow rate through the collective opening **133**.

9. The method of claim 8, wherein rotation of the stem retainer **114** relative to the nozzle retainer **112** adjusts the flow rate of each adjustable flow nozzle **104** within a range between a minimum flow rate and a maximum flow rate.
10. An adjustable flow nozzle **104** comprising:
  - a spray nozzle **110** configured for providing a fluid pathway for a fluid exiting the adjustable flow nozzle **104**;
  - a stem retainer **114** engaged to the spray nozzle **110**, the stem retainer **114** defining a first inlet opening **153** and an axial opening **159** in fluid flow communication with a first chamber **157**;
  - a nozzle retainer **112** engaged to the spray nozzle **110**, wherein the nozzle retainer **112** defines a second inlet opening **171** in communication with a second chamber **179** and wherein the stem retainer **114** is configured to be rotatably disposed within the second chamber **179** of the nozzle retainer **112** such that the first inlet opening **153** of the stem retainer **114** is in an overlapping arrangement with the second inlet opening **171** of the nozzle retainer **112** such that a collective opening **133** is formed between the first inlet opening **153** of the stem retainer

- 114** and the second inlet opening **171** of the nozzle retainer **112** as the stem retainer **114** is rotated; and
- an adjuster **116** in operative engagement with the stem retainer **114** for causing rotation of the stem retainer **114** relative to the nozzle retainer **112** such that the cross-sectional area of the collective opening **133** is adjusted as the stem retainer **114** is rotated.
11. The adjustable flow nozzle **104** of claim 10, further comprising:
- a first key **166A** having an elongated key body **167** defining a proximal portion **169** and a distal portion **168** and having at least one key element **185** extending from the proximal portion **169** of the elongated key body **167**, the at least one key element **185** being configured to engage the nozzle retainer **112** to maintain the nozzle retainer **112** in a stationary position; and
  - a second key **166B** configured to engage the adjuster **116** for rotating the adjuster **116** and the stem retainer **114** together relative to the nozzle retainer **112**.
12. The adjustable flow nozzle **104** of claim 10, wherein the flow rate of the fluid through the adjustable flow nozzle **104** is adjusted through the selective overlap of the first inlet opening **153** of the stem retainer **114** with the second inlet opening **171** of the nozzle retainer **112** such that the adjustable flow nozzle **104** is adjustable between a minimum flow rate when minimum overlap between the first inlet opening **153** and the second inlet opening **171** occurs and a maximum flow rate when maximum overlap between the first inlet opening **153** and the second inlet opening **171** occurs.
13. The adjustable flow nozzle **104** of claim 10, wherein the fluid enters the first chamber **157** of the stem retainer **114** through the collective opening **133** defined by the first inlet opening **153** of the stem retainer **114** and the second inlet opening **171** of the nozzle retainer **112** and wherein the fluid enters the spray nozzle **110** through the axial opening **159** of the stem retainer **114**, wherein the fluid leaves the adjustable flow nozzle **104** through the spray nozzle **110**.

14. The adjustable flow nozzle **104** of claim 10, wherein the stem retainer **114** is rotatable relative to the nozzle retainer **112** and wherein an orientation of the second inlet opening **171** of the nozzle retainer **112** is fixed within a nozzle cavity **138** of an adjustable flow manifold **102**.
15. The adjustable flow nozzle **104** of claim 10, wherein a stem portion defined by the stem retainer **114** is engaged with a first chamber **180** defined by the nozzle retainer **112** and wherein a body portion of the stem retainer **114** is engaged with the second chamber **179** of the nozzle retainer **112**, wherein the first chamber **180** is located superior to the second chamber **179**.