US 20100275359A1

(19) **United States**

(12) **Patent Application Publication**

Guler et al.

(10) **Pub. No.: US 2010/0275359 A1**

(43) **Pub. Date: Nov. 4, 2010**

(54) **OPTICAL SENSORS AND ALGORITHMS FOR CONTROLLING AUTOMATIC BATHROOM FLUSHERS AND FAUCETS**

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(21) Appl. No.: **12/798,667**

(22) Filed: **Apr. 8, 2010**

Related U.S. Application Data

(63) Continuation of application No. 11/159,422, filed on Jun. 22, 2005, now abandoned, which is a continuation of application No. PCT/US03/41303, filed on Dec. 26, 2003, which is a continuation-in-part of application No. PCT/US03/38730, filed on Dec. 4, 2003, which is a continuation-in-part of application No. 10/421,359, filed on Apr. 23, 2003, now Pat. No. 6,948,697, said application No. PCT/US03/41303 is a continuation-in-part of application No. PCT/US02/38757, filed on Dec. 4, 2002, which is a continuation-in-part of application No. PCT/US02/38758, filed on Dec. 4, 2002, which is a continuation-in-part of application No. PCT/US03/20117, filed on Jun. 24, 2003, which is a continuation-in-part of application No. PCT/US02/41576, filed on Dec. 26, 2002.

(60) Provisional application No. 60/513,722, filed on Oct. 22, 2003.

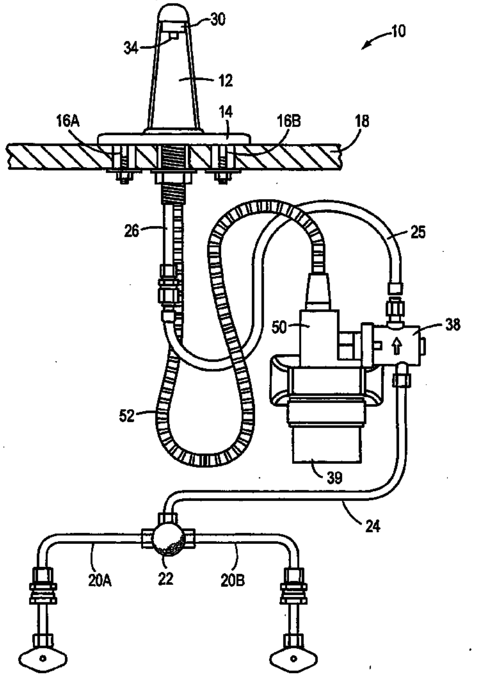
Publication Classification

(51) **Int. Cl.**
E03D 1/24 (2006.01)
E03D 1/30 (2006.01)

(52) **U.S. Cl.** **4/313**; 251/129.01; 251/129.04

(57) **ABSTRACT**

The present invention is directed to novel optical sensors and novel methods for sensing optical radiation that can be used to control the operation of automatic faucets and flushers. The novel sensors and flow controllers require only small amounts of electrical power for sensing users of bathroom facilities, enabling battery operation for many years. An electronic system for controlling fluid flow may include an electromagnetic actuator, a controller and an optical sensor. Preferred embodiments include a control circuit constructed to sample periodically the detector based on the amount of light detected; a control circuit constructed to adjust a sample period based on the detected amount of light after determining whether a facility is in use; a detector optically coupled to the input port using an optical fiber; the input port may be located in an aerator of the electronic faucet; the system includes batteries for powering the electronic faucet. These embodiments may also include a variety of other features. A passive optical sensor includes a light detector sensitive to ambient (room) light for controlling the operation of automatic faucets or automatic bathroom flushers. An active optical sensor includes a light emitter and a light detector. The detected signals may be processed using novel algorithms



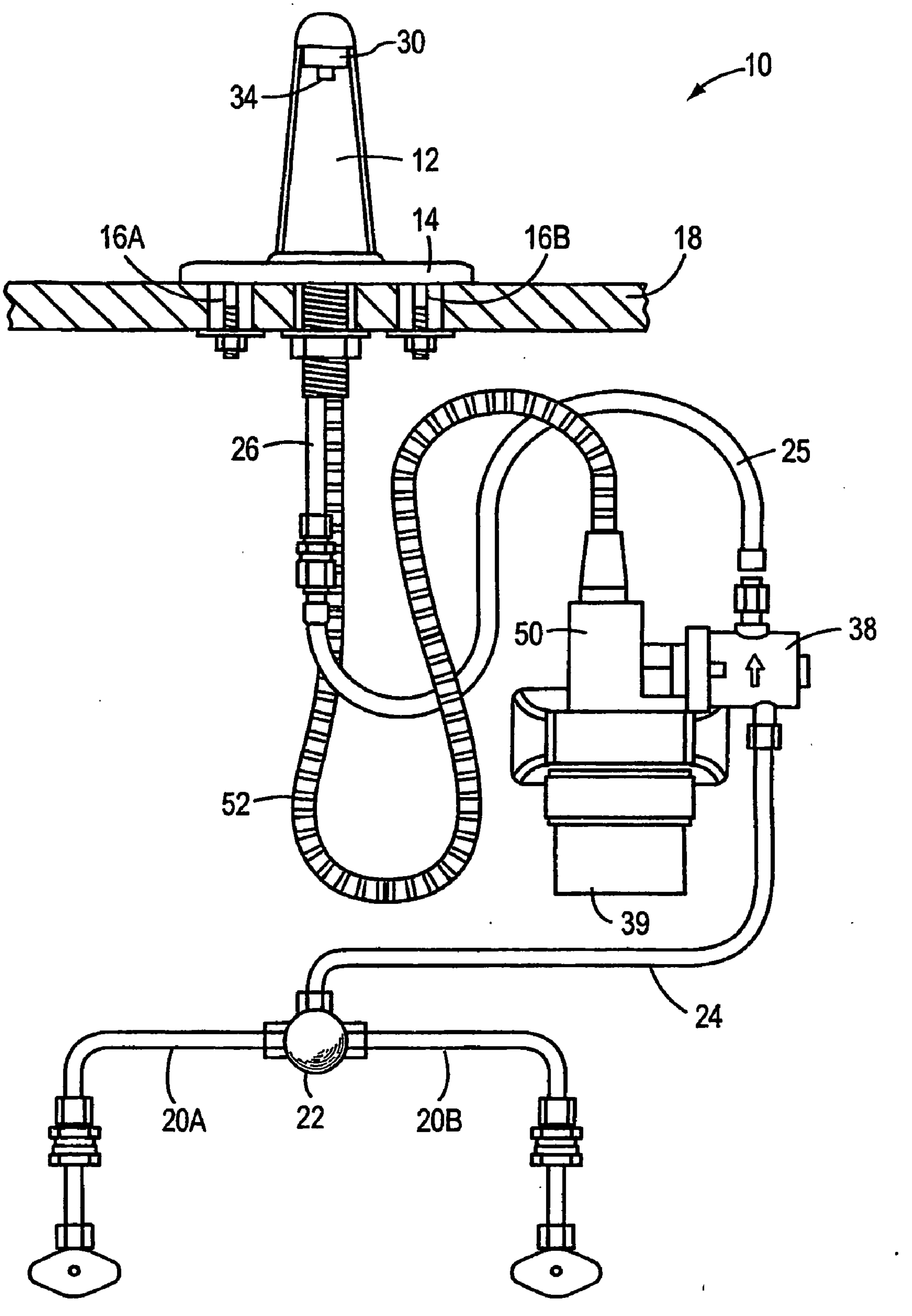


FIG. 1

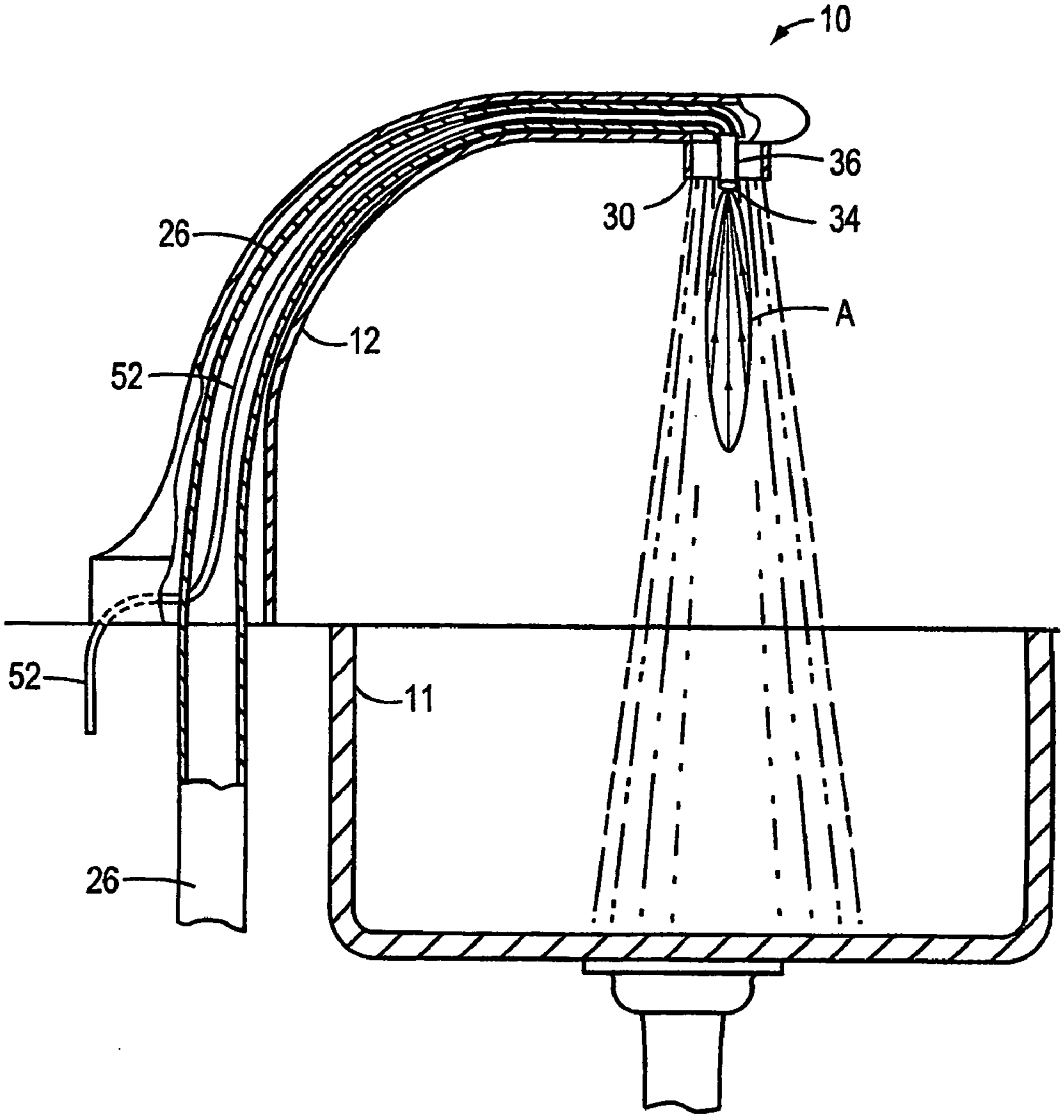


FIG. 1A

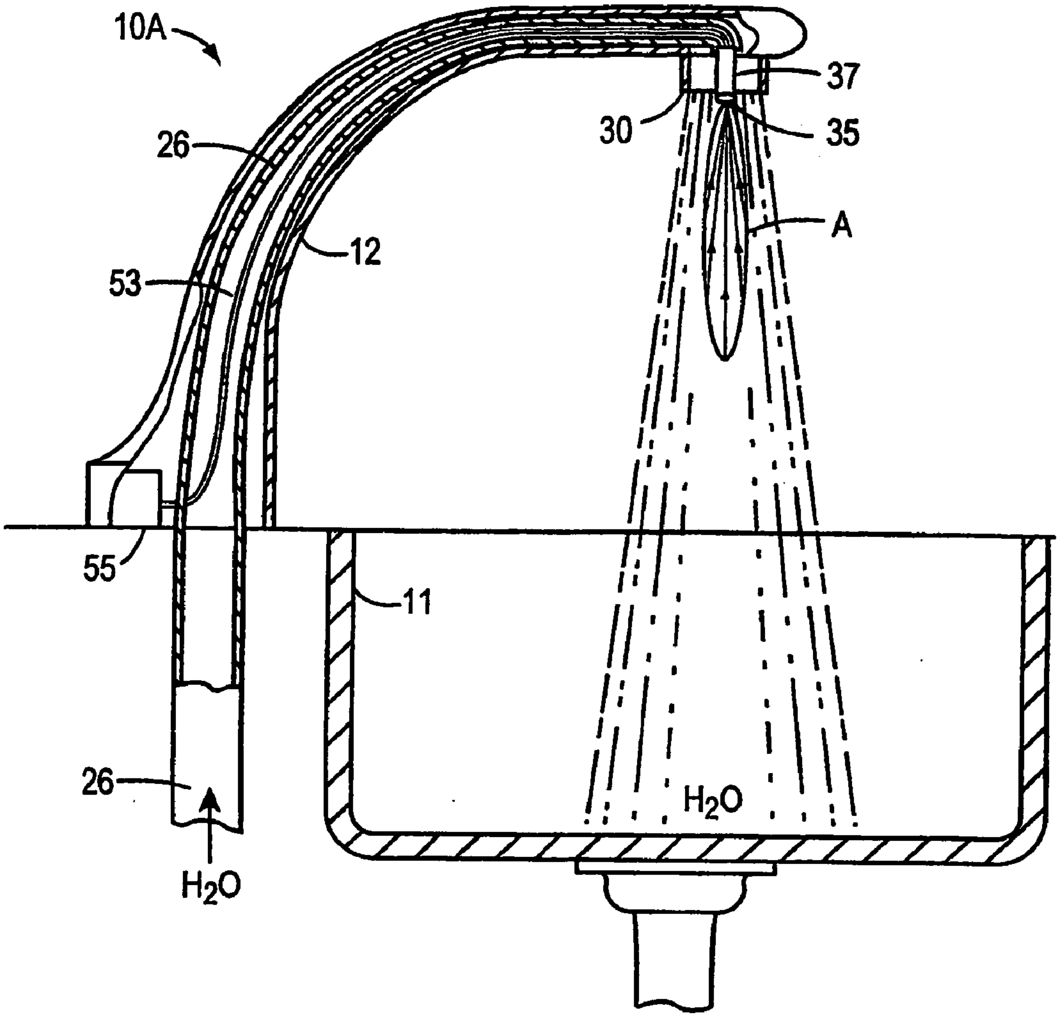
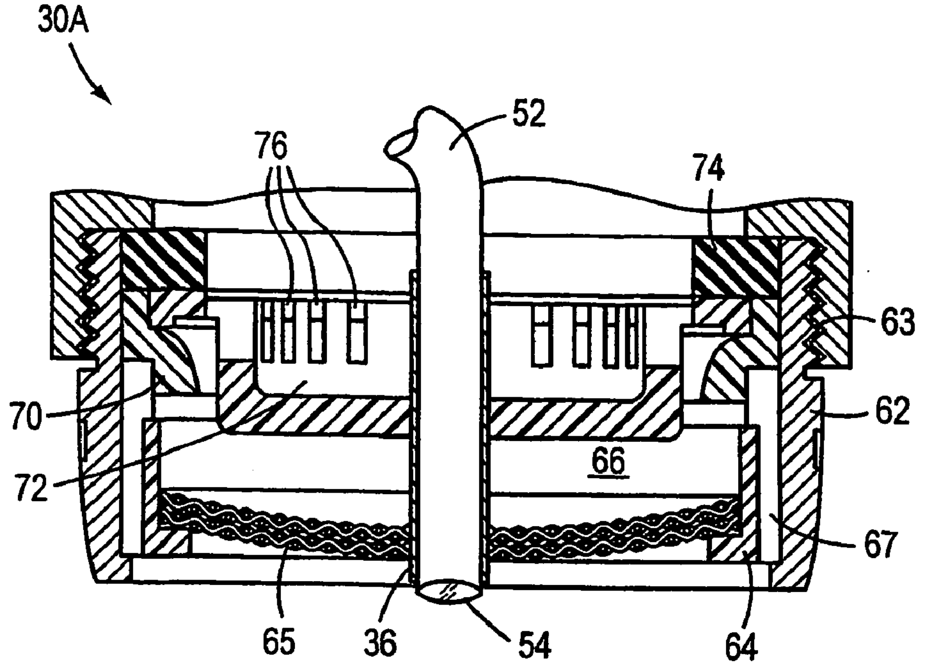


FIG. 1B


30A
52
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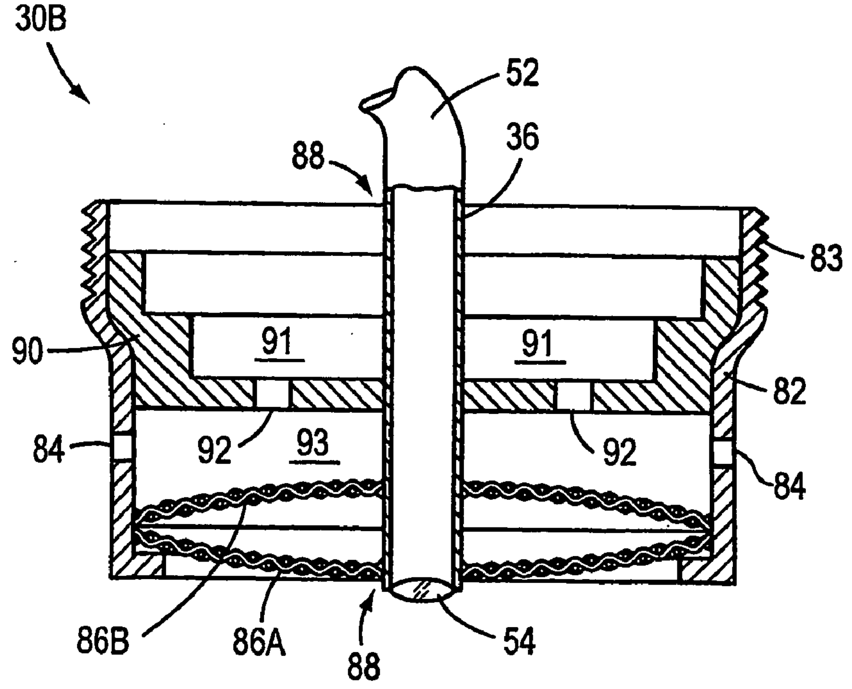
54
64

FIG. 1C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86B
86A
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54

FIG. 1D

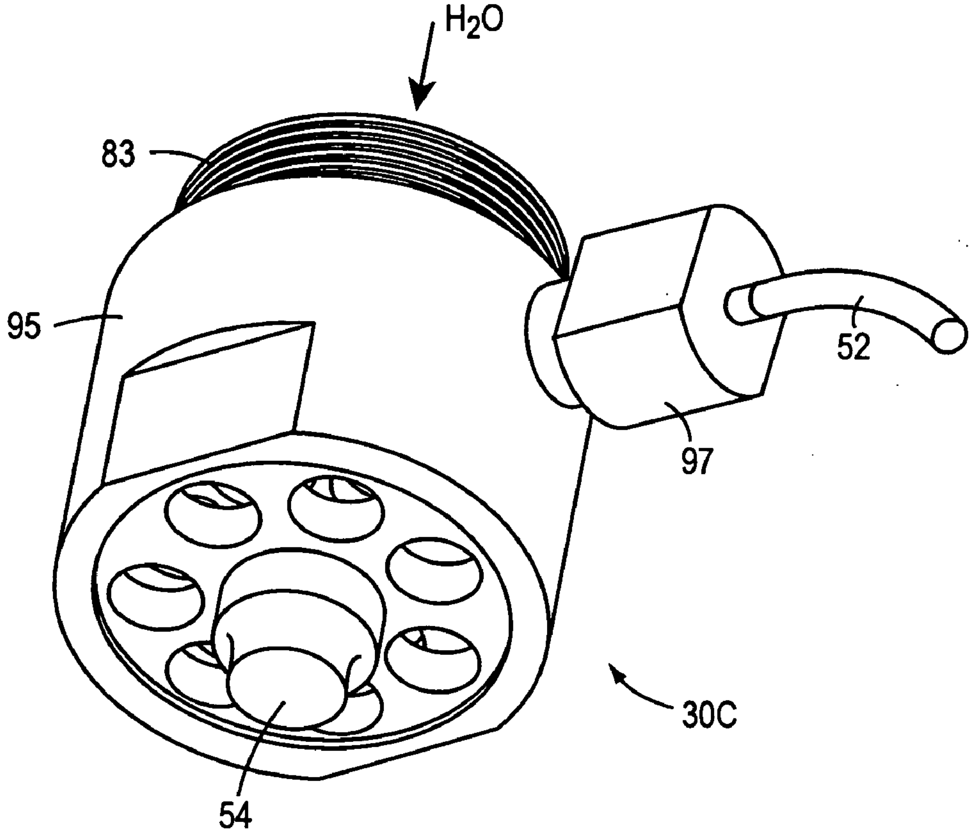


FIG. 1E

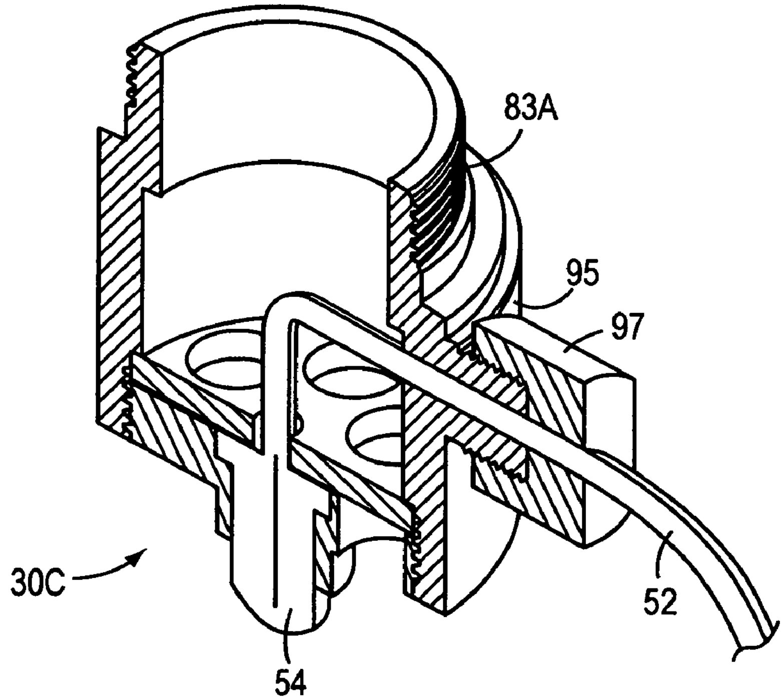


FIG. 1F

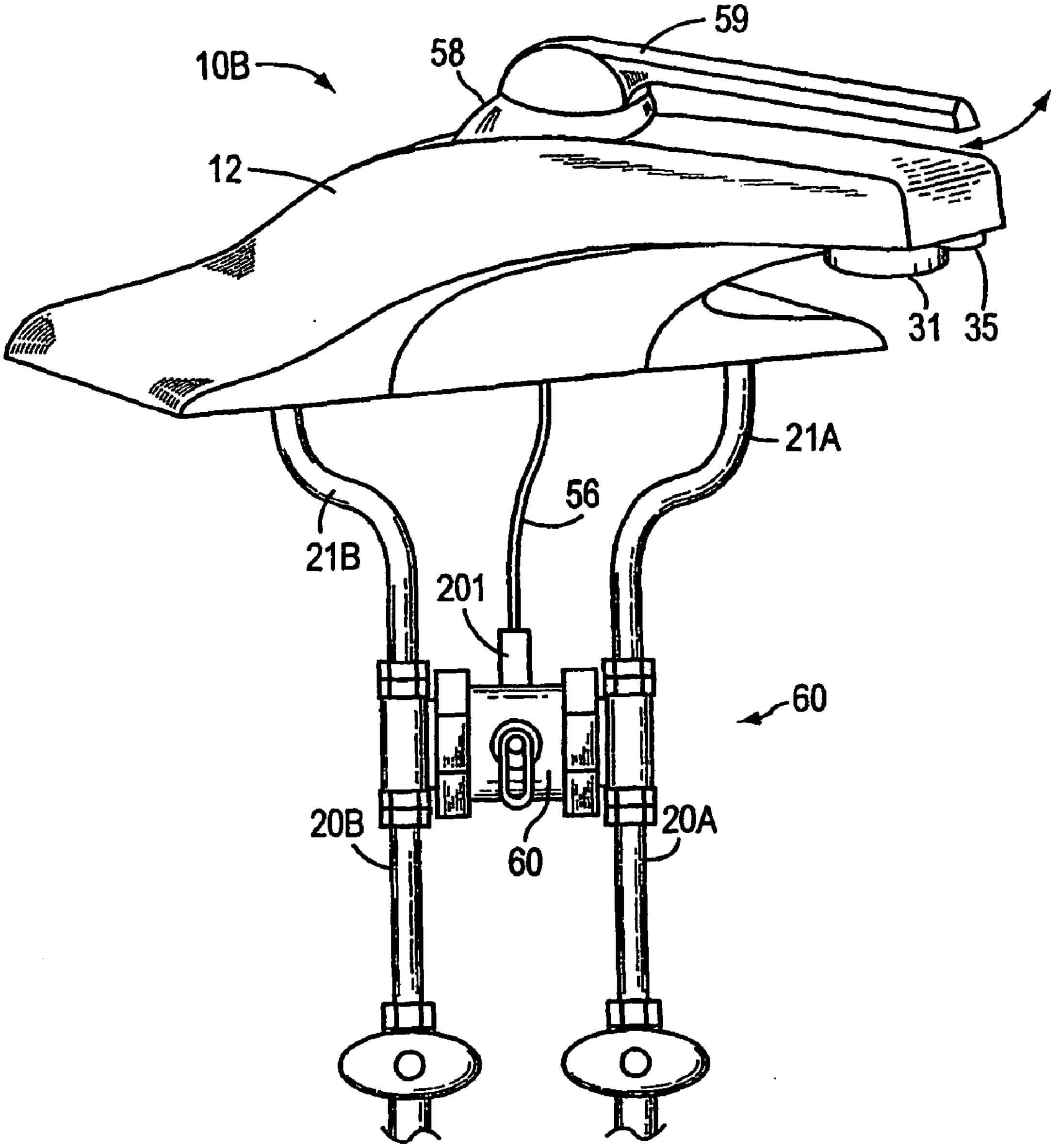


FIG. 2

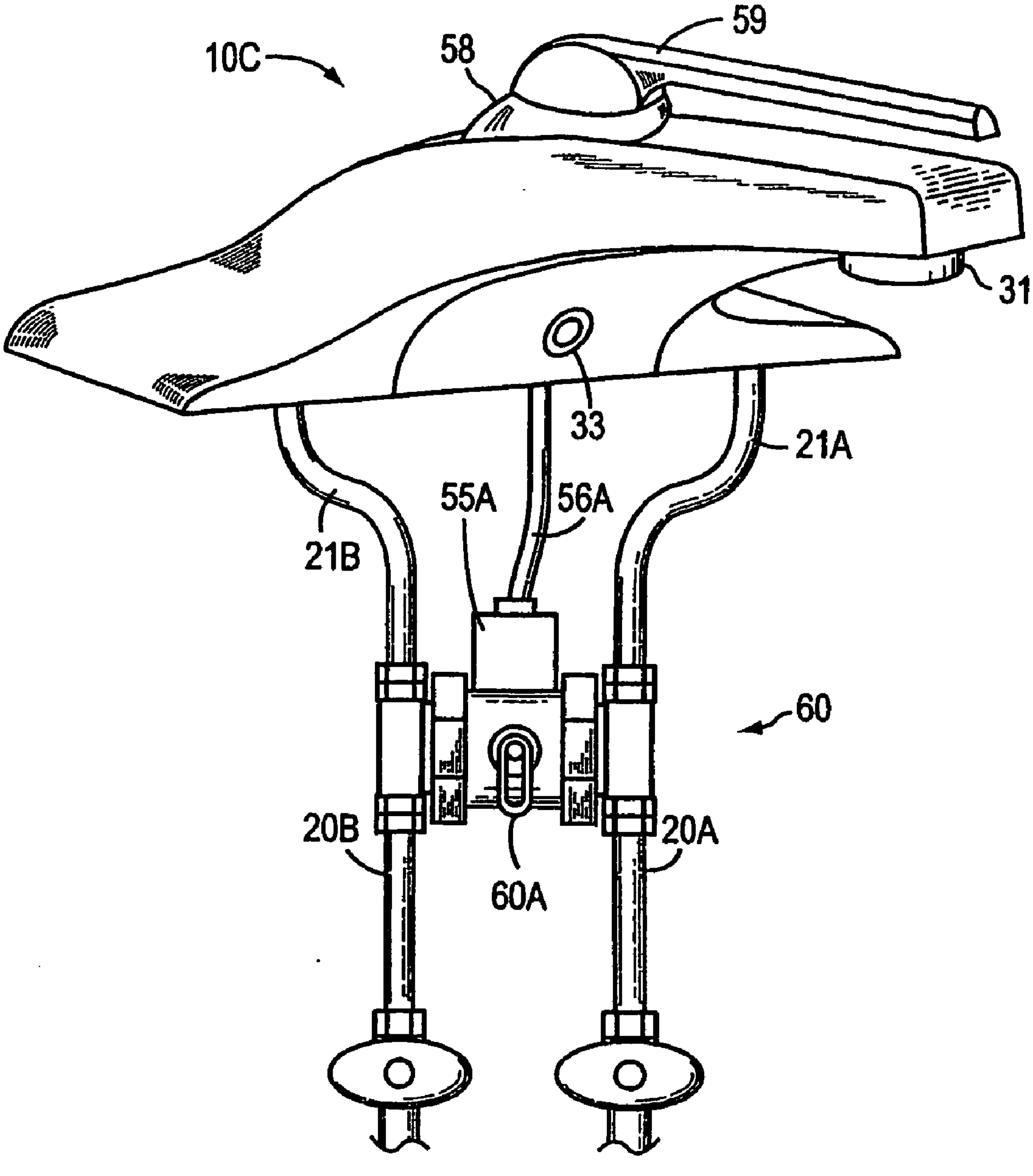


FIG. 2A

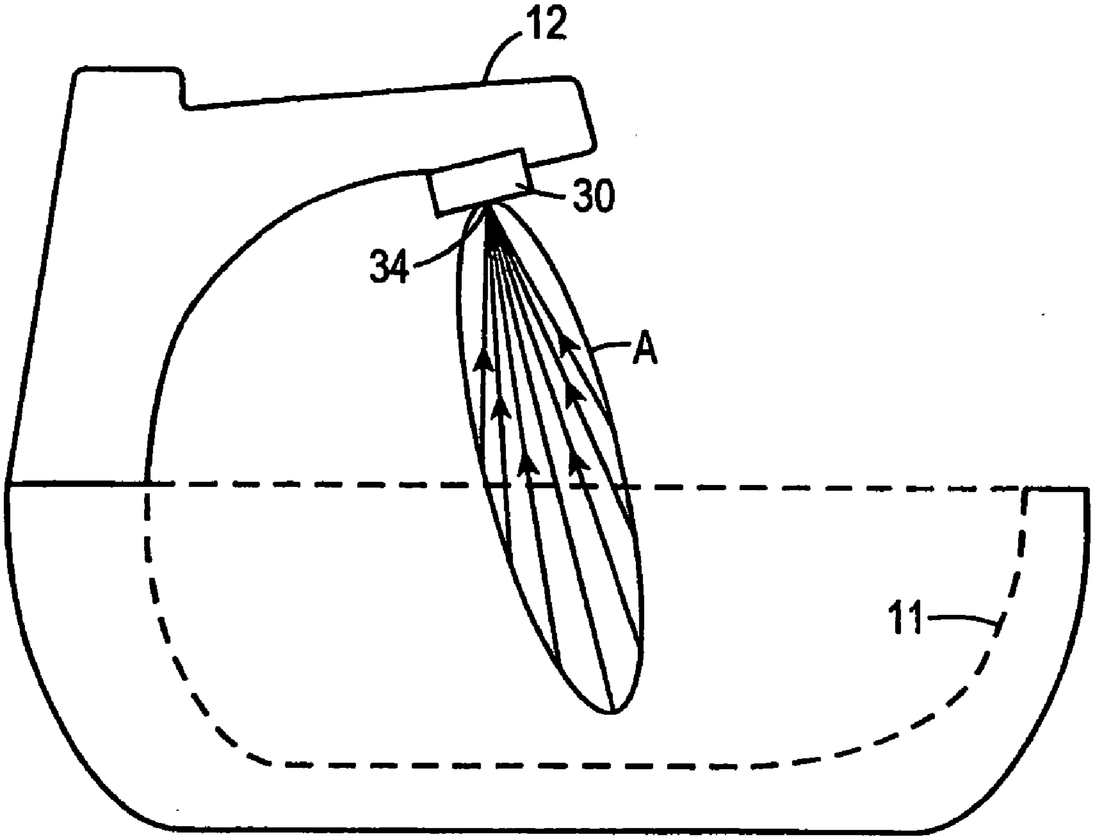


FIG. 3

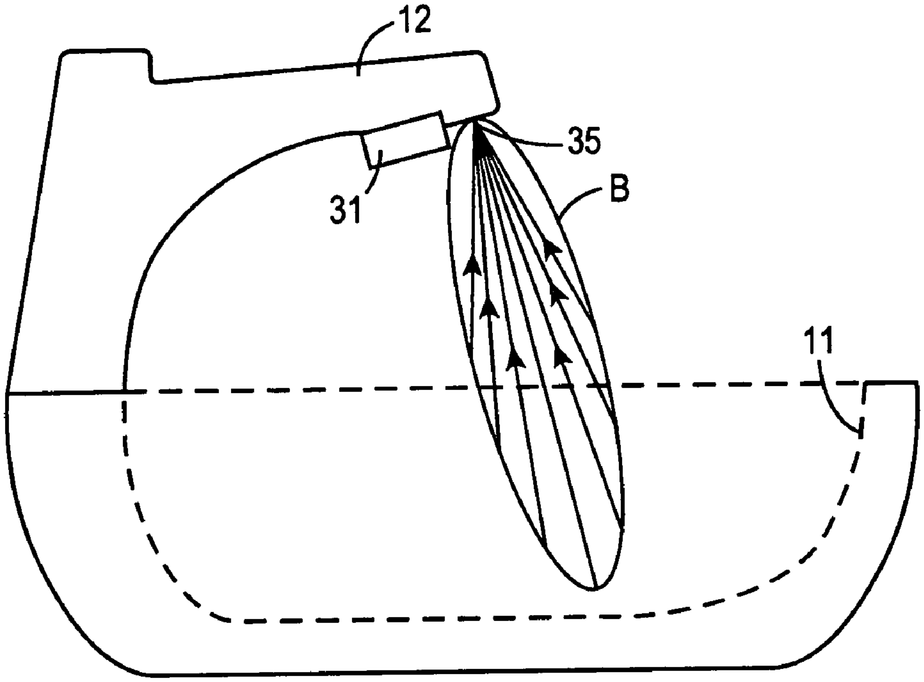


FIG. 3A

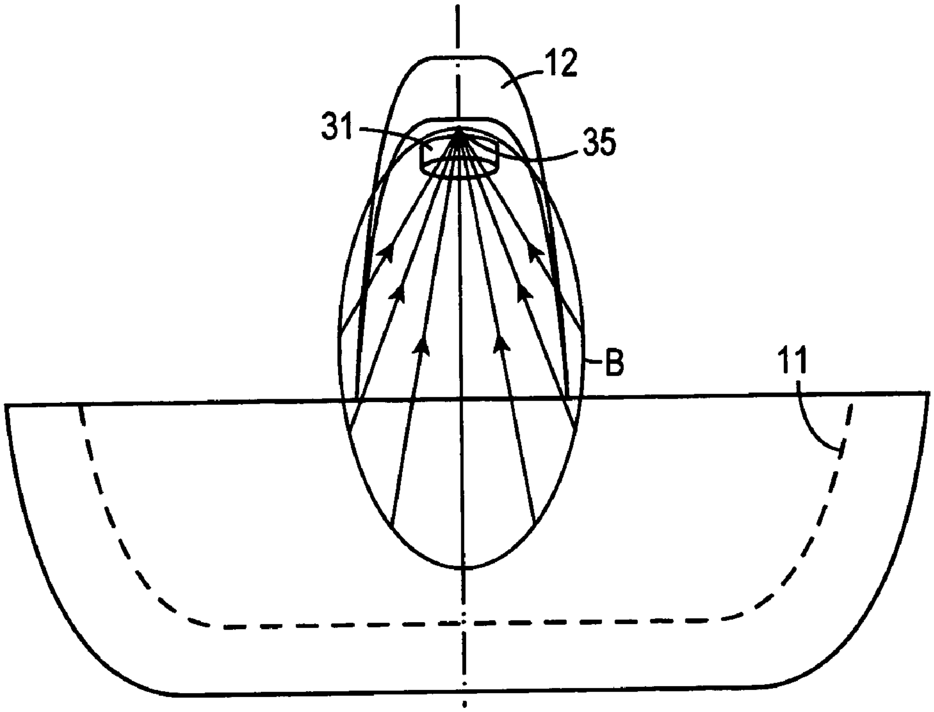


FIG. 3B

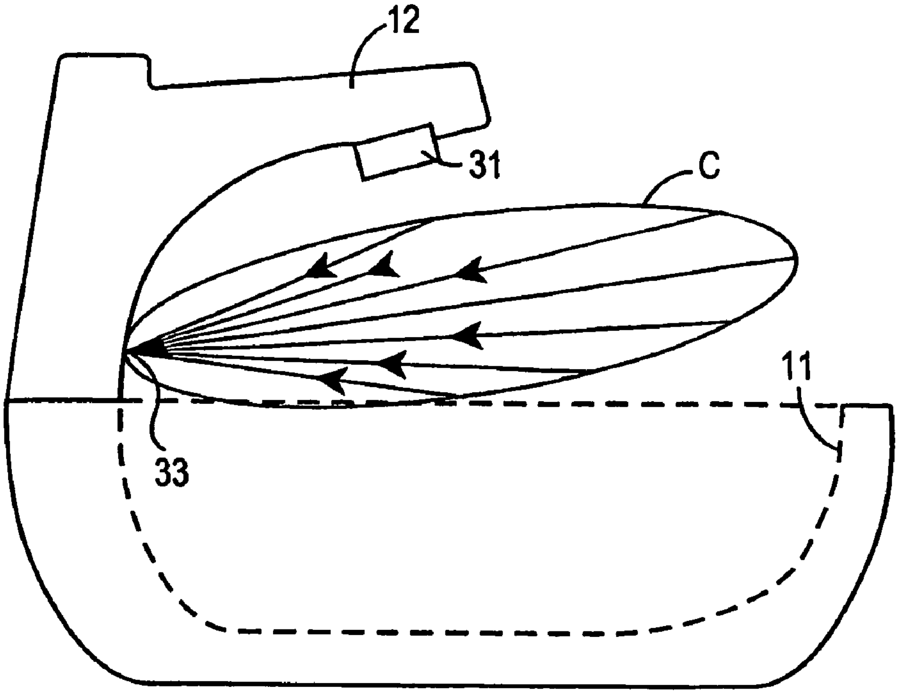


FIG. 3C

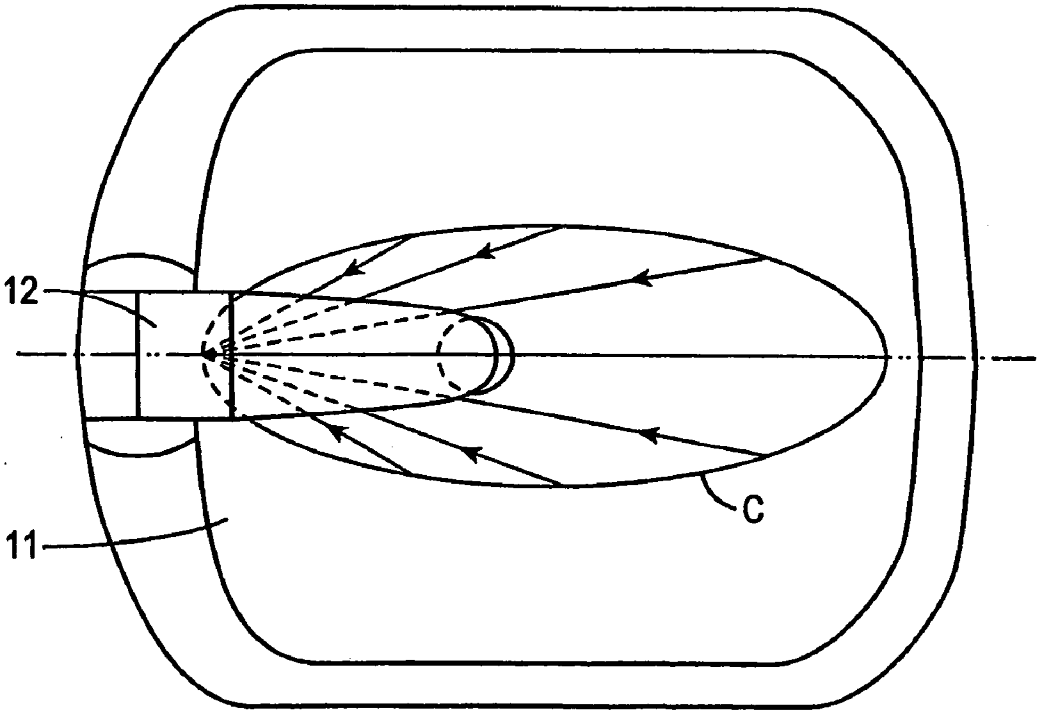


FIG. 3D

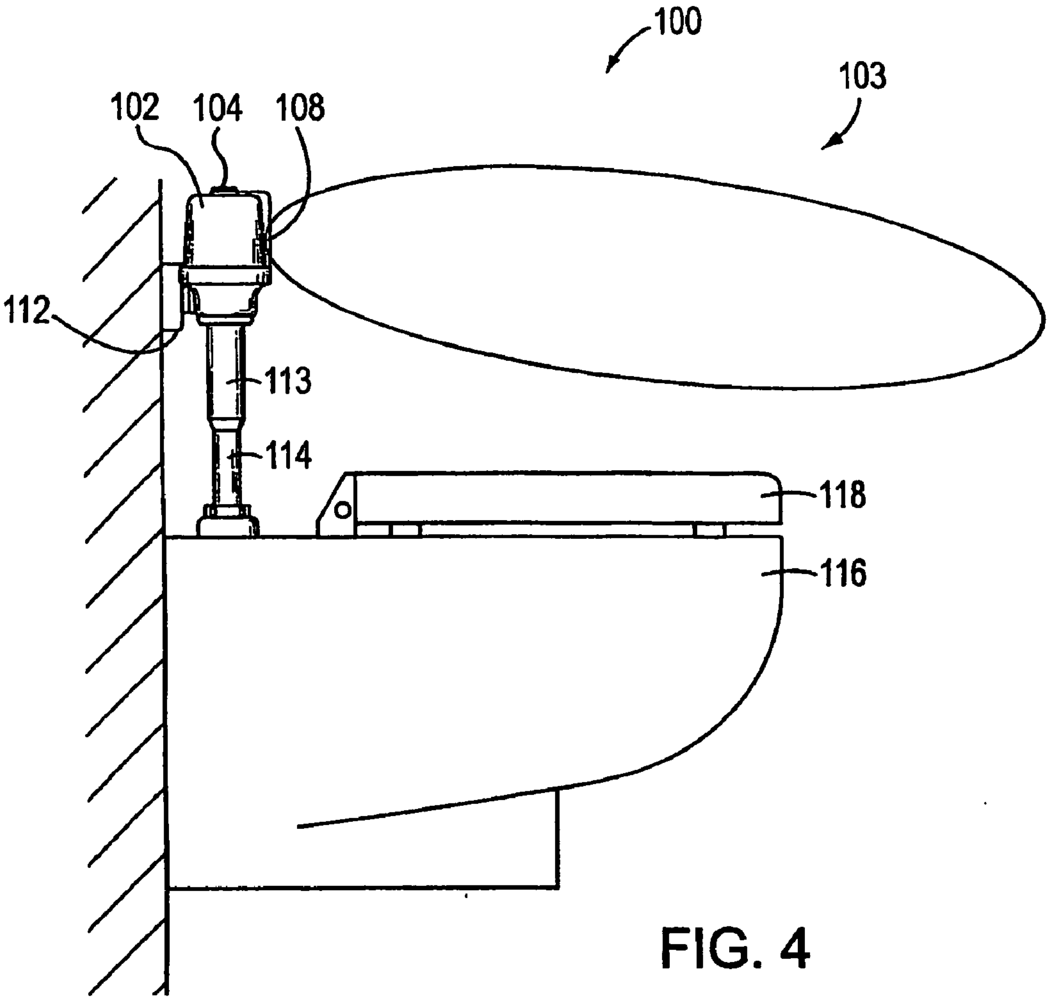


FIG. 4

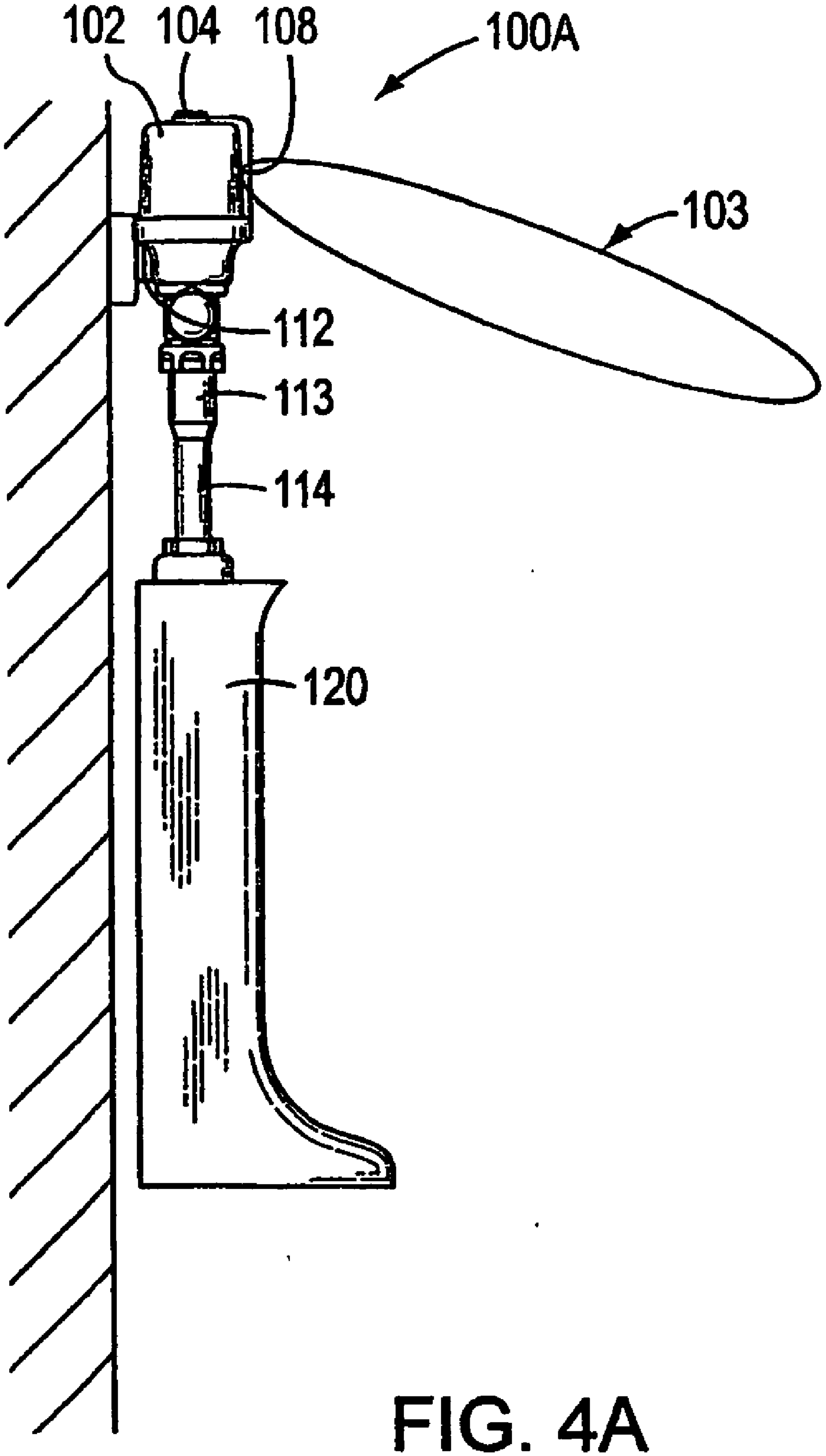
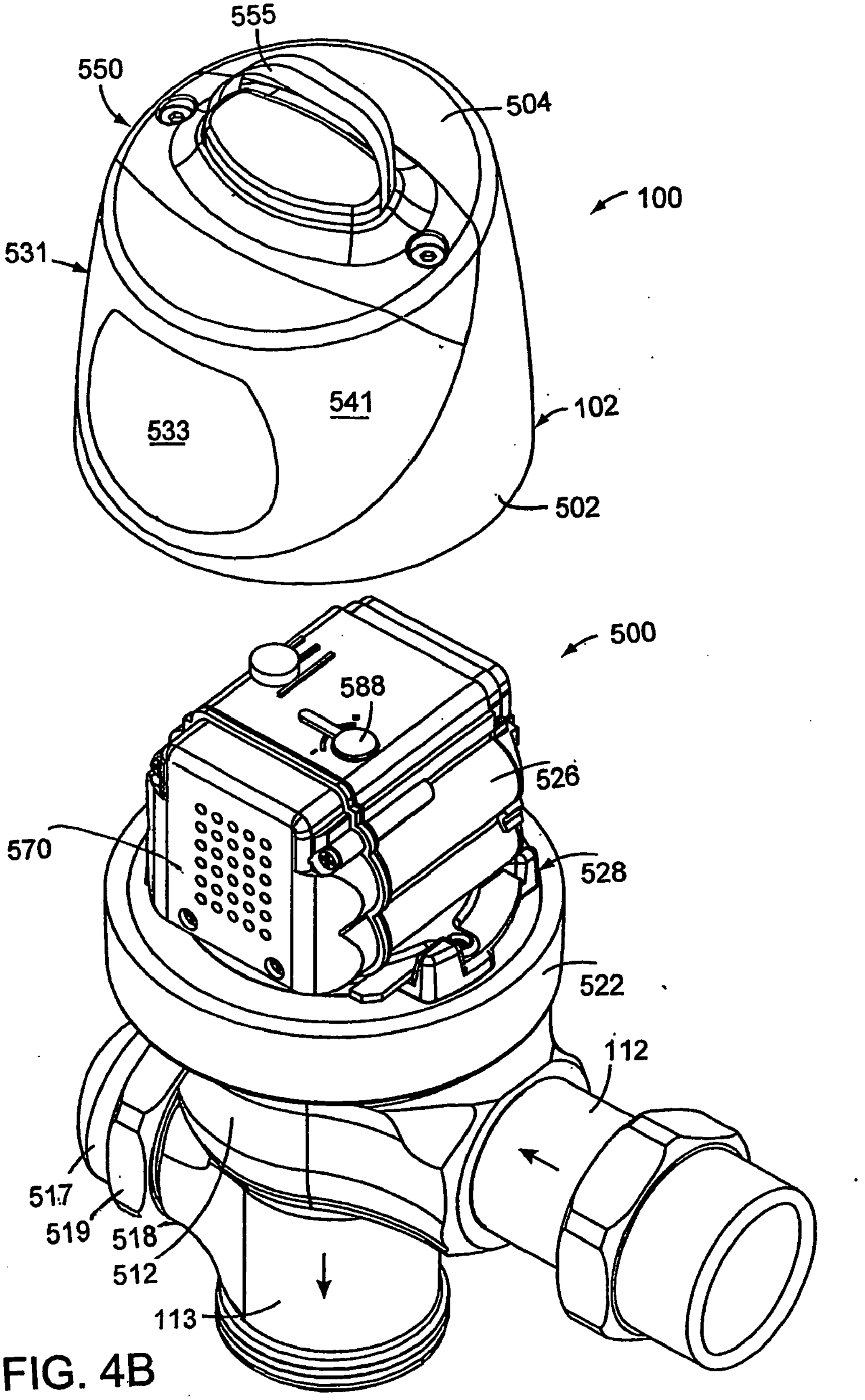


FIG. 4A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550
504
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541
533
102
502
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588
526
570
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522
112
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512
113

FIG. 4B

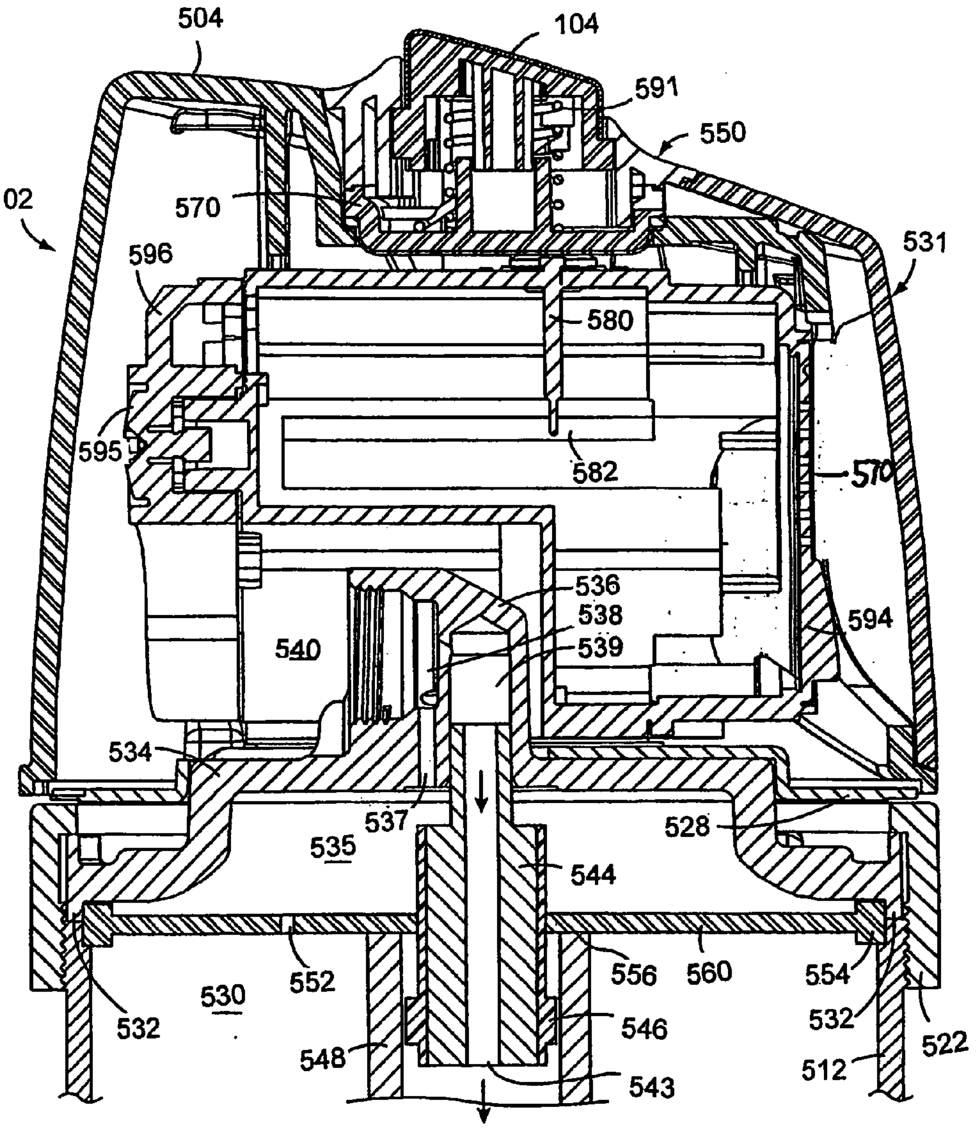
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FIG. 4C

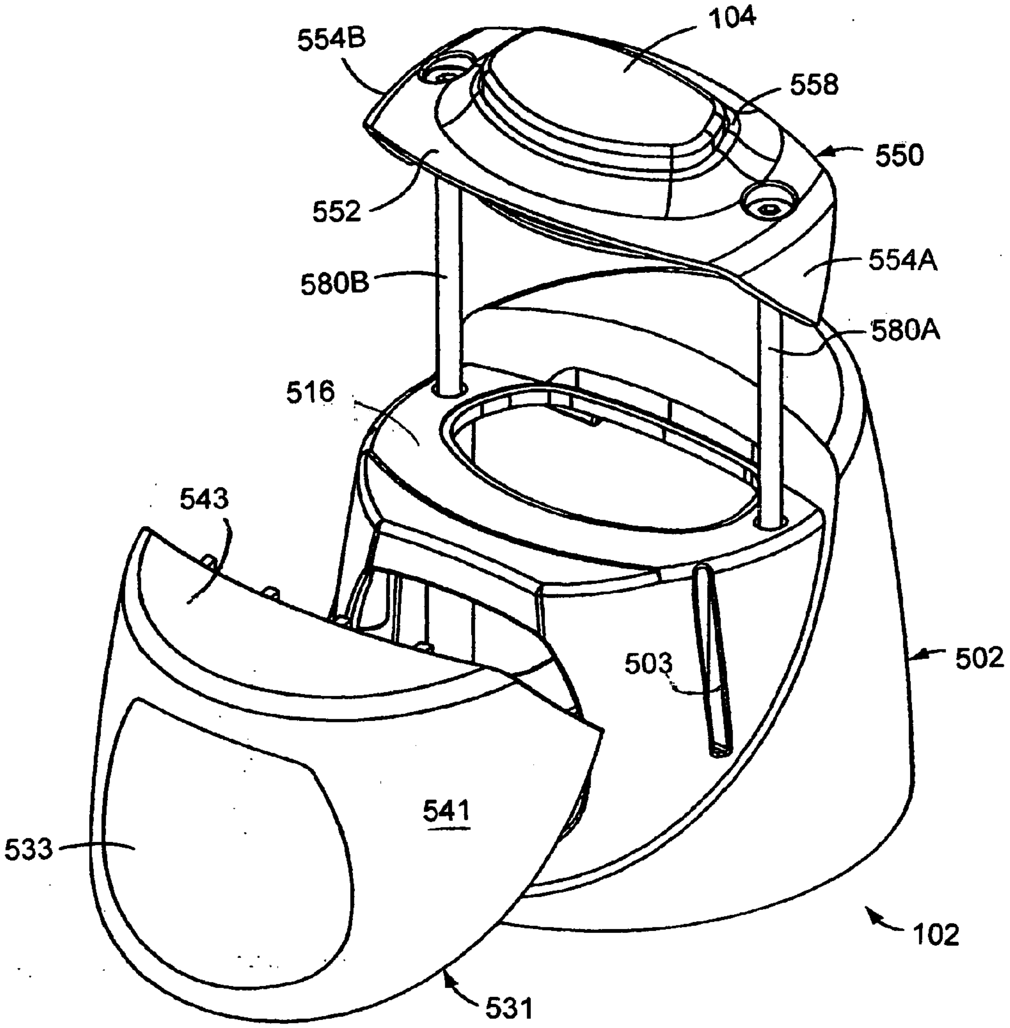
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FIG. 4D

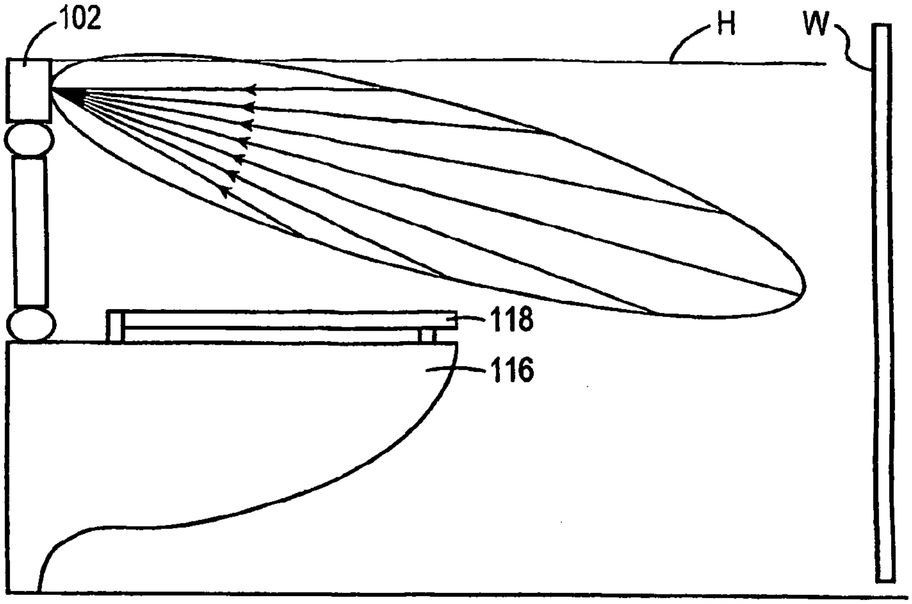


FIG. 5

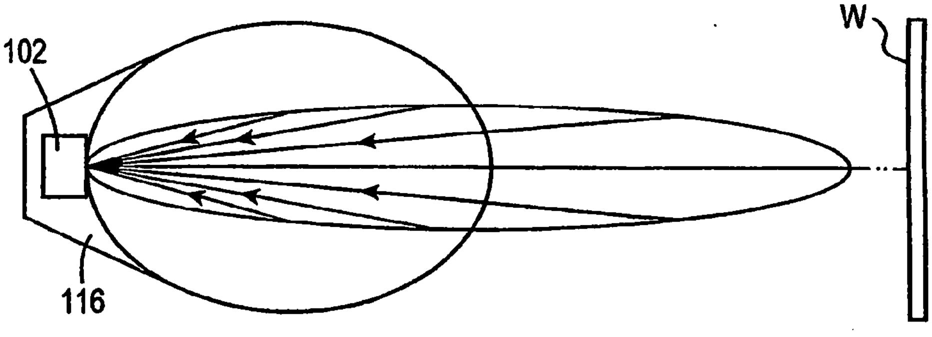


FIG. 5A

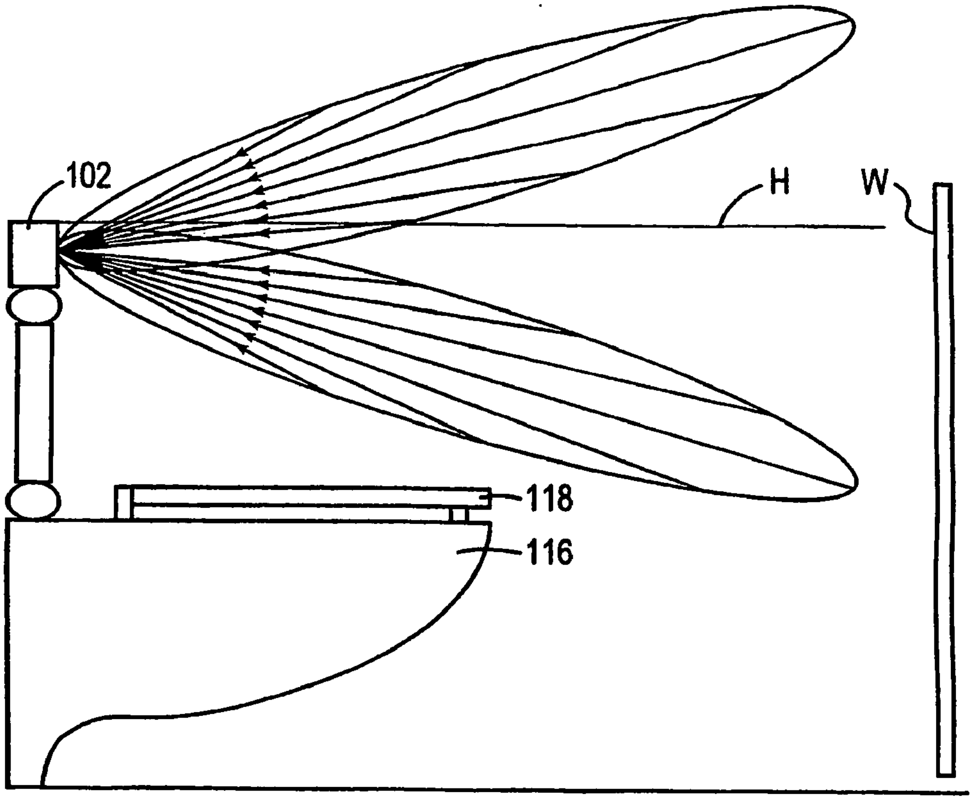


FIG. 5B

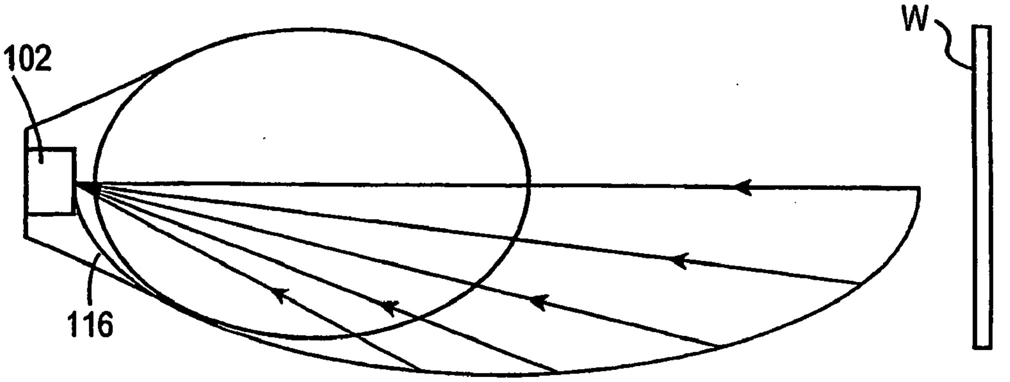


FIG. 5C

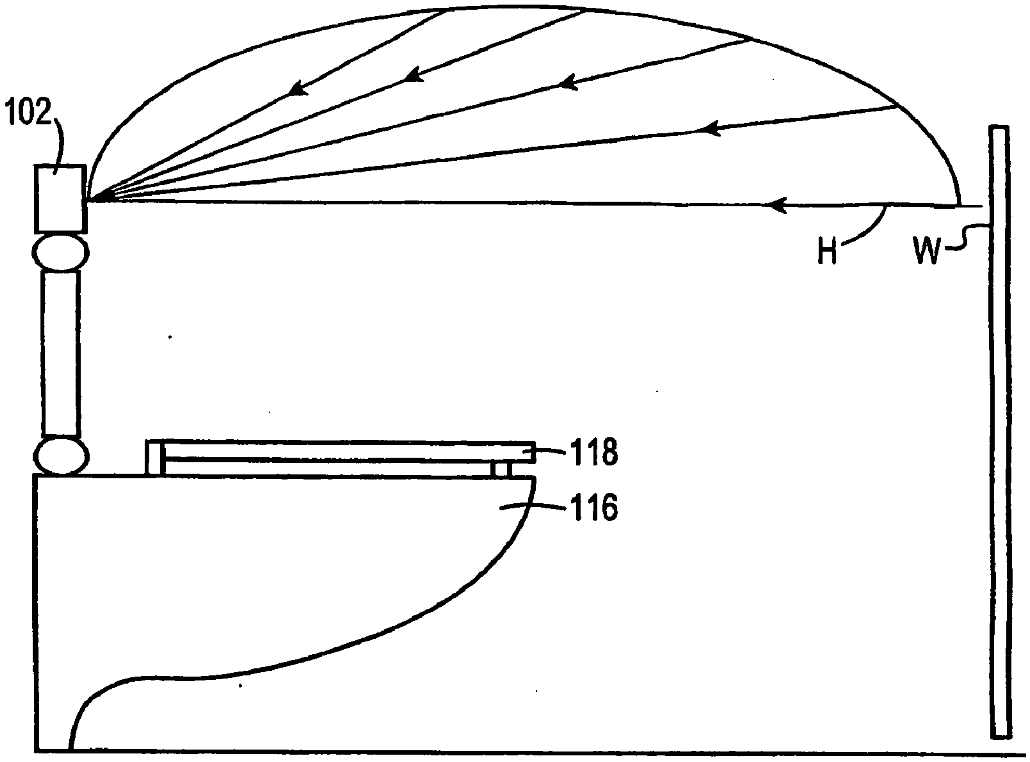


FIG. 5D

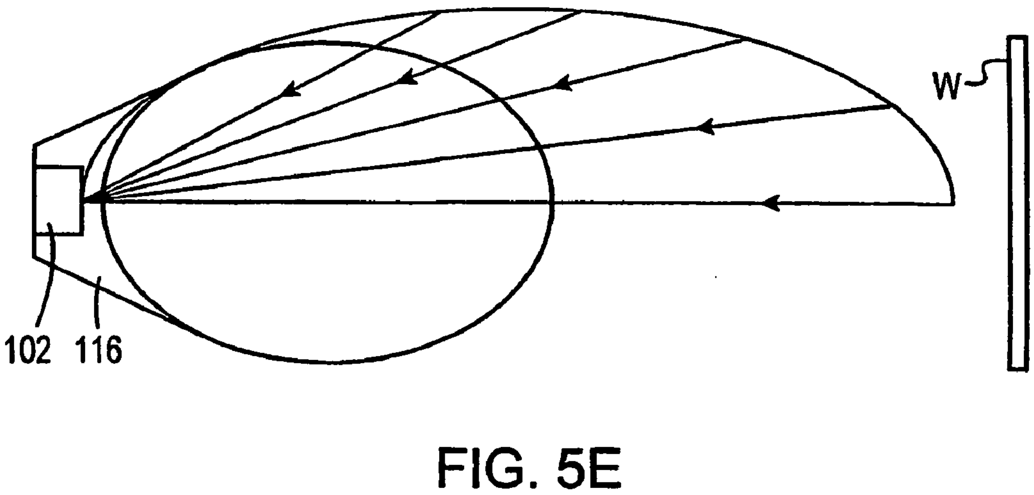


FIG. 5E

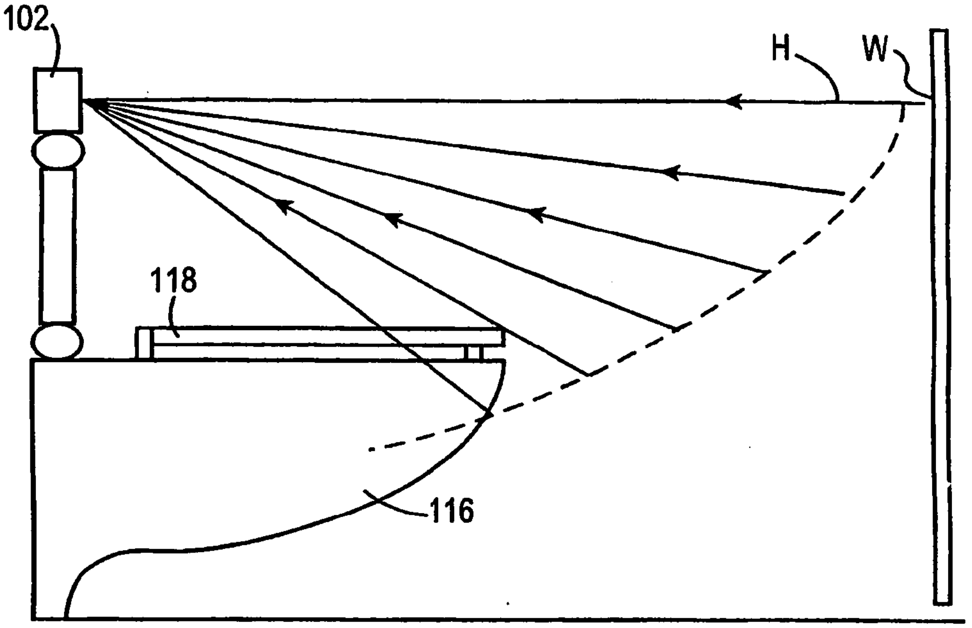


FIG. 5F

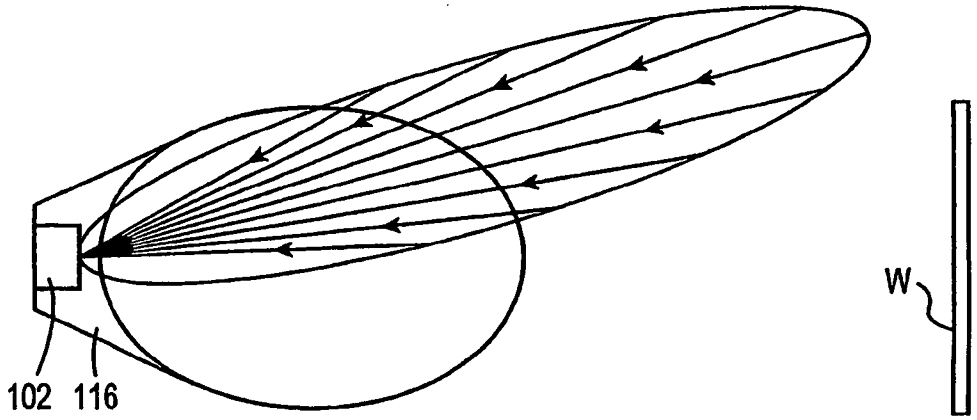


FIG. 5G

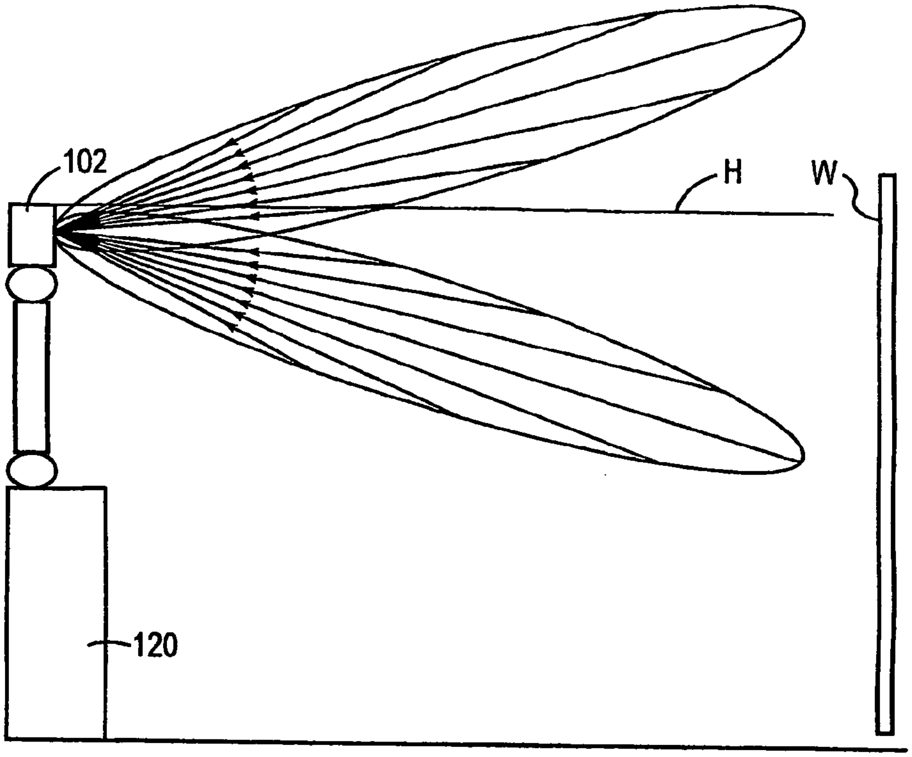


FIG. 5H

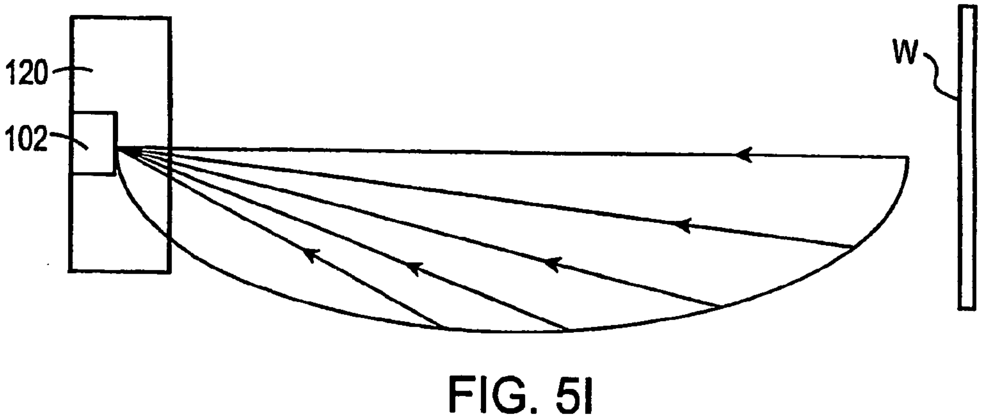


FIG. 5I

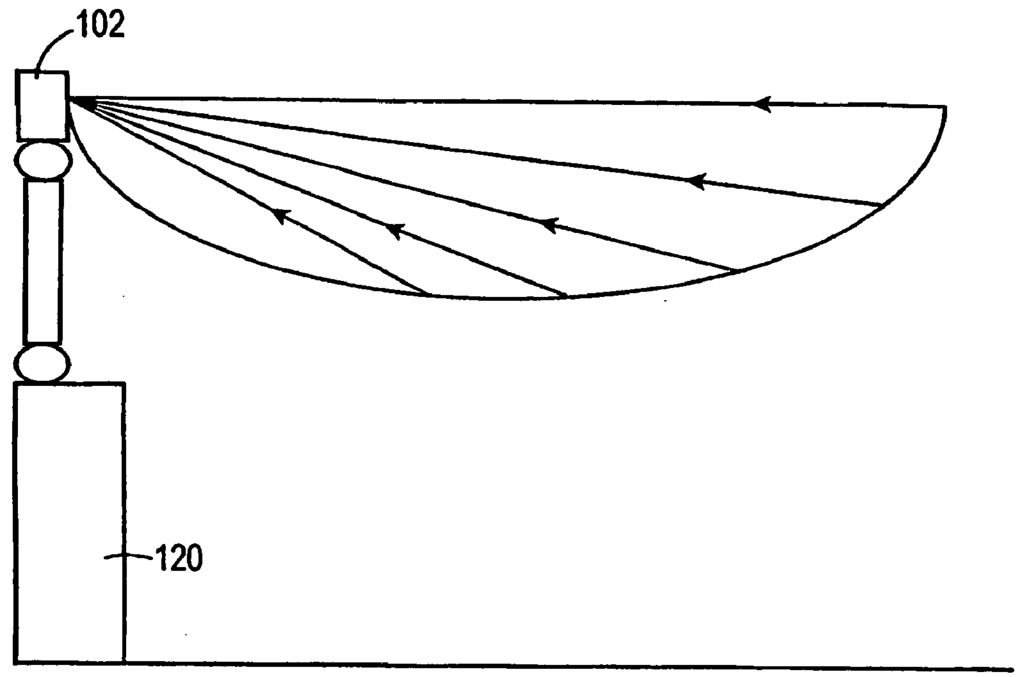


FIG. 5J

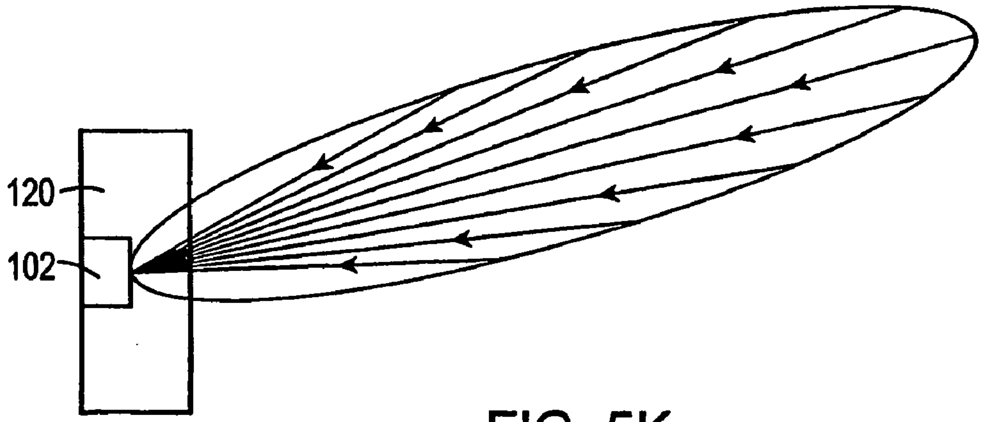


FIG. 5K

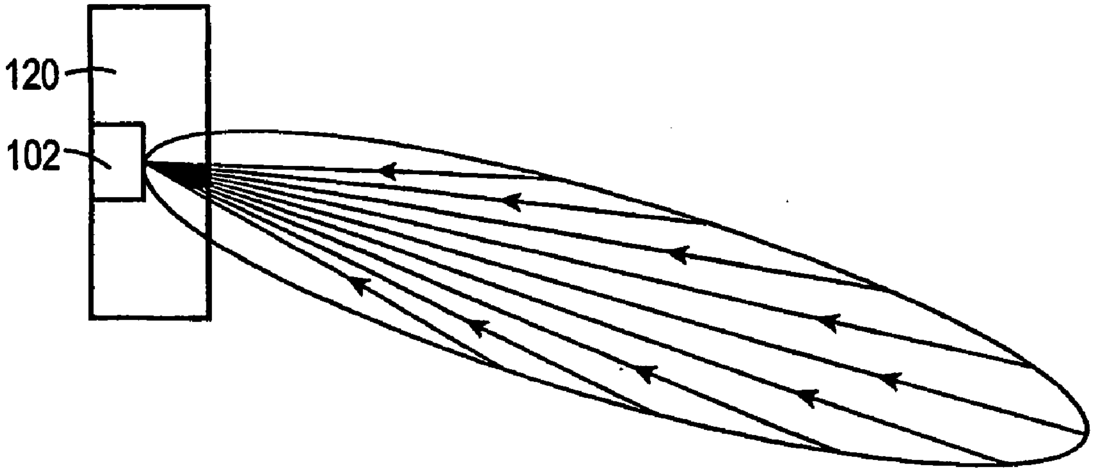


FIG. 5L

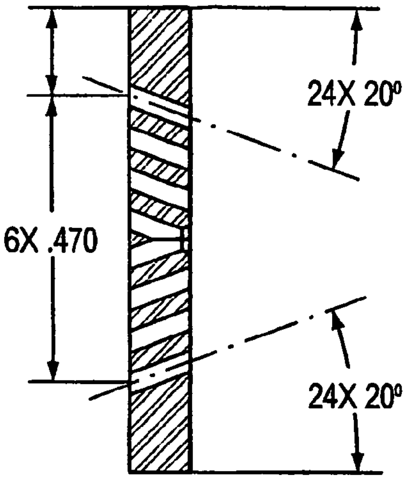


FIG. 6C

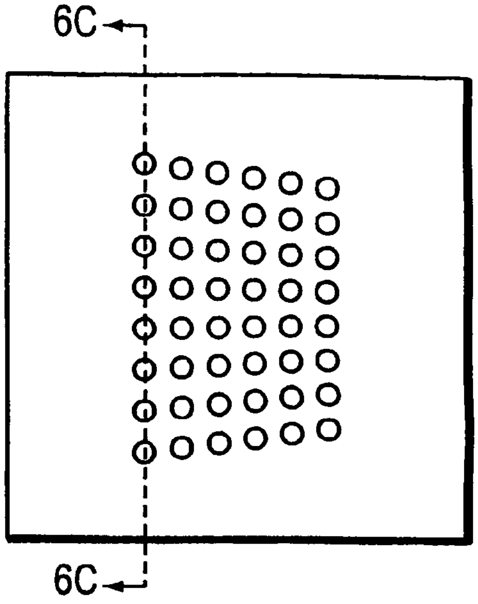


FIG. 6B

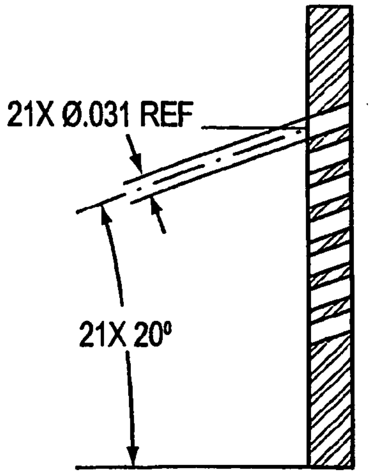


FIG. 6A

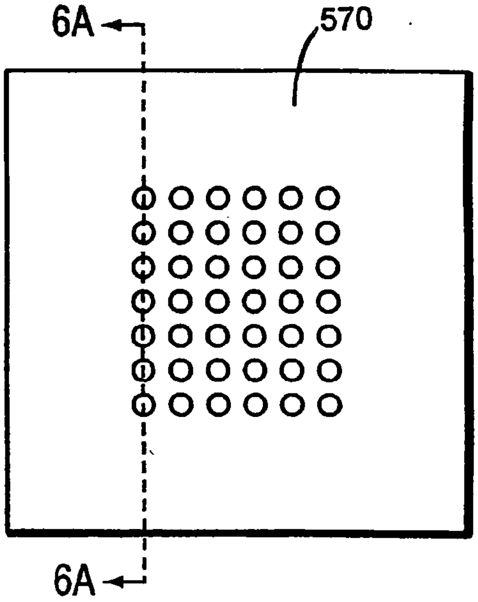


FIG. 6

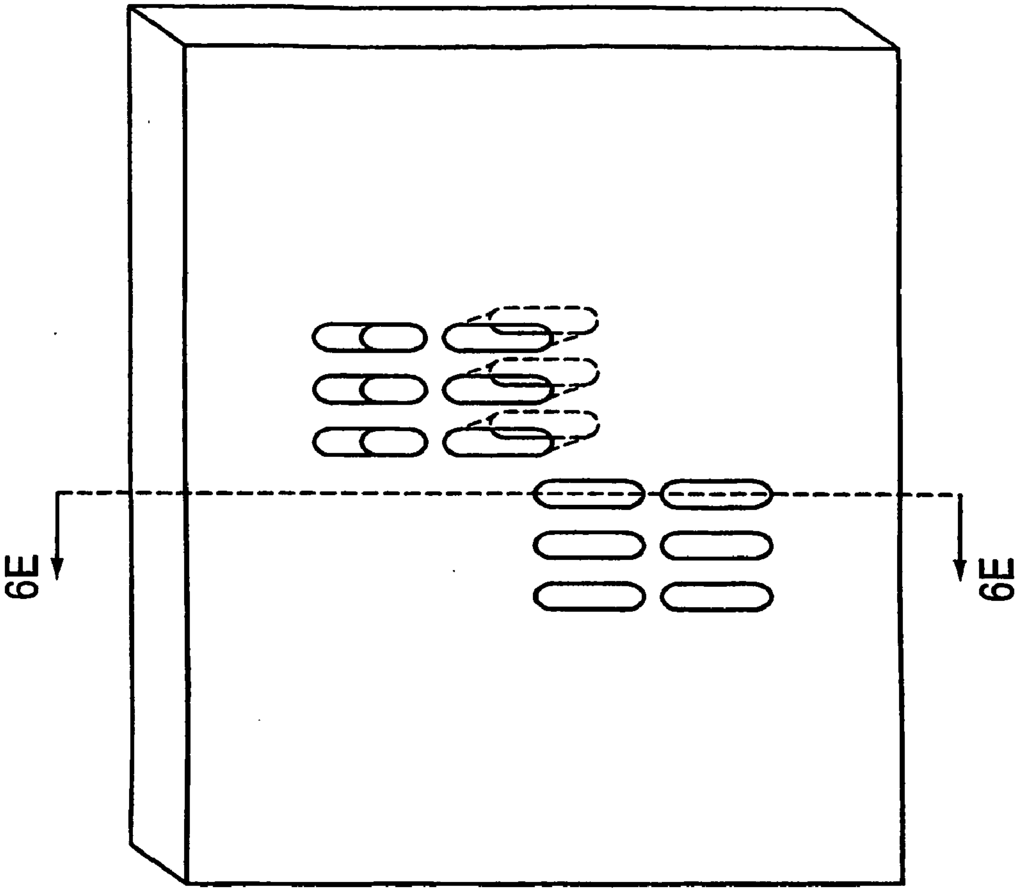


FIG. 6D

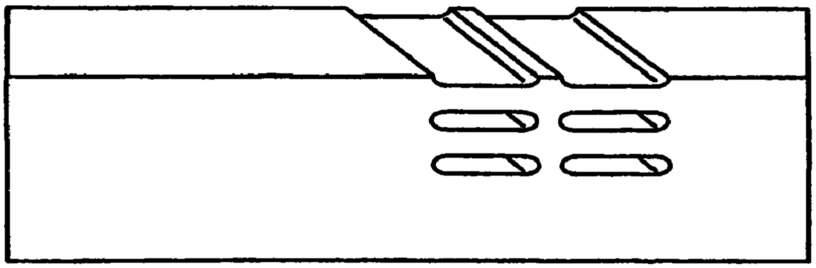
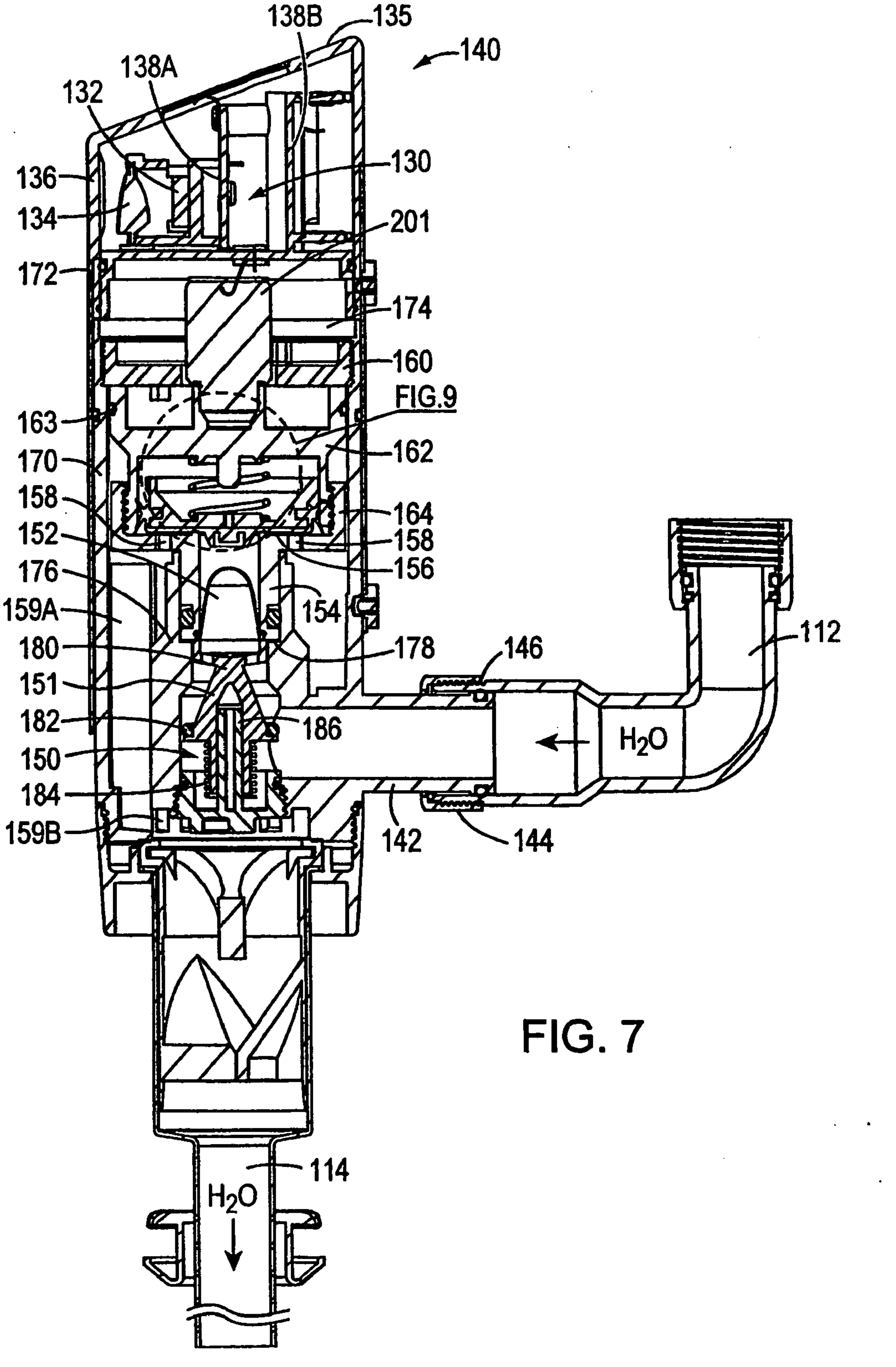


FIG. 6E


138B
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138A
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134
130
201
172
174
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FIG.9
163
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170
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164
152
158
176
156
154
159A
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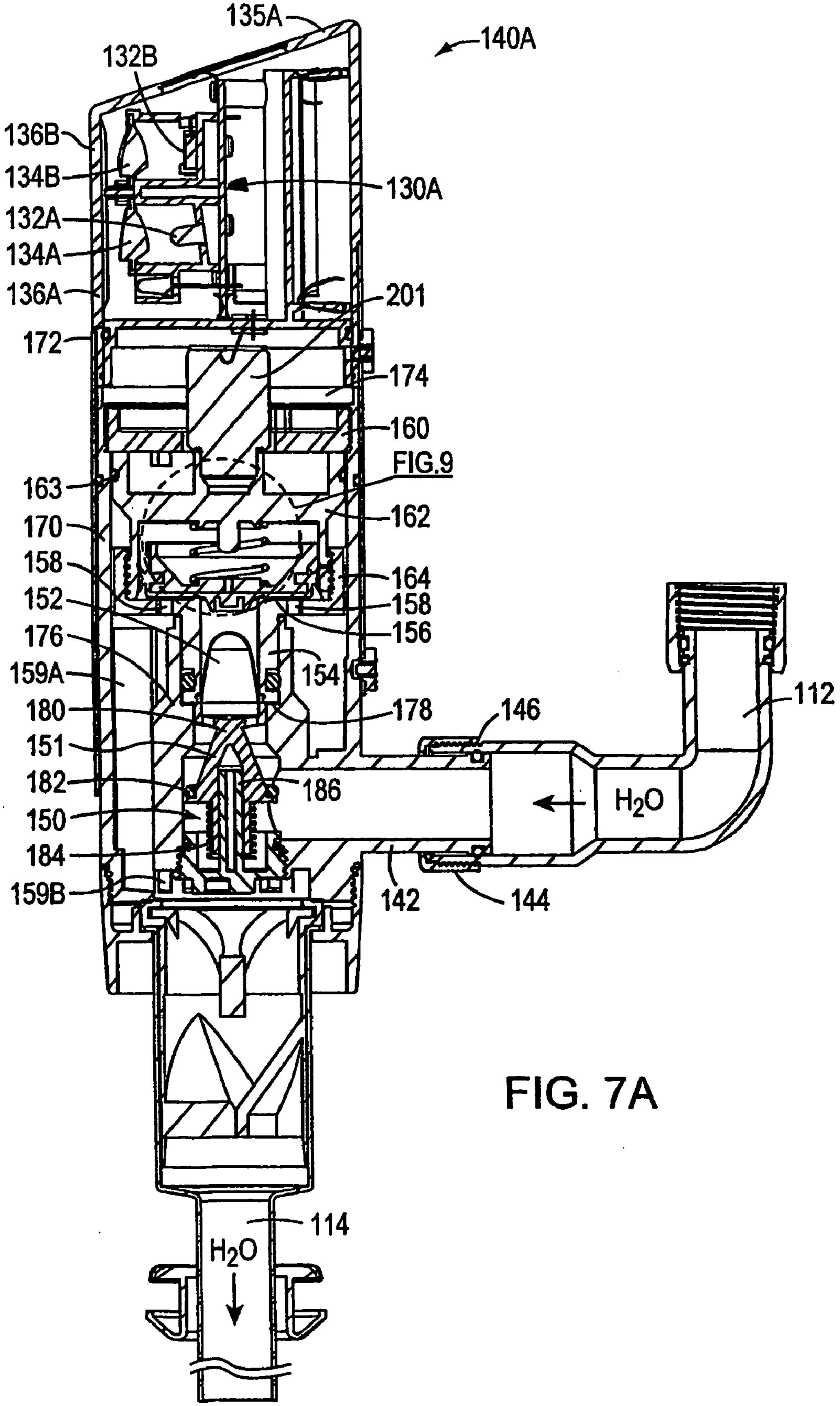
112
151
H2O
182
186
150
184
159B
142
144
114
H2O

FIG. 7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134B
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132A
134A
136A
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174
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FIG.9
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170
158
164
152
158
176
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159A
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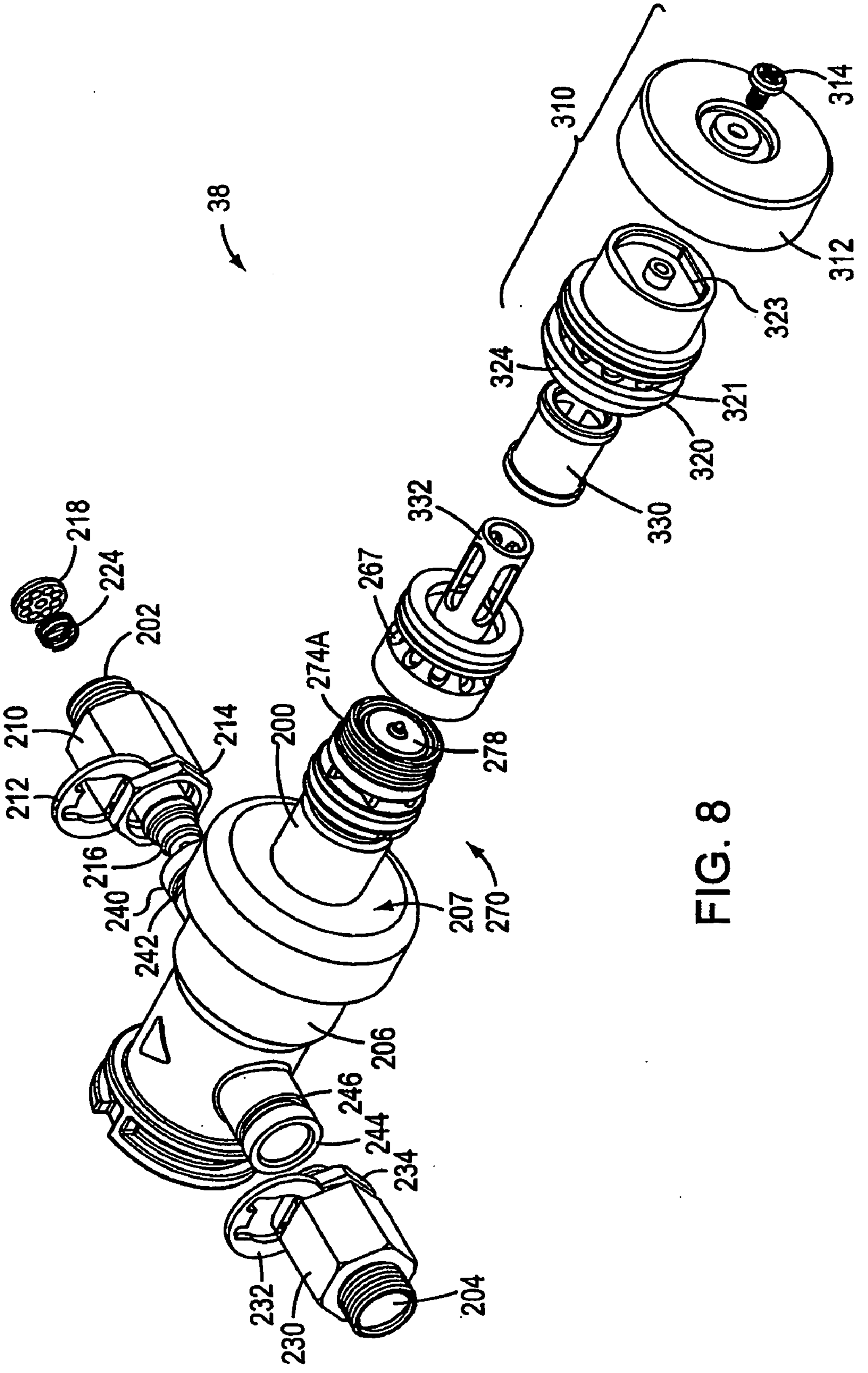
182
186
H_2O
150
184
159B
142
144
114
H_2O

FIG. 7A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323
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321
320
330
332
267
218
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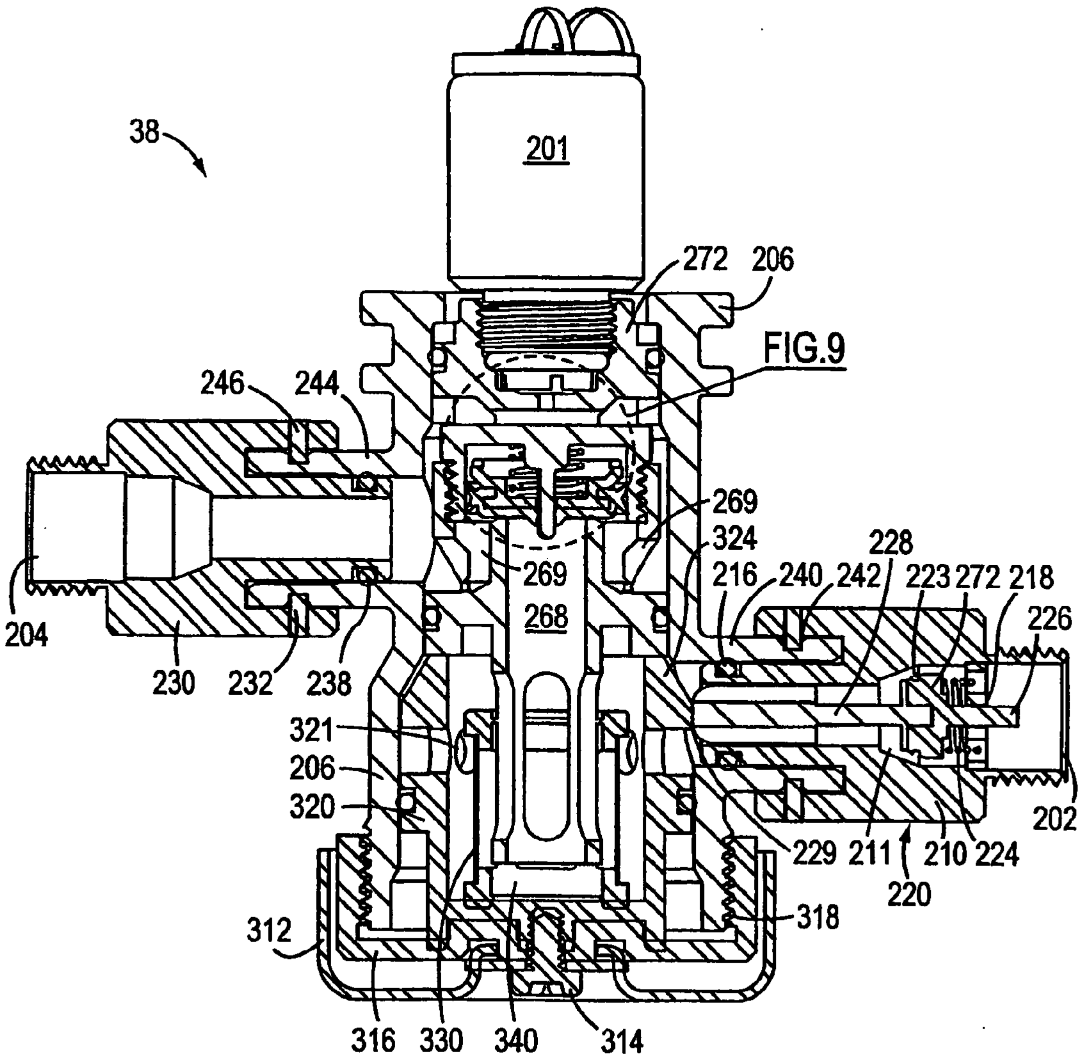
FIG. 8


38
201
272
206
FIG.9
246
244
269
324
228
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240
242
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226
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230
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238
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268
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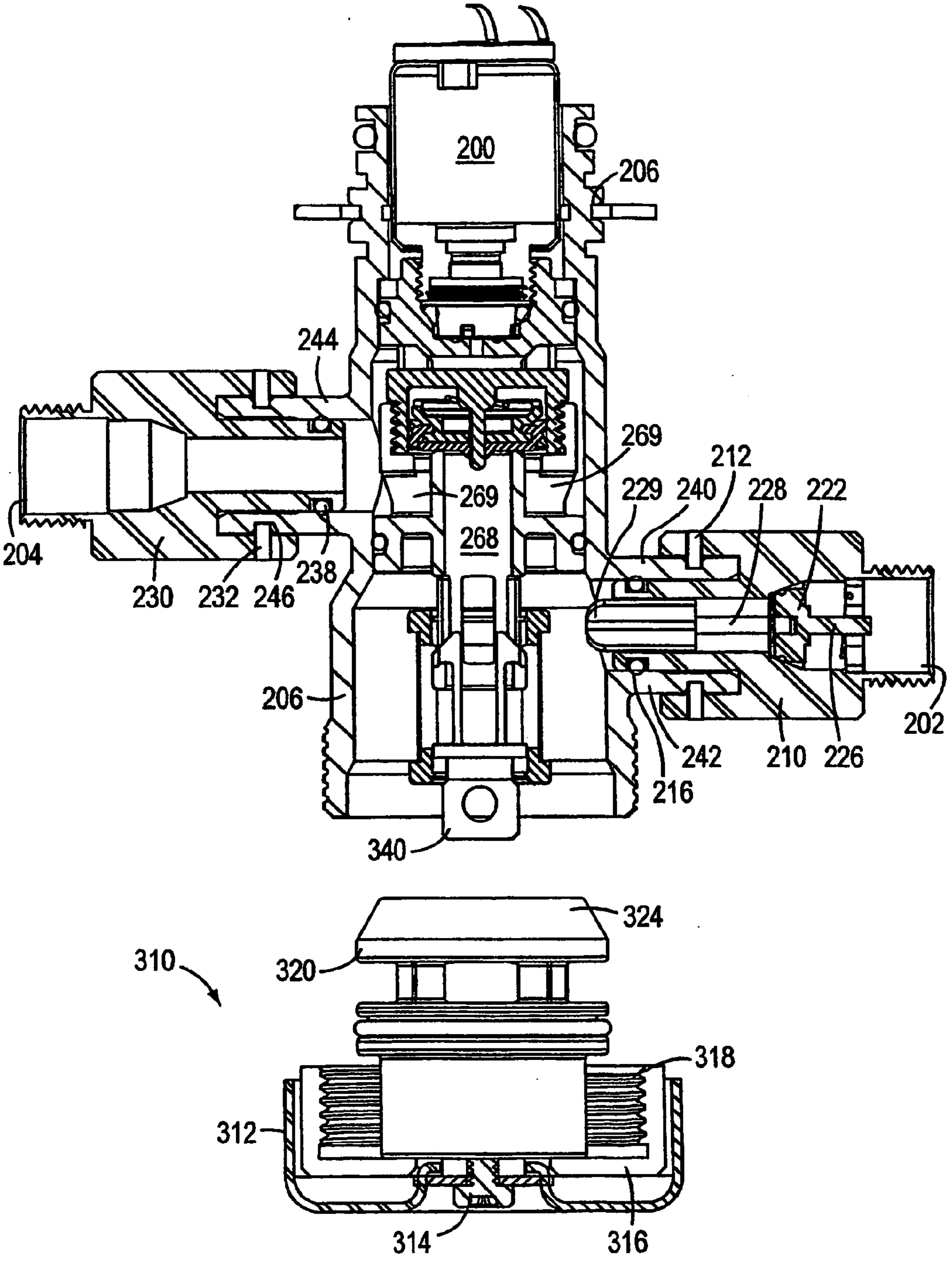
340
314

FIG. 8A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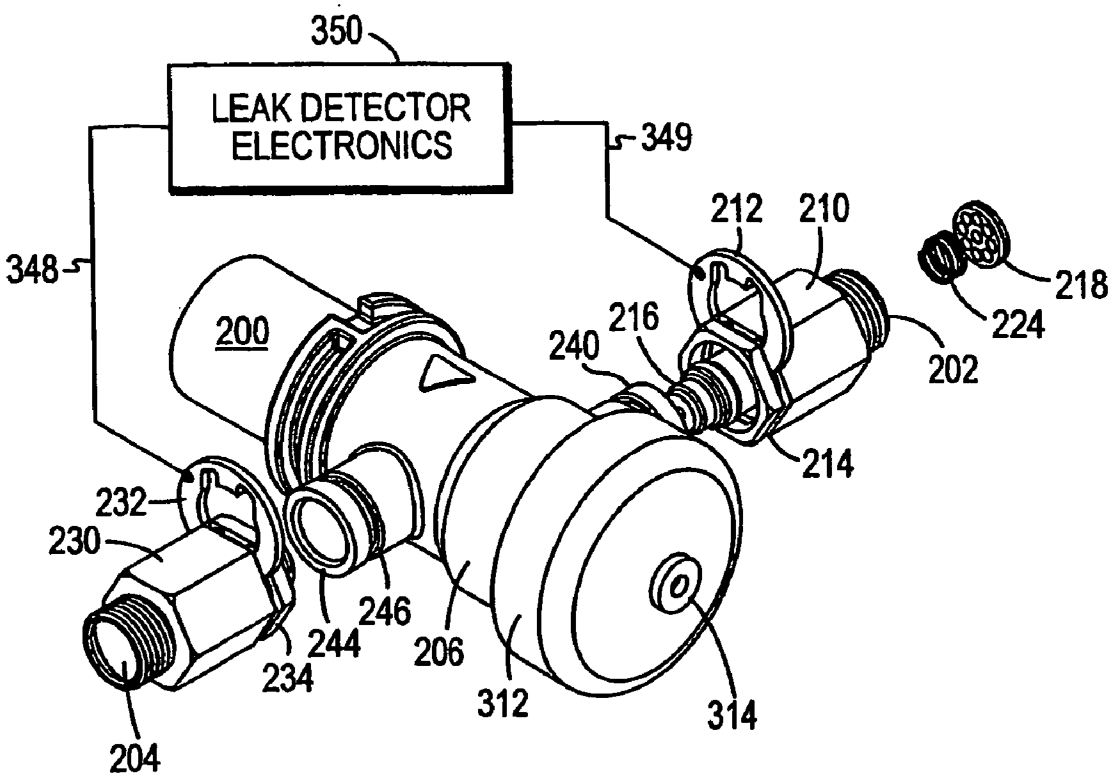
314
316

FIG. 8B


350
LEAK DETECTOR ELECTRONICS
349
348
212
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206
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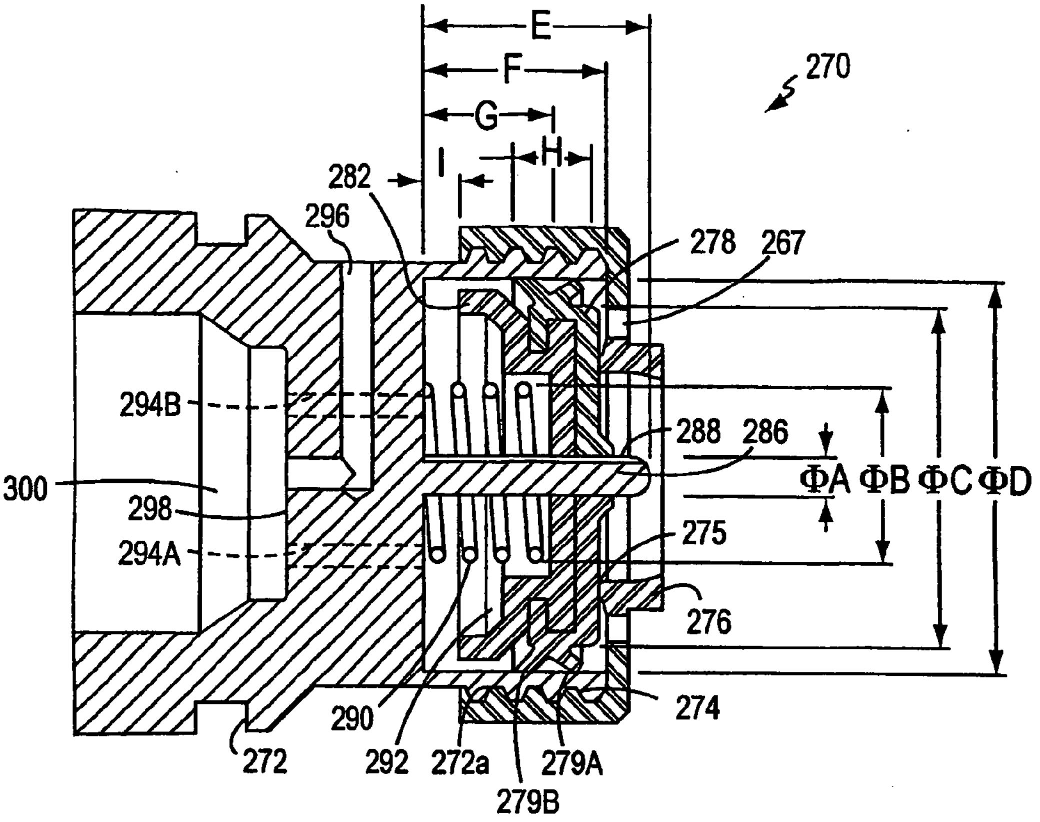
314
204

FIG. 8C


E
F
G
H
I
270
282
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267
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286
ΦA
ΦB
ΦC
ΦD
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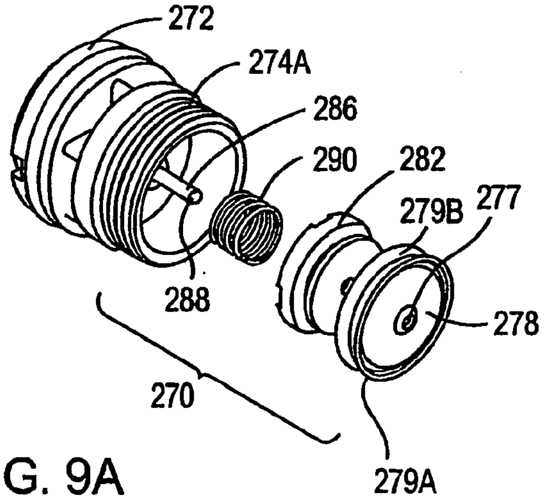
272a
279A
272
279B

FIG. 9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279A

FIG. 9A

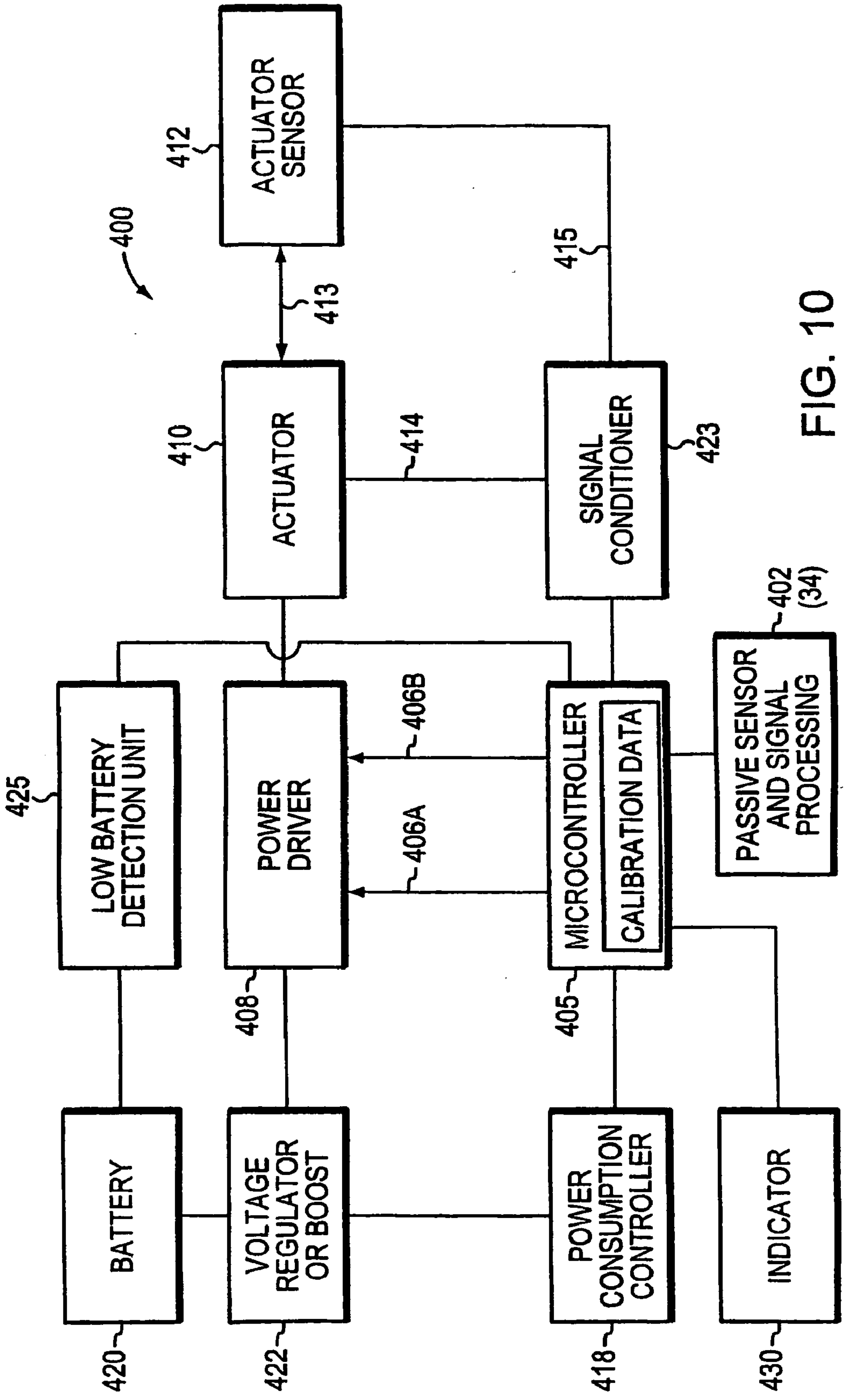

400
ACTUATOR SENSOR
412
413
415
ACTUATOR
410
414
SIGNAL CONDITIONER
423
LOW BATTERY DETECTION UNIT
425
POWER DRIVER
408
406A
406B
MICROCONTROLLER
CALIBRATION DATA
405
PASSIVE SENSOR AND SIGNAL PROCESSING
402
(34)
BATTERY
420
VOLTAGE REGULATOR OR BOOST
422
POWER CONSUMPTION CONTROLLER
418
INDICATOR
430

FIG. 10

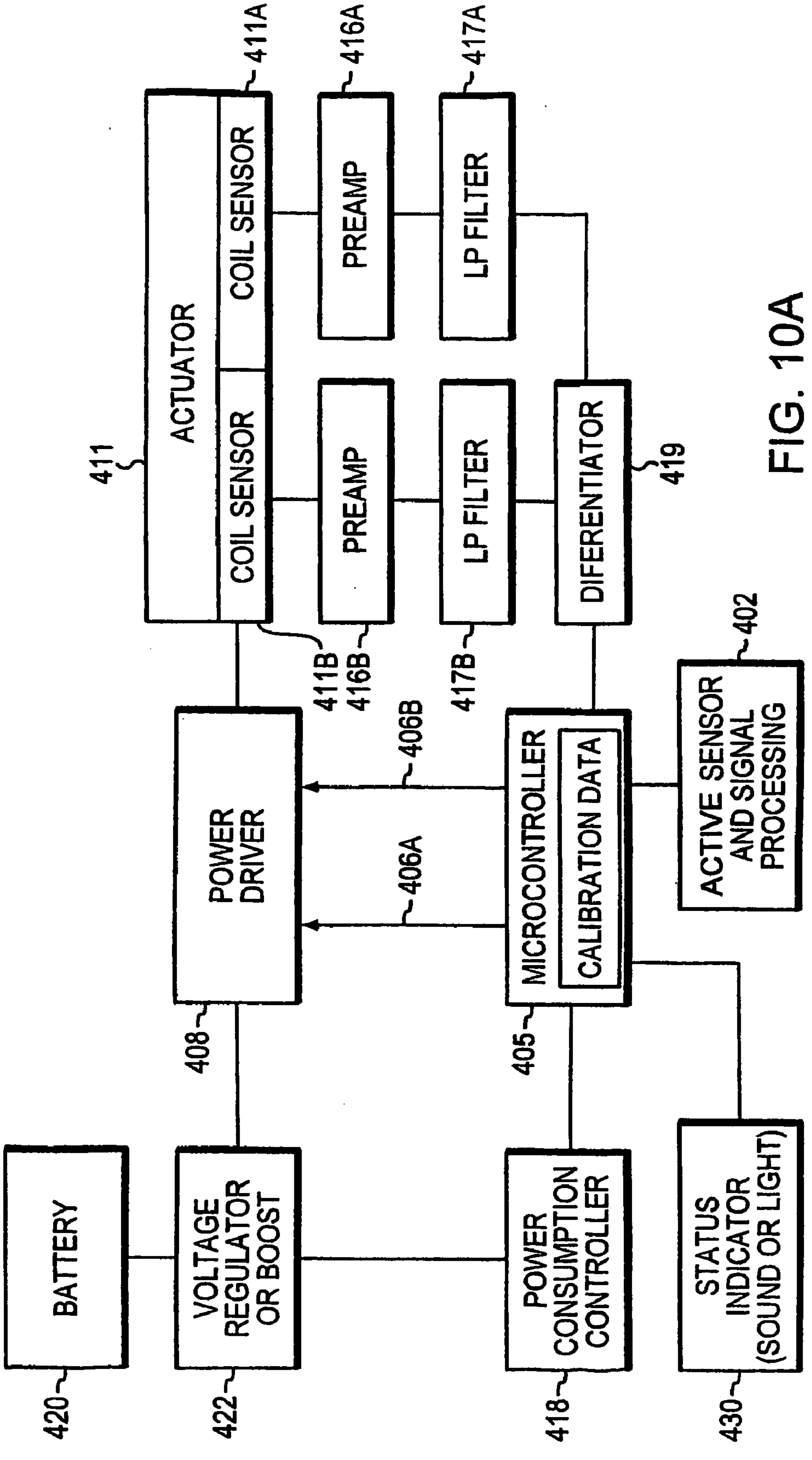

411
ACTUATOR
411A
COIL SENSOR
COIL SENSOR
411B
416A
PREAMP
PREAMP
416B
417A
LP FILTER
LP FILTER
417B
DIFERENTIATOR
419
POWER DRIVER
408
406B
406A
MICROCONTROLLER
CALIBRATION DATA
405
ACTIVE SENSOR AND SIGNAL PROCESSING
402
BATTERY
420
VOLTAGE REGULATOR OR BOOST
422
POWER CONSUMPTION CONTROLLER
418
STATUS INDICATOR (SOUND OR LIGHT)
430

FIG. 10A

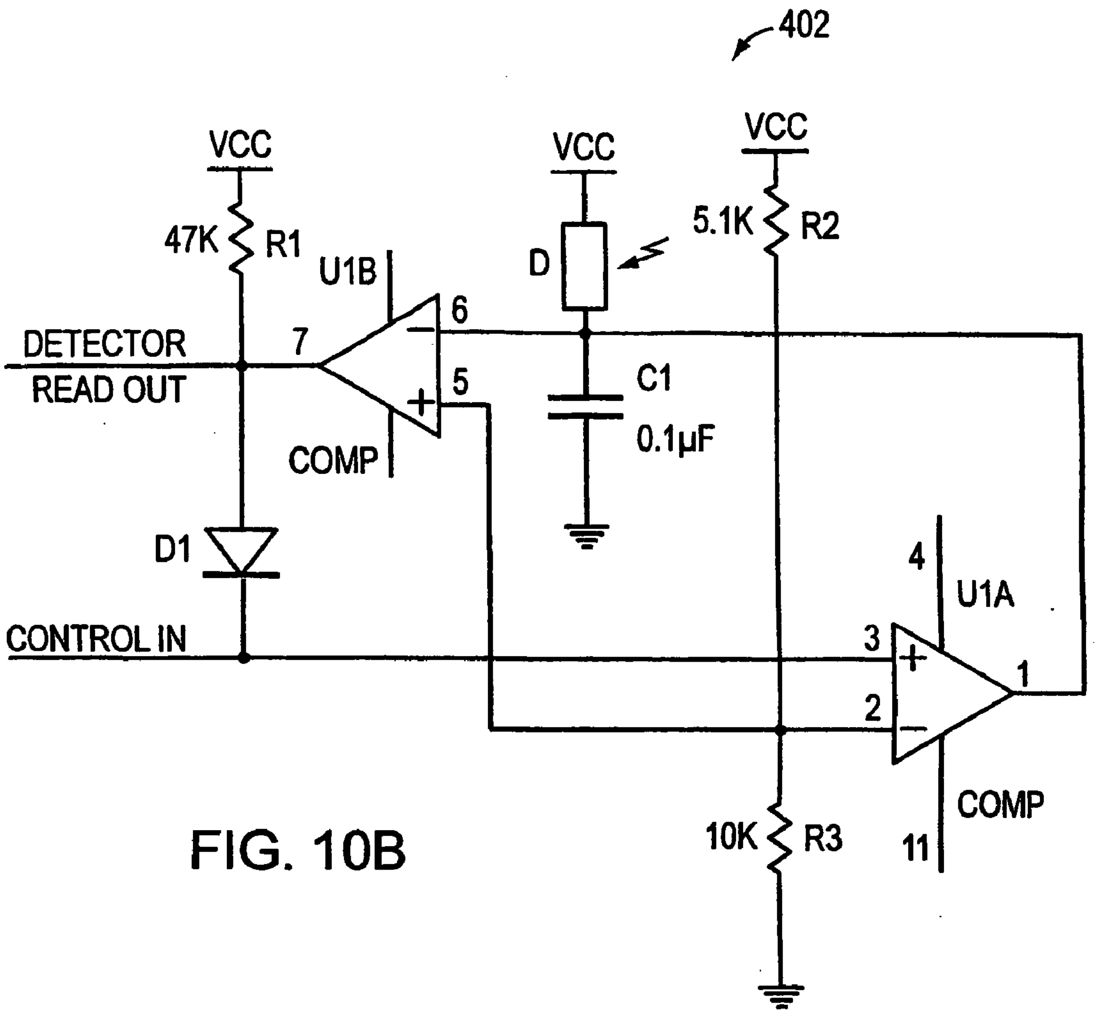
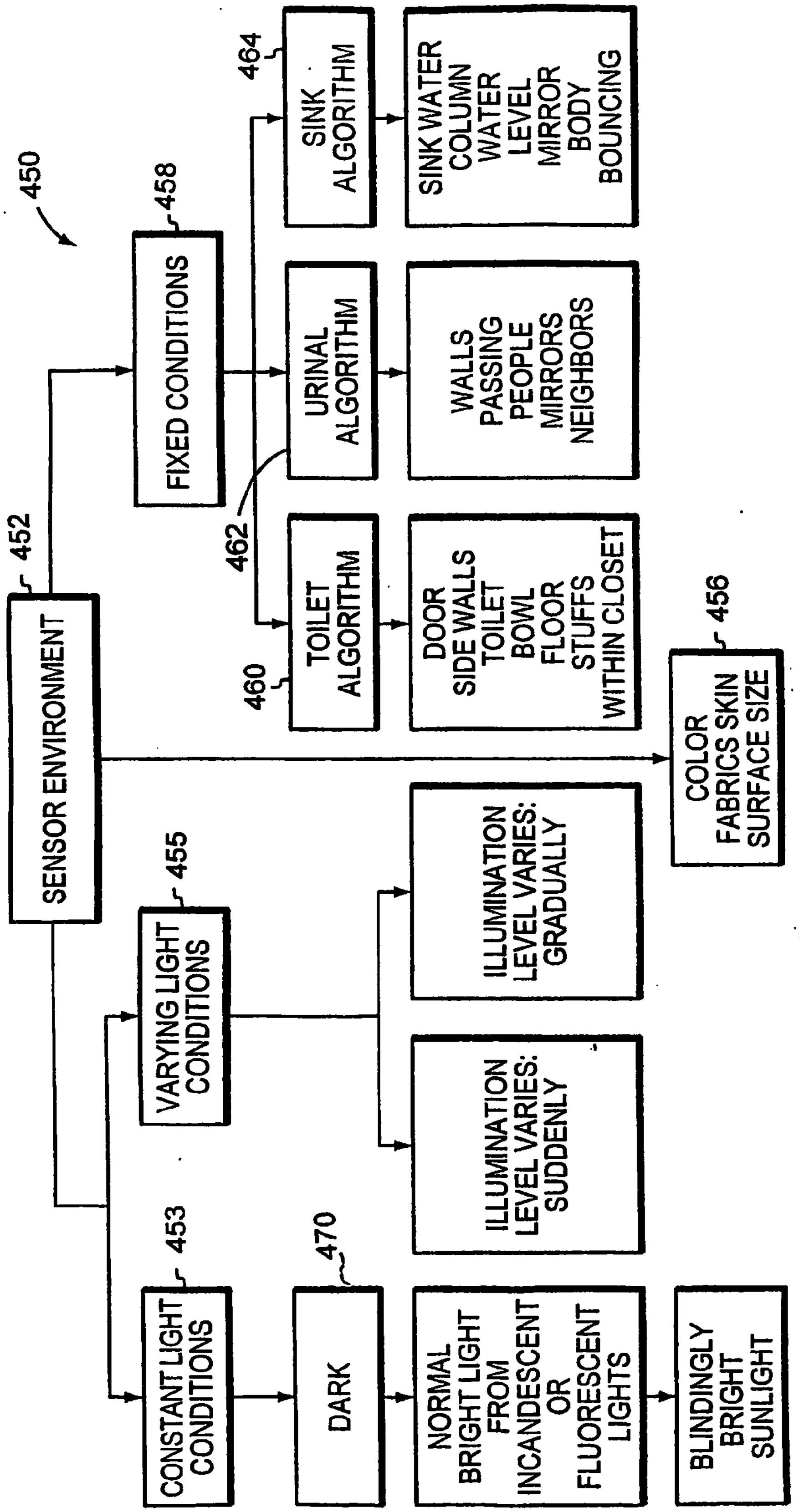

402
VCC
VCC
VCC
47K
R1
U1B
D
5.1K
R2
6
DETECTOR
READ OUT
7
5
C1
0.1μF
COMP
D1
4
U1A
CONTROL IN
3
1
2
COMP
10K
R3
11

FIG. 10B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458
FIXED CONDITIONS
460
TOILET ALGORITHM
462
URINAL ALGORITHM
464
SINK ALGORITHM
DOOR SIDE WALLS TOILET BOWL FLOOR STUFFS WITHIN CLOSET
WALLS PASSING PEOPLE MIRRORS NEIGHBORS
SINK WATER COLUMN WATER LEVEL MIRROR BODY BOUNCING
456
COLOR FABRICS SKIN SURFACE SIZE
455
VARYING LIGHT CONDITIONS
ILLUMINATION LEVEL VARIES: GRADUALLY
ILLUMINATION LEVEL VARIES: SUDDENLY
453
CONSTANT LIGHT CONDITIONS
470
DARK
NORMAL BRIGHT LIGHT FROM INCANDESCENT OR FLUORESCENT LIGHTS
BLINDINGLY BRIGHT SUNLIGHT

FIG. 11

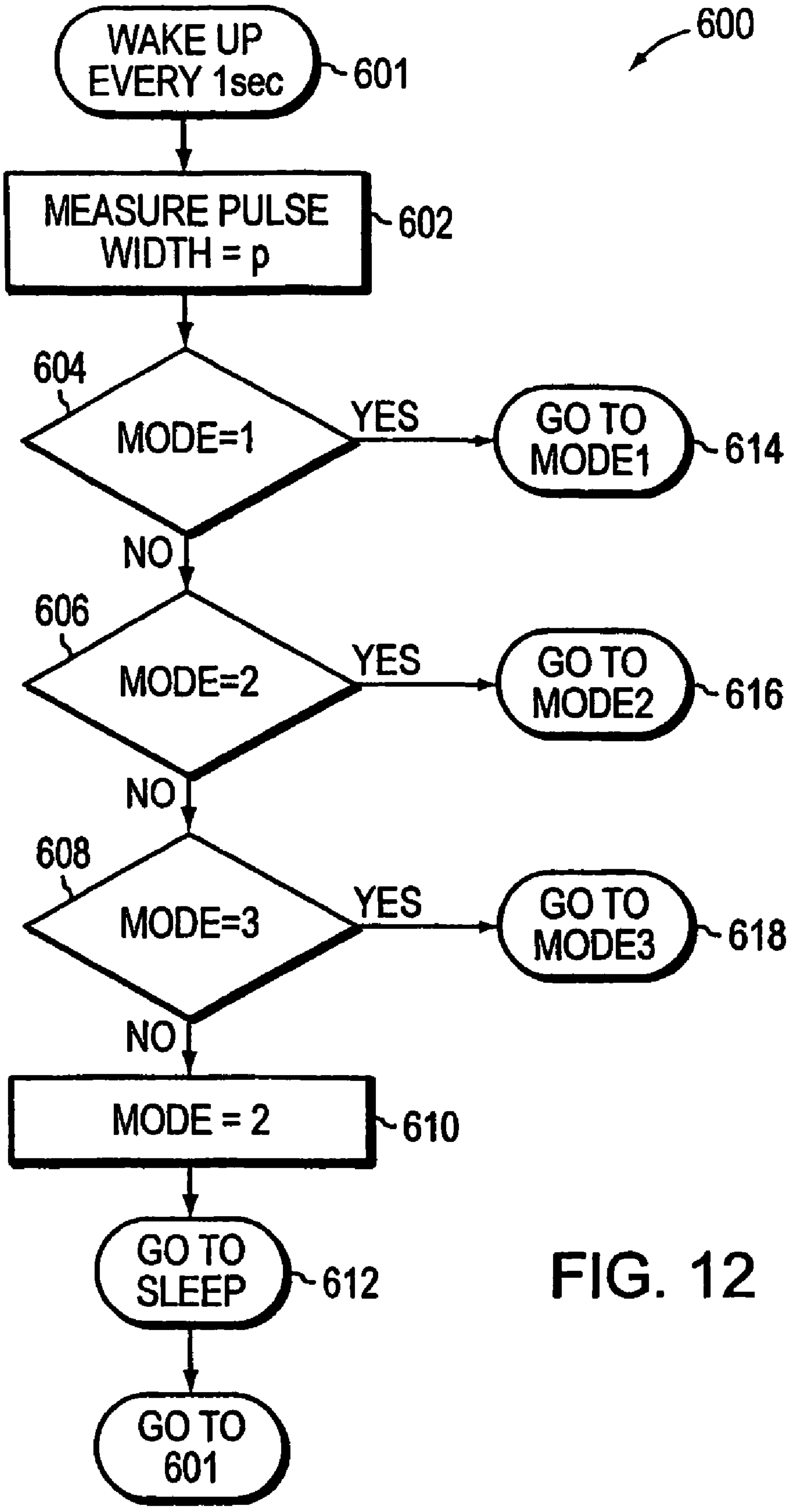
600
WAKE UP EVERY 1sec
601
MEASURE PULSE WIDTH = p
602
604
MODE=1
YES
GO TO MODE1
614
NO
606
MODE=2
YES
GO TO MODE2
616
NO
608
MODE=3
YES
GO TO MODE3
618
NO
MODE = 2
610
GO TO SLEEP
612
GO TO 601

FIG. 12

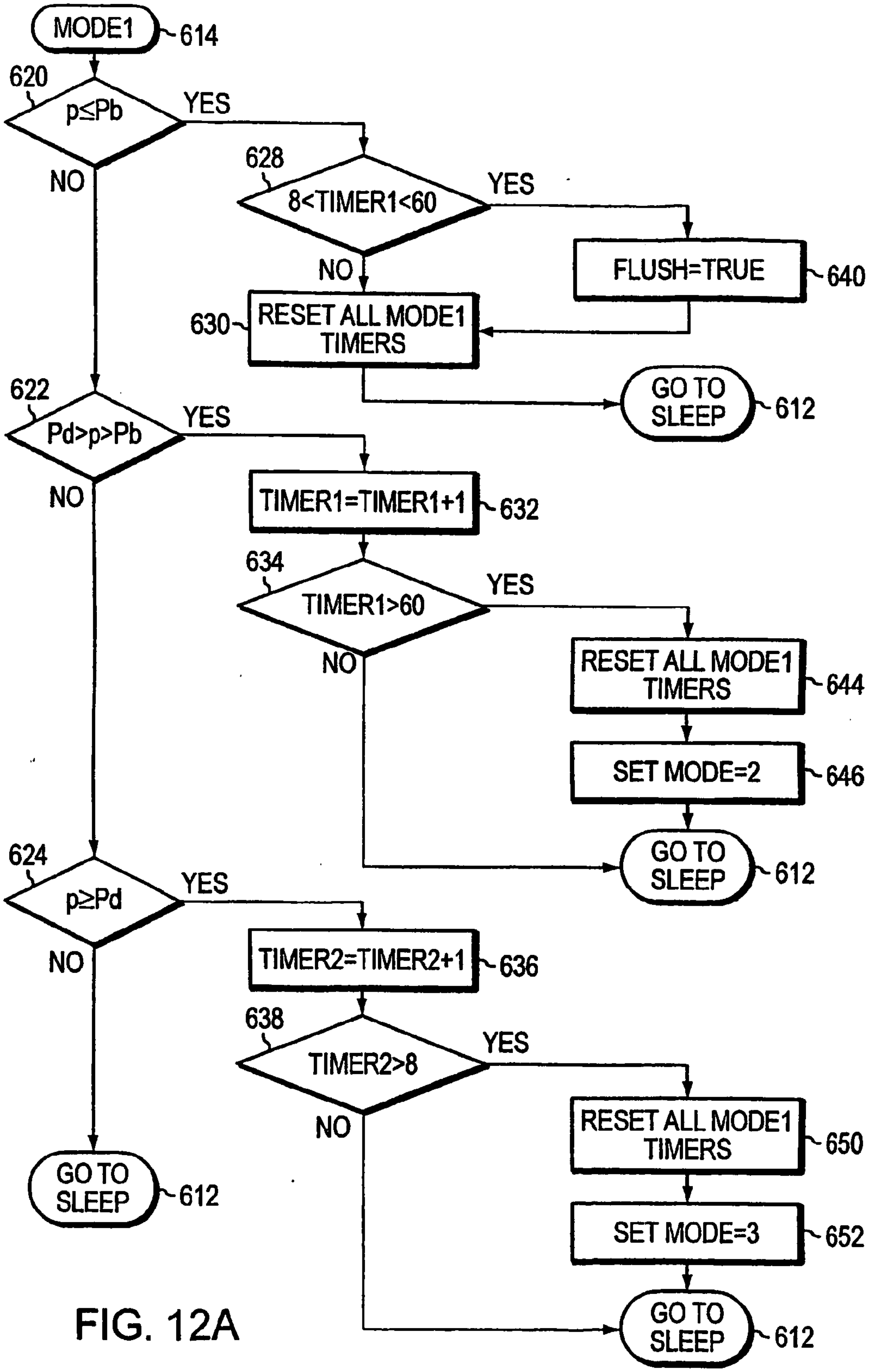
MODE1
614
620
p≤Pb
YES
NO
628
8<TIMER1<60
YES
NO
FLUSH=TRUE
640
630
RESET ALL MODE1 TIMERS
GO TO SLEEP
612
622
Pd>p>Pb
YES
NO
TIMER1=TIMER1+1
632
634
TIMER1>60
YES
NO
RESET ALL MODE1 TIMERS
644
SET MODE=2
646
GO TO SLEEP
612
624
p≥Pd
YES
NO
TIMER2=TIMER2+1
636
638
TIMER2>8
YES
NO
RESET ALL MODE1 TIMERS
650
SET MODE=3
652
GO TO SLEEP
612
GO TO SLEEP
612

FIG. 12A

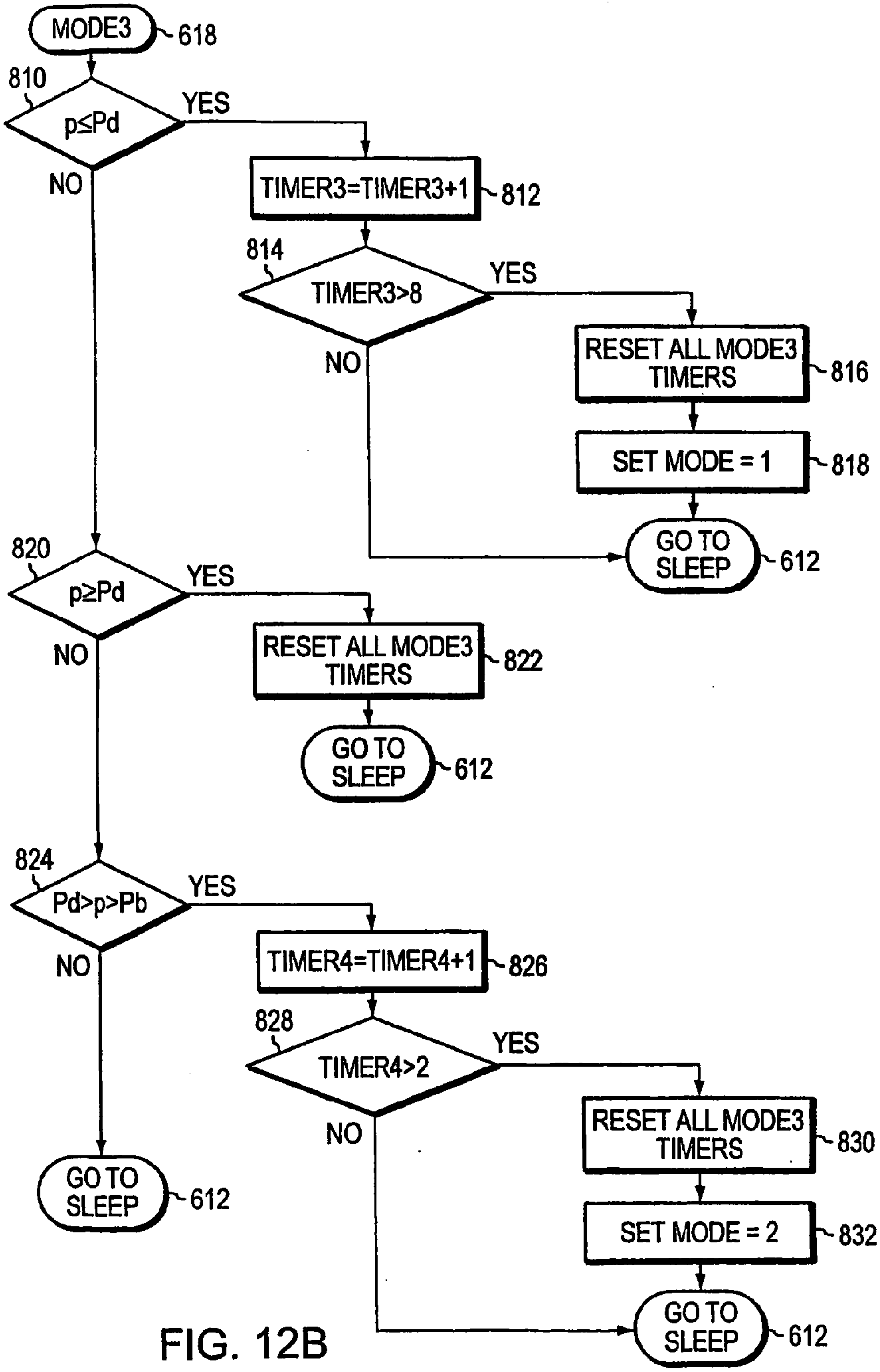
MODE3
618
810
p≤Pd
YES
NO
TIMER3=TIMER3+1
812
814
TIMER3>8
YES
NO
RESET ALL MODE3 TIMERS
816
SET MODE = 1
818
GO TO SLEEP
612
820
p≥Pd
YES
NO
RESET ALL MODE3 TIMERS
822
GO TO SLEEP
612
824
Pd>p>Pb
YES
NO
TIMER4=TIMER4+1
826
828
TIMER4>2
YES
NO
RESET ALL MODE3 TIMERS
830
SET MODE = 2
832
GO TO SLEEP
612
GO TO SLEEP
612

FIG. 12B

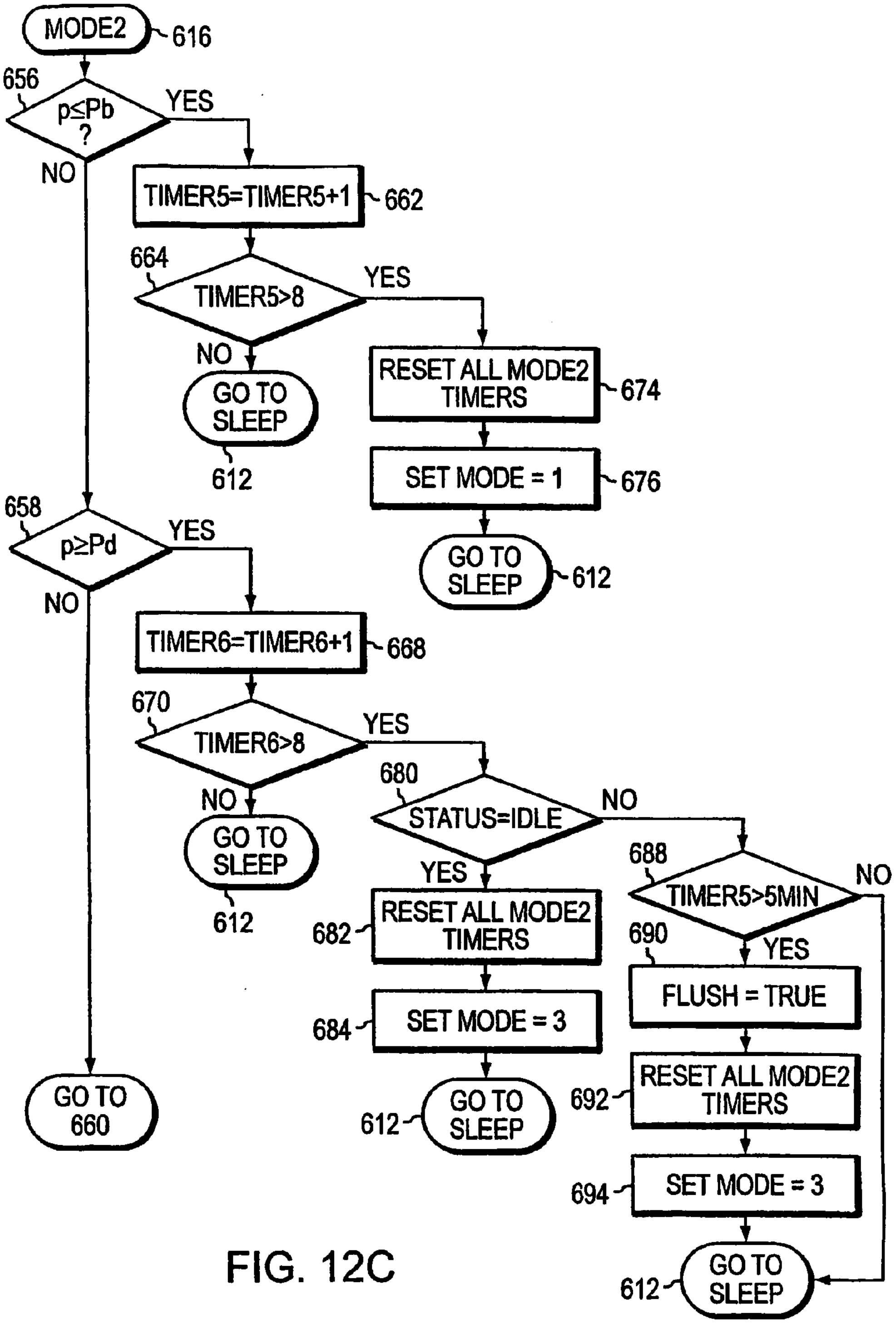
MODE2
616
656
p≤Pb ?
YES
NO
TIMER5=TIMER5+1
662
664
TIMER5>8
YES
NO
GO TO SLEEP
612
RESET ALL MODE2 TIMERS
674
SET MODE = 1
676
GO TO SLEEP
612
658
p≥Pd
YES
NO
TIMER6=TIMER6+1
668
670
TIMER6>8
YES
NO
GO TO SLEEP
612
680
STATUS=IDLE
NO
YES
RESET ALL MODE2 TIMERS
682
SET MODE = 3
684
GO TO SLEEP
612
688
TIMER5>5MIN
NO
690
YES
FLUSH = TRUE
RESET ALL MODE2 TIMERS
692
SET MODE = 3
694
GO TO SLEEP
612
GO TO 660

FIG. 12C

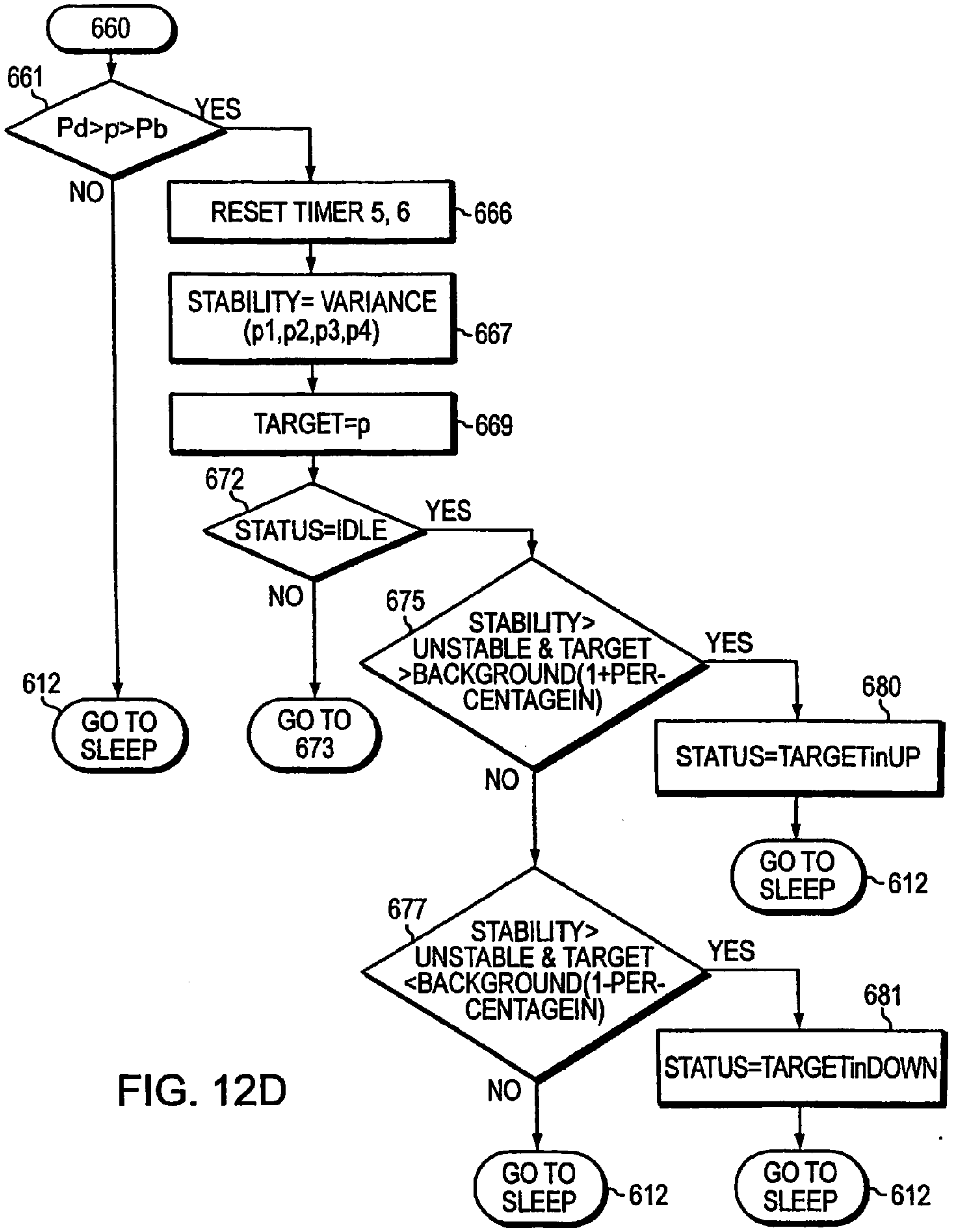
660
661
Pd>p>Pb
YES
NO
RESET TIMER 5, 6
666
STABILITY= VARIANCE (p1,p2,p3,p4)
667
TARGET=p
669
672
STATUS=IDLE
YES
NO
675
STABILITY> UNSTABLE & TARGET >BACKGROUND(1+PER-CENTAGEIN)
YES
NO
612
GO TO SLEEP
GO TO 673
680
STATUS=TARGETinUP
GO TO SLEEP
612
677
STABILITY> UNSTABLE & TARGET <BACKGROUND(1-PER-CENTAGEIN)
YES
NO
681
STATUS=TARGETinDOWN
GO TO SLEEP
612
GO TO SLEEP
612

FIG. 12D

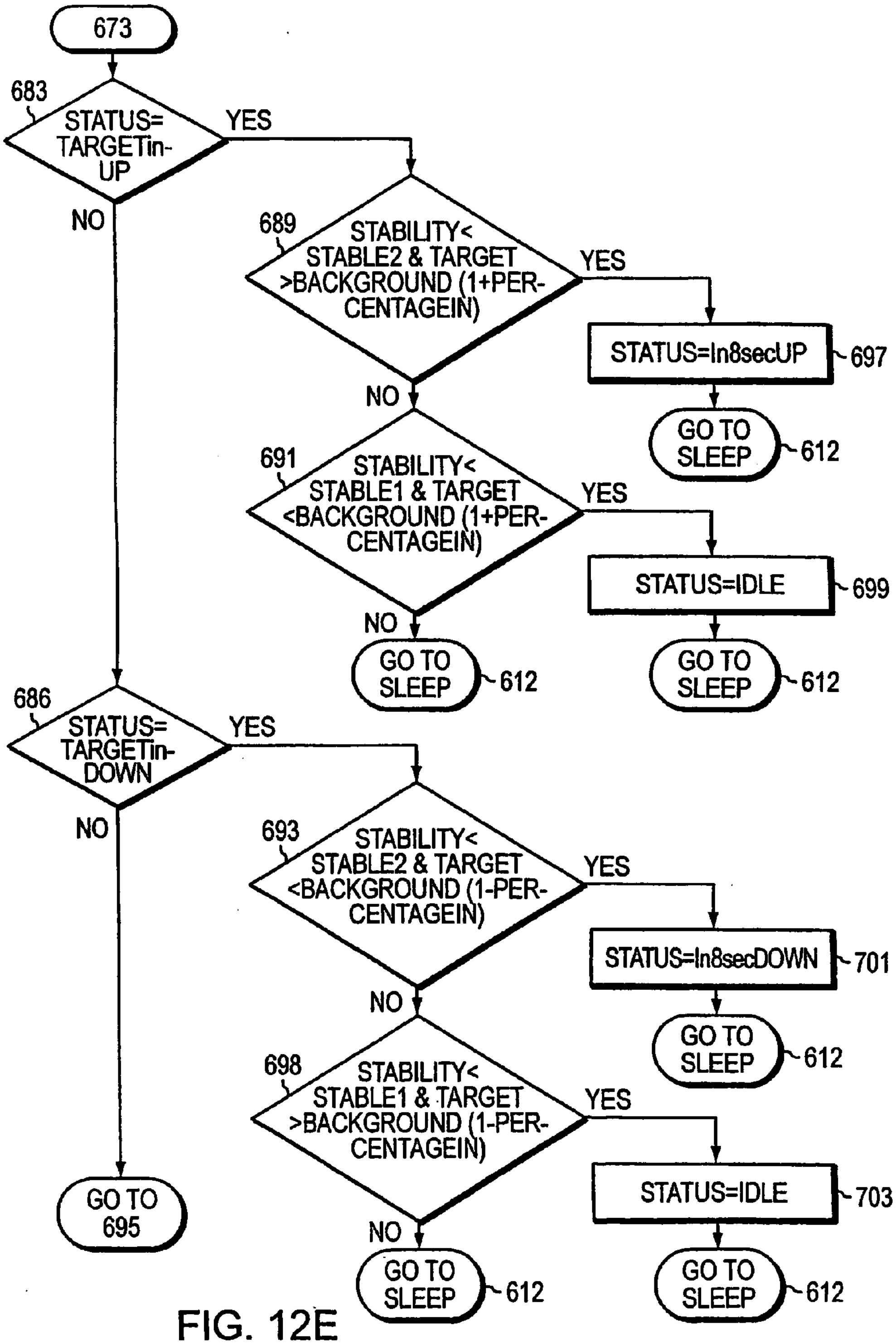
673
683
STATUS= TARGETin-UP
YES
NO
689
STABILITY< STABLE2 & TARGET >BACKGROUND (1+PER-CENTAGEIN)
YES
STATUS=In8secUP
697
GO TO SLEEP
612
NO
691
STABILITY< STABLE1 & TARGET <BACKGROUND (1+PER-CENTAGEIN)
YES
STATUS=IDLE
699
NO
GO TO SLEEP
612
GO TO SLEEP
612
686
STATUS= TARGETin-DOWN
YES
NO
693
STABILITY< STABLE2 & TARGET <BACKGROUND (1-PER-CENTAGEIN)
YES
STATUS=In8secDOWN
701
NO
GO TO SLEEP
612
698
STABILITY< STABLE1 & TARGET >BACKGROUND (1-PER-CENTAGEIN)
YES
STATUS=IDLE
703
GO TO 695
NO
GO TO SLEEP
612
GO TO SLEEP
612

FIG. 12E

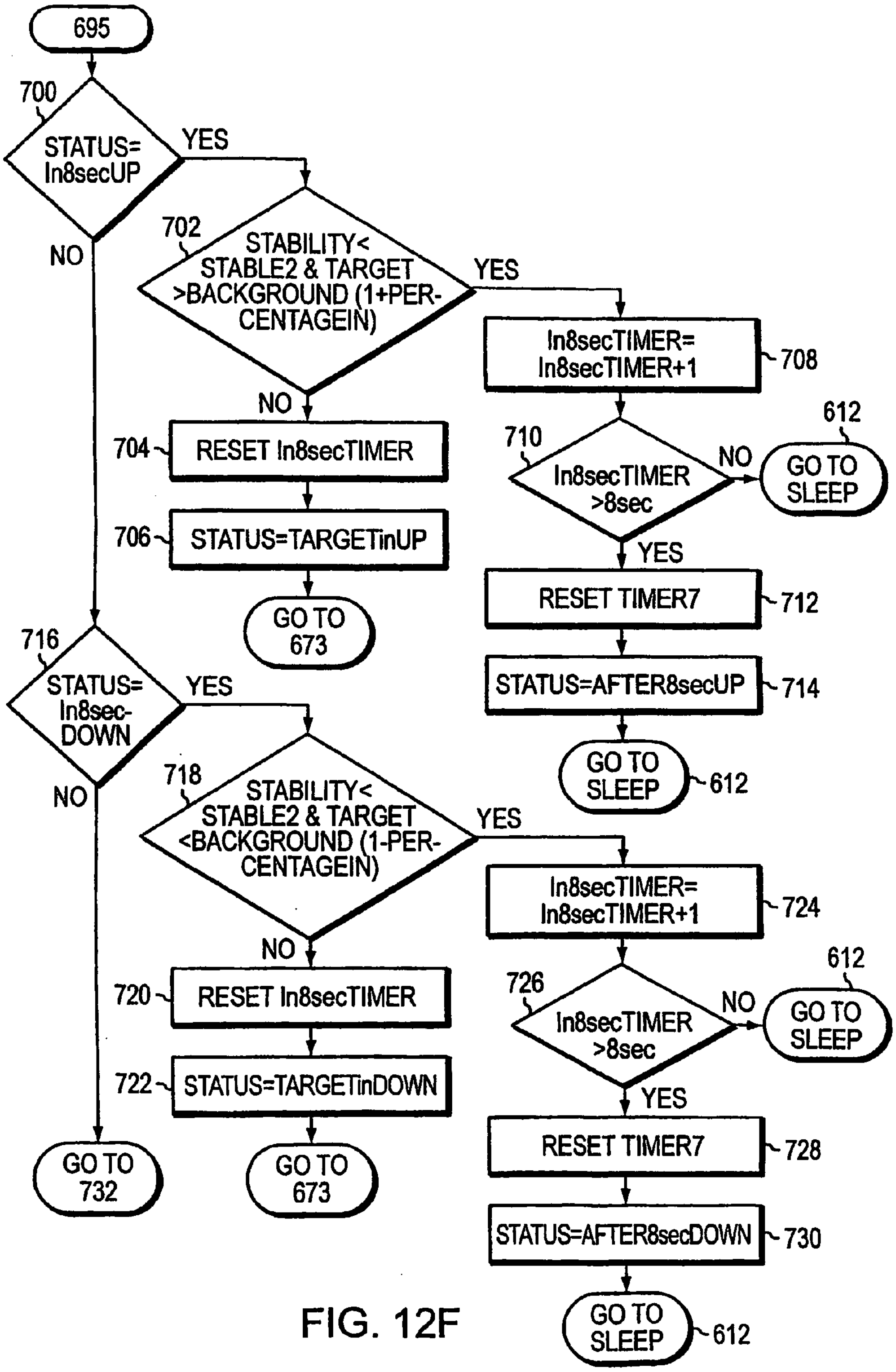
695
700
STATUS= In8secUP
YES
NO
702
STABILITY< STABLE2 & TARGET >BACKGROUND (1+PER-CENTAGEIN)
YES
NO
In8secTIMER= In8secTIMER+1
708
704
RESET In8secTIMER
706
STATUS=TARGETinUP
GO TO 673
710
In8secTIMER >8sec
NO
612
GO TO SLEEP
YES
RESET TIMER7
712
STATUS=AFTER8secUP
714
GO TO SLEEP
612
716
STATUS= In8sec-DOWN
YES
NO
718
STABILITY< STABLE2 & TARGET <BACKGROUND (1-PER-CENTAGEIN)
YES
NO
In8secTIMER= In8secTIMER+1
724
720
RESET In8secTIMER
722
STATUS=TARGETinDOWN
GO TO 732
GO TO 673
726
In8secTIMER >8sec
NO
612
GO TO SLEEP
YES
RESET TIMER7
728
STATUS=AFTER8secDOWN
730
GO TO SLEEP
612

FIG. 12F

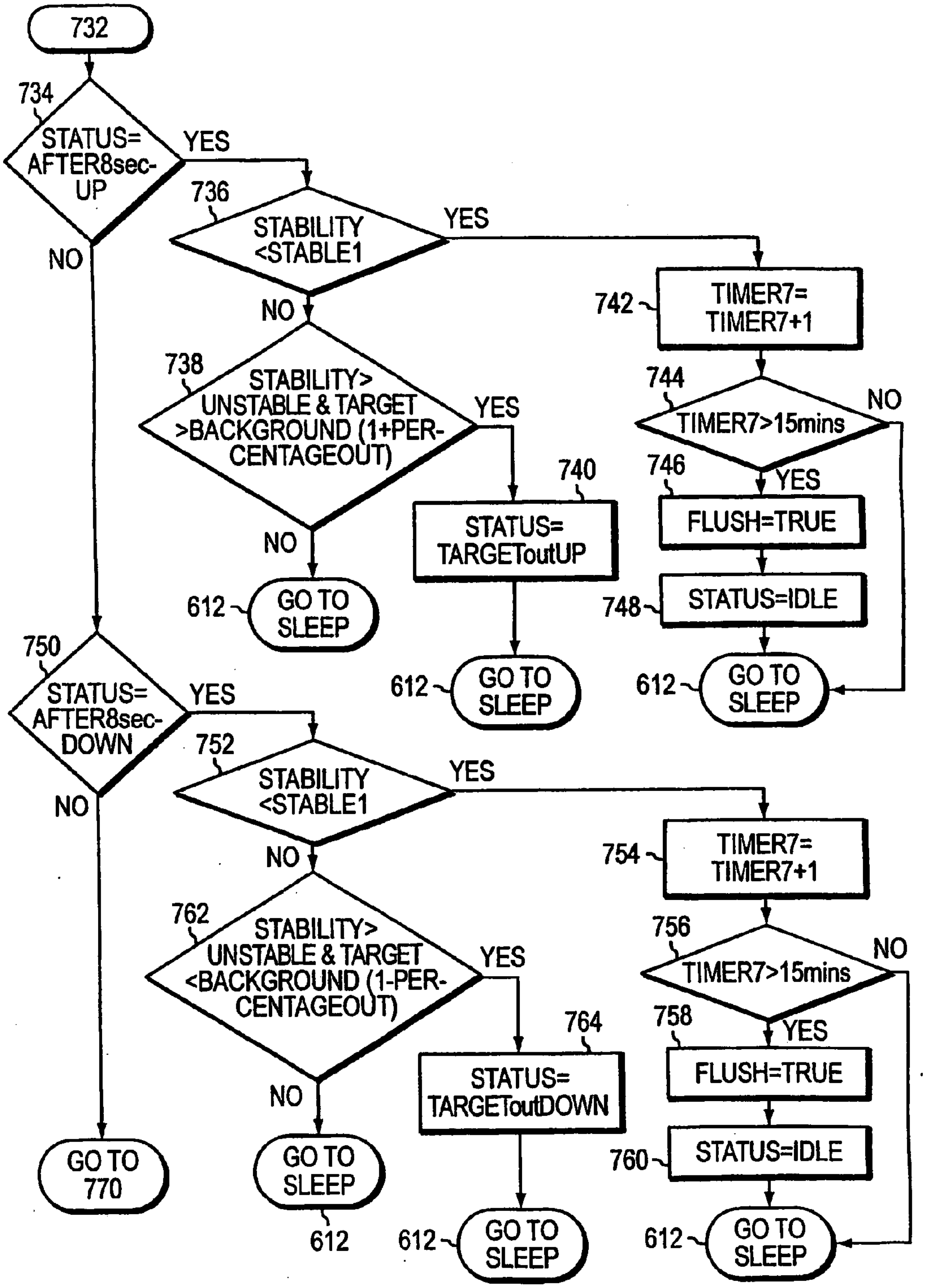
732
734
STATUS= AFTER8sec- UP
YES
NO
736
STABILITY <STABLE1
YES
NO
742
TIMER7= TIMER7+1
738
STABILITY> UNSTABLE & TARGET >BACKGROUND (1+PER- CENTAGEOUT)
YES
NO
744
TIMER7>15mins
NO
YES
746
FLUSH=TRUE
740
STATUS= TARGETOutUP
748
STATUS=IDLE
612
GO TO SLEEP
612
GO TO SLEEP
612
GO TO SLEEP
750
STATUS= AFTER8sec- DOWN
YES
NO
752
STABILITY <STABLE1
YES
NO
754
TIMER7= TIMER7+1
762
STABILITY> UNSTABLE & TARGET <BACKGROUND (1-PER- CENTAGEOUT)
YES
NO
756
TIMER7>15mins
NO
YES
758
FLUSH=TRUE
764
STATUS= TARGEToutDOWN
760
STATUS=IDLE
GO TO 770
GO TO SLEEP
612
612
GO TO SLEEP
612
GO TO SLEEP

FIG. 12G

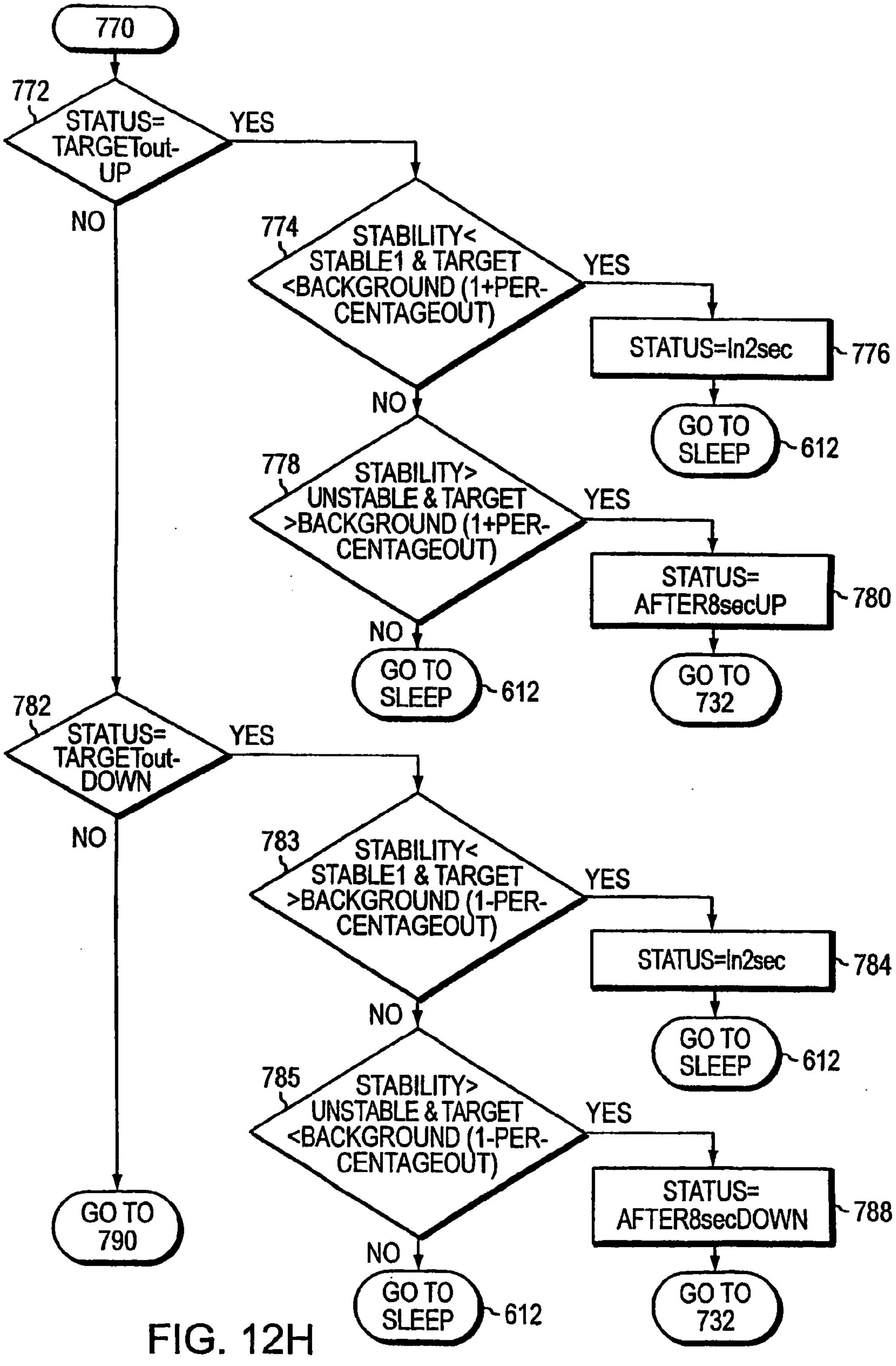
770
772
STATUS= TARGETout-UP
YES
NO
774
STABILITY< STABLE1 & TARGET <BACKGROUND (1+PER-CENTAGEOUT)
YES
STATUS=In2sec
776
GO TO SLEEP
612
NO
778
STABILITY> UNSTABLE & TARGET >BACKGROUND (1+PER-CENTAGEOUT)
YES
STATUS= AFTER8secUP
780
GO TO 732
NO
GO TO SLEEP
612
782
STATUS= TARGETout-DOWN
YES
NO
783
STABILITY< STABLE1 & TARGET >BACKGROUND (1-PER-CENTAGEOUT)
YES
STATUS=In2sec
784
GO TO SLEEP
612
NO
785
STABILITY> UNSTABLE & TARGET <BACKGROUND (1-PER-CENTAGEOUT)
YES
STATUS= AFTER8secDOWN
788
GO TO 732
GO TO 790
NO
GO TO SLEEP
612

FIG. 12H

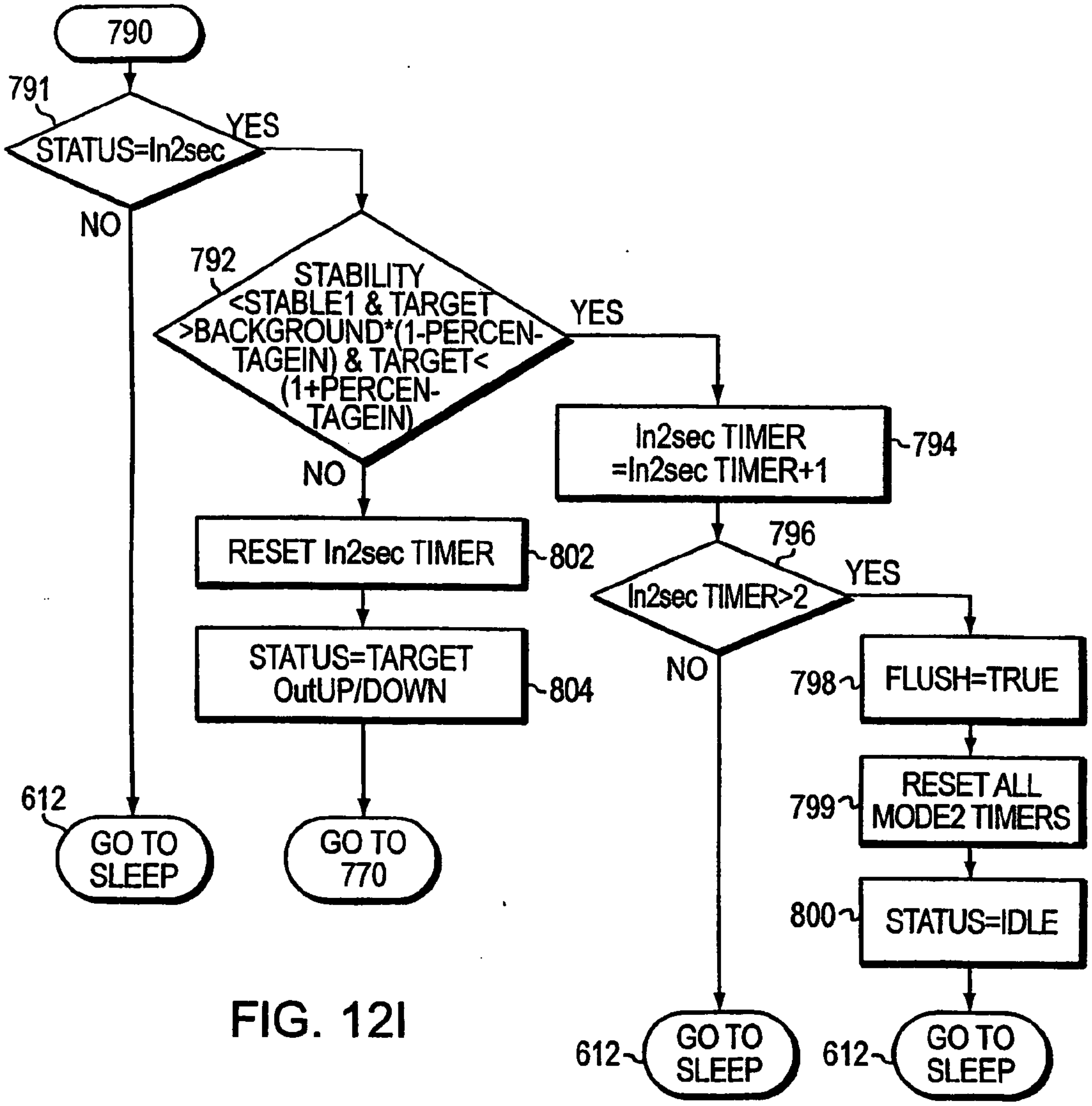
790
791
STATUS=In2sec
YES
NO
792
STABILITY <STABLE1 & TARGET >BACKGROUND*(1-PERCENTAGEIN) & TARGET< (1+PERCENTAGEIN)
YES
NO
In2sec TIMER =In2sec TIMER+1
794
RESET In2sec TIMER
802
STATUS=TARGET OutUP/DOWN
804
796
In2sec TIMER>2
YES
NO
798
FLUSH=TRUE
799
RESET ALL MODE2 TIMERS
800
STATUS=IDLE
612
GO TO SLEEP
GO TO 770
612
GO TO SLEEP
612
GO TO SLEEP

FIG. 12I

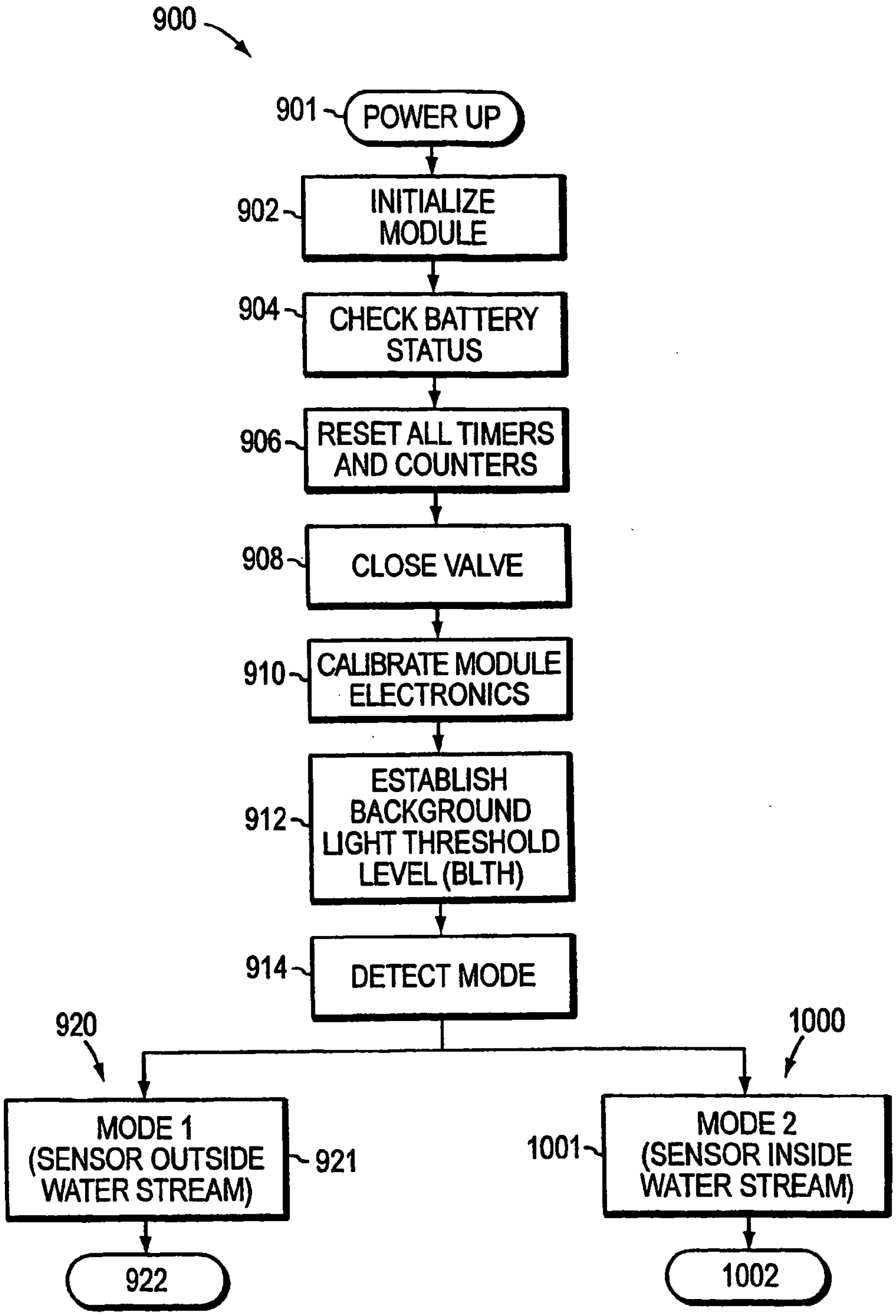
900
901
POWER UP
902
INITIALIZE MODULE
904
CHECK BATTERY STATUS
906
RESET ALL TIMERS AND COUNTERS
908
CLOSE VALVE
910
CALIBRATE MODULE ELECTRONICS
912
ESTABLISH BACKGROUND LIGHT THRESHOLD LEVEL (BLTH)
914
DETECT MODE
920
1000
MODE 1 (SENSOR OUTSIDE WATER STREAM)
921
1001
MODE 2 (SENSOR INSIDE WATER STREAM)
922
1002

FIG. 13

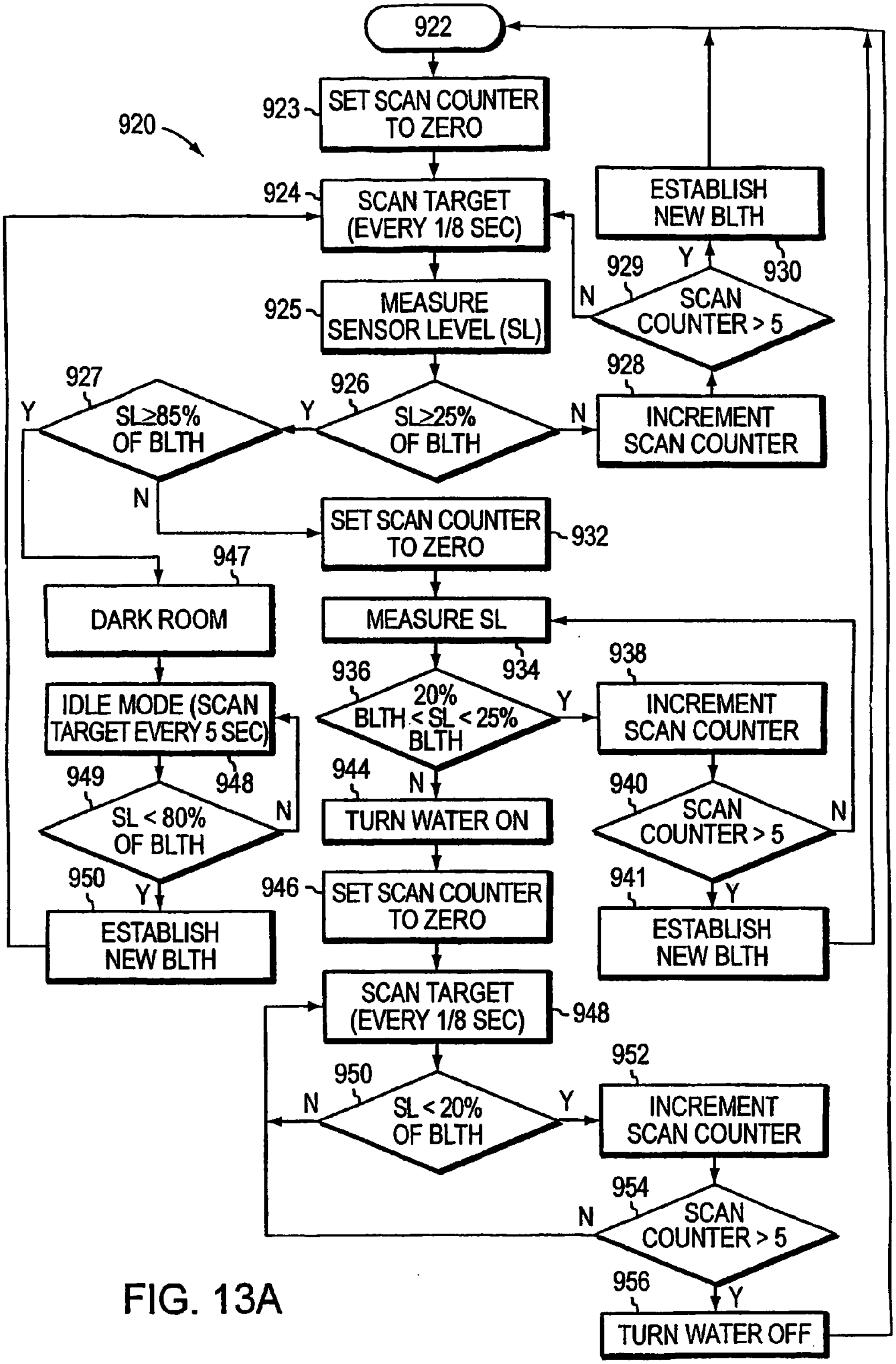
922
923
SET SCAN COUNTER TO ZERO
920
924
SCAN TARGET (EVERY 1/8 SEC)
ESTABLISH NEW BLTH
930
929
Y
N
SCAN COUNTER > 5
925
MEASURE SENSOR LEVEL (SL)
928
927
926
Y
SL≥85% OF BLTH
Y
SL≥25% OF BLTH
N
INCREMENT SCAN COUNTER
N
SET SCAN COUNTER TO ZERO
932
947
DARK ROOM
MEASURE SL
938
936
934
20% BLTH < SL < 25% BLTH
Y
INCREMENT SCAN COUNTER
IDLE MODE (SCAN TARGET EVERY 5 SEC)
949
948
944
N
TURN WATER ON
940
SL < 80% OF BLTH
N
SCAN COUNTER > 5
N
950
Y
946
SET SCAN COUNTER TO ZERO
941
Y
ESTABLISH NEW BLTH
ESTABLISH NEW BLTH
SCAN TARGET (EVERY 1/8 SEC)
948
952
950
N
SL < 20% OF BLTH
Y
INCREMENT SCAN COUNTER
954
N
SCAN COUNTER > 5
956
Y
TURN WATER OFF

FIG. 13A

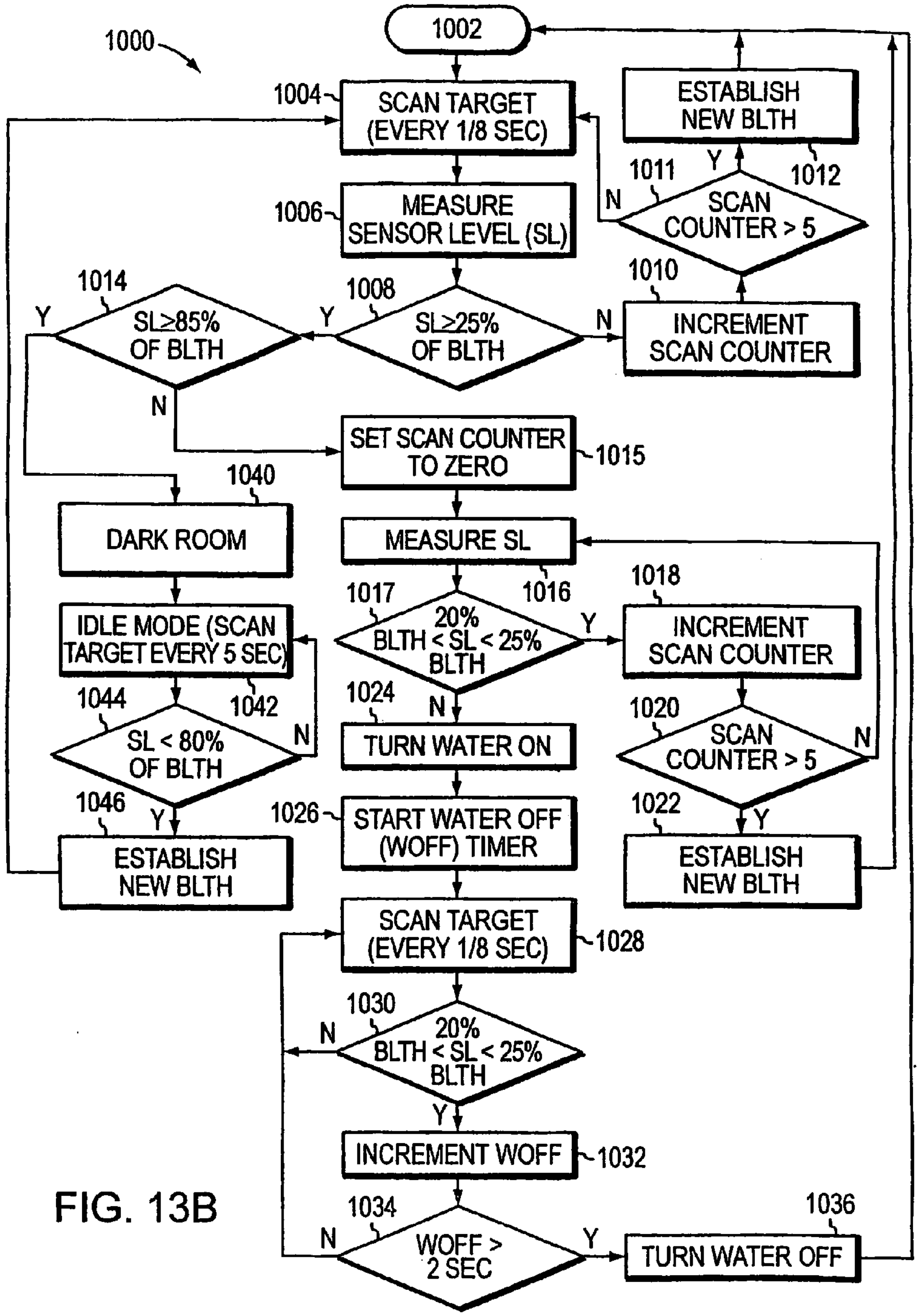
1000
1002
1004
SCAN TARGET (EVERY 1/8 SEC)
1006
MEASURE SENSOR LEVEL (SL)
1008
SL≥25% OF BLTH
Y
N
1010
INCREMENT SCAN COUNTER
1011
SCAN COUNTER > 5
N
Y
1012
ESTABLISH NEW BLTH
1014
SL≥85% OF BLTH
Y
N
1015
SET SCAN COUNTER TO ZERO
1040
DARK ROOM
IDLE MODE (SCAN TARGET EVERY 5 SEC)
1042
1044
SL < 80% OF BLTH
N
Y
1046
ESTABLISH NEW BLTH
MEASURE SL
1016
1017
20% BLTH < SL < 25% BLTH
Y
N
1018
INCREMENT SCAN COUNTER
1020
SCAN COUNTER > 5
N
Y
1022
ESTABLISH NEW BLTH
1024
TURN WATER ON
1026
START WATER OFF (WOFF) TIMER
1028
SCAN TARGET (EVERY 1/8 SEC)
1030
20% BLTH < SL < 25% BLTH
N
Y
1032
INCREMENT WOFF
1034
WOFF > 2 SEC
N
Y
1036
TURN WATER OFF

FIG. 13B

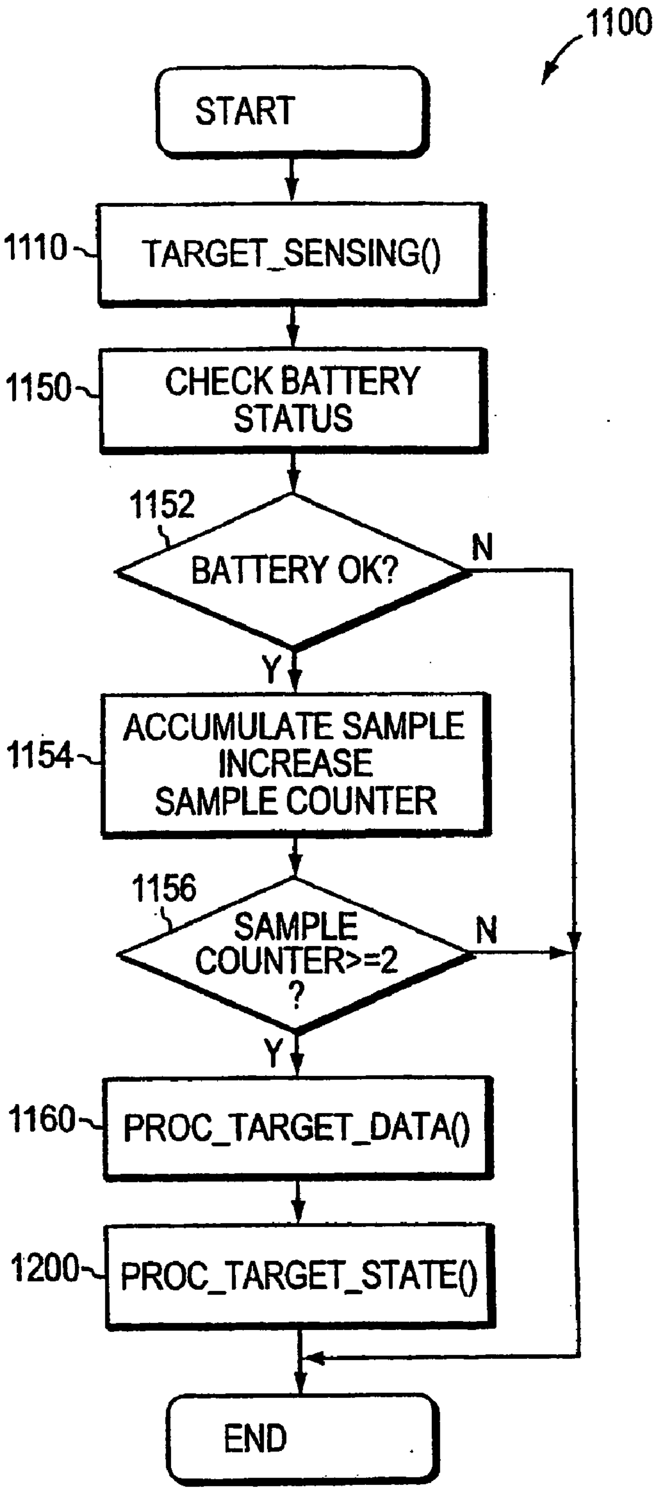
1100
START
1110
TARGET_SENSING()
1150
CHECK BATTERY STATUS
1152
BATTERY OK?
N
Y
1154
ACCUMULATE SAMPLE INCREASE SAMPLE COUNTER
1156
SAMPLE COUNTER>=2 ?
N
Y
1160
PROC_TARGET_DATA()
1200
PROC_TARGET_STATE()
END

FIG. 14

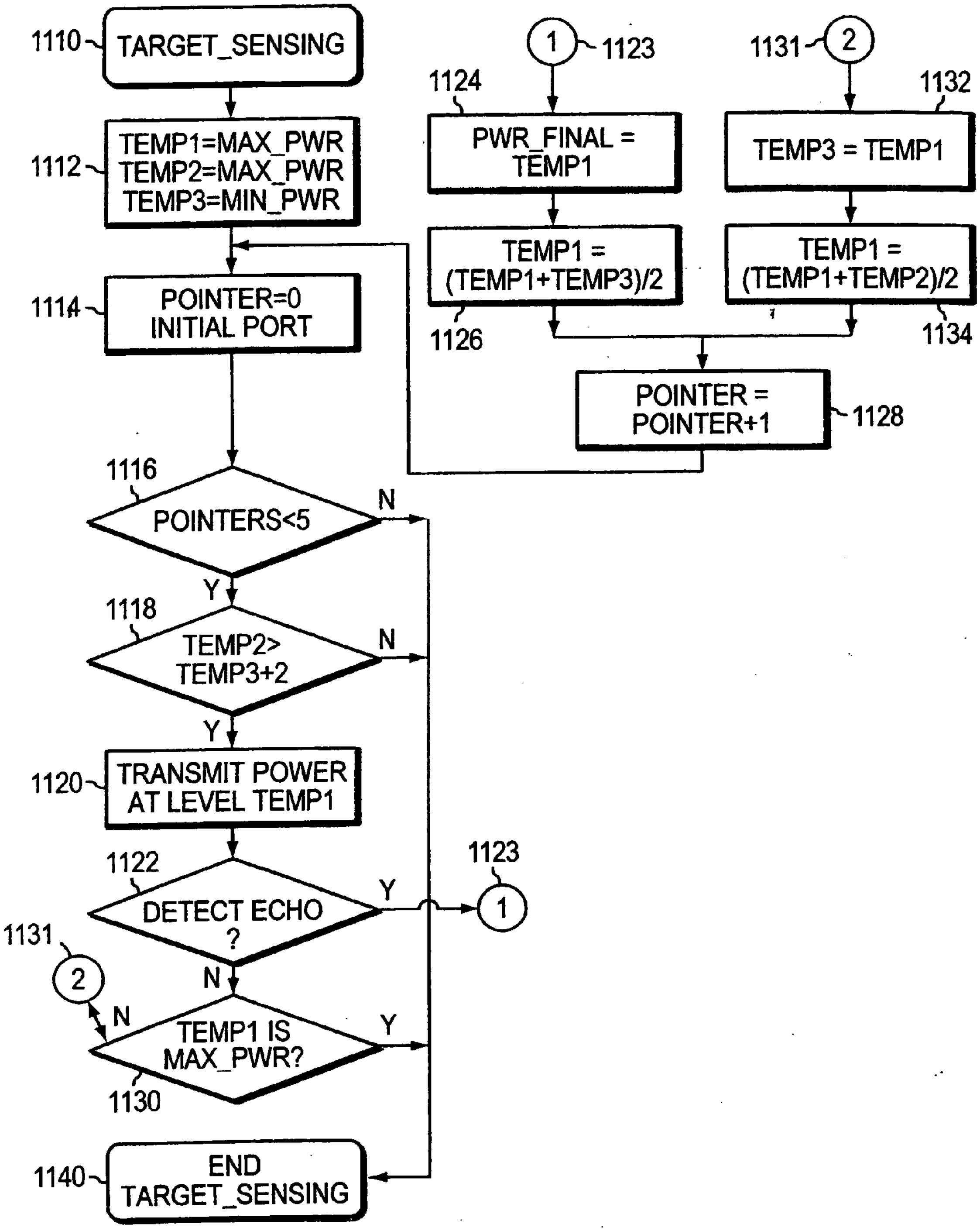
1110
TARGET_SENSING
1112
TEMP1=MAX_PWR
TEMP2=MAX_PWR
TEMP3=MIN_PWR
1114
POINTER=0
INITIAL PORT
1116
POINTERS<5
N
Y
1118
TEMP2>
TEMP3+2
N
Y
1120
TRANSMIT POWER
AT LEVEL TEMP1
1122
DETECT ECHO
?
Y
1123
1
N
1131
2
N
TEMP1 IS
MAX_PWR?
Y
1130
1140
END
TARGET_SENSING
1
1123
1124
PWR_FINAL =
TEMP1
TEMP1 =
(TEMP1+TEMP3)/2
1126
1131
2
1132
TEMP3 = TEMP1
TEMP1 =
(TEMP1+TEMP2)/2
1134
POINTER =
POINTER+1
1128

FIG. 14A

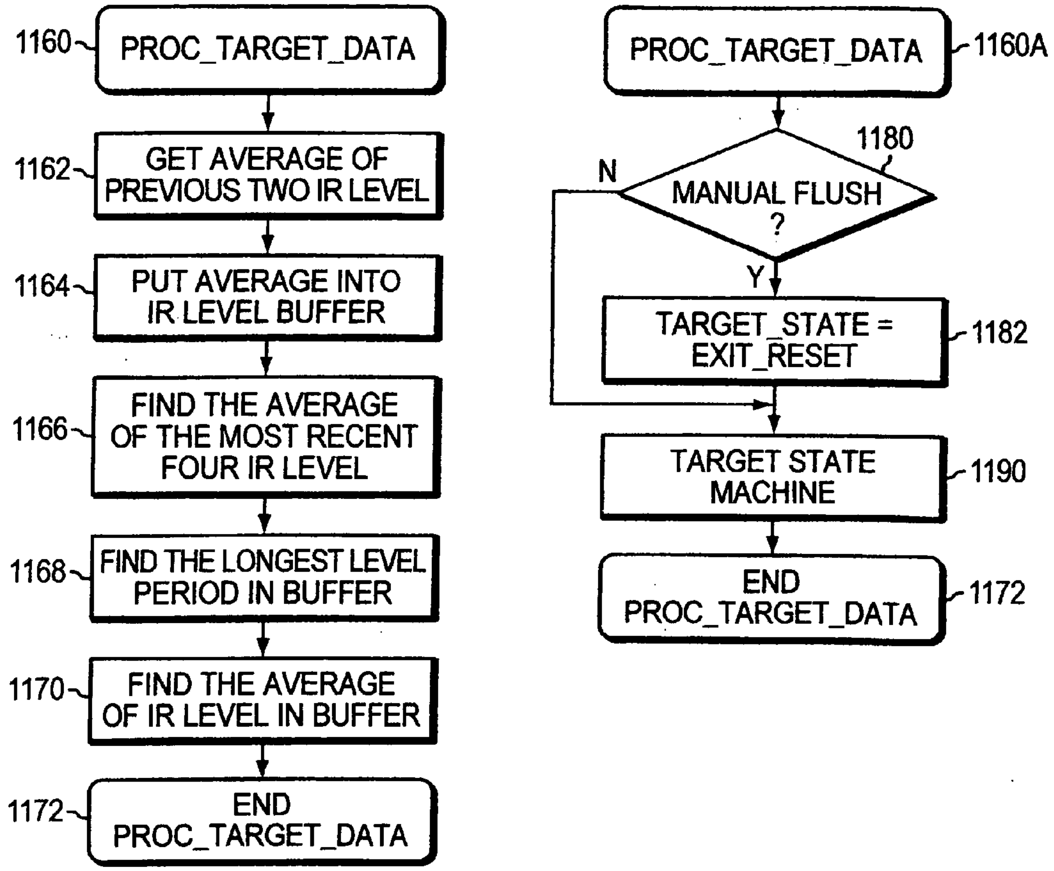
1160
PROC_TARGET_DATA
1162
GET AVERAGE OF PREVIOUS TWO IR LEVEL
1164
PUT AVERAGE INTO IR LEVEL BUFFER
1166
FIND THE AVERAGE OF THE MOST RECENT FOUR IR LEVEL
1168
FIND THE LONGEST LEVEL PERIOD IN BUFFER
1170
FIND THE AVERAGE OF IR LEVEL IN BUFFER
1172
END PROC_TARGET_DATA
PROC_TARGET_DATA
1160A
1180
N
MANUAL FLUSH ?
Y
TARGET_STATE = EXIT_RESET
1182
TARGET STATE MACHINE
1190
END PROC_TARGET_DATA
1172

FIG. 14B

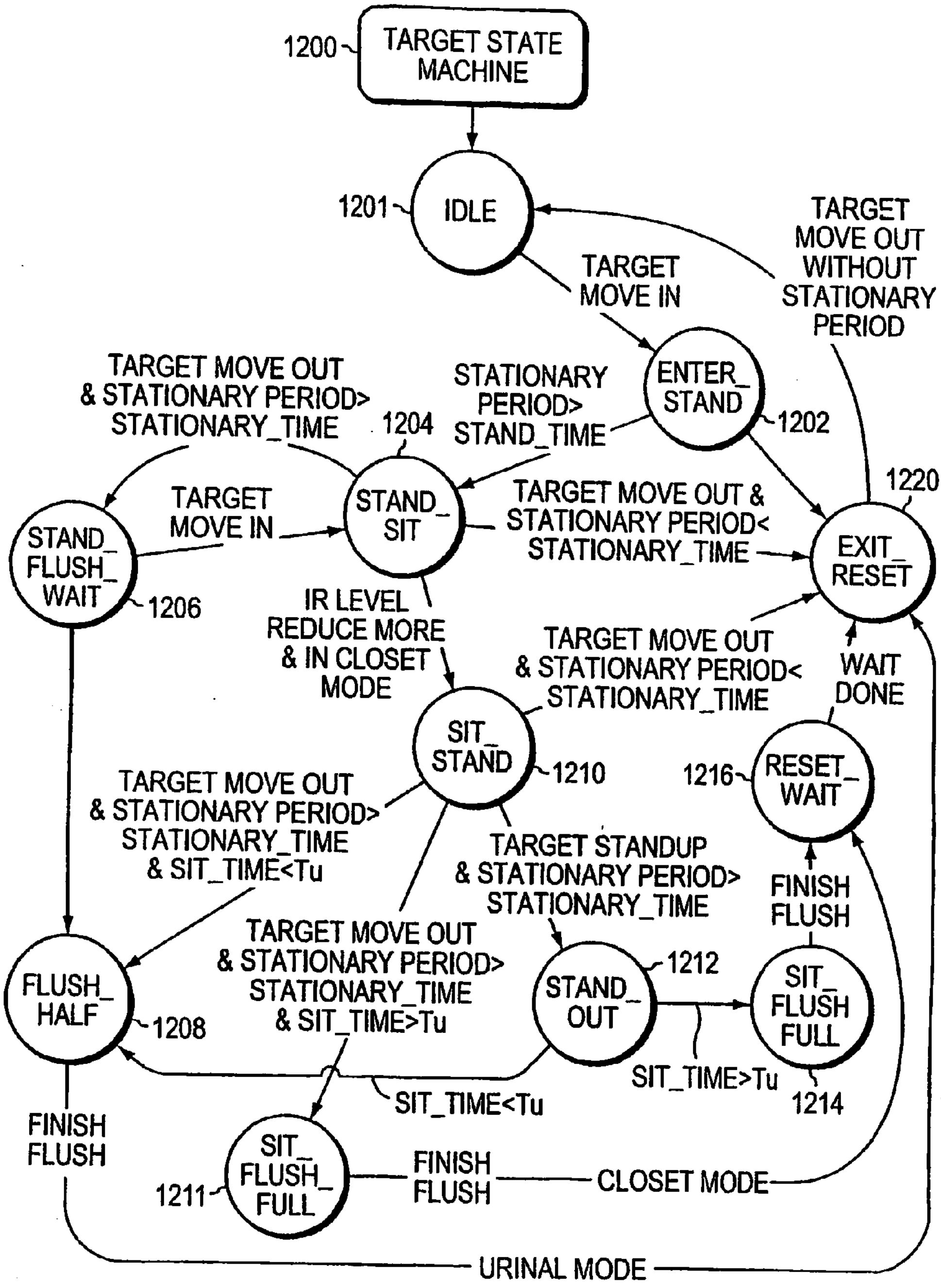
1200
TARGET STATE MACHINE
1201
IDLE
TARGET MOVE IN
TARGET MOVE OUT WITHOUT STATIONARY PERIOD
ENTER_ STAND
1202
STATIONARY PERIOD> STAND_TIME
TARGET MOVE OUT & STATIONARY PERIOD> STATIONARY_TIME
1204
STAND_ SIT
TARGET MOVE IN
STAND_ FLUSH_ WAIT
1206
TARGET MOVE OUT & STATIONARY PERIOD< STATIONARY_TIME
1220
EXIT_ RESET
IR LEVEL REDUCE MORE & IN CLOSET MODE
TARGET MOVE OUT & STATIONARY PERIOD< STATIONARY_TIME
WAIT DONE
SIT_ STAND
1210
1216
RESET_ WAIT
TARGET MOVE OUT & STATIONARY PERIOD> STATIONARY_TIME & SIT_TIME<Tu
TARGET STANDUP & STATIONARY PERIOD> STATIONARY_TIME
FINISH FLUSH
FLUSH_ HALF
1208
TARGET MOVE OUT & STATIONARY PERIOD> STATIONARY_TIME & SIT_TIME>Tu
STAND_ OUT
1212
SIT_ FLUSH FULL
SIT_TIME>Tu
1214
SIT_TIME<Tu
FINISH FLUSH
1211
SIT_ FLUSH_ FULL
FINISH FLUSH
CLOSET MODE
URINAL MODE

FIG. 14C

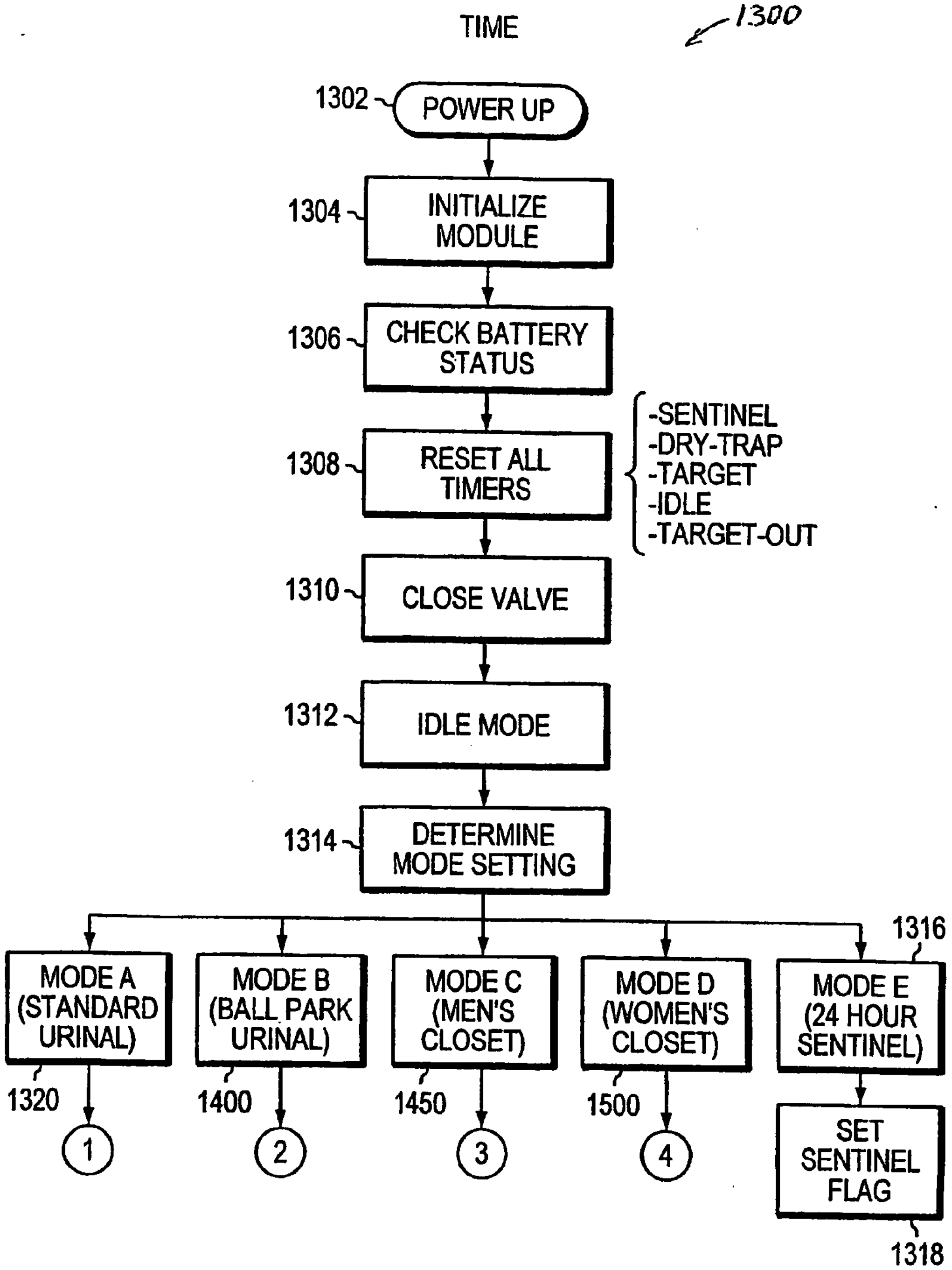
TIME
1300
1302
POWER UP
1304
INITIALIZE MODULE
1306
CHECK BATTERY STATUS
1308
RESET ALL TIMERS
-SENTINEL
-DRY-TRAP
-TARGET
-IDLE
-TARGET-OUT
1310
CLOSE VALVE
1312
IDLE MODE
1314
DETERMINE MODE SETTING
1316
MODE A (STANDARD URINAL)
MODE B (BALL PARK URINAL)
MODE C (MEN'S CLOSET)
MODE D (WOMEN'S CLOSET)
MODE E (24 HOUR SENTINEL)
1320
1400
1450
1500
1
2
3
4
SET SENTINEL FLAG
1318

FIG. 15

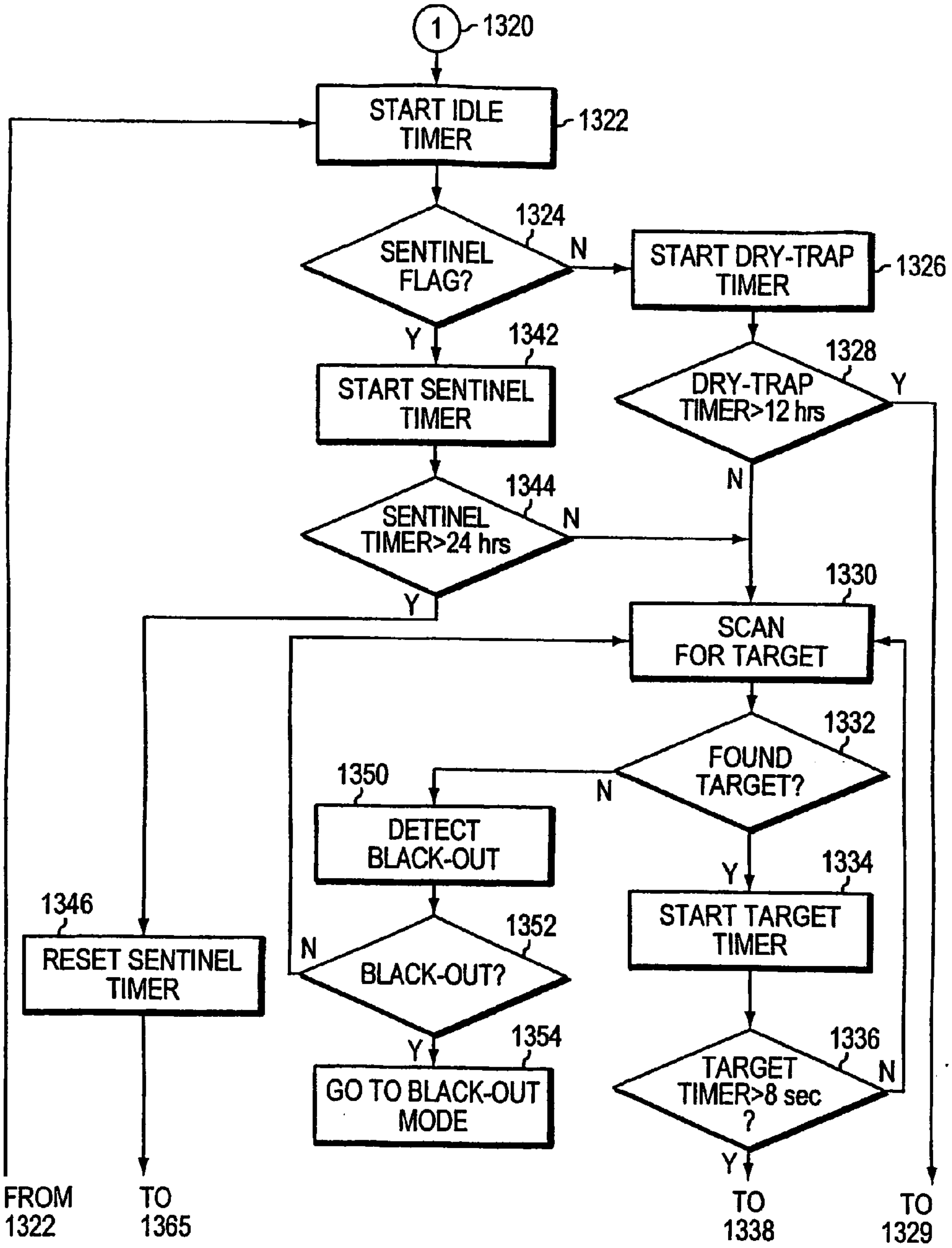
1
1320
START IDLE TIMER
1322
SENTINEL FLAG?
1324
N
START DRY-TRAP TIMER
1326
Y
1342
START SENTINEL TIMER
DRY-TRAP TIMER>12 hrs
1328
Y
N
SENTINEL TIMER>24 hrs
1344
N
Y
SCAN FOR TARGET
1330
FOUND TARGET?
1332
N
1350
DETECT BLACK-OUT
Y
1334
START TARGET TIMER
1346
RESET SENTINEL TIMER
BLACK-OUT?
1352
N
Y
1354
GO TO BLACK-OUT MODE
TARGET TIMER>8 sec ?
1336
N
Y
FROM 1322
TO 1365
TO 1338
TO 1329

FIG. 15A-I

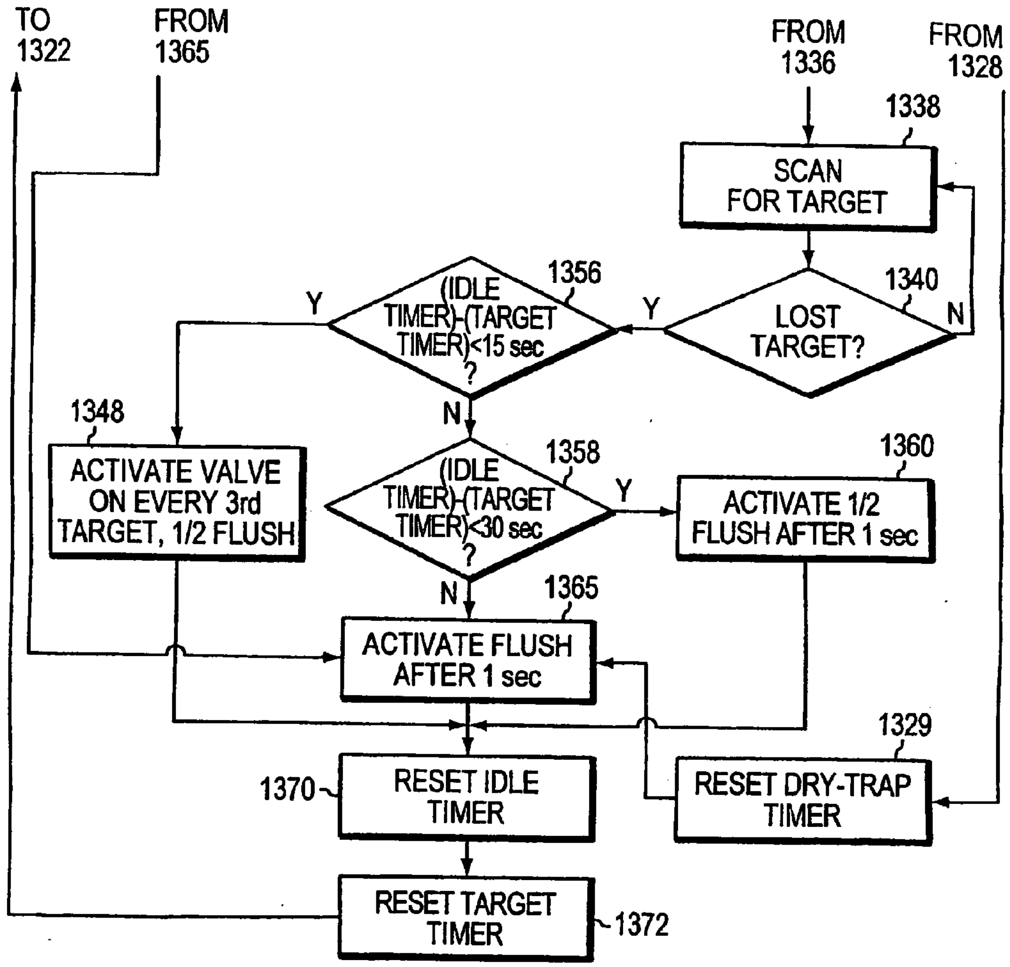
TO 1322
FROM 1365
FROM 1336
FROM 1328
1338
SCAN FOR TARGET
1340
LOST TARGET?
N
Y
1356
(IDLE TIMER)-(TARGET TIMER)<15 sec ?
Y
N
1348
ACTIVATE VALVE ON EVERY 3rd TARGET, 1/2 FLUSH
1358
(IDLE TIMER)-(TARGET TIMER)<30 sec ?
Y
N
1360
ACTIVATE 1/2 FLUSH AFTER 1 sec
1365
ACTIVATE FLUSH AFTER 1 sec
1329
RESET DRY-TRAP TIMER
1370
RESET IDLE TIMER
RESET TARGET TIMER
1372

FIG. 15A-II

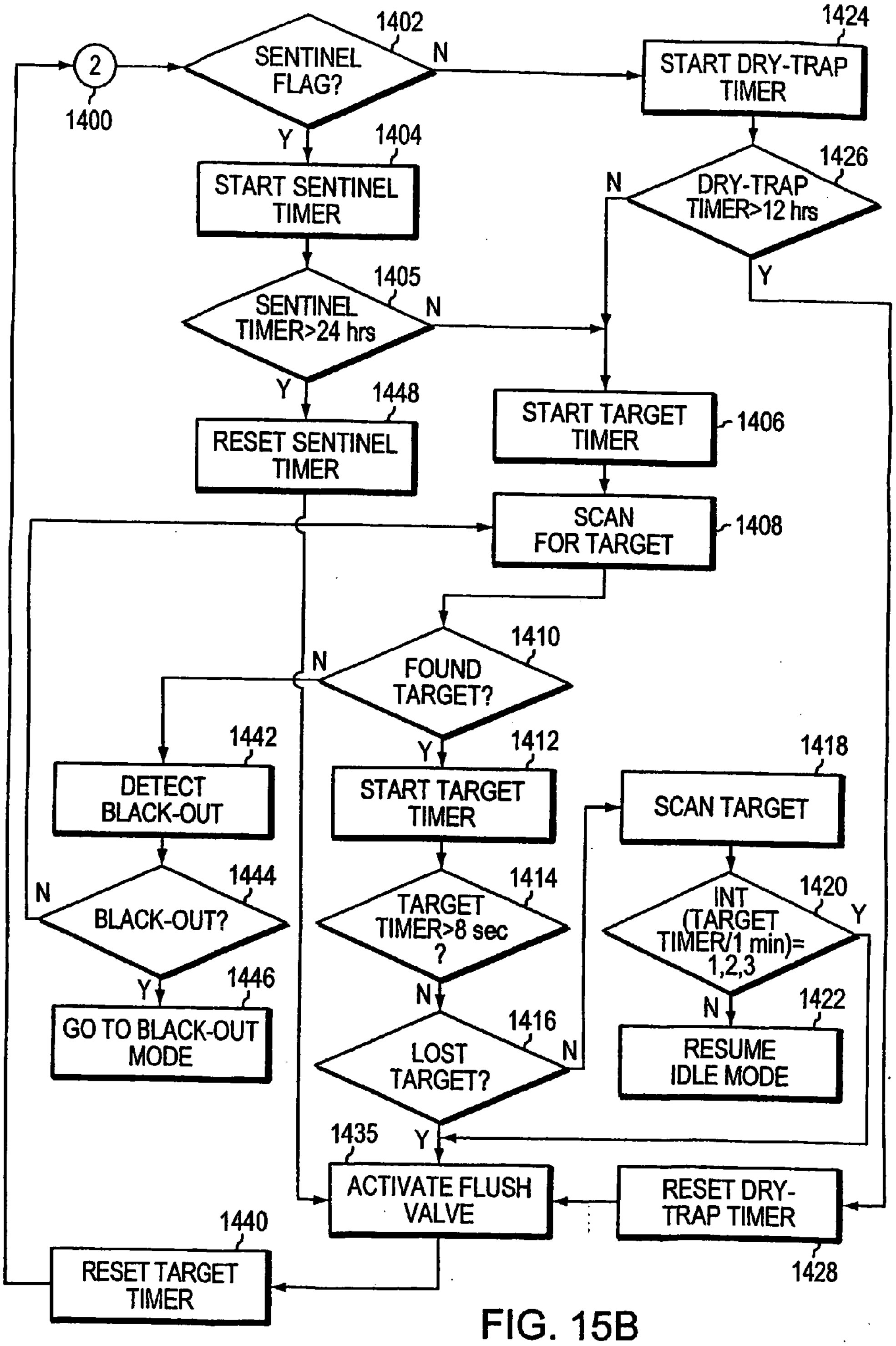
2
1400
SENTINEL FLAG?
1402
N
Y
START DRY-TRAP TIMER
1424
START SENTINEL TIMER
1404
DRY-TRAP TIMER>12 hrs
1426
N
Y
SENTINEL TIMER>24 hrs
1405
N
Y
RESET SENTINEL TIMER
1448
START TARGET TIMER
1406
SCAN FOR TARGET
1408
FOUND TARGET?
1410
N
Y
DETECT BLACK-OUT
1442
START TARGET TIMER
1412
SCAN TARGET
1418
BLACK-OUT?
1444
N
Y
TARGET TIMER>8 sec ?
1414
N
INT (TARGET TIMER/1 min)= 1,2,3
1420
Y
N
GO TO BLACK-OUT MODE
1446
LOST TARGET?
1416
N
Y
RESUME IDLE MODE
1422
1435
ACTIVATE FLUSH VALVE
RESET DRY-TRAP TIMER
1428
1440
RESET TARGET TIMER

FIG. 15B

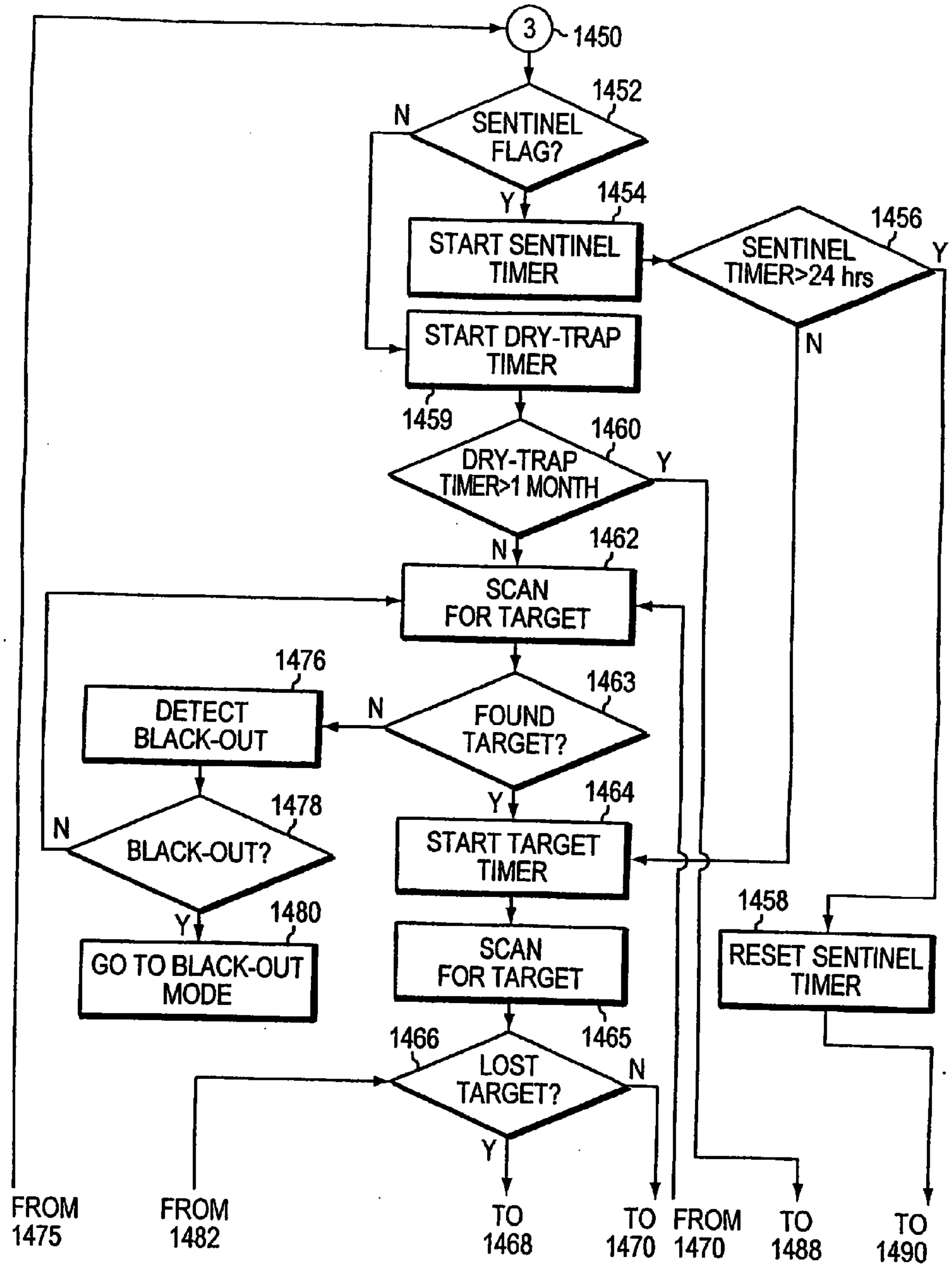
3
1450
SENTINEL FLAG?
1452
N
Y
START SENTINEL TIMER
1454
SENTINEL TIMER>24 hrs
1456
Y
N
START DRY-TRAP TIMER
1459
DRY-TRAP TIMER>1 MONTH
1460
Y
N
SCAN FOR TARGET
1462
DETECT BLACK-OUT
1476
FOUND TARGET?
1463
N
Y
BLACK-OUT?
1478
N
Y
START TARGET TIMER
1464
GO TO BLACK-OUT MODE
1480
SCAN FOR TARGET
1465
1458
RESET SENTINEL TIMER
LOST TARGET?
1466
N
Y
FROM 1475
FROM 1482
TO 1468
TO 1470
FROM 1470
TO 1488
TO 1490

FIG. 15C-I

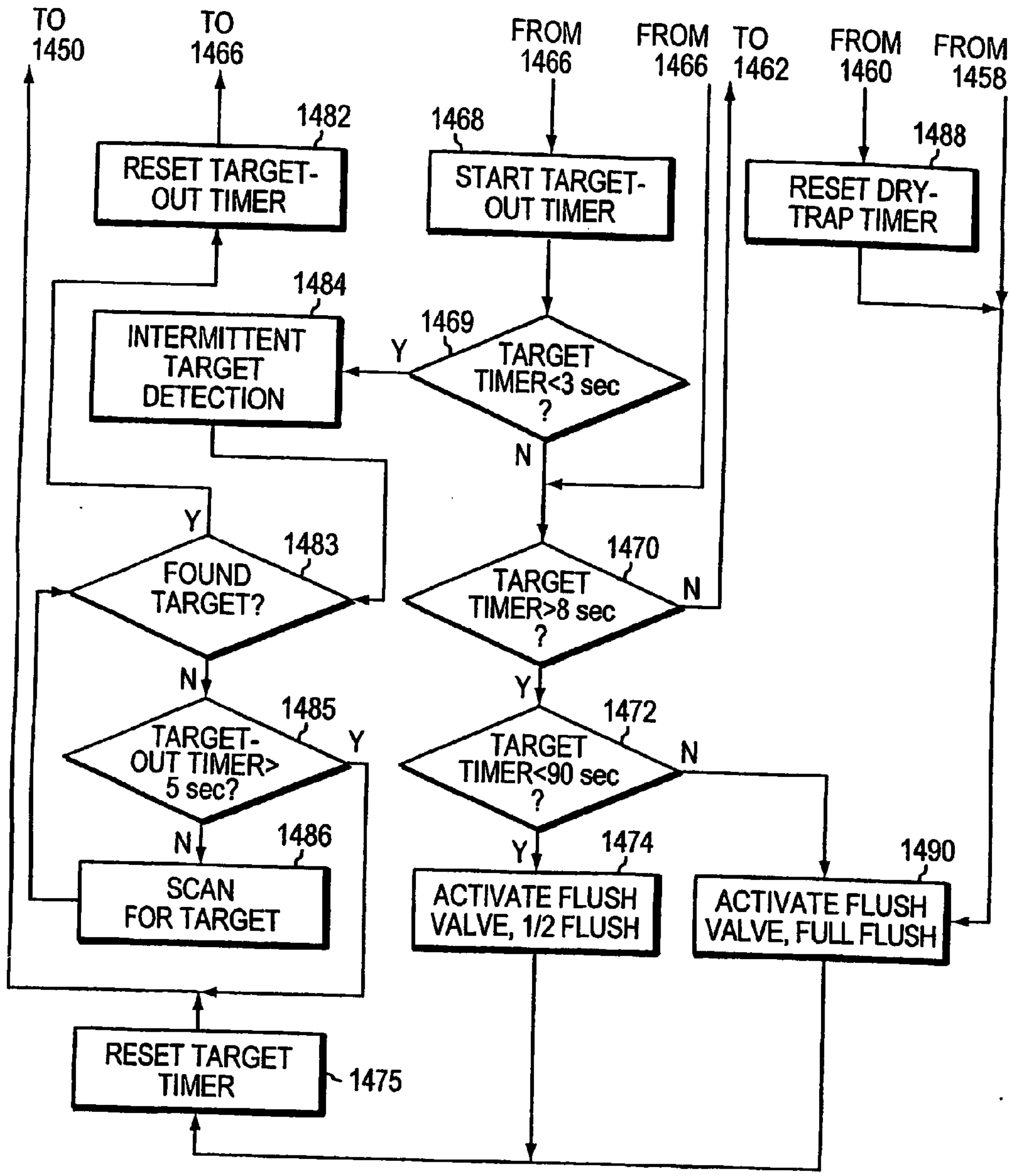
TO 1450
TO 1466
FROM 1466
FROM 1466
TO 1462
FROM 1460
FROM 1458
1482
RESET TARGET-OUT TIMER
1468
START TARGET-OUT TIMER
1488
RESET DRY-TRAP TIMER
1484
INTERMITTENT TARGET DETECTION
1469
Y
TARGET TIMER<3 sec ?
N
Y
1483
FOUND TARGET?
1470
TARGET TIMER>8 sec ?
N
N
1485
TARGET-OUT TIMER> 5 sec?
Y
Y
1472
TARGET TIMER<90 sec ?
N
N
1486
SCAN FOR TARGET
Y
1474
ACTIVATE FLUSH VALVE, 1/2 FLUSH
1490
ACTIVATE FLUSH VALVE, FULL FLUSH
RESET TARGET TIMER
1475

FIG. 15C-II

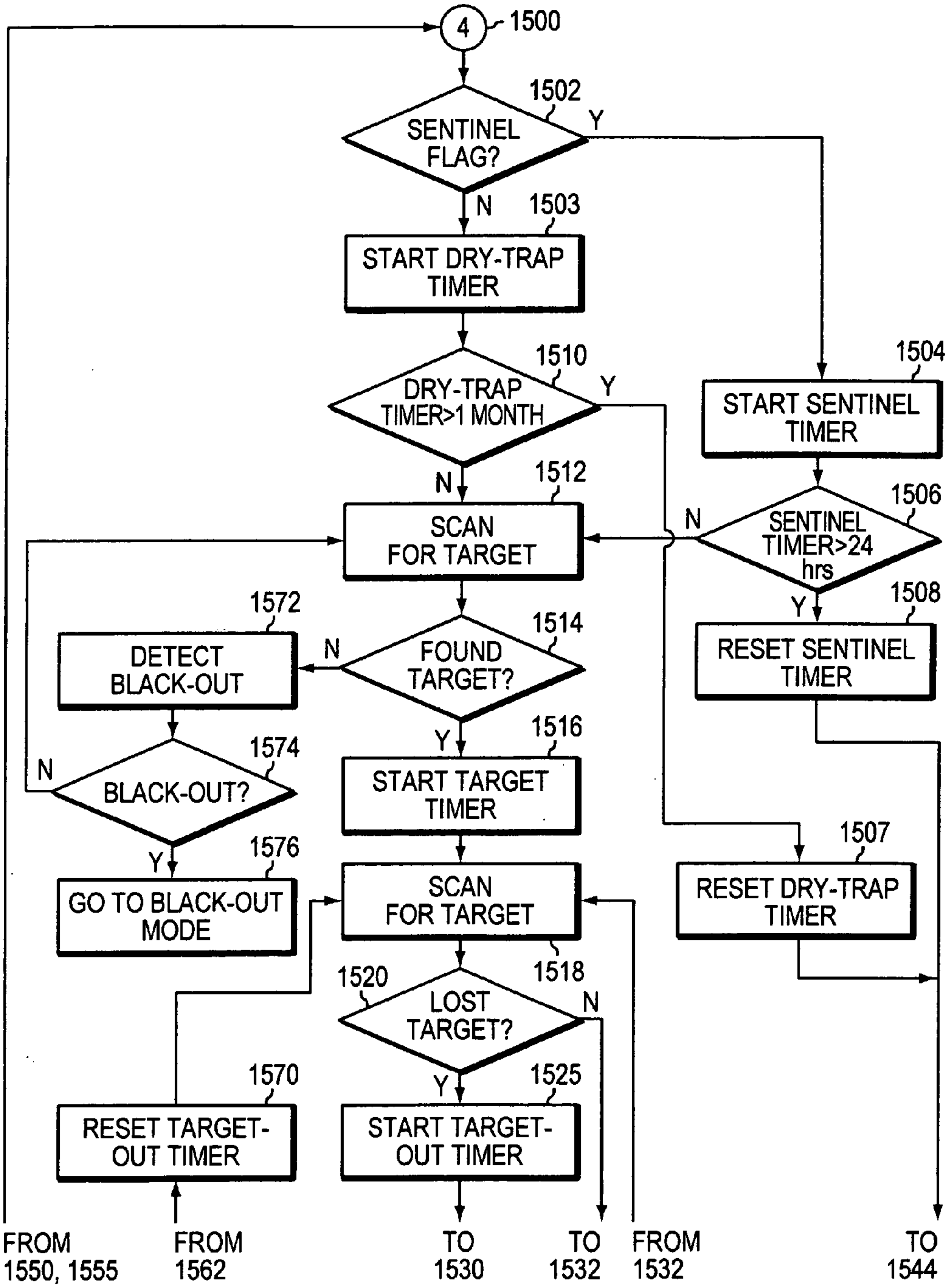
4
1500
SENTINEL FLAG?
1502
Y
N
START DRY-TRAP TIMER
1503
DRY-TRAP TIMER>1 MONTH
1510
Y
N
SCAN FOR TARGET
1512
START SENTINEL TIMER
1504
SENTINEL TIMER>24 hrs
1506
N
Y
RESET SENTINEL TIMER
1508
DETECT BLACK-OUT
1572
FOUND TARGET?
1514
N
Y
BLACK-OUT?
1574
N
Y
START TARGET TIMER
1516
GO TO BLACK-OUT MODE
1576
SCAN FOR TARGET
1518
RESET DRY-TRAP TIMER
1507
LOST TARGET?
1520
N
Y
RESET TARGET-OUT TIMER
1570
START TARGET-OUT TIMER
1525
FROM 1550, 1555
FROM 1562
TO 1530
TO 1532
FROM 1532
TO 1544

FIG. 15D-I

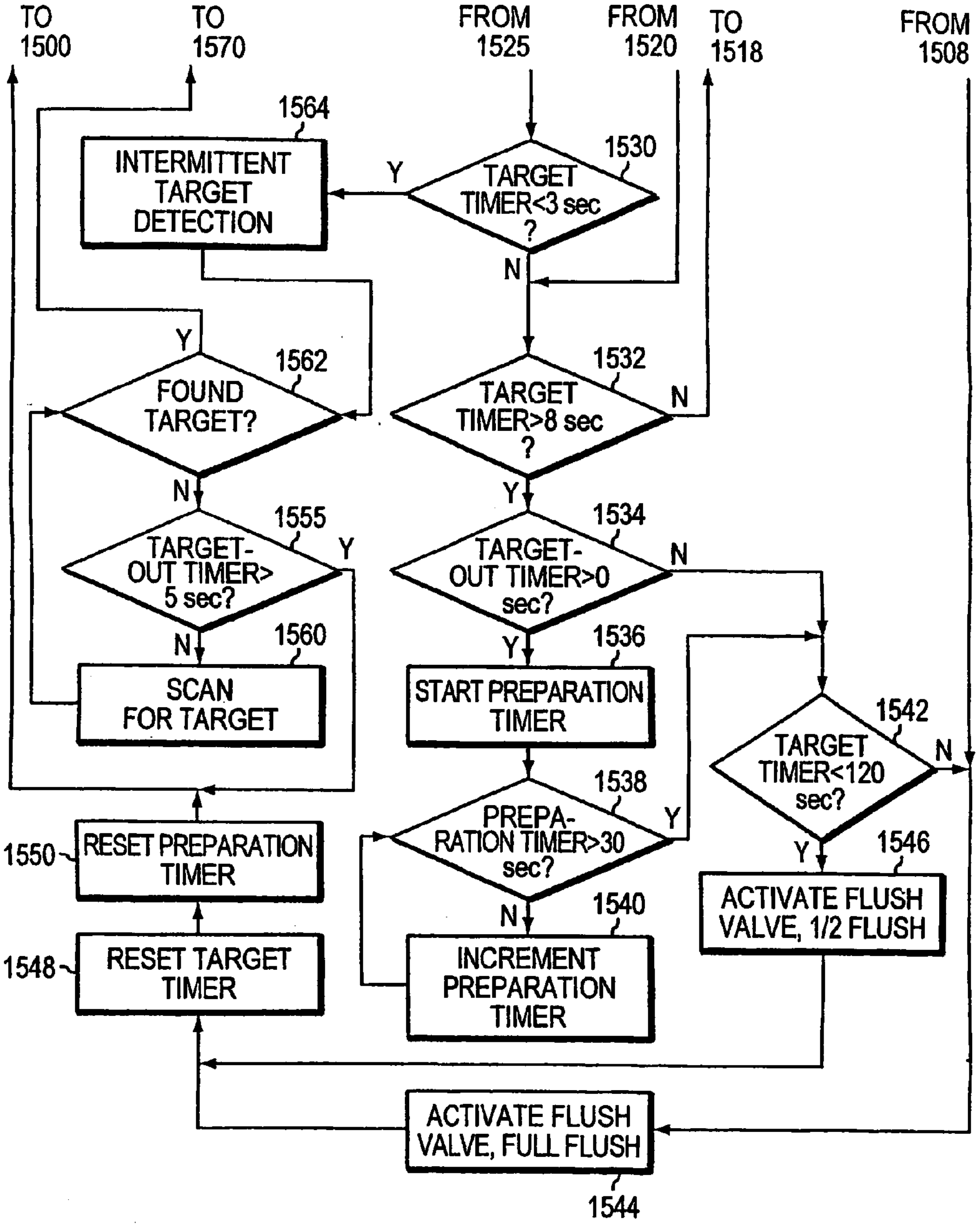
TO 1500
TO 1570
FROM 1525
FROM 1520
TO 1518
FROM 1508
1564
INTERMITTENT TARGET DETECTION
Y
1530
TARGET TIMER<3 sec ?
N
Y
1562
FOUND TARGET?
1532
TARGET TIMER>8 sec ?
N
N
Y
1555
TARGET-OUT TIMER> 5 sec?
Y
1534
TARGET-OUT TIMER>0 sec?
N
N
1560
SCAN FOR TARGET
Y
1536
START PREPARATION TIMER
1542
TARGET TIMER<120 sec?
N
1538
PREPA-RATION TIMER>30 sec?
Y
1550
RESET PREPARATION TIMER
Y
1546
ACTIVATE FLUSH VALVE, 1/2 FLUSH
N
1540
INCREMENT PREPARATION TIMER
1548
RESET TARGET TIMER
ACTIVATE FLUSH VALVE, FULL FLUSH
1544

FIG. 15D-II

OPTICAL SENSORS AND ALGORITHMS FOR CONTROLLING AUTOMATIC BATHROOM FLUSHERS AND FAUCETS

[0001] This application is a continuation of U.S. application Ser. No. 11/159,422 filed on Jun. 22, 2005, which is a continuation of PCT Application PCT/US03/041303, filed on Dec. 26, 2003, which is a continuation-in-part of PCT Application PCT/US03/38730, entitled "Passive Sensors for Automatic Faucets and Bathroom Flushers" filed on Dec. 4, 2003, which claims priority from U.S. Application 60/513,722, "Automatic Faucets with Novel Flow Control Sensors," filed on Oct. 22, 2003 and is a continuation-in-part of PCT Application PCT/US03/20117, "Irrigation Systems and Control Methods," filed on Jun. 24, 2003; and PCT Application PCT/US02/41576, "Automatic Bathroom Flushers" filed on Dec. 26, 2002; all of which are incorporated by reference.

[0002] The PCT/US03/041303 application is also a continuation-in-part of PCT Application PCT/US02/38757, "Electronic Faucets for Long Term Operation," filed on Dec. 4, 2002; and PCT Application PCT/US02/38758, "Automatic Bathroom Flushers," filed on Dec. 4, 2002; both of which are incorporated by reference.

[0003] The present invention is directed to novel optical sensors and algorithms for controlling automatic bathroom flushers and faucets.

BACKGROUND OF THE INVENTION

[0004] Automatic faucets and bathroom flushers have been used for many years. An automatic faucet typically includes an optical or other sensor that detects the presence of an object, and an automatic valve that turns water on and off, based on a signal from the sensor. An automatic faucet may include a mixing valve connected to a source of hot and cold water for providing a proper mixing ratio of the delivered hot and cold water after water actuation. The use of automatic faucets conserves water and promotes hand washing, and thus good hygiene. Similarly, automatic bathroom flushers include a sensor and a flush valve connected to a source of water for flushing a toilet or urinal after actuation. The use of automatic bathroom flushers generally improves cleanliness in public facilities.

[0005] In an automatic faucet, an optical or other sensor provides a control signal and a controller that, upon detection of an object located within a target region, provides a signal to open water flow. In an automatic bathroom flusher, an optical or other sensor provides a control signal to a controller after a user leaves the target region. Such systems work best if the object sensor is reasonably discriminating. An automatic faucet should respond to a user's hands, for instance, it should not respond to the sink at which the faucet is mounted, or to a paper towel thrown in the sink. Among the ways of making the system discriminate between the two it has been known to limit the target region in such a manner as to exclude the sink's location. However, a coat or another object can still provide a false trigger to the faucet. Similarly, this could happen to automatic flushers due to a movement of bathroom doors, or something similar.

[0006] An optical sensor includes a light source (usually an infra-red emitter) and a light detector sensitive to the IR wavelength of the light source. For faucets, the emitter and the detector (i.e., a receiver) can be mounted on the faucet spout near its outlet, or near the base of the spout. For flushers, the emitter and the detector may be mounted on the flusher body or on a bathroom wall. Alternatively, only optical lenses (instead of the emitter and the receiver) can be mounted on these elements. The lenses are coupled to one or several optical fibers for delivering light from the light source and to the light detector. The optical fiber delivers light to and from the emitter and the receiver mounted below the faucet.

[0007] In the optical sensor, the emitter power and/or the receiver sensitivity is limited to restrict the sensor's range to eliminate reflections from the sink, or from the bathroom walls or other installed objects. Specifically, the emitting beam should project on a valid target, normally clothing, or skin of human hands, and then a reflected beam is detected by the receiver. This kind of sensor relies on the reflectivity of a target's surface, and its emitting/receiving capabilities. Frequently, problems arise due to highly reflective doors and walls, mirrors, highly reflective sinks, the shape of different sinks, water in the sink, the colors and rough/shiny surfaces of fabrics, and moving users who are walking by but not using the facility. Mirrors, doors, walls, and sinks are not valid targets, although they may reflect more energy back to the receiver than rough surfaces at the right angle incidence. The reflection of valid targets such as various fabrics varies with their colors and the surface finish. Some kinds of fabrics absorb and scatter too much energy of the incident beam, so that less of a reflection is sent back to the receiver.

[0008] A large number of optical or other sensors are powered by a battery. Depending on the design, the emitter (or the receiver) may consume a large amount of power and thus deplete the battery over time (or require large batteries). The cost of battery replacement involves not only the cost of batteries, but more importantly the labor cost, which may be relatively high for skilled personnel.

[0009] There is still a need for an optical sensor for use with automatic faucets or automatic bathroom flushers that can operate for a long period of time without replacing the standard batteries. There is still a need for reliable sensors for use with automatic faucets or automatic bathroom flushers.

SUMMARY OF THE INVENTION

[0010] The present invention is directed to novel optical sensors and novel methods for sensing optical radiation. The novel optical sensors and the novel optical sensing methods are used, for example, for controlling the operation of automatic faucets and flushers. The novel sensors and flow controllers (including control electronics and valves) require only small amounts of electrical power for sensing users of bathroom facilities, and thus enable battery operation for many years. A passive optical sensor includes a light detector sensitive to ambient (room) light for controlling the operation of automatic faucets or automatic, bathroom flushers. An active optical sensor includes a light emitter and a light detector. The detected signals may be processed using novel algorithms

[0011] According to one aspect an electronic system for controlling fluid flow includes an electromagnetic actuator, a controller and an optical sensor. The controller is coupled to a power driver constructed to provide a drive signal to the actuator and thereby opening or closing a valve for the fluid flow. The optical sensor is constructed and arranged to provide a signal to the controller.

[0012] Preferred embodiments may include one or more of the following: The electronic system includes a leak detector constructed to detect the fluid flow across the closed valve.

The leak detector includes at least two electric leads, wherein the electric leads are coupled to measure electric signal across the closed valve to determine the fluid flow across the valve in the closed state. The leak detector includes the electric leads constructed and arranged to measure resistance, capacitance or inductance across the closed valve.

The electronic system may further include an indicator constructed to indicate a leak detected by the leak detector.

[0013] The electronic system may be installed to control water flow in a faucet. The electronic system may be installed to control water flow in a bathroom flusher.

[0014] According to another aspect, an optical sensor for controlling a valve of an electronic faucet or bathroom flusher includes an optical element located at an optical input port and arranged to partially define a detection field. The optical sensor also includes a light detector and a control circuit. The light detector is optically coupled to the optical element and the input port, wherein the light detector is constructed to detect ambient light. The control circuit is constructed for controlling opening and closing of a flow valve. The control circuit is also constructed to receive signal from the light detector corresponding to the detected light.

[0015] The control circuit is constructed to sample periodically the detector. The control circuit is constructed to sample periodically the detector based on the amount of previously detected light. The control circuit is constructed to determine the opening and closing of the flow valve based on a background level of the ambient light and a present level of the ambient light. The control circuit is constructed to open and close the flow valve based on first detecting arrival of a user and then detecting departure of the user. Alternatively, the control circuit is constructed to open and close the flow valve based on detecting presence of a user.

[0016] The optical element includes an optical fiber, a lens, a pinhole, a slit or an optical filter. The optical input port is located inside an aerator of a faucet or next to an aerator of the faucet.

[0017] According to another aspect, an optical sensor for an electronic faucet includes an optical input port, an optical detector, and a control circuit. The optical input port is arranged to receive light. The optical detector is optically coupled to the input port and constructed to detect the received light. The control circuit controls opening and closing of a faucet valve, or a bathroom flusher valve.

[0018] Preferred embodiments of this aspect include one or more of the following features: The control circuit is constructed to sample periodically the detector based on the amount of light detected. The control circuit is constructed to adjust a sample period based on the detected amount of light after determining whether a facility is in use. The detector is optically coupled to the input port using an optical fiber. The input port may be located in an aerator of the electronic faucet. The system includes batteries for powering the electronic faucet.

[0019] According to yet another aspect, an optical sensor for controlling a valve of an electronic faucet or bathroom flusher include a light emitter, a light detector and a control circuit. The light emitter is constructed and arranged to emit light to a selected direction. The light detector is constructed and arranged to detect light corresponding to a reflection of the emitted light from a target. The control circuit for controlling opening and closing of a flow valve, wherein the control circuit is constructed to direct light emission from the light emitter and constructed to receive signal from the light detector corresponding to the detected light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a schematic view of an automatic faucet system including a control circuit, a valve and a passive optical sensor for controlling water flow.

[0021] FIG. **1**A is a cross-sectional view of a spout and a sink of the automatic faucet system of FIG. **1** using a fiberoptic coupling to the passive optical sensor.

[0022] FIG. **1**B is a cross-sectional view of a spout and a sink of the automatic faucet system of FIG. **1** using an electric coupling to the passive optical sensor.

[0023] FIG. **1**C is a cross-sectional view of an aerator used in the automatic faucet system of FIG. **1**.

[0024] FIG. **1**D is a cross-sectional view of another embodiment of the aerator used in the automatic faucet system of FIG. **1**.

[0025] FIG. **1**E is a perspective view of another embodiment of the aerator used in the automatic faucet system of FIG. **1**.

[0026] FIG. **1**F is a cross-sectional view of the aerator shown in FIG. **1**D.

[0027] FIGS. **2** and **2**A show schematically other embodiments of automatic faucet systems, including another embodiment of a valve and a passive optical sensor for controlling water flow.

[0028] FIGS. **3**, **3**A, **3**B, **3**C and **3**D show schematically a faucet and a sink relative to different optical detection patterns used by passive optical sensors employed in the automatic faucet systems of FIGS. **1**, **1**B, **2**, and **2**A.

[0029] FIG. **4** shows schematically a side view of a toilet including an automatic flusher.

[0030] FIG. **4**A shows schematically a side view of a urinal including an automatic flusher.

[0031] FIG. **4**B is a perspective view of an automatic bathroom flusher used for flushing a toilet or a urinal, having a flusher cover removed.

[0032] FIG. **4**C is a cross-sectional view of the flusher mainly illustrating an electronic control module and a solenoid actuator located inside of the flusher cover.

[0033] FIG. **4**D is a perspective exploded view of the flusher cover shown in FIG. **4**B.

[0034] FIGS. **5**, **5**A, **5**B, **5**C, **5**D, **5**E, **5**F and **5**G show schematically side and top views of different optical detection patterns used by passive optical sensors employed in the automatic toilet flusher of FIG. **4**.

[0035] FIGS. **5**H, **5**I, **5**J, **5**K and **5**L show schematically side and top views of different optical detection patterns used by passive optical sensors employed in the automatic urinal flusher of FIG. **4**A.

[0036] FIGS. **6**, **6**A, **6**B, **6**C, **6**D and **6**E show schematically optical elements used to form the different optical detection patterns shown in FIGS. **3** through **3**D and in FIGS. **5** through **5**L.

[0037] FIG. **7** is a cross-sectional view of another embodiment of an automatic flusher using a passive optical sensor for flushing toilets or urinals.

[0038] FIG. **7**A is a cross-sectional view of another embodiment of an automatic flusher using an active optical sensor for flushing toilets or urinals.

[0039] FIG. **8** is a perspective exploded view of a valve device used in the automatic faucet system of FIG. **1**, **1**A or **1**B.

[0040] FIG. **8**A is an enlarged cross-sectional view of the valve device shown in FIG. **8**.

[0041] FIG. **8**B is an enlarged cross-sectional view of the valve device shown in FIG. **8**A, but partially disassembled for servicing.

[0042] FIG. **8**C is a perspective view of the valve device of FIG. **4**, including a leak detector for detecting water leaks in an automatic faucet system.

[0043] FIG. **9** is an enlarged cross-sectional view of a moving piston-like member used in the valve device shown in FIG. **7** or the valve device shown in FIGS. **8**, **8**A, and **8**B.

[0044] FIG. **9**A is a detailed perspective view of the moving piston-like member shown in FIG. **9**.

[0045] FIG. **10** is block diagram of a control system for controlling a valve operating the automatic faucet systems of FIGS. **1** through **2**A, or bathroom flushers of FIGS. **4**B and **7**.

[0046] FIG. **10**A is block diagram of another control system for controlling a valve operating the automatic faucet systems of FIGS. **1** through **2**A, or bathroom flushers of FIGS. **4**, **4**A and **7**A.

[0047] FIG. **10**B is a schematic diagram of a detection circuit used in passive optical sensor used in the automatic faucet system or the automatic flusher system.

[0048] FIG. **11** is a block diagram that illustrates various factors that affect operation and calibration of the active or passive optical sensor.

[0049] FIGS. **12**, **12**A, **12**B, **12**C, **12**D, **12**E, **12**F, **12**G, **12**H and **12**I show a flow diagram of an algorithm for processing optical data detected by the passive sensor operating the automatic flusher system of FIG. **4**B or FIG. **7**.

[0050] FIGS. **13**, **13**A and **13**B show a flow diagram of an algorithm for processing optical data detected by the passive sensor operating the automatic faucet system.

[0051] FIGS. **14**, **14**A, **14**B and **14**C illustrate flow diagram of an algorithm for processing optical data detected by the active sensor operating the automatic flusher system of FIG. **7**A.

[0052] FIGS. **15**, **15**A-I, **15**A-II, **15**B, **15**C-I, **15**C-II, **16**D-I and **15**D-II illustrate a flow diagram of an algorithm for processing optical data detected by either the active or passive sensor operating the automatic flusher system delivering water amounts depending on actual use.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0053] FIG. **1** shows an automatic faucet system **10** controlled by a sensor providing signals to a control circuit constructed and arranged to control operation of an automatic valve. The automatic valve, in turn, controls the flow of hot and cold water before or after mixing.

[0054] Automatic faucet system **10** includes a faucet body **12** and an aerator **30**, including a sensor port **34**. Automatic faucet system **10** also includes a faucet base **14** and screws **16**A and **16**B for attaching the faucet to a deck **18**. A cold water pipe **20**A and a hot water pipe **20**B are connected to a mixing valve **22** providing a mixing ratio of hot and cold water (which ratio can be changed depending on the desired water temperature). Water conduit **24** connects mixing valve **22** to a solenoid valve **38**. A flow control valve **38** controls water flow between water conduit **24** and a water conduit **25**. Water conduit **25** connects valve **38** to a water conduit **26** partially located inside faucet body **12**, as shown. Water conduit **26** delivers water to aerator **30**. Automatic faucet system **10** also includes a control module **50** for controlling a faucet sensor and solenoid valve **38**, powered by batteries located in battery compartment **39**.

[0055] Referring to FIGS. **1** and **1**A, in a first preferred embodiment, automatic faucet system **10** includes an optical sensor located in control module **50** and optically coupled by a fiberoptic cable **52** to sensor port **34** located in aerator **30**. Sensor port **34** receives the distal end of fiberoptic cable **52**, which may be coupled to an optical lens located at sensor port **34**. The optical lens is arranged to have a selected field of view, which is preferably somewhat coaxial within the water stream discharged from aerator **30**, when the faucet is turned on.

[0056] Alternatively, the distal end of fiberoptic cable **52** is polished and oriented to emit or to receive light directly (i.e., without the optical lens). Again, the distal end of fiberoptic cable **52** is arranged to have the field of view (for example, field of view A, FIG. **1**A) directed toward sink **11**, somewhat coaxial within the water stream discharged from aerator **30**. Alternatively, sensor port **34** includes other optical elements, such as an array of pinholes or an array of slits having a selected size, geometry and orientation. The size, geometry and orientation of the array of pinholes or the array of slits is designed to provide a selected detection pattern (shown in FIGS. **3**-**3**D, for a faucet and FIGS. **5**-**5**L, for a flusher).

[0057] Referring still to FIGS. **1** and **1**A, a fiberoptic cable **52** is preferably located inside water conduit **26** in contact with water. Alternatively, fiberoptic cable **52** could be located outside of the water conduit **26**, but inside of faucet body **12**. FIGS. **1**C, **1**D, and **1**E show alternative ways to provide sensor port **34** inside aerator **30** and alternative ways to arrange an optical fiber **52** coupled to an optical lens **54**. In other embodiments, optical lens **54** is replaced by an array of pinholes or an array of slits.

[0058] FIG. **1**B illustrates a second preferred embodiment of the automatic faucet system. Automatic faucet system **10**A includes faucet body **12** and an aerator **30** including an optical sensor **37** coupled to a sensor port **35**. Optical sensor **37** is electrically connected by a wire **53** to an electronic control module **50** located inside the body of the faucet. In another embodiment, electronic control module **50** is located outside of the faucet body next to control valve **38** (FIG. **1**).

[0059] In another embodiment, sensor port **35** receives an optical lens, located in from of optical sensor **37**, for defining the detection pattern (or optical field of view). Preferably, the optical lens provides a field of view somewhat coaxial within the water stream discharged from aerator **30**, when the faucet is turned on. In yet other embodiments, sensor port **35** includes other optical elements, such as an array of pinholes or an array of slits having a selected size, geometry and orientation. The size, geometry and orientation of the array of pinholes, or the array of slits are designed to provide a selected detection pattern (shown in FIGS. **3**-**3**D, for a faucet and FIGS. **5**-**5**L, for a flusher).

[0060] The optical sensor is a passive optical sensor that includes a visible or infrared light detector optically coupled to sensor port **34** or sensor port **35**. There is no light source (i.e., no light emitter) associated with the optical sensor. The visible or near infrared (NIR) light detector detects light arriving at sensor port **34** or sensor port **35** and provides the corresponding electrical signal to a controller located in control unit **50** or control unit **55**. The light detector (i.e., light receiver) may be a photodiode, or a photoresistor (or some other optical intensity element having an electrical output, whereby the sensory element will have the desired optical sensitivity). The optical sensor using a photo diode also includes an amplification circuitry. Preferably, the light detector detects light in the range from about 400-500 nanometers up to about 950-1000 nanometers. The light detector is primarily sensitive to ambient light and not very sensitive to body heat (e.g., infrared or far infrared light).

[0061] FIGS. **2** and **2**A illustrate alternative embodiments of the automatic faucet system. Referring to FIG. **2**, automatic faucet system **10**B includes a faucet receiving water from a dual-flow faucet valve **60** and providing water from aerator **31**. Automatic faucet **12** includes a mixing valve **58** controlled by a handle **59**, which may be also coupled to a manual override for valve **60**. Dual-flow valve **60** is connected to cold water pipe **20**A and hot water pipe **20**B, and controls water flow to the respective cold water pipe **21**A and hot water pipe **21**B.

[0062] Dual flow valve **60** is constructed and arranged to simultaneously control water flow in both pipes **21**A and **21**B upon actuation by a single actuator **201** (See FIG. **8**A). Specifically, valve **60** includes two flow valves arranged for controlling flow of hot and cold water in the respective water lines. The solenoid actuator **201** (FIG. **8**A) is coupled to a pilot mechanism for controlling two flow valves. The two flow valves are preferably diaphragm operated valves (but may also be piston valves, or large flow-rate "fram" valves described in connection with FIGS. **9** and **9**A). Dual flow valve **60** includes a pressure release mechanism constructed to change pressure in a diaphragm chamber of each diaphragm operated valve and thereby open or close each diaphragm valve for controlling water flow. Dual flow valve **60** is described in detail in PCT Application PCT/US01/43277, filed on Nov. 20, 2001, which is incorporated by reference.

[0063] Referring still to FIG. **2**, coupled to faucet body **12** there is a sensor port **35** for accommodating a distal end of an optical fiber (e.g., fiberoptic cable **52**), or for accommodating a light detector. The fiberoptic cable delivers light from sensor port **35** to a light detector. In one preferred embodiment, faucet body **12** includes a control module with the light detector and a controller described in connection with FIGS. **10** and **10**A. The controller provides control signals to solenoid actuator **201** via electrical cable **56**. Sensor port **35** has a detection field of view (shown in FIGS. **3**A and **3**B) located outside of the water stream emitted from aerator **31**.

[0064] Referring to FIG. **2**A, automatic faucet system **10**C includes faucet body **12** also receiving water from dual-flow faucet valve **60** and providing water from aerator **31**. Automatic faucet **10**C also includes mixing valve **58** controlled by handle **59**. Dual-flow valve **60** is connected to cold water pipe **20**A and hot water pipe **20**B, and controls water flow to the respective cold water pipe **21**A and hot water pipe **21**B.

[0065] A sensor port **33** is coupled to faucet body **12** and is designed to have a field of view shown in FIGS. **3**C and **3**D. Sensor port **33** accommodates the distal end of an optical fiber **56**A. The proximal end of optical fiber **56**A provides light to an optical sensor located in a control module **55**A coupled to dual flow valve **60**. Control module **55**A also includes the control electronics and batteries. The optical sensor detects the presence of an object (e.g., hands), or detects a change in the presence of the object (i.e., movement) in the sink area. Control electronics control the operation of and the readout from the light detector. The control electronics also include a power driver that controls the operation of the solenoid associated with valve **60**. Based on the signal from the light detector, the control electronics direct the power driver to open or close solenoid valve **60** (i.e., to start or stop the water flow). The design and operation of actuator **201** (FIG. **8**A) is described in detail in PCT Applications PCT/US02/38757; PCT/US02/38758; and PCT/US02/41576, all of which are incorporated by reference as if fully provided herein.

[0066] FIG. **1**C shows a vertical cross-section of an aerator **30**A located at the discharge end of the spout of faucet **12**. Aerator **30**A includes a barrel **62** attachable to faucet body **12** using threads **63**. Barrel **62** supports a ring **64** which in turn supports wire mesh screens **65**. Barrel **62** also supports an annular member **70**, a jet-forming member **72**, and an upper washer **74**. Jet forming member **72** includes several elongated slots **76** for providing water passages. Jet forming member **72** and screens **65** include a passage **36** for optical fiber **52**. Water flows through aerator **30**A from top to bottom. In aerator **30**A, a water stream flows from water conduit **26** (FIG. **1**A) and is broken up by the vertically elongated slots **76** of the water jet-forming member **72**. Then water flows through to wire mesh screens **65**, which are supported by ring **64**. Ring **64** also enables air intake (suction) through gaps **67** (which it forms between itself and the barrel **62**) inside a chamber **66**. Just above wire mesh screens **65**, in chamber **66**, air mixes with water so that a mixture of air and water passes through screens **65**. The optical fiber **52** is located in the center of the above described elements inside a tubular member **36**, which holds lens **54**.

[0067] FIG. **1**D shows a second embodiment of an aerator with a centrally located port for a passive sensor. In this embodiment, the aerator **30**B includes at least two lenticularly arranged wire mesh members **86**A and **86**B, providing a central opening for a passage **88**. Aerator **30**B also includes an insert member **90** including several holes **92** and a central hole **88** for accommodating tubular member **52**. Aerator **30**B is attached to faucet **12** using threads **83**. Water flows from water conduit **26** to an upper chamber **91** and then through holes **92**. Air enters chamber **93** via holes **84**. The mixture of water and air then flows through two screens **86**A and **86**B assembled in a lenticular arrangement. Housing **82** has a surrounding support part oriented inwards, which supports the two screens **86**A and **86**B. Optical fiber **52** extends inside water pipe **26** (FIG. **1**A) through aerator **30**B from the top and through the wire mesh screens **86**A and **86**B. As the individual water jets formed by holes **92** enter lower chamber **93**, air is drawn via openings **84** into chamber **93**. Inside chamber **93**, water mixes with air and the mixture is forced through screens **86**A and **86**B.

[0068] FIGS. **1**E and **1**F show alternative ways to provide the optical field aligned with the water stream (i.e., alternative embodiment of an aerator and a sensor port located therein). FIG. **1**E is a perspective view of an aerator **30**C and FIG. **1**F is a cross-sectional view of aerator **30**C used in the automatic faucet system of FIG. **1**. Aerator **30**C is coupled to faucet body **12** and the water conduit **26** using threads **83**. Optical fiber **52** is located outside the water conduit and introduced via an adapter **97**. Alternatively, adapter **97** can include the light detector coupled to a control module using an electrical cable instead of fiberoptic cable **52**. (For simplicity, the wire mesh members and the air openings are not shown in FIGS. **1**E and **1**F).

[0069] FIG. **3** shows schematically a cross-sectional view of a first preferred detection pattern (A) for the passive optical sensor installed in automatic faucet **12**. The detection pattern A is associated with sensor port **34** and is shaped by a lens, or an element selected from the optical elements shown in FIGS. **6**-**6**E. The detection pattern A is selected to receive reflected ambient light primarily from sink **11**. The pattern's width is controlled, but the range is much less controlled (i.e., FIG. **3** shows pattern A only schematically because detection range is not really limited).

[0070] A user standing in front of a faucet will affect the amount of ambient (room) light arriving at the sink and thus will affect the amount of light arriving at the optical detector. On the other hand, a person just moving in the room will not affect significantly the amount of detected light. A user having his hands under the faucet will alter the amount of ambient (room) light being detected by the optical detector even more. Thus, the passive optical sensor can detect the user's hands and provide the corresponding control signal. Here, the detected light doesn't depend significantly on the reflectivity of the target surface (unlike for optical sensors that use both a light emitter and a receiver). After hand washing, the user removing his hands from under the faucet will again alter the amount of ambient light detected by the optical detector. Then, the passive optical sensor provides the corresponding control signal to the controller (explained in connection with FIGS. **10**, **10**A and **10**B).

[0071] FIGS. **3**A and **3**B show schematically a second preferred detection pattern (B) for the passive optical sensor installed in automatic faucet **10**B. The detection pattern B is associated with sensor port **35**, and again may be shaped by a lens, or an optical element shown in FIGS. **6**-**6**E. A user having his hands under faucet **10**B alters the amount of ambient (room) light detected by the optical detector. As mentioned above, the detected light doesn't depend significantly on the reflectivity of the user's hands (unlike for optical sensors that use both a light emitter and a receiver). Thus, the passive optical sensor detects the users hands and provides the corresponding control signal to the controller. FIGS. **13**, **13**A, and **13**B illustrate detection algorithms used for the detection patterns A and B.

[0072] FIGS. **3**C and **3**D show schematically another detection pattern (C) for the passive optical sensor installed in automatic faucet **10**C. The detection pattern C is associated with sensor port **33**, and is shaped a selected optical element. The selected optical element achieves a desired width and orientation of the detection pattern, while the range is more difficult to control. In this embodiment, a user standing in front of faucet **10**C will alter the amount of detected ambient light somewhat more than a user passing by. In this embodiment, light reflections from sink **11** influence the detected light only minimally.

[0073] FIG. **4** shows schematically a side view of a toilet including an automatic flusher **100**, and FIG. **4**A shows schematically a side view of a urinal including an automatic flusher **100**A. Flusher **100** receives pressurized water from a supply line **112** and employs a passive optical sensor to respond to actions of a target within a target region **103**. After a user leaves the target region, a controller directs opening of a flush valve **102** that permits water flow from supply line **112** to a flush conduit **113** and to a toilet bowl **116**.

[0074] FIG. **4**A illustrates bathroom flusher **100**A used for automatically flushing a urinal **120**. Flusher **100**A receives pressurized water from supply line **112**. Flush valve **102** is controlled by a passive optical sensor that responds to actions of a target within a target region **103**. After a user leaves the target region, a controller directs opening of a flush valve **102** that permits water flow from supply line **112** to a flush conduit **113**.

[0075] Bathroom flushers **100** and **100**A may have a modular design, wherein their cover can be partially opened to replace the batteries or the electronic module. Bathroom flushers with such a modular design are described in U.S. Patent Application 60/448,995, filed on Feb. 20, 2003, which is incorporated by reference for all purposes.

[0076] Referring to FIG. **4**B, automatic bathroom flusher **100** includes a flusher body **512** coupled to a water supply line **112** and also coupled to a water output line **113** providing output to the connected toilet or urinal. In the automatic flusher design, manual port **518** is closed off using a cap **519** coupled to port **518** using a lock ring **517**. Automatic bathroom flusher **100** also includes a flusher cover **102**, which is a dome-like outer cover specifically designed for protection and easy servicing of control module **500**. Flusher cover **100** also includes a manual override button **104** used to override the flusher's sensor. Furthermore, flusher cover **102** is designed to protect control module **500** in case of water leaks, as described below.

[0077] As shown in FIGS. **4**B and **4**D, flusher cover **102** includes a main cover body **502**, a front cover **531**, and a top cover **550**. The entire flusher cover **102** is secured in place with respect to the flusher body using an attachment ring **522** connecting a pilot cap **534** to flusher body **512**. Electronic control module **500** is positioned onto an alignment plate **528**, which defines the module's position and orientation with respect to the front of the flusher. Electronic control module **500** includes electronic elements that control the entire operation of flusher **100**, including a sensor and a microcontroller for execution of a detection and flushing algorithm (described below). The microcontroller provides signals to a solenoid driver that in turn provides drive signals to a solenoid actuator **540** (FIG. **4**C). Solenoid actuator **540** controls the operation of the flush valve assembly that opens and closes water flow from input **112** to output **113**. The following description describes this in more detail.

[0078] FIG. **4**C is a cross-sectional view illustrating flusher **100** including electronic control module **500** and solenoid actuator **540**, all located inside of external cover **102**. Flusher body **512** is designed to receive the flush valve assembly including a flexible diaphragm **560**, and a diaphragm feed-though assembly (which is described, for example, in U.S. Pat. Nos. 6,382,586 and 5,244,179 both of which are incorporated by reference). Electronic control module **500** includes a plastic housing **526** for enclosing batteries, electronic circuitry and a sensor. Preferably, the sensor is an optical active sensor that has a light source (i.e., a transmitter) and a light detector (i.e., a receiver) operating in the visible to infrared range. Alternatively, the sensor is an optical passive sensor operating in the visible to near IR range. FIG. **4**B illustrates a passive optical sensor including a pinhole array **570**, shown in FIGS. **6** and **6**B.

[0079] The flushing assembly includes pressure cap (pilot chamber cap) **534**, flexible diaphragm **560**, and a pressure relief assembly coupled to solenoid actuator **540**. Flexible diaphragm **560** separates an annular entrance chamber **530** from pilot chamber **535**, both being located within valve body **512**, wherein a bleed passage **552** provides communication between the two chambers. The pressure relief assembly includes a piloting button **538** coupled to an input passage **537** and an output passage **539** located inside a top part **536** of pilot cap **534**.

[0080] As described in the PCT application PCT/US02/38758, which is incorporated by reference, piloting button **538** is screwed onto the distal part of actuator **540** to create a valve. Specifically, the plunger of actuator **540** acts onto the valve seat inside piloting button **538** to control water flow between passages **537** and **543**. This arrangement provides a reproducible and easily serviceable closure for this solenoid valve. Co-operatively designed with piloting button **538** and actuator **540**, there are several O-rings that provide tight water seals and prevent pressurized water from entering the interior of cover **102**. The O-rings also seal piloting button **538** within the chamber inside the top part **536** and prevent any leakage through this chamber into the bore where actuator **540** is partially located. It is important to note that these seals are not under compression. The seat member precisely controls the stroke of the solenoid plunger as mentioned above. It is desired to keep this stroke short to minimize the solenoid power requirements.

[0081] Inside cover **102**, electronic control module **500** is positioned on alignment plate **528**, which in turn is located in contact with pilot chamber cap **534**. Plate **528** includes an opening designed to accommodate top part **536** of pilot cap **534**. Electronic control module **500** includes two circuit boards with control electronics (including preamplifiers and amplifiers for operating the above-mentioned optical sensor), a solenoid driver, and the batteries, all of which located inside plastic housing **526**.

[0082] Referring still to FIG. **4**C, supply line **112** communicates with entrance chamber **530** defined by valve body **512** and a chamber wall **548** formed near the upper end of flush output **113**. Flexible diaphragm **560** is seated on a main valve seat **556** formed by the mouth of flush output **113**, and has a circularly-shaped outer edge **554** located in contact with the periphery of pilot chamber cap **534**. Retaining ring **522** clamps pilot chamber cap **534** at its periphery **532** with respect to flusher body **512**, wherein outer edge **554** of diaphragm **560** is also clamped between periphery **532** and flusher body **512**.

[0083] In the open state, the water supply pressure is larger in entrance chamber **530** than water pressure in pilot chamber **535**, thereby unseating the flexible diaphragm **560**. When flexible diaphragm **560** is lifted of seat **556**, supply water flows from supply line **112**, through the entrance chamber **530** by valve seat **556** into flush conduit **113**. In the closed state, the water pressure is the same in entrance chamber **530** and in pilot chamber **535** since the pressure is equalized via bleed hole **552**. The pressure equalization occurs when went passage **537** is closed by the plunger of solenoid actuator **540**. Then, water pressure in the upper, pilot chamber **535** acts on a larger surface and thus exerts greater force on diaphragm **560** from above than the same pressure within entrance chamber **530**, which acts on a smaller lower surface of diaphragm **560**. Therefore, flexible diaphragm **560** ordinarily remains seated on seat **556** (when passage **537** is closed for some time and the pressure equalization occurs).

[0084] To flush the toilet, solenoid-operated actuator **540** relieves the pressure in pilot chamber **535** by permitting fluid flow between pilot entrance passage **537** and exit passage **543**. The time in which it takes for the chamber to refill is determined by the stroke of the diaphragm. Furthermore, actuator **540** controls the pressure release time (i.e., time for venting pilot chamber **535**), which in turn determines the time during which the flush valve is open for water to pass. Both actuator **540** and the stroke of the diaphragm assembly control the duration of the flush (for a selected size of bleed passage **552**) and thus the volume of water passing through the flush valve. In many regions with a limited water supply, it is very important to closely control the volume of water that passes through the flush valve each time the flusher is operated. Various governments have passed different regulations defining what water flow is permitted through a flush valve in commercial washrooms. A novel design of the actuator and the control electronics can deliver a relatively precise amount of flush water, as described in PCT applications PCT/US02/38758 or PCT/US02/41576, both of which are incorporated by reference.

[0085] The design of actuator **540** and actuator button **538** is important for reproducible, long-term operation of flusher **100**. Actuator **540** may have its plunger directly acting onto the seat of actuator button **538**, forming a non-isolated design where water comes in direct contact with the moving armature of the solenoid actuator. This embodiment is described in U.S. Pat. No. 6,293,516 or U.S. Pat. No. 6,305,662, both of which are incorporated by reference. Alternatively, actuator **540** may have its plunger enclosed by a membrane acting as a barrier for external water that does not come in direct contact with the armature (and the linearly movable armature is enclosed in armature fluid. In this isolated actuator embodiment, the membrane is forced onto the seat of actuator button **538**, in the closed position. This isolated actuator, including button **538** are described in detail in PCT application PCT/US 01/51098, which is incorporated by reference.

[0086] Referring again to FIG. **4**D, external cover **102** is designed for optimal operation and easy servicing of automatic flusher **100**. Main cover body **502** provides overall protection and rigidity. Front cover **531** and top cover **550** have complementary shapes with main body **502** to form a dome-like structure and to enable easy disassembly (as shown in FIG. **4**D by the exploded view). The main body **502**, front cover **531** and top cover **550** fit together like a simple three-dimensional puzzle. In a preferred embodiment, these elements have surfaces arranged to provide a tight water seal. As also shown in FIG. **4**D, screws **580**A and **580**B hold in place top cover **550** by tightening against the respective cooperating threads **530**A and **530**B located in pilot cap **534** (FIG. **4**C). This arrangement holds in place and attaches together main cover **502** with front cover **531** and top cover **550**, which all are coupled to the pilot chamber cover **534**. This arrangement also holds control module **500** and plate **528** in place with respect to pilot cap **534**, which in turn is attached to flusher body **512** by a retaining ring **522**.

[0087] Importantly, the material of dome cover **102** is selected to provide protection for electronic control module **500** and actuator **540**. Cover **102** is formed of a plastic that is durable and is highly resistant to the chemicals frequently found in washrooms used for cleaning purposes. The materials are also highly impact resistant (depending on the type of installation, i.e., public or private) so as to resist attempts of vandalism.

[0088] Alternatively, main body **502** is made of a non-corrosive metal (instead of plastic), while front cover **531** or top cover **550** are still made of plastic. It has been found that polysulfone is a highly desirable plastic material for this purpose. Front cover **531** includes optical window **533** and can also be made of a polysulfone plastic that does not impede or interfere with the transmission of infrared signals from the sensor. Preferably, window **533** masks or obscures the interior elements in flush valve **100**. Preferably, a pigment is added to the polysulfone so that approximately 70 percent of visible light at all wave lengths will pass through optical window **533** and approximately 30 percent will be impeded. A pigment made by Amoco bearing spec number BK1615 provides a dark (not quite-black), deep lavender window **533**, which obscures the interior components, but yet permits transmission of a very substantial portion of light at the used wavelengths. Window **533** is usually made of the same material as other portions of front cover **531**, but may be more highly polished in contrast with the somewhat matte finish of the remaining portions of front cover **531**.

[0089] Main body **502** is shaped to provide most of the enclosure function of cover **102** including structural support for front cover **531** and top cover **550**. Front cover **531** includes optical sensor window **533**, a wall member **541**, top region **543** and two lips or slides co-operatively arranged with grooves **503**, which are located in the main body **502**. After front cover **531** is attached to main body **502** using the lips or slides, top cover is placed on the top surface **516** of main body **502**. Top cover **550** includes a curved top surface **552** cooperatively arranged with a button retainer and a manual actuation button **104**. Top cover **550** also includes side surfaces **554**A and **554**B, which are functionally important for lifting top cover **550** (after loosening screws **580**A and **580**B) without any tools. Main body **502** also includes a water passage (or a bleed hole) located in the rear of main body **502**. In the case of an unlikely malfunction, there may be a water leak, for example, between passages **537** and **543**, which could create water flow into cover **102**. The water passage prevents water accumulation inside the flusher cover **102** and thus prevents flooding and possibly damaging to electronic module **500**. Water passage, however, does not allow significant water flow from outside to inside of cover **102** (e.g., from the top or the side of cover **102** during cleaning). This is achieved by the shaped surface of the water passage directed downward. Cover **102** is designed to withstand high pressure cleaning, while still providing vent passage (i.e., water bleed opening). Additional description is provided in U.S. Application 60/448,995, filed on Feb. 20, 2003, which is incorporated by reference.

[0090] Top cover **550** is designed for accommodating a manual flush and saving batteries (and other electronic elements) during shipping and storage. The manual flush is performed by pressing on top button **104**. The saving mode is achieved by holding down top button **104** in the depressed position using a shipping and storage strip **555**, as described below. Top button **104** is designed cooperatively with a button insert guide. The button insert guide includes a cylindrical region designed for a magnet that is displaced up and down by the movement of button **104**. The magnet is cooperatively arranged with a reed sensor located inside electronic control module **500**.

[0091] When depressing button **104**, the reed sensor registers the magnet and provides a signal to the microcontroller that in turn initiates a flush cycle, as described in PCT Application PCT/US02/38758. Upon releasing button **104**, a button spring pushes button **104** to its upper position, and thereby also displaces the magnet. In the upper position, the magnet is no longer sensed by the reed sensor. The uniform linear movement of button **104** is achieved by using a bail wire in cooperation with the spring. Manual actuation button **104** overrides the flush algorithm (e.g., as described in FIGS. **14**-**14**C) and initiates a flush.

[0092] FIGS. **5** and **5**A show schematically side and top views of an optical detection pattern used by the passive optical sensor installed in the automatic toilet flusher of FIG. **4**. This detection pattern is associated with sensor port **108** and is shaped by a lens, or an element selected from the optical elements shown in FIGS. **6**-**6**E. The pattern is angled below horizontal (H) and directed symmetrically with respect to toilet **116**. The range is somewhat limited not to be influenced by a wall (W); this can be also done by limiting the detection sensitivity.

[0093] FIGS. **5**B and **5**C show schematically side and top views of a second optical detection pattern used by the passive optical sensor installed in the automatic toilet flusher of FIG. **4**. This detection pattern is shaped by a lens, or another optical element. The pattern is angled both below horizontal (H) and above horizontal (H). Furthermore, the pattern is directed asymmetrically with respect to toilet **116**, as shown in FIG. **5**C.

[0094] FIGS. **5**D and **5**E show schematically side and top views of a third optical detection pattern used by the passive optical sensor installed in the automatic toilet flusher of FIG. **4**. This detection pattern is again shaped by a lens, or another optical element. The pattern is angled above horizontal (H). Furthermore, the pattern is directed asymmetrically with respect to toilet **116**, as shown in FIG. **5**E.

[0095] FIGS. **5**F and **5**G show schematically side and top views of a fourth optical detection pattern used by the passive optical sensor installed in the automatic toilet flusher of FIG. **4**. This detection pattern is angled below horizontal (H) and is directed asymmetrically across toilet **116**, as shown in FIG. **5**G. This detection pattern is particularly useful for "toilet side flushers," described in U.S. application Ser. No. 09/916,468, filed on Jul. 27, 2001, or U.S. application Ser. No. 09/972,496, filed on Oct. 6, 2001, both of which are incorporated by reference.

[0096] FIGS. **5**H and **5**I, show schematically side and top views of an optical detection pattern used by the passive optical sensor installed in the automatic urinal flusher of FIG. **4**A. This detection pattern is shaped by a lens, or another optical element. The pattern is angled both below horizontal (H) and above horizontal (H) to target ambient light changes caused by a person standing in front of urinal **120**. This pattern is directed asymmetrically with respect to urinal **120** (as shown in FIG. **5**I), for example, to eliminate or at least reduce light changes caused by a person standing at a neighboring urinal.

[0097] FIGS. **5**J, **5**K and **5**L, show schematically side and top views of another optical detection pattern used by the passive optical sensor installed in the automatic urinal flusher of FIG. **4**A. This detection pattern is shaped by a lens, or another optical element, as mentioned above. The pattern is angled below horizontal (H) to eliminate the influence of light caused by a ceiling lamp. This pattern may be directed asymmetrically to the left or to the right with respect to urinal **120** (as shown in FIG. **5**K or **5**L). These detection patterns are particularly useful for "urinal side flushers," described in U.S. application Ser. No. 09/916,468, filed on Jul. 27, 2001, or U.S. application Ser. No. 09/972,496, filed on Oct. 6, 2001.

[0098] In general, the field of view of a passive optical sensor can be formed using optical elements such as beam forming tubes, lenses, light pipes, reflectors, arrays of pinholes and arrays of slots having selected geometries. These optical elements can provide a down-looking field of view that eliminates the invalid targets such as mirrors, doors, and walls. Various ratios of the vertical field of view to horizontal field of view provide different options for target detection. For example, the horizontal field of view may be 1.2 wider than the vertical field of view or vice versa. A properly selected field of view can eliminate unwanted signals from an adjacent faucet or urinal. The detection algorithm includes a calibration routine that accounts for a selected field of view including the field's size and orientation.

[0099] FIGS. **6** through **6**E illustrate different optical elements for producing desired detection patterns of the passive sensor. FIGS. **6** and **6**B illustrate different arrays of pinholes. The thickness of the plate, the size and the orientation of the pinholes (shown in cross-section in FIGS. **6**A and **6**C) define the properties of the field of view. FIGS. **6**D and **6**E illustrate an array of slits for producing a detection pattern shown in FIGS. **5**B and **5**H. This plate may also include a shutter for covering the top or the bottom detection field.

[0100] FIGS. **7** and **7**A illustrate in detail automatic flush valves suitable for use with automatic bathroom flusher **100** or automatic bathroom flusher **100**A. Other flush valves are described in the above-referenced PCT applications. Yet other suitable flush valves are described in U.S. Pat. Nos. 6,382,586 and 5,244,179, both of which are incorporated by reference. In each case, the flush valve is controlled by a passive optical sensor described herein.

[0101] Referring to FIG. **7**, an automatic flush valve **140** is a high performance, electronically controlled or manually controlled tankless flush valve, which uses a passive optical sensor **130**. Passive optical sensor **130** includes a lens **134** for defining the detection field and providing ambient light to a light receiver **132**. Plastic enclosure **135** includes an optical window **136**, which may also include optical elements described in connection with FIGS. **6**-**6**E. The controller is located on a circuit board **138**. Plastic enclosure **135** also houses the batteries for powering the entire flushing system.

[0102] Referring to FIG. **7**A, an automatic flush valve **140** A is a high performance, electronically controlled or manually controlled tankless flush valve, which uses an active optical sensor **130**A. Active optical sensor **130**A includes a light emitter **132**A (e.g., a light emitting diode, LED) and a light receiver **132**A (e.g., an IR diode). The light emitted from LED **132**A is focused by a lens **134**A and the reflected signal is collected by s lens **1348** and focused onto detector **132**B. Lenses **134**A and **134**B are designed for defining the detection region for the active optical sensor. Plastic enclosure **135**A includes optical windows **136**A and **136**B, which may also include optical elements described in connection with FIGS. **6**-**6**E. The control electronics is located on a circuit board. Plastic enclosure **135**A also houses the batteries for powering the entire flushing system.

[0103] Referring to FIGS. **7** and **7**A, flush valve **140**, includes an input union **112**, preferably made of a suitable plastic resin. Union **112** is attached via threads to an input fitting that interacts with the building water supply system. Furthermore, union **112** is designed to rotate on its own axis when no water is present so as to facilitate alignment with the inlet supply line. Union **112** is attached to an inlet pipe **142** by a fastener **144** and a radial seal **146**, which enables union **112** to move in or out along inlet pipe **142**. This movement aligns the inlet to the supply line. However, with fastener **144** secured, there is a water pressure applied by the junction of union **112** to inlet **142**. This forms a unit that is rigidly sealed through seal **146**. The water supply travels through union **112** to inlet **142** and through the inlet valve assembly **150** an inlet screen filter **152**, which resides in a passage formed by member **178** and is in communication with a main valve seat **156**. The operation of the entire main valve can be better understood by also referring to FIGS. **9**, and **9**A.

[0104] As also described in connection with FIGS. **8**, **9**, and **9**A, electro-magnetic actuator **201** controls operation of the main valve, which is a "fram piston valve" **270**. In the opened state, water flows thru a passage **152** and thru passages **158** into passages **159**A and **159**B, into main outlet **114**. In the closed state, the fram element **278** (FIGS. **9** and **9**A) seals the valve main seat **156** thereby closing flow through passage **158**. Automatic flusher **140** includes an adjustable input valve **150** controlled by rotation of a valve element **174** threaded together with valve elements **162** and **164**. Valve elements **162** and **164** are sealed from body **170** via one or several o-rings **163**. Furthermore, valve elements **162** and **164** are held down by threaded element **160**, when element **174** is threaded all the way. This force is transferred to element **154** and **178**. The resulting force presses down element **180**.

[0105] When valve element **160** is unthreaded all the way, valve assembly **150** and **151** moves up due to the force of spring **184** located on guide element **186** in this adjustable input valve. The spring force combined with inlet fluid pressure from pipe **142** forces element **151** against the valve seat in contact with O-ring **182** resulting in a sealing action of the O-ring **182**. O-Ring **182** (or another sealing element) blocks the flow of water to inner passage of **152**, which in turn enables servicing of all internal valve elements including elements behind shut-off valve **150** without the need to shut off the water supply at the inlet **112**. This is a major advantage of this embodiment.

[0106] According to another function of adjustable valve **140**, the threaded retainer is fastened part way resulting in valve body elements **162** and **164** to push down the valve seat only partially. There is a partial opening that provides a flow restriction reducing the flow of input water thru valve **150**. This novel function is designed to meet application specific requirements. In order to provide for the installer the flow restriction, the inner surface of the valve body includes application specific marks such as 1.6 W.C. 1.0 GPF urinals etc. for calibrating the input water flow.

[0107] Automatic flush valve **140** is equipped with the above-described sensor-based electronic system located in housing **135**. Alternatively, the sensor-based electronic flush system may be replaced by an all mechanical activation button or lever. Alternatively, the flush valve may be controlled by a hydraulically timed mechanical actuator that acts upon a hydraulic delay arrangement, as described in PCT Application PCT/US01/43273, which is incorporated by reference. The hydraulic system can be adjusted to a delay period corresponding to the needed flush volume for a given fixture such a 1.6 GPF W.C. etc. The hydraulic delay mechanism can open the outlet orifice of the pilot section instead of electro-magnetic actuator **201** for duration equal to the installer preset value.

[0108] Referring again to FIGS. **7** and **7**A, depending on the passive optical sensor signal (or the active optical sensor signal), the microcontroller executes a control algorithm and provides ON and OFF signals to valve actuator **201**, which, in turn, opens or closes water delivery. The microcontroller can also execute a half flush or delayed flush depending on the mode of use (e.g., a toilet, a urinal, a frequently used urinal as in a ball park). The microcontroller can also execute a timed flush (one flush per day or per week in facilities such as ski resorts in summer) to prevent drying of the water trap.

[0109] FIGS. **8**, **8**A and **8**B illustrate an automatic valve **38** constructed and arranged for controlling water flow in automatic faucet **10**. Specifically, automatic valve **38** receives water at a valve input port **202** and provides water from a valve output port **204**, in the open state. Automatic valve **38** includes a body **206** made of a durable plastic or metal. Preferably, valve body **206** is made of a plastic material but includes a metallic input coupler **210** and a metallic output coupler **230**. Input and output couplers **210** and **230** are made of metal (such as brass, copper or steel) so that they can provide gripping surfaces for a wrench used to connect them to water lines **24** and **25**, respectively. Valve body **206** includes a valve input port **240**, and a valve output port **244**, and a cavity **207** for receiving the individual valve elements shown in FIG. **8**.

[0110] Metallic input coupler **210** is rotatably attached to input port **240** using a metal C-clamp **212** that slides into a slit **214** inside input coupler **210** and also a slit **242** inside the body of input port **240** (FIG. **8**). Metallic output coupler **230** is rotatably attached to output port **244** using a metal C-clamp **232** that slides into a slit **234** inside output coupler **230** and also a slit **246** inside the body of output port **244**. When servicing the faucet **12**, this rotatable arrangement prevents tightening the water line connection to any of the two valve couplers unless attaching the wrench to the designated surfaces of couplers **210** and **230**. (That is, a service person cannot tighten the water input and output lines by gripping on valve body **206**.) This protects the relatively softer plastic body **206** of automatic valve **38**. However, body **206** can be made of a metal in which case the above-described rotatable coupling is not needed. A sealing O-ring **216** seals input coupler **210** to input port **240**, and a sealing O-ring **238** seals output coupler **230** to input port **244**.

[0111] Referring to FIGS. **8**, **8**A, and **8**B, metallic input coupler **210** includes an inlet flow adjuster **220** cooperatively arranged with a flow control mechanism **310** (FIG. **8**). Inlet flow adjuster **220** includes an adjuster piston **222**, a closing spring **224** arranged around an adjuster pin **226** and pressing against a pin retainer **218**. Input flow adjuster **220** also includes an adjuster rod **228** coupled to and displacing adjuster piston **222**. Flow control mechanism **310** includes a spin cap **312** coupled by screw **314** to an adjustment cap **316** in communication with a flow control cam **320**. Flow control cam **320** slides linearly inside body **206** upon turning adjustment cap **316**. Flow control cam **320** includes inlet flow openings **321**, a locking mechanism **323** and a chamfered surface **324**. Chamfered surface **324** is cooperatively arranged with a distal end **229** of adjuster rod **228**. The linear movement of flow control cam **320**, within valve body **206**, displaces chamfered surface **324** and thus displaces adjuster rod **228**. Adjuster piston **222** also includes an inner surface **223** cooperatively arranged with an inlet seat **211** of input coupler **210**. The linear movement of adjuster rod **228** displaces adjuster piston **222** between a closed position and an open position. In the closed position, sealing surface **223** seals inner seat **211** by the force of closing spring **224**. In the opened position, adjuster rod **228** displaces adjuster pin **222** against closing spring **224** thereby providing a selectively sized opening between inlet seat **211** and sealing surface **223**. Thus, by turning adjustment cap **316**, adjuster rod **228** opens and doses inlet adjuster **220**. Inlet adjuster **220** controls or closes completely the water flow from water line **24**. The above-described manual adjustment can be replaced by an automatic motorized adjustment mechanism controlled by a microcontroller.

[0112] Referring still to FIGS. **8**, **8**A and **8**B, automatic valve **38** also includes a removable inlet filter **330** removably located over an inlet filter holder **332**, which is part of the lower valve housing. Inlet filter holder **332** also includes an O-ring and a set of outlet holes **267** shown in FIG. **8**. The “fram piston” **270** is shown in detail in FIGS. **9** and **9**A. Referring again to FIG. **8**A, water flows from input port **202** of input coupler **210** through inlet flow adjuster **220** and then through inlet flow openings **321**, and through inlet filter **330** inside inlet filter holder **332**. Water then arrives at an input chamber **268** inside a cylindrical input element **276** providing pressure against a pliable member **278** (FIG. **9**).

[0113] Automatic valve **38** also includes a service loop **340** (or a service rod) designed to pull the entire valve assembly, including attached actuator **200**, out of body **206**, after removing of plug **316**. The removal of the entire valve assembly also removes the attached actuator **200** (or actuator **201**) and the piloting button described in PCT Application PCT/US02/38757 and in PCT Application PCT/US02/38757, both of which are incorporated by reference. To enable easy installation and servicing, there are rotational electrical contacts located on a PCB at the distal end of actuator **200**. Specifically, actuator **200** includes, on its distal end, two annular contact regions that provide a contact surface for the corresponding pins, all of which can be gold plated for achieving high quality contacts. Alternatively, a stationary PCB can include the two annular contact regions and the actuator may be connected to movable contact pins. Such distal, actuator contact assembly achieves easy rotational contacts by just sliding actuator **200** located inside valve body **206**.

[0114] FIG. **8**C illustrates automatic valve **38** including a leak detector for indicating a water leak or water flow across valve device **38**. The leak detector includes an electronic measurement circuit **350** and at least two electrodes **348** and **349** coupled respectively to input coupler **210** and output coupler **230**. (The leak detector may also include four electrodes for a four-point resistivity measurement). Valve body **206** is made of plastic or another non-conductive material. In the closed state, when there is no water flow between input coupler **210** and output coupler **230**, electronic circuit **350** measures a very high resistance value between the two electrodes. In the open state, the resistance value between input coupler **210** and output coupler **230** drops dramatically because the flowing water provides a conductive path.

[0115] There are various embodiments of electronics **350**, which can provide a DC measurement, an AC measurement including eliminating noise using a lock-in amplifier (as known in the art). Alternatively, electronics **350** may include a bridge or another measurement circuit for a precise measurement of the resistivity. Electronic circuit **350** provides the resistivity value to a microcontroller and thus indicates when valve **38** is in the open state. Furthermore, the leak detector indicates when there is an undesired water leak between input coupler **210** and output coupler **230**. The entire valve **38** is located in an isolating enclosure to prevent any undesired ground paths that would affect the conductivity measurement. Furthermore, the leak detector can indicate some other valve failures when water leaks into the enclosure from valve **38**. Thus, the leak detector can sense undesired water leaks that would be otherwise difficult to observe. The leak detector is constructed to detect the open state of the automatic faucet system to confirm proper operation of actuator **200**.

[0116] Automatic valve **38** may include a standard diaphragm valve, a standard piston valve, or a novel "fram piston" valve **270** explained in detail in connection with FIGS. **9** and **9**A. Referring to FIG. **9**, valve **270** includes a distal body **276**, which includes an annular lip seal **275** arranged, together with pliable member **278**, to provide a seal between input port chamber **268** and output port chamber **269**. The distal body **276** also includes one or several flow channels **267** (also shown in FIG. **8**) providing communication (in the open state) between input chamber **268** and output chamber **269**. Pliable member **278** also includes sealing members **279**A and **279**B arranged to provide a sliding seal, with respect to valve body **272**, between pilot chamber **292** and output chamber **271**. There are various possible embodiments of seals **279**A and **279**B (FIG. **9**). This seal may be a one-sided seal or a two-sided seal as **279**A and **279**B shown in FIG. **9**. Furthermore, there are various additional embodiments of the sliding seal including O-rings, etc.

[0117] The present invention envisions valve device **270** having various sizes. For example, the "full" size embodiment has the pin diameter A=0.070", the spring diameter B=0.310", the pliable member diameter C=0.730", the overall fram and seal's diameter D=0.412", the pin length E=0.450", the body height F=0.2701", the pilot chamber height G=0.220", the fram member size H=0.160", and the fram excursion I=0.100". The overall height of the valve is about 1.35" and diameter is about 1.174".

[0118] The "half size" embodiment of the "fram piston" valve has the following dimensions provided with the same reference letters. In the "half size" valve A=0.070", B=0.30, C=0.560", D=0.650", E=0.34", F=0.310", G=0.215", H=0.125", and I=0.60". The overall length of the ½ embodiment is about 1.350" and the diameter is about 0.455". Different embodiments of the "fram piston" valve device may have various larger or smaller sizes.

[0119] Referring to FIGS. **9** and **9**A, the fram piston valve **270** receives fluid at input port **268**, which exerts pressure onto diaphragm-like member **278** providing a seal together with a lip member **275** in a closed state. Groove passage **288** inside pin **286** provides pressure communication with pilot chamber **292**, which is in communication with actuator cavity **300** via communication passages **294**A and **294**B. An actuator (described in PCT Application PCT/US02/38757) provides a seal at surface **298** thereby sealing passages **294**A and **294**B and thus pilot chamber **300**. When the plunger of actuator **200** moves away from surface **298**, fluid flows via passages **294**A and **294**B to control passage **296** and to output port **269**. This causes pressure reduction in pilot chamber **292**. Therefore, diaphragm-like member **278** and piston-like member **288** move linearly within cavity **292**, thereby providing a relatively large fluid opening at lip seal **275**. A large volume of fluid can flow from input port **268** to output port **269**.

[0120] When the plunger of actuator **200** seals control passages **294**A and **294**B, pressure builds up in pilot chamber **292** due to the fluid flow from input port **268** through "bleed" groove **288** inside guide pin **286**. The increased pressure in pilot chamber **292** together with the force of spring **290** displace linearly, in a sliding motion over guide pin **286**, from member **270** toward sealing lip **275**. When there is sufficient pressure in pilot chamber **292**, diaphragm-like pliable member **278** seals input port chamber **268** at lip seal **275**. The soft member **278** includes an inner opening that is designed with guiding pin **286** to clean groove **288** during the sliding motion. That is, groove **288** of guiding pin **286** is periodically cleaned.

[0121] The embodiment of FIG. **9** shows the valve having a central input chamber **268** (and guide pin **286**) symmetrically arranged with respect to vent passages **294**A and **294**B (and the location of the plunger of actuator **200**). However, the valve device may have input chamber **268** (and guide pin **286**) non-symmetrically arranged with respect to passages **294**A, **294**B and output vent passage **296**. That is, in such a design, this valve has input chamber **268** and guide pin **286** non-symmetrically arranged with respect to the location of the plunger of actuator **200**. The symmetrical and non-symmetrical embodiments are equivalent.

[0122] Automatic valve **38** has numerous advantages related to its long term operation and easy serviceability. Automatic valve **38** includes inlet adjusted **220**, which enables servicing of the valve without shutting off the water supply at another location. The construction of valve **38**, including the inner dimensions of cavity **207** and actuator **200**, enables easy replacement of the internal parts. A service person can remove screw **314** and spin cap **312**, and then remove adjustment cap **316** to open valve **38**. Valve **38** includes service loop **340** (or a service rod) designed to pull the entire valve assembly, including attached actuator **200**, out of body **206**. The service person can then replace any defective part, including actuator **200**, or the entire assembly and insert the repaired assembly back inside valve body **206**. Due to the valve design, such repair would take only a few minutes and there is no need to disconnect valve **38** from the water line or close the water supply. Advantageously, the "fram piston" design **270** provides a large stroke and thus a large water flow rate relative to its size.

[0123] Another embodiment of the "fram piston" valve device is described in PCT applications PCT/US02/34757, filed Dec. 4, 2002, and PCT/US03/20117, filed Jun. 24, 2003, both of which are incorporated by reference as if fully reproduced herein. Again, the entire operation of this valve device is controlled by a single solenoid actuator that may be a latching solenoid actuator or an isolated actuator described in PCT application PCT/US01/51054, filed on Oct. 25, 2001, which is incorporated by reference as if fully reproduced herein.

[0124] FIG. **10** schematically illustrates control electronics **400**, powered by a battery **420**. Control electronics **400** includes battery regulation unit **422**, no or low battery detection unit **425**, passive sensor and signal processing unit **402**, and the microcontroller **405**. Battery regulation unit **422** provides power for the whole controller system. It provides 6.0 V power through 6.0V power **1** to "no battery" Detector; it provides 6.0 V power to low battery detector; it also provides 6.0 V to power driver **408**. It provides a regulated 3.0 V power to microcontroller **405**.

[0125] "No battery" detector generates pulses to microcontroller **405** in form of "Not Battery" signals to notify microcontroller **405**. Low Battery detector is coupled to the battery/power regulation through the 6.0V power. When power drops below 4.2V, the detector generates a pulse to the microcontroller (i.e., low battery signal). When the "low battery" signal is received, microcontroller will flash indicator **430** (e.g., an LED) with a frequency of 1 Hz, or may provide a sound alarm.

After flushing 2000 times under low battery conditions, microcontroller will stop flushing, but still flash the LED.

[0126] As described in connection with FIG. **10**B, passive sensor and signal processing module **402** converts the resistance of a photoresistor to a pulse, which is sent to microcontroller through the charge pulse signal. The pulse width changes represent the resistance changes, which in turn correspond to the illumination changes. The control circuit also includes a clock/reset unit that provides clock pulse generation, and it resets pulse generation. It generates a reset pulse with 4 Hz frequency, which according to the clock pulse, is the same frequency. The reset signal is sent to microcontroller **405** through "reset" signal to reset the microcontroller or wake up the microcontroller from sleep mode.

[0127] A manual button switch may be formed by a reed switch, and a magnet. When the button is pushed down by a user, the circuitry sends out a signal to the clock/reset unit through manual signal IRQ, then forces the clock/reset unit to generate a reset signal. At the same time, the level of the manual signal level is changed to acknowledge to microcontroller **405** that it is a valid manual flush signal.

[0128] Referring still to FIG. **10**, control electronics **400** receives signals from optical sensor unit **402** and controls an actuator **412**, a controller or microcontroller **405**, an input element (e.g., the optical sensor), a solenoid driver **408** (power driver) receiving power from a battery **420** regulated by a voltage regulator **422**. Microcontroller **405** is designed for efficient power operation. To save power, microcontroller **405** is initially in a low frequency sleep mode and periodically addresses the optical sensor to see if it was triggered. After triggering, the microcontroller provides a control signal to a power consumption controller **418**, which is a switch that powers up voltage regulator **422** (or a voltage boost **422**), optical sensor unit **402**, and a signal conditioner **416**. (To simplify the block diagram, connections from power consumption controller **418** to optical sensor unit **402** and to signal conditioner **416** are not shown.)

[0129] Microcontroller **405** can receive an input signal from an external input element (e.g., a push button) that is designed for manual actuation or control input for actuator **410**. Specifically, microcontroller **405** provides control signals **406**A and **406**B to power driver **408**, which drives the solenoid of actuator **410**. Power driver **408** receives DC power from battery and voltage regulator **422** regulates the battery power to provide a substantially constant voltage to power driver **408**. An actuator sensor **412** registers or monitors the armature position of actuator **410** and provides a control signal **415** to signal conditioner **423**. A low battery detection unit **425** detects battery power and can provide an interrupt signal to microcontroller **405**.

[0130] Actuator sensor **412** provides data to microcontroller **405** (via signal conditioner **423**) about the motion or position of the actuator's armature and this data is used for controlling power driver **408**. The actuator sensor **412** may be an electromagnetic sensor (e.g., a pick up coil) a capacitive sensor, a Hall effect sensor, an optical sensor, a pressure transducer, or any other type of a sensor.

[0131] Preferably, microcontroller **405** is an 8-bit CMOS microcontroller TMP86P807M made by Toshiba. The microcontroller has a program memory of an 8 Kbytes and a data memory of 256 bytes. Programming is done using a Toshiba adapter socket with a general-purpose PROM programmer. The microcontroller operates at 3 frequencies (f_c=16 MHz, f_c=8 MHz and f_s=332.768 kHz), wherein the first two clock frequencies are used in a normal mode and the third frequency is used in a low power mode (i.e., a sleep mode). Microcontroller **405** operates in the sleep mode between various actuations. To save battery power, microcontroller **405** periodically samples optical sensor **402** for an input signal, and then triggers power consumption controller **418**. Power consumption controller **418** powers up signal conditioner **423** and other elements. Otherwise, optical sensor **402**, voltage regulator **422** (or voltage boost **422**) and a signal conditioner **423** are not powered to save battery power. During operation, microcontroller **405** also provides indication data to an indicator **430**. Control electronics **400** may receive a signal from the passive optical sensor or the active optical sensor described above. The passive optical sensor includes only a light detector providing a detection signal to microcontroller **405**.

[0132] Low battery detection unit **425** may be the low battery detector model no. TC54VN4202EMB, available from Microchip Technology. Voltage regulator **422** may be the voltage regulator part no. TC55RP3502EMB, also available from Microchip Technology (http://www.microchip.com). Microcontroller **405** may alternatively be a microcontroller part no. MCU COP8SAB728M9, available from National Semiconductor.

[0133] FIG. **10**A schematically illustrates another embodiment of control electronics **400**. Control electronics **400** receives signals from optical sensor unit **402** and controls actuator **411**. As described above, the control electronics also includes microcontroller **405**, solenoid driver **408** (i.e., power driver), voltage regulator **422**, and a battery **420**. Solenoid actuator **411** includes two coil sensors **411**A and **411**B. Coil sensors **411**A and **411**B provide a signal to the respective preamplifiers **416**A and **416**B and low pass filters **417**A and **417**B. A differentiator **419** provides the differential signal to microcontroller **405** in a feedback loop arrangement.

[0134] To open a fluid passage, microcontroller **405** sends OPEN signal **406**B to power driver **408**, which provides a drive current to the drive coil of actuator **410** in the direction that will retract the armature. At the same time, coils **411**A and **411**B provide induced signal to the conditioning feedback loop, which includes the preamplifier and the low-pass filter. If the output of a differentiator **419** indicates less than a selected threshold calibrated for the retracted armature (i.e., the armature didn't reach a selected position), microcontroller **405** maintains OPEN signal **406**B asserted. If no movement of the solenoid armature is detected, microcontroller **405** can apply a different (higher) level of OPEN signal **406**B to increase the drive current (up to several times the normal drive current) provided by power driver **408**. This way, the system can move the armature, which is stuck due to mineral deposits or other problems.

[0135] Microcontroller **405** can detect the armature displacement (or even monitor armature movement) using induced signals in coils **411**A and **411**B provided to the conditioning feedback loop. As the output from differentiator **419** changes in response to the armature displacement, microcontroller **405** can apply a different (lower) level of OPEN signal **406**B, or can turn off OPEN signal **406**B, which in turn directs power driver **408** to apply a different level of drive current. The result usually is that the drive current has been reduced, or the duration of the drive current has been much shorter than the time required to open the fluid passage under worst-case conditions (that has to be used without using an armature sensor). Therefore, the control system saves considerable energy and thus extends the life of battery **420**.

[0136] Advantageously, the arrangement of coil sensors **411**A and **411**B can detect latching and unlatching movement of the actuator armature with great precision. (However, a single coil sensor, or multiple coil sensors, or capacitive sensors may also be used to detect movement of the armature.) Microcontroller **405** can direct a selected profile of the drive current applied by power driver **408**. Various profiles may be stored in, microcontroller **405** and may be actuated based on the fluid type, the fluid pressure (water pressure), the fluid temperature (water temperature), if the time actuator **410** has been in operation since installation or last maintenance, a battery level, input from an external sensor (e.g., a movement sensor or a presence sensor), or other factors. Based on the water pressure and the known sizes of the orifices, the automatic flush valve can deliver a known amount of flush water.

[0137] FIG. **10**B provides a schematic diagram of a detection circuit used for the passive optical sensor **50**. The passive optical sensor does not include a light source (no light emission occurs) and only includes a light detector that detects arriving light. As compared to the active optical sensor, the passive sensor enables reduced power consumption since all power consumption related to the IR emitter is eliminated. The light detector may be a photodiode, a photo-resistor or some other optical element providing electrical output depending on the intensity or the wavelength of the received light. The light receiver is selected to be active in the range or 350 to 1,500 nanometers and preferably 400 to 1,000 nanometers, and even more preferably, 500 to 950 nanometers. Thus, the light detector is not sensitive to body heat emitted by the user of faucet **10**, **10**A, **10**B or **10**C, or body heat emitted by the user located in front of flushers **100** or **100**A.

[0138] FIG. **10**B shows a schematic diagram of the detection circuit used by the passive sensor, which enables a significant reduction in energy consumption. The detection circuit includes a detection element D (e.g., a photodiode or a photo-resistor), two comparators (U1A, and U1B) connected to provide a read-out from the detection element upon receipt of a high pulse. Preferably, the detection element is a photo-resistor. The voltage V_{CC} is +5 V (or +3V) received from the power source. Resistors R_2 and R_3 are voltage dividers between V_{CC} and the ground. Diode D_1 is connected between the pulse input and output line to enable the readout of the capacitance at capacitor C_1 charged during the light detection.

[0139] Preferably, the photo-resistor is designed to receive light of intensity in the range of 1 lux to 1000 lux, by appropriate design of optical lens **54** or the optical elements shown in FIGS. **6** through **6**E. For example, optical lens **54** may include a photochromatic material or a variable size aperture. In general, the photo-resistor can receive light of intensity in the range of 0.1 lux to 500 lux for suitable detection. The resistance of the photodiode is very large for low light intensity, and decreases (usually exponentially) with the increasing intensity.

[0140] Referring still to FIG. **10**B, upon receiving a “high” pulse at the input connection, comparator U_{1A} receives the “high” pulse and provides the “high” pulse to node A. At this point, the corresponding capacitor charge is read out through comparator U_{1B} to the output **7**. The output pulse is a square wave having a duration that depends on the photocurrent (that charged capacitor C_1 during the light detection time period). Thus, microcontroller **34** receives a signal that depends on the detected light.

[0141] In the absence of the high signal, comparator U_{1A} provides no signal to node A, and therefore capacitor C_1 is being charged by the photocurrent excited at the photo resistor D between V_{CC} and the ground. The charging and reading out (discharging) process is being repeated in a controlled manner by providing a high pulse at the control input. The output receives a high output, i.e., the square wave having duration proportional to the photocurrent excited at the photo resistor. The detection signal is in a detection algorithm executed by microcontroller **405**.

[0142] By virtue of the elimination of the need to employ an energy consuming IR light source used in the active optical sensor, the system can be configured so as to achieve a longer battery life (usually many years of operation without changing the batteries). Furthermore, the passive sensor enables a more accurate means of determining presence of a user, the user motion, and the direction of user’s motion.

[0143] The preferred embodiment as it relates to which type of optical sensing element is to be used is dependent upon the following factors: The response time of a photo-resistor is on the order or 20-50 milliseconds, whereby a photo-diode is on the order of several microseconds, therefore the use of a photo-resistor will require a significantly longer time form which impacts overall energy use.

[0144] Furthermore, the passive optical sensor can be used to determine light or dark in a facility and in turn alter the sensing frequency (as implemented in the faucet detection algorithm). That is, in a dark facility the sensing rate is reduced under the presumption that in such a modality the faucet or flusher will not be used. The reduction of sensing frequency further reduces the overall energy consumption, and thus this extends the battery life.

[0145] FIG. **11** illustrates various factors that affect operation and calibration of the passive optical system. The sensor environment is important since the detection depends on the ambient light conditions. If the ambient light in the facility changes from normal to bright, the detection algorithm has to recalculate the background and the detection scale. The detection process differs when the lighting conditions vary (**585**), as shown in the provided algorithms. There are some fixed conditions (**588**) for each facility such as the walls, toilet locations, and their surfaces. The provided algorithms periodically calibrate the detected signal to account for these conditions. The above-mentioned factors are incorporated in the following algorithm.

[0146] Referring to FIGS. **12**-**12**I, the microcontroller is programmed to execute a flushing algorithm **600** for flushing toilet **116** or urinal **120** at different light levels. Algorithm **600** detects different users in front of the flusher as they are approaching the unit, as they are using the toilet or urinal, and as they are moving away from the unit. Based on these activities, algorithm **600** uses different states. There are time periods between each state in order to automatically flush the toilet at appropriately spaced intervals. Algorithm **600** also controls flushes at particular periods to make sure that the toilet has not been used without detection. The passive optical detector for algorithm **600** is preferably a photoresistor coupled to a readout circuit shown in FIG. **10**B.

[0147] Algorithm **200** has three light modes: a Bright Mode (Mode **1**), a Dark Mode (Mode **3**), and a Normal Mode (Mode **2**). The Bright Mode (Mode **1**) is set as the microcontroller mode when resistance is less than 2 kΩ (Pb), corresponding to large amounts of light detected (FIG. **12**). The Dark Mode (Mode **3**) is set when the resistance is greater than 2 MΩ (Pd), corresponding to very little light detected (FIG. **12**). The Normal Mode (Mode **2**) is defined for a resistance is between 2 kΩ and 2 MΩ, corresponding to ambient, customary amounts of light are present. The resistance values are measured in terms of a pulse width (corresponding to the resistance of the photoresistor in FIG. **10**B). The above resistance threshold values differ for different photoresistors and are here for illustration only.

[0148] The microcontroller is constantly cycling through algorithm **600**, where it will wake up (for example) every 1 second, determine which mode it was last in (due to the amount of light it detected in the prior cycle). From the current mode, the microcontroller will evaluate what mode it should go to based on the current pulse width (p) measurement, which corresponds to the resistance value of the photoresistor.

[0149] The microcontroller goes through 6 states in Mode **2**. The following are the states required to initiate the flush: An Idle status in which no background changes in light occur, and in which the microcontroller calibrates the ambient light; a TargetIn status, in which a target begins to come into the field of the sensor; an In8 Seconds status, during which the target comes in towards the sensor, and the pulse width measured is stable for 8 seconds (if the target leaves after 8 seconds, there is no flush); an After 8 Seconds status, in which the target has come into the sensor's field, and the pulse width is stable for more than 8 seconds, meaning the target has remained in front of the sensor for that time (and after which, if the target leaves, there is a cautionary flush); a TargetOut status, in which the target is going away, out of the field of the sensor; an In2Seconds status, in which the background is stable after the target leaves. After this last status, the microcontroller flushes, and goes back to the Idle status.

[0150] When the target moves closer to the sensor, the target can block the light, particularly when wearing dark, light-absorbent clothes. Thus, the sensor will detect less light during the TargetIn status, so that resistance will go up (causing what will later be termed a TargetInUp status), while the microcontroller will detect more light during the TargetOut status, so that resistance will go down (later termed a TargetOutUp status). However, if the target wears light, reflective clothes, the microcontroller will detect more light as the target gets closer to it, in the TargetIn status (causing what will later be described as a TargetInDown status), and less during the TargetOut status (later termed a TargetOutDown status). Two seconds after the target leaves the toilet, the microcontroller will cause the toilet to flush, and the microcontroller will return to the Idle status.

[0151] To test whether there is a target present, the microcontroller checks the Stability of the pulse width, or how variable the p values have been in a specific period, and whether the pulse width is more variable than a constant, selected background level, or a provided threshold value of the pulse width variance (Unstable). The system uses two other constant, pre-selected values in algorithm **600**, when checking the Stability of the p values to set the states in Mode **2**. One of these two pre-selected values is Stable**1**, which is a constant threshold value of the pulse width variance. A value below means that there is no activity in front of unit, due to the p values not changing in that period being measured. The second pre-selected value used to determine Stability of the p values is Stable**2**, another constant threshold value of the pulse width variance. In this case a value below means that a user has been motionless in front of the microcontroller in the period being measured.

[0152] The microcontroller also calculates a Target value, or average pulse width in the After 8Sec status, and then checks whether the Target value is above (in the case of TargetInUp) or below (in the case of TargetInDown) a particular level above the background light intensity: BACKGROUND×(1+PERCENTAGEIN) for TargetInUp, and BACKGROUND×(1−PERCENTAGEIN) for TargetInDown. To check for TargetOutUp and TargetOutDown, the microcontroller uses a second set of values: BACKGROUND×(1+PERCENTAGEOUT) and BACKGROUND×(1−PERCENTAGEOUT).

[0153] Referring to FIG. **12**, every 1 second (**601**), the microcontroller will wake up and measure the pulse width, p (**602**). The microcontroller will then determine which mode it was previously in: If it was previously in Mode **1** (**604**), it will enter Mode **1** (**614**) now. It will similarly enter Mode **2** (**616**) if it had been in Mode **2** in the previous cycle (**606**), or Mode **3** (**618**) if it had been in Mode **3** in the previous cycle (**608**). The microcontroller will enter Mode **2** as default mode (**610**), if it cannot determine which mode it entered in the previous cycle. Once the Mode subroutine is finished, the microcontroller will go into sleep mode (**612**) until the next cycle **600** starts with step **601**.

[0154] Referring to FIG. **12**A (MODE **1**—bright mode), if the microcontroller was previously in Mode **1** based on the p value being less than or equal to 2 kΩ, and the value of p now remains as greater than or equal to 2 kΩ (**620**) for a time period measured by timer **1** as greater than 8 seconds, but less than 60 seconds (**628**), the microcontroller will cause a flush (**640**), all Mode **1** timers (timers **1** and **2**) will be reset (**630**), and the microcontroller will go to sleep (**612**) until the next cycle **600** starts at step **601**. However, if p changes while timer **1** counts for more than 8 seconds, or less than 60 (**628**), there will be no flush (**640**). Simply, all Mode **1** timers will be reset (**630**), the microcontroller will go to sleep (**612**), and Mode **1** will continue to be set as the microcontroller mode until the next cycle **600** starts.

[0155] If the microcontroller was previously in Mode **1**, but the value of p is now greater than 2 kΩ but less than 2 MΩ (**622**), for greater than 60 seconds (**634**) based on the timer **1** count (**632**), all Mode **1** timers will be reset (**644**), the microcontroller will set Mode **2** (**646**) as the system mode, so that the microcontroller will start in Mode **2** in the next cycle **600**, and the microcontroller will go to sleep (**612**). However, if p changes while timer **1** counts for 60 seconds (**134** to **148**), Mode **1** will remain the microcontroller mode and the microcontroller will go to sleep (**612**) until the next cycle **600** starts.

[0156] If the microcontroller was previously in Mode **1**, and p is now greater than or equal to 2 MΩ (**624**) while timer **2** counts (**636**) for greater than 8 seconds (**638**), all Mode **1** timers will be reset (**650**), the microcontroller will set Mode **3** (**652**) as the new system mode, and the microcontroller will go to sleep (**612**) until the next cycle **600** starts. However, if p changes while timer **2** counts for 8 seconds, the microcontroller will go to sleep (steps **638** to **612**), and Mode **1** will continue to be set as the microcontroller mode until the start of the next cycle **600**.

[0157] Referring to FIG. **12**B (MODE **3**—dark mode), if the microcontroller was previously in Mode **3** based on the value of p having been greater than or equal to 2 MΩ, but the value of p is now less than or equal to 2 kΩ (**810**) for a period measured by timer **3** (**812**) as greater than 8 seconds (**814**), the microcontroller will reset timers **3** and **4**, or all Mode **3** timers (**816**), the microcontroller will set Mode **1** as the state (**818**) until the start of the next cycle **600**, and the microcontroller will go to sleep (**612**). However, if the value of p changes while timer **3** counts for 8 seconds, the microcontroller will go from step **814** to **612**, so that the microcontroller will go to sleep, and Mode **3** will continue to be set as the microcontroller mode until the next cycle **600** starts.

[0158] If the microcontroller was previously in Mode **3** based on the value of p having been greater than or equal to 2 MΩ, and the value of p is still greater than or equal to 2 MΩ (**820**), the microcontroller will reset timers **3** and **4** (**822**), the microcontroller will go to sleep (**612**), and Mode **3** will continue to be set as the microcontroller mode until the start of the next cycle **600**.

[0159] If the microcontroller was previously in Mode **3**, but p is now between 2 kΩ and 2 MΩ (**824**), for a period measured by timer **4** (**826**) as longer than 2 seconds (**828**), timers **3** and **4** will be reset (**830**), Mode **2** will be set as the mode (**832**) until the next cycle **600** starts, and the microcontroller will go to sleep (**612**). However, if p changes while timer **4** counts for longer than 2 seconds, Mode **3** will remain the microcontroller mode, and the microcontroller will go from step **828** to step **612**, going to sleep until the next cycle **600** starts. If an abnormal value of p occurs, the microcontroller will go to sleep (**612**) until a new cycle starts.

[0160] Referring to FIG. **12**C (MODE **2**—normal mode), if the microcontroller mode was previously set as Mode **2**, and now p is less than or equal to 2 kΩ (**656**), for a period measured by timer **5** (**662**) as more than 8 seconds (**664**), all Mode **2** timers will be reset (**674**), Mode **1** (Bright Mode) will be set as the microcontroller mode (**676**), and the microcontroller will go to sleep (**612**). However, if p changes while timer **5** counts for longer than 8 seconds, the microcontroller will go to sleep (steps **664** to **612**), and Mode **2** will remain the microcontroller mode until the next cycle **600** starts.

[0161] However, if now p is greater than or equal to 2 MΩ (**658**) for a period measured by timer **6** (**668**) as longer than 8 seconds (**670**), the toilet is not in Idle status (i.e., there are background changes, 680), and p remains greater than or equal to 2 MΩ while timer **6** counts for over 5 minutes (**688**), the system will flush (**690**). After flushing, timers **5** and **6** will be reset (**692**), Mode **3** will be set as the microcontroller mode (**694**), and the microcontroller will go to sleep (**612**). Otherwise, if p changes while timer **6** counts for longer than 5 minutes, the system will go from step **688** to **612**, and go to sleep.

[0162] If the microcontroller mode was previously set as Mode **2**, now p is greater than or equal to 2 MΩ (**658**) for a period measured by timer **6** (**668**) as more than 8 seconds (**670**), but the toilet is in Idle status (**680**), timers **5** and **6** will be reset (**682**), Mode **3** will be set as microcontroller mode (**684**), and the microcontroller will go to sleep at step **612**.

[0163] If p is greater or equal to 2 MΩ, but changes while timer **6** counts (**668**) to greater than 8 seconds (**670**), the microcontroller will go to sleep (**612**), and Mode **2** will remain as the microcontroller mode. If p is within a different value, the microcontroller will go to step **660** (shown in FIG. **12**D).

[0164] Referring to FIG. **12**D, alternatively, if the microcontroller mode was previously set as Mode **2**, and p is greater than 2 kΩ and less than 2 MΩ (**661**), timers **5** and **6** will be reset (**666**), pulse width Stability will be checked by assessing the variance of the last four pulse width values (**667**), and the Target value is found by determining the pulse width average value (step **669**).

[0165] At this point, when the status of the microcontroller is found to be Idle (**672**), the microcontroller goes on to step **675**. In step **675**, if the Stability is found to be greater than the constant Unstable value, meaning that there is a user present in front of the unit, and the Target value is larger than the Background×(1+PercentageIn) value, meaning that the light detected by the microcontroller has decreased, this leads to step **680** and a TargetInUp status (i.e., since a user came in, towards the unit, resistance increased because light was blocked or absorbed), and the microcontroller will go to sleep (**612**), with Mode **2** TargetInUp as the microcontroller mode and status.

[0166] When the conditions set in step **675** are not true, the microcontroller will check if those in **677** are. In step **677**, if the Stability is found to be greater than the constant Unstable value, due to a user in front of the unit, but the Target value is less than the Background×(1−PercentageIn) value, due to the light detected increasing, this leads to a "TargetInDown" status in step **681**, (i.e., since a user came in, resistance decreased because light off of his clothes is reflected), and the microcontroller will go to sleep (**612**), with Mode **2** TargetInDown as the microcontroller mode and status. However, if the microcontroller status is not Idle (**672**), the microcontroller will go to step **673** (shown in FIG. **12**E).

[0167] Referring to FIG. **12**E, if the system starts in the TargetInUp status (**683**), at step **689** the system will check whether the Stability value is less than the constant Stable**2**, and whether the Target value is greater than Background×(1+PercentageIn) (**689**). If both of these conditions are simultaneously met, which would mean that a user is motionless in front of the unit, blocking light, the microcontroller will now advance to In8SecUp status (**697**), and go to sleep (**612**). If the two conditions in step **689** are not met, the system will check whether Stability is less than Stable**1** and Target is less than Background×(1+PercentageIn) at the same time (**691**), meaning that there is no user in front of the unit, and there is a large amount of light being detected by the unit. If this is the case, the system status will now be set as Mode **2** Idle (**699**), and the microcontroller will go to sleep (**612**). If neither of the sets of conditions in steps **689** and **691** is met, the system will go to sleep (**612**).

[0168] If the TargetInDown status (**686**) had been set in the previous cycle, the system will check whether Stability is less than Stable**2** and Target is less than Background×(1−PercentageIn) at the same time in step **693**. If this is so, which would mean that there is a user motionless in front of the unit, with more light being detected, the microcontroller will advance status to In8SecDown (**701**), and will then go to sleep (**612**).

[0169] If the two requirements in step **693** are not met, the microcontroller will check if Stability is less than Stable**1** while at the same time Target is greater than Background×(1−PercentageIn) in step **698**. If both are true, the status will be set as Mode **2** Idle (**703**), due to these conditions signaling that there is no activity in front of the unit, and that there is a large amount of light being detected by the unit, and it will go to sleep (**612**). If Stability and Target do not meet either set of requirements from steps **693** or **698**, the microcontroller will go to sleep (**612**), and Mode **2** will continue to be the microcontroller status. If status is not Idle, TargetInUp or TargetInDown, the microcontroller will continue as in step **695** (shown in FIG. **12**F)

[0170] Referring to FIG. **12**F, if In8SecUp had been set as the status (**700**), the unit will check whether Stability is less than Stable**2**, and at the same time Target is greater than Background×(1+PercentageIn) in step **702**. If these conditions are met, meaning that there is a motionless user before the unit, and that there is still less light being detected, the timer for the In8Sec status will start counting (**708**). If the two conditions continue to be the same while the timer counts for longer than 8 seconds, timer **7** is reset (**712**), the microcontroller advances to After 8SecUp status (**714**), and finally goes to sleep (**612**). If the two conditions change while the timer counts to above 8 seconds (**710**), the microcontroller will go to sleep (**612**). If in step **702** the requirements are not met by the values of Stability and Target, the In8Sec timer is reset (**704**), in step **706** the microcontroller status is set as TargetInUp, and the microcontroller will proceed to step **673** (FIG. **12**E).

[0171] Referring to FIG. **12**F, if the microcontroller status was set as In8SecDown (**716**), the microcontroller checks whether Stability is less than Stable**2**, and at the same time Target is less than Background×(1-PercentageIn) in step **718**, to check whether the user is motionless before the unit, and whether it continues to detect a large amount of light. If the two values meet the simultaneous requirement, the In8Sec status timer will start counting (**724**). If it counts for longer than 8 seconds while the two conditions are met (**726**), timer **7** will be reset (**728**), the status will be advanced to After 8SecDown (**730**), and the microcontroller will go to sleep (**612**).

[0172] If the timer does not count for longer than 8 seconds while Stability and Target remain at those ranges, the microcontroller will not advance the status, and will go to sleep (**612**). If the requirements of step **718** are not met by the Stability and Target values, the In8SecTimer will be reset (**720**), and the microcontroller status will be set to TargetInDown (**722**), where the microcontroller will continue to step **673** (FIG. **12**E). If the Mode **2** state is none of those covered in FIGS. **12**C-F, the system continues through step **732** (shown in FIG. **12**G)

[0173] Referring to FIG. **12**G, in step **734**, if the system was in the After 8SecUp status (**734**), it will check whether Stability is less than Stable**1**, that is, whether there is no activity before the unit. If so, timer **7** will start counting (**742**), and if Stability remains less than Stable**1** until timer **7** counts for longer than 15 minutes (**744**), the microcontroller will flush (**746**), the Idle status will be set (**748**), and the microcontroller will go to sleep (**612**). If Stability does not remain less than the Stable**1** value until timer **7** counts for longer than 15 minutes, the microcontroller will go to sleep (**612**) until the next cycle.

[0174] If Stability was not less than Stable**1**, the microcontroller checks whether it is greater than Unstable, and whether Target is greater than Background×(1+PercentageOut) (**738**). If both simultaneously meet these criteria, meaning that there is a user moving in front of the unit, but there is more light being detected because they are moving away, the microcontroller advances to Mode **2** TargetOutUp as the microcontroller status (**740**), and the microcontroller goes to sleep (**612**). If Stability and Target do not meet the two criteria in step **738**, the microcontroller goes to sleep (**612**).

[0175] If the microcontroller was in After 8SecDown (**750**), it will check whether the Stability is less than Stable**1** at step **752**. If so, timer **7** will begin to count (**754**), and if it counts for greater than 15 minutes (**756**), the microcontroller will flush (**758**), Idle status will be set (**760**), and the microcontroller will go to sleep (**612**). If Stability does not remain less than Stable**1** until timer **7** counts to greater than 15 minutes, the microcontroller will go to sleep (**612**) until the next cycle.

[0176] If the Stability is not found to be less than Stable**1** at step **752**, the microcontroller will check whether Stability is greater than Unstable, while at the same time Target is less than Background×(1−PercentageOut) at step **762**. If so, this means that there is a user in front of the unit, and that it detects less light because they are moving away, so that it will advance the status to TargetOutDown at step **764**, and will go to sleep (**612**). Otherwise, if both conditions in step **762** are not met, the microcontroller will go to sleep (**612**). If the Mode **2** state is none of those covered in FIGS. **12**C-G, system continues through step **770** (shown in FIG. **12**H).

[0177] Referring to FIG. **12**H, if TargetOutUp had been set as the status (**772**), the microcontroller will check whether Stability is less than Stable**1** while Target is less than Background×(1+PercentageOut), in step **774**. If so, it will set the status as In2Sec (**776**), and the microcontroller will go to sleep (**612**). However, if Stability and Target do not simultaneously meet the criteria in step **774**, the microcontroller will check if Stability is greater than Unstable and at the same time Target is greater than Background×(1+PercentageOut) in step **778**. If so, it will set the status as After 8SecUp (**780**), and it will go to **732** where it will continue (See FIG. **12**). If Stability and Target do not meet the criteria of either step **774** or **778**, the microcontroller will go to sleep (**612**).

[0178] If the microcontroller is in TargetOutDown status (**782**), it will check whether Stability is less than Stable**1**, and Target greater than Background×(1−PercentageOut) simultaneously (**783**). If so, it would mean that there is no activity in front of the unit, and that there is less light reaching the unit, so that it will advance status to In2Sec (**784**), and go to sleep (**612**). However, if Stability and Target do not meet both criteria of step **783**, the microcontroller will check whether Stability is greater than Unstable, and Target is less than Background×(1−PercentageOut) simultaneously in step **785**. If so, the microcontroller will set status as After 8SecDown (**788**), and go to step **732** where it will continue (See FIG. **12**G). If Stability and Target meet neither set of criteria from steps **783** or **785**, the microcontroller will go to sleep (**612**).

[0179] Referring to FIG. **12**I, if the microcontroller set In2Sec status in the previous cycle (**791**), it will check whether Stability is less than Stable**1** (**792**), which is the critical condition: since the user has left, there are no fluctuations in the light detected via resistance. It will also check whether the Target value is either greater than Background×(1−PercentageIn), or less than Background×(1+PercentageIn), in step **792**. If this is the case, there is no activity in front of the unit, and the light detected is neither of the two levels required to signify a user blocking or reflecting light, which would indicate that there is no user in front of the unit. The system would then start the In2Sec status timer in step **794**, and if it counts for longer than 2 seconds (**796**) with these conditions still at hand, the microcontroller will flush (**798**), all Mode **2** timers will be reset in step **799**, the status will be set back to Idle in step **800**, and the microcontroller will go to sleep (**612**). If the Stability and Target values change while the In2Sec timer counts to greater than 2 seconds (**796**), the microcontroller will go to sleep (**612**) until the start of the next 600 cycle.

[0180] If Stability and Target values do not meet the two criteria set in step **792**, the In2Sec timer is reset (**802**), the status is changed back to either TargetOutUp or TargetOut-

Down in step **804**, and the microcontroller goes to step **770** (FIG. **12**H). If the microcontroller is not in In2Sec status either, the microcontroller will go to sleep (**612**), and start algorithm **600** again.

[0181] FIGS. **13**, **13**A, and **13**B illustrate a control algorithm for faucets **10**, **10**A and **10**B. Algorithm **900** includes two modes. Mode **1** is used when the passive sensor is located outside the water stream (faucet **10**B), and Mode **2** is used when the passive sensor's field of view is inside the water stream (faucets **10** and **10**A). In Mode **1** (algorithm **920**) the sensor located outside the water stream detects the blocking of the light by a nearby user's hands, and checks for how long the low light remains steady, interpreting it as the user at the sink, but also excluding a darkening of the room the unit is placed in as a similar signal. This sensor then will directly turn off the water once the user has left the faucet, or once it no longer detects unstable, low levels of light.

[0182] In Mode **2** (algorithm **1000**), the photoresistor inside the water stream also uses the above variables, but takes an additional factor into consideration: running water can also reflect light, so that the sensor may not be able to completely verify the user having left the faucet. In this case, the algorithm also uses a timer to turn the water off, while then actively checking whether the user is still there. Modes **1** or **2** may be selectable, for example, by a dipswitch.

[0183] Referring to FIG. **13**, algorithm **900** commences after the power goes on (**901**), and the unit initializes the module in step **902**. The microcontroller then checks the battery status (**904**), resets all timers and counters (**906**), and closes the valve (shown in FIGS. **1**, **2**, **4** and **4**A) in step **908**. All electronics are calibrated (**910**), and the microcontroller establishes a background light threshold level, (BLTH), in step **912**. The microcontroller will then determine which mode to use in step **914**: In Mode **1**, the microcontroller executes algorithm **920** (to step **922**, FIG. **13**A) and in Mode **2**, the microcontroller executes algorithm **1000** (to step **1002**, FIG. **13**B).

[0184] Referring to FIG. **13**A, if the microcontroller uses Mode **1**, the passive sensor scans for a target every ⅛ of a second (**924**). The scan and sleep time may be different for different light sensors (photodiode, photoresistor, etc. and their read out circuits). For example, the scan frequency can be every ¼ second or every ¾ second. Also, just as in the algorithm shown in FIG. **12**, the microcontroller will go through the algorithm and then go to sleep in between the executed cycles. After scanning, the microcontroller measures the sensor level (SL), or value corresponding to the resistance of the photoresistor, at step **925**. It will then compare the sensor level to the background light threshold level (BLTH): if the SL is greater than or equal to 25% of the BLTH (**926**), the microcontroller will further determine whether it is greater than or equal to 85% of the BLTH (**927**). These comparisons determine the level of ambient light: if the SL is higher than or equal to 85% of the BLTH calculated in step **912**, it would mean that it is now suddenly very dark in the room (**947**), so that the microcontroller will go into Idle Mode, and scan every 5 seconds (**948**) until it detects the SL being less than 80% of the BLTH, meaning there is now more ambient light (**949**). Once this is detected, the microcontroller will establish a new BLTH for the room (**950**), and cycle back to step **924**, at which it will continue to scan for a target every ⅛ of a second with the new BLTH.

[0185] If SL is smaller than 25% of the previously established BLTH, this would mean that the light in the room has suddenly dramatically increased (direct sunlight, for example). The scan counter starts counting to see if this change is stable (**928**) as the microcontroller cycles through steps **924**, **925**, **926**, **928** and **929**, until it reaches five cycles (**929**). Once it does reach the five cycles under the same conditions, it will establish a new BLTH in step **930** for the now brightly lit room, and begin a cycle anew at step **922** using this new BLTH.

[0186] If, however, the SL is between 25% greater than or equal to, but no greater than 85% of the BLTH (at steps **926** and **927**), light is not at an extreme range, but regular ambient light, and the microcontroller will set the scan counter to zero at step **932**, measure SL once more to check for a user (**934**), and assess whether the SL is between greater than 20% BLTH or less than 25% BLTH (20% BLTH<SL<25% BLTH) at step **936**. If not, this would mean that there is a user in front of the unit sensor, as the light is lower than regular ambient light, causing the microcontroller to move on to step **944**, where it will turn the water on for the user. Once the water is on, the microcontroller will set the scan counter to zero (**946**), scan for the target every ⅛ of a second (**948**), and continue to check for a high SL, that is, for low light, in step **950** by checking whether the SL is less than 20% of the BLTH. When SL decreases to less than 20% of BLTH (**950**), meaning that the light detected increased, the microcontroller will move on to step **952**, turning on a scan counter. The scan counter will cause the microcontroller to continue scanning every ⅛ of a second and checking that SL is still less than 20% of BLTH until over 5 cycles through **948**, **950**, **952** and **954** have passed (**954**), which would mean that there now has been an increase in light which has lasted for more than 5 of these cycles, and that the user is no longer present. At this point the microcontroller will turn the water off (**956**). Once the water is turned off, the whole cycle is repeated from the beginning.

[0187] Referring to FIG. **13**B (algorithm **1000** for faucet **10**), the microcontroller scans for a target every ⅛ of a second (**1004**), although, again, the time it takes between any of the scans could be changed to another period, for example, every ¼ of a second. Once more, the microcontroller will go through the algorithm and then go to sleep in between cycles just as in the algorithm shown in FIG. **12**. After scanning, the microcontroller will measure the sensor level (**1006**), and compare the SL against the BLTH. Once again, if the SL is greater than or equal to 25% of the BLTH, the microcontroller will check whether it is greater than or equal to 85% of the BLTH. If it is, it will take it to mean that the room must have been suddenly darkened (**1040**). The microcontroller will then go into Idle Mode at step **1042**, and scan every 5 seconds until it detects the SL being less than 80% of the BLTH, meaning it now detects more light (**1044**). Once it does, the microcontroller will establish a new BLTH for the newly lit room (**1046**), and it will cycle back to step **1004**, starting the cycle anew with the new BLTH for the room.

[0188] If the SL is between greater than or equal to 25% or less than 85% of the BLTH, the microcontroller will continue through step **1015**, and setting the scan counter to zero. It will measure the SL at step **1016**, and assess if it is greater than 20% BLTH, but smaller than 25% BLTH (20% BLTH<SL<25% BLTH), at step **1017**. If it is not, meaning there is something blocking light to the sensor, the microcontroller will turn water on (**1024**); this also turns on a Water Off timer, or WOFF (**1026**). Then, the microcontroller will continue to scan for a target every ⅛ of a second (**1028**). The new SL is checked against the BLTH, and if the value of SL is not between less than 25% BLTH, but greater than 20% BLTH (20% BLTH<SL<25% BLTH), the microcontroller will loop back to step **1028** and continue to scan for the target while the water runs. If the SL is within this range (**1030**), the WOFF timer now starts to count (**1032**), looping back to the cycle at step **1028**. The timer's function is simply to allow some time to pass between when the user is no longer detected and when the water is turned off, since, for example, the user could be moving the hands, or getting soap, and not be in the field of the sensor for some time. The time given (2 seconds) could be set differently depending upon the use of the unit. Once 2 seconds have gone by, the microcontroller will turn the water off at step **1036**, and it will cycle back to **1002**, where it will repeat the entire cycle.

[0189] However, if at step **1017** SL is greater than 20% BLTH, but smaller than 25% BLTH (20% BLTH<SL<25% BLTH), the scan counter will begin to count the number of times the microcontroller cycles through steps **1016**, **1017**, **1018** and **1020**, until more than five cycles are reached. Then, it will go to step **1022**, where a new BLTH will be established for the light in the room, and the microcontroller will cycle back to step **1002**, where a new cycle through algorithm **1000** will occur, using the new BLTH value.

[0190] As described above, in general, the active optical sensor emits light at different light intensities and detects the corresponding echo from a target. (This intensity scanning is described in FIGS. **14**A and **14**B.) The passive optical sensor uses only a light detector that measures the increase or decrease or stability (over short times on the order of less than 2 sec.) of primarily ambient light. This sensor's algorithm executes several states described above. The state TargetIn is entered when the target is moving in; the state In8Sec is entered just after the somewhat stationary target reached the sensor, after which point the After 8Sec state is entered. Upon the departure of the target, the algorithm enter the TargetOut state, followed by the In2Sec state initiating a flush. From each of these states, the algorithm can enter the idle state (or a ResetWait state) if an error cause the prior state. The following active sensor detection algorithm uses similar states.

[0191] FIGS. **14**, **14**A, **14**B and **14**C illustrate an active sensor detection algorithm (ASDA) for detecting an object such as pants (i.e. "pants" detection algorithm). Algorithm **1100** is designed for use with an active optical sensor having a light source (e.g., a light emitting diode **132**A and light detector, e.g., IR diode **132**B (FIG. **7**A). The microcontroller directs the source driver to provide an adjustable IR emitter current intensity for light emitting diode **132**A while maintaining a fixed amplifier gain for IR receiver **132**B.

[0192] In general, algorithm **1100** detects user movement by using up to 32 different IR beam intensities (emitted from LED **132**A) scanned and reflected IR signals detected in succession. For example, the IR current needs to be higher when sensing a target far away from the flusher. On the other hand, algorithm **1100** can identify a user moving in or out (that is, closer and away from the active optical sensor) by using a comparison of detected IR current changes. The IR emitter scans the emitted light intensity from max IR beam to min IR beam (the LED current is changed form high to low). When gradually detecting the target (or user) at lower light intensities, the target is moving toward the flusher. The optical sensor may use various noise-reduction techniques. For example, the emitter may emit modulated light (use modulated source current) and the detector may be "locked" onto the modulation. For example, the light emitter may use a selected number of pulses and the detector will "look" for reflected light corresponding to these pulses. If the selected number of pulses is not detected, the detector received some outside noise and not a signal corresponding to the emitted light. Alternatively, the light emitter may use a sinusoidal excitation current and the light detector may be coupled to a lock-in amplifier for eliminating the noise.

[0193] As shown in FIG. **14**C, the control logic uses different target states as follows: IDLE (**1201**), ENTER_STAND (**1202**), STAND_SIT (**1204**), SIT_STAND (**1210**), STAND_FLUSH_WAIT (**1206**), FLUSH_HALF (**1208**), SIT_FLUSH_FULL (**1211**), STAND_OUT (**1212**), SIT_FLUSH_FULL (**1214**), RESET_WAIT (**1216**), and EXIT_RESET (**1220**). All the states are based upon a target or user behavior in the IR sensing field. When a target or user enters the optical field (emitted from LED and detected IR echo), the state will be set to ENTER_STAND state. The state will be set into STAND_SIT state while a target stops moving after an ENTER_STAND state set, that is, the target is substantially stationary for longer than "STAND_TIME".

[0194] For example, when a user moves toward the sensing field, the state will change from IDLE to ENTER_STAND. If a user spends enough time in front of the flusher, the state will be changed to STAND_SIT. If the user gets even closer to the flusher, the state will become SIT_STAND. Each state can proceed to a subsequent "Use" state or can enter the EXIT_RESET state if the prior state was entered in error. Thus, the algorithm provides a "self correction". Then, the unit will turn back to idle state again.

[0195] Referring to FIG. **14**, the active sensor detection algorithm (ASDA) **1100** uses a target sensing sub-routine **1110** that cycles through up to 32 different levels of light emission intensity emitted from IR light emitting diode **132**A (FIG. **7**A). For each intensity, IR detector **132**B detects the corresponding reflected signal. When using a noise-reduction technique, IR light emitting diode **132**A emits, for example, 4 pulses of equal intensity having a duration of about 20 μsec and being spaced apart 100 μsec. IR detector **132**B detects the reflected light that should also consist of 4 pulses. Any other signal corresponds to noise.

[0196] As shown in FIG. **14**A, the maximum and minimum light source powers are selected and stored in temporary buffers (step **1112** through **1118**). Light source **132**A emits the corresponding optical signal at the power level stored in a temporary buffer **1**, and light detector **132**B detects the corresponding reflected signal. As shown in step **1122** if no echo is detected, the power level is cycled one step higher up to maximum power. Alternatively, the power level may be cycled from maximum value down to a minimum value. The power increase is performed according to steps **1132** and **1134** and the entire process is repeated starting with step **1114**. In step **1122**, if the corresponding echo signal is detected, the current power level is assigned the final value (step **1124**). The next power level is averaged as shown in block **1126**, and the pointer numbering is increased (step **1128**). Next, the entire cycle is repeated starting with step **1114**. This way, the light source increases the power values up to a specific power value where the corresponding echo is detected.

[0197] Referring still to FIG. **14**, in steps **1150** through and **1152**, the processor checks the battery status and then proceeds to accumulating sample data as shown in step **1154**. The accumulated optical data is processed using the algorithm shown in FIG. **14**B. In steps **1162** through **1166**, the processor finds the average of the most recent four IR detection levels. Next, the processors finds the longest level period in the buffer (Step **1168**), and finds the average of the IR level in the buffer (step **1170**)). Before each data is processed, the processor checks if a manual flush was actuated by a user (step **1180**). If a manual flush was actuated, the processor exits the present target state as shown in block **1182**; that is, the processor enters EXIT_RESET (**1220**) and initiates a flush. The flush will be a full flush unless the prior state was STAND_FLUSH_WAIT (**1206**), in which case the processor initiates a half flush. Alternatively, if no manual flush was actuated, the processor continues determining the individual target states, as shown in FIG. **14**C.

[0198] Referring to FIG. **14**C, the processor is in IDLE (**1201**) until a user is detected. The IR emitter scans the IR intensities, and when at an intensity the IR echo is detected, the sensor moves to a lower intensity. If a user is detected for five IR values that are less than IR max, and the target appears in three samples saved in the roll (explained in connection with FIG. **14**A), the processor moves to ENTER_STAND (**1202**). Subsequently, if the target is not detected in three subsequent samples in the roll, the processor will go to EXIT_RESET (**1220**). Alternatively, if the stationary period is larger than 2.5 seconds (i.e., stand time), the processor enters STAND_SIT (**1204**). Next, if the IR detected power level is smaller than the preceding IR power level for five or six subsequent detection steps (i.e., the detected IR value is less than the recent 8 second average IR level) and this occurs repeatedly in two samples in the roll, the processor will enter SIT_STAND (**1210**). In this state, the user is likely sitting on the toilet, or is very close. The IR detection occurs at a very low intensity level. Otherwise, if the stationary period is less than the stationary time, the processor will move to EXIT_RESET (**1220**).

[0199] In STAND_SIT (**1204**), if the stationary period is larger than stationary time and the target moves out, the processor will enter STAND_FLUSH_WAIT (**1206**). From this state, the processor may move to FLUSH_HALF (**1208**), in which a flush is initiated. Alternatively, the target may move in and the processor will enter STAND_SIT (**1204**). This happens, for example, when a user moves inside a bathroom stall. When the IR detection level is reduced (as described above), the processor enters SIT_STAND (**1210**). In this state, the user is very close to the flusher. When the target moves out (detected at a higher IR level) and the stationary period is larger than stationary time (selected, for example, 6 seconds), the processor can execute either a half flush or a full flush algorithm. If the stationary period is larger than a selected stationary time, and sit time is smaller than selected use time, the processor enters FLUSH_HALF (**1208**).

[0200] In FLUSH_HALF, a half flush is initiated, usually after a user providing a liquid waste. This state saves flush water and proceeds to EXIT_RESET (**1220**). If the target stood up and the stationary period is larger than stationary time, the processor enters STAND_OUT (**1212**). From this state, if the sit time is less than use time (Tu), the processor enters FLUSH_HALF (**1208**). Otherwise, the processor enters SIT_FLUSH_FULL (**1214**), and the algorithm initiates a full flush usually after the user deposited a solid waste.

[0201] In SIT_STAND (**1210**), if the target moves out and the stationary period is larger than the selected stationary time, and the sit time is larger than use time (Tu), the processor enters SIT_FLUSH_FULL (**1214**). In this state, the processor initiates a full flush and moves to RESET_WAIT (**1216**). The flush is initiated usually after a short delay time to enable the user's movement away from the toilet. STAND_OUT (**1212**) is designed for a user who used the toilet, stood up and was waiting for a flush before leaving the bathroom stall. In this state, the active sensor still registers the user, but at a distance.

[0202] The system may determine whether the absolute value of the difference between the current gain and the gain listed in the top stack entry exceeds a threshold gain change. If it does not, the current call of this routine results in no new entry's being pushed onto the stack, but the contents of the existing top entry's timer field are incremented. The result is instead that the gain's changed absolute value was indeed greater than the threshold, then the routine pushes a new entry onto the stack, placing the current gain in that entry's gain field and giving the timer field the value of zero. In short, a new entry is added whenever the target's distance changes by a predetermined step size, and it keeps track of how long the user has stayed in roughly the same place without making a movement as great as that step size.

[0203] The routine also gives the entry's in/out field an "out" value, indicating that the target is moving away from the flusher if the current gain exceeds the previous entry's gain, and it gives that field an "in" value if the current gain is less than the previous entry's gain. In either case, the routine then performs the step of incrementing the timer (to a value of "1") and moves from the stack-maintenance part of the routine to the part in which the valve-opening criteria are actually applied.

[0204] Applying the first criterion, (i.e., namely, whether the top entry's in/out field indicates that the target is moving away), if the target does not meet this criterion, the routine performs the step of setting the flush flag to the value that will cause subsequent routines not to open the flush valve, and the routine returns. If that criterion is met, on the other hand, the routine performs the step of determining whether the top entry and any immediately preceding entries indicate that the target is moving away are preceded by a sequence of a predetermined minimum number of entries that indicated that the target was moving in. If they were not, then it is unlikely that a user had actually approached the facility, used it, and then moved away, so the routine again returns after resetting the flush flag. Note that the applied criterion is independent of absolute reflection percentage; it is based only on reflection-percentage changes, requiring that the reflection percentage traverse a minimum range as it increases.

[0205] If the system determines that the requisite number of inward-indicating entries did precede the outward-indicating entries, then the routine imposes the criterion of determining whether the last inward-movement-indicating entry has a timer value representing at least, e.g., 5 seconds. This criterion is imposed to prevent a flush from being triggered when the facility was not actually used. Again, the routine returns after resetting the flush flag if this criterion is not met.

[0206] If it is met, on the other hand, then the routine imposes the criteria of which are intended to determine whether a user has moved away adequately. If the target appears to have moved away by more then a threshold amount, or has moved away slightly less but has appeared to remain at that distance for greater then a predetermined duration, then, the routine sets the flush flag before returning. Otherwise, it resets the flush flag.

[0207] The above described flusher uses a novel algorithm for delivering variable amounts of water for flushing. The flush algorithm is executed by the microcontroller, which controls the operation of the solenoid actuator as described above. The algorithm causes delivery of a selected amount of water depending on the use. For example, the algorithm can direct delivery of a "full" amount of water for a "full flush," 50% of the full amount of water i.e., "half flush", or any other selected amount of water for varying pressure levels in the input water pipe. The delivered amount of water depends on the water pressure, detected by the actuator, the size of the valve opening, and the open time of the flusher valve. The following algorithm explains specifically various important concepts and the logic of the flush system. Each block in algorithm **1300** may represent one or several steps or subroutines, or several blocks may be combined into a single step or subroutine. A person of ordinary skill in the art can use various ways to write a source code for executing algorithm **1300**, and similarly algorithm **1300** can be illustrated differently while still embodying the presently described concept and logic of the flush actuation.

[0208] Algorithm **1300** is used in various toilet and urinal flushers and includes different modes of operation for different uses and different amounts of flush water used. Depending on the use, the various modes may be selected initially at the time of installation using appropriate dip switches mounted on the flusher. Alternatively, the various modes may be selected via a user interface at the time of installation, or subsequently by an operator. Upon providing power, the entire system powers up (Step **1302**) and the electronic module is initialized (step **1304**). The microcontroller receives battery check status data (step **1306**), and the unit resets all timers used in the algorithm described below (step **1308**). The solenoid valve is initially closed (step **1310**), and the unit enters the idle mode (step **1312**). Depending on the mode setting, the algorithm enters mode A, B, C, D, or E, as described below.

[0209] FIG. **15** illustrates flush algorithm **1300** for delivering selected water amounts depending on the use. Algorithm **1300** includes several modes that can be selected manually (using a dip switch upon installation) or automatically (step **1314**). Algorithm **1300** can be executed for optical data detected either by the active optical sensor or the passive optical sensor.

[0210] FIGS. **15**A-I and **15**A-II illustrate a standard urinal mode (**1320**). The algorithm starts the idle timer at step **1322**. In step **1324**, if the sentinel flag is set (step **1318**), the algorithm starts the sentinel timer (step **1342**). After starting the sentinel timer at step **1342**, if the timer counts for longer than 24 hours before the urinal is flushed or used (step **1344**), it is reset at step **1346**, and the microcontroller activates a flush after one second (Step **1365**). In Step **1344**, if the timer counts for less than 24 hours before the facility is flushed, the flusher will simply scan for a target (step **1330**). The scan for target routine (step **1330**) is also executed when the sentinel flag is not set at step **1324**, a dry trap timer is started (step **1326**), and it counts for longer than 12 hours (step **1328**).

[0211] In general, for all modes, the scan for target routine is executed differently for the passive optical sensor and for the active optical sensor. The passive optical sensor detects an approaching target as described in FIGS. **12-12**I. The active optical sensor detects an approaching target as described in FIGS. **14-14**C.

[0212] At Step **1332**, if a target is found, the algorithm starts a target timer (Step **1334**). If the target timer counts for less than 8 seconds, the algorithm returns to step **1330**, and continues scanning for a target. If the target's timer counts for longer than 8 seconds, the algorithm performs another scan for a target in Step **1338**. In Step **1340**, if the target is lost, the algorithm checks for the value of the time counted by the idle timer minus the target timer (Step **1356**). If the difference between the times counted by the two timers is less than 15 seconds, the algorithm activates the valve on every third target detected, providing a water amount equivalent to a half flush (Step **1348**). After providing a half flush (Step **1348**), the algorithm resets the idle timer (Step **1370**), resets the target timer (**1372**), and starts the idle timer once more to begin the cycle anew at Step **1322**.

[0213] If the difference between the times counted by the idle timer and the target timer is greater than 15 but less than 30 seconds (Step **1358**), the flusher executes a half-flush after one second at Step **1360**. It will then restart the algorithm, resetting the idle and target timers (steps **1370** and **1372**), and starting the idle timer (step **1322**).

[0214] If the difference in times counted by the idle timer and the target timer is also greater than 30 seconds (step **1358**), then the algorithm executes a full flush after one second (Step **1365**). After flushing the toilet or urinal, the idle timer and target timers are reset (Steps **1370** and **1372**), and the system restarts the idle timer in Step **1322**. At this time, the entire Mode A is repeated.

[0215] If a target is not found at step **1332**, the algorithm executes a detect blackout routine (Step **1350**), where light in the bathroom is measured. If there is light in the bathroom, i.e., there is no "blackout," the algorithm continues scanning for a target at Step **1330**. If there is a blackout (Step **1352**), the algorithm enters the blackout mode (Step **1354**), in which the flusher enters a "sleep mode" to save battery power. This subroutine detects no use, for example, at night or on weekends.

[0216] FIG. **15**B illustrates a "Ball Park Urinal Mode" (**1400**). If the sentinel flag is set at step **1402**, the algorithm starts the sentinel timer (Step **1404**). If this timer counts for less than 24 hours before the toilet is flushed, a target timer is started (step **1406**) and the system scans for a target at step **1408**. If a target is found, the target timer is started (step **1412**). When the target timer does not count for longer than 8 seconds at step **1414**, if the target is lost (step **1416**), the flush valve will be activated at step **1435**, and the target timer will be reset (step **1440**), so the algorithm can begin anew. If the target is not lost at step **1416**, a new target scan will take place at step **1418**.

[0217] Once the sentinel timer counts for longer than 24 hours before the urinal is flushed, the timer is reset (step **1448**), the flush valve is activated (step **1435**), and the target timer is reset (step **1440**), so the whole cycle begins anew.

[0218] If a sentinel flag is not set at step **1402**, a dry-trap timer is started at step **1424**. If at step **1426** this timer has counted for less than 12 hours before the urinal is flushed, the algorithm will next resume at step **1406**, where the target timer will begin to count. However, if the dry-trap timer has counted for longer than 12 hours without the urinal being flushed, the timer is reset (step **1428**), the flush valve is activated (step **1435**), and the target timer is reset (step **1440**), so the algorithm can begin once more. If a target is not found at step **1410**, the algorithm executes a detect blackout routine (Step **1442**). If there is no blackout, the algorithm continues to step **1408**, to scan for a target. If a blackout is detected, the algorithm enters the blackout mode (Step **1446**).

[0219] FIGS. **15**C-I and **15**C-II illustrate a "men's closet mode" (**1450**). If the sentinel flag is set at step **1452**, a sentinel timer is started (step **1454**), and if it has counted for less than 24 hours (step **1456**) before the toilet is flushed, the target timer is started (step **1464**). The flusher scans for the target at step **1465**, and if it lost the target (step **1466**), the target-out timer is started (step **1468**). Otherwise, the algorithm resumes at step **1470**. If the target timer counts for less than three seconds (step **1469**), the microcontroller starts intermittent target detection at step **1484**. The three second objective has been added to ascertain that any target found is not simply a passerby. If a target is found (step **1483**), the target-out timer is reset at step **1482**, and the algorithm goes back to step **1466** to check whether the target is lost once more.

[0220] If the target timer counted for over three seconds (step **1469**), the microcontroller checks whether the target timer has counted for longer than 8 seconds (step **1470**) while the target was lost. If so, it will check whether the period of time counted by the target timer was less than 90 seconds: that is, how long the user was in the facility. If use was for longer than 90 seconds, it will cause a full flush to occur (step **1490**). If the timer counted for less than 90 seconds, it will activate the flush valve and cause a half flush (step **1474**). Once either flush has occurred, the target timer will be reset at step **1475**, and the algorithm will begin once more.

[0221] However, if after intermittent target detection the target is still not found at step **1483**, the microcontroller checks whether the target-out timer has counted for greater than 5 seconds. It will check for a target (cycle from step **1486** through **1483**) until the target-out timer counts for longer than 5 seconds, at which point the algorithm begins anew.

[0222] If the sentinel timer counts for longer than 24 hours before flushing occurs (**1456**), it is reset at step **1458**, and a full flush is initiated at step **1490**. The target timer is reset at step **1475**, and the cycle begins once more.

[0223] If the sentinel flag is not set at step **1452**, the dry-trap timer will start (step **1459**), and if it counts for a short period of time before detecting use, it will begin to scan for a target at step **1462**. However, once the timer counts for over one month (step **1460**), it will be reset at step **1488**, the flush valve will be activated, causing a full flush (step **1490**), and the target timer will be reset at step **1475**. At that point the algorithm will start once more.

[0224] If no target is found at step **1463**, the microcontroller will check for a blackout (steps **1476** and **1478**). If none is detected at step **1478** it will go back to scanning for a target (step **1462**). However, if one is detected, the algorithm will go to blackout mode (step **1480**).

[0225] FIGS. **15**D-I and **15**D-II) illustrate a "women's closet mode" (**1500**). If the sentinel flag is set (step **1502**), the sentinel timer starts (step **1504**). If the sentinel timer counts for less than 24 hours before the toilet is flushed (**1506**), target scanning will begin at step **1512**. If a target is found (step **1514**), the target timer will start (step **1516**), and another target scan will occur (step **1518**). If the target is lost (step **1520**), the target-out timer will be started at step **1525**. If in the meantime the target timer has counted for less than three seconds at step **1530**, the algorithm will determine that it is sensing intermittent target detection (step **1564**), and it will check for a found target once more at step **1562**. If a target is not found at step **1562**, and the target-out timer has counted for less than 5 seconds (step **1555**), the unit will scan for a target once more (step **1560**), and move to step **1562**. Once a target is found at step **1562**, the algorithm will go on to step **1570**, reset the target-out timer, and go back to step **1518**, where it will continue to scan for a target. If the target is not lost at step **1520**, the algorithm will go directly to step **1532**.

[0226] If the target timer has counted for longer than three seconds at step **1530**, it will move on to step **1532**, where it will determine if it has counted for greater than 8 seconds. If it has yet to count for more than 8 seconds, the algorithm will go back to step **1518**. However, once the target timer has counted for longer than 8 seconds, the microcontroller will go to step **1534**, to determine if any time has passed since it activated the target-out timer at step **1525**. If the target-out timer has counted at all, the preparation timer will start (step **1536**). The algorithm will cause the preparation timer to count for over 30 seconds (steps **1538** and **1540**), at which point the microcontroller will determine whether the target timer has counted for less than 120 seconds. If so, the flush valve will be activated, and a half flush will occur (step **1546**), after which the target timer and preparation timers will be reset (steps **1548** and **1550**), and the algorithm will begin once more.

[0227] However, if the target timer has counted for longer than 120 seconds while the preparation timer was counting, the flush valve will be activated, and a full flush will occur at step **1544**, after which the target and preparation timers will be reset in steps **1548** and **1550**, and the algorithm will begin anew.

[0228] If the sentinel flag is not set at step **1502**, the dry-trap timer will start (step **1503**). If the dry-trap timer counts for a short period of time (step **1510**), if will begin to scan for a target at step **1512**. However, once the timer counts for over one month (step **1510**), it will be reset at step **1507** or **1508**, the flush valve will be activated, causing a full flush (step **1544**), and the target and preparation timers will be reset at steps **1548** and **1550**, so that the algorithm can start once more.

[0229] If no target is found at step **1514**, the microcontroller will check for a blackout (steps **1572** and **1574**). If none is detected at step **1574** it will go back to scanning for a target (step **1512**). However, if a blackout is detected, the algorithm will go to blackout mode (step **1576**).

[0230] Importantly, algorithm **1300** may use the above-described states for the passive optical sensor (FIGS. **12**-**12**I) and the above-described states for the active optical sensor (FIGS. **14**-**14**C). The use of these states significantly reduces errors arising due to variation in target optical properties and ambient light.

[0231] Having described various embodiments and implementations of the present invention, it should be apparent to those skilled in the relevant art that the foregoing is illustrative only and not limiting, having been presented by way of example only. There are other embodiments or elements suitable for the above-described embodiments, described in the above-listed publications, all of which are incorporated by reference as if fully reproduced herein. The functions of any one element may be carried out in various ways in alternative embodiments. Also, the functions of several elements may, in alternative embodiments, be carried out by fewer, or a single, element.

1-56. (canceled)

57. A sensor-based automatic flusher system, comprising:

a flusher body including a water conduit having at least one inlet for receiving water and at least one outlet for providing water to a toilet or a urinal;

an optical sensor;

a control circuit arranged to control operation of said optical sensor,

said control circuit including a controller executing an algorithm identifying behavior of a user over a predefined time period within a sensing field of said optical sensor and based on said behavior issuing a flush command for a predefined amount of water; and

a main valve controlled by an actuator receiving signals corresponding to said flush command for switching between an open state of said valve and a closed state of said valve; said open state permitting water flow of said amount of water, and a closed state of said valve preventing fluid flow from said outlet.

58. (canceled)

59. An automatic toilet room flush valve, comprising:

a valve body including an inlet and an outlet and a valve seat inside said body; and

a valve member cooperatively arranged with said valve seat, said valve member being constructed and arranged to control water flow between said inlet and said outlet, movement of said valve member between open and closed positions being controlled by water pressure inside a pilot chamber; and

an external cover designed for enclosing an electronic control module comprising a battery, and a sensor and enclosing an actuator for controlling operation of said flush valve, said external cover including at least two cover parts separately removable, said external cover being attachable with respect to said valve body in a manner also removably attaching said control module.

60. The flush valve of claim **59** wherein said parts of said external cover enable separate servicing and replacement of said cover parts.

61. The flush valve of claim **59** wherein said external cover enable replacement of batteries without closing water.

62. The flush valve of claim **59** wherein said external cover includes said cover parts forming a main cover body, a front cover and a top cover, said front cover including a sensor window.

63. The flush valve of claim **59** wherein said main cover body provides overall rigidity to said external cover.

64. The flush valve of claim **59** wherein said top cover is removable while maintaining said front cover including a sensor window located in place with respect to said main cover body.

65. The flush valve of claim **62** wherein said sensor is an optical sensor and said sensor window in an optical window.

66. The flush valve of claim **63** further constructed to adjust detection sensitivity of said sensor while maintaining said optical window located on said main cover body.

67. The sensor-based automatic flusher system of claim **57** wherein said controller is programmed to execute an algorithm including several predefined target states based on a possible behavior of said user over a predefined time period within said sensing field of said optical sensor.

68. The sensor-based automatic flusher system of claim **67** wherein said controller algorithm identifying said user initially moving in and thus entering a first of said predefined target states and progressing through a succession of said target states and later moving away from said optical sensor.

69. The sensor-based automatic flusher system of claim **68** wherein said target states include sitting and standing action of said user.

70. The sensor-based automatic flusher system of claim **67** wherein said controller issues said flush command including a half-flush of said water amount.

71. The sensor-based automatic flusher system of claim **67** wherein said controller issues said flush command including a full-flush of said water amount.

72. The sensor-based automatic flusher system of claim **67** wherein said controller issues said flush command after a predefined time period regardless of any action by said user.

73. The sensor-based automatic flusher system of claim **72** wherein said predefined time period is 24 hours.

74. The sensor-based automatic flusher system of claim **67** wherein said controller includes a microcontroller.

75. The sensor-based automatic flusher system of claim **74** wherein said microcontroller operates at three frequencies.

76. A method for controlling a sensor-based automatic flusher, comprising:

providing a flusher body including a water conduit having at least one inlet for receiving water and at least one outlet for providing water to a toilet or a urinal and being controlled by a main valve controlled by an actuator;

providing an optical sensor and a control circuit including a controller;

initiating said optical sensor to sense a user;

executing an algorithm for identifying behavior of a user over a predefined time period within a sensing field of said optical sensor;

issuing a flush command for a predefined amount of water based on said behavior of said user; and

switching between an open state of said main valve and a closed state of said main valve; said open state permitting water flow of said amount of water, and a closed state of said valve preventing fluid flow from said outlet.

77. The method for controlling a sensor-based automatic flusher according to claims **76** including identifying predefined target states based on a possible behavior of said user over a predefined time period within said sensing field of said optical sensor.

78. The method for controlling a sensor-based automatic flusher according to claim **77** including identifying said user initially moving in and thus entering a first of said predefined target states and progressing through a succession of said target states and later moving away from said optical sensor.

79. The method for controlling a sensor-based automatic flusher according to claim **78** wherein said target states include sitting and standing action of said user.

80. The method for controlling a sensor-based automatic flusher according to claim **76** wherein said issuing said flush command includes a half-flush of said water amount.

81. The method for controlling a sensor-based automatic flusher according to claim **76** wherein said issuing said flush command includes a full-flush of said water amount.

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