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**Lamego et al.**

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(54) **PATIENT MONITORING SYSTEM**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,717,100 A 9/1955 Engelder
2,974,503 A 3/1961 Newton

(Continued)

FOREIGN PATENT DOCUMENTS

GB 948 351 A 1/1964
WO WO 2013/170095 11/2013
WO WO 2015/020911 2/2015

OTHER PUBLICATIONS

Ultraflate: http://www.genuineinnovations.com/us/products/inflators/ultraflate.php.*

(Continued)

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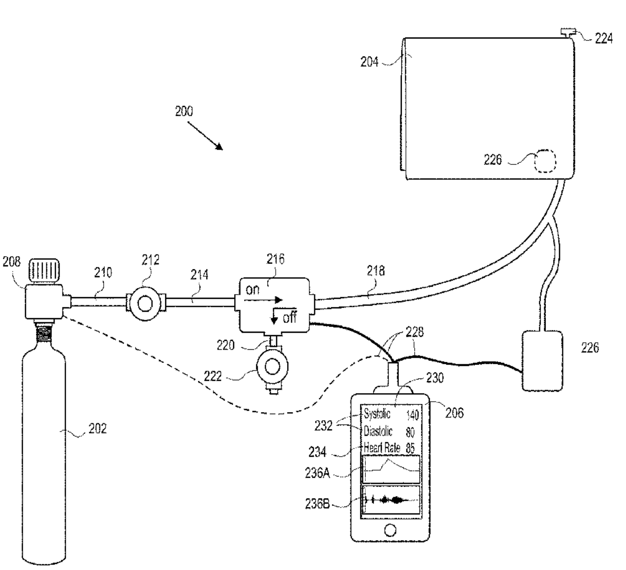
(57) **ABSTRACT**

A patient monitoring system includes an inflatable cuff, a gas reservoir containing a compressed gas, and a sensor. When the inflatable cuff is coupled to a wearer, the gas reservoir supplies gas to the inflatable cuff to inflate the inflatable cuff via gas pathways. As the inflatable cuff inflates, a patient monitor can receive blood pressure data from the sensor and use the blood pressure data to determine the blood pressure of the wearer. The patient monitor can also receive blood pressure data during deflation of the inflatable cuff to determine the blood pressure of the wearer.

**16 Claims, 35 Drawing Sheets**



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(56) **References Cited**

U.S. PATENT DOCUMENTS


3,316,395 A 4/1967 Lavin
3,316,396 A 4/1967 Lavin
4,163,290 A 7/1979 Sutherlin et al.
4,305,059 A 12/1981 Benton
4,491,725 A 1/1985 Pritchard
4,800,982 A 1/1989 Perry et al.
4,960,128 A 10/1990 Gordon et al.
4,964,408 A 10/1990 Hink et al.
4,973,024 A * 11/1990 Homma ................ F16K 31/002 137/594
5,041,187 A 8/1991 Hink et al.
5,069,213 A 12/1991 Polczynski
5,163,438 A 11/1992 Gordon et al.
5,319,355 A 6/1994 Russek
5,337,744 A 8/1994 Branigan
5,341,805 A 8/1994 Stavridi et al.
D353,195 S 12/1994 Savage et al.
D353,196 S 12/1994 Savage et al.
5,377,676 A 1/1995 Vari et al.
D359,546 S 6/1995 Savage et al.
5,431,170 A 7/1995 Mathews
D361,840 S 8/1995 Savage et al.
D362,063 S 9/1995 Savage et al.
5,452,717 A 9/1995 Branigan et al.
D363,120 S 10/1995 Savage et al.
5,456,252 A 10/1995 Vari et al.
5,479,934 A 1/1996 Imran
5,482,036 A 1/1996 Diab et al.
5,490,505 A 2/1996 Diab et al.
5,494,043 A 2/1996 O'Sullivan et al.
5,533,511 A 7/1996 Kaspari et al.
5,534,851 A 7/1996 Russek
5,561,275 A 10/1996 Savage et al.
5,562,002 A 10/1996 Lalin
5,590,649 A 1/1997 Caro et al.
5,590,696 A 1/1997 Phillips et al.
5,602,924 A 2/1997 Durand et al.
5,632,272 A 5/1997 Diab et al.
5,638,816 A 6/1997 Kiani-Azarbayjany et al.
5,638,818 A 6/1997 Diab et al.
5,645,440 A 7/1997 Tobler et al.
5,685,299 A 11/1997 Diab et al.
D393,830 S 4/1998 Tobler et al.
5,743,262 A 4/1998 Lepper, Jr. et al.
5,758,644 A 6/1998 Diab et al.
5,760,910 A 6/1998 Lepper, Jr. et al.
5,769,785 A 6/1998 Diab et al.
5,782,757 A 7/1998 Diab et al.
5,785,659 A 7/1998 Caro et al.
5,791,347 A 8/1998 Flaherty et al.
5,810,734 A 9/1998 Caro et al.
5,823,950 A 10/1998 Diab et al.
5,830,131 A 11/1998 Caro et al.
5,833,618 A 11/1998 Caro et al.
5,860,919 A 1/1999 Kiani-Azarbayjany et al.
5,890,929 A 4/1999 Mills et al.
5,904,654 A 5/1999 Wohltmann et al.
5,919,134 A 7/1999 Diab
5,934,925 A 8/1999 Tobler et al.
5,940,182 A 8/1999 Lepper, Jr. et al.
5,995,855 A 11/1999 Kiani et al.
5,997,343 A 12/1999 Mills et al.
6,002,952 A 12/1999 Diab et al.
6,011,986 A 1/2000 Diab et al.
6,027,452 A 2/2000 Flaherty et al.
6,036,642 A 3/2000 Diab et al.
6,045,509 A 4/2000 Caro et al.
6,067,462 A 5/2000 Diab et al.
6,081,735 A 6/2000 Diab et al.
6,088,607 A 7/2000 Diab et al.
6,110,522 A 8/2000 Lepper, Jr. et al.
6,124,597 A 9/2000 Shehada
6,128,521 A 10/2000 Marro et al.
6,129,675 A 10/2000 Jay
6,144,868 A 11/2000 Parker
6,151,516 A 11/2000 Kiani-Azarbayjany et al.
6,152,754 A 11/2000 Gerhardt et al.
6,157,850 A 12/2000 Diab et al.
6,165,005 A 12/2000 Mills et al.
6,184,521 B1 2/2001 Coffin, IV et al.
6,206,830 B1 3/2001 Diab et al.
6,229,856 B1 5/2001 Diab et al.
6,232,609 B1 5/2001 Snyder et al.
6,236,872 B1 5/2001 Diab et al.
6,241,683 B1 6/2001 Macklem et al.
6,253,097 B1 6/2001 Aronow et al.
6,256,523 B1 7/2001 Diab et al.
6,263,222 B1 7/2001 Diab et al.
6,278,522 B1 8/2001 Lepper, Jr. et al.
6,280,213 B1 8/2001 Tobler et al.
6,285,896 B1 9/2001 Tobler et al.
6,301,493 B1 10/2001 Marro et al.
6,317,627 B1 11/2001 Ennen et al.
6,321,100 B1 11/2001 Parker
6,325,761 B1 12/2001 Jay
6,328,280 B1 12/2001 Davidson
6,334,065 B1 12/2001 Al-Ali et al.
6,336,901 B1 1/2002 Itonaga et al.
6,343,224 B1 1/2002 Parker
6,349,228 B1 2/2002 Kiani et al.
6,360,114 B1 3/2002 Diab et al.
6,368,283 B1 4/2002 Xu et al.
6,371,921 B1 4/2002 Caro et al.
6,377,829 B1 4/2002 Al-Ali
6,388,240 B2 5/2002 Schulz et al.
6,397,091 B2 5/2002 Diab et al.
6,405,943 B1 * 6/2002 Stadnyk .................... A47L 1/06 222/5
6,430,437 B1 8/2002 Marro
6,430,525 B1 8/2002 Weber et al.
6,463,311 B1 10/2002 Diab
6,470,199 B1 10/2002 Kopotic et al.
6,501,975 B2 12/2002 Diab et al.
6,505,059 B1 1/2003 Kollias et al.
6,515,273 B2 2/2003 Al-Ali
6,519,487 B1 2/2003 Parker
6,525,386 B1 2/2003 Mills et al.
6,526,300 B1 2/2003 Kiani et al.
6,541,756 B2 4/2003 Schulz et al.
6,542,764 B1 4/2003 Al-Ali et al.
6,543,444 B1 4/2003 Lewis
6,565,524 B1 5/2003 Itonaga et al.
6,580,086 B1 6/2003 Schulz et al.
6,584,336 B1 6/2003 Ali et al.
6,595,316 B2 7/2003 Cybulski et al.
6,597,932 B2 7/2003 Tian et al.
6,597,933 B2 7/2003 Kiani et al.
6,606,511 B1 8/2003 Ali et al.
6,632,181 B2 10/2003 Flaherty et al.
6,639,668 B1 10/2003 Trepagnier
6,640,116 B2 10/2003 Diab
6,643,530 B2 11/2003 Diab et al.
6,650,917 B2 11/2003 Diab et al.
6,654,624 B2 11/2003 Diab et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,658,276 B2 12/2003 Kiani et al.
6,661,161 B1 12/2003 Lanzo et al.
6,671,531 B2 12/2003 Al-Ali et al.
6,678,543 B2 1/2004 Diab et al.
6,684,090 B2 1/2004 Ali et al.
6,684,091 B2 1/2004 Parker
6,697,656 B1 2/2004 Al-Ali
6,697,657 B1 2/2004 Shehada et al.
6,697,658 B2 2/2004 Al-Ali
RE38,476 E 3/2004 Diab et al.
6,699,194 B1 3/2004 Diab et al.
6,714,804 B2 3/2004 Al-Ali et al.
RE38,492 E 4/2004 Diab et al.
6,721,582 B2 4/2004 Trepagnier et al.
6,721,585 B1 4/2004 Parker
6,725,075 B2 4/2004 Al-Ali
6,728,560 B2 4/2004 Kollias et al.
6,735,459 B2 5/2004 Parker
6,745,060 B2 6/2004 Diab et al.
6,760,607 B2 7/2004 Al-Ali
6,770,028 B1 8/2004 Ali et al.
6,771,994 B2 8/2004 Kiani et al.
6,792,300 B1 9/2004 Diab et al.
6,813,511 B2 11/2004 Diab et al.
6,816,741 B2 11/2004 Diab
6,822,564 B2 11/2004 Al-Ali
6,826,419 B2 11/2004 Diab et al.
6,830,711 B2 12/2004 Mills et al.
6,843,465 B1 * 1/2005 Scott .................... F16K 31/025 251/129.06
6,850,787 B2 2/2005 Weber et al.
6,850,788 B2 2/2005 Al-Ali
6,852,083 B2 2/2005 Caro et al.
6,861,639 B2 3/2005 Al-Ali
6,898,452 B2 5/2005 Al-Ali et al.
6,920,345 B2 7/2005 Al-Ali et al.
6,931,268 B1 8/2005 Kiani-Azarbayjany et al.
6,934,570 B2 8/2005 Kiani et al.
6,939,305 B2 9/2005 Flaherty et al.
6,943,348 B1 9/2005 Coffin, IV
6,950,687 B2 9/2005 Al-Ali
6,961,598 B2 11/2005 Diab
6,970,792 B1 11/2005 Diab
6,979,812 B2 12/2005 Al-Ali
6,985,764 B2 1/2006 Mason et al.
6,988,992 B2 1/2006 Just et al.
6,993,371 B2 1/2006 Kiani et al.
6,996,427 B2 2/2006 Ali et al.
6,997,878 B2 2/2006 Inagaki et al.
6,999,904 B2 2/2006 Weber et al.
7,003,338 B2 2/2006 Weber et al.
7,003,339 B2 2/2006 Diab et al.
7,015,451 B2 3/2006 Dalke et al.
7,024,233 B2 4/2006 Ali et al.
7,027,849 B2 4/2006 Al-Ali
7,030,749 B2 4/2006 Al-Ali
7,039,449 B2 5/2006 Al-Ali
7,041,060 B2 5/2006 Flaherty et al.
7,044,918 B2 5/2006 Diab
7,067,893 B2 6/2006 Mills et al.
7,096,052 B2 8/2006 Mason et al.
7,096,054 B2 8/2006 Abdul-Hafiz et al.
7,132,641 B2 11/2006 Schulz et al.
7,142,901 B2 11/2006 Kiani et al.
7,149,561 B2 12/2006 Diab
7,153,269 B1 12/2006 Blansett
7,166,076 B2 1/2007 Poliac et al.
7,186,218 B2 3/2007 Hersh et al.
7,186,966 B2 3/2007 Al-Ali
7,190,261 B2 3/2007 Al-Ali
7,215,984 B2 5/2007 Diab
7,215,986 B2 5/2007 Diab
7,221,971 B2 5/2007 Diab
7,225,006 B2 5/2007 Al-Ali et al.
7,225,007 B2 5/2007 Al-Ali
RE39,672 E 6/2007 Shehada et al.
7,239,905 B2 7/2007 Kiani-Azarbayjany et al.
7,245,953 B1 7/2007 Parker
7,254,429 B2 8/2007 Schurman et al.
7,254,431 B2 8/2007 Al-Ali
7,254,433 B2 8/2007 Diab et al.
7,254,434 B2 8/2007 Schulz et al.
7,272,425 B2 9/2007 Al-Ali
7,274,955 B2 9/2007 Kiani et al.
D554,263 S 10/2007 Al-Ali
7,280,858 B2 10/2007 Al-Ali et al.
7,289,835 B2 10/2007 Mansfield et al.
7,292,883 B2 11/2007 De Felice et al.
7,295,866 B2 11/2007 Al-Ali
7,311,670 B2 12/2007 Just et al.
7,328,053 B1 2/2008 Diab et al.
7,332,784 B2 2/2008 Mills et al.
7,340,287 B2 3/2008 Mason et al.
7,341,559 B2 3/2008 Schulz et al.
7,343,186 B2 3/2008 Lamego et al.
D566,282 S 4/2008 Al-Ali et al.
7,355,512 B1 4/2008 Al-Ali
7,356,365 B2 4/2008 Schurman
7,371,981 B2 5/2008 Abdul-Hafiz
7,373,193 B2 5/2008 Al-Ali et al.
7,373,194 B2 5/2008 Weber et al.
7,376,453 B1 5/2008 Diab et al.
7,377,794 B2 5/2008 Al Ali et al.
7,377,899 B2 5/2008 Weber et al.
7,383,070 B2 6/2008 Diab et al.
7,415,297 B2 8/2008 Al-Ali et al.
7,428,432 B2 9/2008 Ali et al.
7,438,683 B2 10/2008 Al-Ali et al.
7,440,787 B2 10/2008 Diab
7,454,240 B2 11/2008 Diab et al.
7,467,002 B2 12/2008 Weber et al.
7,469,157 B2 12/2008 Diab et al.
7,471,969 B2 12/2008 Diab et al.
7,471,971 B2 12/2008 Diab et al.
7,483,729 B2 1/2009 Al-Ali et al.
7,483,730 B2 1/2009 Diab et al.
7,489,958 B2 2/2009 Diab et al.
7,496,391 B2 2/2009 Diab et al.
7,496,393 B2 2/2009 Diab et al.
D587,657 S 3/2009 Al-Ali et al.
7,499,741 B2 3/2009 Diab et al.
7,499,835 B2 3/2009 Weber et al.
7,500,950 B2 3/2009 Al-Ali et al.
7,509,154 B2 3/2009 Diab et al.
7,509,494 B2 3/2009 Al-Ali
7,510,849 B2 3/2009 Schurman et al.
7,526,328 B2 4/2009 Diab et al.
7,530,942 B1 5/2009 Diab
7,530,949 B2 5/2009 Al Ali et al.
7,530,955 B2 5/2009 Diab et al.
7,563,110 B2 7/2009 Al-Ali et al.
7,596,398 B2 9/2009 Al-Ali et al.
7,618,375 B2 11/2009 Flaherty
D606,659 S 12/2009 Kiani et al.
7,647,083 B2 1/2010 Al-Ali et al.
D609,193 S 2/2010 Al-Ali et al.
7,678,057 B2 3/2010 Berkow et al.
D614,305 S 4/2010 Al-Ali et al.
RE41,317 E 5/2010 Parker
7,729,733 B2 6/2010 Al-Ali et al.
7,734,320 B2 6/2010 Al-Ali
7,761,127 B2 7/2010 Al-Ali et al.
7,761,128 B2 7/2010 Al-Ali et al.
7,764,982 B2 7/2010 Dalke et al.
D621,516 S 8/2010 Kiani et al.
7,791,155 B2 9/2010 Diab
7,801,581 B2 9/2010 Diab
7,822,452 B2 10/2010 Schurman et al.
RE41,912 E 11/2010 Parker
7,844,313 B2 11/2010 Kiani et al.
7,844,314 B2 11/2010 Al-Ali
7,844,315 B2 11/2010 Al-Ali
7,865,222 B2 1/2011 Weber et al.
7,873,497 B2 1/2011 Weber et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 7,880,606 | B2 | 2/2011 | Al-Ali |
| 7,880,626 | B2 | 2/2011 | Al-Ali et al. |
| 7,891,355 | B2 | 2/2011 | Al-Ali et al. |
| 7,894,868 | B2 | 2/2011 | Al-Ali et al. |
| 7,899,507 | B2 | 3/2011 | Al-Ali et al. |
| 7,899,518 | B2 | 3/2011 | Trepagnier et al. |
| 7,904,132 | B2 | 3/2011 | Weber et al. |
| 7,909,772 | B2 | 3/2011 | Popov et al. |
| 7,910,875 | B2 | 3/2011 | Al-Ali |
| 7,919,713 | B2 | 4/2011 | Al-Ali et al. |
| 7,937,128 | B2 | 5/2011 | Al-Ali |
| 7,937,129 | B2 | 5/2011 | Mason et al. |
| 7,937,130 | B2 | 5/2011 | Diab et al. |
| 7,941,199 | B2 | 5/2011 | Kiani |
| 7,951,086 | B2 | 5/2011 | Flaherty et al. |
| 7,957,780 | B2 | 6/2011 | Lamego et al. |
| 7,962,188 | B2 | 6/2011 | Kiani et al. |
| 7,962,190 | B1 | 6/2011 | Diab et al. |
| 7,976,472 | B2 | 7/2011 | Kiani |
| 7,988,637 | B2 | 8/2011 | Diab |
| 7,990,382 | B2 | 8/2011 | Kiani |
| 7,991,446 | B2 | 8/2011 | Ali et al. |
| 8,000,761 | B2 | 8/2011 | Al-Ali |
| 8,008,088 | B2 | 8/2011 | Bellott et al. |
| RE42,753 | E | 9/2011 | Kiani-Azarbayjany et al. |
| 8,019,400 | B2 | 9/2011 | Diab et al. |
| 8,028,701 | B2 | 10/2011 | Al-Ali et al. |
| 8,029,765 | B2 | 10/2011 | Bellott et al. |
| 8,036,728 | B2 | 10/2011 | Diab et al. |
| 8,046,040 | B2 | 10/2011 | Ali et al. |
| 8,046,041 | B2 | 10/2011 | Diab et al. |
| 8,046,042 | B2 | 10/2011 | Diab et al. |
| 8,048,040 | B2 | 11/2011 | Kiani |
| 8,050,728 | B2 | 11/2011 | Al-Ali et al. |
| RE43,169 | E | 2/2012 | Parker |
| 8,118,620 | B2 | 2/2012 | Al-Ali et al. |
| 8,126,528 | B2 | 2/2012 | Diab et al. |
| 8,128,572 | B2 | 3/2012 | Diab et al. |
| 8,130,105 | B2 | 3/2012 | Al-Ali et al. |
| 8,145,287 | B2 | 3/2012 | Diab et al. |
| 8,150,487 | B2 | 4/2012 | Diab et al. |
| 8,175,672 | B2 | 5/2012 | Parker |
| 8,180,420 | B2 | 5/2012 | Diab et al. |
| 8,182,443 | B1 | 5/2012 | Kiani |
| 8,185,180 | B2 | 5/2012 | Diab et al. |
| 8,190,223 | B2 | 5/2012 | Al-Ali et al. |
| 8,190,227 | B2 | 5/2012 | Diab et al. |
| 8,203,438 | B2 | 6/2012 | Kiani et al. |
| 8,203,704 | B2 | 6/2012 | Merritt et al. |
| 8,224,411 | B2 | 7/2012 | Al-Ali et al. |
| 8,228,181 | B2 | 7/2012 | Al-Ali |
| 8,229,533 | B2 | 7/2012 | Diab et al. |
| 8,233,955 | B2 | 7/2012 | Al-Ali et al. |
| 8,244,325 | B2 | 8/2012 | Al-Ali et al. |
| 8,255,026 | B1 | 8/2012 | Al-Ali |
| 8,255,027 | B2 | 8/2012 | Al-Ali et al. |
| 8,255,028 | B2 | 8/2012 | Al-Ali et al. |
| 8,260,577 | B2 | 9/2012 | Weber et al. |
| 8,265,723 | B1 | 9/2012 | McHale et al. |
| 8,274,360 | B2 | 9/2012 | Sampath et al. |
| 8,301,217 | B2 | 10/2012 | Al-Ali et al. |
| 8,310,336 | B2 | 11/2012 | Muhsin et al. |
| 8,315,683 | B2 | 11/2012 | Al-Ali et al. |
| RE43,860 | E | 12/2012 | Parker |
| 8,337,403 | B2 | 12/2012 | Al-Ali et al. |
| 8,346,330 | B2 | 1/2013 | Lamego |
| 8,353,842 | B2 | 1/2013 | Al-Ali et al. |
| 8,355,766 | B2 | 1/2013 | Macneish, III et al. |
| 8,359,080 | B2 | 1/2013 | Diab et al. |
| 8,364,223 | B2 | 1/2013 | Al-Ali et al. |
| 8,364,226 | B2 | 1/2013 | Diab et al. |
| 8,374,665 | B2 | 2/2013 | Lamego |
| 8,385,995 | B2 | 2/2013 | Al-Ali et al. |
| 8,385,996 | B2 | 2/2013 | Smith et al. |
| 8,388,353 | B2 | 3/2013 | Kiani et al. |
| 8,399,822 | B2 | 3/2013 | Al-Ali |
| 8,401,602 | B2 | 3/2013 | Kiani |
| 8,405,608 | B2 | 3/2013 | Al-Ali et al. |
| 8,414,499 | B2 | 4/2013 | Al-Ali et al. |
| 8,418,524 | B2 | 4/2013 | Al-Ali |
| 8,423,106 | B2 | 4/2013 | Lamego et al. |
| 8,428,967 | B2 | 4/2013 | Olsen et al. |
| 8,430,817 | B1 | 4/2013 | Al-Ali et al. |
| 8,437,825 | B2 | 5/2013 | Dalvi et al. |
| 8,455,290 | B2 | 6/2013 | Siskavich |
| 8,457,703 | B2 | 6/2013 | Al-Ali |
| 8,457,707 | B2 | 6/2013 | Kiani |
| 8,463,349 | B2 | 6/2013 | Diab et al. |
| 8,466,286 | B2 | 6/2013 | Bellot et al. |
| 8,471,713 | B2 | 6/2013 | Poeze et al. |
| 8,473,020 | B2 | 6/2013 | Kiani et al. |
| 8,483,787 | B2 | 7/2013 | Al-Ali et al. |
| 8,489,364 | B2 | 7/2013 | Weber et al. |
| 8,498,684 | B2 | 7/2013 | Weber et al. |
| 8,509,867 | B2 | 8/2013 | Workman et al. |
| 8,515,509 | B2 | 8/2013 | Bruinsma et al. |
| 8,523,781 | B2 | 9/2013 | Al-Ali |
| 8,529,301 | B2 | 9/2013 | Al-Ali et al. |
| 8,532,727 | B2 | 9/2013 | Ali et al. |
| 8,532,728 | B2 | 9/2013 | Diab et al. |
| 8,547,209 | B2 | 10/2013 | Kiani et al. |
| 8,548,548 | B2 | 10/2013 | Al-Ali |
| 8,548,550 | B2 | 10/2013 | Al-Ali et al. |
| 9,649,054 | B2 | 5/2017 | Lamego et al. |
| 2003/0125609 | A1 | 7/2003 | Becker |
| 2003/0205578 | A1 | 11/2003 | Newport |
| 2005/0056747 | A1 | 3/2005 | Belcourt et al. |
| 2005/0288597 | A1 | 12/2005 | Kishimoto et al. |
| 2006/0211923 | A1 | 9/2006 | Al-Ali |
| 2007/0073173 | A1 | 3/2007 | Lam et al. |
| 2007/0276263 | A1 | 11/2007 | Eide |
| 2007/0287923 | A1* | 12/2007 | Adkins .................. A61B 5/412 600/485 |
| 2008/0045846 | A1* | 2/2008 | Friedman ........... A61B 5/02141 600/490 |
| 2008/0236586 | A1* | 10/2008 | McDonald ........... A62B 18/084 128/205.24 |
| 2008/0294455 | A1 | 11/2008 | Bharara |
| 2009/0194718 | A1* | 8/2009 | Kulesha ................ F16K 31/002 251/74 |
| 2009/0234381 | A1 | 9/2009 | Karo |
| 2010/0211096 | A1* | 8/2010 | McEwen ............ A61B 17/1355 606/203 |
| 2011/0009757 | A1 | 1/2011 | Sano et al. |
| 2011/0092827 | A1 | 4/2011 | Hu et al. |
| 2011/0109459 | A1 | 5/2011 | Poeze |
| 2011/0112412 | A1 | 5/2011 | Sano et al. |
| 2011/0166459 | A1* | 7/2011 | Kopetsch ............... A61B 5/021 600/485 |
| 2012/0041276 | A1 | 2/2012 | Doreus et al. |
| 2012/0059267 | A1* | 3/2012 | Lamego ................. A61B 5/021 600/483 |
| 2012/0232416 | A1 | 9/2012 | Gilham et al. |
| 2012/0240377 | A1 | 9/2012 | Ashida |
| 2012/0316449 | A1 | 12/2012 | Uesaka et al. |
| 2012/0330112 | A1 | 12/2012 | Lamego et al. |
| 2012/0330169 | A1 | 12/2012 | Sano et al. |
| 2013/0060153 | A1 | 3/2013 | Kobayashi et al. |
| 2015/0038859 | A1 | 2/2015 | Dalvi et al. |
| 2017/0196470 | A1 | 7/2017 | Lamego |

OTHER PUBLICATIONS

Innovations Ultraflate Plus: https://www.youtube.com/watch?v=nUcx-e91zz0.*

Innovations Ultraflate Plus CO2 Amazon customer review, Mar. 2008: http://www.amazon.com/Genuine-Innovations-2425-Ultraflate-Plus/product-reviews/B00278XO0Q.*

International Search Report and Written Opinion re PCT Application No. PCT/US2014/049490, dated Mar. 31, 2015.

Bureau of Indian Standards: "Fire Extinguisher, Carbon Dioxide Type (Portable and Trolley Mounted)—Specification," Aug. 1,

(56) **References Cited**

OTHER PUBLICATIONS

2004, retrieved from the Internet: URL:https://law.resource.org/pub/in/bis/S03/is.2878.2004.html.
PCT, International Search Report and Written Opinion, re PCT Application No. PCT/US2013/040438, dated Jul. 26, 2013.
Jun Onoderan, Validation of inflationary non-invasive blood pressure monitoring in adult surgical patients, Journal of Anesthesiology, 2011, vol. 25, pp. 127-130.
Osamu Tochikubo, A New Portable Device for Recording 24-h Indirect Blood Pressure in Hypertensive Outpatients, Journal of Hypertension, 1985, vol. 3, pp. 355-357.
International Preliminary Report on Patentability re PCT Application No. PCT/US2014/049490, dated Feb. 9, 2016.
PCT, Inviation to Pay, re PCT Application No. PCT/US2014/049490, dated Nov. 11, 2014.
Advanced/Deluxe One Step Auto-Inflation Blood Pressure monitor model UA-767 Plus. User guide [online]. Life Source, 2009 [retrieved on Apr. 28, 2016]. Retrieved from internet <URL:https://www.andonline.com/uploads/documents/I-MAN-AU-767PV_0409.pdf>.
PCT, Invitation to Pay, re PCT Application No. PCT/US2014/049490, dated Nov. 26, 2014.

* cited by examiner

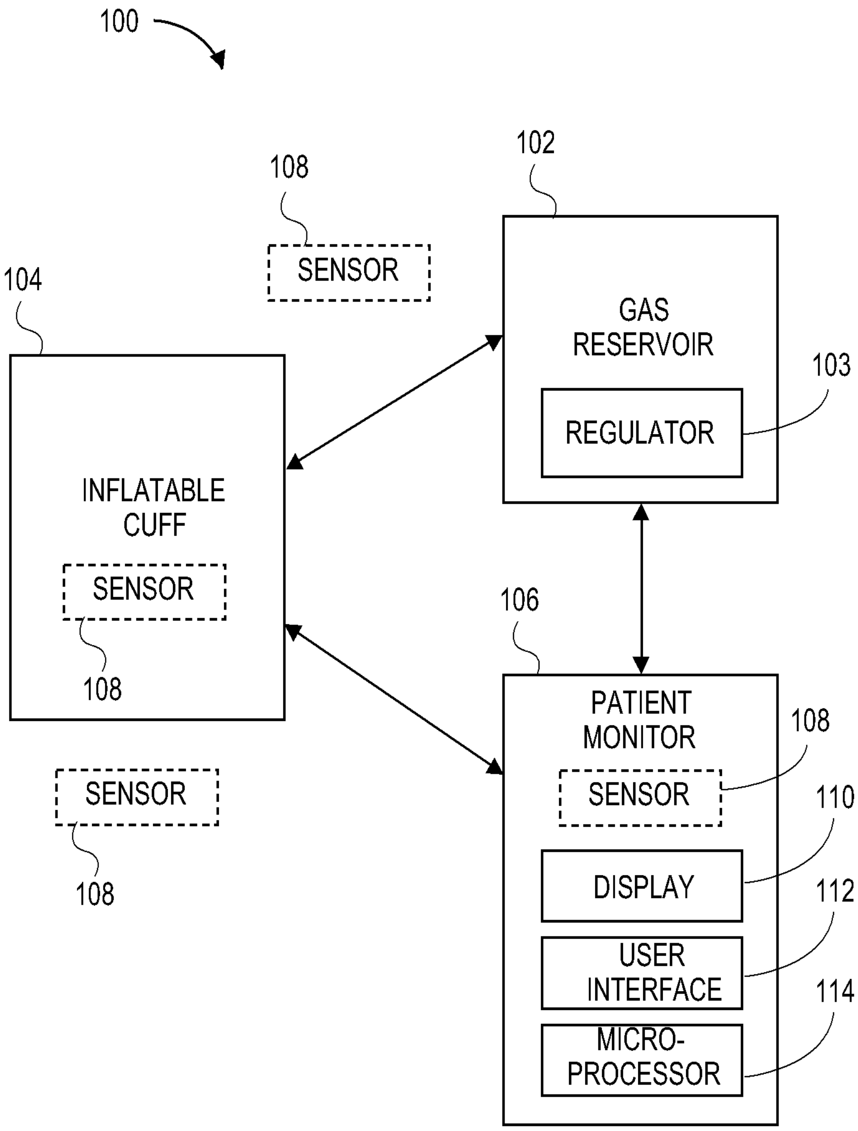

100
108
SENSOR
102
GAS
RESERVOIR
103
REGULATOR
104
INFLATABLE
CUFF
SENSOR
108
106
PATIENT
MONITOR
108
SENSOR
110
DISPLAY
112
USER
INTERFACE
114
MICRO-
PROCESSOR
SENSOR
108

FIG. 1A

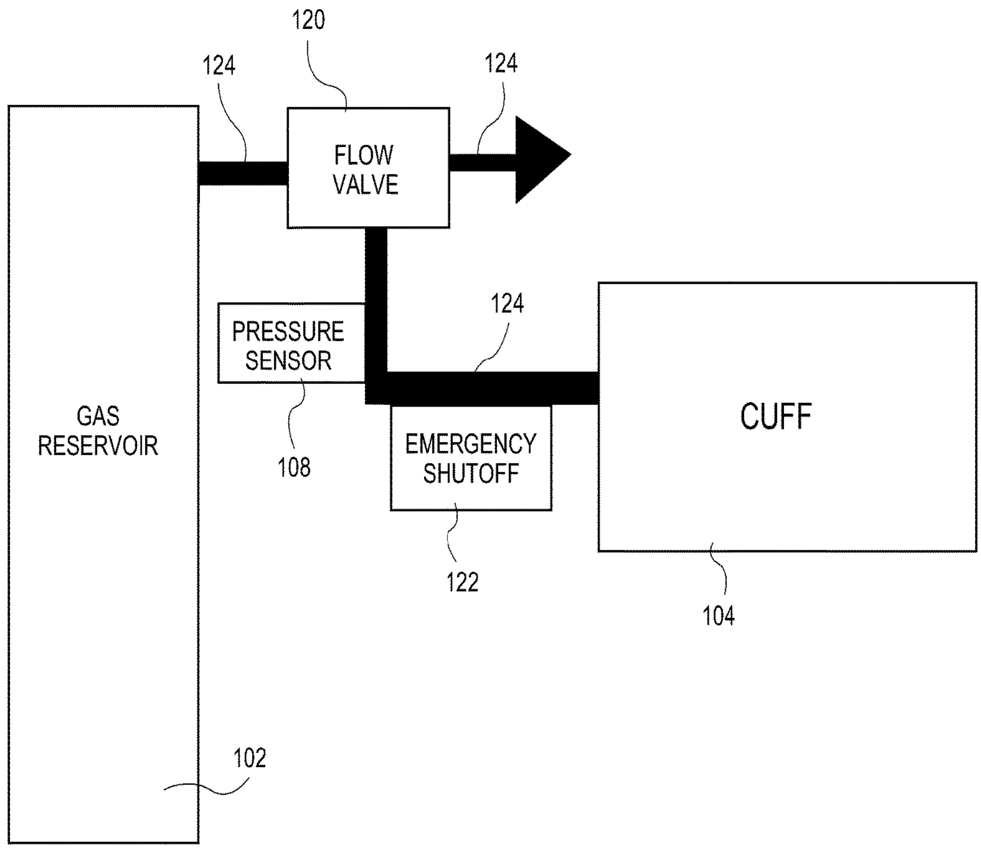

120
124
124
FLOW VALVE
124
PRESSURE SENSOR
108
GAS RESERVOIR
EMERGENCY SHUTOFF
122
CUFF
104
102

FIG. 1B

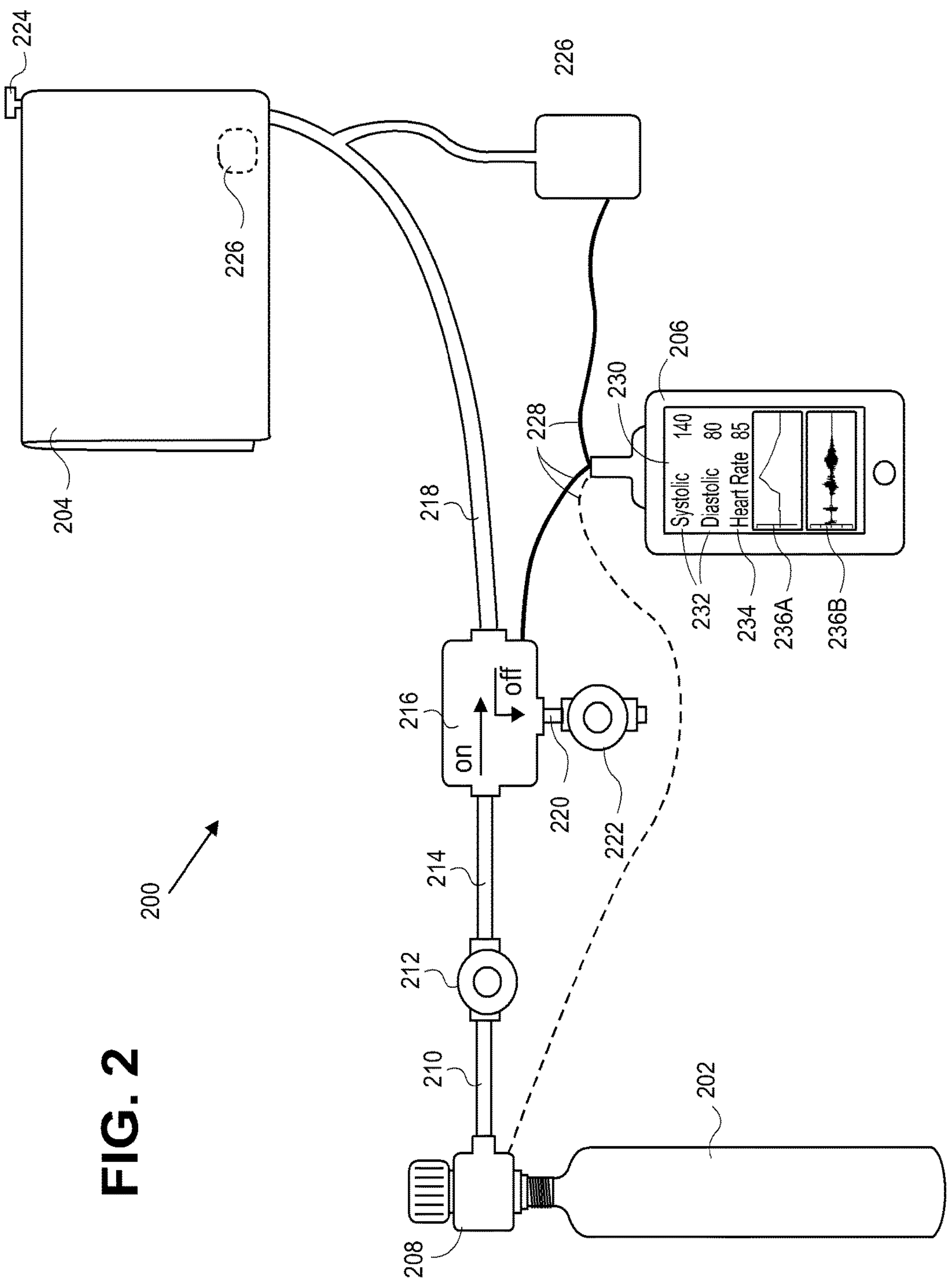

200
202
204
206
208
210
212
214
216
218
220
222
224
226
226
228
230
232
234
236A
236B
on
off
Systolic 140
Diastolic 80
Heart Rate 85

FIG. 2

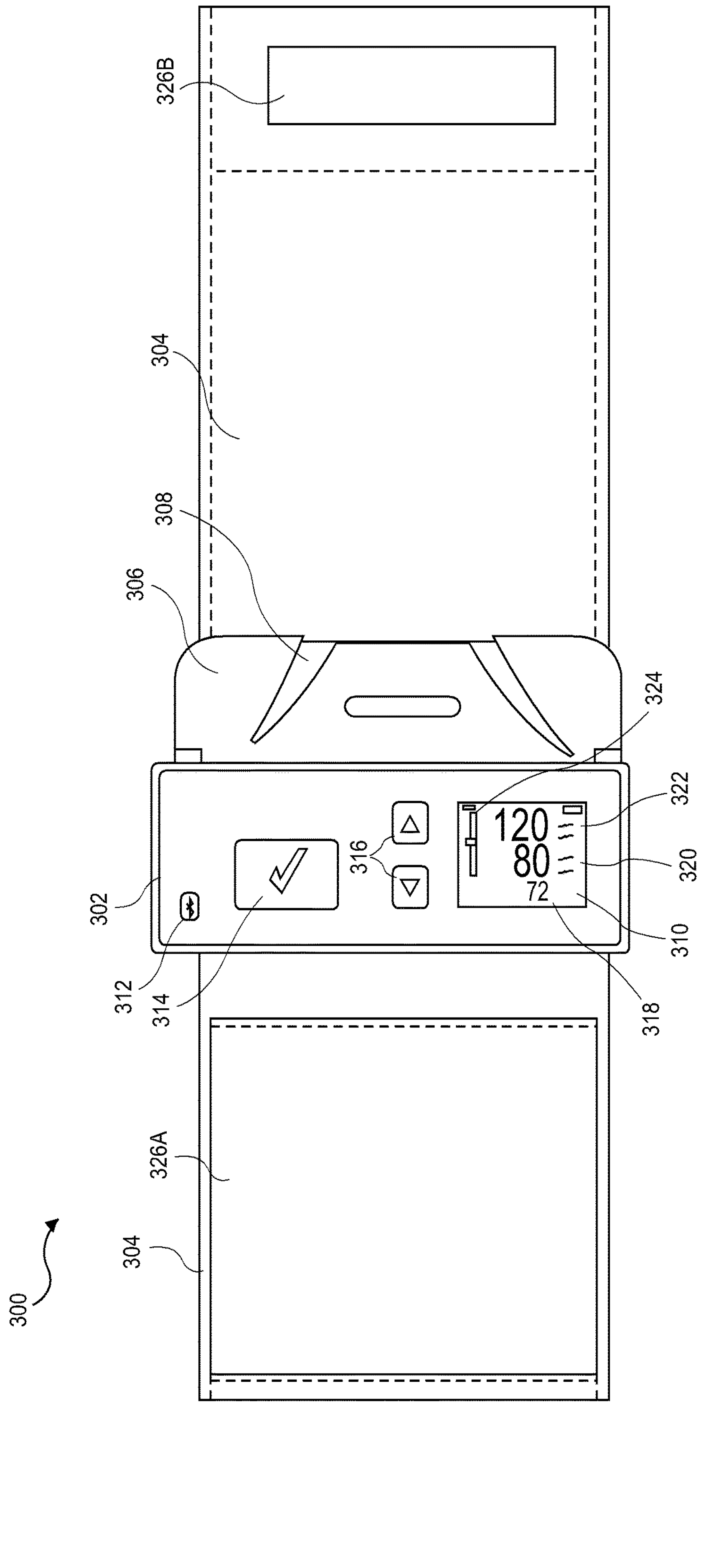

300
302
304
306
308
310
312
314
316
318
320
322
324
326A
326B
120
80
72

FIG. 3A

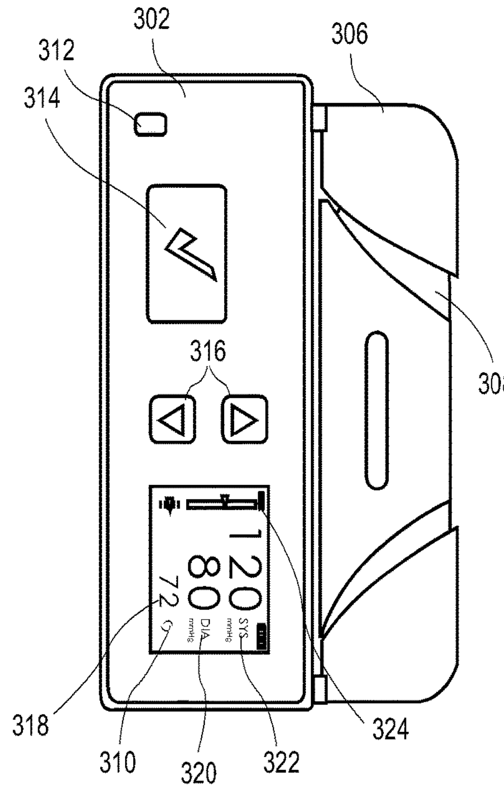

302
312
314
306
316
308
318
310
320
322
324
120
80
72
SYS
DIA

FIG. 3B

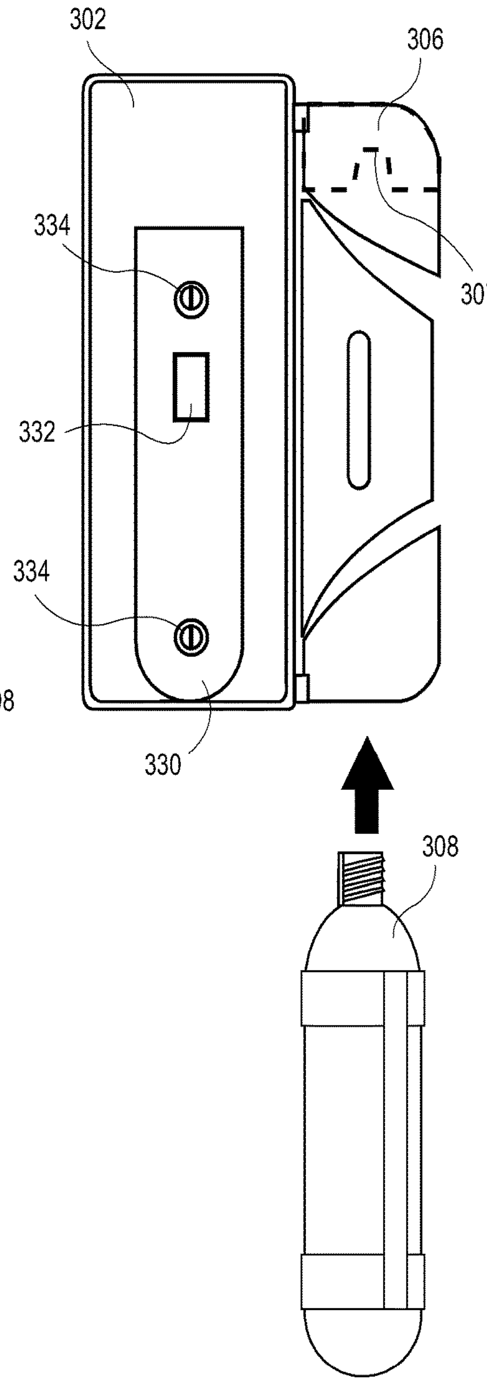

302
306
334
307
332
334
330
308

FIG. 3C

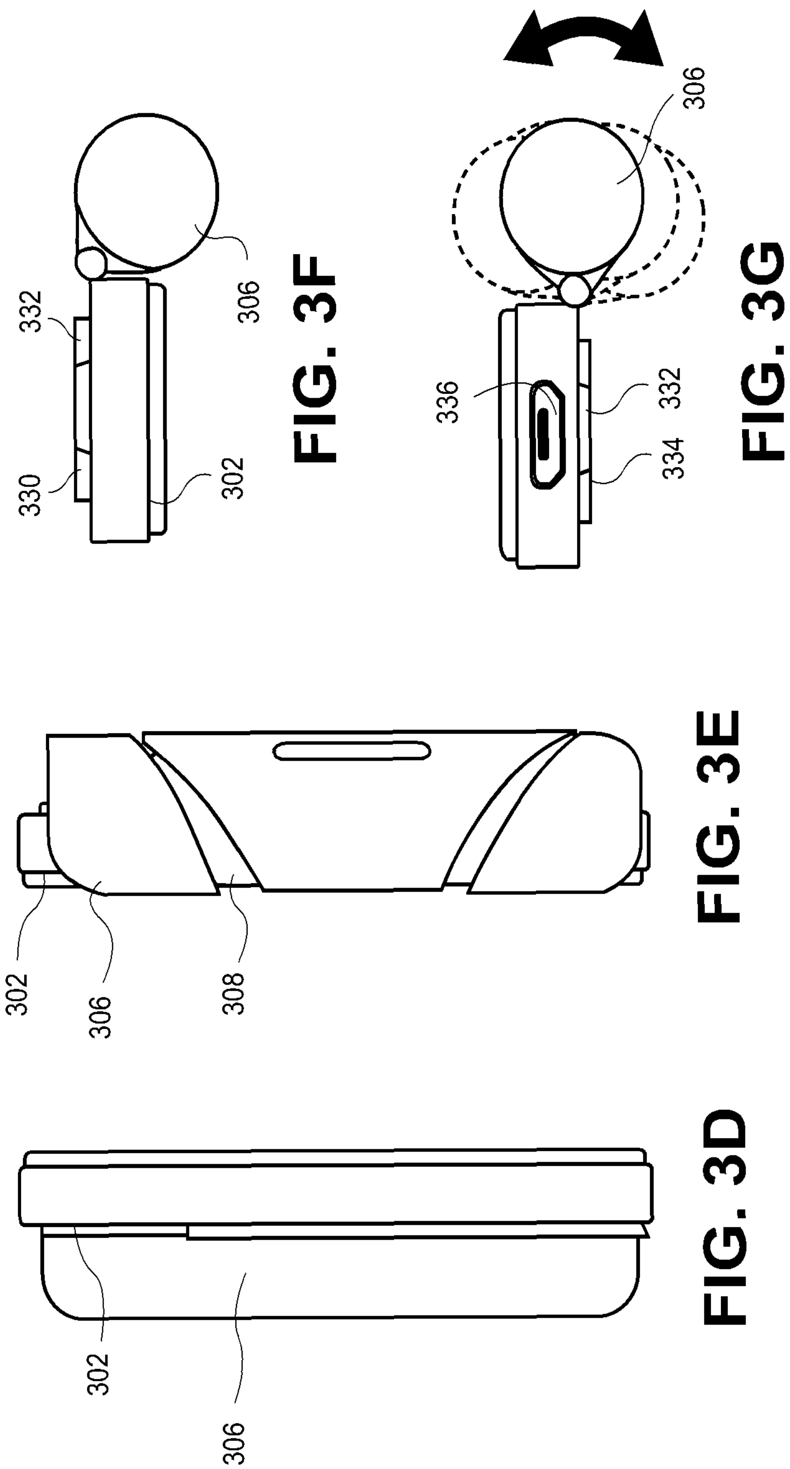



FIG. 3F

FIG. 3G

FIG. 3E

FIG. 3D

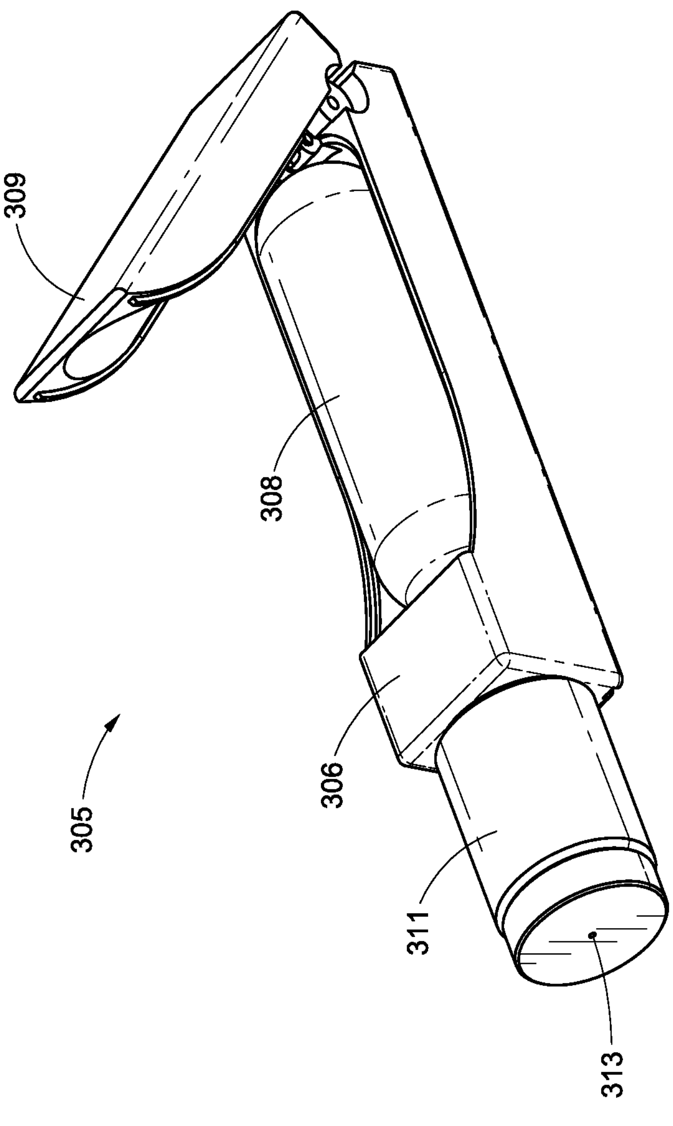



FIG. 3H

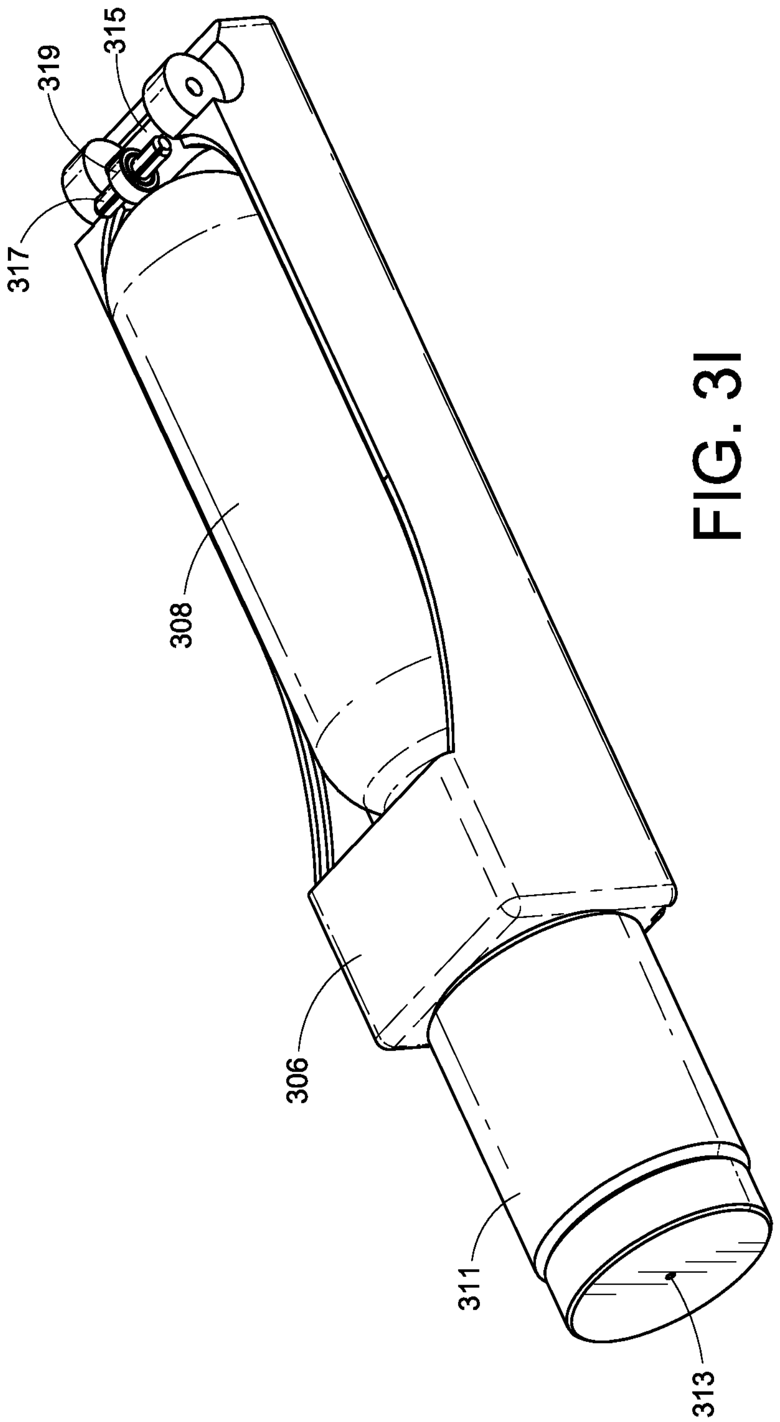



FIG. 3I

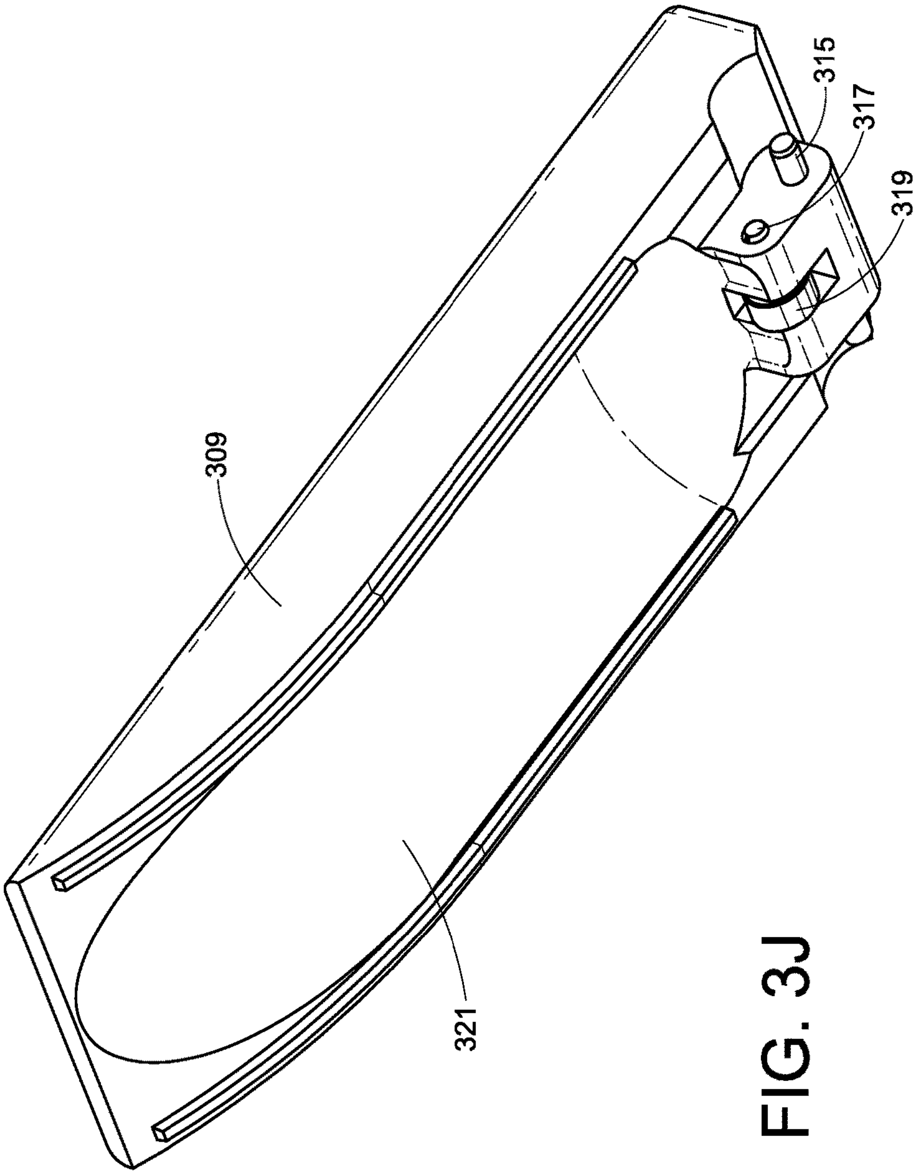



FIG. 3J

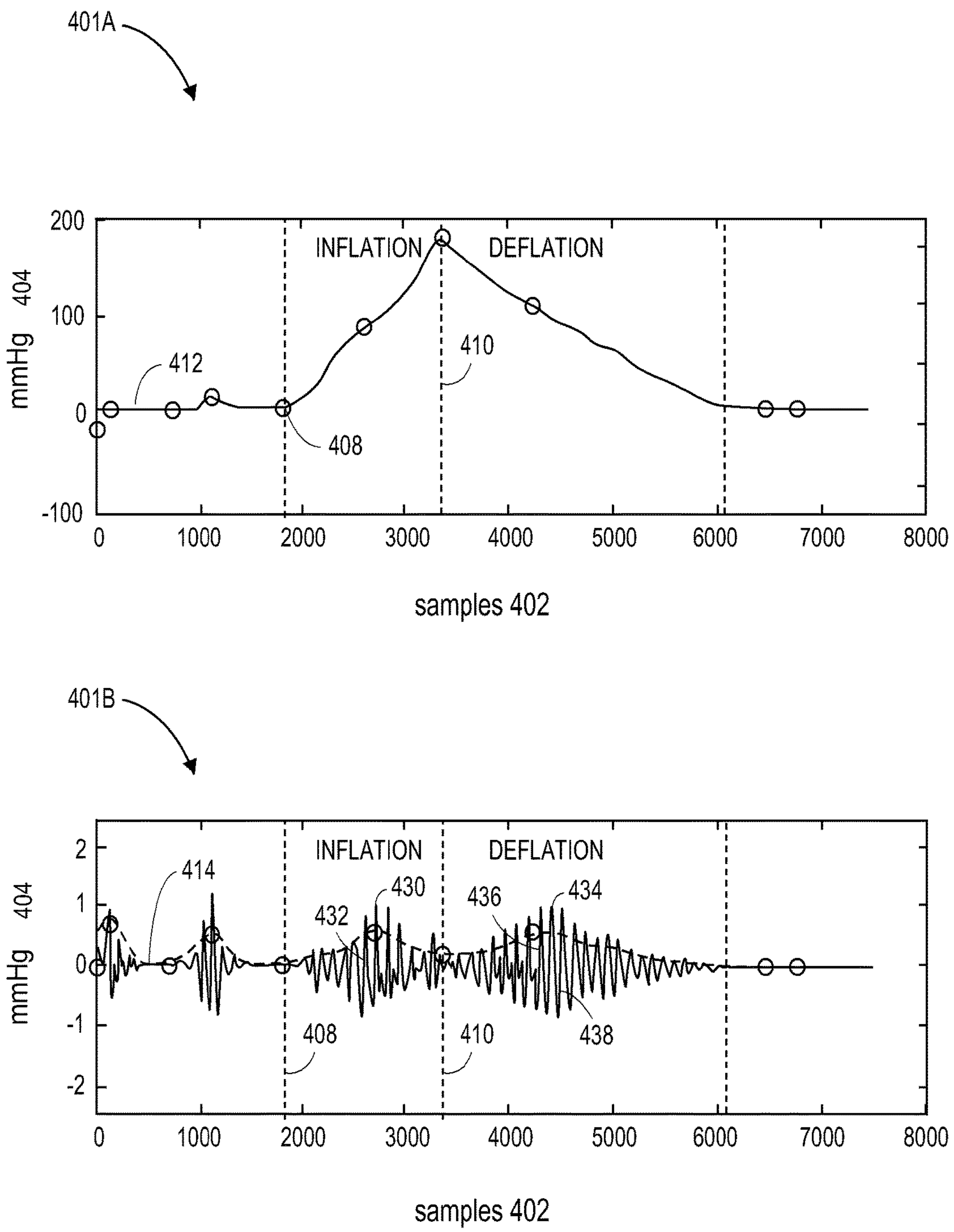

401A
200
100
0
-100
mmHg 404
INFLATION
DEFLATION
412
410
408
0
1000
2000
3000
4000
5000
6000
7000
8000
samples 402
401B
2
1
0
-1
-2
mmHg 404
414
432
430
436
434
438
408
410
samples 402

FIG. 4A

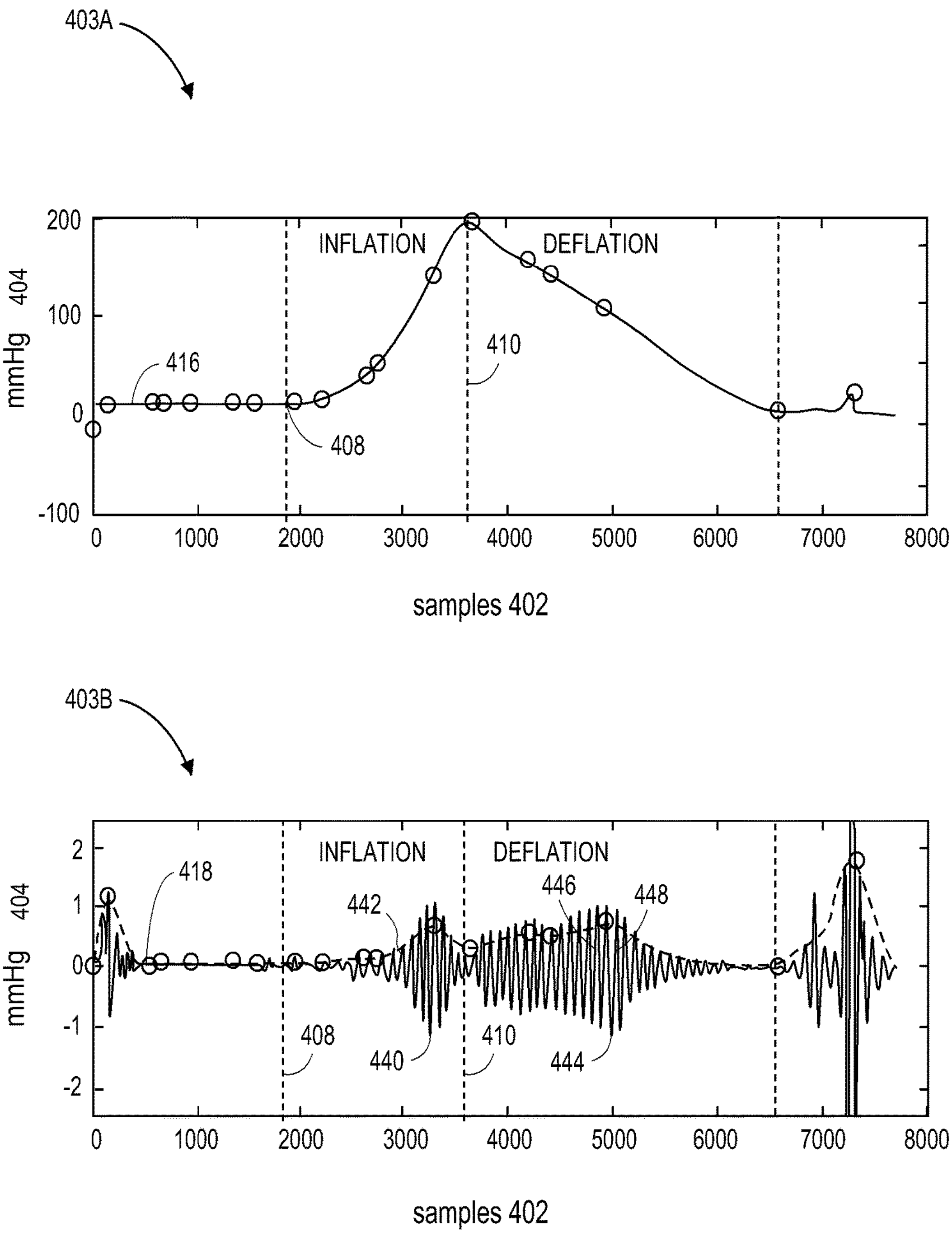

403A
200
100
0
-100
mmHg 404
INFLATION
DEFLATION
416
408
410
0 1000 2000 3000 4000 5000 6000 7000 8000
samples 402
403B
2
1
0
-1
-2
mmHg 404
INFLATION
DEFLATION
418
442
446
448
408
440
410
444
0 1000 2000 3000 4000 5000 6000 7000 8000
samples 402

**FIG. 4B**

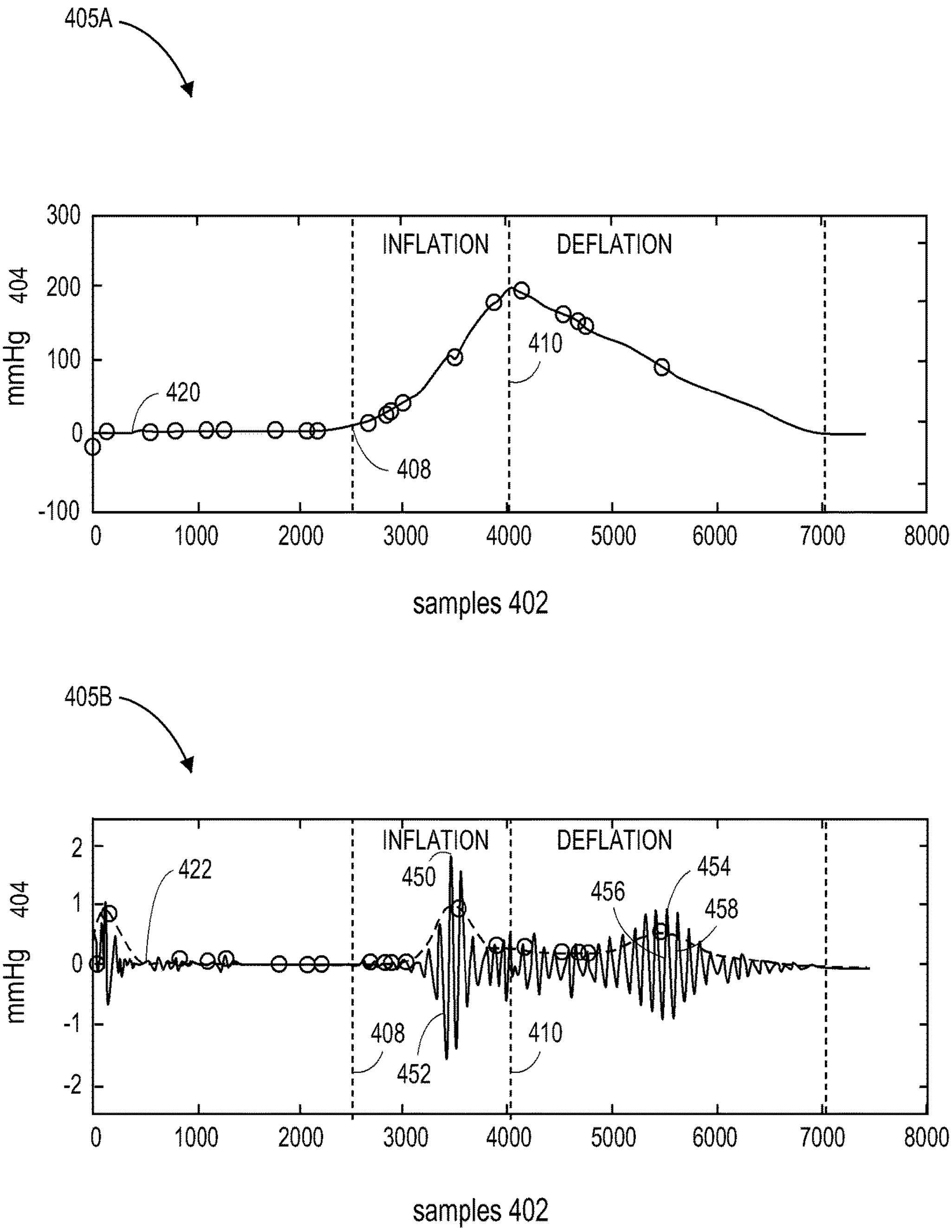

405A
300
200
100
0
-100
mmHg 404
INFLATION
DEFLATION
420
408
410
0
1000
2000
3000
4000
5000
6000
7000
8000
samples 402
405B
2
1
0
-1
-2
mmHg 404
422
450
452
454
456
458
408
410
samples 402

FIG. 4C

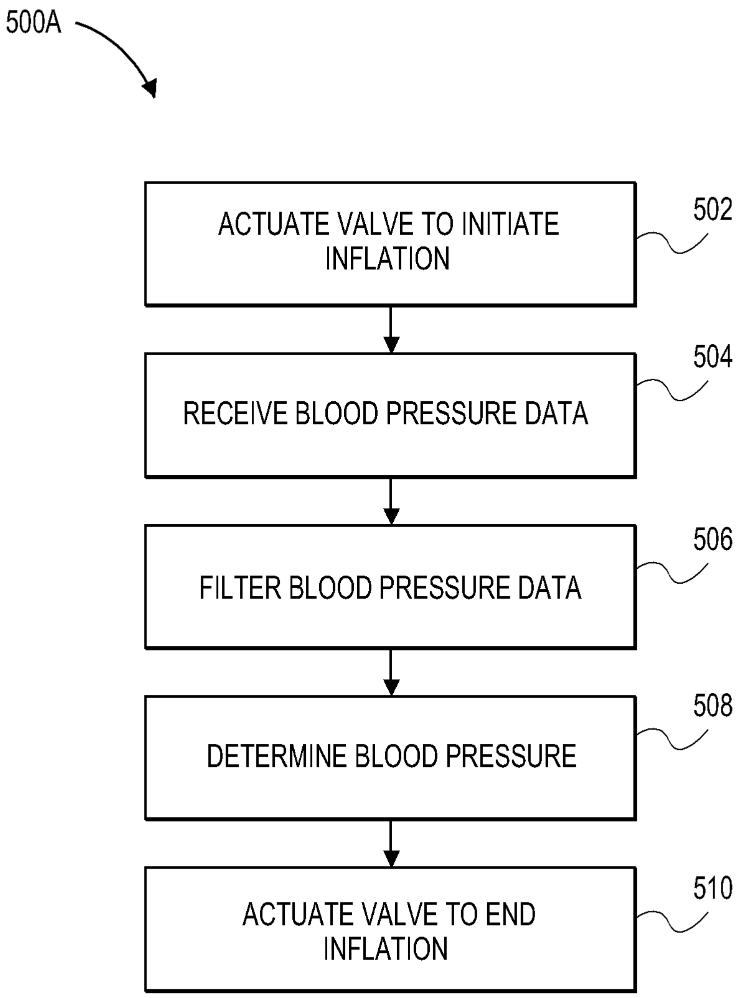

500A
ACTUATE VALVE TO INITIATE INFLATION
502
RECEIVE BLOOD PRESSURE DATA
504
FILTER BLOOD PRESSURE DATA
506
DETERMINE BLOOD PRESSURE
508
ACTUATE VALVE TO END INFLATION
510

FIG. 5A

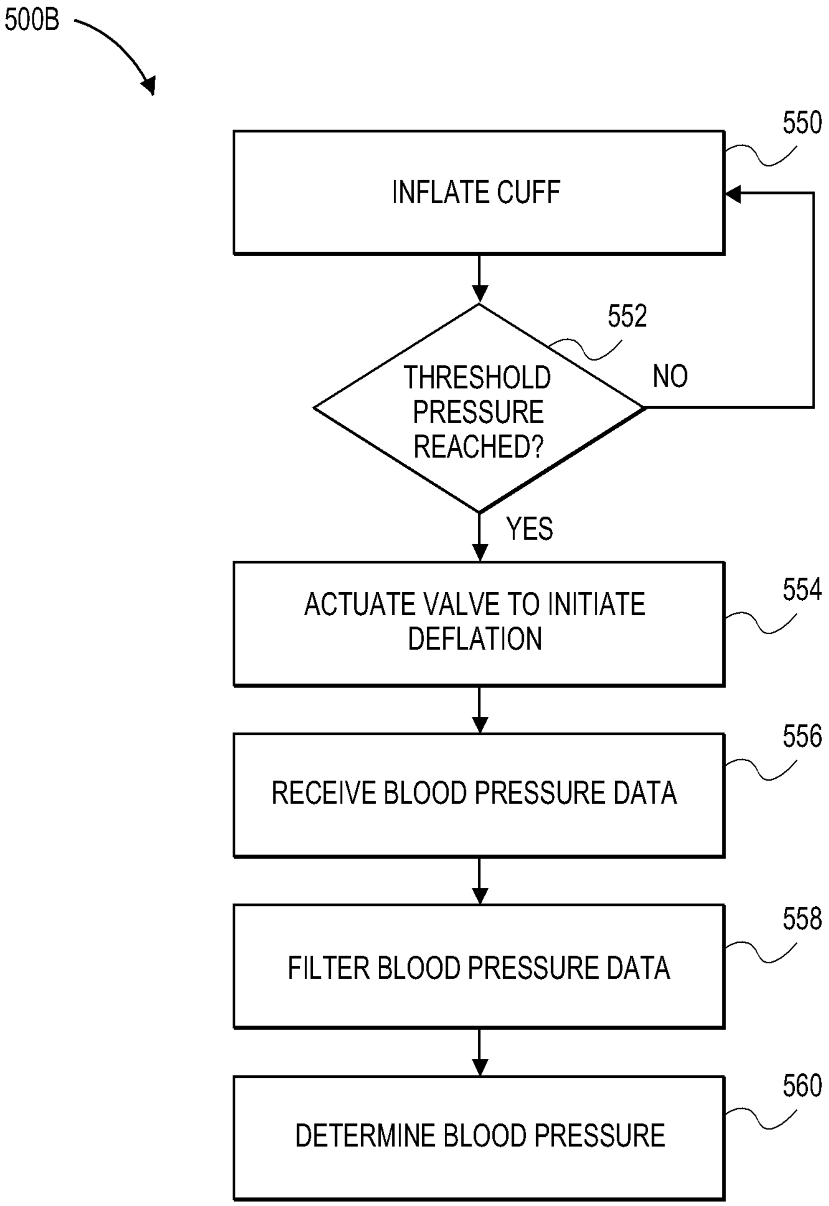

500B
550
INFLATE CUFF
552
THRESHOLD PRESSURE REACHED?
NO
YES
554
ACTUATE VALVE TO INITIATE DEFLATION
556
RECEIVE BLOOD PRESSURE DATA
558
FILTER BLOOD PRESSURE DATA
560
DETERMINE BLOOD PRESSURE

FIG. 5B

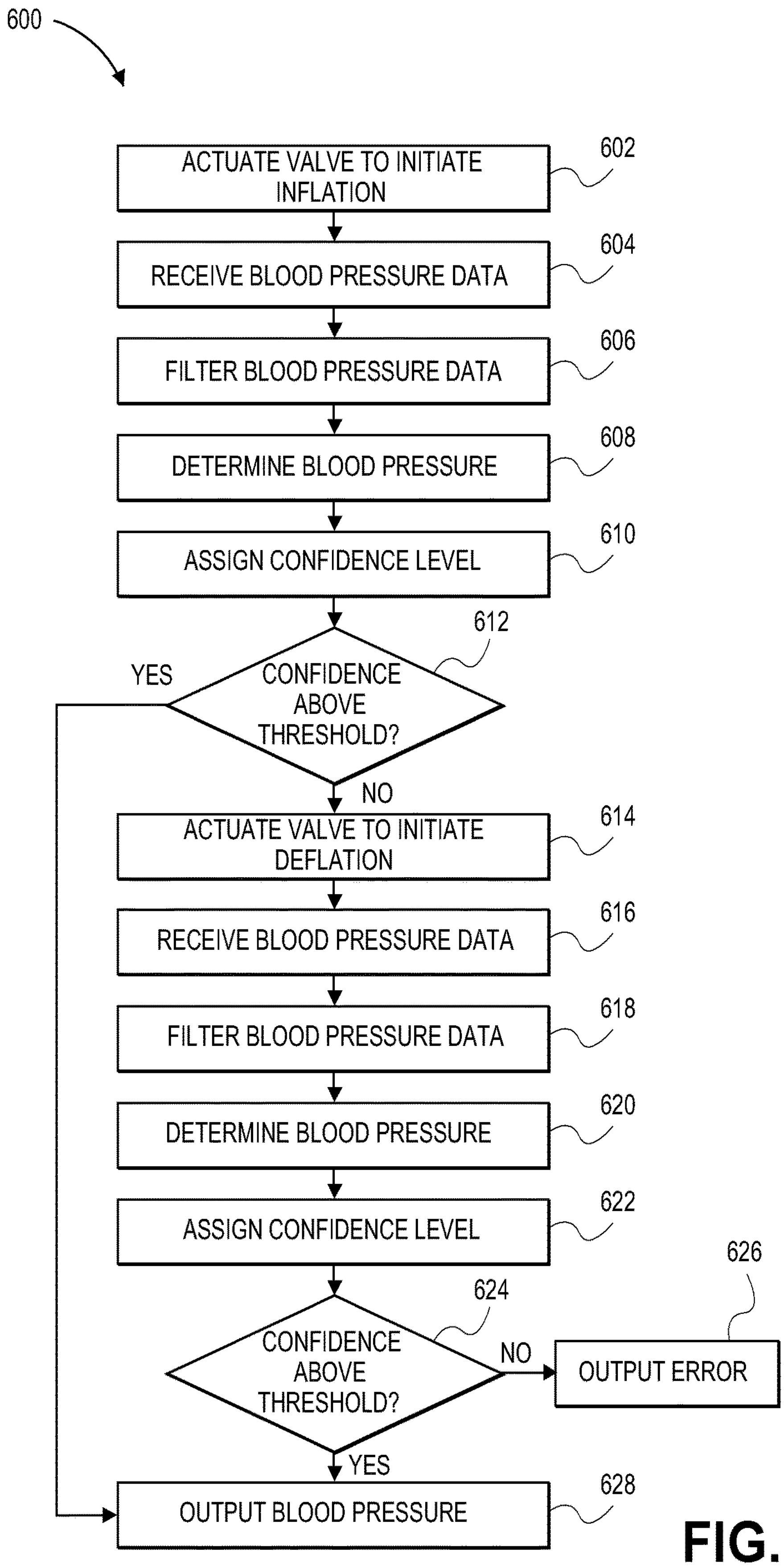

600
ACTUATE VALVE TO INITIATE INFLATION
602
RECEIVE BLOOD PRESSURE DATA
604
FILTER BLOOD PRESSURE DATA
606
DETERMINE BLOOD PRESSURE
608
ASSIGN CONFIDENCE LEVEL
610
CONFIDENCE ABOVE THRESHOLD?
612
YES
NO
ACTUATE VALVE TO INITIATE DEFLATION
614
RECEIVE BLOOD PRESSURE DATA
616
FILTER BLOOD PRESSURE DATA
618
DETERMINE BLOOD PRESSURE
620
ASSIGN CONFIDENCE LEVEL
622
CONFIDENCE ABOVE THRESHOLD?
624
NO
OUTPUT ERROR
626
YES
OUTPUT BLOOD PRESSURE
628

FIG. 6A

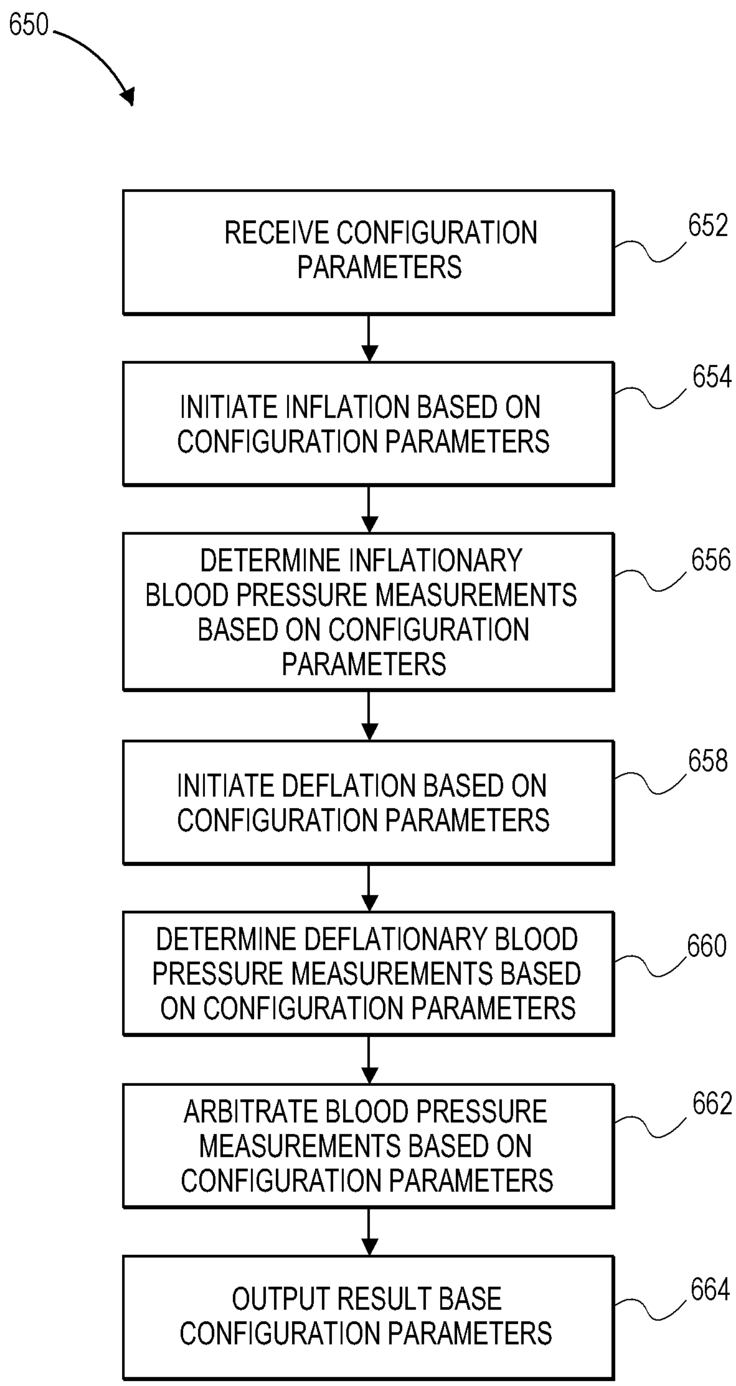

650
RECEIVE CONFIGURATION PARAMETERS
652
INITIATE INFLATION BASED ON CONFIGURATION PARAMETERS
654
DETERMINE INFLATIONARY BLOOD PRESSURE MEASUREMENTS BASED ON CONFIGURATION PARAMETERS
656
INITIATE DEFLATION BASED ON CONFIGURATION PARAMETERS
658
DETERMINE DEFLATIONARY BLOOD PRESSURE MEASUREMENTS BASED ON CONFIGURATION PARAMETERS
660
ARBITRATE BLOOD PRESSURE MEASUREMENTS BASED ON CONFIGURATION PARAMETERS
662
OUTPUT RESULT BASE CONFIGURATION PARAMETERS
664

FIG. 6B

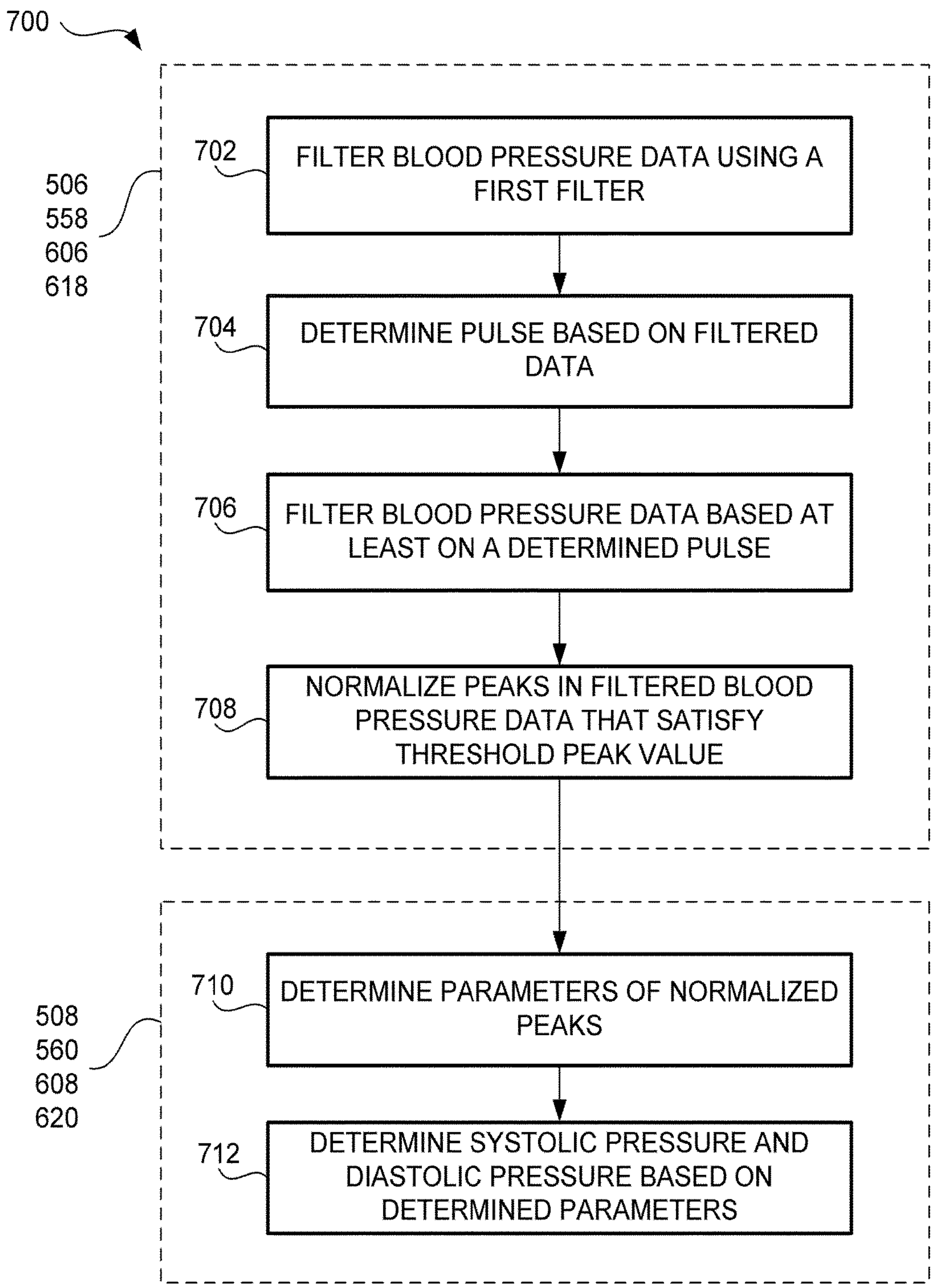

700
506
558
606
618
702
FILTER BLOOD PRESSURE DATA USING A FIRST FILTER
704
DETERMINE PULSE BASED ON FILTERED DATA
706
FILTER BLOOD PRESSURE DATA BASED AT LEAST ON A DETERMINED PULSE
708
NORMALIZE PEAKS IN FILTERED BLOOD PRESSURE DATA THAT SATISFY THRESHOLD PEAK VALUE
508
560
608
620
710
DETERMINE PARAMETERS OF NORMALIZED PEAKS
712
DETERMINE SYSTOLIC PRESSURE AND DIASTOLIC PRESSURE BASED ON DETERMINED PARAMETERS

FIG. 7A

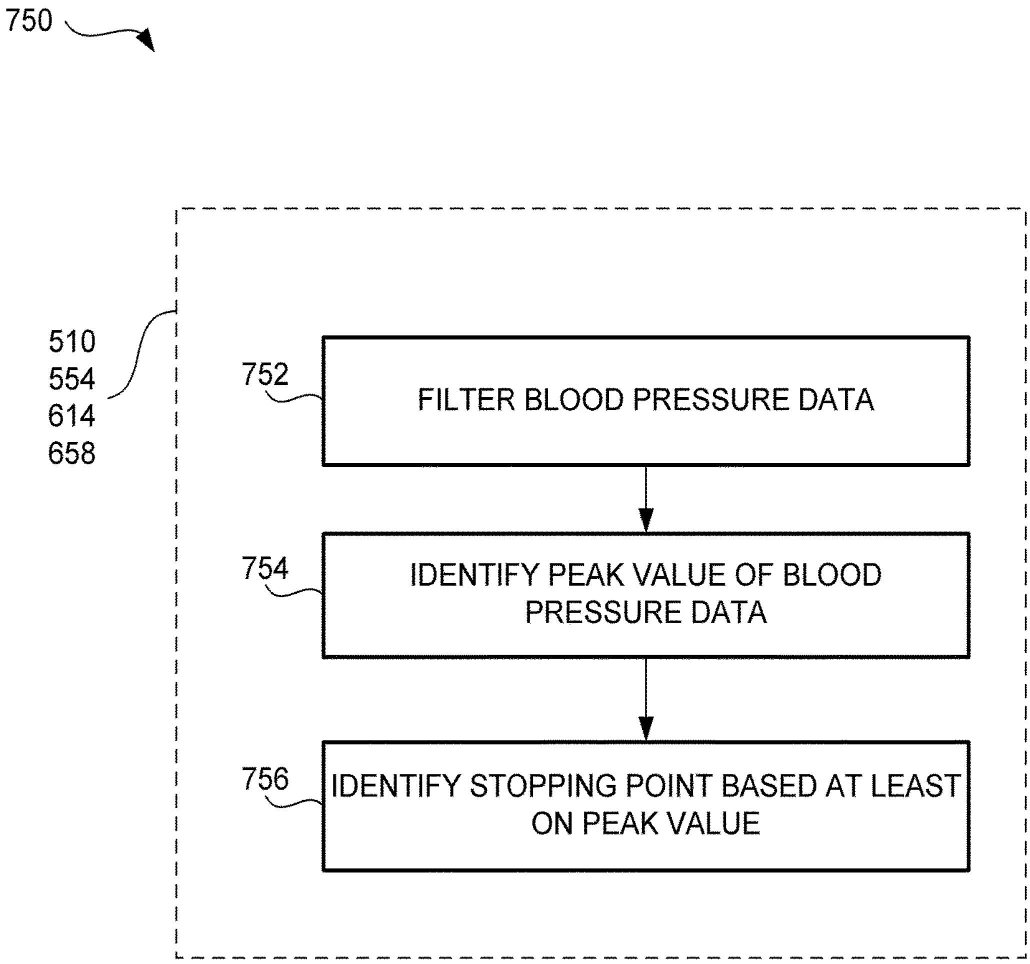

750
510
554
614
658
752
FILTER BLOOD PRESSURE DATA
754
IDENTIFY PEAK VALUE OF BLOOD PRESSURE DATA
756
IDENTIFY STOPPING POINT BASED AT LEAST ON PEAK VALUE

FIG. 7B

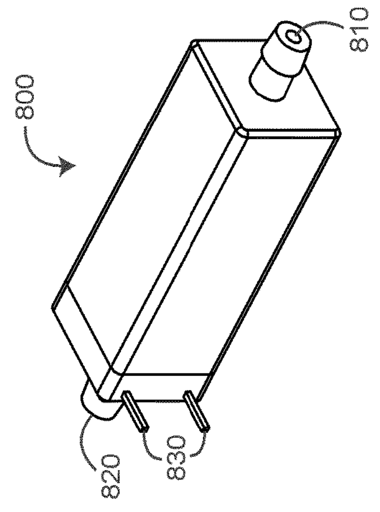


FIG. 8A

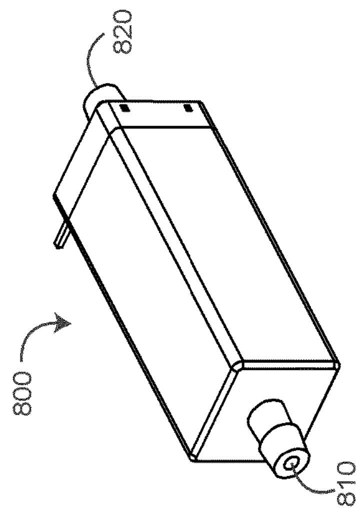


FIG. 8B

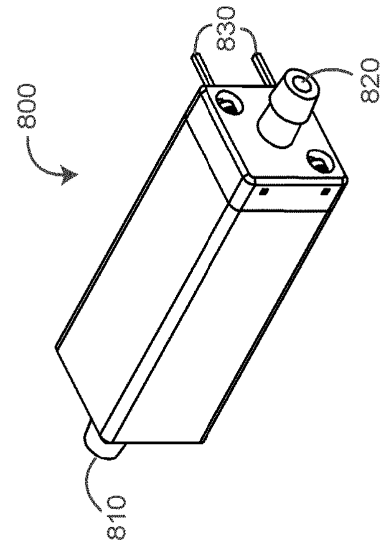


FIG. 8C

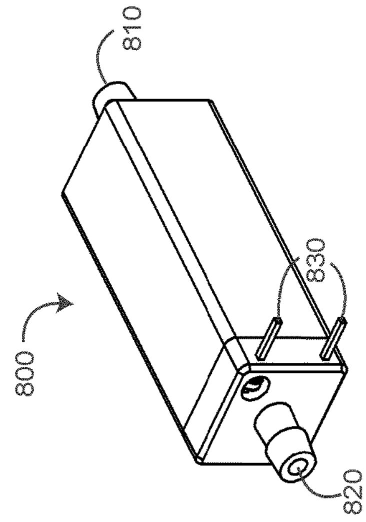


FIG. 8D

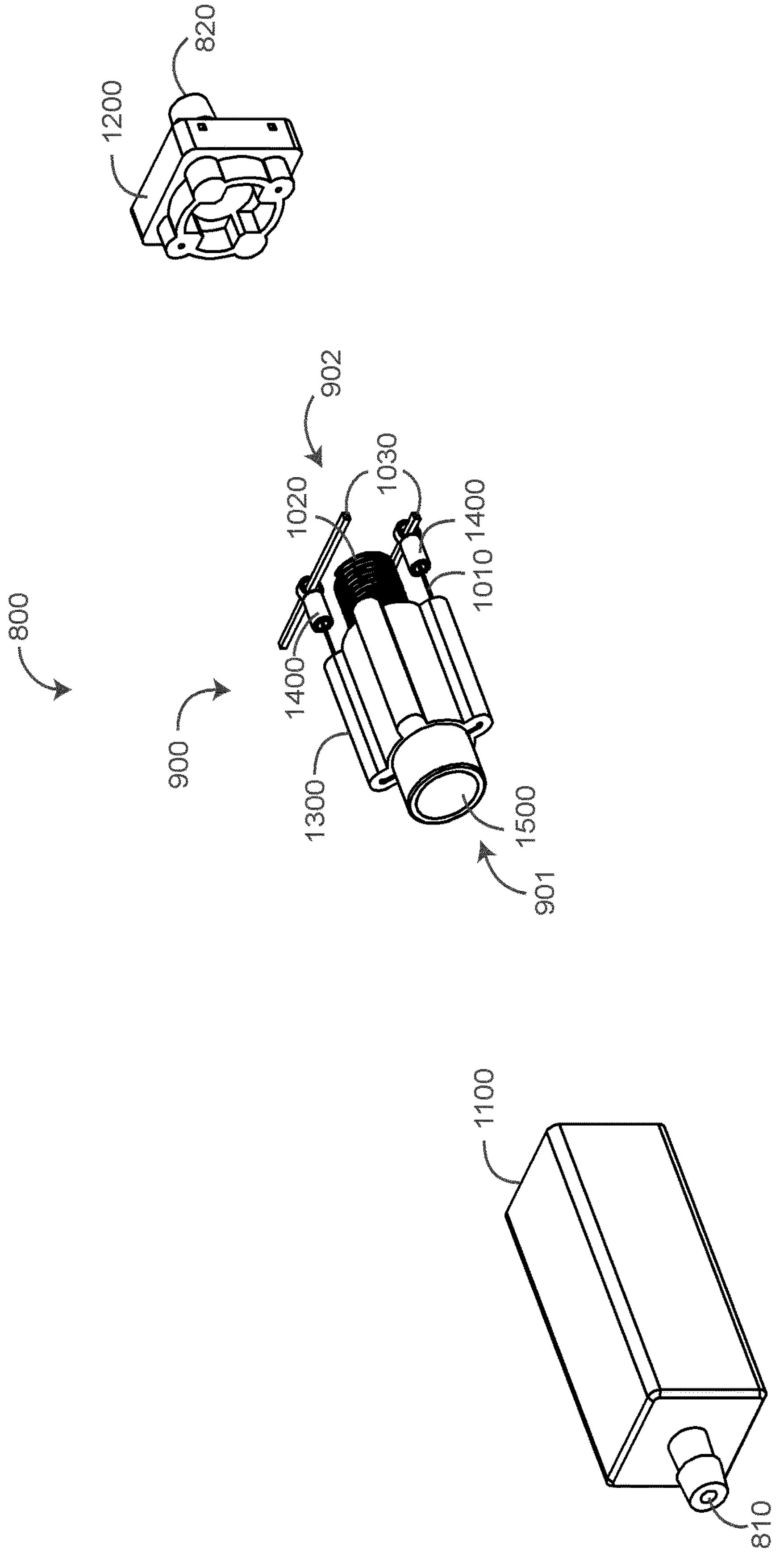

820
1200
902
1030
1020
1400
1010
800
1400
900
1300
1500
901
1100
810

FIG. 9

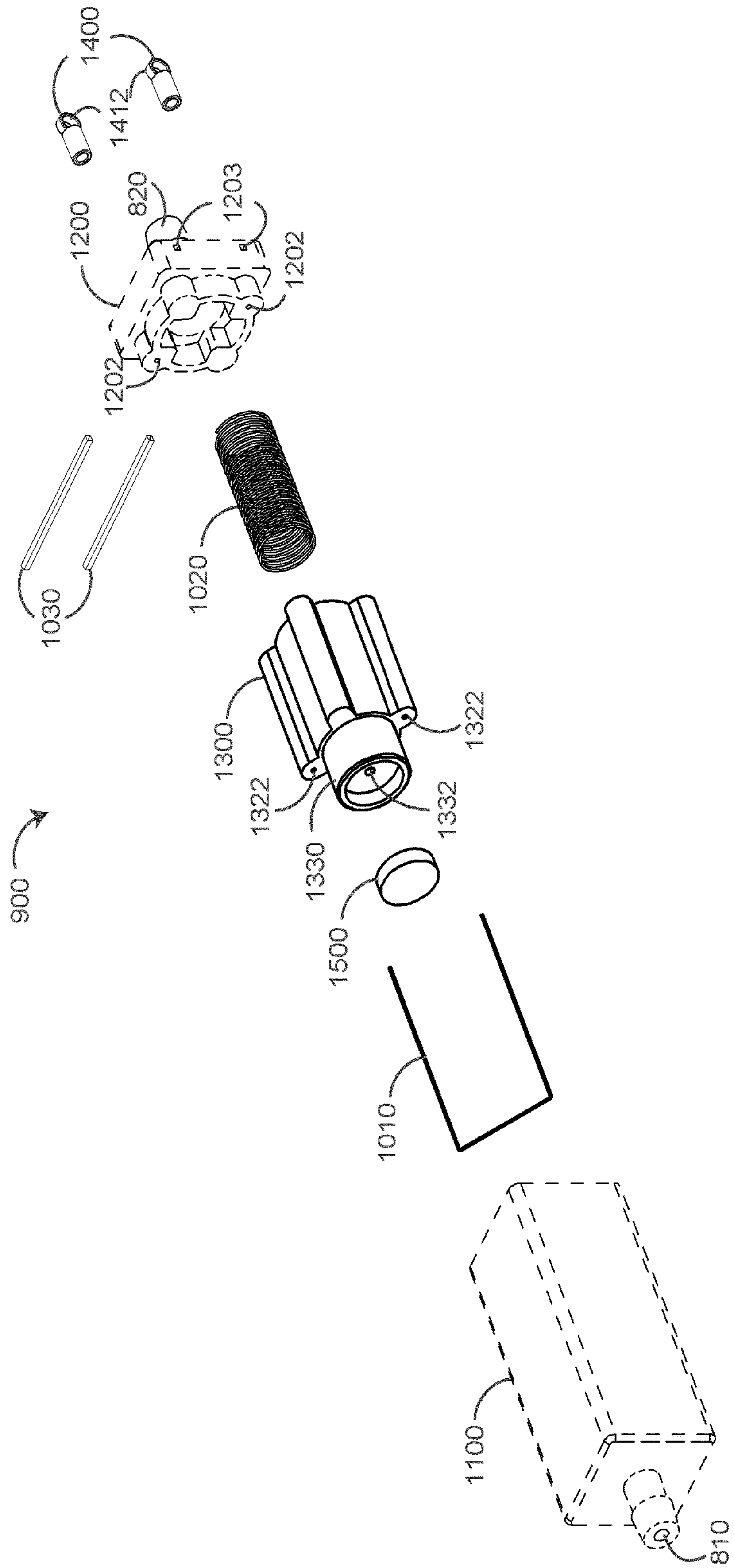

1400
1412
820
1203
1200
1202
1202
1030
1020
1300
1322
1322
1332
1330
900
1500
1010
1100
810

FIG. 10

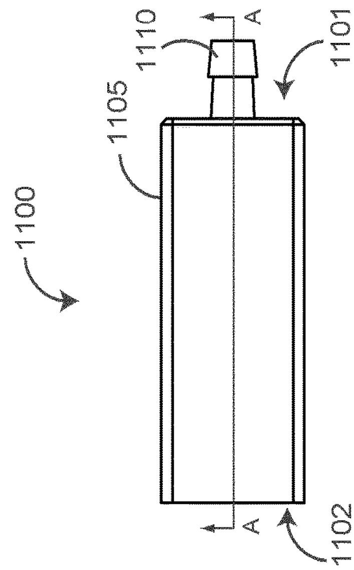


FIG. 11A

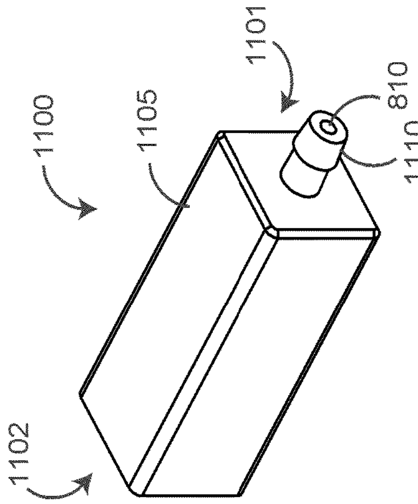


FIG. 11B

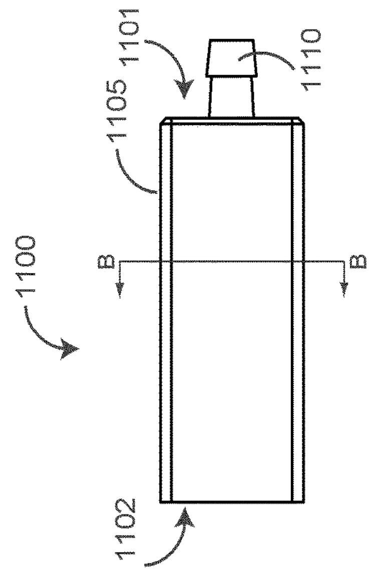


FIG. 11C

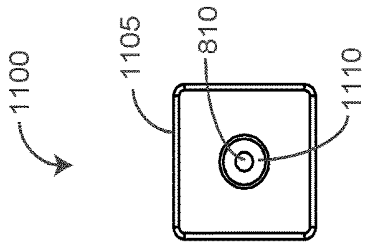


FIG. 11D

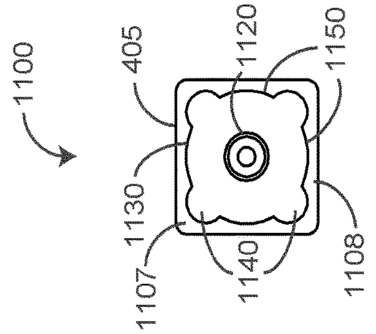
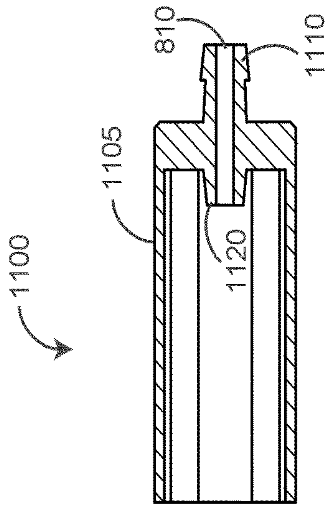
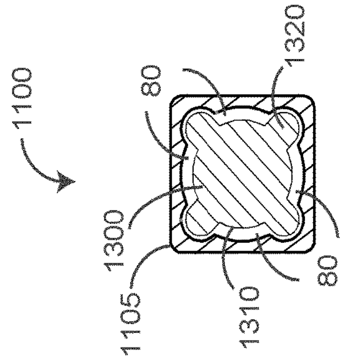


FIG. 11E



CROSS-SECTION A-A
FIG. 11F



CROSS-SECTION B-B
FIG. 11G

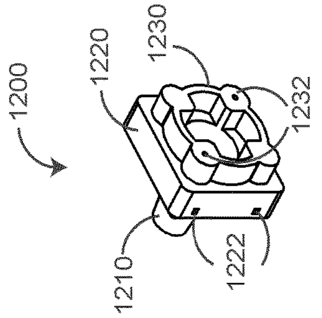


FIG. 12B

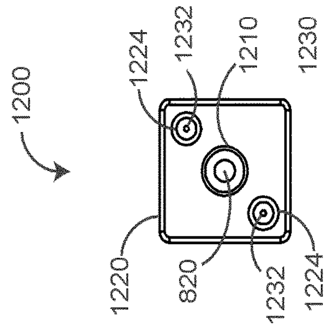


FIG. 12E

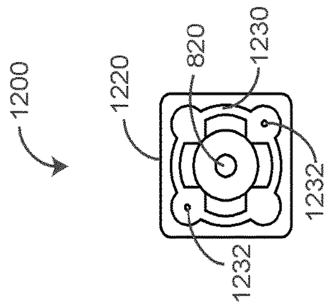


FIG. 12D

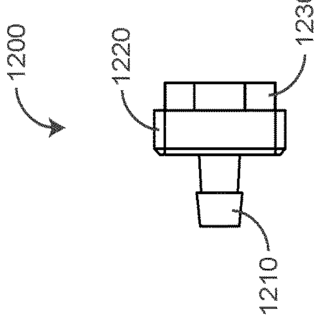


FIG. 12A

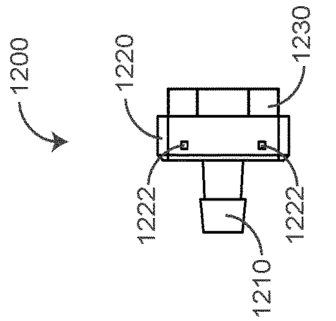


FIG. 12C

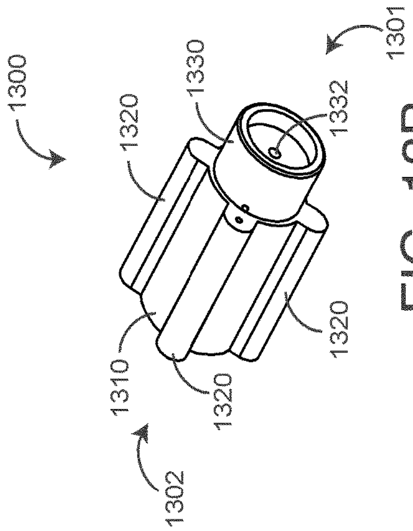


FIG. 13B

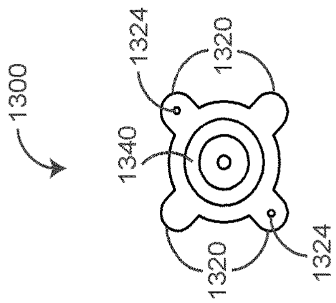


FIG. 13E

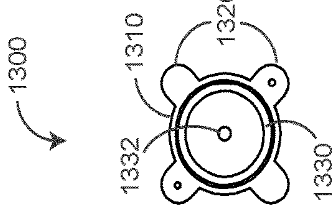


FIG. 13D

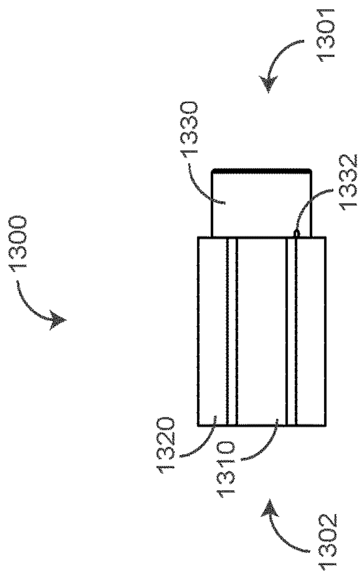


FIG. 13A

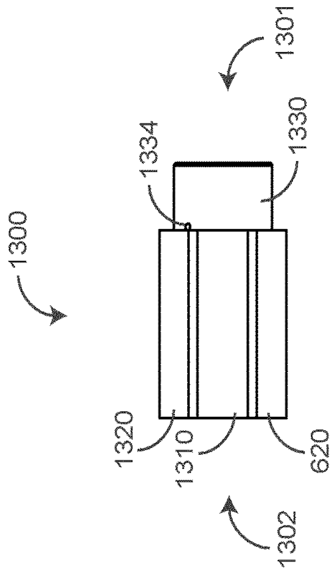


FIG. 13C

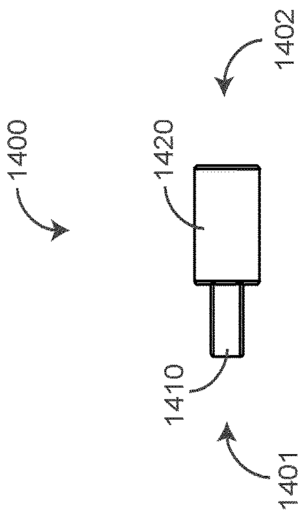



FIG. 14A

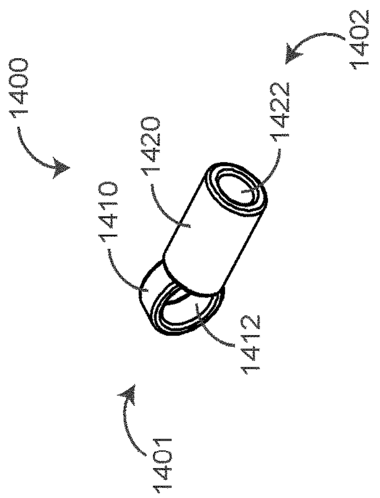



FIG. 14B

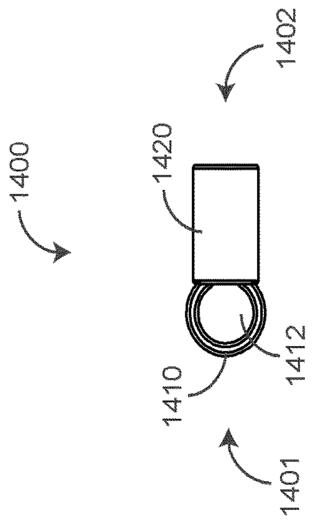



FIG. 14C

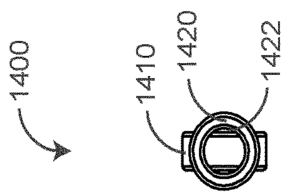



FIG. 14D

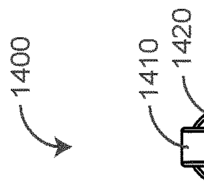



FIG. 14E

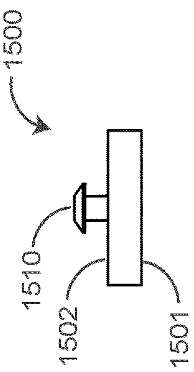



FIG. 15A

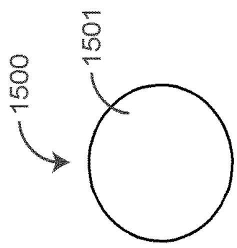



FIG. 15B

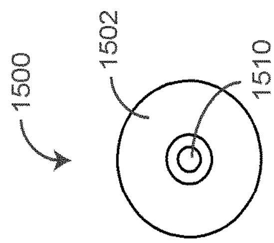



FIG. 15C

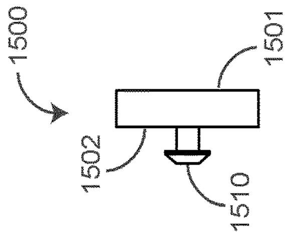



FIG. 15D

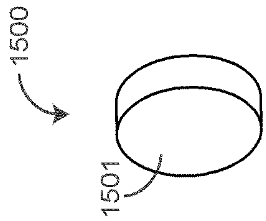



FIG. 15E

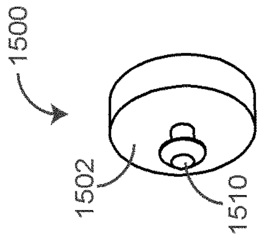



FIG. 15F

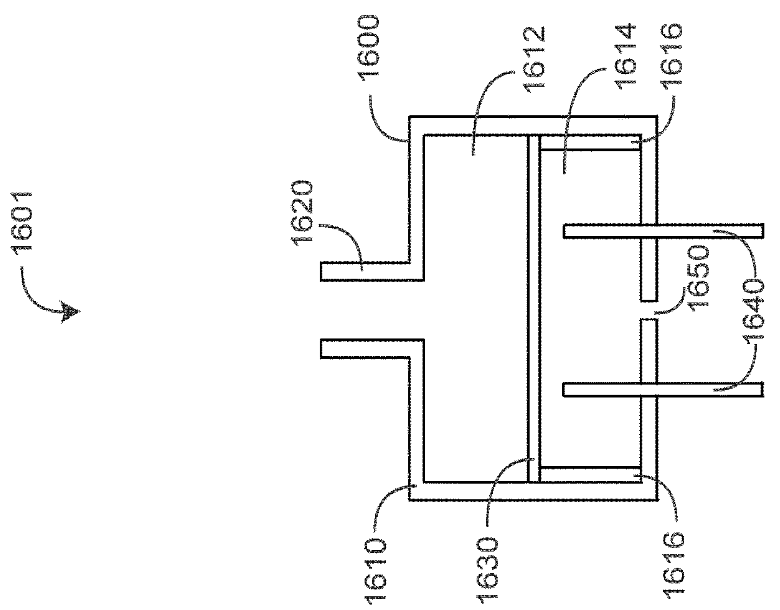



FIG. 16A

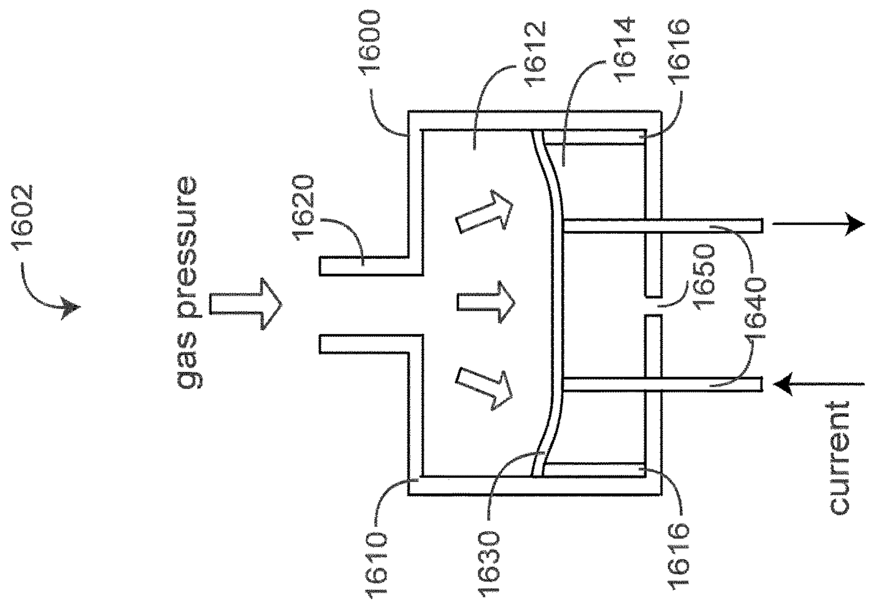



FIG. 16B

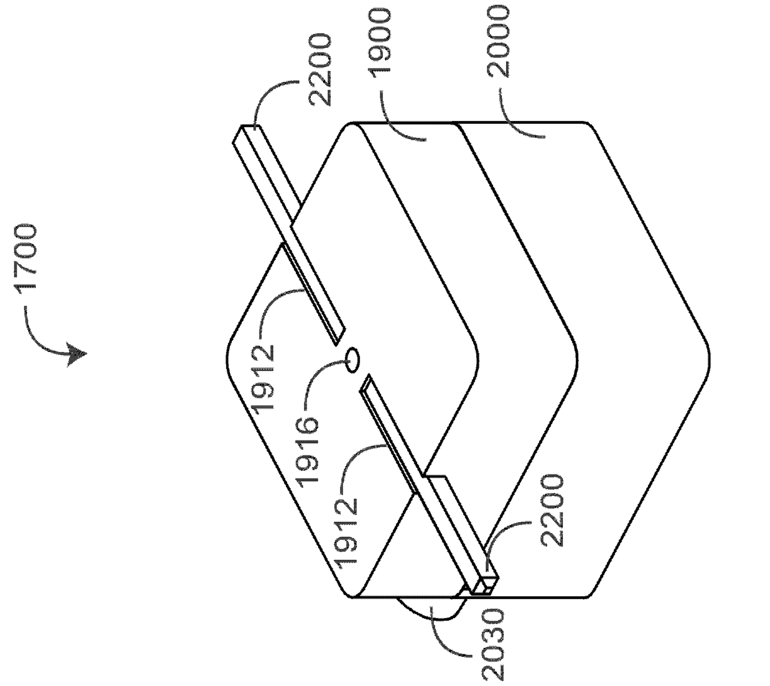



FIG. 17B

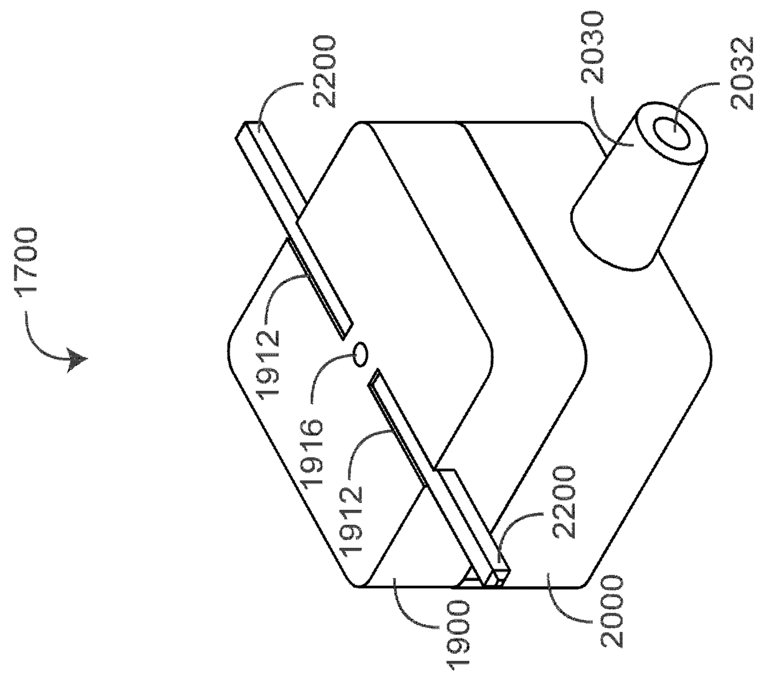



FIG. 17A

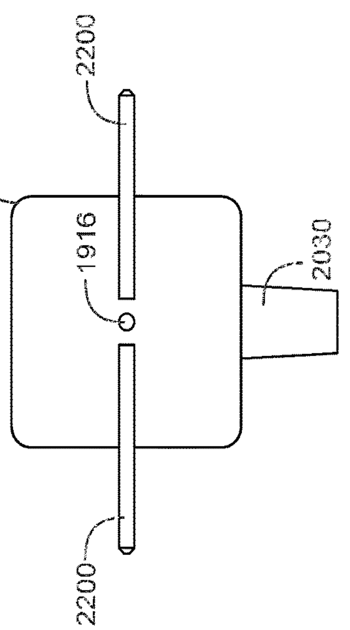



FIG. 17C

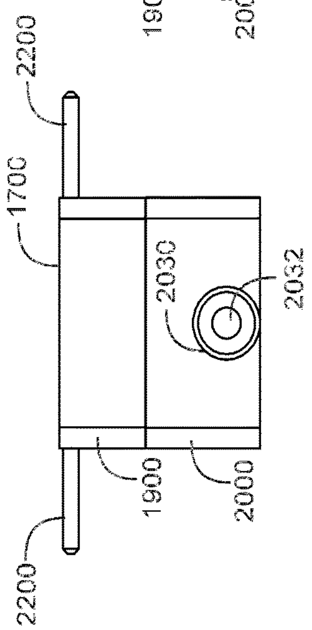



FIG. 17D

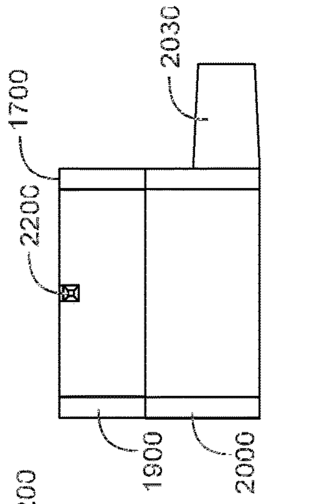



FIG. 17E

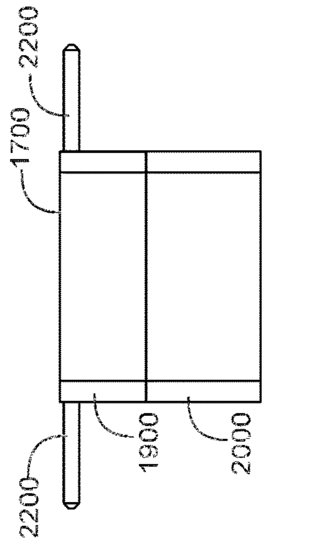
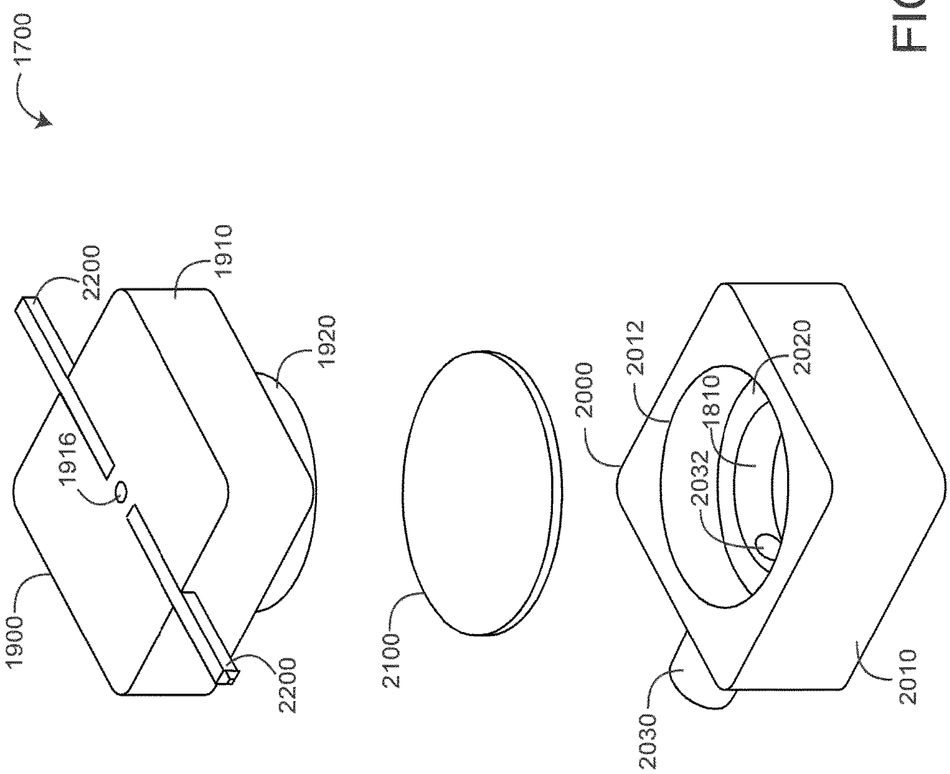



FIG. 17F


1700
2200
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1920
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2012
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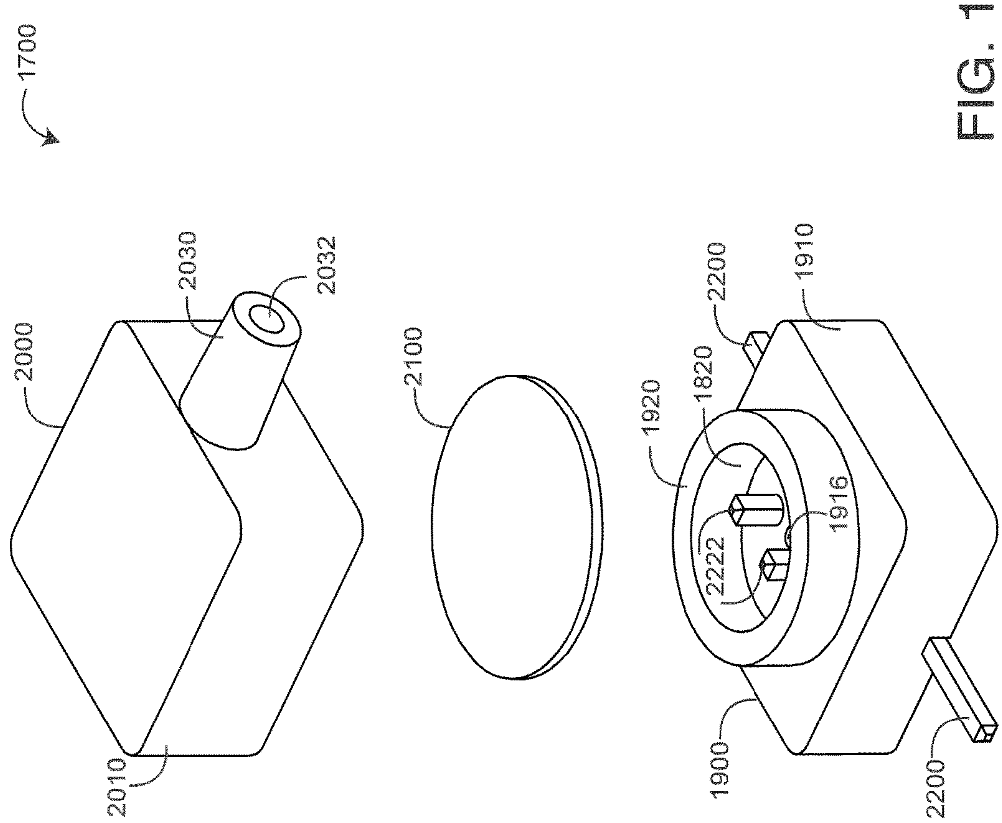
2032
2030
2010

FIG. 18A



1700
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2222
1916
2200
1910
1900
2200


FIG. 18B

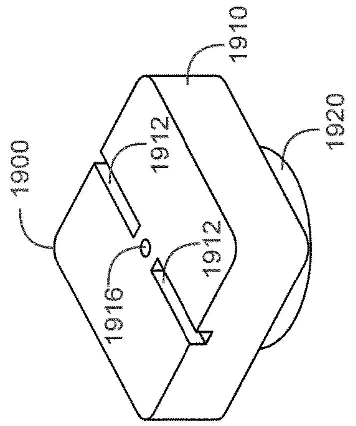


FIG. 19D

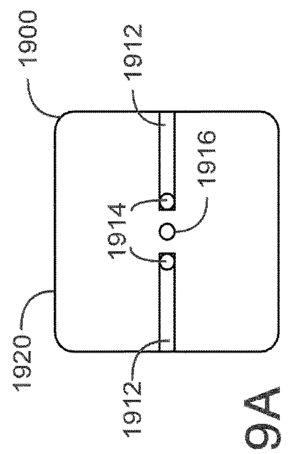


FIG. 19A

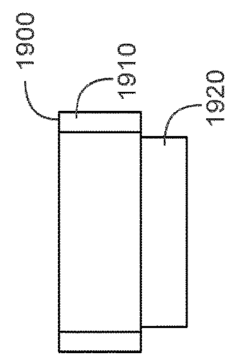


FIG. 19B

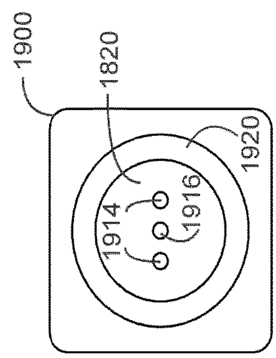


FIG. 19C

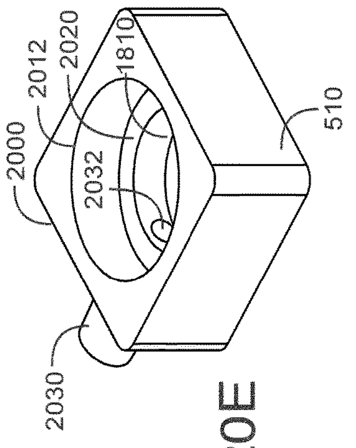


FIG. 20E

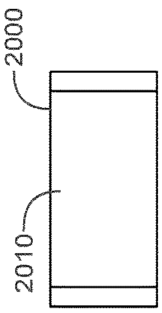


FIG. 20D

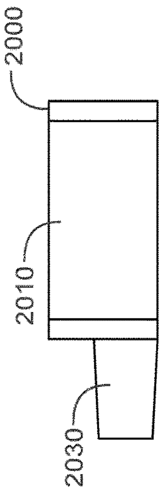


FIG. 20C

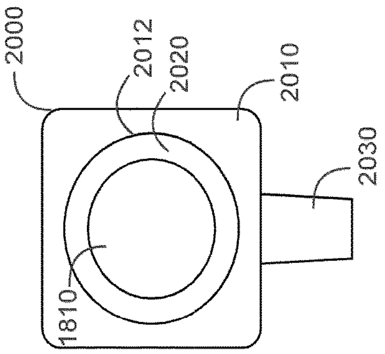


FIG. 20A

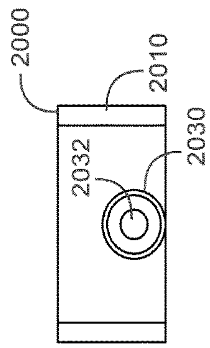


FIG. 20B

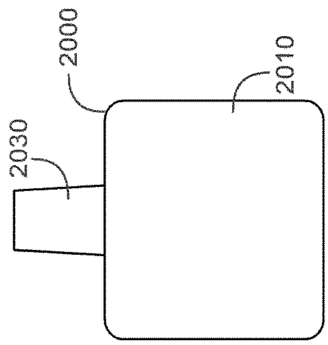


FIG. 20F

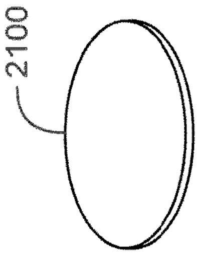


FIG. 21C

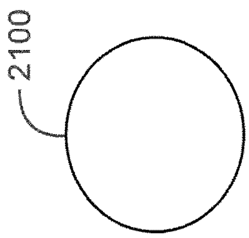


FIG. 21A

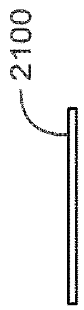


FIG. 21B

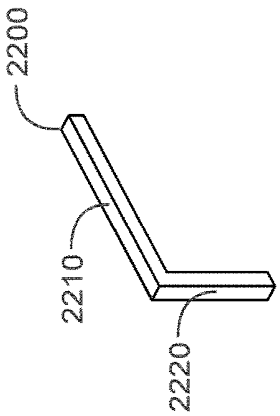

FIG. 22B

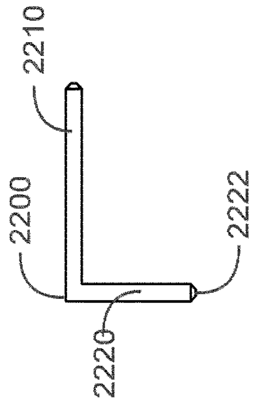

FIG. 22D

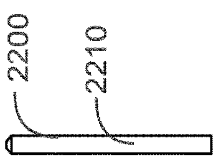

FIG. 22A

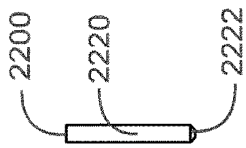

FIG. 22C

# PATIENT MONITORING SYSTEM

## PRIORITY CLAIM

This application claim priority benefit to U.S. Prov. App. Nos. 61/645,570 filed May 10, 2012, 61/713,482 filed Oct. 13, 2012, and 61/775,567 filed Mar. 9, 2013, each of which is hereby incorporated by reference herein in its entirety. This application is also a continuation-in-part of U.S. application Ser. No. 13/527,370, filed Jun. 19, 2012, entitled PATIENT MONITORING SYSTEM, which claims priority benefit to U.S. Prov. App. Nos. 61/499,515, filed Jun. 21, 2011, entitled BLOOD PRESSURE MONITORING SYSTEM, and 61/645,570, filed May 10, 2012, entitled PATIENT MONITORING SYSTEM.

## BACKGROUND

Hospitals, nursing homes, and other wearer care facilities typically include patient monitoring devices at one or more bedsides in the facility. Patient monitoring devices generally include sensors, processing equipment, and displays for obtaining and analyzing a medical wearer's physiological parameters such as blood oxygen saturation level, respiratory rate, and the like. Clinicians, including doctors, nurses, and other users, use the physiological parameters obtained from patient monitors to diagnose illnesses and to prescribe treatments. Clinicians also use the physiological parameters to monitor wearers during various clinical situations to determine whether to increase the level of medical care given to wearers. Additionally, monitoring equipment is often used in corporate care facilities, fitness facilities, recreational and home care applications, as well as mobile or other emergency care environments.

Blood pressure (which can refer to diastolic pressure, systolic pressure, and/or some combination or mathematical representation of same) considered one of the principal vital signs, is one example of a physiological parameter that can be monitored. Blood Pressure monitoring is an important indicator of a wearer's cardiovascular status. Many devices allow blood pressure to be measured by manual or digital sphygmomanometer systems that utilize an inflatable cuff applied to a person's arm. The term "sphygmomanometer" is meant to receive its ordinary broad meaning known to an artisan to include devices used to measure blood pressure. These devices often include an inflatable cuff to restrict blood flow and a device capable of measuring the pressure. Other device(s) are used to determine at what pressure blood flow is just starting and at what pressure it is just unimpeded, commonly referred to as "systolic" and "diastolic," respectively. The term "systolic blood pressure" is meant to receive its ordinary broad meaning known to an artisan to include the pressure exerted on the bloodstream by the heart when it contracts, forcing blood from the ventricles of the heart into the pulmonary artery and the aorta. The term "diastolic blood pressure" is meant to receive its ordinary broad meaning known to an artisan to include the pressure in the bloodstream when the heart relaxes and dilates, filling with blood.

In a typical pressure monitoring system, a hand actuated pump or an electric motor inflates the inflatable cuff to a pressure level at or above the expected systolic pressure of the wearer and high enough to occlude an artery. Automated or motorized blood pressure monitoring systems use a motor or pump to inflate the inflatable cuff, while manual blood pressure monitors typically use an inflation bulb. As the air from the inflatable cuff is slowly released, the wearer's



blood pressure can be determined by detecting Korotkoff sounds using a stethoscope or other detection device placed over an artery.

Alternatively, digital sphygmomanometers compute diastolic and systolic pressure as the inflatable cuff deflates based on the oscillations observed by a pressure sensor on the cuff. For example, some digital sphygmomanometers calculate the systolic blood pressure as the pressure at which the oscillations become detectable and the diastolic pressure as the pressure at which the oscillations are no longer detectable. Other digital sphygmomanometers calculate the mean arterial pressure first (the pressure on the cuff at which the oscillations have the maximum amplitude). The diastolic and systolic pressures are then calculated based on their fractional relationship with the mean arterial pressure. Other algorithms are used, such as identifying the change in slope of the amplitude of the pressure fluctuations to calculate the diastolic pressure.

As mentioned above, the foregoing methods of determining blood pressure include inflating the cuff to a pressure high enough to occlude an artery and then determining blood pressure during deflation of the inflatable cuff. Occluding the artery and then determining blood pressure during deflation can have a number of drawbacks. For example, inflating the inflatable cuff to a pressure higher than systolic pressure can cause pain and discomfort to the wearer. Other adverse effects can include limb edema, venous stasis, peripheral neuropathy, etc, or simply wearer interruption. In addition, as the artery is completely occluded prior to each measurement, sufficient time must elapse between measurements to ensure accurate results. Furthermore, manual systems make it difficult to measure blood pressure during inflation of the inflatable cuff due to the difficult of inflating the inflatable cuff at an approximately constant rate using an inflation bulb.

Digital blood pressure monitors can have additional drawbacks. The motors used to pump gas into the cuff are often noisy and can disturb wearers at rest. This is especially problematic in recovery situations. In addition to auditory noise in automated or motorized systems, the motors can cause electrical noise in sensor signals making signal processing used to identify reference points for blood pressure detection unreliable and difficult. Furthermore, portable motorized blood pressure monitors require a significant amount of power to produce the air pressure required to inflate the cuff. Since batteries are often used to provide power, designers often use large batteries and/or batteries that frequently need to be recharged or replaced. When a large batter is chosen, its size often offsets the goals of portability as an appropriate housing becomes more cumbersome and less convenient.

## SUMMARY

Based on at least the foregoing drawbacks, a need exists for a patient monitoring system that relatively quickly determines blood pressure measurements without necessarily greatly disturbing a patient. Moreover, a need exists for a portable patient monitoring system with battery longevity. Accordingly, the present disclosure includes embodiments of a patient monitoring system including a gas reservoir filled with a sufficient quantity of compressed gas to inflate an inflatable cuff and a sensor to detect blood pressure data. The gas in the gas reservoir can inflate the inflatable cuff at a controlled rate, such as, for example, at an approximately constant rate. Manual and/or electronically controlled regulators and/or valves can be used to control the flow rate of the gas into and out of the inflatable cuff. In some embodiments, the regulators and/or valves can be electronically controlled using pulse-width modulation (PWM) schemes.

A patient monitor can also be included as part of the patient monitoring system. During inflation or deflation of the inflatable cuff, the patient monitor can receive the blood pressure data from the sensor and use the blood pressure data to determine output measurements responsive to the blood pressure of the wearer. The sensor can be a pressure sensor and can be used to detect pressure variations in the inflatable cuff due to inflation, deflation, and blood flow in an artery of the wearer. Alternatively, the sensor can be an auditory sensor or stethoscope. A caregiver can use the stethoscope or auditory sensor to determine blood pressure measurements without the use of the patient monitor.

In some embodiments, an on-off linear valve controls the flow of high pressure gas. The valve has a body, a cap and an actuator. The body has an input nozzle defining the input port. The cap has an output nozzle defining the output port. The actuator is disposed between the body and the cap. The actuator has an open position that allows gas flow from the input port to the output port and a closed position that prevents gas flow from the input port to the output port. The actuator has a shape memory alloy (SMA) wire loop in communication with an electrical plug. The SMA wire loop contracts and expands in response to current applied to the electrical contacts so as to move the actuator between the closed position and the open position.

In an embodiment, the on-off linear valve actuator has a plunger, a seal, a spring and an SMA wire loop. The plunger has a seal end and a spring end. A seal is disposed at the seal end and is configured to press against a seat disposed in the body proximate the input port. The seal prevents gas flow through the input port in the valve closed position. A spring is disposed at the spring end so as to bias the seal against the seat. The SMA wire loop has a closed end strung through the plunger and open ends fixedly secured proximate the cap. The SMA wire loop pulls the actuator against the force of the spring when current flows through the electrical contacts so as to move the seal away from the seat as the actuator moves from the closed position to the open position.

In various other embodiments, the on-off linear valve plunger has a cylindrical piston and semi-cylindrical rails disposed around the walls of the piston. The body has a generally elongated hollow shell with a closed first end defining the input nozzle and a generally open second end that receives the cap. A generally square cross-sectioned exterior defines body edges, and a fluted interior accommodates the actuator. In particular, the fluted interior has semi-cylindrical grooves proximate the shell edges and partially-cylindrical grooves proximate the shell sides. The semi-cylindrical grooves receive the plunger rails which slidably fit within the grooves. The partially-cylindrical grooves receive the relatively smaller-diameter piston so as to define gas channels that accommodate gas flow between the input port of the body and the output port of the end cap. This gas flow initiates when the seal is pulled away from the seal seat by the SMA wire in opposition to the spring during valve actuation.

In some embodiments, a pressure sensor is responsive to a predetermined gas pressure threshold so as to create a conductive path across sensor contacts. The pressure sensor includes a sensor housing and a chamber defined within the housing. A nozzle extends externally from the sensor housing, and an nozzle aperture is defined within the nozzle and extends to the chamber. Electrical contacts are partially disposed within the chamber and extend from the chamber to a terminus external to the housing. A flexible conductive element is disposed within the chamber proximate the contacts. The conductive element is responsive to gas pressure exerted at the nozzle and translated into the chamber via the nozzle aperture so as to cause the conductive element to bridge the electrical contacts. The electrical contacts are configured to conduct current when bridged by the conductive element so as to indicate a gas pressure threshold at the nozzle.

## BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will be described hereinafter with reference to the accompanying drawings. These embodiments are illustrated and described by example only, and are not intended to limit the scope of the disclosure. In the drawings, similar elements have similar reference numerals.

FIG. **1**A is an exemplary block diagram illustrating an embodiment of a patient monitoring system;

FIG. **1**B is an exemplary block diagram illustrating an embodiment of gas pathways between different components of the patient monitoring system of FIG. **1**A;

FIG. **2** is an exemplary system diagram illustrating an embodiment of the patient monitoring system of FIG. **1**;

FIGS. **3**A-**3**G illustrate an exemplary embodiment of a patient monitoring system configured to be worn by a user;

FIGS. **3**H-**3**J are perspective views of an embodiment of the gas reservoir assembly.

FIGS. **4**A-**4**C are plot diagrams illustrating embodiments of pressure variations of an inflatable cuff associated with a wearer during blood pressure measurement; and

FIGS. **5**A and **5**B are flow diagrams illustrating embodiments of a process implemented by a patient monitor for measuring the blood pressure of a wearer.

FIG. **6**A is a flow diagram illustrating another embodiment of a process implemented by the patient monitor for measuring blood pressure of a wearer.

FIG. **6**B is a flow diagram illustrating yet another embodiment of a process implemented by the patient monitor for measuring blood pressure of a wearer.

FIG. **7**A is a flow diagram illustrating an embodiment of a process implemented by the patient monitor for filtering the blood pressure data and determining blood pressure.

FIG. **7**B is a flow diagram illustrating an embodiment of a process **750** implemented by the patient monitor **206** for determining an end of inflation point for the blood pressure cuff.

FIGS. **8**A-D are input-port/pin-side, input-port/stub-side, output-port/stub-side and output-port/pin-side perspective views, respectively, of an on-off linear valve;

FIG. **9** is an exploded perspective view of an on-off linear valve;

FIG. **10** is a exploded perspective view of an on-off linear valve actuator;

FIGS. **11**A-G are top, perspective, side, port end, open end, side cross-section and open-end cross-section views, respectively, of an on-off linear valve body;

FIGS. **12**A-E are top, perspective, side, insert end, and output-port end views, respectively, of an on-off linear valve cap;

FIGS. **13**A-E are top, perspective, side, seal end and spring end views, respectively, of an on-off linear valve plunger;

FIGS. **14**A-E are top, perspective, side, wire-end and plug-end views, respectively, of a lock pin; and

FIGS. **15**A-F are top, front, back, side, front-perspective and back perspective views, respectively, of a high pressure port seal.

FIGS. **16**A-B are cutaway side views of a pressure sensor in a normally open position and a closed position, respectively;

FIGS. **17**A-F are front and back perspective views, and top, front, side and back views, respectively, of a pressure sensor embodiment;

FIGS. **18**A-B are top and bottom partial exploded views, respectively, of a pressure sensor embodiment;

FIGS. **19**A-D are top, side, bottom and top perspective views, respectively, of a contact housing;

FIGS. **20**A-F are top, front, left, back, top perspective and bottom views, respectively, of a nozzle housing;

FIGS. **21**A-C are top, side and perspective views, respectively, of a conductive disk; and

FIGS. **22**A-D are top, perspective, side and front views, respectively, of an electrical contact pin.

## DETAILED DESCRIPTION

A patient monitoring system advantageously includes a gas reservoir filled with sufficient quantities of compressed gas to inflate an inflatable cuff. The gas reservoir provides several advantages to the blood pressuring monitoring system, including portability, reusability, disposability, reduction in auditory noise and electrical noise, and the ability to measure blood pressure during inflation of the blood pressure cuff.

In an embodiment, the gas reservoir of the patient monitoring system inflates the inflatable cuff at an approximately constant rate with less auditory noise. By providing a quieter environment, the patient monitoring system is capable of taking blood pressure measurements without significantly disturbing the wearer. In addition, the use of the gas reservoir can significantly reduce the amount of potentially interfering electrical noise on electrical signals from one or more sensors. Furthermore, the addition of the gas reservoir allows the patient monitor to take blood pressure measurements during inflation of the inflatable cuff.

Measuring blood pressure during inflation can reduce the time required for blood pressure measurements and the amount of pressure used. In some embodiments, the patient monitoring system can measure blood pressure in 15-20 seconds or less. Furthermore, measuring blood pressure during inflation can reduce or eliminate the need to occlude a wearer's artery.

In addition, the gas reservoir of the present disclosure can be manufactured as a smaller portable patient monitor. The gas reservoir can eliminate the need for a pump and/or motor in the portable patient monitor, thereby reducing its size. In an embodiment, the gas in the gas reservoir can be used to generate electricity for the portable patient monitor, thereby reducing or eliminating the need for a battery and further reducing the size of the portable patient monitor.

In addition to the foregoing, other embodiments of the present disclosure include patient monitoring systems with canister inflation and one or more backup inflation systems. For example, in an embodiment, when the patient monitor is for whatever reason without sufficient gas to make a reliable, accurate blood pressure measurement, a motor and pump and/or inflation bulb may advantageously be used in place of the canister. In an embodiment, the foregoing backup inflation system(s) is part of the patient monitoring system and is activated when gas from the gas canister is unavailable, unwanted, insufficient, or the like. For example, in an embodiment, a user may designate which inflation system they would prefer based on, for example, proximity to power, battery use desires, gas use management, portability, emergency, surgical, other critical monitoring environments, or the like. In still further additional embodiments, the forgoing backup inflation system(s) are separate systems that connect to the monitor in place of the canister.

In an embodiment, measurements by a patient monitoring system of the present disclosure may be controlled through applications or software executing on one or more computing devices, such as a smart phone, tablet computer, portable digital devices of all types, or other computing devices or systems or combinations of the same. In an embodiment, the computing device may include modules governing the measurement frequency during periodic measurements. In an embodiment, the applications or software may include exercise related software configured to use blood pressure measurements to enhance feedback to users on a performance of the exercise, such as, for example, calories spent, heart rate trending or the like. Additionally, inputs may include type of exercise, user demographics like height, sex, age, weight or the like. Based on the inputs, the portable digital device can provide exercise recommendations, such as walking, running, cycling or other physical activities.

In still additional embodiments of the disclosure, the patient monitoring system may communicate with electronics of the canister for quality control to ensure it is an authorized canister, for canister characteristics information, such as type, pressure, size, manufacturer, or the like. Simultaneously, the monitor may communicate with electronics of the cuff and or sensors.

In additional embodiments of the disclosure, a patient monitoring system may connect to a gas supply supplied at a premises. For example, a hospital or other caregiver environment may have pressurized gas available from connection in a room, group of rooms, beds, instruments, or the like and straightforward connection of the monitor to the gas supply may supplement or replace the canister.

In yet another embodiment, a display of a patient monitoring system may present measurement data in a manner that reduces a need for translation when used by speakers of different languages. For example, the display may include icons, numbers, colors, analog style digital gauge icons, such as a dial, gas bar or the like, audible and/or visual alarms, combinations of the same or the like to convey measurement information to a user or caregiver.

In still further embodiments, the monitor may be entirely portable and configured to mount to an arm, wrist, waist or belt harness, carried in a pocket of the like.

Various embodiments will be described hereinafter with reference to the accompanying drawings. These embodiments are illustrated and described by example only, and are not intended to be limiting.

Patient Monitoring System

FIG. **1** is a block diagram illustrating an embodiment of a patient monitoring system **100** for measuring blood pressure of a wearer, which may also be referred to as taking blood pressure measurements, using an inflatable cuff **104**. The patient monitoring system **100** can be used to measure the blood pressure of a wearer during inflation, deflation or both. In an embodiment, the patient monitoring system **100** includes a gas reservoir **102**, the inflatable cuff **104** and a patient monitor **106**.

The gas reservoir **102** houses compressed gas and is operatively connected to the inflatable cuff **104** via a gas pathway. In an embodiment, a regulator **103** is in the gas pathway between the inflatable cuff **104** and reservoir **102**.

In an embodiment, the regulator **103** provides a desired pressure or flow in the cuff-side so long as there is sufficient pressure on the reservoir side. Thus, gas flows from the gas reservoir **102**, through the regulator **103** to the bladder of the inflatable cuff **104**. In one embodiment, the gas pathway is an airtight pathway constructed of any number of materials including, but not limited to, metal, plastic, cloth, combinations of the same or some other airtight material.

The gas reservoir **102** can be implemented using one or more disposable or reusable gas tanks, cylinders, bottles, canisters, or cartridges, of any number of shapes or sizes, and can be located in the same room as the wearer, or can be remotely located from the wearer, such as in a different room or even in a different building. For example, the gas reservoir **102** can include a large gas tank that remains in a stationary location. The gas reservoir **102** can be large enough to contain sufficient gas for a large number of blood pressure readings (e.g. more than 100). Furthermore, the gas reservoir **102** can store compressed gas at any number of PSI levels. For example, the gas reservoir can store compressed gas up to about 6000 PSI or more, depending on the safety conditions of the environment. Furthermore, the gas tank can be configured to supply gas to multiple inflatable cuffs **104**, thereby limiting the number of gas tanks used for multiple wearers. When the pressure levels in the gas tank reach a threshold, the gas tank can either be refilled, replaced or a combination of both. For example a rotating cache of gas tanks can be used as the gas reservoir **102**.

Alternatively, the gas reservoir **102** can be implemented using a small gas tank of any number of sizes. For example, the gas reservoir **102** can be implemented using a gas tank that is small enough to fit in the palm of a hand, such as a carbon dioxide ($CO_2$) cartridges similar to or the same as those used for paint ball guns, tire inflation, or the like, $CO_2$ cartridges are available from a number of different manufacturers and distributors, such as the AirSource 88 Gram Pre-filled Disposable $CO_2$ cartridge available from Crosman (Product Code: CRO-88-GRAM). The PSI levels for smaller gas tanks can also differ greatly and can store compressed gas up to about 2000 PSI or more. In one embodiment, the gas reservoir **102** is implemented using a gas tank of compressed gas at about 1000 PSI. The small gas reservoir **102** can be used where mobility is desired. For example, paramedics or first responders can carry a small gas reservoir **102** for measuring blood pressure of persons needing emergency medical care. Using the gas reservoir **102**, the emergency personnel (or some other user) can measure the blood pressure of the wearer during inflation of the inflatable cuff, deflation, or a combination of the two. The measurements can be taken using a patient monitor **106**, manually using a stethoscope, or other methods.

In one embodiment, a pressure regulator, or regulator **103**, placed at an opening of the gas reservoir **102** controls whether gas can exit the gas reservoir and the amount of gas allowed to exit. In one embodiment, the regulator **103** is a valve. The regulator **103** can also be configured to control the rate at which gas flows to the inflatable cuff **104**, as well as the pressure of the gas or PSI level. The regulator **103** can include a second regulator near the opening of the gas reservoir **102** or in the gas pathway to form a two-stage pressure regulator. Additional regulators can be added as desired. The regulator **103** and/or valve can be implemented using any number of different valves, such as a globe valve, butterfly valve, poppet valve, needle valve, etc., or any other type of valve capable of operating as a variable restriction to the gas flow. Furthermore, the regulator **103** can include a pressure gauge to identify the pressure levels of the gas exiting the gas reservoir **102** and/or in the gas pathway.

Using the regulator **103**, the inflatable cuff **104** can be inflated at a controlled rate, such as, for example, an approximately constant rate or linear rate. By inflating the inflatable cuff at a controlled rate, the wearer's blood pressure can be measured during inflation and without occluding the artery. The regulator **103** can further include a wireless transmitter for communication with the patient monitor **106**, which in turn may electronically control and/or monitor the flow of gas through the regulator **103**. Alternatively, the regulator **103** can communicate with the patient monitor via wired communication. Additionally, the gas reservoir **102** can include a pressure gauge to monitor the remaining pressure and/or the amount of compressed gas remaining in the gas reservoir **102**. The pressure gauge can communicate the pressure levels to the patient monitor **106** via wired or wireless communication, similar to the regulator **103**. Once the pressure gauge indicates a threshold pressure level or gas level has been reached, the patient monitor **106** can indicate that the gas reservoir **102** should be replaced or refilled.

The gas reservoir **102** can contain any number of compressed gases to inflate the inflatable cuff **104**. For example, the gas reservoir **102** can contain compressed air, carbon dioxide, nitrogen, oxygen, helium, hydrogen, etc. Any number of other gases can be used to inflate the inflatable cuff **104**. Furthermore, the gas reservoir **102** may house enough gas to inflate the inflatable cuff **104** without the use of a motor or pump during the inflation. The gas reservoir **102** can be pre-filled with gas near the wearer or at a remote site away from the wearer. In one embodiment, the gas reservoir **102** is filled with gas prior to being associated with the inflatable cuff **104**. Pre-filling the gas reservoir **102** prior to use can significantly reduce the ambient noise caused during inflation of the inflatable cuff **104**. In addition, by using the gas reservoir **102**, the electrical noise from a motor can be removed. The reduction in ambient and electrical noise and the approximately constant rate of inflation of the inflatable cuff **104** allows the patient monitor **106** to measure the wearer's blood pressure while the inflatable cuff **104** is inflating. In addition, the gas reservoir **102** can be used to quickly inflate the inflatable cuff **104** for blood pressure measurements taken during deflation of the inflatable cuff **104**.

In some embodiments, multiple gas reservoirs **102** are included as part of the patient monitoring system **100**. The multiple gas reservoirs **102** can be used for backup purposes or for different tasks. For example, a first gas reservoir **102** can be a large gas reservoir and can be used to supply gas to the inflatable cuff **104** when the user is stationary. A second optionally smaller gas reservoir **102** can also be provided. When the user moves away from the first gas reservoir **102**, the first gas reservoir can be disconnected from the inflatable cuff **104** and the second gas reservoir **102** will supply the gas to the inflatable cuff **104**. In certain embodiments, a pump may be connected to the inflatable cuff **104** and used when the user is stationary. When the user moves, the pump is disconnected and the gas reservoir **102** supplies the gas to the inflatable cuff **104**.

In some embodiments the gas reservoir **102** includes an identifier that identifies the gas reservoir **102** to the patient monitor **106**. The identifier can be implemented using one or more memory chips or RFIDS located on the gas reservoir and/or one or more circuit elements, such as resistors, capacitors, inductors, op-amps, etc. The identifier can include additional information regarding the gas reservoir **102**, such as the type of gas reservoir, manufacturing date and/or location, storage capacity or amount of gas that the gas reservoir **102** can hold, the quantity of gas in the gas reservoir, PSI levels, usage data, expiration dates, product histories, etc.

The patient monitor **106** can use the identifier to determine whether to use the gas reservoir **102**, whether the gas reservoir **102** is compatible with the patient monitor **106**, or whether the reservoir **102** is from an authorized supplier. The identifier can be unique for each gas reservoir **106** or for a set of gas reservoirs **102**. In some embodiments, the identifier indicates that the gas reservoir can be used with the patient monitor **106**. In certain embodiments, only gas reservoirs **102** with a particular identifier are used with the patient monitor **106**. Accordingly, gas reservoirs **102** that do not include the particular identifier can be rejected and/or ignored by the patient monitor **106**. In an embodiment, an emergency use override may allow for measurements, or a specific number of measurements in an emergency situation, even when, for example, the identifier does not indicate an authorized supplier but is otherwise safe for use.

It is to be understood that other techniques exist for implementing the gas reservoir **102** without departing from the spirit and scope of the description. For example, the gas reservoir **102** can be implemented using the central gas line of a building, such as a hospital or other healthcare facility. Alternatively, the gas reservoir **102** can be implemented using a bulb, bladder, pump, or the like. In still further embodiments, the foregoing alternatives may serve as backup options if the reservoir **102** is empty or otherwise not functional.

The inflatable cuff **104** includes a bladder and fills with gas in a manner controlled by the patient monitor **106** or manually, and is used to at least partially obstruct the flow of blood through a wearer's artery in order to measure the wearer's blood pressure. The inflatable cuff **104** can be attached to a wearer's arm or other location, and can be inflated automatically (e.g., via intelligent cuff inflation) or manually to obtain blood pressure data. Blood pressure data can include any type of signal received from a sensor sufficiently responsive to blood pressure to provide an indicator thereof to a user. Blood pressure data can be in the form of pressure sensor data, auditory sensor data, and the like.

The inflatable cuff **104** can further include a wireless transmitter for wireless communication with the patient monitor **106**. Alternatively, the inflatable cuff can include cables for sending and receiving information to and from the patient monitor **106**. The inflatable cuff can receive gas from a gas reservoir **102** via a gas pathway. Furthermore, the inflatable cuff can include a release valve for releasing the gas stored in the inflatable cuff once inflated. The release valve can be actuated electronically by the patient monitor **106** or manually by a user. In some embodiments, the release valve can be used when the pressure in the inflatable cuff **104** reaches unsafe levels or when the inflatable cuff **104** has been inflated beyond a threshold period of time. In certain embodiments, the release valve can be actuated electronically using PWM signals. In some embodiments, the inflatable cuff **104** is a disposable cuff that can be discarded after a one or a few uses. In certain embodiments, the inflatable cuff **104** can be reused many times and cleaned or sterilized between uses.

A sensor **108** can be placed in close proximity to the inflatable cuff **104** to monitor the inflatable cuff **104** during inflation and deflation. Alternatively, the sensor **108** can be located in the patient monitor **106** along a gas pathway between the gas reservoir **102** and inflatable cuff **104**, or at some other location where it is able to collect sufficient data for the patient monitor **106** to determine the blood pressure of the wearer.

The sensor **108** can be a pressure sensor or an auditory sensor. In one embodiment, the sensor **108** communicates signals responsive to the pressure in the inflatable cuff **104** to the patient monitor **106** via wired or wireless communication. The patient monitor uses the signal to determine a blood pressure measurement or change in blood pressure of the wearer. The patient monitor **106** can additionally use the pressure measurements to determine if the pressure in the inflatable cuff **104** is above a threshold or is at an unsafe level. If the pressure in the inflatable cuff **104** is above a threshold or is at an unsafe level, the patient monitor **106** can actuate an emergency release valve to deflate the inflatable cuff **104**. In an embodiment where the sensor **108** is an auditory sensor, the sensor **108** can be used to detect Korotkoff sounds. In one embodiment, the sensor **108** comprises a stethoscope.

In an embodiment, the patient monitor **106** includes a display device **110**, a user interface **112**, and a microprocessor or microcontroller or combination thereof **114**. The patient monitor **106** can further include a number of components implemented by the microprocessor **114** for filtering the blood pressure data received from the sensor **108** and determining the blood pressure of the wearer. The patient monitor **106** can be a dedicated device for determining blood pressure and other physiological parameters, a portable electronic device configured to execute a program or application that determines blood pressure and other physiological parameters, or can be part of a larger patient monitoring device, such as those devices described in U.S. patent application Ser. No. 09/516,110, titled "Universal/Upgrading Pulse Oximeter" filed Mar. 1, 2000 (MASIMO.162C1); U.S. patent application Ser. No. 12/534,827, titled "Multi-Stream Data Collection System For Noninvasive Measurement Of Blood Constituents," filed Aug. 3, 2009 (MLHUM.002A); U.S. patent application Ser. No. 12/497,523, titled "Contoured Protrusion For Improving Spectroscopic Measurement Of Blood Constituents," filed Jul. 2, 2009 (MLHUM.007A); U.S. patent application Ser. No. 12/882,111, titled "Spot Check Monitor Credit System," filed Sep. 14, 2010 (MLHUM.022A); U.S. patent application Ser. No. 13/308,461, titled "Handheld Processing Device Including Medical Applications For Minimally And Non Invasive Glucose Measurements," filed Nov. 30, 2011 (MLHUM.039A) and U.S. patent application Ser. No. 11/366,995, titled "Multiple Wavelength Sensor Equalization," filed Mar. 1, 2006 (MLR.003A). Each of which is incorporated by reference herein.

In some embodiments, the patient monitor **106** is configured to communicate with the inflatable cuff **104** and/or the gas reservoir **102** via wired or wireless communication, such as LAN, WAN, Wi-Fi, infra-red, Bluetooth, radio wave, cellular, or the like, using any number of communication protocols. The patient monitor **106** can further be configured to determine blood pressure measurements of a wearer when the inflatable cuff **104** is being inflated with gas from the gas reservoir **102**, during deflation of the inflatable cuff **104**, or a combination of both. The patient monitor **106** can use the microprocessor **114**, the filtering component, and blood pressure monitoring component to determine the blood pressure measurements. The blood pressure measurements determined by the patient monitor **106** can be displayed on the display **110**. In addition, the display **110** can display blood pressure data and filtered blood pressure data in the form of plots of the pressure of the inflatable cuff and plots of the pressure oscillations in the inflatable cuff **104** caused by blood flowing through an artery of the wearer. Furthermore, the patient monitor **102** can calculate and the display **110** can display additional physiological parameters, such as heart rate, perfusion, oxygen saturation, respiration rate, activity information, temperature, and the like, combinations thereof or the trend of any of the above.

The user interface **112** can be used to allow a user to operate the patient monitor **106** and obtain the blood pressure measurements and/or other physiological parameters. Furthermore, the user interface **112** can allow a user to set or change any number of configuration parameters. For example, using the user interface **112**, a user can determine what is displayed on the display **110**, such as the blood pressure measurements during inflation and/or deflation, additional physiological parameters, the pressure plots, and/or other physiological parameters, etc. Furthermore, the user interface **112** can allow a user to set what measurements of what parameters the patient monitor **106** should take. For example, the user can set the configuration parameters to take blood pressure measurements only during inflation or deflation. Alternatively, the user can use the user interface **112** to set the configuration parameters to take blood pressure measurements during inflation and deflation and then use both measurements to determine an appropriate blood pressure. In addition, using the user interface **112**, the user can determine how often the patient monitor **106** takes blood pressure measurements, or other physiological parameter measurements. The user interface **112** can further be used for any other type of configuration parameters that can be set or changed by a user. In some embodiments, the user interface **112** is implemented as an application of a portable electronic device.

In some embodiments, the patient monitor **106** monitors the use of the gas reservoir. To monitor the use of the gas reservoir **102**, the patient monitor can monitor the number of times that the gas reservoir **102** is used to fill the inflatable cuff **104**, the amount of time that the gas reservoir **102** is supplying gas, current pressure levels within the gas reservoir **102**, and the like.

The patient monitor **106** can store usage data of the gas reservoir **102** in a memory device located on or in the gas reservoir **102**. In some embodiments, the memory device is the identifier discussed previously. In certain embodiments, the memory device is located in the patient monitor **106** or some other location, and a unique identifier of the gas reservoir **102** can be used to correlate a particular gas reservoir **102** with its usage data.

Each time the gas reservoir **102** is used to inflate the inflatable cuff **104**, the patient monitor **106** can update the usage data. In some embodiments, the usage data reflects a total number of instances in which the gas reservoir has been used to inflate the cuff **104**. In certain embodiments, the usage data reflects the amount of time that the gas reservoir **102** has been supplying gas and the rate at which the gas has been supplied. Further embodiments can use any combination of the embodiments described herein.

Using the number of times that the gas reservoir has been used to fill the inflatable cuff **104** and other data regarding the gas reservoir **102**, the patient monitor **106** can determine when the gas reservoir **102** will run out of gas and/or the number of remaining uses. In certain embodiments, the patient monitor **106** uses the storage capacity of the gas reservoir **102** and the amount of gas used to fill the inflatable cuff **104** to determine the number of times the gas reservoir can be used to fill the inflatable cuff **104** before it should be replaced. In some embodiments, the patient monitor **106** calculates the total amount of time the gas reservoir **102** is able to output gas before it should be replaced based on the storage capacity and the rate of flow of the gas. The patient monitor **106** can also account for any change to the rate of flow. Additional methods can be used to calculate whether the gas reservoir **102** should be replaced. For example, a pressure sensor can be used to determine the pressure levels within the gas reservoir **102**.

When the usage data indicates that the capacity of the gas reservoir **102** is about to be (or has been) met, the patient monitor **106** can alert a user that the gas reservoir **102** should be replaced. The patient monitor **106** can alert a user by sounding an alarm, flashing a light, sending an email, text message, fax, page, or the like to a user.

In an embodiment where many canisters may be in circulation with one or more monitors, the monitor may use a canister ID to track usages for different canisters, such as, for example, the identifier. In embodiments where each canister includes accessible memory storage, the usage information stored in such memory may be updated by the monitor or canister during use.

FIG. **1B** illustrates a block diagram of gas pathways between different components of the patient monitoring system **100**. As described previously, the patient monitoring system **100** can include a gas reservoir **102**, an inflatable cuff **104**, a patient monitor (not shown), a pressure sensor **108**, a flow valve **120**, an emergency shutoff **122**, and gas pathways **124**. The gas from the gas reservoir **102** travels via the gas pathways **124** and valve **120** to the inflatable cuff **104**.

The flow valve **120** can direct the gas from the gas reservoir **102** to the cuff **104** or to an exit pathway. During deflation of the cuff **104**, the flow valve can direct the gas from the cuff **104** to the exit pathway. In some embodiments, the flow valve is controlled using PWM signals. The pressure sensor **108** measures the pressure within the gas pathway as well as the changes in pressure due to the blood pressure of the wearer. The emergency shutoff **122** can be used to quickly deflate the cuff **104** as desired. The components illustrated in FIG. **1B** can be located in different positions. For example, the pressure sensor **108** and emergency shutoff **122** can be located on or in the cuff **104**.

FIG. **2** illustrates a patient monitoring system **200** similar to the patient monitoring system **100** of FIG. **1**. Similar to the patient monitoring system **100** of FIG. **1**, the patient monitoring system **200** of FIG. **2** includes a gas reservoir **202**, an inflatable cuff **204**, a patient monitor **206**, and a sensor **226** a like gas pathway between the reservoir **202** and cuff **204**. In addition, the patient monitoring system **200** includes the gas pathway having a number of gas pathway segments **210**, **214**, **218** and valves **212**, **216**, **222** facilitating the movement of gas throughout the system. The gas reservoir **202**, the inflatable cuff **204**, the patient monitor **206**, the valve **216**, and the sensor **226** can communicate using wired or wireless communication. Cables **228** can be used to facilitate communication between the various components of the patient monitoring system **200**. The various components can be connected to each other or connected to a central location, such as the patient monitor **206**. Alternatively, the cables **228** can be removed and the patient monitor **202** can communicate with the other components of the patient monitoring system via wireless communication.

As mentioned previously with reference to FIG. **1**, the gas reservoir **202** can be implemented using one or more gas tanks of any number of different sizes. In addition, the gas reservoir **202** can be located in the same room as the wearer or can be located at a remote location, such as in a different room or different building from the wearer. In such an embodiment, the gas pathway runs from the wearer to the remote location where the gas reservoir **202** is located. In addition, the gas reservoir **202** can be filled with any number of different gases prior to use with the wearer **218**. In other words, the gas reservoir **202** can be filled with gas prior to installation with the other components of the patient monitoring system **200**. In one embodiment, the gas reservoir **202** is filled with a compressed gas.

Furthermore, in an embodiment, the gas from the gas reservoir **202** can be used to generate electricity for the patient monitoring system **200**. A small turbine can be located near the opening of the gas reservoir **202**, along the gas pathway, or near an opening of the inflatable cuff **204**. As the gas flows by the turbine and into the inflatable cuff **202**, the turbine rotates. The rotation of the turbine can be used to generate electricity for the patient monitoring system **200**. The electricity can be fed to the patient monitor **206** so that the patient monitor **206** can process received signals and determine output measurements for the blood pressure of the wearer as the inflatable cuff inflates. Another turbine can be located near the release valve **224** of the inflatable cuff **204** or the gas pathway segment **220**. When the release valve **224** of the inflatable cuff **204** is opened or the valve **216** is actuated, the exiting gas causes the turbine to rotate, thereby generating electricity. The generated electricity can be fed to the patient monitor **206**, allowing the patient monitor to process received signals and determine output measurements for the blood pressure of the wearer as the inflatable cuff **204** deflates.

Using the gas reservoir **202** to inflate the inflatable cuff **204** can significantly reduce the ambient noise caused by the patient monitoring system, resulting in a quieter environment for the wearer. In addition, the gas reservoir **202** can supply gas at an approximately constant pressure and rate. Thus, the patient monitoring system **200** can inflate the inflatable cuff at an approximately constant rate without the auditory and electrical interfering noise of a motor or pump, resulting in a cleaner signal for the patient monitor **206**. Furthermore, by using the gas reservoir **202**, the patient monitor can measure the wearer's blood pressure during inflation of the inflatable cuff **204**.

By measuring the blood pressure during inflation of the inflatable cuff, the patient monitoring system **200** can measure the blood pressure in less time and using less pressure. Furthermore, measuring blood pressure during inflation of the inflatable cuff can reduce, and in some embodiments completely remove, the amount of time that the artery is occluded, allowing for more frequent blood pressure readings and reduced discomfort for the patient.

The gas reservoir **202** is operatively connected with the inflatable cuff **204** via the regulator **208**, gas pathway segments **210**, **214**, **218** and valves **212**, **216**. The gas pathway and gas pathway segments **210**, **214**, **218** can be made of any air-tight material, such as a plastic tube, metal, cloth, combinations or the like. Gas from the gas reservoir **202** flows through the gas pathway segments **210**, **214**, **218** to inflate the inflatable cuff **204**. In an embodiment, the regulator **208**, the gas pathway segments **210**, **214**, **218** and the valves **212**, **216**, **222** control the direction and rate of gas flow throughout the patient monitoring system **200**. The regulator **208**, which can also be a valve, located near the opening of the gas reservoir **202** controls the pressure of the gas exiting the gas reservoir **202** and along the gas pathway segment **210**. The valve **212** controls the pressure of the gas exiting gas pathway segment **210** and along gas pathway segments **214**, **218** to the inflatable cuff **204**. The regulator **208** and valve **212** can be configured as a two-stage pressure regulator and used to maintain an approximately constant pressure of gas entering the inflatable cuff **204**. The approximately constant pressure of gas may advantageously lead to an approximately constant rate of inflation of the inflatable cuff **204**. The regulator **208** and valve **212** can be configured to maintain any number of pressure levels in the gas pathway segments **210**, **214**, **218**. In one embodiment, the regulator **208** and valve **212** are configured to maintain a pressure of approximately 6 PSI (pounds per square inch) along the gas pathway segment **214** and gas pathway segment **218**.

The valve **216** located along the gas pathway segments **210**, **214**, **218** can be used to control the direction of the gas flow throughout the patient monitoring system **200**. In an "on" configuration, the valve **216** allows the gas to pass from the gas pathway segment **214** to the gas pathway segment **218** into the inflatable cuff **204**. In an "off" configuration, the valve **216** closes the gas pathway between the gas reservoir **202** and the inflatable cuff **204** and opens a gas pathway from the inflatable cuff **204** and gas pathway segment **218** to the gas pathway segment **220** and through valve **222**. The valve **216** can be actuated electronically using the patient monitor **206** or manually by a user. For safety, the default position for the valve **216** can be the "off" configuration. In this way, should there be any malfunctions, the inflatable cuff **204** can deflate. In an embodiment, the valve **216** is a three-way valve. The valve **216** can be implemented in a number of different ways without departing from the spirit and scope of the description.

The valve **222** is similar in most respects to the valve **212** and can control the rate at which gas is allowed to exit the inflatable cuff **204**. The valves **212**, **222** can be implemented as any number of different valves, such as globe valve, butterfly valves, poppet valves, needle valves, proportional valves, etc., or any other type of valve capable of operating as a variable restriction to the gas flow. Furthermore, the valves **212**, **222** can be actuated manually by a user or electronically by the patient monitor **206**.

A number of alternative embodiments exist for implementing the patient monitoring system **200** without departing from the spirit and scope of the description. For example, the valve **216** can be located in the inflatable cuff **204** or nearby. In addition, the valves **216**, **222** can be removed completely. In this embodiment, the patient monitor **206** can actuate the regulator **208** and/or valve **212** to inflate the inflatable cuff **204**. When the inflatable cuff **204** is to be deflated, the patient monitor **206** can actuate the regulator **208** and/or valve **212** a second time, as well as actuate the release valve **224**. Alternatively, two valves can be used in place of the valve **216**. One valve can be used to allow gas to flow from the gas reservoir to the inflatable cuff. The second valve can be used to release gas from the inflatable cuff. The two valves can be actuated independently or at the same time. Furthermore, the two valves can be actuated electronically using the patient monitor **206** or manually by a user.

In addition, the regulator **208** and valve **212** can be implemented using any number of different configurations. For example, regulator **208** and valve **212** can be implemented as two separate devices as shown or as one single device. Alternatively, the patient monitoring system **200** can be implemented using only the regulator **208** and/or the valve **212**. In addition, the regulator **208** or any of the valves **212**, **216**, **222** can further include a pressure gauge to identify the pressure levels of the gas. In addition, the regulator **208** and each valve **212**, **216**, **222** can communicate with the patient monitor **206** via wired or wireless communication.

As mentioned previously, the inflatable cuff **204** is used to at least partially obstruct an artery of a wearer to measure the wearer's blood pressure. In an embodiment, the inflatable cuff **204** partially obstructs the wearer's artery without occluding, or completely closing, the artery to determine a blood pressure measurement of the wearer.

In one embodiment, the inflatable cuff **204** includes a bladder, a release valve **224** and an attachment mechanism. The bladder contains the gas received from the gas reservoir **202**, via the gas pathway and can be made of any material capable of holding gas. For example, the bladder can be made of plastic, cloth, or some other airtight material. Furthermore, the bladder can be configured to hold gas at any number of PSI levels. In one embodiment, the bladder is capable of holding gas at about 4 PSI. However, it is to be understood that the bladder can hold gas at greater than or less than about 4 PSI. An opening in the bladder allows the gas from the gas reservoir to enter exit.

The attachment mechanism allows the inflatable cuff **204** to be attached to a wearer. The attachment mechanism can be made of hook and loop type fasteners, cloth, a clip, flexible materials, water wicking materials, or other material that allows the inflatable cuff **204** to attach to a wearer. The release valve **224** can be actuated manually by a user, electronically by the patient monitor **206**, or automatically based on a predefined threshold pressure level. The release valve **224** can be used to release the gas from the inflatable cuff **204** when the pressure reaches a predetermined threshold or unsafe level, or when the inflatable cuff **204** has been inflated above a threshold pressure for a predetermined amount of time.

The sensor **226** can be located on the inside of the inflatable cuff **204**, at the patient monitor **206**, along the gas pathway segments **210**, **214**, **218** or along a separate gas pathway segment, as illustrated in FIG. **2**. Alternatively, the sensor **226** can be located at the wearer's ear, wrist, finger, or other location. When obtaining blood pressure data from the finger, wrist, or ear less pressure is needed to identify the blood pressure of a wearer, which increases the amount of blood pressure measurements that can be taken by the gas reservoir **202**. As mentioned previously, the sensor **226** can be used to collect blood pressure data from the wearer. In an embodiment, the sensor **226** is a pressure sensor capable of measuring the pressure of the inflatable cuff **204** as the inflatable cuff **204** inflates and/or deflates. In another embodiment, the sensor **226** is an auditory sensor used to identify Korotkoff sounds as the inflatable cuff **204** inflates and/or deflates. The cables **228** can be used to communicate the information from the sensor **226** to the patient monitor **206**. Alternatively, the sensor **226** can use a wireless transmitter to communicate the blood pressure data to the patient monitor **206**.

As mentioned previously, the patient monitor **206** includes a display **230** capable of displaying the diastolic and systolic pressure **232** of the wearer as determined by the patient monitor **206** during inflation and/or deflation. Furthermore, the patient monitor **206** can display the blood pressure measured during inflation and deflation, thereby allowing the user to compare the values. The display **230** of the patient monitor **206** can further be configured to display pressure plots, which can include plots of the blood pressure data **236**A and filtered blood pressure data **236**B. The plots of the blood pressure data **236**A can include the pressure of the inflatable cuff **204** over time, and the plots of the filtered blood pressure data **236**B can include the pressure oscillations observed by the sensor, as will be described in greater detail below with reference to FIGS. **3**A-**3**C. In addition, the patient monitor **206** can be configured to display additional physiological parameters **234** as further illustrated on the display device **208**. These physiological parameters can include, but are not limited to, heart rate, oxygen saturation, perfusion, glucose measurements, and the like. In addition, the patient monitor **206** can include configuration parameters to control the display **230**, as well as the patient monitor **206**. Using the configuration parameters, a user can initiate blood pressure measurements of the wearer **218** to control the patient monitor **206**.

The patient monitor can also include a user interface for setting or changing the configuration parameters. The configuration parameters can be use to set the frequency and type of blood pressure measurements taken as well as the manner in which to display the measurements. In an embodiment, a periodic or other schedule can be set to obtain measurement; for example, times of day, duration between, or the like may be used to set measurement schedules. In other embodiments, the monitor may monitor other parameters, such for example, oxygen saturations, where a predetermined change in the other parameters triggers a blood pressure measurement.

The configuration parameters can determine how often a blood pressure measurement should be taken, whether it should be taken during inflation, deflation or both. Furthermore the configuration parameters can determine how the patient monitor calculates the blood pressure measurements, such as using the inflationary blood pressure measurements, the deflationary blood pressure measurements, arbitrating between the two, or using a combination such as any a statistical combination of the two or additional measurements like, for example, past measurements. Furthermore, the configuration parameters can determine how the blood pressure measurements should be displayed. For example, the configuration parameters can dictate that only inflationary blood pressure measurements, deflationary blood pressure measurements, the more reliable measurement, or combinations thereof are to be displayed. Furthermore, the configuration parameters can determine if and how the pressure plots, and other physiological parameters are to be displayed.

In addition, the patient monitor **206** can be configured to determine blood pressure measurements while the inflatable cuff **204** is inflating and without occluding the wearer's artery. The patient monitor **206** can be configured to actuate a valve connected to the gas reservoir **202**, causing gas to flow from the gas reservoir **202** to the inflatable cuff **204**. As the inflatable cuff **204** inflates, the patient monitor **206** can calculate the diastolic pressure and systolic pressure of the wearer **218** using any number of techniques, as described in greater detail below with reference to FIGS. **4**A and **4**B. For example, the patient monitor **206** can calculate the diastolic pressure and systolic pressure by measuring oscillations of blood flow in an artery or auditory cues as the inflatable cuff **204** inflates and/or deflates. By measuring the wearer's blood pressure during inflation of the inflatable cuff, both the diastolic and systolic pressure can be determined by partially obstructing the wearer's artery and without occluding it. Once the systolic pressure is measured, the patient monitor can actuate the valve **216** or a release valve **224** on the inflatable cuff **204** to release the gas within the inflatable cuff **204**.

FIGS. **3**A-**3**G illustrate an embodiment of a patient monitoring system **300** configured to be worn by a user. FIG. **3**A is a front perspective view of an embodiment of the patient monitoring system **300**. The patient monitoring system **300** includes a patient monitor **302**, an inflatable cuff **304**, and a chamber **306** to retain a gas reservoir **308**. The inflatable cuff **304** and chamber **306** can be removably attached to the patient monitor **302**. The patient monitor **302**, chamber **306**, and gas reservoir **308** will be described in greater detail below, with reference to FIGS. **3**B-**3**G.

The inflatable cuff **304** is similar to the inflatable cuffs described in greater detail above, with respect to FIGS. **1**A, **1**B, and **2**. In the illustrated embodiment, the inflatable cuff **304** includes an arm band and can be wrapped around an arm of a user. The inflatable cuff **304** can include one or more attachment surfaces **326**A, **326**B to maintain the inflatable cuff **304** in a relatively fixed position around the arm of the user. In the illustrated embodiment, the attachment surfaces **326**A, **326**B are located on either side of the patient monitor **302**. In some embodiments, the attachment surfaces **326**A, **326**B are located on one side of the patient monitor **302**, or there is only one attachment surface. The attachment surfaces **326**A, **326**B can be made from a variety of different materials, such as, but not limited to, hook and loop type fasteners, buttons, snaps, hooks, latches, tape, or other device capable of maintaining the inflatable cuff **304** in a substantially fixed position about the user.

Although not illustrated in FIG. **3**A, the patient monitoring system **300** can further include one or more sensors capable of detecting one or more physiological parameters of the user. The sensors can communicate with the patient monitor **302** via wired or wireless communication using a variety of protocols, including, but not limited to, TCP/IP, Bluetooth, ANT, ANT+, USB, Firewire, etc. For example, the patient monitoring system **300** can include one or more pressure sensors, auditory sensors, pulse oximetry sensors, thermometers, accelerometers, and/or gyroscopes. The physiological parameters detected by the various sensors can include, but are not limited to, blood pressure, heart rate, temperature, perfusion, respiration, activity rate, etc. One or more of the sensors can be located within the inflatable cuff **304** or elsewhere on the user. For example, an auditory sensor can be located on the chest of the user to collect respiration data about the user. Another auditory sensor can be located within the inflatable cuff **304** to collect blood pressure data.

FIG. **3**B is a front perspective view of an embodiment of the patient monitor **302** and the chamber **306**. In the illustrated embodiment, the patient monitor **302** includes a display **310**, a communications link indicator **312**, and user interface objects **314**, **316**. In some embodiments, the patient monitor **302** can further include a power monitor that determines the amount of power remaining for use by the patient monitor **302**. When the patient monitor is battery-operated, the power monitor can determine the amount of time or the number of blood pressure measurements that remain before the batteries are to be replaced or recharged.

The patient monitor **302** can be a device dedicated to the measurement of physiological parameters or can be a portable electronic device configured to measure physiological parameters. In some embodiments, the patient monitor **302** is a portable electronic device, such as a smartphone, tablet, or the like, running a program or application configured to calculate physiological parameters based on signals received from the sensors.

The patient monitor **302** receives data from one or more sensors and processes the data to extract physiological parameters of the user. For example, the patient monitor **302** can receive data from a pressure and/or auditory sensor and calculate the patient's blood pressure. In some embodiments, the patient monitor **302** uses accelerometer and gyroscope data to calculate an activity level of the user.

The patient monitor **302** can also provide activity recommendations based on the physiological parameters of the user. For example, the patient monitor can use the patient's height, weight, age, sex, blood pressure readings, heart rate, etc., to recommend a physical activity such as walking, running, or cycling. Furthermore, during an activity the patient monitor **302** can provide recommendations as to whether the patient should increase or decrease their activity levels.

The display **310** is an embodiment of the display **110** described above with reference to FIG. **1**A. The display **310** can be implemented using a touch screen, LCD screen, LED screen, or other type of screen and can be used to display one or more physiological parameters, plot diagrams, or user interface information, etc. The display **310** can be any number of different sizes, and in some embodiments, covers a majority of one side of the patient monitor **302**. In the illustrated embodiment, the display **310** displays heart rate data **318**, blood pressure data **320**, **322**, and a health indicator **324**. However, additional physiological parameters can be displayed, such as, but not limited to, temperature, respiration data, perfusion index data, plethysmograph data, metabolism data, such as calories/hour, etc.

The health indicator **324** can be based on the heart rate data **318**, blood pressure data **320**, **322**, other physiological parameters, or any combination thereof, and can indicate an overall well being of a user. For example, if the patient monitor **302** determines that the blood pressure data **320**, **322** is normal, an arrow can point to the middle of the health indicator **324** or the health indicator **324** can be green, etc. If the patient monitor **302** determines that the blood pressure data **320**, **322** is high or low, the arrow can point to the top or bottom health or the health indicator **324** can be red or blue, etc. Similarly, other physiological parameters or a combination of physiological parameters can be used by the health indicator **324**.

The communication link indicator **312** can be used to indicate whether a communication link is established with one or more devices, such as the sensors, a computer, a portable electronic device, etc. The communication link indicator **312** can change colors or blink depending on the status of the communication link. For example, the communication link indicator **312** can blink during initialization, can turn green once connected, and turn red when a signal is lost or is below a threshold level.

The user interface objects **314**, **316** can be implemented using hardware or software. For example, the user interface objects **314**, **316** can be buttons or keys, form part of the display **310**, or any combination thereof. The user interface objects **314**, **316** can be used to interface with the patient monitor **302**. For example, the user interface object **314** can be used to select one or more options from the patient monitor **302**, such as which physiological parameters to display, how to display the physiological parameters, toggle between which sensors to use, view historical physiological parameter data, etc. In addition, the user interface objects **314**, **316** can be used to determine the frequency with which blood pressure measurements should be taken. For example, using the user interface objects **314**, **316** the patient monitor **302** can be configured to automatically take blood pressure measurements sequentially as determined by a user, or can be configured to take only one blood pressure measurement before requiring additional input from the user. For example, in some embodiments, by pushing or holding down a user interface object, the patient monitor **302** will automatically toggle between a single measurement mode and a sequential measurement mode. Furthermore, the user interface objects

316 can be used to scroll through one or more options displayed on the display 310. Other user interface objects can be used as desired.

With continued reference to FIG. 3B, the chamber 306 can be in physical contact with the patient monitor 302. In some embodiments, the patient monitor 302 fits into a pre-formed case, which also contains the chamber 306. In certain embodiments, the patient monitor 302 includes attachment mechanisms to connect with the chamber 306. The attachment mechanisms can include, but are not limited to, clips, screws, screw holes, bars, snaps, buttons, and the like. The gas reservoir 308 fits into the chamber 308 as illustrated and as will be described in greater detail with reference to FIG. 3C. Furthermore, the chamber 306 can be adjusted to fit different sized gas reservoirs 308.

FIG. 3C is a back perspective view of the patient monitor 302 and chamber 306. The illustrated embodiment further includes a gas reservoir interface 307 as part of the chamber 306. The gas reservoir interface 307 interacts with the gas reservoir 308 to maintain the gas reservoir within the chamber 306. The gas reservoir interface 307 can include a locking mechanism that prevents the use of unapproved or unauthorized gas reservoirs 208. The locking mechanism can be a mechanical or electronic locking mechanism.

A mechanical locking mechanism can include many forms, such as threads, a clamp, lock and key designs, etc. For example, in some embodiments, the gas reservoir interface 307 can includes threads that complement threads of the gas reservoir 308. Accordingly, the gas reservoir 308 can be screwed into the chamber 306 using the gas reservoir interface 307. In some embodiments, gas reservoirs 308 that include a different number of threads, a different design of threads, or that do not include threads will not properly interface with the gas reservoir interface 307. In certain embodiments, a clamp can act as the locking mechanism to keep the gas reservoir 308 in place. In certain embodiments, the mechanical locking mechanism can be in the form of a proprietary connector. The gas reservoir interface 307 can include a particular physical layout that is uniquely designed to interface with approved or authorized gas reservoirs 308, similar to a lock and key design.

The locking mechanism can also be implemented as an electronic locking mechanism. The electronic locking mechanism of the gas reservoir interface 307 can include an electronic interface that allows the patient monitor 302 to communicate with the gas reservoir 308. The electronic interface can include a memory chip, processor, RFID, resistor, or other circuit elements that can interface with electronics on the gas reservoir 308. Authorized or approved gas reservoirs 308 can include the circuit elements that can unlock the electronic locking mechanism of the gas reservoir interface 307 and allow the gas reservoir 308 to be used with the patient monitor 302.

The illustrated embodiment also includes an interface 330 attached to the patient monitor 302 and used to maintain the patient monitor 302 in close proximity to the inflatable cuff 304. The recess 332 of interface 330 can complement a portion of the cuff 304 to lock the patient monitor 302 in place with the cuff 304. Screws 334 can be used to maintain the interface 330 attached to the patient monitor 302.

FIGS. 3D and 3E are side perspective views of the patient monitor 302 and chamber 308. FIGS. 3F and 3G are top and bottom perspectives of the patient monitor and chamber 308, respectively. With reference to FIG. 3G, the patient monitor 302 can include an electronic interface 336, such as a USB or mini-USB port. The electronic interface 336 can be used to communicate with another electronic device, such as a computer or portable electronic device. FIG. 3G further illustrates that the chamber 306 can be rotated forwards and backwards as desired. For example, the chamber 306 can be physically attached to the patient monitor 302 via a pivot that allows the chamber 306 to swing about one or more axes. The pivot can be implemented using a hinge, ball-and-socket joint, link, pin, spring, swivel, bolt, and the like. The pivot can also include a locking mechanism that can lock the chamber 306 in a certain position with respect to the patient monitor 302. The locking mechanism can be implemented using a clamp, ratchet, pin, grooves within a link, pin, spring, or bolt, and the like. In this way, the chamber 306 can be rotated to a preferred position and then locked in place for use. For example, a user can adjust the chamber 306 so that it fits snugly against their arm, or other limb, and then lock the chamber in that position so that it stays in its position when the user moves.

FIGS. 3H-3J are perspective views of an embodiment of the gas reservoir assembly 305. In the illustrated embodiment, the gas reservoir assembly 305 interfaces with the gas reservoir 308 and includes the chamber 306, a chamber cover 309, and a valve 311. Each component of the gas reservoir assembly 305 can be made of plastic, metal, or a combination thereof.

The valve 311 and the chamber 306 can each include complementary threads that allow the two components to be coupled together. In some embodiments, the valve 311 and the chamber 306 can be pressed together or use some other mechanical locking mechanism to be coupled together. The chamber 306 and chamber cover 309 can be coupled or hinged via a dowel pin 315 that is placed through hollowed portions of the chamber 306 and the chamber cover 309. The chamber 306 and chamber cover can further interface via a spring pin 317 and a ball bearing 319. The spring pin 317 can be placed through hollowed portions of the chamber cover 309 and a center of the ball bearing 319, as illustrated in FIG. 3J. As further illustrated in FIG. 3J, an inner surface 321 of the chamber cover 308 can be grooved to be form fitted with the spherical gas reservoir 308. Although illustrated as being rounded, it will be understood that the inner portion 321 of the chamber cover 309 can be any shape to interface with the gas reservoir 308.

When opened, the chamber cover 309 provides space for a user to insert the gas reservoir 308 into the chamber 306. Once closed, the chamber cover 309 and/or ball bearing 319 exert a force on the gas reservoir 308, which causes the gas reservoir 308 to be pushed into and engage the valve 311. Although not seen, a valve interface at the bottom portion of the valve 311 interfaces with the upper portion, or seal, of the gas reservoir 308. The valve interface can be hollow and relatively pointed or sharpened. Accordingly, when a sufficient force is exerted against the gas reservoir 308, the seal of the gas reservoir is broken by the valve interface, allowing the gas from the gas reservoir 308 to move freely through the gas pathway 313 of the valve 311. The valve 311 can further interface with the patient monitor 302 and the inflatable cuff 304 to inflate the inflatable cuff 304.

In addition, when closed, the chamber cover 309 can interact with the chamber 306 so that it remains closed. For example, a clasp, hook, magnet or other mechanism can interlock the chamber cover 309 with the chamber 306 to prevent the chamber cover 309 from opening during use.

FIGS. 4A-4C are plot diagrams illustrating embodiments of various plots that can be displayed by the display 230, 310 described previously. The plots in FIGS. 4A-4C are plot diagrams illustrating some embodiments of the pressure at the inflatable cuff **204**, including the oscillations of pressure, observed by the sensor **226** during inflation and deflation.

Plot **401**A is a plot diagram illustrating an embodiment of the pressure of the inflatable cuff **204** during inflation and deflation, which can also be referred to as blood pressure data. The x-axis of plot **401**A represents the number of samples taken by the patient monitor **206** over time. The patient monitor **206** can be configured to take samples at any number of increments to achieve a desired data resolution. For example, the patient monitor **206** can sample the inflatable cuff every second, millisecond, microsecond, etc. Although illustrated in increments of samples, time can also be used for the x-axis **402**. The y-axis **404**A of plot **401**A represents the pressure level, in mmHg, of the inflatable cuff **204**. The line **412** represents the pressure level of the inflatable cuff **204** over time.

Prior to point **408**, signals on the line **412** represent electronic noise caused by the environment or the patient monitoring system **200**. At point **408**, the valve **216** is actuated. The valve **216** can be actuated electronically by the patient monitor **206** or manually by a user. Once actuated, gas from the gas reservoir **202** begins to inflate the inflatable cuff **204** at a rate determined by a user electronically using the patient monitor **206** or manually using the regulator **208** and/or valve **212**. In one embodiment, the inflation rate is an approximately constant rate, which leads to an approximately constant increase in pressure in the inflatable cuff. The sensor **226** reads the rise in pressure in the inflatable cuff **204**, as indicated by the rise in line **412** of the plot **401**A. Thus, from point **408** to point **410**, the inflatable cuff is in an inflation mode and is inflating.

At point **410**, the valve **216** is actuated again, ending the inflation of the inflatable cuff **204**. Although illustrated at 200 mmHg, the point **410** can be located at any desired pressure level. In one embodiment, the **216** valve is actuated when the measured pressure level within the inflatable cuff **204** is greater than the expected systolic pressure of the wearer. The expected systolic pressure of the wearer can be determined by previous blood pressure measurements, historical information, clinical data from one or more wearers, or the like. In one embodiment, the point **410** changes between blood pressure measurements. For example, the inflatable cuff can be configured to inflate to 200 mmHg for the first measurement. If it is determined during the first measurement that the wearer's systolic pressure is measurably less than 200, then during the proximate measurement, the inflatable cuff **204** can be inflated to a lower pressure. Varying the pressure level to which the inflatable cuff **204** inflates can conserve gas. Likewise, if the wearer's measured systolic pressure is greater than the expected systolic pressure, the inflatable cuff **204** can be inflated to a greater pressure during the proximate measurement. Alternatively, the valve **216** can be actuated once the inflatable cuff **204** reaches any desired or predefined pressure level, such as 160 mmHg, 200 mmHg, 400 mmHg, etc.

In some embodiments, in addition to ending the inflation of the inflatable cuff, actuating the valve **216** also begins a deflation mode of the inflatable cuff. For example, actuating the valve **216** can close the gas pathway between the gas reservoir **202** and the inflatable cuff **204** and open the gas pathway between the inflatable cuff **204** and ambient air, allowing the gas to exit the inflatable cuff **204**. Once the valve **216** is actuated, the inflatable cuff **204** deflates leading to a decrease in pressure within the inflatable cuff **204**. Actuating the valve **216**, as well as the valve **222** can be configured so that the pressure within the inflatable cuff **204** decreases at any desired rate. In one embodiment, the pressure within the inflatable cuff **204** decreases at an approximately constant rate. Additional blood pressure measurements can be taken during the deflation of the inflatable cuff **204**, as described in greater detail below with reference to FIGS. **5**A and **5**B.

The patient monitor **206** can calculate the blood pressure of the wearer at any time during inflation and/or deflation, once it has received sufficient blood pressure data. In some embodiments, the patient monitor **206** can calculate the diastolic pressure followed by the systolic pressure during inflation of the inflatable cuff **204**. In certain embodiments, the patient monitor can calculate both diastolic and systolic pressure simultaneously once the valve **216** is actuated or during inflation, once the patient monitor **206** has sufficient blood pressure data. The patient monitor **206** can alternatively wait until additional measurements are taken during the deflation of the inflatable cuff **204** before calculating the diastolic and systolic pressure. In this way, the patient monitor can compare or arbitrate the diastolic and systolic measurements during inflation and deflation of the inflatable cuff **204** to achieve greater reliability in the measurements.

With continued reference to FIG. **4**A, the plot **401**B is a plot diagram illustrating an embodiment of the change in pressure in the inflatable cuff **204** due to blood flow in the artery during inflation and deflation of the inflatable cuff **204**. In one embodiment, the line **414** is obtained by filtering the plot **401**A and normalizing the data based on the change in pressure due to the inflation and deflation of the inflatable cuff **204** and can be referred to as filtered blood pressure data. The plot **401**B of the pressure oscillations due to the blood flow in the artery of the wearer, or filtered blood pressure data, can be displayed on the display **230**, **310** along with the plot **401**A, the blood pressure readings, and/or other physiological parameters. Similar to plot **401**A, the x-axis **402** of plot **401**B represents the number of samples taken by the patient monitor **206** over time. The y-axis **404**B of plot **401**B represents normalized changes in pressure in the inflatable cuff **204**.

As illustrated in the plot **401**B, when the valve **216** is actuated at point **408**, the inflatable cuff **204** inflates and exerts pressure against the wearer's artery. As the inflatable cuff **204** exerts pressure against the wearer's artery, the sensor **226** is able to detect the variations in pressure in the inflatable cuff **204** due to blood flow within the artery, which are also referred to as pressure variations or pressure oscillations. The pressure oscillations are illustrated in plot **401**A as small deviations or bumps in the line **412**.

As further illustrated by the plot **401**B, as the inflatable cuff **204** continues to inflate, the artery becomes increasingly obstructed, leading to greater pressure variations observed by the pressure sensor, which leads to greater oscillations in the line **414**. With continued inflation of the inflatable cuff, the variations in pressure eventually begin to decrease as the blood flow becomes occluded. At point **410**, the pressure exerted by the inflatable cuff completely occludes the artery. As mentioned previously, in one embodiment, once the artery is occluded, the valve **216** is actuated allowing the gas to exit the inflatable cuff **204** and the inflatable cuff **204** to deflate. In another embodiment, the valve **216** is actuated prior to the occlusion of the artery.

As further illustrated by the plot **401**, as the inflatable cuff **204** begins to deflate, the oscillations of the pressure observed by the pressure sensor **226** again begin to increase significantly as blood flow in the artery increases. As the inflatable cuff **204** further deflates, the pressure exerted on the artery decreases leading to a decrease in pressure variation observed by the pressure sensor **226**. Eventually, the inflatable cuff **204** exerts little to no pressure on the artery, and the blood flow in the artery has little to no effect on the pressure in the inflatable cuff **226**. The patient monitor **206** uses the characteristics of the oscillations of pressure due to blood flow through an artery of the wearer, such as the slope of the oscillations and/or the magnitude or amplitude of the oscillations, to determine the blood pressure. The patient monitor **206** can use the blood pressure data obtained during inflation and/or deflation of the inflatable cuff to determine the blood pressure.

In one embodiment, to determine the blood pressure during inflation, the patient monitor identifies the pressure in the inflatable cuff at which the largest magnitude oscillation, also referred to as the maximum deflection point or largest amplitude oscillation, during inflation is detected. In the illustrated embodiment, the pressure monitor identifies the largest magnitude oscillation at point **430**. The pressure in the inflatable cuff at which the largest magnitude oscillation during inflation is detected approximately coincides with the systolic blood pressure of the wearer. In one embodiment, the patient monitor also identifies the pressure in the inflatable cuff at which the largest slope in the oscillations prior to the largest magnitude oscillation during inflation is detected. In the illustrated embodiment, the pressure monitor identifies the largest slope in the oscillations prior to the largest magnitude oscillation at point **432**. The largest slope in the oscillations prior to the largest magnitude oscillation during inflation approximately coincides with the diastolic pressure of the wearer.

In addition, the patient monitor can determine the blood pressure of the wearer during deflation. In one embodiment, to determine the blood pressure during deflation, the patient monitor identifies the largest magnitude oscillation during deflation (point **434** in the illustrated embodiment). The patient monitor further identifies the pressure in the inflatable cuff at which the largest slope in the oscillations prior to the largest magnitude oscillation during deflation is detected (point **436** in the illustrated embodiment). The largest slope in the oscillations prior to the largest magnitude oscillation during deflation approximately coincides with the systolic pressure of the wearer. The patient monitor also identifies the pressure in the inflatable cuff at which the largest slope in the oscillations after the largest magnitude oscillation during deflation (point **436** in the illustrated embodiment). The largest slope in the oscillations after the largest magnitude oscillation during approximately deflation coincides with the diastolic pressure of the wearer.

A number of alternate methods exist for determining blood pressure during inflation and deflation of the inflatable cuff. For example, during deflation the patient monitor can calculate the systolic blood pressure as the pressure at which the oscillations become detectable and the diastolic pressure as the pressure at which the oscillations are no longer detectable. Alternatively, the patient monitor can calculate the mean arterial pressure first (the pressure on the cuff at which the oscillations have the maximum amplitude). The patient monitor can then calculate the diastolic and systolic pressures based on their relationship with the mean arterial pressure. Additional methods can be used without departing from the spirit and scope of the description. For example, pressure values at locations other than the largest magnitude oscillation or maximum deflection point and largest slope can also be used.

Plots **401**A and **401**B further illustrate the potentially adverse effect signal noise can have on the blood pressure measurements. As illustrated, signal noise is detected at least twice in line **414** prior to inflation. The detected signal noise in at least one instance exceeds the maximum deflection point during inflation. In addition, the signal noise may also contain the largest slope prior to the maximum deflection. In either event, if the signal noise is not accounted for, the patient monitor **206** is in danger of calculating diastolic and systolic pressures of the wearer at points other than during inflation or deflation. In some embodiments, based on the amount and magnitude of signal noise detected, the patient monitor can assign confidence levels to the blood pressure measurements. Based on line **414**, the patient monitor **206** can place a lower confidence level in the blood pressure measurement during inflation due to the observed signal noise.

As mentioned above, the plots **401**A, **401**B can both be displayed on the display **230**, **310** of the patient monitor **206**, **302**. The plots **401**A, **401**B can be displayed simultaneously or consecutively. In addition the plots **401**A, **401**B can be displayed along with the diastolic pressure and systolic pressure as measured by the patient monitor **206**. Furthermore, the measured diastolic pressure and systolic pressure during inflation can be displayed along with the measured diastolic pressure and systolic pressure during deflation. In addition, the patient monitor **206** can further display additional physiological parameters measured by the patient monitor **206**.

FIGS. **4**B and **4**C include plot diagrams illustrating additional embodiments of the pressure of the inflatable cuff **204** during inflation and deflation. Plots **403**A and **405**A correspond to plot **401**A, and plots **403**B and **405**B correspond to plot **401**B. Similar to plots **401**A and **401**B, plots **403**A, **403**B, **405**A, and **405**B illustrate the inflation of the inflatable cuff **204** beginning at point **408** and ending at point **410**. In addition the deflation of the inflatable cuff begins at point **410** in plots **403**A, **403**B, **405**A, and **405**B.

Plots **403**A and **403**B further illustrate signal noise being exhibited at different points throughout the lines **416** and **418**. The first observed signal noise occurs near the beginning of the lines **418** and another occurs near the end. Similar to the oscillations due to blood flow in the artery, signal noise is exhibited as small displacements on the line **416** and oscillations in the line **418**. As illustrated, unless accounted for, the signal noise occurring in plots **403**A and **403**B can have an adverse affect on blood pressure measurements due at least to their magnitude. The first detected signal noise results in the maximum deflection point prior to deflation and the last detected signal noise results in the maximum deflection point after deflation. In embodiments, where maximum deflection points are used, if inflation and deflation are not demarcated appropriately or if signal noise is not accounted for, the patient monitor **206** can erroneously determine the blood pressure measurements based on the signal noise.

The plot **403**B further illustrates an example where a blood pressure measurement taken during inflation can in some instance have a higher confidence level than the blood pressure measurement taken during deflation. As mentioned previously, during inflation, the diastolic pressure can be determined as the pressure at which the largest slope in line **418** prior to the maximum deflection point during inflation occurs (point **442** in the illustrated embodiment). The systolic pressure can be calculated as the pressure at which the maximum deflection point of line **418** occurs during inflation (point **440** in the illustrated embodiment). Upon deflation, the systolic pressure is calculated as the pressure at which the largest slope in line **418** prior to the maximum deflection point (point **444** in the illustrated embodiment) during deflation occurs (point **446** in the illustrated embodiment). Similarly, the diastolic pressure is calculated as the pressure at which the largest slope in line **418** after the maximum deflection point during deflation occurs (point **448** in the illustrated embodiment). As illustrated in plot **403**B, the maximum deflection point during deflation can be difficult to identify, which can make it difficult to calculate the diastolic and systolic pressure of the wearer accurately. Accordingly, the confidence placed in the blood pressure measurement during deflation can be relatively low compared to the confidence level placed in the blood pressure measurement during inflation. Accordingly, the patient monitor **204** can determine that the blood pressure measurement taken during inflation is likely more accurate. In addition, depending on the amount and magnitude of the signal noise detected, the patient monitor **206** can determine that neither blood pressure measurement reaches a threshold confidence level and that blood pressure measurements should be retaken.

Plots **405**A and **405**B illustrate yet another example of blood pressure measurements taken during inflation and deflation of the inflatable cuff **204**. As illustrated, signal noise is detected near the beginning of lines **420** and **422**, resulting in oscillations observed in line **422**. As mentioned previously, if not accounted for, the signal noise can adversely affect the blood pressure measurements during inflation. However, in the line **422**, the maximum deflection point prior to deflation occurs during inflation. Thus, the signal noise at the beginning of the line **422** should not affect the blood pressure measurements. Plots **405**A and **405**B further illustrate an example where the blood pressure measurement taken during inflation can have a similar confidence level as the confidence level of the blood pressure measurement taken during deflation. As illustrated, the line **418** exhibits a distinctive maximum amplitude during inflation (point **450** in the illustrated embodiment) and during deflation (point **454** in the illustrated embodiment). In the illustrated embodiment, the patient monitor calculates the largest slope during inflation as the slope at point **452**. During deflation, the patient monitor calculates the largest slop prior to the maximum amplitude at point **456** and the largest slop following the maximum amplitude at point **458**.

FIG. **5**A is a flow diagram illustrating an embodiment of a process **500**A for measuring blood pressure during inflation of an inflatable cuff **204**. As illustrated in FIG. **5**A, the process **500**A begins at block **502** by actuating a valve, which allows gas to flow from a gas reservoir **202** to the inflatable cuff **204**, causing the inflatable cuff **204** to inflate. The valve can be located near an opening of the gas reservoir **202**, at some point along the gas pathway or at the inflatable cuff **204**. In one embodiment, multiple valves **212**, **216** and/or regulators **208** can be included between the gas reservoir **202** and the inflatable cuff **204**. Each valve and/or regulator can be actuated prior to inflating the inflatable cuff **204**. The valve(s) can be actuated manually by a user or electronically by a patient monitor **206**. For example, a user can manually open the valve **216** to allow gas to flow from the gas reservoir **202** to the inflatable cuff **204**. The user can open the valve in a way that allows for the inflation of the inflatable cuff **204** at an approximately constant rate of inflation. A regulator **208** can also be used to achieve the approximately constant rate of inflation. Alternatively, a patient monitor **206** in communication with the gas reservoir can actuate the valve **216**, allowing the gas to flow from the gas reservoir **202** to the inflatable cuff **206**. Communication from the patient monitor **206** can occur by wired or wireless communication, such as a LAN, WAN, Wi-Fi, infra-red, Bluetooth, radio wave, cellular, or the like, using any number of communication protocols.

To actuate the valve, an input to the patient monitor **206** such as a button can be used. Alternatively, the patient monitor can automatically actuate the valve once the patient monitor is turned on or based on one or more configuration parameters. For example, the patient monitor can be configured to determine the blood pressure of a wearer once every time period. The timer period can be configured as any period of time, such as 6 minutes, 15 minutes, 60 minutes, etc. In yet another embodiment, the patient monitor **206** determines if the inflatable cuff is attached to a wearer. If the patient monitor **206** determines that the inflatable cuff is attached to a wearer, the patient monitor **206** can actuate the valve at predefined time intervals. Any number of methods can be used to determine if the inflatable cuff is attached to a wearer. For example, the patient monitor **206** can determine whether the inflatable cuff is attached to a wearer using infra-red sensors, pressure sensors, capacitive touch, skin resistance, processor polling or current sensing or the like.

Once the inflatable cuff **204** is inflating, the patient monitor **206** receives blood pressure data from the sensors, as illustrated in block **504**. The blood pressure data can be obtained at the inflatable cuff **204** using any number of different sensors or methods. For example, a pressure sensor can be used to identify the air pressure due to the inflation and deflation of the inflatable cuff **204**. The pressure sensor can be located at the inflatable cuff, the patient monitor **206**, at some point along the gas pathway, or some other location where it is capable of measuring the pressure of the inflatable cuff **204**. Alternatively, an auditory sensor communicatively coupled to the patient monitor **206** can be used to detect Korotkoff sounds, similar to the method used for manual determination of blood pressure using a stethoscope.

At block **506**, the patient monitor **206** filters the blood pressure data. Filtering the blood pressure data can reduce the effects of, or completely remove, environmental noise and/or the electrical noise found within the patient monitoring system. Furthermore, during filtering, the patient monitor **206** can normalize the blood pressure data to account for the changes in pressure due to the inflation and deflation of the inflatable cuff. In one embodiment, after filtering the blood pressure data, only the pressure oscillations in the inflatable cuff **204** due to blood flow in an artery of the wearer remain, and in some instances signal noise. Upon filtering the blood pressure data, the patient monitor **206** can determine the blood pressure of the wearer, as illustrated in block **508**.

The patient monitor **206** can determine the blood pressure using any number of different methods as described above with reference to FIGS. **4**A-**4**C. For example, the patient monitor **206** can determine the blood pressure of the wearer using the slopes and/or amplitude of the pressure oscillations, the mean arterial pressure, and/or the Korotkoff sounds.

Once the patient monitor **206** determines the blood pressure of the wearer, the patient monitor **206** can actuate a valve to stop gases from flowing from the gas reservoir to the inflatable cuff, as illustrated in block **510**. In one embodiment, the valve is a three-way valve **216** and actuating the valve to stop the gases from flowing from the gas reservoir to the inflatable cuff also opens the gas pathway segment **220** to release the gas from the inflatable cuff.

Fewer, more, or different blocks can be added to the process **500**A without departing from the spirit and scope of the description. For example, the patient monitor **206** can filter the blood pressure data to determine the diastolic pressure first. As the diastolic pressure is being calculated, the patient monitor **206** can continue receiving and filtering the blood pressure data to determine the systolic pressure. In an embodiment, the patient monitor can determine the blood pressure without filtering the blood pressure data. In addition, a user can determine the blood pressure measurements without the use of the patient monitor **206**. In an embodiment, a user using a stethoscope can determine the diastolic and systolic pressure during inflation of the inflatable cuff without filtering the blood pressure data.

As mentioned previously, by measuring the blood pressure during inflation of the inflatable cuff **204**, the blood pressure of the wearer can be measured in less time and using less pressure. Furthermore, because the artery is occluded for less time, or not occluded at all, the blood pressure can be measured more frequently.

FIG. **5**B illustrates a flow diagram of a process **500**B for measuring blood pressure during deflation of an inflatable cuff. At block **550**, the inflatable cuff **204** is inflated. In one embodiment, the inflatable cuff **204** is inflated using gas from a gas reservoir **202**. Using the gas from the gas reservoir **202**, the inflatable cuff **204** can be inflated very quickly leading to a relatively short wait time before blood pressure measurements can be taken.

As the inflatable cuff **204** inflates, the patient monitor determines whether a threshold pressure has been reached, as illustrated in block **552**. The threshold pressure can be any pressure level and can vary between blood pressure measurements. Furthermore, the threshold pressure can be determined based on previous blood pressure measurements, historical information, clinical data from one or more wearers, or the like. In one embodiment, the threshold pressure is above an expected systolic pressure of the wearer. In another embodiment, the threshold pressure is above an expected occlusion pressure or the pressure at which the artery is occluded. The inflation can be initiated in a manner similar to that described above with reference to FIG. **5**A. If the patient monitor **206** determines that the threshold pressure has not been reached, the inflatable cuff **204** continues to inflate. However, if the patient monitor **206** determines that the threshold pressure has been reached, the process moves to block **554**.

At block **554**, the patient monitor **206** actuates the valve to initiate deflation of the inflatable cuff **206**. In one embodiment, the valve is a three-way valve similar to valve **216** of FIG. **2**, such that the inflation of the inflatable cuff **204** ends at the same time deflation begins. Once the deflation of the inflatable cuff **204** begins, the process moves to block **556** and the patient monitor receives blood pressure data, filters the blood pressure data **558**, and determines blood pressure **560**. Greater detail regarding receiving blood pressure data **556**, filtering the blood pressure data **558** and determining blood pressure is described above with reference to blocks **504**-**408** of FIG. **5**A.

Fewer, more, or different blocks can be added to the process **500**B without departing from the spirit and scope of the description. For example, the patient monitor **206** can determine the systolic pressure prior to receiving the blood pressure data or filtering the blood pressure data to determine the diastolic pressure. In addition, the process **500**B can be implemented without the use of the patient monitor **206**. For example, a user can receive blood pressure data via a stethoscope. The user can determine the blood pressure of the wearer using Korotkoff sounds, and can also determine the blood pressure of the wearer without filtering the blood pressure data. Furthermore, process **500**A and **500**B can be combined and measurements taken during inflation and deflation of the inflatable cuff. Furthermore, the measurements taken during deflation of the inflatable cuff can be used to verify the blood pressure readings taken during inflation of the inflatable cuff **204**.

FIG. **6**A is a flow diagram illustrating another embodiment of a process **600** implemented by the patient monitor for measuring blood pressure of a wearer. FIG. **6**A is similar in many respects to FIGS. **5**A and **5**B. For example, blocks **602**-**508** of FIG. **6**A correspond to blocks **502**-**408** of FIG. **5**A, respectively. Furthermore, blocks **614**-**520** correspond to blocks **554**-**460** of FIG. **5**B, respectively.

As described above with reference to FIG. **5**A and illustrated in blocks **602**-**508**, the patient monitor **206** actuates a valve to initiate inflation, receives blood pressure data during inflation, filters the blood pressure data, and determines the blood pressure of the wearer. Upon determining the blood pressure of the wearer, the patient monitor assigns a confidence level to the blood pressure measurements, as illustrated in block **610**. The confidence level assigned can be determined in any number of ways. For example, the patient monitor can assign the confidence level based on the amount and magnitude of the noise observed in the blood pressure data, determined systolic and/or diastolic values, determined pulse pressure, determined pulse rate, and the like. In some embodiments, if an anomaly in the blood pressure data is detected or if the blood pressure data deviates beyond a threshold level a lower confidence level can be assigned to the blood pressure measurements. In an embodiment, prior measurements or other expectations or trend information may be used to determine confidence levels.

At determination block **612**, the patient monitor **206** determines if the confidence level assigned to the inflationary blood pressure measurements are above a threshold confidence level. The threshold confidence level can be determined based on previous blood pressure measurements, historical information, clinical data from one or more wearers, or the like. If the confidence level assigned to the blood pressure measurements during inflation satisfies the threshold confidence level, the patient monitor **206** outputs the inflationary blood pressure measurements, as illustrated in block **628**. The inflationary blood pressure measurements can be output to a display, a printer, another patient monitor, etc. Once output, the patient monitor **206** can actuate a valve to deflate the inflatable cuff **204** at a rate greater than would be used if the blood pressure measurements were taken during deflation. Alternatively, the patient monitor **206** can deflate the inflatable cuff **204** at the same rate as when blood pressure measurements taken during deflation.

If on the other hand, the confidence level assigned to the inflationary blood pressure measurements is less than the threshold confidence level, then the patient monitor can actuate the valve to initiate deflation of the inflatable cuff, as illustrated in block **614**. As blocks **614**-**520** correspond to blocks **554**-**460** of FIG. **5**B, additional details with respect to blocks **614**-**520** are provided above with reference to FIG. **5**B.

Upon determining the blood pressure during deflation, the patient monitor **206** can assign a confidence level to the deflationary blood pressure measurements, as illustrated in block **622** and described in greater detail above with reference to block **610**. Upon assigning the confidence level to the deflationary blood pressure measurements, the patient monitor **206** determines if the confidence level exceeds a threshold confidence, as illustrated in determination block **624**, similar to the determination made in block **612**. If the patient monitor **206** determines that the confidence level assigned to the deflationary blood pressure measurements does not exceed the confidence threshold, the patient monitor **206** can output an error, as illustrated in block **626**. The error can indicate that neither the inflationary blood pressure measurements nor the deflationary blood pressure measurements exceeded the confidence threshold. In addition, the patient monitor **206** can recommend that additional blood pressure measurements be taken.

If on the other hand, the patient monitor determines that the confidence level assigned to the deflationary blood pressure measurements exceeds the confidence threshold, the patient monitor outputs the deflationary blood pressure measurements, as shown in block **628**.

Fewer, more, or different blocks can be added to the process **600** without departing from the spirit and scope of the description. For example, in an embodiment, the patient monitor **206** automatically returns to step **602** upon outputting the error or determining that the confidence level did not exceed the confidence threshold, and repeats the process **600**. In yet another embodiment, the patient monitor **206** outputs the error as well as the blood pressure measurements having the highest confidence level.

FIG. **6**B is a flow diagram illustrating yet another embodiment of a process **650** implemented by the patient monitor **206** for measuring blood pressure of a wearer. At block **652**, the patient monitor **206** receives configuration parameters. The configuration parameters can be set by a user, another patient monitor, or preset. The configuration parameters can include when to measure blood pressure, how to calculate the diastolic and systolic blood pressure, what measurements to display, confidence thresholds, etc. For example the configuration parameters can include whether to take blood pressure measurements during inflation, deflation, or both. In addition, the configuration parameters can include information regarding what process to use to determine the blood pressure measurements. For example, the patient monitor can determine the blood pressure measurements using the measured arterial pressure, the slopes of the pressure oscillations, maximum deflection points of the filtered blood pressure data, or other criteria. The configuration parameters can also include the confidence level to be used in determining whether the blood pressure measurements should be accepted. Furthermore, the configuration parameters can include what blood pressure measurements are to be output and how to determine which blood pressure measurements to output. For example, the configuration parameters can dictate that only blood pressure measurements having a confidence level greater than a threshold are to be output, or that the blood pressure measurements having the highest threshold are to be output. Additionally, the configuration parameters can dictate that both blood pressure measurements, average blood pressure measurements, and the like are to be output. Furthermore, the configuration parameters can include the frequency with which the blood pressure measurements are to be taken.

At block **654**, the patient monitor initiates inflation based on the received configuration parameters. For example, the configuration parameters can dictate the rate at which the inflatable cuff **204** is to be inflated using the gas reservoir **202**. In an embodiment, the inflatable cuff **204** is inflated at an approximately constant rate. In another embodiment, the inflatable cuff is not inflated at an approximately constant rate. In an embodiment, the inflatable cuff **204** is inflated in a relatively short amount of time or at a very high rate of inflation. In another embodiment, the inflatable cuff **204** is inflated more slowly.

At block **656** the inflationary blood pressure measurements are determined by the patient monitor **656** based on the configuration parameters. The configuration parameters can dictate whether and what method to use in determining the inflationary blood pressure measurements. Furthermore, the configuration parameters can dictate whether the blood pressure data is filtered and how. In an embodiment, the configuration parameters dictate that the inflationary blood pressure measurements are not to be taken based on the inflation rate. In another embodiment, the patient monitor determines the inflationary blood pressure measurements based on the slope and magnitude of the oscillations of the filtered blood pressure data during inflation based on the configuration parameters. In addition, the patient monitor can set confidence levels and perform other operations based on the configuration parameters.

Upon determining the inflationary blood pressure measurements, the patient monitor initiates deflation of the inflatable cuff **204** based on the configuration parameters. The configuration parameters can dictate the time and rate at which the inflatable cuff **204** deflates. For example, the configuration parameters can dictate a threshold pressure that when reached initiates the deflation. The threshold pressure can be based on personal information of the wearer or general safety levels. In an embodiment, the patient monitor initiates deflation based on a threshold pressure being reached for a predefined period of time based on the configuration parameters. In another embodiment, the patient monitor initiates deflation once the inflationary blood pressure measurements are taken.

Upon initiating deflation, the patient monitor determines deflationary blood pressure measurements based on one or more configuration parameters, as illustrated in block **660**. As discussed previously, with reference to block **656** the configuration parameters can include any number of parameters that determine if and how the deflationary blood pressure measurements are taken, as well as if and how the blood pressure data is filtered. In addition, the patient monitor can set confidence levels and perform other operations based on the configuration parameters.

Upon determining the deflationary blood pressure measurements, the patient monitor arbitrates blood pressure measurements based on the configuration parameters. The patient monitor can arbitrate the blood pressure measurements based on any number of configuration parameters. For example, the patient monitor can arbitrate the blood pressure measurements based on the highest confidence level or whether a threshold confidence level was reached. Furthermore, the patient monitor can arbitrate based on expected values, previous values, averages or the like. Alternatively, the patient monitor can select both the inflationary and deflationary blood pressure measurements.

At block **664**, the patient monitor outputs the results of the arbitration based on the configuration parameters. The output can include the inflationary blood pressure measurements, the deflationary blood pressure measurements, both or a combination of the two. The output can further include additional information, such as inflation rate, deflation rate, average blood pressure measurements depending on whether they were determined during inflation or deflation, etc.

Fewer, more, or different blocks can be added to the process **650** without departing from the spirit and scope of the description. For example, based on the blood pressure measurements, the configuration parameters can be changed and the process **650** can begin again.

FIG. **7**A is a flow diagram illustrating an embodiment of a process **700** implemented by the patient monitor **206** for filtering the blood pressure data and determining blood pressure. Blocks **702-710** correspond to filtering the blood pressure data, as described previously with reference to blocks **506** and **558** of FIGS. **5**A and **5**B, respectively, and blocks **606**, and **618** of FIG. **6**A. Blocks **712** and **714** correspond to determining the blood pressure data, as described previously with reference to blocks **508** and **560** of FIGS. **5**A and **5**B, respectively, and blocks **608**, and **620** of FIG. **6**A. Furthermore, in some embodiments, steps **702-714** can correspond to block **656** and **660** of FIG. **6**B.

At block **702**, the patient monitor **206** filters the blood pressure data using a first filter. In some embodiments, the first filter can be a lowpass filter and can be used to remove noise and reduce the sample rate of the blood pressure data. In some embodiments, the first filter can decimate the blood pressure data. However, it will be understood that other techniques and filters can be used to filter the blood pressure data.

At block **704**, the patient monitor **206** determines a pulse based at least on the filtered data. In some embodiments, to determine the pulse, the patient monitor **206** further filters the blood pressure data and transforms the blood pressure data into the frequency domain. To further filter the data, the patient monitor **206** can use a bandpass filter or detrend the blood pressure data. However, it will be understood that other techniques and filters can be used to further filter the data. Furthermore, the patient monitor **206** can use a Fast-Fourier Transform (FFT) to transform the blood pressure data to the frequency domain. However, it will be understood that other techniques and transforms can be used to transform the blood pressure data to the frequency domain. Once in the frequency domain, the patient monitor **206** can determine the pulse rate.

At block **706**, the patient monitor **206** further filters the blood pressure data based at least on the determined pulse. In some embodiments, the filter can be a bandpass filter that is based at least on the determined pulse rate. However, it will be understood that other techniques and filters can be used to further filter the blood pressure data. For example, in some embodiments, the blood pressure data is filtered without the use of the pulse, or can be detrended.

At block **708**, the patient monitor **206** normalizes the peaks within the filtered data that satisfy the threshold peak value. In some embodiments, the threshold peak value can be determined based at least on the value of the peak with the maximum amplitude. For example, the threshold peak value can be a percentage of the maximum peak value, such as fifty or sixty percent. Thus, the patient monitor can normalize only those peaks that are at least fifty or sixty percent of the maximum amplitude. In certain embodiments, the threshold peak value varies based on the location of the peak. For example, a first peak threshold value can be used for peaks that come before the maximum amplitude and a second peak threshold value can be used for peaks that come after the maximum amplitude.

At block **710**, the patient monitor **206** determines parameters of the normalized peaks. In some embodiments, the patient monitor **206** determines statistical parameters of the normalized peaks, such as, but not limited to, the mean, median and/or mode, the standard deviation, the skewness, maximum peak value, minimum peak value, etc. Although illustrated as part of the determining blood pressure block, it will be understood that block **710** can also form part of the filtering of the blood pressure data.

At block **712**, the patient monitor **206** determines the systolic and diastolic pressure based at least on the determined parameters of the normalized peaks. In some embodiments, the patient monitor **206** dynamically determines the systolic and diastolic pressure using one or more of the determined parameters. In certain embodiments, the patient monitor **206** uses a lookup table or calibration curve to determine the systolic and diastolic pressure using one or more of the determined parameters.

Fewer, more, or different blocks can be added to the process **700** without departing from the spirit and scope of the description. For example, the blood pressure data can be filtered once, peaks can be identified and normalized from the filtered data, and the patient monitor can determine parameters of the normalized peaks to lookup the systolic and diastolic pressure.

FIG. **7**B is a flow diagram illustrating an embodiment of a process **750** implemented by the patient monitor **206** for determining an end of inflation point for the blood pressure cuff. In some embodiments, process **750** and blocks **752-758** can be used to determine the time at which to actuate the valve to end inflation and/or begin deflation and mentioned previously with reference to block **510** of FIG. **5**A, block **554** of FIG. **5**B, block **614** of FIG. **6**A, and block **658** of FIG. **6**B, described previously.

At block **752**, the patient monitor **206** filters the blood pressure data. As part of the filtering, the patient monitor **206** can decimate and/or detrend the blood pressure data as described previously with reference to blocks **702** and **704** of FIG. **7**A. However, it will be understood that other techniques can be used to filter the blood pressure data. For example, the patient monitor **206** can use a lowpass filter, highpass filter, and/or bandpass filter to filter the blood pressure data, etc.

At block **754**, the patient monitor **206** identifies a peak value of the blood pressure data. In some embodiments, the patient monitor **206** determines an envelope of the filtered blood pressure data and identifies the maximum value of the envelope of the filtered data. In certain embodiments, the patient monitor **206** can determine the standard deviation of the blood pressure data to determine the envelope of the data. In some embodiments, the patient monitor **206** identifies the maximum amplitude of the blood pressure data as the peak value.

At block **756**, the patient monitor **206** identifies a stopping point of the blood pressure data in relation to the peak value. In some embodiments, the patient monitor **206** identifies a threshold value as a stopping point. In certain embodiments, the patient monitor **206** can identify a percentage of the peak value as the stopping point. For example, when the blood pressure data falls below the threshold value, the patient monitor **206** can actuate the valve to end inflation and/or begin deflation. In certain embodiments, the threshold value can be a predefined pressure or a pressure determined based on the peak value. For example, the threshold value can be the pressure that is twenty or thirty percent greater than the pressure measured at the peak value. Accordingly, once the threshold value is reached, the patient monitor **206** can actuate the valve to end inflation and/or begin deflation. Fewer, more, or different blocks can be added to the process **750** without departing from the spirit and scope of the description.

Depending on the embodiment, certain acts, events, or functions of any of the methods described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all described acts or events are necessary for the practice of the method). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors, rather than sequentially.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein can be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. The described functionality can be implemented in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosure.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor can be a microprocessor, but in the alternative, the processor can be any conventional processor, controller, microcontroller, or state machine. A processor can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps of a method or algorithm described in connection with the embodiments disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium can be integral to the processor. The processor and the storage medium can reside in an ASIC. The ASIC can reside in a user terminal. In the alternative, the processor and the storage medium can reside as discrete components in a user terminal.

Conditional language used herein, such as, among others, “can,” “could,” “might,” “may,” “e.g.,” and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

Valve

FIGS. **8**A-D generally illustrate an on-off linear valve **800** having an input port **810**, an output port **820** and an electrical plug **830**. In an embodiment, the on-off linear valve **800** is unidirectional, with the input port **810** configured for connection to a high pressure gas source and the output port **820** connected to a gas receptacle. Advantageously, the on-off linear valve **800** has a relatively small size that is compatible with a blood pressure cuff inflation application utilizing a $CO_2$ cartridge.

As shown in FIGS. **8**A-D, the electrical plug **830** connects to a DC electrical source so as to heat an internal SMA (shape memory alloy) wire. The SMA wire contracts as it heats so as to open the input port **810**, as described with respect to FIGS. **9**-**10**, below. In an embodiment, the maximum plug current is 700 mA, depending on the SMA wire diameter and length. In an embodiment, the valve body **1100** (FIGS. **11**A-G) and end cap **1200** (FIGS. **12**A-E) are made of ABS or nylon 66 material so as to form a 13×13×16 mm body and a corresponding 13×13×49 mm valve. The on-off linear valve **800** also prevents any high pressure gas leaks and has a quick response time.

FIG. **9** further illustrates an on-off linear valve **800** having a valve body **1100** and a valve cap **1200**, which enclose and slidably contain a valve actuator **900**. The valve actuator **900** has a seal end **901** that prevents gas flow through the input port **810** when the valve is off and a flow end **902** that directs gas through the output port **820** when the valve is on. The valve actuator **900** has a plunger **1300**, lock pins **1400**, a seal **1500**, an SMA wire **1010**, a spring **1020** and conductors **1030**. The seal **1500** provides a pliant surface that internally seals the input port **810**. In a normally closed position with no power applied to the conductors **1030**, the spring **1020** forces the plunger away from the end cap **1200**, which presses the seal **1500** against a seat **1120** (FIG. **11**F), so as to prevent gas flow into the input port **810**. In an open position with power applied to the conductors **1030**, the SMA wire **1010** pulls the plunger toward the end cap **1200** so as to remove the seal **1500** from the seat **1120** (FIG. **11**F). This allows gas to flow into the input port **810**, across the plunger **1300** surface and out through the output port **820** accordingly.

As shown in FIG. **9**, the SMA wire **1010** is strung through extended thru-holes disposed lengthwise on either side of plunger **1300** and via thru-holes disposed widthwise proximate the plunger seal end **901**. Current applied to the conductors **1030** via the electrical plug **830** (FIG. **8**) portion of the conductors **1030** heats the SMA wire **1010**; causing the SMA wire **1010** length to contract against the force of the spring **1020** and pull the seal end **901** from the input port seat **1120** (FIG. **11**F). Accordingly, high pressure gas flows through the input port **820**, through actuator **900** channels **80** (FIG. **11**G) to the end cap **1200** and on through the output port **820**. When current is no longer applied to the electrical plug **830** (FIG. **8**), the SMA wire **1010** cools, its length expands, and the spring **1020** forces the seal **1500** against the seat **1120** (FIG. **11**F) so as to stop the gas flow through the valve **800**.

FIG. **10** further illustrates an on-off linear valve actuator **900** having a plunger **1300**, lock pins **1400**, seal **1500**, SMA wire **1010**, spring **1020** and conductors **1030**, as cited above. The seal **1500** is disposed in a seal housing **1330** so that a catch **1510** (FIG. **15**A) is press fit into a catch aperture **1332**. SMA wire **1010** is threaded through plunger vias **1322** and end cap vias **1202** and fixedly disposed within the lock pins **1400**. The conductors **1030** are routed through lock pin apertures **1412** and staked into end cap holes **1203** with the spring **1020** captured between the plunger **1300** and the end cap **1200**. In this manner, the SMA wire can be advantageously cut-to-length to calibrate the “valve closed” pressure of the seal **1500** against the seal seat **1120** (FIG. **11**F) so as to prevent high pressure gas from entering the input port **810**. The lock pins **1400** and attached SMA wire is accessible through end cap apertures **1224** (FIG. **12**E).

FIGS. **11**A-G illustrate an on-off linear valve body **1100** having a generally elongated hollow shell **1105** extending between an enclosed first end **1101** and an open second end **1102**. The first end **1101** has an externally extending input nozzle **1110** and an internally extending seal seat **1120** (FIGS. **11**E-F). An input port **810** provides an opening for gas flow that extends from the external input nozzle **1110** to the internal seal seat **1120**.

As shown in FIGS. **11**E& G, the body shell **1105** has a fluted interior **1130** that includes semi-cylindrical grooves **1140** proximate the shell corners **1107** and partially-cylindrical grooves **1150** proximate the shell sides **1108**. The semi-cylindrical grooves **1140** accommodate corresponding plunger rails **1320** (FIGS. **13**A-E), which slidably fit within the grooves **1140**. Advantageously, the partially-cylindrical grooves **1150** and the relatively smaller-diameter plunger piston **1310** (FIGS. **13**A-E) define gas channels **80** that accommodate gas flow between the input port **810** and the output port **820** (FIGS. **8**A-D) when the seal **1500** (FIG. **9**) is pulled away from the seal seat **1120** (FIG. **11**F) by the SMA wire **1010** (FIG. **9**) opposing the spring **1020** (FIG. **9**) during valve actuation.

FIGS. **12**A-E illustrate a valve cap **1200** having an output nozzle **1210**, a lid **1220** and an insert **1230**. The insert **1230** fits into the body open end **1102** (FIGS. **11**A, **11**C, **11**E) so that the lid **1220** encloses the body **1100** and the output nozzle **1210** extends external to the body **1100**. The output nozzle **1210** defines an output port **820** for expelling gas entering from the input port **810** (FIGS. **8**A-D). The insert **1230** fits within and conforms to the body fluted interior **1130** (FIG. **11**E). The lid **1220** has conductor apertures **1222** that accept the conductors **1030** (FIGS. **9-10**) and lock pin apertures **1224** that accept the lock pins **1400** (FIGS. **9-10**). The insert **1230** has wire apertures **1232** that accept the SMA wire **1010** (FIGS. **9-10**).

As shown in FIGS. **12**A-E, the conductors **1030** (FIGS. **9-10**) are fixedly staked through the conductor apertures **1222** and through lock pins **1400** (FIGS. **9-10**) so as to form the electrical plug **830** (FIGS. **8**A-D) and so as to secure the lock pins **1400** (FIGS. **9-10**) within the lock pin apertures **1224**. The SMA wire **1010** (FIGS. **9-10**) is fed through the wire apertures **1232** and terminated at and fixedly secured within the lock pins **1400** (FIGS. **9-10**), as described with respect to FIGS. **14**A-E, below.

FIGS. **13**A-E illustrate a plunger **1300** having a seal end **1301** and a spring end **1302**. The plunger **1300** has a piston **1310**, semi-cylindrical rails **1320** disposed along the length of the piston **1310** at 90° intervals, a seal housing **1330** extending from the piston **1310** at the seal end **1301** and a spring housing **1340** disposed within the piston **1310** at the spring end **1302**. The SMA wire **1010** (FIGS. **9-10**) is fed through the wire apertures **1324**, **1334** defined within an opposing pair of the rails **1320** and across the seal housing **1330**. A seal **1500** (FIGS. **15**A-F) is disposed within the seal housing **1330** so that a flanged seal stem **1510** is inserted into and fixedly secured within a catch aperture **1332** so as to secure the seal **1500** (FIGS. **15**A-F) within the seal housing **1330**. A spring **1020** (FIGS. **9-10**) is disposed within the spring housing **1340**.

FIGS. **14**A-E illustrate a lock pin **1400** having a conductor aperture **1412** disposed at a conductor end **1401** and a wire aperture **1422** disposed at a wire end **1402**. Generally, a pair of lock pins **1400** terminate the SMA wire **1010** (FIGS. **9-10**) at both ends after the SMA wire is strung through the plunger **900** and the valve cap **1200** (FIGS. **12**A-E) and soldered or otherwise electrically connected and mechanically secured within the wire apertures **1422**. Further, the lock pins **1400** are anchored within lock pin apertures **1224** (FIG. **12**E) by conductors **1030** disposed through and soldered or otherwise electrically connected and mechanically secured within the conductor apertures **1412** and staked or otherwise secured within the valve cap body **1220**.

FIGS. **15**A-F illustrate a generally disc-shaped seal **1500** having a seat side **1501** and an opposite stem side **1502**. The seat side **1501** provides a seal surface that covers and is pressed against the seal seat **1120** (FIG. **11**F) under force of the spring **1020** (FIGS. **9-10**). The stem side **1502** has a flanged stem **1510** that is pressed through and fixedly held within a catch aperture **1332** (FIG. **13**B).

An on-off linear valve has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the disclosure herein. One of ordinary skill in art will appreciate many variations and modifications.

Pressure Sensor

FIGS. **16**A-B illustrate a pressure sensor **1600** that advantageously indicates the presence of a predetermined minimum pressure level. The pressure sensor **1600** has an enclosure **1610**, a nozzle **1620**, a flexible conductive **1630**, a contact set **1640** and a vent **1650**. The conductive element **1630** rests on supports **1616** so as to divide the enclosure **1610** interior into a pressure chamber **1612** and a contact chamber **1614**. As shown in FIG. **16**B, the conductive element **1630** is responsive to gas pressure at the nozzle **1620** so as to flex toward the contacts **1640**. The vent **1650** releases pressure in the contact chamber **1614** as the conductive element **1630** flexes toward the contacts **1640**.

As shown in FIGS. **16**A-B, operationally, the pressure sensor **1600** has a normally open position **1601** (FIG. **16**A) and a closed position **1602** (FIG. **16**B) responsive to a gas pressure threshold so as to complete an electrical circuit. In particular, in the normally open position **1601**, with no or insufficient gas pressure present at the nozzle **1620**, the conductive element **1630** is unflexed or insufficiently flexed so as to be distal the contacts **1640**. As such, there is no conductive path between the contacts **1640** so as to complete a circuit. In the closed position **1602**, the flexible conductive element **1630** is flexed in response to sufficient gas pressure so that the conductive element **1630** bridges the contacts **1640** allowing electrical current to flow through the contacts **1640**. In this manner, the pressure sensor **1600** provides an electrical indication of a predetermined pressure threshold. The pressure threshold may indicate, for example, that a minimum gas pressure exists at the nozzle **1620** or that a maximum gas pressure at the nozzle has been exceeded. The nozzle gas pressure that bridges the contacts depends on the mechanical (flex) characteristics of the conductive element **1630**, the proximity and configuration of the contacts **1640** with respect to the conductive element **1630** and the supports **1616** configuration. In various embodiments, the enclosure **1610** is cubic, a rectangular cuboid or cylindrical. The nozzle **1620** may be cylindrical or tapered cylindrical and is located over or off-the-side of the chamber, to name a few configurations. The conductive element **1630** may be round, square or rectangular, and the contacts **1640** may be angled or straight, as a few examples.

FIGS. **17**A-F illustrate a generally-cubic pressure sensor **1700** embodiment having a contact housing **1900** fixedly joined to a nozzle housing **2000** so as to define an internal sensor chamber **1810**, **1820** (FIGS. **18**A-B). A pair of electrical contacts **2200** extend within contact slots **1912** along the contact housing **1900** top and from the contact housing **1900** sides. A nozzle **2030** extends from the nozzle housing **2000** front proximate the nozzle housing **2000** bottom. A nozzle aperture **2032** is defined in the nozzle **2030**, which extends from the nozzle end to an interior pressure chamber **1810** (FIG. **18**A), as described with respect to FIGS. **18**A-B, below. Operationally, the nozzle **2030** accepts a pressure tube, hose or similar transport for carrying a pressurized gas such as air, oxygen or carbon dioxide, to name a few. The nozzle aperture **2032** transports pressurized gas to the pressure chamber **1810** (FIG. **18**A). The pressure sensor **1700** is responsive to pressurized gas so as to provide a conductive path between the contacts **2200** when the predetermined pressure level is met or exceeded. Accordingly, the pressure sensor **1700** provides an electrical indication of the predetermined gas pressure level to a remote device in electrical communications with the contacts **2200**.

FIGS. **18**A-B further illustrate a pressure sensor **1700** embodiment having a contact housing **1900** fixedly joined to a nozzle housing **2000** so as to define a sensor chamber **1810** (FIG. **18**A), **1820** (FIG. **18**B). In particular, an annular contact housing wall **1920** inserts into a nozzle housing aperture **2012** so as to capture a flexible conductive disk **2100** between the contact housing wall **1920** and a corresponding annular nozzle housing wall **2020** defined within the nozzle housing aperture **2012**. The disk **2100** advantageously divides the sensor chamber **1810**, **1820** into a pressure chamber **1810** and a contact chamber **1820**. The pressure chamber **1810** pressurizes in response to gas pressure at the nozzle **2030** and specifically from gas pressure routed into the pressure chamber via the nozzle aperture **2032**. The disk **2100** is responsive to pressurized gas in the pressure chamber **1810** so as to flex into the contact chamber **1820**. At a critical gas pressure at the nozzle **2030**, the disk **2100** flexes sufficiently to bridge contact points **2222** defined by the contacts **2200** and recessed within the contact chamber **1820**. A contact chamber vent **1916** releases any counter-pressure on the disk that may result as the disk **2100** flexes into the contact chamber **1820**. Advantageously, the pressure sensor **1700** may be incorporated into an electrical circuit, which is completed when the conductive disk **2100** bridges the contact points **2222**. The size and mechanical characteristics of the disk **2100**, the configuration of the sensor chamber walls **1920**, **2020**, and the configuration of the contact points **2222** within the contact chamber **1820** are all included in the design choices that determine the minimum gas pressure level at the nozzle **2030** which allows electrical current to flow through the contacts **2200**.

In an embodiment, the pressure sensor **1700** is responsive to and indicative of sufficient remaining pressure in a $CO_2$ cartridge or similar pressurized gas container, which is in communication with the sensor **1700** via a hose fitted to the nozzle **2030**. In an embodiment, a sealing material or compound applied where housing walls **1920**, **2020** contact the disk **2100** renders the sensor chamber **1810**, **1820** gas tight and, in particular, prevents gas leaking from the pressure chamber **1810** into the contact chamber **1820**.

FIGS. **19**A-D illustrate a contact housing **1900** having a generally rectangular cuboid top **1910** and a generally annular contact housing wall **1920** extending from the top **1910**. Contact slots **1912** extend across the top **1910** and contact apertures **1914** extend through the top within each of the slots **1912** so as to receive a pair of contacts **2200**, as described above with respect to FIGS. **17**A-F. A chamber vent **1916** is disposed through the top **1916**, as described above with respect to FIGS. **17**A-F. Contacts **2200** (FIGS. **22**A-D) extend through the contact apertures **1914** into a contact chamber **1820** defined by the annular wall **1920** so as to provide contact points **2222** (FIGS. **22**A-D) for the conductive disk **2100** (FIGS. **21**A-C), as described above with respect to FIGS. **18**A-B.

FIGS. **20**A-F illustrate a nozzle housing **2000** having a generally rectangular cuboid body **2010**, a nozzle housing aperture **2012** defined within the body **2010** and a generally annular nozzle housing wall **2020** defined within the housing aperture **2012**. A nozzle **2030** extends from the housing body **2010** and defines a nozzle aperture **2032** extending from the nozzle **2030** end through the nozzle housing wall **2020** so as to allow gas pressure to be exerted through the nozzle and into the pressure chamber **1810**, as described above.

As shown in FIGS. **20**A-F, the nozzle housing aperture **2012** snugly accommodates the contact housing wall **1920** (FIGS. **19**A-D), which mates with the nozzle housing wall **2020** to form a sensor chamber **1810**, **1820** (FIGS. **18**A-B), as described above. A conductive disk **2100** (FIGS. **21**A-C) is captured between the housing walls **1920**, **2020** (FIGS. **19-20**), as also described above.

FIGS. **21**A-C illustrate a conductive disk **2100** that is a generally flexible, conductive body having a diameter substantially greater than its thickness. In an embodiment, the disk **2100** is a conductive plastic. In an embodiment, the disk diameter is defined by the diameter of the nozzle housing aperture **2012** (FIG. **18**A) so that the disk **2100** is captured between the contact housing wall **1920** (FIGS. **19**A-D) and the nozzle housing wall **2020** (FIGS. **20**A-F), as described above.

FIGS. **22**A-D illustrate a contact **2200** having a relatively long first leg **2210** and a relatively short second leg **2220** extending perpendicularly from an end of the first leg **2210**. A disk contact **2222** is defined at the end of the short leg **2220**. A pair of the contacts **2200** are embedded in contact slots **1912** (FIGS. **19**A, **19**D) so that the long legs **2210** extend from the sides of the contact housing top **1910** (FIGS. **19**A-D) and so that the short legs **2220** extend through a corresponding pair of contact apertures **1914** (FIG. **19**C) and into the contact chamber **1820** (FIG. **19**C), as described with respect to FIGS. **18**A-B, above.

A pressure sensor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the disclosure herein. One of ordinary skill in art will appreciate many variations and modifications.

While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the device or process illustrated can be made without departing from the spirit of the disclosure. As will be recognized, certain embodiments of the inventions described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others. The scope of the inventions is indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

**1**. A patient monitoring system comprising a pressure sensor, the pressure sensor comprising:

a sensor housing having an external nozzle defining a nozzle aperture;

a chamber defined within the sensor housing;

the nozzle aperture extending from the external nozzle to the chamber;

a plurality of electrical contacts disposed within the chamber and extending from the chamber to a terminus external to the sensor housing; and

a flexible conductive element disposed within the chamber proximate the plurality of electrical contacts, the flexible conductive element responsive to gas pressure exerted at the external nozzle and translated into the chamber via the nozzle aperture so as to cause the flexible conductive element to bridge the plurality of electrical contacts, and the plurality of electrical contacts configured to conduct current when bridged by the flexible conductive element so as to indicate a gas pressure threshold at the external nozzle.

**2**. A patient monitoring system comprising:

an inflatable cuff attachable to a wearer;

a gas reservoir coupled to the inflatable cuff and configured to provide gas to the inflatable cuff via a gas pathway; and

a pressure sensor configured to obtain blood pressure data from the inflatable cuff, the pressure sensor comprising a flexible conductive element disposed within a chamber proximate a plurality of electrical contacts, the plurality of electrical contacts configured to conduct current when bridged by the flexible conductive element so as to indicate a gas pressure threshold at a nozzle, the flexible conductive element responsive to gas pressure exerted at the nozzle and translated into the chamber via a nozzle aperture so as to cause the flexible conductive element to bridge the electrical contacts.

**3**. The patient monitoring system of claim **2**, wherein the gas is compressed gas.

**4**. The patient monitoring system of claim **2**, wherein the gas reservoir comprises at least one of a gas tank, a gas cylinder, or a bottled gas and at least one of a pre-filled gas or compressed gas.

**5**. The patient monitoring system of claim **2**, wherein the gas reservoir is replaceable.

**6**. The patient monitoring system of claim **2**, wherein the gas from the gas reservoir is used to generate electricity for the patient monitoring system.

**7**. The patient monitoring system of claim **2**, further comprising a valve associated with the gas pathway and configured to open to allow gas to flow from the gas reservoir to the inflatable cuff.

**8**. The patient monitoring system of claim **7**, wherein the valve comprises:

a body having an input nozzle defining an input port;

a cap having an output nozzle defining an output port; and

an actuator disposed between the body and the cap,

the actuator having an open position that allows gas flow from the input port to the output port and a closed position that prevents gas flow from the input port to the output port,

the actuator having a shape memory alloy (SMA) wire loop in communication with an electrical plug, and

the SMA wire loop contracting and expanding in response to current applied to electrical contacts so as to move the actuator between the closed position and the open position.

**9**. The patient monitoring system of claim **8**, wherein the actuator comprises:

a plunger having a seal end and a spring end;

a seal disposed at the seal end, the seal configured to press against a seat disposed in the body proximate the input port so as to prevent gas flow through the input port in the closed position; and

a spring disposed at the spring end, the spring biasing the seal against the seat,

the SMA wire loop having a closed end strung through the plunger and open ends fixedly secured proximate the cap, and

the SMA wire loop configured to pull the actuator against a force of the spring when current flows through the electrical contacts so as to move the seal away from the seat as the actuator moves from the closed position to the open position.

**10**. The patient monitoring system of claim **9**, wherein the plunger comprises:

a cylindrical piston; and

a plurality of semi-cylindrical rails disposed around walls of the cylindrical piston.

**11**. The patient monitoring system of claim **10**, wherein the body comprises an elongated hollow shell having a closed first end defining the input nozzle and an open second end that receives the cap, the elongated hollow shell having a fluted interior configured to accommodate the actuator and a square cross-sectioned exterior defining edges, wherein the fluted interior of the elongated hollow shell comprises:

a plurality of semi-cylindrical grooves proximate the edges of the elongated hollow shell; and

a plurality of cylindrical grooves proximate sides of the elongated hollow shell,

the plurality of semi-cylindrical grooves receive the semi-cylindrical rails which slidably fit within the plurality of semi-cylindrical grooves,

the plurality of cylindrical grooves receive the cylindrical piston so as to define gas channels that accommodate gas flow between the input port of the body and the output port of the cap when the seal is pulled away from the seat by the SMA wire loop in opposition to the spring during valve actuation.

**12**. The patient monitoring system of claim **8**, wherein the body comprises an elongated hollow shell having a closed first end defining the input nozzle and an open second end that receives the cap, the elongated hollow shell having a fluted interior configured to accommodate the actuator and a square cross-sectioned exterior defining edges.

**13**. The patient monitoring system of claim **7**, wherein the chamber is a first chamber, the patient monitoring system further comprising:

a second chamber coupled to the valve; and

a chamber cover hingedly coupled to the second chamber, wherein when the chamber cover is closed the chamber cover and the second chamber encapsulate the gas reservoir and the chamber cover exerts a force on the gas reservoir in a direction of the valve.

**14**. The patient monitoring system of claim **2**, further comprising a two-stage regulator configured to maintain pressure in a segment of the gas pathway at an approximately constant pressure.

**15**. The patient monitoring system of claim **2**, wherein the pressure sensor is communicably coupled to a patient monitor configured to receive the blood pressure data from the pressure sensor to determine a blood pressure measurement of the wearer.

**16**. The patient monitoring system of claim **15**, wherein the patient monitor is configured to filter the blood pressure data to generate filtered blood pressure data, the filtered blood pressure data comprising pressure oscillations in the inflatable cuff due to blood flow in an artery of the wearer.

* * * * *

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| 其他公开文献 | US20140163402A1 | | |
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摘要(译)

患者监测系统包括可膨胀套囊，含有压缩气体的气体储存器和传感器。当充气袖带连接到穿着者身上时，气体贮存器向充气袖带供应气体以通过气体通道给充气袖带充气。当充气袖带充气时，患者监护仪可以接收来自传感器的血压数据并使用血压数据来确定佩戴者的血压。病人监护仪还可以在充气袖套放气期间接收血压数据以确定穿用者的血压。