US 20160122208A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2016/0122208 A1
(43) Pub. Date: May 5, 2016
Denkewicz et al.

(54) **COMBINED ULTRAVIOLET AND OZONE FLUID STERILIZATION SYSTEM**

(71) Applicant: **Hayward Industries, Inc.**, Elizabeth, NJ (US)

(72) Inventors: **Ray Denkewicz**, East Greenwich, RI (US); **Douglas Sawyer, JR.**, Seekonk, MA (US); **James Carter**, East Greenwich, RI (US); **Jon Stone**, Clemmons, NC (US); **Seth Renigar**, Winston-Salem, NC (US); **Rolf Engelhard**, Prescott, AZ (US)

(73) Assignee: **HAYWARD INDUSTRIES, INC.**, Elizabeth, NJ (US)

(21) Appl. No.: **14/839,166**

(22) Filed: **Aug. 28, 2015**

Related U.S. Application Data

(60) Provisional application No. 62/043,087, filed on Aug. 28, 2014.

Publication Classification

(51) **Int. Cl.**

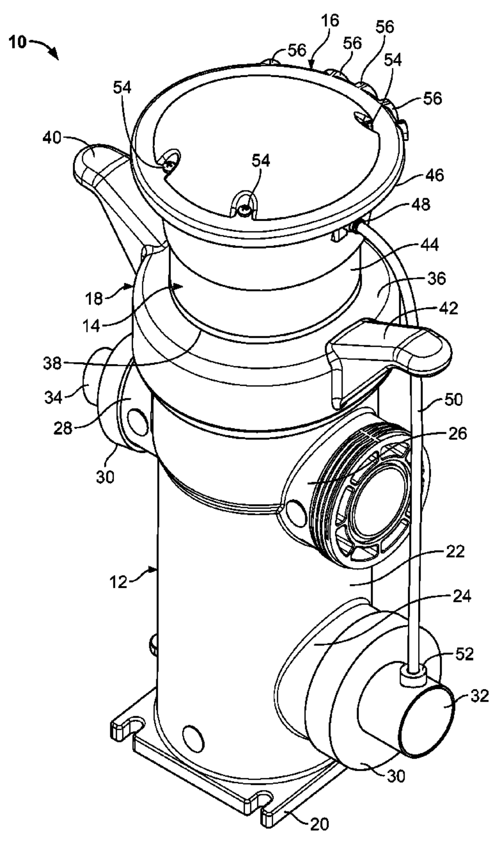
C02F 1/32	(2006.01)
C02F 1/00	(2006.01)
C02F 1/78	(2006.01)

(52) **U.S. Cl.**

CPC . ***C02F 1/325*** (2013.01); ***C02F 1/78*** (2013.01); ***C02F 1/008*** (2013.01); *C02F 2303/04* (2013.01); *C02F 2201/3228* (2013.01); *C02F 2201/782* (2013.01); *C02F 2201/328* (2013.01); *C02F 2201/326* (2013.01)

(57) **ABSTRACT**

A combined ultraviolet light and ozone fluid sterilization system for sterilizing fluid that includes a removable and replaceable internal reflective sleeve is provided. The sterilization system includes a lower housing, an upper housing, a winged nut, a UV light manifold, a plurality of UV light assemblies, a plurality of UV light securing assembly, and a reflective sleeve. The UV light assemblies include a UV light and an ozone siphon pipe positioned within a quartz casing, which is sealed with an endcap. The ozone siphon pipe of each UV light assembly can be operatively connected with a venturi for introducing ozone into the fluid. The sleeve includes perforated ends which create a more uniform flow within the sleeve, reduce air pockets, normalize the residence time of the fluid molecules, normalize the velocity of the fluid, and increase overall uniformity of treatment.



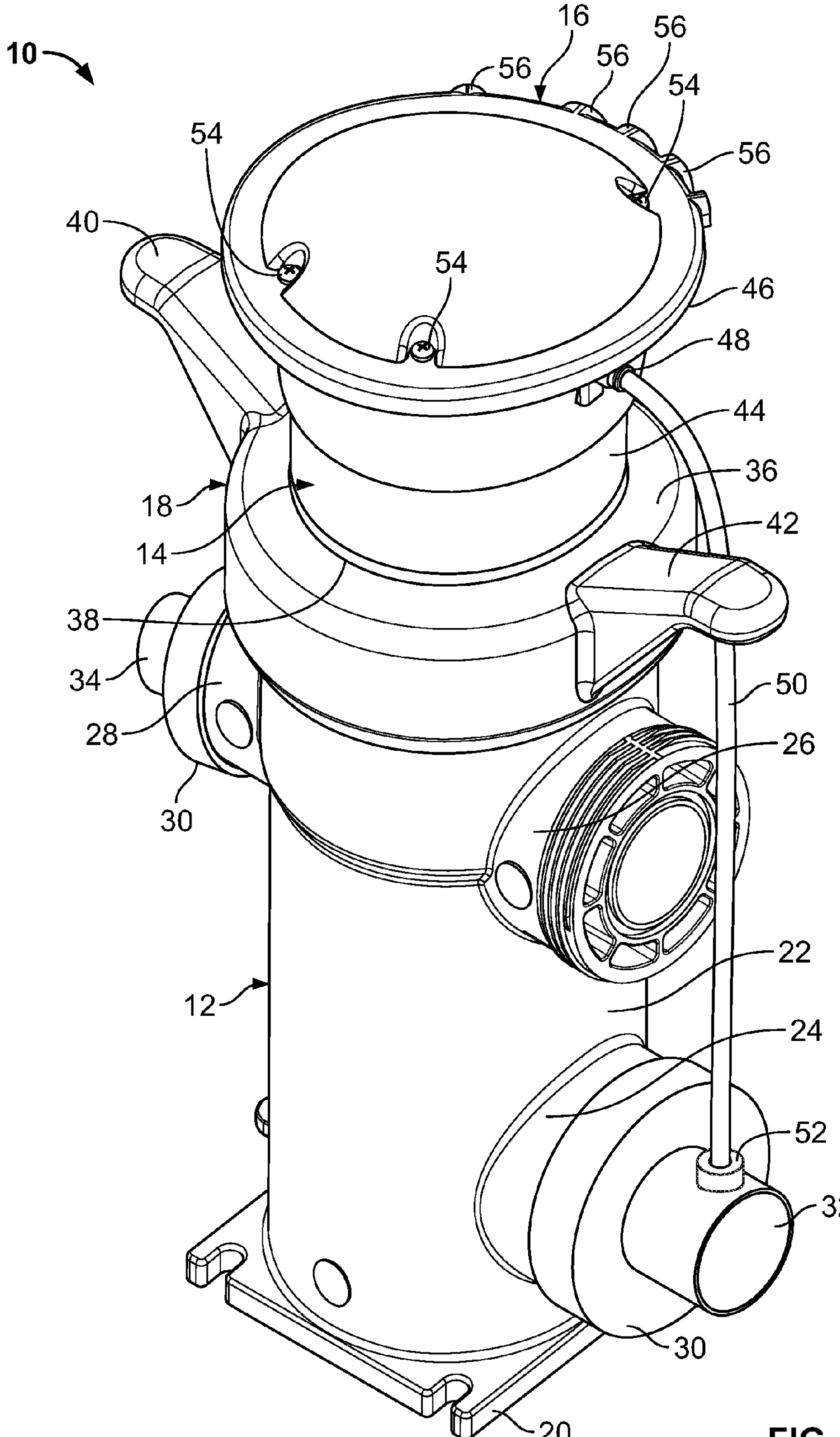

10
16
56
56
56
54
54
56
40
54
54
46
48
44
36
18
14
42
38
34
50
28
26
30
22
12
24
52
32
30
20

FIG. 1

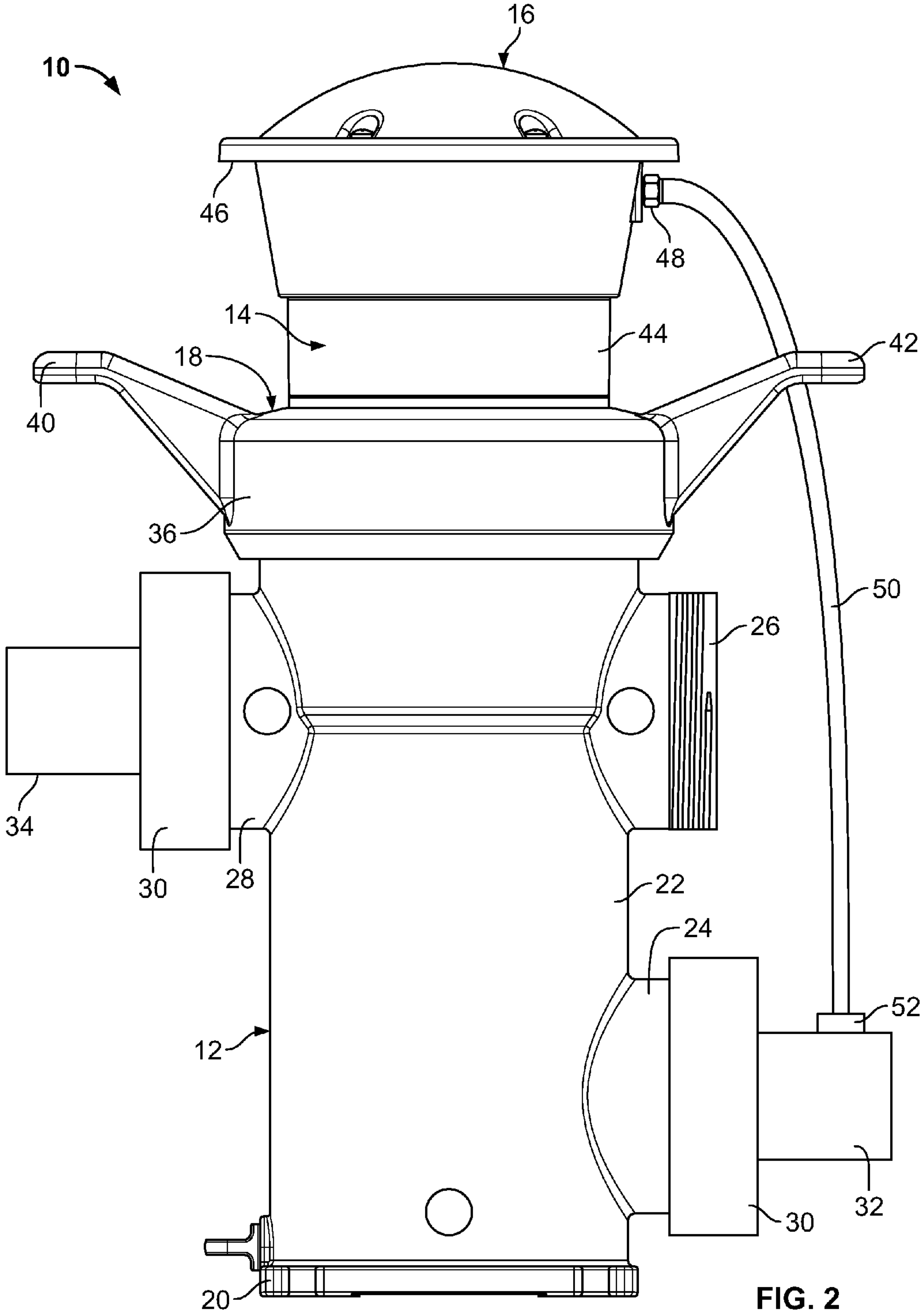


FIG. 2

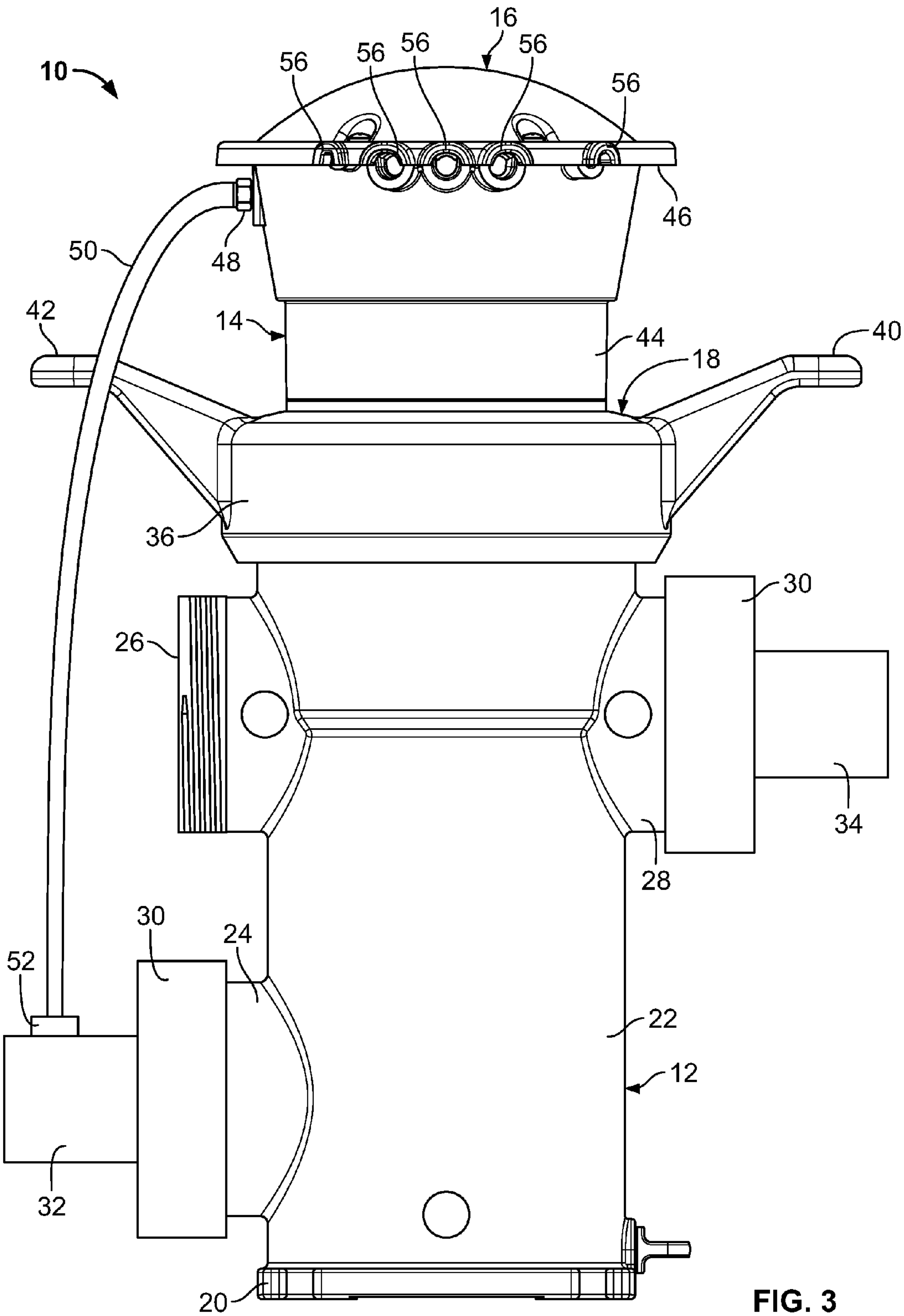

10
16
56
56
56
56
56
46
48
50
42
14
44
18
40
36
30
26
34
28
30
24
52
22
12
32
20

FIG. 3

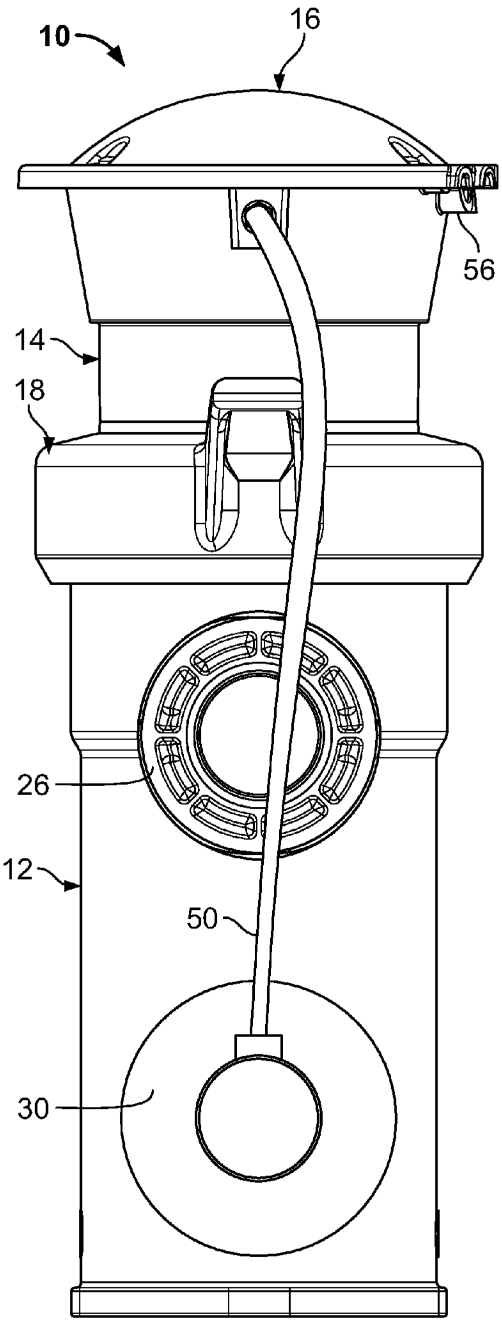


FIG. 4

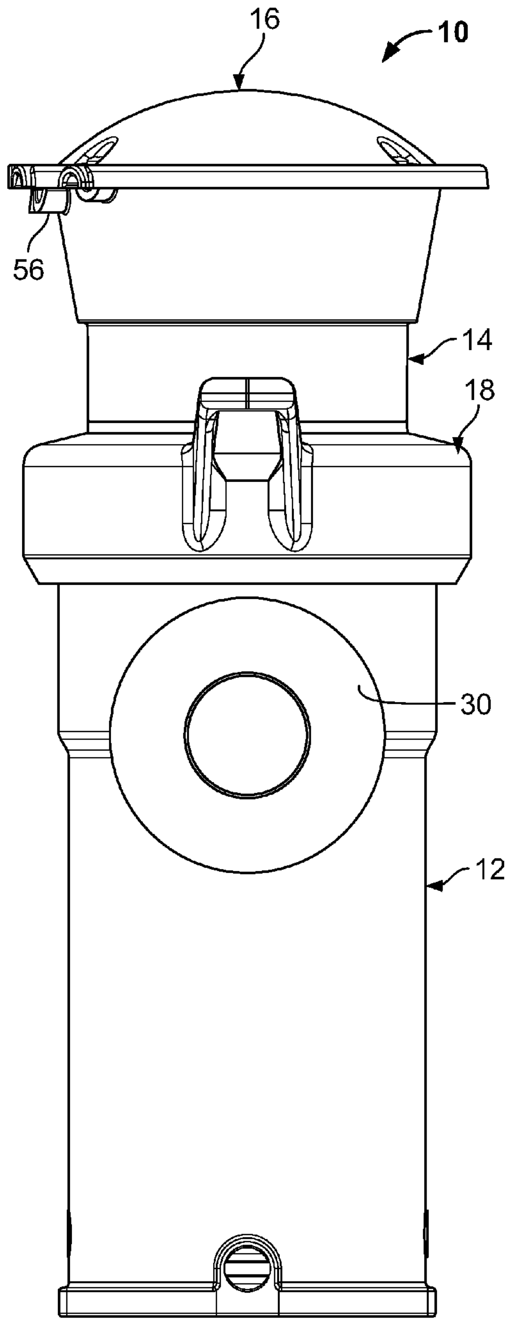


FIG. 5

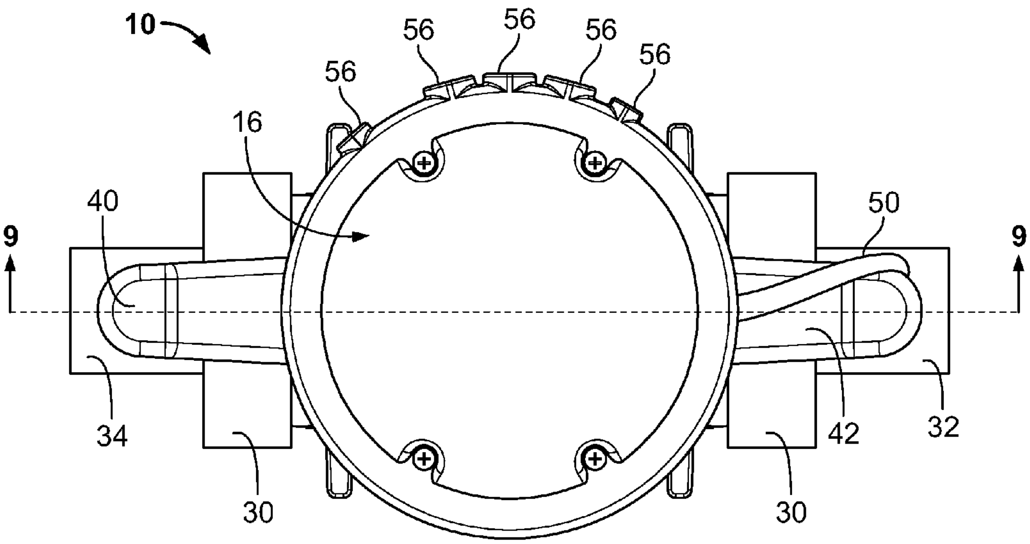

10
56
56
56
56
56
16
40
50
9
9
34
30
42
32
30

FIG. 6

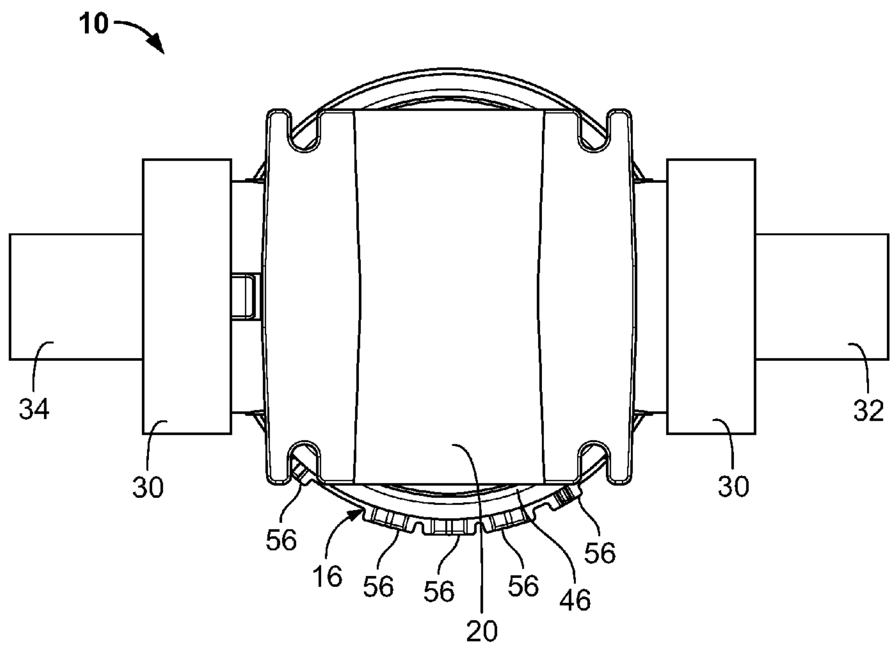

10
34
30
32
30
56
16
56
56
56
20
46
56

FIG. 7

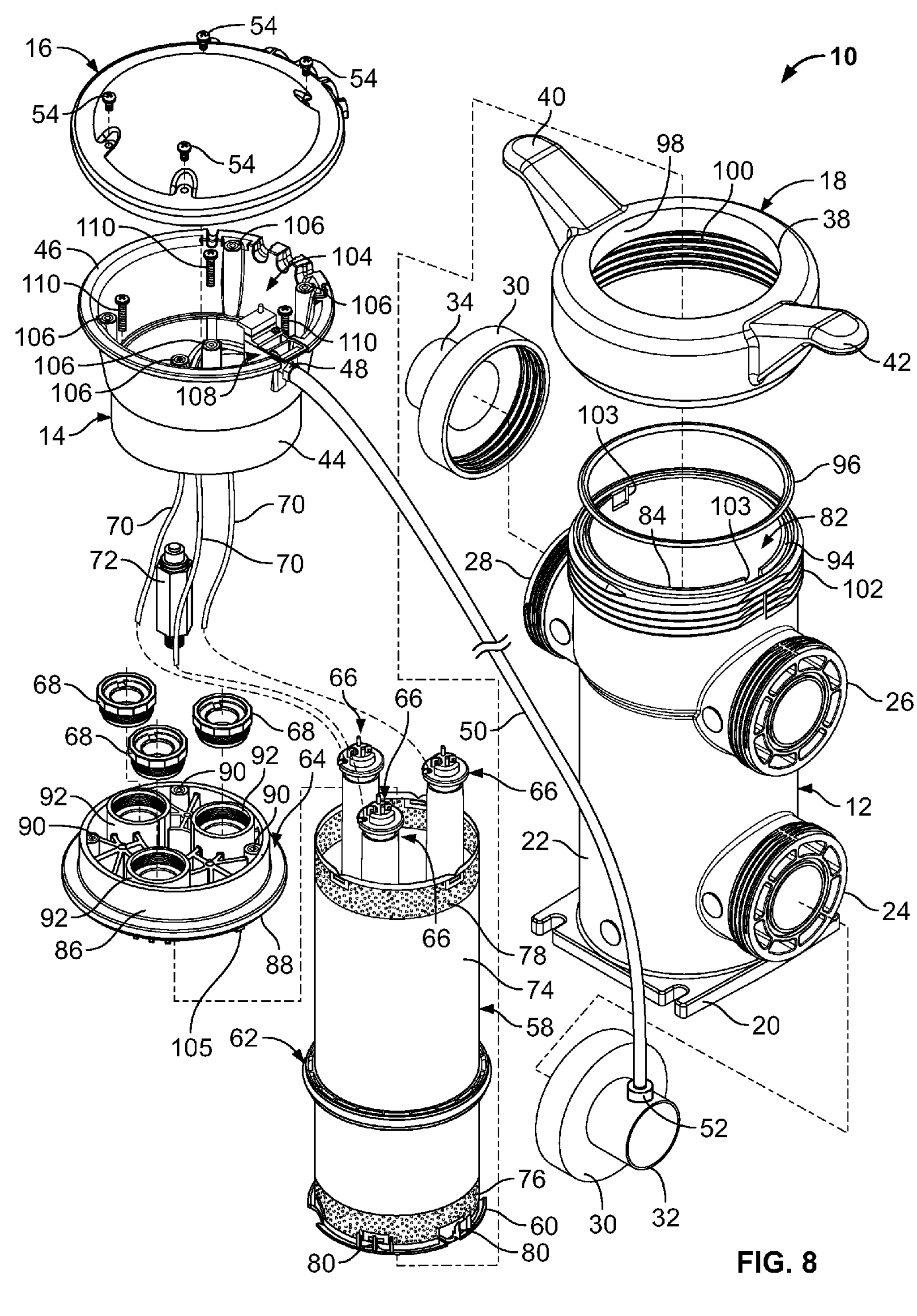

54
16
54
54
54
10
40
98
100
18
38
110
106
46
104
110
106
106
110
106
48
106
108
34
30
42
14
44
103
96
70
70
103
82
84
70
94
72
28
102
68
66
66
68
68
50
26
92
90
64
92
90
66
12
90
22
92
66
24
86
88
78
74
105
62
58
20
52
76
60
30
32
80
80

FIG. 8

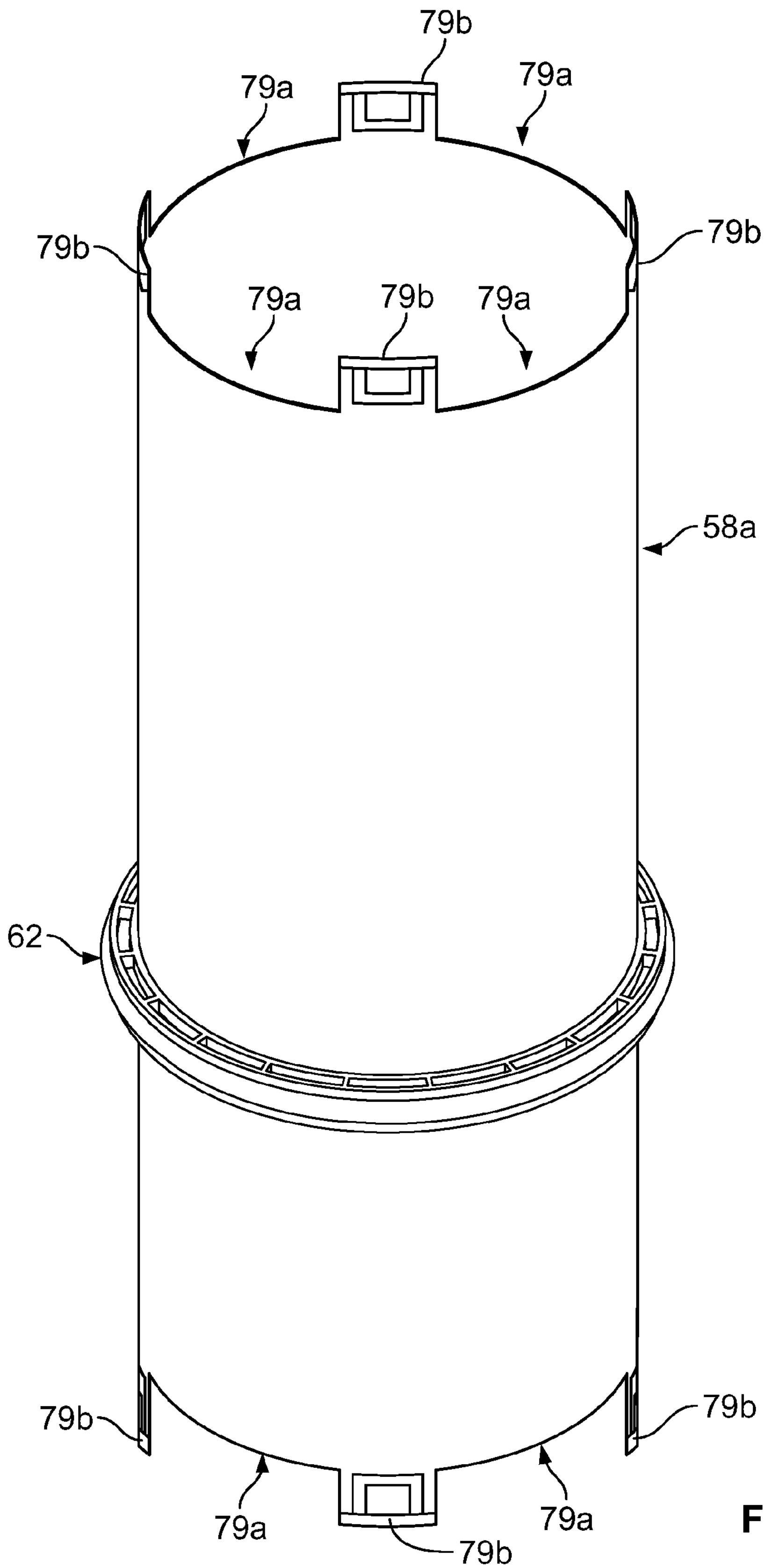


FIG. 8A

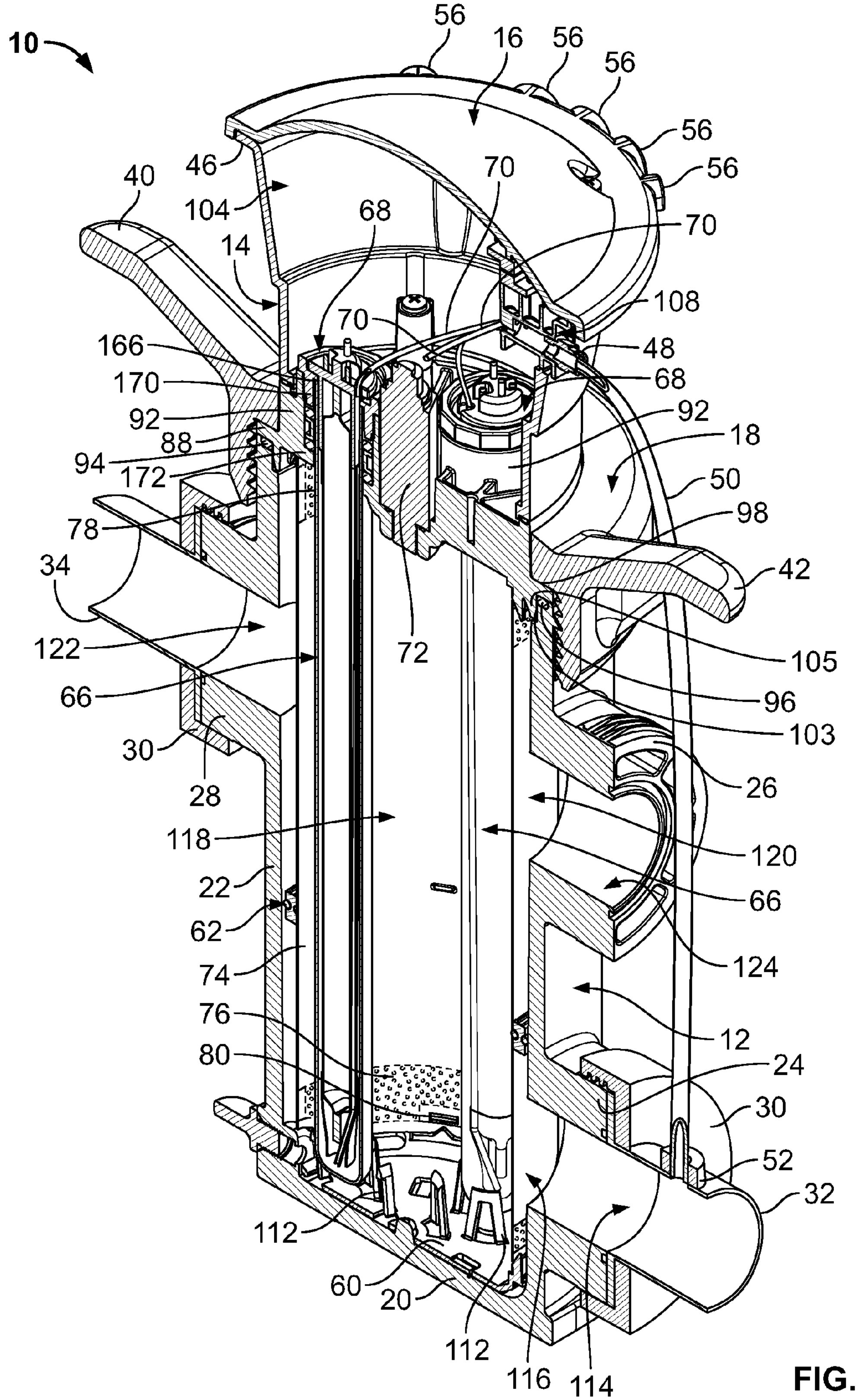
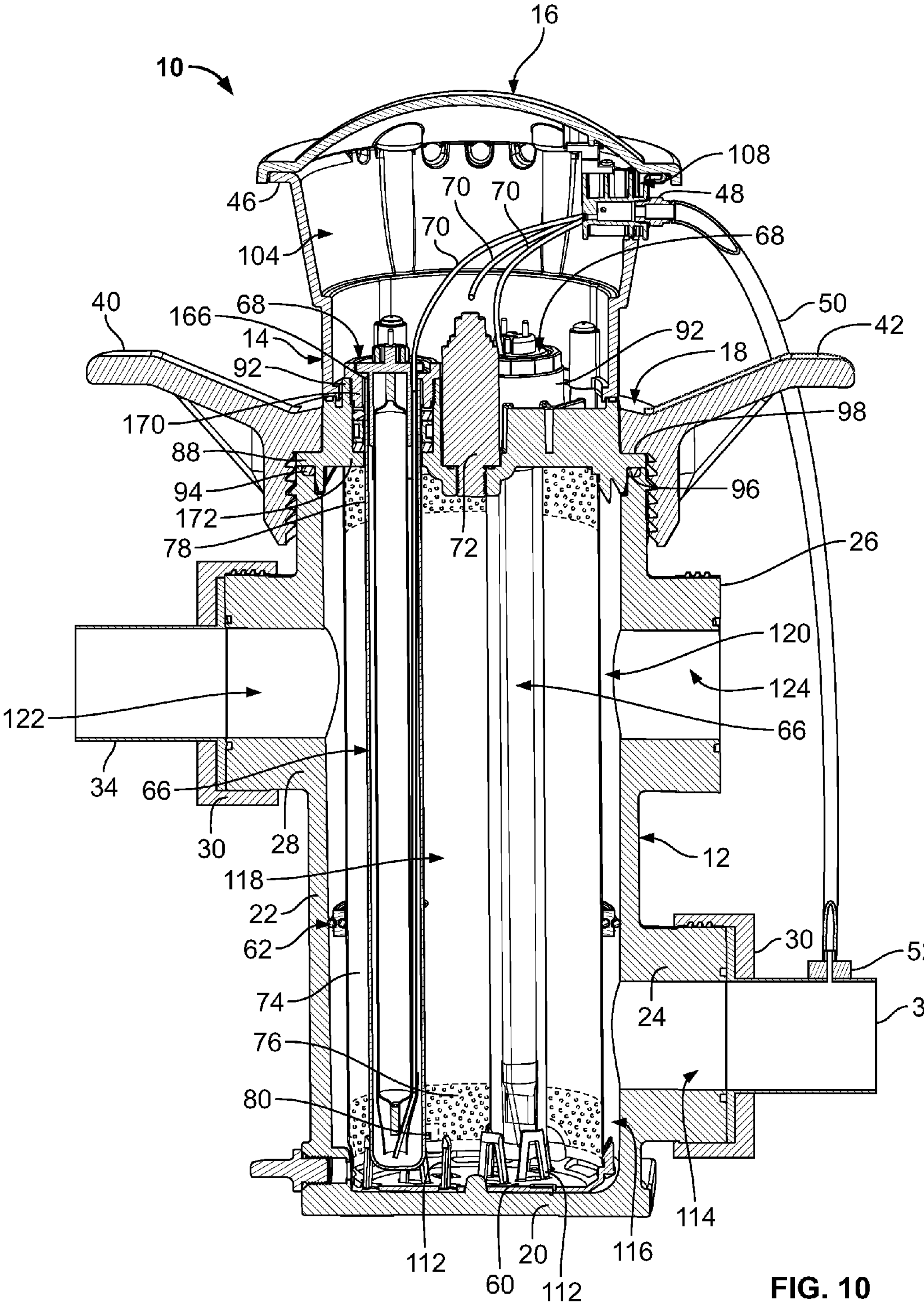

10
56
16
56
56
56
56
46
40
104
70
68
70
14
108
70
166
48
170
68
92
92
88
18
94
172
50
78
98
34
42
72
122
105
66
96
103
30
28
26
118
120
22
66
62
124
74
12
76
24
80
30
52
32
112
60
20
112
116
114

FIG. 9



10
16
108
48
70
70
46
70
68
104
40
68
50
42
166
92
14
18
92
98
170
88
94
96
172
72
78
26
120
124
122
66
34
66
30
28
12
118
22
62
30
52
74
24
32
76
80
114
116
112
20
60
112

FIG. 10

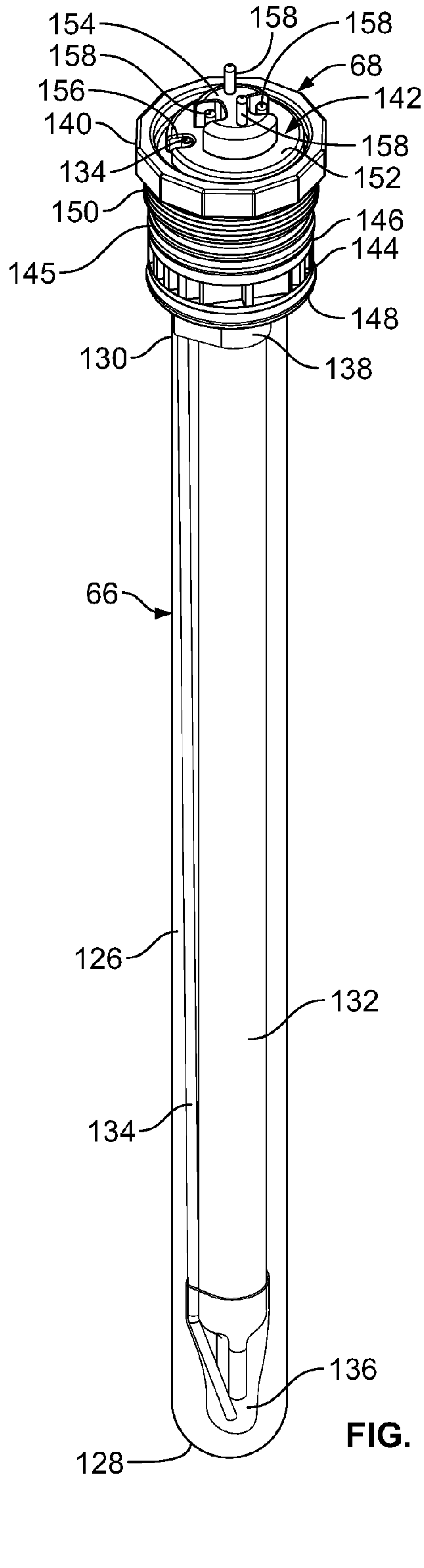

154
158
158
158
68
156
142
140
158
134
152
150
146
145
144
148
130
138
66
126
132
134
136
128

FIG. 11

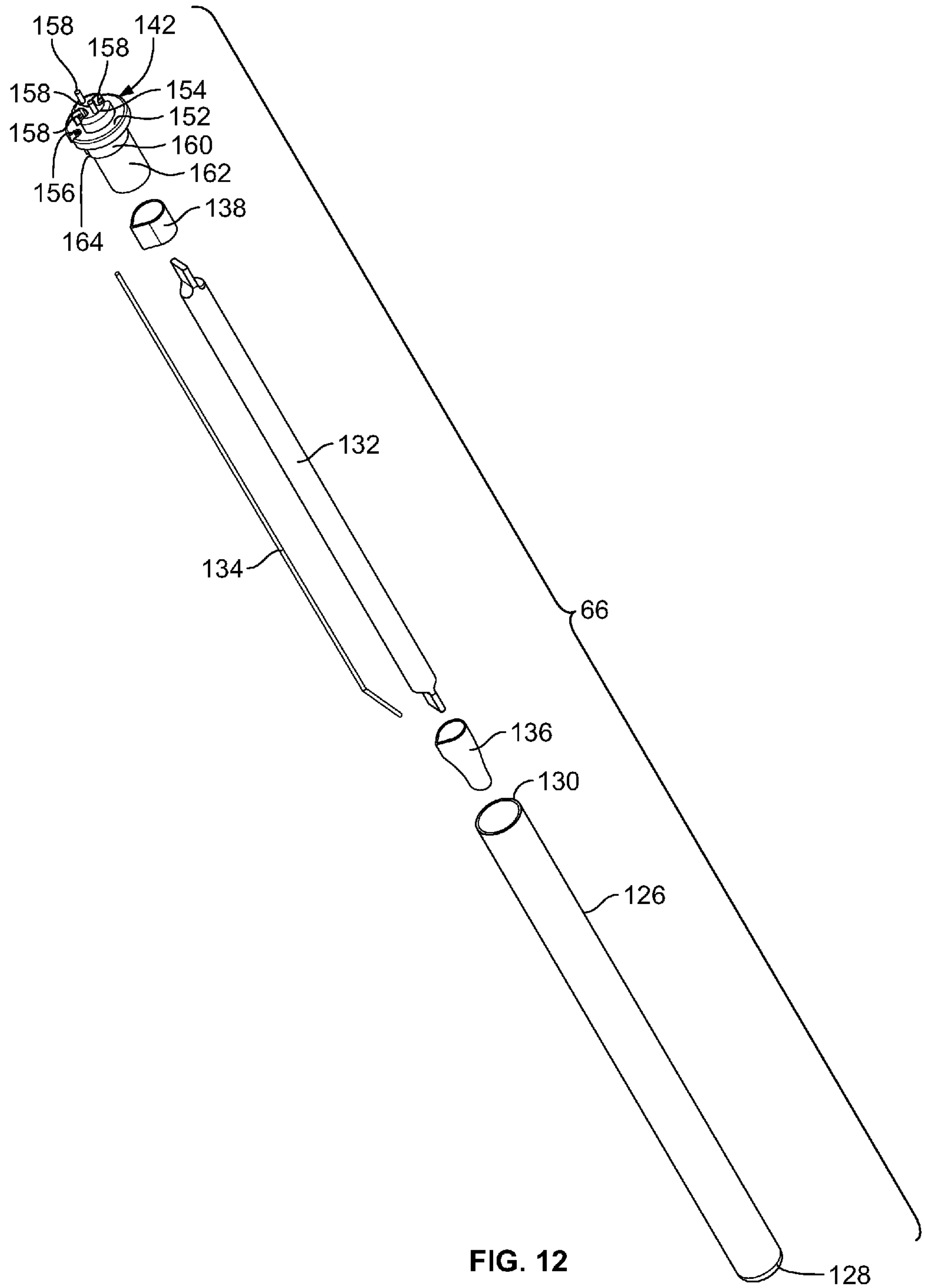

158
158
142
158
154
152
158
160
162
156
138
164
132
134
66
136
130
126
128

FIG. 12

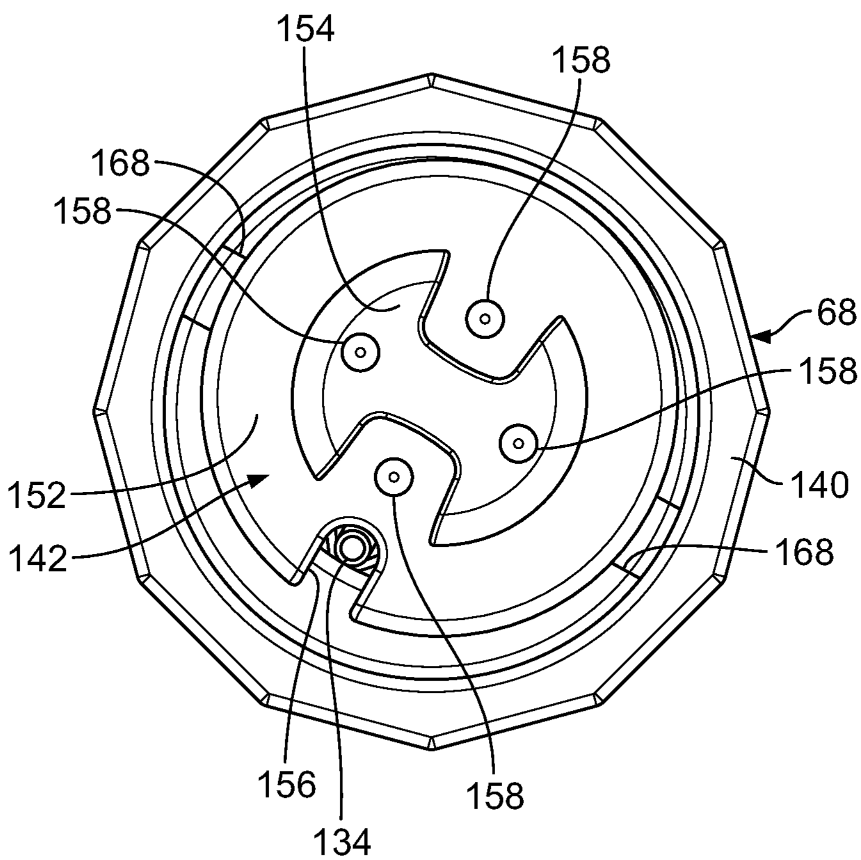


FIG. 13

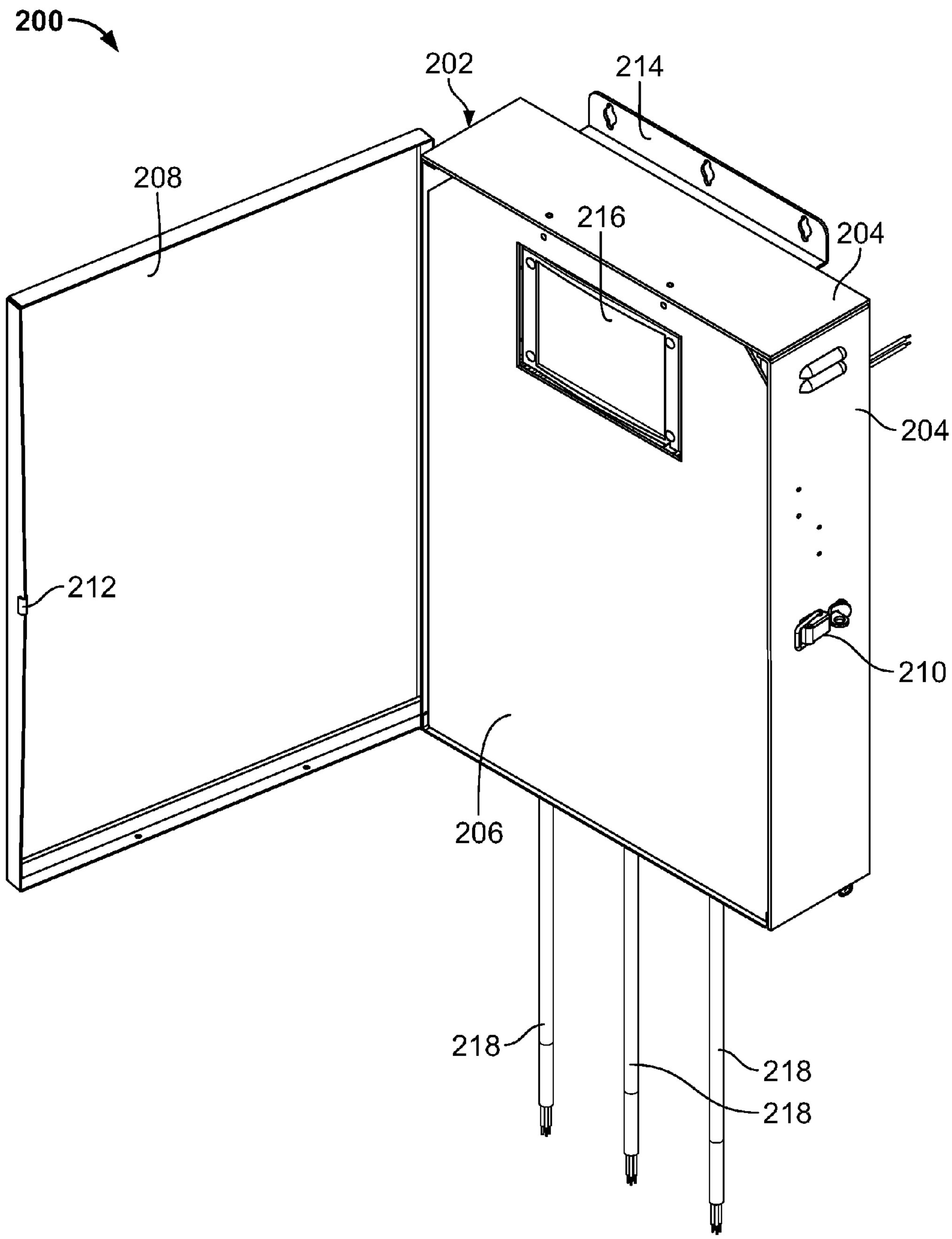


FIG. 14

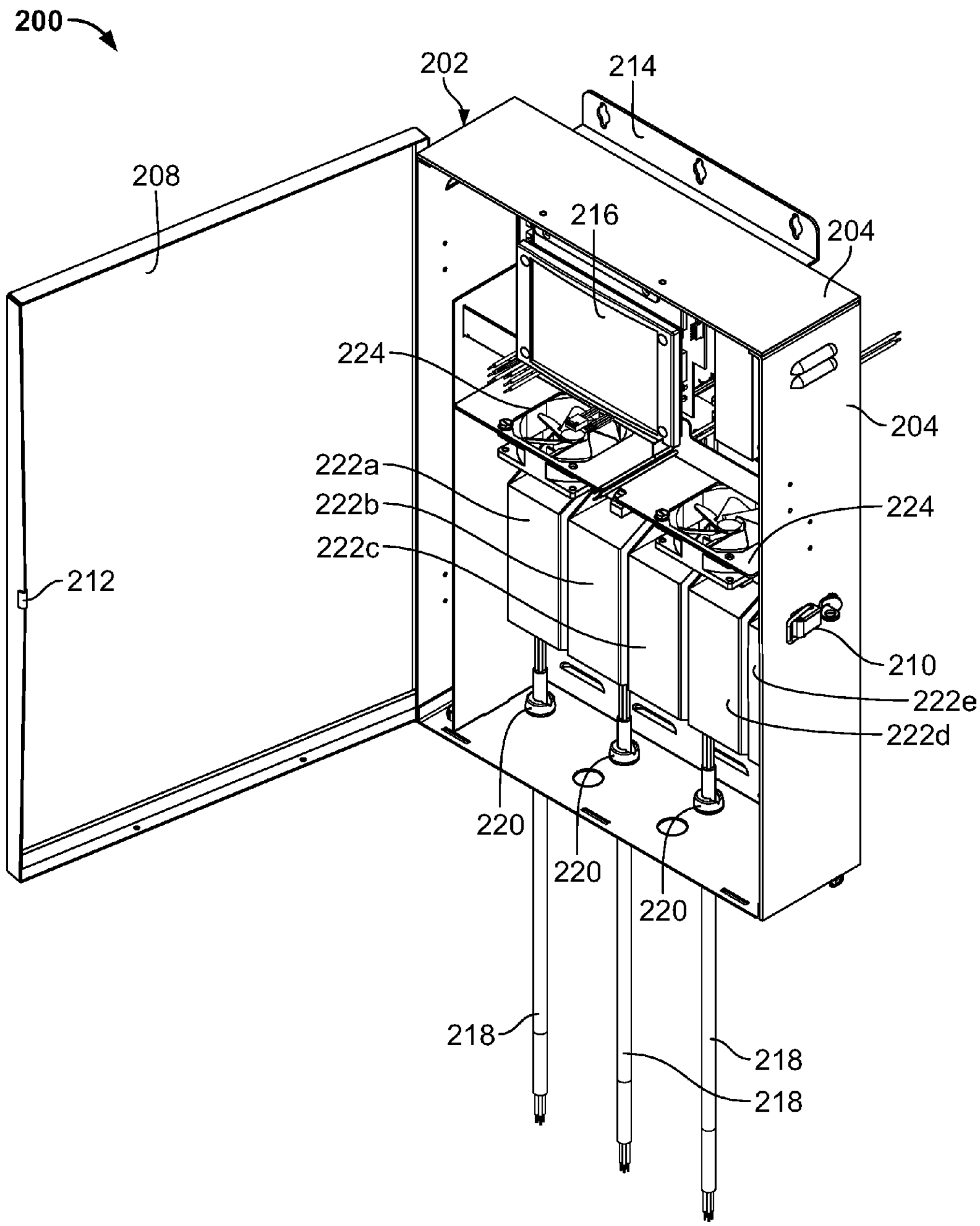

200
202
214
208
216
204
224
204
222a
222b
224
222c
212
210
222e
222d
220
220
220
218
218
218

FIG. 15

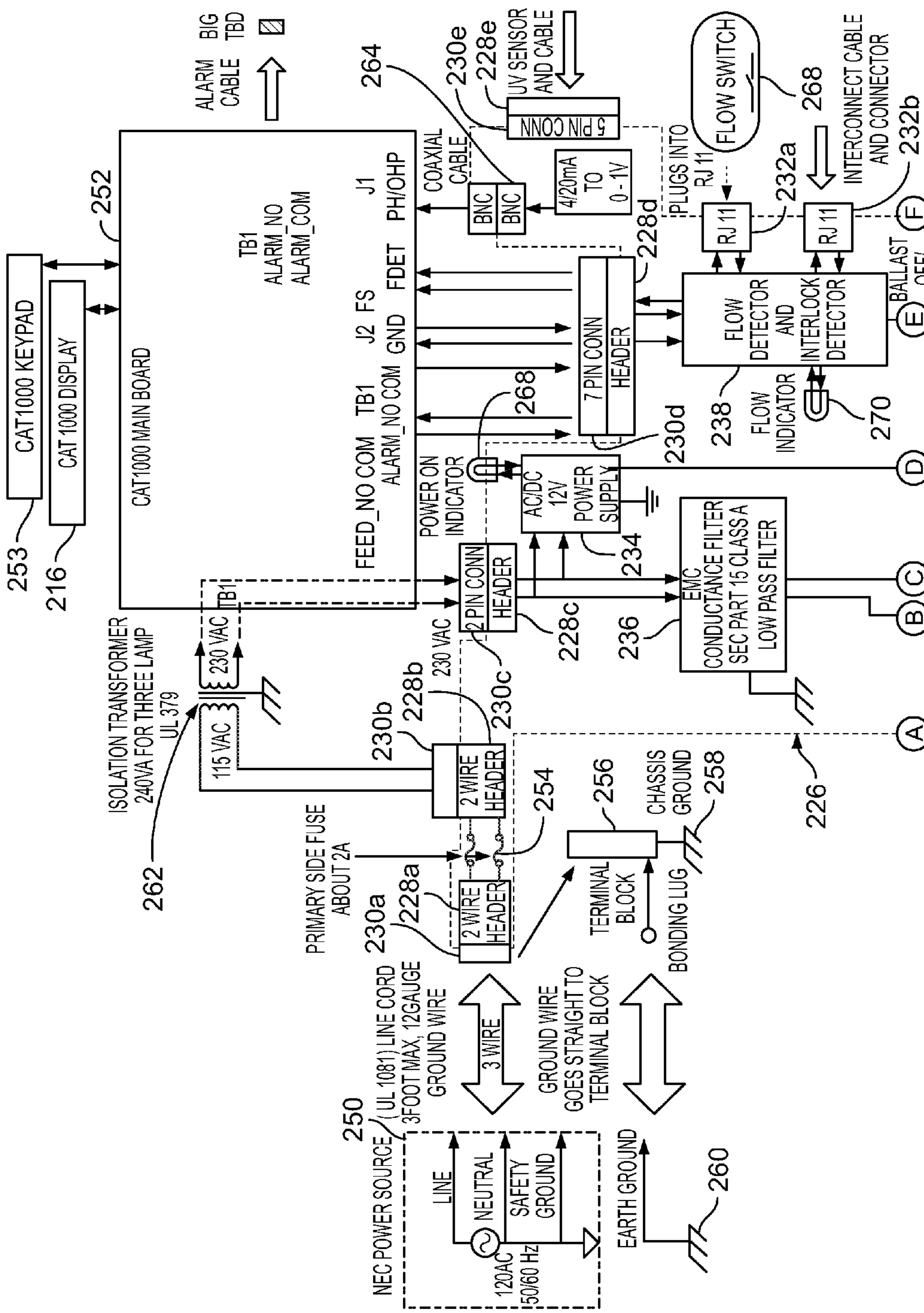

CAT1000 KEYPAD
CAT 1000 DISPLAY
CAT1000 MAIN BOARD
253
216
252
TB1
ALARM_NO
ALARM_COM
J1
PH/OHP
FDET
J2 FS
GND
TB1
ALARM_NO COM
FEED_NO COM
ALARM CABLE
BIG TBD
COAXIAL CABLE
BNC
BNC
264
230e
228e
UV SENSOR AND CABLE
5 PIN CONN
4/20mA TO 0 - 1V
228d
PLUGS INTO RJ 11
FLOW SWITCH
268
232a
RJ 11
RJ 11
INTERCONNECT CABLE AND CONNECTOR
232b
F
7 PIN CONN
HEADER
FLOW DETECTOR AND INTERLOCK DETECTOR
BALLAST OFF/ ALARM
E
238
FLOW INDICATOR
270
268
230d
POWER ON INDICATOR
AC/DC 12V POWER SUPPLY
D
234
EMC CONDUCTANCE FILTER SEC PART 15 CLASS A LOW PASS FILTER
C
B
236
2 PIN CONN
HEADER
228c
230c
230 VAC
230 VAC
TB1
ISOLATION TRANSFORMER 240VA FOR THREE LAMP UL 379
115 VAC
262
228b
230b
2 WIRE HEADER
A
226
PRIMARY SIDE FUSE ABOUT 2A
254
230a
228a
2 WIRE HEADER
256
TERMINAL BLOCK
CHASSIS GROUND
258
BONDING LUG
NEC POWER SOURCE
250
(UL 1081) LINE CORD 3FOOT MAX, 12GAUGE GROUND WIRE
3 WIRE
GROUND WIRE GOES STRAIGHT TO TERMINAL BLOCK
LINE
NEUTRAL
SAFETY GROUND
120AC 50/60 Hz
EARTH GROUND
260

FIG. 16

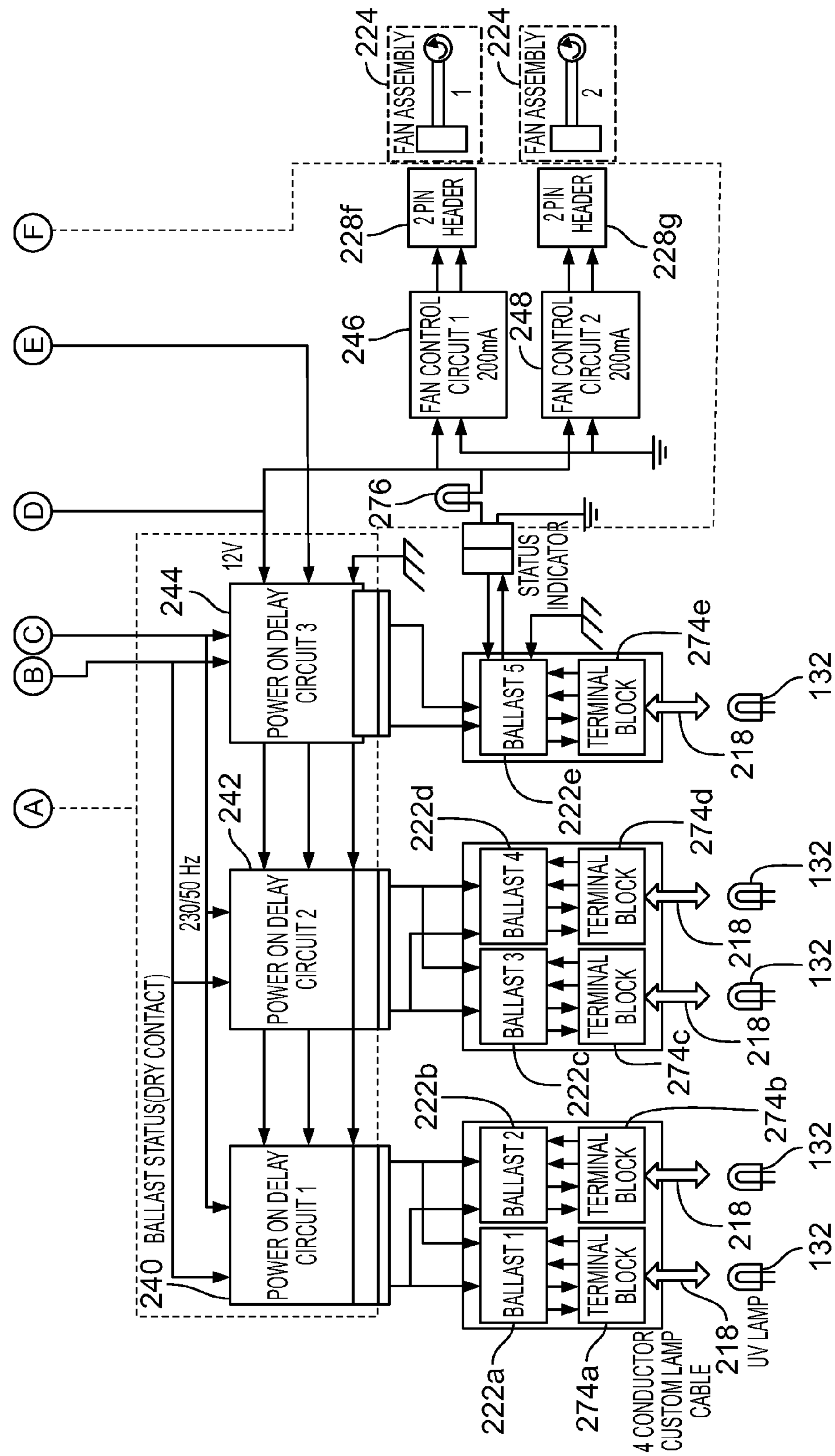

A
B
C
D
E
F
240
BALLAST STATUS(DRY CONTACT)
230/50 Hz
12V
242
244
POWER ON DELAY CIRCUIT 1
POWER ON DELAY CIRCUIT 2
POWER ON DELAY CIRCUIT 3
246
FAN CONTROL CIRCUIT 1 200mA
248
FAN CONTROL CIRCUIT 2 200mA
228f
2 PIN HEADER
228g
2 PIN HEADER
224
FAN ASSEMBLY
1
224
FAN ASSEMBLY
2
276
STATUS INDICATOR
222a
222b
222c
222d
222e
BALLAST 1
BALLAST 2
BALLAST 3
BALLAST 4
BALLAST 5
TERMINAL BLOCK
274a
274b
274c
274d
274e
218
132
4 CONDUCTOR CUSTOM LAMP CABLE
UV LAMP

FIG. 16 (Cont.)

COMBINED ULTRAVIOLET AND OZONE FLUID STERILIZATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of priority to U.S. Provisional Patent Application No. 62/043,087, filed on Aug. 28, 2014, the entire disclosure of which is expressly incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a fluid sterilization system and, more specifically, to a combined ultraviolet light and ozone fluid sterilization system for sterilizing fluid which includes a removable and replaceable internal reflective sleeve.

[0004] 2. Related Art

[0005] In general, fluid sanitization systems are known. For example, assemblies for sanitizing and/or disinfecting water have been developed. Fluid (e.g., water) sanitization assemblies are useful in a myriad of different environments for various uses/applications, such as commercial and/or industrial applications. In some sanitization systems, ultraviolet lights are used which can emit ultraviolet light in the 254 nanometer and 185 nanometer ranges (UVC). Ultraviolet light in the 254 nanometer range can effectively destroy the nucleic acids in microorganisms, disrupting DNA and removing reproductive capabilities to kill such organisms. Further, ultraviolet light in the 185 nanometer range can convert oxygen present in air into ozone, which can be introduced into the fluid for further sterilization.

[0006] Existing systems utilizing ultraviolet light often include internal reflective sleeves for reflecting the emitted ultraviolet light and increasing the effectiveness thereof. However, these sleeves can become tarnished, dented, or otherwise damaged over time. As a result, reflectivity and effectiveness decreases, thereby negatively affecting the fluid sterilization capabilities of the entire system, and sometimes necessitating replacement of the entire system because the reflective sleeves are not easily removed and/or replaced from such systems.

[0007] Thus, a need exists for a combined ultraviolet light and ozone fluid sterilization system having an easily accessible and replaceable internal reflective sleeve. This and other needs are addressed by the combined ultraviolet and ozone sterilization system of the present disclosure.

SUMMARY

[0008] The present disclosure is directed to a combined ultraviolet light and ozone fluid sterilization system for sterilizing fluid that includes a removable and replaceable internal reflective sleeve. The sterilization system includes a lower housing, an upper housing, a winged nut, a UV light manifold, a plurality of UV light assemblies, a plurality of UV light securing assembly, and a reflective sleeve. The lower housing defines a central cavity, has an open top and a closed bottom, and includes an inlet and one or more outlets. The inlet can be connected with an inlet fluid supply pipe, and one of the outlets can be connected with an outlet fluid pipe. The inlet pipe can include a venturi. The reflective sleeve is a tubular component that is perforated at both ends and includes a solid central portion. The reflective sleeve is removably positioned within the central cavity of the lower housing, and is removably secured with the lower housing by a plurality of locking tabs that engage the reflective sleeve. The upper housing is connectable to the UV light manifold, which is positionable adjacent the open top of the lower housing and connectable thereto. The UV light manifold and the lower housing can be secured with the winged nut. The UV light assemblies include a UV light and an ozone siphon pipe positioned within a quartz casing, which is sealed with an endcap. The UV light can generate UV light (e.g., UVC light), in both the 254 nanometer range and the 185 nanometer range. The UV light assemblies can each extend through, and be secured to, one of the plurality of UV light securing assemblies. The UV light manifold includes a plurality of UV light mounts, such that each of the UV light assemblies can be inserted into a respective UV light mount and a connected UV light securing assembly can be removably secured to the UV light mount.

[0009] The UV light assemblies are replaceable and can be removed from the UV light mount for replacement. The ozone siphon pipe of each UV light assembly can be operatively connected with the venturi, e.g., through a series of tubes, which can generate a suction effect to suction ozone generated by the UV lights through the ozone siphon pipe and introduce the ozone into the fluid stream. The positions and configuration of the reflective sleeve forces turbulent fluid to flow across the first perforated end and into the middle of the reflective sleeve where it is exposed to ultraviolet light, and then across the second perforated end where it exits the lower housing. The perforated ends of the reflective sleeve create a more uniform flow within the reflective sleeve, reduce air pockets, normalize the residence time of the fluid molecules, normalize the velocity of the fluid, and overall increase uniformity of treatment.

[0010] The sterilization system can be connected with a control panel that includes a controller, a plurality of ballasts, a plurality of fans, and a display. The controller can be connected with a main board for further control. The controller can include a plurality of power on delay circuits connected with the ballasts for delaying the start time of each ballast to prevent an overload situation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing features of the invention will be apparent from the following Detailed Description, taken in connection with the accompanying drawings, in which:

[0012] FIG. **1** is a perspective view of a fluid sterilization system in accordance with the present disclosure;

[0013] FIG. **2** is a front view of the fluid sterilization system of FIG. **1**;

[0014] FIG. **3** is a rear view of the fluid sterilization system of FIG. **1**;

[0015] FIG. **4** is a right side view of the fluid sterilization system of FIG. **1**;

[0016] FIG. **5** is a left side view of the fluid sterilization system of FIG. **1**;

[0017] FIG. **6** is a top view of the fluid sterilization system of FIG. **1**;

[0018] FIG. **7** is a bottom view of the fluid sterilization system of FIG. **1**;

[0019] FIG. **8** is an exploded view of the fluid sterilization system of FIG. **1**;

[0020] FIG. **8**A is a perspective view of another embodiment of the reflective sleeve of the present disclosure;

[0021] FIGS. **9-10** are sectional views of the fluid sterilization system taken along line **9-9** of FIG. **6**;

[0022] FIG. **11** is a perspective view of an ultraviolet light assembly and an associated light end cap assembly of the fluid sterilization system of FIG. **1**;

[0023] FIG. **12** is an exploded perspective view of the ultraviolet light assembly of FIG. **11**;

[0024] FIG. **13** is a top view of the ultraviolet light assembly and UV light end cap assembly of FIG. **11**;

[0025] FIG. **14** is a perspective view of a control panel for controlling the fluid sterilization system;

[0026] FIG. **15** is a perspective view of the control panel of FIG. **14**, showing the front cover removed and internal components of the control panel; and

[0027] FIG. **16** is an electrical schematic diagram of a controller included in the control panel of FIG. **14**.

DETAILED DESCRIPTION

[0028] The present disclosure relates to a combined ultraviolet light and ozone fluid sterilization system, as described in detail below in connection with FIGS. **1-16**.

[0029] With specific reference to FIGS. **1-10**, an ultraviolet ("UV") and ozone fluid sterilization system **10** is illustrated. In particular, FIG. **1** is a perspective view of the sterilization system **10**, and FIGS. **2-7** are respectively, front, rear, right side, left side, top, and bottom views of the sterilization system **10**. The sterilization system **10** can be installed in the return fluid line (e.g., fluid conduits) of a pool or spa filtration system, in industrial applications, or in the return fluid lines of aquariums. The sterilization system **10** includes a lower housing **12**, an upper housing **14**, a cap **16**, and a winged nut **18**. The lower housing **12** includes a base **20**, a tubular body **22**, an inlet port **24**, a first outlet port **26**, and a second outlet port **28**. The inlet port **24** can be located adjacent to the base **20** at a first end of the tubular body **22**, and the first and second outlet ports **26**, **28** can be located at a second end of the tubular body **22** opposite the first end. The first and second outlet ports **26**, **28** can be generally coaxial aligned and located opposite one another, and the inlet port **24** can be longitudinally aligned with one of the first or second outlet ports **26**, **28**. Generally, only one of the outlet ports **26**, **28** would be used while the other outlet port **26**, **28** can be sealed with a cap (not shown), but of course, both ports **26**, **28** could be used if desired. Positioning of the two outlet ports **26**, **28** opposite one another allows a user to install the sterilization system **10** at various locations based on where the return line to the pool or spa is located. The inlet port **24** and the outlet ports **26**, **28** can be externally threaded to allow an internally threaded fitting **30** to be threadably attached thereto. The fitting **30** can be configured to secure an inlet pipe **32** to the inlet port **24**, and an outlet pipe **34** to one of the outlet ports **26**, **28**.

[0030] The upper housing **14** is secured to the UV light manifold **64** by screws **110**. The UV light manifold **64** is secured to the lower housing **12** by the winged nut **18**. The winged nut **18** includes a body **36**, a central opening **38**, and first and second wings **40**, **42** that facilitate user attachment and detachment of the winged nut **18** to the lower housing **12**. The upper housing **14** includes a body **44**, an upper rim **46**, and an outlet port **48**. A venturi tube **50** is connected to the outlet port **48** of the upper housing **14** and runs to a venturi **52** that is positioned on the inlet pipe **32**. The outlet port **48**, venturi tube **50**, and venturi **52** are discussed in greater detail below. The cap **16** is positioned adjacent the upper rim **46** of the upper housing **14**, and is connected to the upper housing **14** by a plurality of screws **54**. When connected, the cap **16** and the upper housing **14** form a plurality of inlets **56**. The inlets **56** provide access points for various electrical cables/wiring.

[0031] FIG. **8** is an exploded perspective view of the sterilization system **10** of FIG. **1** showing the components in greater detail. The sterilization system **10** further includes a reflective sleeve **58**, a bottom plate **60**, an O-ring assembly **62**, a UV light manifold **64**, a plurality of UV light assemblies **66**, a plurality of UV light securing assemblies **68**, and a plurality of ozone siphon tubes **70**. The UV light manifold **64** includes a sensor **72** connected thereto. The sensor **72** can include a UV light intensity sensor and/or an interlock alarm. The UV light intensity sensor can measure the intensity of the UV light being emitted and generate an alarm if the UV light is below a certain percentage of a normal operating intensity, e.g., an audible alarm can be sounded if the UV light emitted is less than 70% of the normal operating intensity. The normal operating intensity can be calibrated when a new UV light bulb is inserted and based thereon. The interlock alarm can turn the UV light assemblies **66** off when the system **10** is opened so that a user's eyes are not directly exposed to the illuminated UV light assemblies **66**.

[0032] The reflective sleeve **58** is tubular in shape and has a solid central annular portion **74**, a perforated lower annular portion **76**, and a perforated upper annular portion **78**. The reflective sleeve **58** connects to the bottom plate **60** by a plurality of snap-style locking tabs **80**. The locking tabs **80** removably secure the reflective sleeve **58** in place, and allow the reflective sleeve **58** to be removed. Additionally, the reflective sleeve **58** is secured to the UV light manifold **64**, which can include a plurality of locking tabs such as the locking tabs **80**. Optionally, a separate and independent top plate could be provided and connected to the reflective sleeve **58**. As such, the reflective sleeve **58** is removable and replaceable. This is beneficial as the reflective sleeve **58** can become tarnished over time, damaged, or dented for various reasons. In such instances, the reflective sleeve **58** could have a reduced level of reflectivity. When the reflectivity of the sleeve **58** is reduced, it can be desirable to remove and replace the damaged reflective sleeve **58** with a new one. In such circumstances, a user would simply disassemble the sterilization system **10**, remove the damaged reflective sleeve **58**, and replace it with a new reflective sleeve. Alternatively, a user can remove the reflective sleeve **58** for cleaning and/or maintenance purposes. The reflective sleeve **58** is generally formed of a material that reflects ultraviolet light and does not absorb ultraviolet light. For example, the reflective sleeve **58** can be made of, or coated with, a plurality of different materials, including, but not limited to, stainless steel, composites, reflectively coated thermoplastics, reflective PTFE or PFA, etc. It is noted that perforations need not be provided on the sleeve **58**, and that a single opening could be provided on each of the top and bottom portions of the sleeve **58**, if desired, to allow water inflow and outflow for the sleeve **58** while still achieving the desired flow characteristics through the sleeve **58**.

[0033] An alternative embodiment of the reflective sleeve **58** is shown in FIG. **8**A, which is a perspective view of an alternative reflective sleeve **58***a*. The alternative reflective sleeve **58***a* includes a plurality of cut-outs **79***a* that replace the perforated lower and upper annular portions **76**, **78** of the reflective sleeve **58** and form stand-offs **79***b*. The lower stand-offs **79***b* engage the bottom plate **60**. Fluid flows across the cut-outs **79***a* of the sleeve **58***a* (as it would flow through the perforated annular portions **76**, **78** of the reflective sleeve **58**). The sleeve **58***a* of FIG. **8**A is similar in structure and construction to the reflective sleeve **58** of FIG. **8** and includes all the same characteristics thereof except where identified otherwise.

[0034] The perforations of the sleeve **58** shown in FIG. **8** can be used to increase open flow area without losing 100% of the reflective surface for a particular area. Particularly, if a perforation size and pattern is chosen with an open area of 45%, then 55% of the stainless steel around the perforations remains intact and contributes to the reflectivity of the sleeve **58** in the perforated lower and upper annular portions **76**, **78**. This is in contrast to a configuration where an entire region, e.g., 100% of an area, is removed to accommodate for an opening, wherein the reflectivity contribution would be lost in this area and would not be evenly distributed around an inner surface of the sleeve. Additionally, the perforations in the sleeve **58** increase the exposure time of some of the water entering the sleeve **58** because the perforations allow some UV light to escape the confines of the sleeve **58** and start exposing the water to UV before it enters the sleeve **58**.

[0035] As illustrated in FIG. **8**, the lower housing **12** defines a central cavity **82** and includes an upper opening **84**. The lower housing **12** receives the reflective sleeve **58** through the upper opening **84**, and houses the reflective sleeve **58** in the central cavity **82** thereof. When the reflective sleeve **58** is within the central cavity **82** of the lower housing **12**, the O-ring assembly **62** engages an internal wall of the lower housing tubular body **22**, and the outer wall of the solid center portion **74** of the sleeve **58** and creates a generally fluid-tight seal between the solid center portion **74** of the reflective sleeve **58** and the lower housing tubular body **22**. The fluid-tight seal created by the O-ring assembly **62** mechanically separates the central cavity **82** into an untreated portion and a treated portion, as discussed in greater detail below. Additionally, this seal prevents the bypass of untreated water into the treated water portion, thus ensuring that all of the fluid flowing through the vessel is treated.

[0036] The UV light manifold **64** includes an annular wall **86**, an annular flange **88** extending radially from the annular wall **86**, a plurality of mounting holes **90**, and a plurality of UV light mounts **92**. The UV light manifold **64** includes a number of mounting holes **90** and UV light mounts **92** corresponding to the number of UV light assemblies **66** to be implemented in the system **10**. In some embodiments, the UV light manifold **64** is interchangeable such that a user can have different UV light manifolds **64** for accommodating different specific applications. For example, the UV light manifold **64** can have a different number of UV light assemblies **66**, e.g., three, four, five, etc. In such instances, a user might desire more or less UV light assemblies **66** based upon the need to increase or decrease the intensity and/or dosage of the UV light. The UV light manifold **64** is positionable over the lower housing **12** with the annular flange **88** being adjacent the upper opening **84** of the lower housing **12**. The upper opening **84** can include a groove **94** that houses an O-ring **96**. When the UV light manifold **64** is positioned adjacent the upper opening **84**, the O-ring **96** is within the groove **94** and between the UV light manifold annular flange **88** and the groove **94**. The winged nut **18** includes an annular shoulder **98** that extends radially inward to form the central opening **38**, and internal threading **100**. The winged nut **18** can be positioned over the UV light manifold **64** and threadedly secured to the lower housing **12** through engagement of the winged nut's internal threading **100** with external threads **102** of the lower housing **12**, which are adjacent the groove **94** and upper opening **84**. As the winged nut **18** is threadedly engaged with the lower housing **12**, the annular shoulder **98** of the winged nut **18** engages the UV light manifold annular flange **88**. Further tightening of the winged nut **18** compresses the O-ring **96** between the UV light manifold annular flange **88** and the groove **94**, creating a water-tight seal.

[0037] Additionally, the groove **94** can include one or more notches **103** while the UV light manifold **64** can include one or more bosses **105** extending from a bottom of the annular flange **88**. The bosses **105** are sized and positioned to engage the notches **103** when the UV light manifold **64** is placed over the lower housing **12**. The spacing and engagement of the bosses **105** with the notches **103** ensures proper orientation and alignment of the UV light manifold **64**, and subsequently the UV light assemblies **66**, relative to the inlet port **24** and outlet ports **26**, **28** during assembly of the sterilization assembly **10**.

[0038] The upper housing **14** can also be attached to the UV light manifold **64**. Specifically, the upper housing **14** defines an interior space **104**, and includes internal mounts **106** and a siphon tube manifold **108** that includes the outlet port **48**. A portion of the upper housing body **44** is configured to be positioned over the annular wall **86** of the UV light manifold **64**, and connected to the UV light manifold **64** by a plurality of screws **110** that engage the plurality of mounting holes **90** of the UV light manifold **64**. The cap **16** is then attached to the upper housing **14** by screws **54**.

[0039] FIG. **9** is a first sectional view of the sterilization system **10**, and FIG. **10** is a second sectional view of the sterilization system **1**, both taken along the line **9**-**9** of FIG. **6**. As can be seen in FIGS. **9** and **10**, when the sterilization system **10** is fully assembled, the UV light assemblies **66** are positioned within the interior of the reflective sleeve **58**, which is positioned within the lower housing **12**. The UV light assemblies **66** generally extend the length of the reflective sleeve **58** to the bottom plate **60**. The bottom plate **60** includes a plurality of positioning tabs **112** that form groups matching the UV light assemblies **66**. The positioning tabs **112** are located on the bottom plate **60** so that each group is aligned with a respective UV light assembly **66** and surrounds a bottom portion of the respective UV light assembly **66**. Accordingly, the positioning tabs **112** act to position the UV light assemblies **66** and prevent the UV light assemblies **66** from lateral movement.

[0040] When the sterilization system **10** is fully assembled, there are a plurality of distinct regions for fluid flow. Specifically, there is an inlet flow region **114**, a pre-sterilization region **116**, a sterilization region **118**, a post-sterilization region **120**, a first outlet flow region **122**, and a second outlet flow region **124**. The pre-sterilization region **116**, sterilization region **118**, and post-sterilization region **120** are within the tubular body **22** of the lower housing **12**. The inlet flow region **114** is formed by the inlet port **24** and provides fluid to the pre-sterilization region **116**, which is internal to the lower housing **12**. The pre-sterilization region **116** is an annular region formed external to the sleeve **58**, and between the sleeve **58**, the tubular body **22**, and the O-ring assembly **62**. The pre-sterilization region **116** is adjacent the inlet flow region **114**. The sterilization region **118** is a tubular flow region that is internal to the sleeve **58**. The post-sterilization region **120** is similar to the pre-sterilization region **116**, and is an annular region formed external to the sleeve **58** between the sleeve **58**, the tubular body **22**, and the O-ring assembly **62**. The post-sterilization region **120** is adjacent the first and second outlet flow regions **122**, **124**. The pre-sterilization region **116** and the post-sterilization region **120** are external to the sleeve **58** and separated from one another by the O-ring assembly **62**. The flow of fluid through the sterilization system **10** is discussed in greater detail below.

[0041] FIGS. **11-13** show the UV light assemblies **66** and UV light securing assembly **68** in greater detail. Each of the UV light assemblies **66** further include a quartz casing **126** having a closed lower end **128** and an open upper end **130**, a low pressure ultraviolet amalgam lamp **132**, an ozone siphoning pipe **134**, a first fastener **136**, a second fastener **138**, and an end cap **142**. The UV light securing assembly **68** includes a securing collar **140**, a spacer **144**, a washer **145**, and first and second O-rings **146**, **148**. The spacer **144**, the washer **145**, and the first and second O-rings **146**, **148** are placed around the quartz casing **126**, with the spacer **144** being placed between the first and second O-rings **146**, **148**, and the washer **145** being placed between the first O-ring **146** and the securing collar **140**. The first and second O-rings **146**, **148** engage the quartz casing **126** and the respective UV light mount **92** when the UV light assembly **66** is installed therein to create a water proof seal therewith.

[0042] The securing collar **140** includes an externally threaded wall **150** for securing with one of the UV light mounts **92**. The end cap **142** includes a base **152** and a shaped boss **154** extending from the base **152**. The base **152** includes a removed section or notch **156** that provides a space for the ozone siphoning pipe **134** to extend through and connect with one of the ozone siphon tubes **70**. A plurality of electrical contact pins **158** extend through the end cap **142**. As shown, two contact pins **158** extend through the end cap base **152** and two contact pins **158** extend through the end cap boss **154**, each of which is in electrical communication with the UV amalgam lamp **132**. The shaped boss **154** is generally shaped with a matching geometry to a plug (not shown) for connecting the UV light assembly **66** with a power and/or control source.

[0043] As shown in FIG. **12**, which is an exploded view of the light assembly **66**, the end cap **142** also includes a centered cylindrical wall **160** extending from the base **152** and an off-center cylindrical wall **162** extending from the centered cylindrical wall **160**. The centered cylindrical wall **160** includes a notch **164** that is aligned with the base notch **156**. This off-centered arrangement allows the ozone siphoning pipe **134** to extend along the off-centered cylindrical wall **162**, and across the centered cylindrical wall notch **164** and the base notch **156**.

[0044] The UV light assemblies **66** are each configured as follows: the securing collar **140** is placed over the centered and off-center cylindrical walls **160**, **162** of the end cap **142** such that the securing collar **140** is adjacent the end cap base **152**. The UV lamp **132** is secured with the ozone siphoning pipe **134** by the first and second fasteners **136**, **138**, such that the ozone siphoning pipe **134** generally extends across the entirety of the UV lamp **132**. The first and second fasteners **136**, **138** retain the ozone siphoning pipe **134** in close proximity to the UV lamp **132**. The UV lamp **132** is inserted into the off-center cylindrical wall **162** of the end cap **142** and engages the contact pins **158** extending through the end cap **142**. The ozone siphoning pipe **134** is positioned on the outside of the off-center cylindrical wall **162** and extends across the centered cylindrical wall notch **164** and the base notch **156**. The quartz casing **126** is positioned over the UV lamps **132**, the first and second fasteners **136**, **138**, the ozone siphoning pipe **134**, the end cap centered cylindrical wall **160**, and the end cap off-center cylindrical wall **162**, and is between the interior face of the externally threaded wall **150** of the securing collar **140** and the end cap's centered cylindrical wall **160**. The open end of the quartz casing **126** abuts an internally extending radial shoulder **166** (see FIG. **9**). The washer **145**, the first O-ring **146**, the spacer **144**, and the second O-ring **148** are then placed over the quartz casing **126** with the washer **145** abutting the bottom of the securing collar's externally threaded wall **150**. As can be seen in FIG. **13**, which is a top view of the UV light assembly **66**, the securing collar **140** includes a plurality of vents **168** that provide access for air, e.g., oxygen, to flow into the quartz casing **126**, the importance of which is discussed below.

[0045] Each UV light assembly **66** can be attached to a UV light securing assembly **68** and inserted into a respective UV light mount **92** and secured thereto through threaded engagement of the externally threaded wall **150** of the securing collar **140** with an internally threaded wall **170** of the respective UV light mount **92** (see FIGS. **9** and **10**). When the UV light assembly **66** and the UV light securing assembly **68** is fully engaged with the UV light mount **92**, the UV lamp **132** and quartz casing **126** are positioned within the lower housing **12**. Additionally, the first O-ring **146** and second O-ring **148** are compressed between an inwardly extending circumferential shoulder **172** of the UV light mount **92** and the bottom of the externally threaded wall **150** of the securing collar **140**, and also compressed between an interior wall of the UV light mount **92** and the quartz casing **126**, thus creating a fluid tight seal so that fluid flowing through the lower housing **12** does not escape into the upper housing **14**. Additionally, when the UV light assembly **66** is fully inserted into the lower housing **12**, each quartz casing **126** is positioned between, and secured by, a set of positioning tabs **112** located on the bottom plate **60**. Once each UV light assembly **66** is installed, a respective siphon tube **70** is connected to a portion of the siphoning pipe **134** that extends from the end cap **142**.

[0046] The UV lamps **132** are preferably low-pressure, amalgam ultraviolet lamps that generate two different wavelengths, e.g., about 254 nanometers (254 nm) and about 185 nanometers (185 nm) of UVC light. The UVC light emitted in the 254 nm range can effectively destroy the nucleic acids in microorganisms, which disrupts their DNA and removes their reproductive capabilities, eliminating the formation of subsequent generations, and eventually killing them. Accordingly, the 254 nm wavelength UV light disinfects and sanitizes the water. Additionally, as discussed above, the sleeve **58** is made of a reflective material, e.g., stainless steel, so that the generated UV light reflects off of the sleeve **58** to increase the exposure of the water to the 254 nm wavelength UV light. Additionally, the sleeve **58** reduces UV exposure of the lower housing **12** itself, which may be constructed of a clear UV-resistant plastic polymer that can be damaged over time due to excessive UV exposure. Thus, the sleeve **58** prolongs the life of the lower housing **12**, as well as any other components constructed from the plastic polymer. The UVC light emitted in the 185 nm range is utilized for ozone generation. Particularly, the UVC light emitted in the 185 nm range converts oxygen to ozone through corona discharge and the passing of air containing oxygen over the UV lamps **132**. Therefore, the oxygen contained within the air between the quartz casing

126 and the UV lamp 132 is converted into ozone by the 185 nm wavelength UV light emitted by the UV lamp 132. As the ozone is generated, it is contained by the quartz casing 126 and drops to the bottom of the lower end 128 of the quartz casing 126 because the generated ozone has a greater density than air. The generated ozone is removed from the quartz casing 126 and introduced into the fluid stream through a tubing system in which the siphoning pipes 134 are connected to the siphon tubes 70 that, in turn, are connected to the siphon tube manifold 108 which, in turn, is connected with the venturi tube 50, which is finally connected with the venturi 52 located on the inlet pipe 32. When water flows through the inlet pipe 32 and into the lower housing 12 a pressure differential is created in the venturi 52 causing a suction effect to occur in the venturi tube 50 connected with the venturi 52. This suction effect causes the siphoning pipes 134 to draw ozone from the bottoms of the quartz casings 126, through the siphoning pipes 134, the siphoning tubes 70, the siphon tube manifold 108, the venturi tube 50, and the venturi 52, whereupon the ozone is introduced/injected into the water flowing through the inlet pipe 32. As the ozone is removed, air is drawn into the quartz casing 126 through the plurality of vents 168 that are provided in the securing collar 140, which are open to atmosphere. Accordingly, the oxygen supply is constantly being replenished as ozone is generated. The ozone that is introduced into the water acts to oxidize, and thus destroy, organic matter, further sterilizing the water. It is noted that the UV lamps 132 need not emit wavelengths in both the 254 nanometer range and the 185 nanometer range, and that the UV lamps 132 could emit a single wavelength of light, if desired.

[0047] Turning now to the flow of fluid through the sterilization system 10, fluid generally flows into the sterilization system 10 at the inlet port 24 and exits the sterilization system 10 at one of the first and second outlet ports 26, 28. The fluid flowing through the sterilization system 10 generally flows in a serpentine pattern due to the orientation of the flow regions, which will now be discussed in greater detail. Particularly, fluid is provided to the system 10 by the inlet pipe 32 and generally flows through the system 10 as follows: from the inlet flow region 114, to the pre-sterilization region 116, to the sterilization region 118, to the post-sterilization region 120, and finally to one of the first and second outlet flow regions 122, 124 where the water is circulated to the pool or spa by the outlet pipe 34. The inlet pipe 32 is in fluidic communication with the pool or spa, such that the water flowing through the inlet pipe 32 is pool/spa water that is recirculated to the pool/spa after sterilization by the outlet pipe 34.

[0048] Fluid is first introduced to the system 10 at the inlet pipe 32 where it flows across the inlet flow region 114 and the venturi 52. As the fluid flows across the venturi 52, a pressure differential is created in the venturi 52 and ozone is suctioned therethrough, as discussed above, and introduced into the flow. As the liquid flows from the inlet flow region 114 to the pre-sterilization region 116, the fluid flows towards the perforated lower annular portion 76 of the sleeve 58. The fluid then flows across the perforated lower portion 76 of the sleeve 58 and into the sterilization region 118 within the sleeve 58. The UV light assemblies 66 are positioned within the sterilization region 118, such that they sterilize fluid flowing through the sterilization region 118. Accordingly, the fluid flows through the sterilization region 118, and across the UV light assemblies 66, and toward the perforated upper annular portion 78. The fluid is sterilized by the UV light assemblies 66 while it is in the sterilization region 118, as well as by the ozone introduced by the venturi 52 in the inlet flow region 114. The fluid then flows across the perforated upper portion 78 and into the post-sterilization region 120. From there, the fluid flows into one of the first and second outlet flow regions 122, 124, exits through one of the first and second outlet ports 26, 28, and is returned to the pool/spa through the outlet pipe 34.

[0049] The fluid flowing into the system 10 and toward the perforated lower portion 76 is generally very turbulent prior to flowing across the perforated lower portion 76 and into the sterilization region 118. However, the perforated lower portion 76 is specifically designed to create a more uniform flow within the sterilization region 118, reduce air pockets, normalize the residence time of the fluid molecules, normalize the velocity of the fluid, and increase uniformity of treatment. Without the perforated lower portion 76, the fluid flowing through the system 10 would be very turbulent and generally random, meaning that some of the fluid molecules may flow through the entire system very quickly, e.g., have a low residence time, while other fluid molecules may take a very long time to flow through the system, e.g., have a high residence time. In this situation, there would be a discrepancy between treatment and sterilization of the fluid molecules that form the flowing fluid, with some of the fluid molecules not having a sufficient “residence” time to be fully sterilized.

[0050] As described above, with the sleeve 58 installed in the lower housing 12, water is forced into a more controlled flow pattern where it cannot flow directly from the inlet to the outlet, but instead must flow in a serpentine pattern. Essentially, the water flows through the system 10 in a controlled plug flow pattern that enhances the effectiveness of the sterilization system 10. Additionally, the sleeve 58 reduces air buildup and/or entrapment of air in the top of the lower housing 12, especially at lower flow rates. This occurs because the sleeve 58 creates a “stovepipe” effect where the flow is forced over the top of the sleeve 58, e.g., through the perforated upper annular portion 78, which evacuates air from the top portion of the central cavity 82. Additionally, the perforated lower portion 76 and the perforated upper portion 78 lower the pressure across the system 10, and can result in greater open flow area that reduces the head loss through the system 10. Further, the sleeve 58 can be sized so that the annular regions between the sleeve 58 and the inside wall of the lower housing 12, e.g., the pre-sterilization region 116 and the post-sterilization region 120, are sized with an open area equal to or greater than the port area of the pipes 32, 34 connected to the sterilization system 10, resulting in reduced head loss through the sterilization system 10.

[0051] Further, the perforations included in the sleeve 58 act as a baffle with the effect of causing large bubbles of air or gas, e.g., ozone, to break apart, resulting in smaller bubble sizes, which in turn can result in a greater mass transfer through the unit thus enhancing the sterilization performance of the system 10. Additionally, utilizing a cylindrical sleeve, e.g., sleeve 58, as a baffle provides greater surface area to generate a baffle effect than traditional baffles, which are generally flat, perforated plates. The traditional flat, perforated plate baffles are limited in surface area to less than the cross-sectional area of an associated pipe or vessel, while the cylindrical sleeve 58 is capable of having an increased surface area for generating a baffle effect.

[0052] The perforations included in the perforated upper and lower annular portions 76, 78 can be any size and/or shape, and can also be patterned to shape the flow into, across, and out of the sleeve **58**, as well as direct flow to different parts of the vessel to enhance treatment of the water. For example, a mixture of small and large perforations can be included, with the small perforations being on a portion of the perforated upper and lower annular portions **76**, **78** adjacent the inlet flow region **114** and one of the outlet flow regions **122**, **124** and the large perforations being on an opposite side of the small perforations. Such a configuration could allow more equal distribution of flow and more normalized fluid velocities through the sterilization region **118**. In another example, varying patters of perforations around the perforated upper and lower annular portions **76**, **78** could be utilized to direct flow to desired sections of the sterilization region **118** and to optimize head loss characteristics within the lower housing **12**. The perforations included in the upper and lower annular portions **76**, **78** could be patterned to allow light to escape the sleeve **58** in a desired pattern or orientation, such that a company logo or other indicia can be displayed when the sterilization system **10** is operating in order to achieve a desired aesthetic or marketing goal.

[0053] Additionally, the sleeve **58**, and more specifically the perforated upper and lower annular portions **76**, **78** thereof, can be utilized to strain fluid entering the sterilization region **118** to prevent ingress of debris into the sterilization region **118**, which could damage the UV light assemblies **66**, and particularly the quartz casing **126**. Further, the sleeve **58** and the perforated upper and lower annular portions **76**, **78** thereof can be used to strain fluid leaving the sterilization region **118** to prevent the egress of debris from the treatment chamber in the event that the quartz casings **126**, or other component of the UV light assemblies **66**, are damaged, e.g., fractured.

[0054] The sleeve **58** also significantly reduces, or eliminates, direct impingement of incoming fluid on the quartz casings **126**, reducing the likelihood of fracturing the quartz casings **126** due to the force of flow through the system **10**, e.g., at startup. The sleeve **58** additionally reduces vibration of the quartz casings **126** during operation since the perforated upper and lower annular portions **76**, **78** thereof redirects flow around the sleeve **58**, thus reducing the turbulence of flow and forces that would otherwise act directly on, and result in extreme vibration of, the quartz casings **126**.

[0055] Furthermore, the O-ring assembly **62**, and the fluid-tight seal created thereby, ensures that there are no stagnant areas in the lower housing **12** during operation, thereby eliminating the possibility of waterborne buildup of bacteria, etc., in the areas within the vessel that are not exposed to UV light. In shut-off conditions, all fluid that was retained in the sterilization region **118** and the post-sterilization region **120** has been treated, while all fluid in the pre-sterilization region **116** will be automatically forced through the sterilization region **118** once the system **10** is restarted, ensuring that no untreated water leaves the system **10**.

[0056] The present disclosure provides for additional modularity in implementation, whereby a user can mix lamps of different intensities and/or wavelengths within the same unit. For example, in a three lamp system, such as the one illustrated in connection with FIGS. **1-10**, a user may desire to have one UV lamp at a first intensity and the other two UV lamps at a higher or lower intensity so that different treatment zones could be created within the system. Additionally and/or alternatively, a user may desire to have one UV lamp generating only 185 nm wavelength UV light for the production of ozone, while the other two UV lamps generate 254 nm wavelength UV light for the purpose of direct treatment of the fluid. The modularity of the lamps can be combined with the perforation design discussed above to further create various treatment zones as well as optimize performance. For example, in areas of the system where fluid velocities are higher, a higher intensity lamp could be positioned to normalize the dosage of UV light with areas of lower fluid velocities, which could have lower intensity UV lamps installed therein. This modularity allows for a user to achieve different results based on a desired application.

[0057] FIGS. **14** and **15** show the control panel **200** of the present disclosure. The control panel **200** includes a housing **202** having a body **204**, a front cover **206**, and a cover panel **208** pivotably mounted to the body **204**. The housing **204** includes a latch **210** that is configured to engage a hook **212** on the cover panel **208** such that the latch **210** can be secured with the hook **212** so that the cover panel **208** is secured across the front cover **206**. The housing **204** further includes a mounting bracket **214** that assists with mounting the control panel **200** to a wall. The control panel **200** further includes a display **216** and a plurality of cables **218** that extend from the control panel **200** to the sterilization system **10** to provide power and control of the UV light assemblies **66**. The cables **218** can access the sterilization system **10** through the plurality of inlets **56**. Additionally, the cables **218** can each include a plug (not shown) that can mate with the end cap **142**. As shown in FIG. **15**, which is a perspective view of the control panel **200** with the front cover **206** removed, the body **204** includes a plurality of grommets **220** through which the control cables **218** extend. The control cables **218** are each operatively connected with a plurality of ballasts **222*a*-222*e*** housed by the housing **202**. The housing additionally includes a plurality of fans **224** for cooling the ballasts **222*a*-222*e***. The ballasts **222*a*-222*e*** start and regulate electrical current supplied to the UV lamps **132**.

[0058] FIG. **16** is a schematic diagram of a controller **226** included in the control panel **200** of FIG. **14**. The controller **226** includes a plurality of headers **228*a***, **228*b***, **228*c***, **228*d***, **228*e***, **228*f***, **228*g*** a plurality of connectors **230*a***, **230*b***, **230*c***, **230*d***, **230*e*** and a plurality of inputs **232*a***, **232*b***. The controller **226** can further include an AC/DC 12 volt power supply **234**, an EMC conductance filter **236**, a flow detector and interlock detector **238**, a first power-on delay circuit **240**, a second power-on delay circuit **242**, a third power-on delay circuit **244**, a first fan control circuit **246**, and a second fan control circuit **248**. The controller **226** can be connected with a power source **250** and a main control board **252**. The power source **250** can be connected to the first connector **228*a*** and header **230*a***, which in turn is in electrical communication with the second header **228*b*** and connector **230*b*** with an intermediate fuse **254** therebetween. The first header **228*a*** and connector **230*a*** can be connected with a terminal block **256** for grounding with a chassis ground **258** and an earth ground **260**. The second connector **230*b*** can be connected with an isolation transformer **262** that is connected with the main control board **252**. The isolation transformer **262** receives 115V AC power from the second header **228*b*** and connector **230*b*** and transforms it to 230V AC power.

[0059] The main control board **252** is connected with the display **216** and can be connected with a keypad **253**. The main control board **252** is connected with the controller **226** at the third connector **230*c***, the fourth connector **230*d***, and also with a BNC connector **264** of the controller **226**. The BNC connector **264** is connected with a converter **266**. The main control board **252** provides the controller **226** with power through the third header **228***c* and third connector **230***c*, and provides commands through the fourth header **228***d* and fourth connector **230***d*. The main control board **252** also receives data from the controller **226** through the fourth header **228***d* and fourth connector **230***d*. The third header **228***c* is connected with the AC/DC 12V power supply **234** and the EMC conductance filter **236**. The AC/DC 12V power supply **234** is connected with a power on indicator **268** and provides power to the first, second, and third power on delay circuits **240**, **242**, **244** and the first and second fan control circuits **246**, **248**. The first and second fan control circuits **246**, **248** are connected to and control the fans **224**. The fourth header **228***d* is connected with the flow detector and interlock detector **238**, and connects the flow detector and interlock detector **238** with the main control board **252**, such that the main control board **252** can provide instructions and data to the flow detector and interlock detector **238** and can receive data from the flow detector and interlock detector **238**. The flow detector and interlock detector **238** can be connected with the first and second inputs **232***a*, **232***b*, which can be respectively connected with a flow switch **268** and the sensor **72**. The flow detector and interlock detector **238** is also in communication with the first, second, and third power delay circuits **240**, **242**, **244** and provides instructions for the ballasts **222***a*-**222***e* to be turned off when the detector **238** determines that the sterilization system **10** has been opened or there is no flow through the sterilization system **10**. The flow detector and interlock detector **238** can also include a flow detector light **270** that is illuminated when a flow is detected through the sterilization system **10**.

[0060] FIGS. **15** and **16** illustrate five ballasts **222***a*-**222***e*, demonstrating that the controller **226** can be used with a sterilization system having up to five UV lamps **132**. However, the controller **226** can be used with a sterilization system having less than five UV lights, e.g., the sterilization system **10** of FIGS. **1-13** that has three UV lamps **132**. Alternatively, the controller **226** can be provided with more than five ballasts so that the sterilization system **10** can have more than five UV lights. Accordingly, the number of ballasts and UV lights described herein is for illustrative purposes only, and the present disclosure should not be limited to these numbers. Each of the power-on delay circuits **240**, **242**, **244** can be connected with one or two ballasts **222***a*-**222***e* (FIG. **16** shows the first and second power on delay circuits **240**, **242** connected with two ballasts **222***a*-**222***d* each, and the third power on delay circuit **244** connected with a single ballast **222***e*). The power on delay circuits **240**, **242**, **244** delay (stagger) the start times of the ballasts **222***a*-**222***e* so that an overload does not occur. Each of the ballasts **222***a*-**222***e* is connected to a terminal block **274***a*-**274***e* that is connected with a UV lamp **132** by a control cable **218**, which places the ballast **222***a*-**222***e* in electrical communication with a respective UV lamp **132**. The ballasts **222***a*-**222***e* and the first and second fan control circuits **246**, **248** can be in communication with a status indicator **276** that illuminates when the ballasts **222***a*-**222***e* and the fan control circuits **246**, **258** are operational.

[0061] Having thus described the invention in detail, it is to be understood that the foregoing description is not intended to limit the spirit or scope thereof. It will be understood that the embodiments of the present invention described herein are merely exemplary and that a person skilled in the art may make many variations and modification without departing from the spirit and scope of the invention. All such variations and modifications, including those discussed above, are intended to be included within the scope of the invention.

What is claimed is:

1. A fluid sterilization system, comprising:

a housing having a body, a fluid inlet, and a fluid outlet, wherein fluid to be sterilized flows into the fluid inlet and into the body, and sterilized fluid flows out of the fluid outlet;

a sleeve positioned within the central cavity, the sleeve including a first plurality of openings disposed radially about a first end of the sleeve and a second plurality of openings disposed radially about a second end of the sleeve, wherein the fluid to be sterilized flows through the first plurality of openings and into the sleeve, and sterilized fluid flows out of the second plurality of openings, and wherein the sleeve creating uniform fluid flow through the sleeve and between the first plurality of openings and the second plurality of openings;

at least one ultraviolet light assembly positioned within the sleeve and generating ultraviolet light for sterilizing fluid within the sleeve; and

means for injecting ozone into the fluid to be sterilized proximal to the fluid inlet.

2. The fluid sterilization system of claim **1**, further comprising an O-ring assembly positioned about an outer surface of the sleeve and dividing a space between the sleeve and the body of the housing into an untreated fluid region and a treated fluid region, the O-ring assembly creating a seal between the outer surface of the sleeve and an inner surface of the body.

3. The fluid sterilization system of claim **1**, wherein the first plurality of openings comprises a first plurality of cutouts formed in the sleeve and the second plurality of openings comprises a second plurality of cutouts formed in the sleeve.

4. The fluid sterilization system of claim **1**, wherein the housing comprises a lower housing portion and a base portion attached to the lower housing portion.

5. The fluid sterilization system of claim **4**, further comprising an upper housing portion attached to an upper end of the lower housing portion.

6. The fluid sterilization system of claim **5**, further comprising a cap attached to the upper housing portion and a nut for coupling the upper housing portion to the lower housing portion.

7. The fluid sterilization system of claim **5**, further comprising a manifold attached to the upper housing portion, the at least one ultraviolet light assembly coupled to and supported by the manifold.

8. The fluid sterilization system of claim **7**, further comprising a securing assembly for securing the at least one ultraviolet light assembly to the manifold.

9. The fluid sterilization system of claim **7**, wherein the at least one ultraviolet lamp assembly is removable from the manifold and the sterilization system.

10. The fluid sterilization system of claim **1**, wherein the means for injecting ozone comprises a venturi assembly for injecting ozone into the fluid to be sterilized.

11. The fluid sterilization system of claim **10**, wherein the at least one ultraviolet light assembly comprises a quartz tube, an ultraviolet lamp positioned within the quartz tube, and a siphon tube positioned within the quartz tube.

12. The fluid sterilization system of claim **11**, wherein the ultraviolet lamp generates ozone within the quartz tube, and the siphon tube suctions the ozone out of the quartz tube.

13. The fluid sterilization system of claim **12**, further comprising a venturi tube interconnecting the siphon tube to the venturi assembly, the venturi tube transferring ozone from the siphon tube to the venturi assembly.

14. The fluid sterilization system of claim **1**, further comprising a sensor for sensing output of the at least one ultraviolet light assembly.

15. The fluid sterilization system of claim **1**, further comprising a controller in electrical communication with the at least one ultraviolet light assembly, the controller controlling operation of the at least one ultraviolet light assembly.

16. The fluid sterilization system of claim **15**, wherein the controller activates an alarm if the housing of the fluid sterilization system is not closed prior to operation.

17. The fluid sterilization system of claim **1**, wherein the sleeve is reflective.

18. The fluid sterilization system of claim **1**, wherein the sleeve is formed from stainless steel, a composite material, a thermoplastic material, polytetrafluoroethylene, or perfluoroalkoxy.

19. The fluid sterilization system of claim **1**, wherein the sleeve is removable from the housing.

20. The fluid sterilization system of claim **19**, wherein the sleeve is replaceable.

21. The fluid sterilization system of claim **1**, wherein the first and second plurality of openings comprises first and second perforations formed in the sleeve.

22. The fluid sterilization system of claim **21**, wherein the first and second perforations allow fluid to pass therethrough and retain a high percentage of reflective surface.

23. The fluid sterilization system of claim **1**, wherein the first plurality of openings form a first cylindrical baffle that has an open area equal to or greater than an open area of the fluid inlet, and the second plurality of openings form a second cylindrical baffle that has an open area equal to or greater than an open area of the fluid outlet.

24. The fluid sterilization system of claim **23**, wherein the first and second cylindrical baffles diffuse the fluid flowing through the housing to regulate bubble size and increase mass transfer of the fluid sterilization system.

25. The fluid sterilization system of claim **1**, wherein the first and second plurality of openings are patterned to shape or direct the flow through the sleeve to enhance treatment of the fluid.

26. The fluid sterilization system of claim **1**, wherein the sleeve is perforated to form indicia on the sleeve, through which light from the at least one ultraviolet light assembly shines when the sterilization system is in operation.

27. The fluid sterilization system of claim **1**, wherein the at least one ultraviolet lamp assembly is modular, removable, and replaceable.

28. The fluid sterilization system of claim **27**, wherein the at least one ultraviolet lamp assembly is replaceable by a second at least one ultraviolet lamp assembly having a different lamp wattage or wavelength.

29. The fluid sterilization system of claim **1**, further comprising a first number of ultraviolet lamp assemblies, the first number of ultraviolet lamp assemblies being replaceable by a second number of ultraviolet lamp assemblies, the second number being different than the first number.

30. A method of sterilizing fluid, comprising:

providing a fluid sterilization system having a housing with an inlet port and an outlet port, a sleeve positioned within the housing, at least one ultraviolet lamp assembly positioned within the sleeve, and means for generating ozone;

allowing fluid to be sterilized to flow into the inlet port;

introducing ozone generated by the means for generating ozone into the fluid proximal the inlet port, the ozone sterilizing the fluid;

directing the fluid through a first plurality of openings formed in the sleeve proximal to a first end of the sleeve, the sleeve creating uniform fluid flow within the sleeve;

exposing the fluid to ultraviolet light generated by the at least one ultraviolet lamp assembly, the ultraviolet light sterilizing the fluid; and

directing the fluid through a second plurality of openings formed in the sleeve proximal to a second end of the sleeve, and out the outlet port of the fluid sterilization system.

31. The method of claim **30**, wherein the step of introducing the ozone into the fluid comprises introducing the ozone into the fluid using a venturi assembly mounted proximal to the inlet port.

32. The method of claim **31**, further comprising straightening flow of the fluid past the at least one ultraviolet lamp assembly using the sleeve.

33. A fluid sterilization system, comprising:

a housing having a body, a fluid inlet, and a fluid outlet, wherein fluid to be sterilized flows into the fluid inlet and into the body, and sterilized fluid flows out of the fluid outlet;

a sleeve positioned within the central cavity, the sleeve including a first plurality of openings disposed radially about a first end of the sleeve and a second plurality of openings disposed radially about a second end of the sleeve, wherein the fluid to be sterilized flows through the first plurality of openings and into the sleeve, and sterilized fluid flows out of the second plurality of openings; and

at least one ultraviolet light assembly positioned within the sleeve and generating ultraviolet light for sterilizing fluid within the sleeve.

34. The fluid sterilization system of claim **33**, further comprising an O-ring assembly positioned about an outer surface of the sleeve and dividing a space between the sleeve and the body of the housing into an untreated fluid region and a treated fluid region, the O-ring assembly creating a seal between the outer surface of the sleeve and an inner surface of the body.

35. The fluid sterilization system of claim **33**, wherein the first plurality of openings comprises a first plurality of cutouts formed in the sleeve and the second plurality of openings comprises a second plurality of cutouts formed in the sleeve.

36. The fluid sterilization system of claim **33**, wherein the housing comprises a lower housing portion and a base portion attached to the lower housing portion.

37. The fluid sterilization system of claim **36**, further comprising an upper housing portion attached to an upper end of the lower housing portion.

38. The fluid sterilization system of claim **37**, further comprising a cap attached to the upper housing portion and a nut for coupling the upper housing portion to the lower housing portion.

39. The fluid sterilization system of claim **37**, further comprising a manifold attached to the upper housing portion, the at least one ultraviolet light assembly coupled to and supported by the manifold.

40. The fluid sterilization system of claim **39**, further comprising a securing assembly for securing the at least one ultraviolet light assembly to the manifold.

41. The fluid sterilization system of claim **39**, wherein the at least one ultraviolet lamp assembly is removable from the manifold and the sterilization system.

42. The fluid sterilization system of claim **33**, further comprising a venturi assembly for injecting ozone into the fluid to be sterilized.

43. The fluid sterilization system of claim **42**, wherein the at least one ultraviolet light assembly comprises a quartz tube, an ultraviolet lamp positioned within the quartz tube, and a siphon tube positioned within the quartz tube.

44. The fluid sterilization system of claim **43**, wherein the ultraviolet lamp generates ozone within the quartz tube, and the siphon tube suctions the ozone out of the quartz tube.

45. The fluid sterilization system of claim **44**, further comprising a venturi tube interconnecting the siphon tube to the venturi assembly, the venturi tube transferring ozone from the siphon tube to the venturi assembly.

46. The fluid sterilization system of claim **33**, further comprising a sensor for sensing output of the at least one ultraviolet light assembly.

47. The fluid sterilization system of claim **33**, further comprising a controller in electrical communication with the at least one ultraviolet light assembly, the controller controlling operation of the at least one ultraviolet light assembly.

48. The fluid sterilization system of claim **47**, wherein the controller activates an alarm if the housing of the fluid sterilization system is not closed prior to operation.

49. The fluid sterilization system of claim **33**, wherein the sleeve is reflective.

50. The fluid sterilization system of claim **33**, wherein the sleeve is formed from stainless steel, a composite material, a thermoplastic material, polytetrafluoroethylene, or perfluoroalkoxy.

51. The fluid sterilization system of claim **33**, wherein the sleeve is removable from the housing.

52. The fluid sterilization system of claim **51**, wherein the sleeve is replaceable.

53. The fluid sterilization system of claim **33**, wherein the first and second plurality of openings comprises first and second perforations formed in the sleeve.

54. The fluid sterilization system of claim **53**, wherein the first and second perforations allow fluid to pass therethrough and retain a high percentage of reflective surface.

55. The fluid sterilization system of claim **33**, wherein the first plurality of openings form a first cylindrical baffle that has an open area equal to or greater than an open area of the fluid inlet, and the second plurality of openings form a second cylindrical baffle that has an open area equal to or greater than an open area of the fluid outlet.

56. The fluid sterilization system of claim **55**, wherein the first and second cylindrical baffles diffuse the fluid flowing through the housing to regulate bubble size and increase mass transfer of the fluid sterilization system.

57. The fluid sterilization system of claim **33**, wherein the first and second plurality of openings are patterned to shape or direct the flow through the sleeve to enhance treatment of the fluid.

58. The fluid sterilization system of claim **33**, wherein the sleeve is perforated to form indicia on the sleeve, through which light from the at least one ultraviolet light assembly shines when the sterilization system is in operation.

59. The fluid sterilization system of claim **33**, wherein the at least one ultraviolet lamp assembly is modular, removable, and replaceable.

60. The fluid sterilization system of claim **59**, wherein the at least one ultraviolet lamp assembly is replaceable by a second at least one ultraviolet lamp assembly having a different lamp wattage or wavelength.

61. The fluid sterilization system of claim **33**, further comprising a first number of ultraviolet lamp assemblies, the first number of ultraviolet lamp assemblies being replaceable by a second number of ultraviolet lamp assemblies, the second number being different than the first number.

* * * * *