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Gas-inflatable personal flotation devices

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(54) **GAS-INFLATABLE PERSONAL FLOTATION DEVICES**

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(Continued)

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CPC ***B63C 9/18*** (2013.01); ***A41D 7/00*** (2013.01); ***A61B 5/0488*** (2013.01);
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(58) **Field of Classification Search**
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See application file for complete search history.

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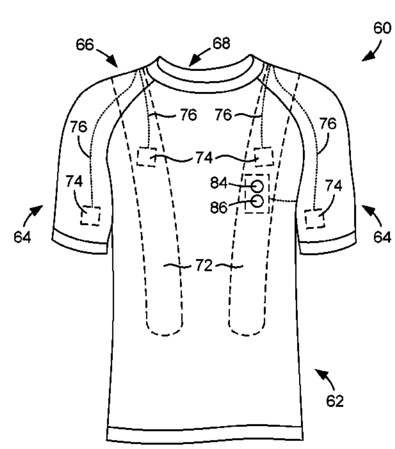
(57) **ABSTRACT**

In one embodiment, a personal flotation device that can be worn by a user includes an inflation system including an inflatable bladder and a gas-generating component, the gas-generating component being configured to generate gas using a chemical reaction and inject the generated gas into
(Continued)



the bladder to inflate it, and an inflation control system configured to control activation of the gas-generating component.

15 Claims, 7 Drawing Sheets

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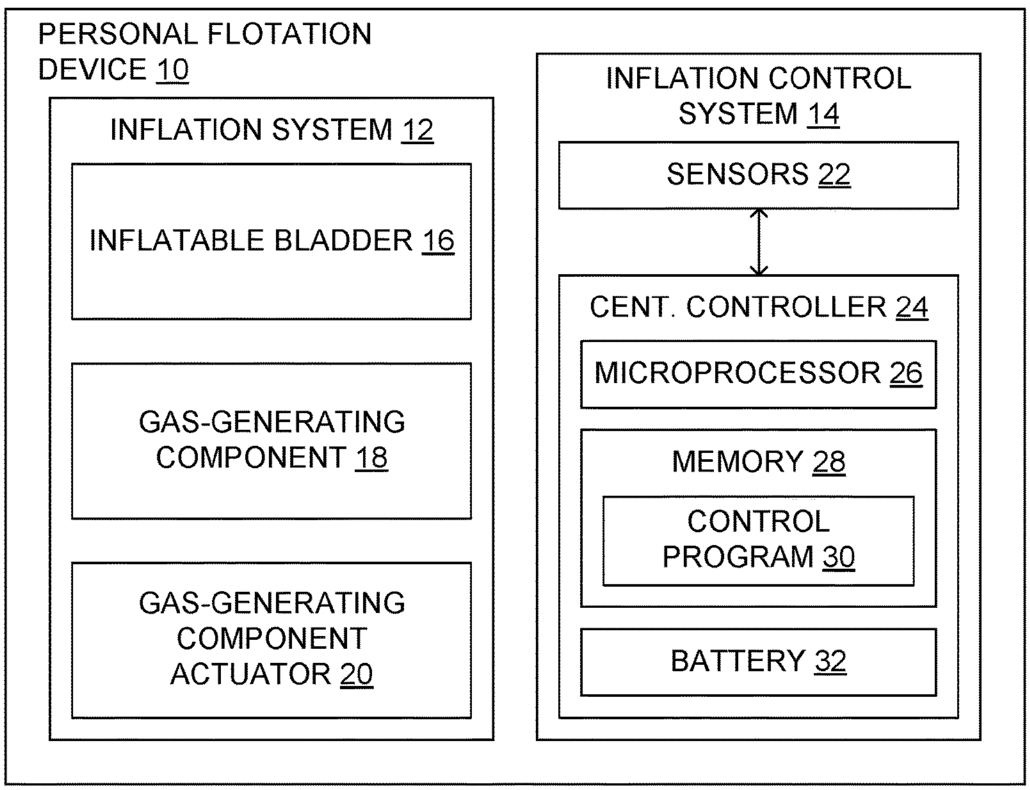

PERSONAL FLOTATION DEVICE 10
INFLATION SYSTEM 12
INFLATABLE BLADDER 16
GAS-GENERATING COMPONENT 18
GAS-GENERATING COMPONENT ACTUATOR 20
INFLATION CONTROL SYSTEM 14
SENSORS 22
CENT. CONTROLLER 24
MICROPROCESSOR 26
MEMORY 28
CONTROL PROGRAM 30
BATTERY 32

FIG. 1

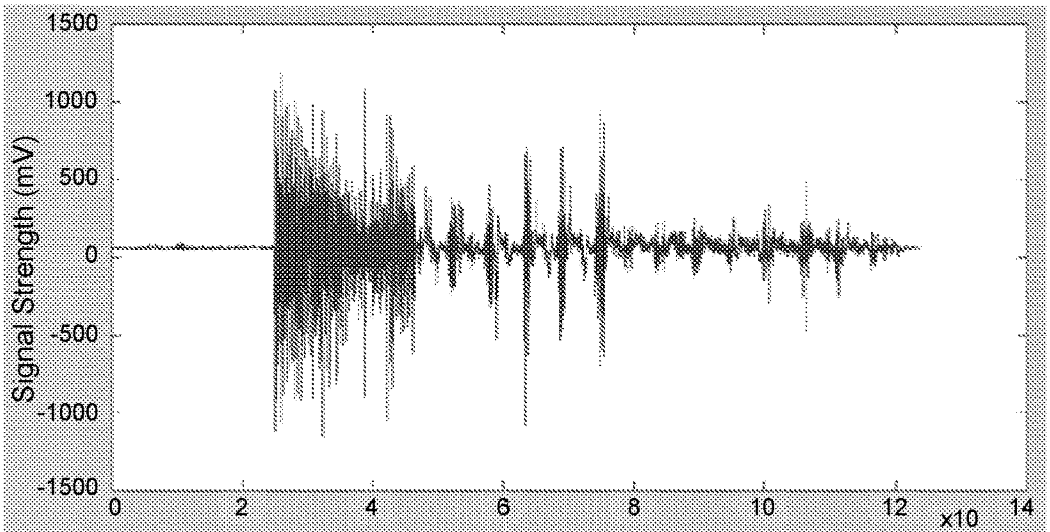

1500
1000
500
0
-500
-1000
-1500
Signal Strength (mV)
0
2
4
6
8
10
12
14
x10

FIG. 2

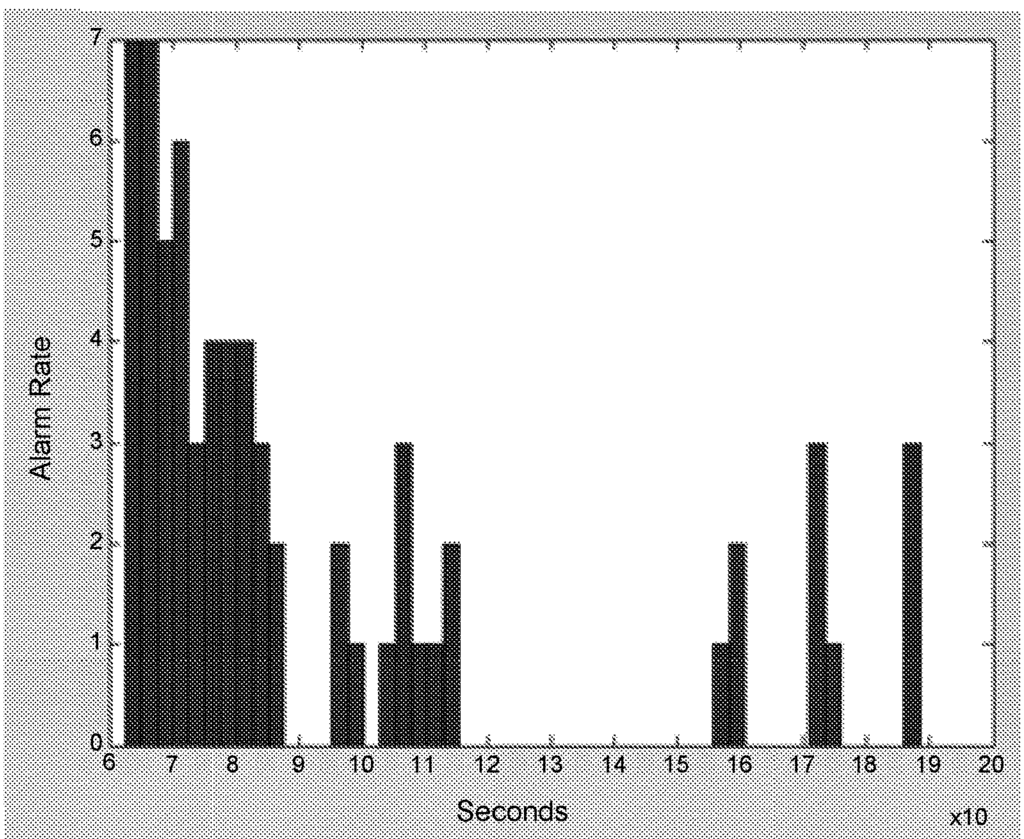
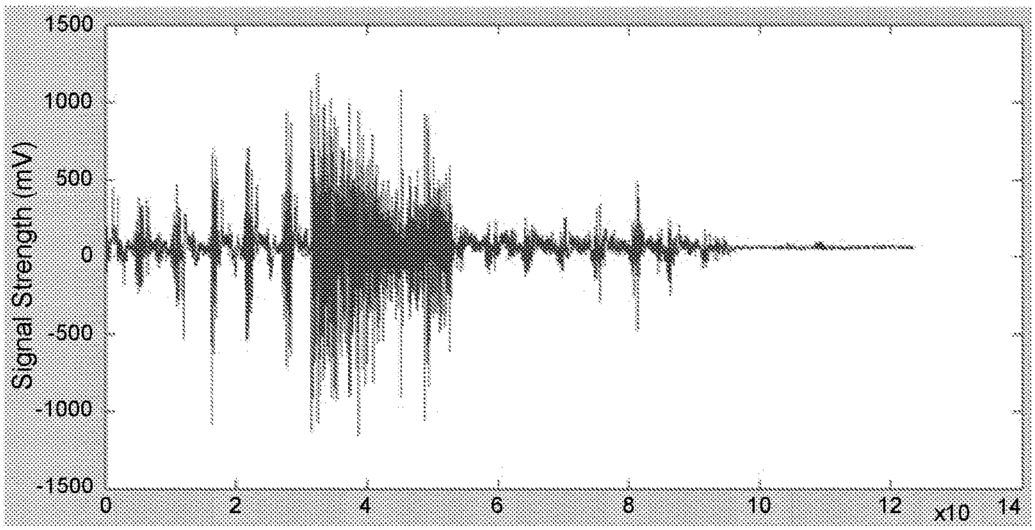
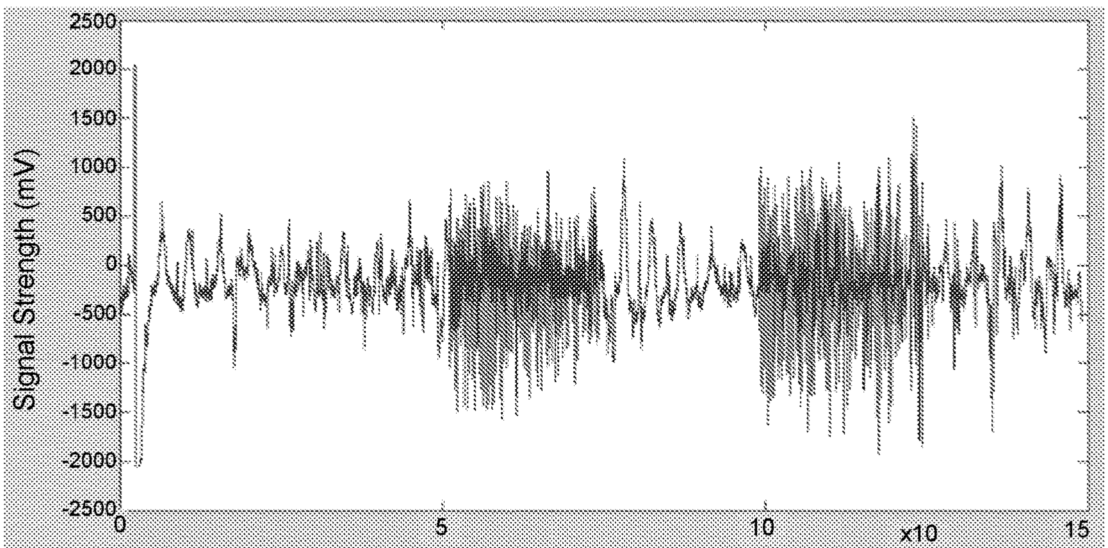

7
6
5
4
3
2
1
0
Alarm Rate
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Seconds
x10

FIG. 3



Seizure cetected at point				
32764	35930	39048	42097	49749
33223	36289	39507	42754	50483
33667	36835	40177	43700	51026
34031	37846	41017	44891	51576
34989	38356	41547	48802	52557

FIG. 4A



Seizure detected at point		
52679	108163	
57089	123983	
58348	136888	
59583		
102112		

FIG. 4B

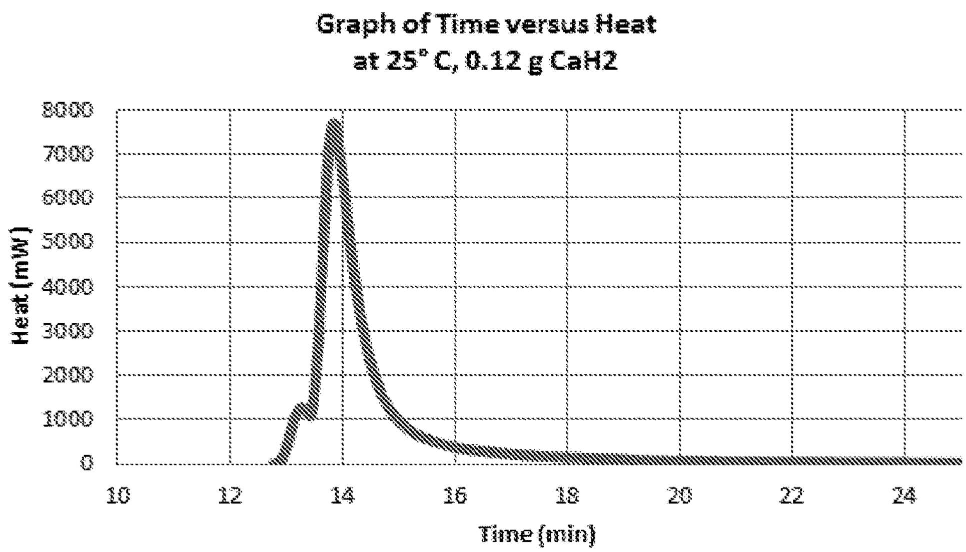

Graph of Time versus Heat
at 25° C, 0.12 g CaH2
Heat (mW)
8000
7000
6000
5000
4000
3000
2000
1000
0
10
12
14
16
18
20
22
24
Time (min)

FIG. 5

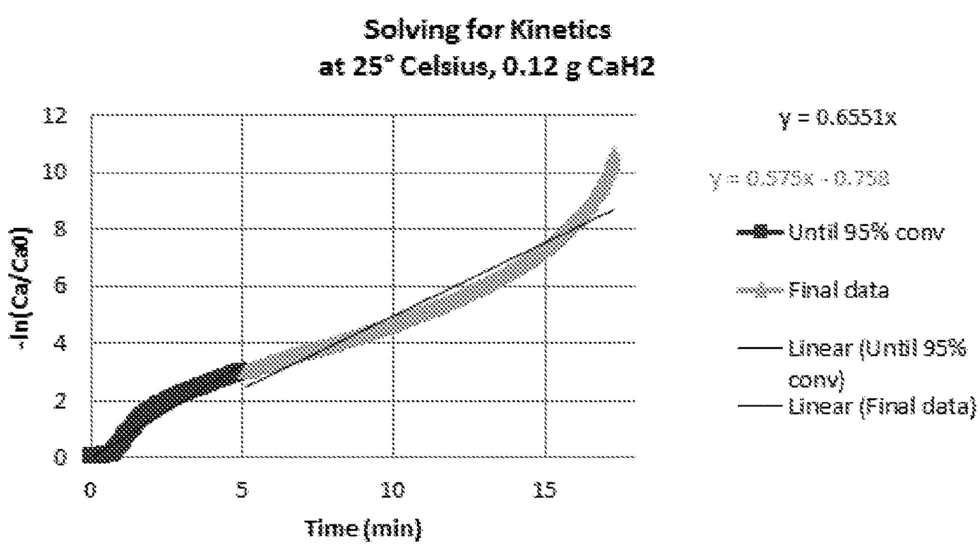

Solving for Kinetics
at 25° Celsius, 0.12 g CaH2
-ln(Ca/Ca0)
12
10
8
6
4
2
0
0
5
10
15
Time (min)
y = 0.6551x
y = 0.575x - 0.758
Until 95% conv
Final data
Linear (Until 95% conv)
Linear (Final data)

FIG. 6

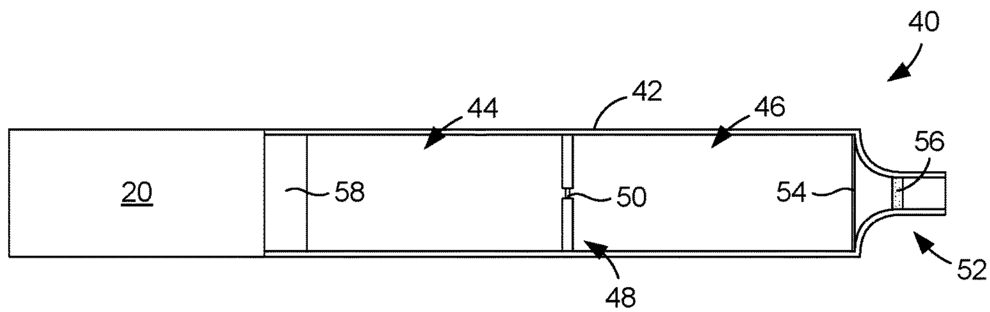


FIG. 7A

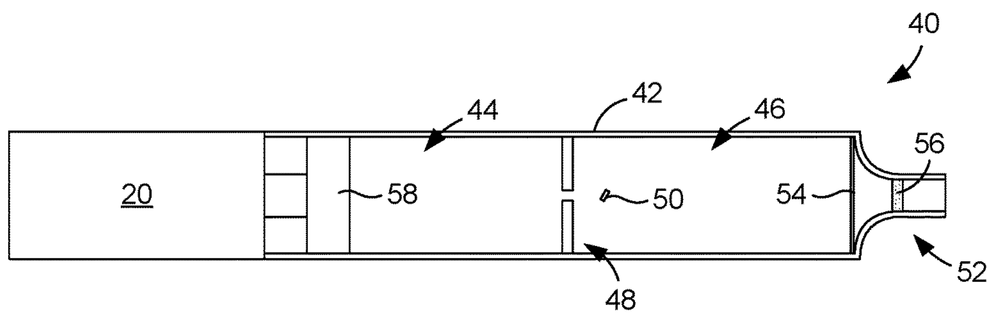


FIG. 7B

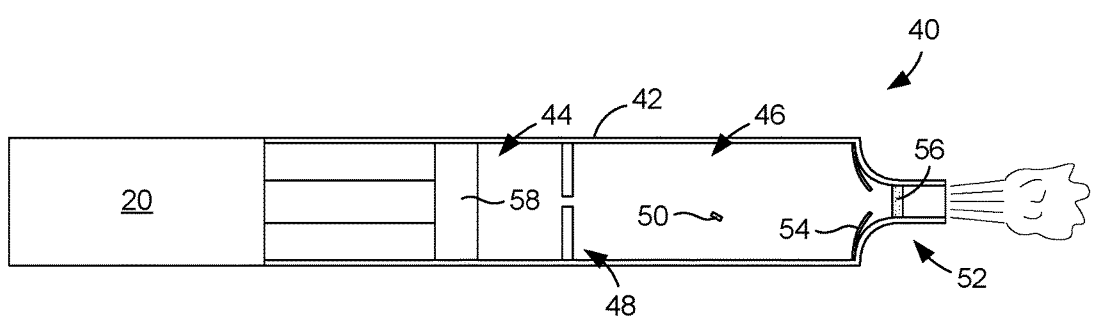


FIG. 7C

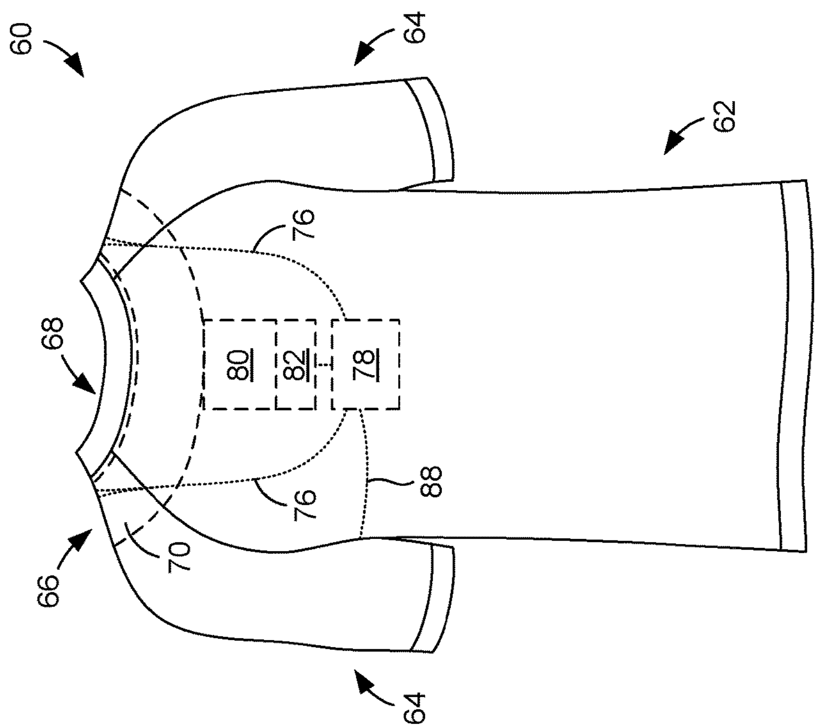

60
64
62
76
68
80
82
78
88
76
66
70
64

FIG. 8B

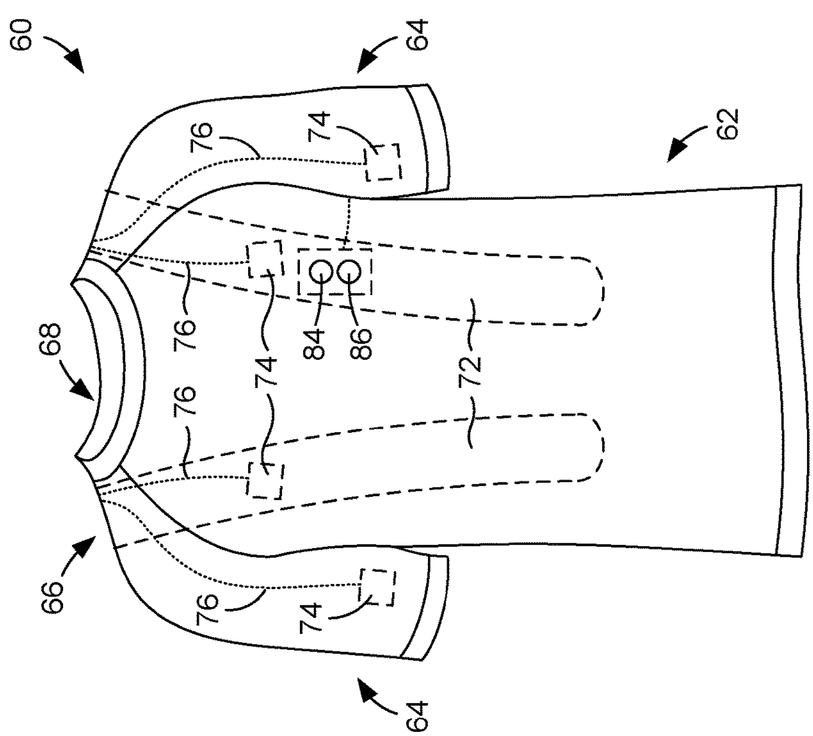

60
64
62
76
74
68
76
74
84
86
72
76
74
66
76
74
64

FIG. 8A

GAS-INFLATABLE PERSONAL FLOTATION DEVICES

CROSS-REFERENCE TO RELATED APPLICATION

This application is the 35 U.S.C. § 371 national stage application of PCT Application No. PCT/US2016/042593, filed Jul. 15, 2016, where the PCT claims priority to U.S. Provisional Application Ser. No. 62/192,841, filed Jul. 15, 2015, both of which are herein incorporated by reference in their entireties.

BACKGROUND

Swimming and water sports are very popular activities. Many people are unable to participate in these activities, however, due to medical conditions, such as epilepsy and other neurological conditions, which put them at risk of drowning. While such individuals could wear conventional flotation devices, such as foam vests or inflated vests or arm cuffs, such devices interfere with water activities. For example, such devices are typically cumbersome and hinder body motion, and further make swimming difficult, particularly under water. While inflatable vests, such as those that use carbon dioxide cartridges, are available on the market, they must be manually activated to inflate. Unfortunately, the user may not be able to activate the vest when the user is experiencing a medical emergency, such as a seizure.

From the above discussion, it can be appreciated that it would be desirable to have a personal flotation device that can provide buoyancy to an individual experiencing a medical event, such as a seizure, which does not interfere with normal water activity in which the individual is participating and which does not require the individual to activate.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be better understood with reference to the following figures. Matching reference numerals designate corresponding parts throughout the figures, which are not necessarily drawn to scale.

FIG. **1** is a block diagram of an embodiment of a flotation device.

FIG. **2** is a graph that plots motor neuron action potential activity of a subject as sample point versus signal strength (mV).

FIG. **3** is a histogram that shows the frequency at which local maxima in the data of FIG. **2** reached amplitude thresholds.

FIG. **4**A is a data set for a first subject comprising a graph that plots the subject's motor neuron action potential activity and a table that identifies detected seizures.

FIG. **4**B is a data set for a second subject comprising a graph that plots the subject's motor neuron action potential activity and a table that identifies detected seizures.

FIG. **5** is a graph that plots heat versus time for a gas-generating reaction.

FIG. **6** is an illustration of an example of a graphical method for solving the kinetics of the reaction of FIG. **5**.

FIGS. **7**A-**7**C are drawings of an embodiment of a gas-generating component in various stages of activation.

FIGS. **8**A and **8**B are front and back views, respectively, of an embodiment of a swimming garment that incorporates a flotation device.

DETAILED DESCRIPTION

As described above, it would be desirable to have a personal flotation device that can provide buoyancy to an

individual experiencing a medical event, such as an epileptic seizure, which does not interfere with normal water activity in which the individual is participating and which does not require the individual to activate. Disclosed herein are embodiments of such devices, which can be integrated with a swimming garment, such as a recreational or competitive swimming shirt. The personal flotation device comprises an inflatable bladder that can be inflated by an inflation system under the control of an inflation control system. In some embodiments, the inflation system uses a chemical reaction to generate gas that rapidly fills the bladder to provide buoyancy to the user. In some embodiments, the inflation control system automatically activates the inflation system in response to a determination that the user is having a medical event, such as an epileptic seizure. In some embodiments, this determination is made by sensing and analyzing skeletal muscle contractions of the user.

In the following disclosure, various specific embodiments are described. It is to be understood that those embodiments are example implementations of the disclosed inventions and that alternative embodiments are possible. All such embodiments are intended to fall within the scope of this disclosure.

FIG. **1** illustrates the primary components of a personal flotation device **10** that can be worn by a user. In some embodiments, the flotation device **10** can be used as an independent device separate from a swimming garment. In other embodiments, the flotation device **10** can be used with a swimming garment, such as a swimming shirt. In the latter case, the flotation device **10** can be integrated into the garment during its manufacture or added to the garment afterward in a retrofitting scenario.

As shown in FIG. **1**, the flotation device **10** generally comprises an inflation system **12** and an inflation control system **14**. The inflation system **12** includes an inflatable bladder **16** that can be rapidly filled with a gas to provide buoyancy to the device user. The gas that fills the bladder **16** is produced by a gas-generating component **18**. As described below, the gas-generating component **18** can, in some embodiments, generate gas through a chemical reaction that occurs when the gas-generating component is activated by a gas-generating component actuator **20**.

The inflation control system **14** includes one or more sensors **22** that can be used to sense one or more physiological parameters of the user that can be indicative of a medical event that places the user at risk of drowning. As described below, the sensors **22** can, in some embodiments, comprise electrodes that are placed on the user's skin on particular parts of the body and used to sense the user's muscle contractions. The sensors **22** are in electrical communication with a central controller **24** of the flotation device **10** that is used to control activation of the actuator **20**. More particularly, the central controller **24** is configured to activate the actuator **20** when the parameters sensed by the sensors **22** are indicative of a medical event occurring.

As shown in FIG. **1**, the central controller **24** can include a microprocessor **26**, memory **28** (which can optionally be integrated into the microprocessor), and a battery **32**. Stored within the memory **28** (a non-transitory computer-readable medium) is a control program **30** that can be executed by the microprocessor **26** to determine when the actuator **20** should be activated. The control program **30** comprises one or more algorithms (computer logic and executable instructions) configured to analyze the data collected by the sensors **22** and determine whether or not a medical event is occurring. If it is determined that such a medical event is occurring, the microprocessor **26** can send a signal to the gas-generating

component actuator **20** to activate it and cause the gas-generating component **20** to inflate the bladder **16**.

In some embodiments, the flotation device **10** can be specifically configured for use by persons who have epilepsy and, therefore, suffer from epileptic seizures that put them at risk of drowning when participating in water activities. In such an application, the device **10** can be configured to detect the onset of an epileptic seizure and, in response, immediately inflate to prevent drowning. One way in which such seizures can be detected is by capturing and analyzing electromyography (EMG) signals from the user's muscles. EMG signals measure the motor neuron action potential in skeletal muscles. Because seizures involve involuntary strong and rapid contractions of the skeletal muscles that do not normally occur during normal movement or exercise, signals that identify such contractions can provide an indication of when the user is having a seizure. The EMG signals can be collected with the sensors **22**, in the form of EMG electrodes that are placed on the skin surface. These signals can be provided to the central controller **24** and analyzed by executing the control program **30**, which can be specifically configured to identify contractions indicative of an epileptic seizure.

Experiments were performed to determine which muscle groups are best for use detecting epileptic seizures using EMG. In these experiments, subjects simulated swimming movements as well as muscle contractions of the type that result when an epileptic seizure occurs. It was found that EMG signals obtained from the pectoralis major and bicep muscles provide signals that most clearly identify the seizure-like contractions. After these initial findings, additional testing was performed with a focus on these targeted areas. With two subjects performing swimming activities and simulated seizures, the data collected via EMG was uploaded to MATLAB and stored as a single array of voltage values. Qualitative analysis indicated that most of the predicted seizures were due to large changes in amplitude and an increase in the frequency of waves in the range of these increased amplitudes. Taking this information as a genesis for quantitative analysis, a MATLAB program was created to examine these observations. The effectiveness of this post-processing technique determined the viability of seizure detection through EMG in the bicep and pectoral muscles.

As a preliminary examination into the characteristics of the data set, all of the activities of an initial subject were captured via a forearm EMG electrode were combined into a single data set and plotted. In this case, the data was plotted as sample point versus signal strength (mV), as shown in FIG. **2**. It was apparent from this graph that a majority of the waves in the seizure portion of the data set exceeded 500 mV. The next step was to determine what the distribution looked like for signals that reached above this 500 mV envelope. A simple program was created to identify all of the local maxima in the data set that had at least a 40 sample separation between other peaks and was at least 500 mV in strength. Sample location values were divided by 4000 to yield final results in seconds. The data collection system ran at 4000 samples/sec. Finally, a histogram (FIG. **3**) was created to show the frequency at which local maxima were reaching these amplitude requirements.

It is apparent from the histogram that amplitude analysis would see significant consideration given the overwhelming frequency in the seizure portion. The histogram also shows small rates falling outside of the seizure portion of the data. Given this dynamic, the program would still need to mitigate the chance of a false positive reading by minimizing the effects of these outliers.

To determine the capability for the program to recognize seizures while also mitigating the chance for false positives, all of the activities for a particular muscle group were combined to form a single continuous array. After forming a single data array, an envelope requirement was created based on a statistical analysis of the local maxima in the data. Using a MATLAB peak finder, finding every maximum that is at least 40 data points from the last maxima, an average and standard deviation was taken over all of those peaks. A separation of at least 40 samples was used to minimize the effects of outliers in the data set caused by movement of the electrodes or erratic movements during testing. An envelope was then calculated based off of the mean and standard deviation. This automated envelope helped determine the minimum size before a peak becomes significant in determining whether a seizure is occurring. Multiple envelope values were tried and it was found through continuous testing that one standard deviation above the mean peak value would yield the most accurate results.

The same automated peak finder was utilized again. However, the additional minimum peak size requirement was added to isolate only those peaks above a particular size and separation. From this data set, each peak value contained its peak size and location in the data set. From these location values, a new variable pkint (peak interval) was created by finding the separation between peak locations. An additional value of zero was added to the beginning of the data set for general indexing and matrix formatting purposes.

The number of elements in the pkint array were counted. Two important variables were then created. A two-columned warning matrix was formed to dictate whether an area of the overall data set would begin to indicate a seizure occurring. This was determined by piecing together a picture of each data point and the area previous to said data point. During each iteration of the program, an average was taken for each new data point that includes the previous nine values. This average represents the average separation between peaks above the minimum envelope over a set of ten peaks. A logic operator was used to determine if the average of each set was less than 250 data points per peak. If the average was less than 250, a value of 1 was assigned to the corresponding data point. Otherwise, the data point was assigned a 0.

This introduces the next significant variable, the initiate. The initiate variable is a counter that indicates to the device to initiate the inflation sequence. Each time a warning value is assessed a value of 1, the initiate counter increases by 1. In the case that the warning value is a 0, the initiate counter is decreased by 1. The counter cannot fall below the value 0. In the event that the counter reaches a value of 5, the counter resets and an inflate determination is reached.

With two different test subjects having provided data for the same activities, the program was then evaluated. The effectiveness of the MATLAB code was governed by two principles: (a) detect a seizure within (certain time frame) seconds and (b) eliminate all false positives. All data sets were tested in various orders of activity and reached similar results. FIGS. **4**A and **4**B illustrate two data sets from two different test subjects, respectively, and show the capability of the program. The first data set (FIG. **4**A) shows a very visible distinction between swimming motions, a baseline, and a seizure. The second data set (FIG. **4**B) shows activities performed that are less distinguishable from one to another.

Comparing the two data sets, false positives were absent in both, but the less distinguishable the seizure was from activities, the less often the system recognized seizures. However this was not seen as a major issue, as even in the second data set the seizure was detected approximately once every second.

The above-described findings confirm both that the amplitude and frequency of the EMG signals obtained from the bicep and/or pectoral region can be used to detect epileptic seizures and, therefore, can be used to determine when to trigger inflation of the flotation device **10**. Accordingly, in some embodiments, the control program **30** can be configured to analyze EMG signals collected by the sensors **22** and determine from the amplitude and frequency of those signals whether or not the user is having an epileptic seizure. For example, if a threshold number of contractions that exceed a predetermined amplitude threshold are detected within a predetermined period of time, it can be concluded that the user is having a seizure. In such a case, the microprocessor **26** can activate the actuator **20** to cause the gas-generating component **18** to fill the bladder **16** with gas.

In some embodiments, the flotation device **10** can be specifically calibrated for each particular user. In such cases, a calibration process can be performed during which the user performs particular physical activities while the flotation is connected to the body to enable the central controller **24** to store data in memory **28** that will be used in the seizure determination. These activities serve as a safe means to accurately calibrate the controller **24** to each individual user. By way of example, the activities can be conducted out of the water and comprise mimicking freestyle swimming, mimicking breast-stroke, mimicking treading water, full-body tensing (to calibrate maximal voluntary contraction), and sitting in a relaxed position (to calibrate baseline muscle activity).

As noted above, the gas-generating component **18** can generate gas through a chemical reaction. In some embodiments, the chemical reaction can utilize a hydrogen-generating compound that generates hydrogen gas. One example of a hydrogen-generating compound is calcium hydride (CaH_2), which reacts with water to create calcium oxide and hydrogen gas:

$$CaH_2+2H_2O\rightarrow Ca(OH)_2+2H_2 \quad \text{[Equation 1]}$$

The kinetics of the calcium hydride/water reaction was investigated. Calculations were performed to determine the water requirements to properly feed the reaction. An experimental amount of approximately 0.1 gram calcium hydride was mixed with water in four trials. Two trials were performed at 25° C. and two trials were performed at 30° C. The two trials performed at the same temperatures had different amounts of calcium hydride on the order of +/−0.025 grams approximately. Calcium hydride was placed in a small reaction vial, which was lowered into a calorimeter. The calorimeter reached steady state conditions and proper temperature values. Next, 3 grams of distilled water (3 mL) was injected into the reaction vial. In order to minimize pressure build up, a vent was placed in the top of the reaction vial to vent the hydrogen gas. Once the water was injected, the reaction was monitored until values returned to the steady state conditions of the system. With the four trials completed, kinetic data was calculated for the reaction of calcium hydride with water.

FIG. **5** shows the results from the calorimeter testing performed at 25° C. with 0.12 gm of calcium hydride reacting. FIG. **6** shows an example of a graphical method for solving the kinetics. Table 1 shows the k values calculated for each trial and the time it took for each trial to reach 95% conversion. Based on the information gathered from experimentation, the average k value was 0.576 min^{-1}. The reaction is pseudo-first order due to the excess water utilized to quench the reaction. The results of testing suggest that the reaction is highly independent of temperature and therefore has low activation energy. The time for the reaction to occur was minimal. This experimentation confirmed that calcium hydride is a viable option for use in the gas-generating component **18** and for inflation of the bladder **16**.

TABLE 1

Final Kinetic Data			
Temperature (° C.)	Amount CaH_2 (g)	K value	Time to Reach 95% conversion
25	0.120	0.655	5.10 min
25	0.114	0.665	4.72 min
30	0.123	0.529	6.15 min
30	0.154	0.454	7.35 min

In addition to providing buoyancy to the user, the flotation device **10** must also not harm the user. The calcium hydride/water reaction is an exothermic reaction ($\Delta H_{Rxn}=-249.72$ kJ/mol). Therefore, it is important to insure that the user of the device **10** is not burned upon inflation. The amount of calcium hydride needed for inflation can be calculated from the amount of pressure of hydrogen gas required to provide buoyancy to the user. In some embodiments, 34 lbf of buoyancy is provided to comply with U.S. Coast Guard life jacket standards. In such a case, approximately 5 gm of calcium hydride is needed. An amount of water in excess of that needed for the reaction can be used to quench the reaction and absorb much of the generated heat.

With this in mind, it was determined to charge the vessel with approximately 10 times the stoichiometric amount of water (50 mL) required for the 5 gm of calcium hydride. Next, a simple energy balance was used:

$$Q_{Rxn}=Q_w+Q_p=m\Delta H=mC_p\Delta T \quad \text{[Equation 2]}$$

This equation states that the heat produced by the reaction (Q_{Rxn}) is equal to the heat used to get the water to boiling point (Q_w) plus the heat used for phase change (Q_p). With 5 gm of calcium hydride, the reaction will produce approximately 30 kJ of energy. This is enough energy to take the water to 100° C. and partially into the two-phase region. This high temperature should be kept in mind when designing the gas-generating component **18** and determining its location relative to the user's body.

Hydrogen has a very low heat capacity. It therefore is not likely to carry much of the heat produced by the reaction that occurs in the gas-generating component **18** into the bladder **16**. However, if a significant amount of steam, which has a much higher heat capacity, is produced, this steam could carry a significant amount of heat into the bladder **16**. Assuming the final quality of the system is approximately 11%, about 0.3 moles of water would be turned into steam. However, the drastic change in volume that would occur during filling of the bladder **16** would cause most, if not all, of the steam to condense. Therefore, the heat of the reaction is less of a concern for the bladder **16**.

FIGS. **7A-7C** illustrate an embodiment of a gas-generating component **40** that can be used in the flotation device **10**. As indicated in these figures, the component **40** comprises a sealed, rigid outer housing **42** that defines an interior space that is divided into a first compartment **44** and a second compartment **46** by a divider wall **48**. In some embodiments,

the housing **42** is made of a polymeric material having good heat insulating properties, such as polycarbonate. The housing **42** can have dimensions that enable the gas-generating component **40** to be unobtrusive to the user when participating in water activities. The two compartments **44**, **46** are configured to contain water and a gas-generating compound (e.g., calcium hydride), respectively, in amounts appropriate for generating a volume of gas that will rapidly fill the bladder.

As shown in FIG. **7**A, the divider wall **48** incorporates a first sacrificial element **50** that will break when a predetermined amount of pressure is applied to the portion to enable the water and the gas-generating compound to mix. By way of example, the sacrificial element **50** can comprise a weak point in the wall or a relatively weak member, such as a thin membrane, that is incorporated into the wall.

With further reference to FIG. **7**A, the gas-generating component **40** further includes an exit nozzle **52** through which gas generated by the reaction between the water and the gas-generating compound can escape the component and be injected into the bladder **16**. As shown in the figure, a second sacrificial element **54**, such as a thin membrane, separates the nozzle **52** from the second compartment **46**. This sacrificial element **54** is designed to break a when the generated gas applies a predetermined amount of pressure. In some embodiments, the nozzle **52** includes a filter **56** that prevents the sacrificial elements **50**, **54** and the reactants from passing into the bladder **16**.

As described above, the gas-generating component **40** is activated by the gas-generating component actuator **20**. In some embodiments, the actuator **20** applies pressure to the water contained in the first compartment **44**. As illustrated in FIG. **7**B, this pressure can be applied, for example, using a piston **58** that is driven into the gas-generating component **18** by the actuator **20**. This pressure is transferred by the water to the first sacrificial element **50** so as to cause it to break or detach from the divider wall **48**, as shown in FIG. **7**B.

Once the first sacrificial element **50** has broken or has been detached, the water, under the pressure applied by the actuator **20**, enters the second compartment **46** and mixes with the gas-generating compound contained therein. The water and the gas-generating compound react with each other and rapidly produce a substantial volume of gas, such as hydrogen gas. As this gas is produced, it exerts pressure on the second sacrificial element **54** to cause it to break, as shown in FIG. **7**C. This enables the gas to escape the second compartment **46** and the gas-generating component **40**, and inflate the bladder **16**.

While a particular physical configuration for the gas-generating component **18** has been illustrated in FIG. **7** and described above, it is noted that the physical details of this configuration are not critical. Instead, the functionality provided by the component **18** (i.e., separately containing water and a gas-generating compound, enabling the water and gas-generating compound to mix, and enabling gas generated from the reaction between the water and gas-generating compound to fill the bladder **16**) is was is important. Accordingly, it will be appreciated that any physical configuration that can provide such functionality can be used for the gas-generating component **18**.

As noted above, the flotation device **10** can be integrated with a swimming garment, such as a swimming shirt. FIGS. **8**A and **8**B illustrate an embodiment of such a shirt **60**. As shown in these figures, the shirt **60** generally comprises a body **62** and sleeves **64** that are attached to the body. The shirt body **62** is generally configured to cover the user's torso, while the shirt sleeves **64** are generally configured to cover the user's upper arms. While short sleeves are illustrated in FIGS. **8**A and **8**B, it is noted that the sleeves **64** can alternatively be long sleeves that cover the user's entire arms. The body **62** and sleeves **64** can be made of any suitable materials. In some embodiments, they are made of synthetic elastic materials that do not interfere with the user's mobility while worn in the water. By way of example, the body **62** and sleeves **64** can be made of a neoprene material, which can be approximately 1 to 2 mm thick. When neoprene is used, the shirt **60** inherently provides insulation to the user from the heat generated by the flotation device **10**.

As shown in the figures, the shirt **60** incorporates the various components of the flotation device **10**. These components include an inflatable bladder **66**. In the embodiment of FIG. **8**, the bladder **66** has a yoke-like design in which the bladder comprises a continuous, elongated, tubular element that extends around the back of the shirt collar **68** (see FIG. **8**B) and down the front of the shirt **60** on both sides of the user's body (see FIG. **8**A). More particularly, the bladder **66** has a neck portion **70** that extends from one lateral side of the collar **68**, around the back of the collar, and to the other lateral side of the collar, and two opposed elongated torso portions **72** that each extends down from the neck portion along the front of the shirt **60** so as to extend across the user's chest and stomach on either side of the user's sagittal plane when the shirt is worn. In some embodiments, the bladder **66** can be made of polyurethane coated nylon. As indicated by dashed lines, the bladder **66** can be integrated into the material of the shirt body **62**. For example, the bladder **66** can be sewn into an internal pocket formed in the shirt body **62** so as to be inconspicuous and hydrodynamic.

With reference to FIG. **8**A, the shirt **60** also includes one or more sensors **74** that are placed at strategic positions within the shirt. More particularly, the shirt **60** includes one sensor **74** incorporated into each shirt sleeve **64** at a position at which they will overlie the biceps muscles when the shirt is worn, and two sensors **74** incorporated into the shirt body **62** at positions at which they will overlie the pectoralis muscles when the shirt is worn. Each sensor **74** can comprise an EMG electrode that is affixed (e.g., sewn or glued) to the interior surface of the shirt **62** such that the sensor can make direct contact with the skin of the user. In some embodiments, each sensor **62** can comprise a waterproof foam/gel surface electrode.

Connected to each sensor **74** is an electrical conductor **76**, such as an insulated metal wire, that extends from the sensor to the back of the shirt **60** and a central controller **78**, which is integrated therewith. Like the bladder **66**, the central controller **78** can be can be sewn into an internal pocket formed in the shirt body **62** so as to be inconspicuous and hydrodynamic. As noted above, this central controller **78** can comprise the microprocessor **26**, memory **28**, and battery **32**. In the illustrated embodiment, the central controller **78** is integrated with the shirt body **62** so as to be positioned at the middle or upper back of the user when the shirt is worn.

Also integrated with the back of the shirt body **62** is the gas-generating component **80** and the gas-generating component actuator **82**, which is in electrical communication with the central controller **78**. The gas-generating component **80** is coupled to the bladder **66** such that the gas generated within the component is ejected into the bladder when it is activated by the actuator **82** under the control of the central controller **78**. Like the central controller **78**, the gas-generating component **80** and the gas-generating component actuator **82** can be can be sewn into internal pockets

formed in the shirt body **62** so as to be inconspicuous and hydrodynamic. In at least the case of the pocket used to contain the gas-generating component **80**, the pocket can be opened and closed by the user to remove and replace the gas-generating component once it has been used.

In some embodiments, the shirt **60** and its flotation device can include manual controls that enable the user to determine when the bladder **66** is or is not inflated. As shown in FIG. **8**A, an inflation activation button **84** and an inflation cancelation button **86** can be provided on the exterior of the front of the shirt **60** and electrically connected to the central controller **78** with an electrical conductor **88**. When provided, the activation button **84** can be pressed by the user to activate the actuator **82** and inflate the bladder **66**. In such a case, the inflation device of the shirt **60** can be activated by the user when he or she feels a seizure coming on. More generally, however, the inflation device of the shirt **60** can be used by anyone who wishes to use a manually activated flotation device.

When the cancelation button **86** is provided, it can be pressed by the user to prevent activation of the actuator **82** and inflation of the bladder **66**. In such a case, the inflation device can incorporate an auditory and/or vibratory alarm that is activated by the central controller **78** when it determines that the user is having a seizure. The central controller **78** can be configured to delay activation of the actuator **82** for a few seconds after the alarm is initiated, however, to provide the user with an opportunity to override inflation of the bladder **66** in cases in which the user is not actually experiencing a seizure (i.e., a false positive determination has been made by the controller).

The invention claimed is:

1. A personal flotation device adapted to be worn by a user comprising:

an inflation system including an inflatable bladder and a gas-generating component, the gas-generating component being configured to generate gas using a chemical reaction and inject the generated gas into the bladder to inflate it, the gas-generating component comprising a first compartment that contains water, a second compartment that contains a gas-generating compound, a first sacrificial element that separates the water from the gas-generating compound that is configured to fail when pressure is applied to the element by the water, and a second sacrificial element that separates the second compartment from an interior of the bladder that is configured to fail when pressure is applied to the element by the generated gas; and

an inflation control system configured to control activation of the gas-generating component.

2. The device of claim **1**, wherein the gas-generating compound is a hydrogen-generating compound and the gas-generating component is configured to inject hydrogen gas into the bladder.

3. The device of claim **2**, wherein the hydrogen-generating compound is calcium hydride.

4. The device of claim **1**, wherein the inflation control system is configured to activate the gas-generating component when the control system determines that the user is experiencing a seizure.

5. The device of claim **4**, wherein the inflation control system comprises electrodes configured for application to the user's skin and a central controller that receives electromyography (EMG) signals from the electrodes that are indicative of the user's muscle contractions.

6. The device of claim **5**, wherein the central controller is configured to analyze the EMG signals and activate the gas-generating component when the amplitude and frequency of the signals exceed predetermined thresholds, which is indicative of the user having a seizure.

7. The device of claim **1**, wherein the device is integrated into a swimming garment.

8. A swimming garment configured to prevent drowning of a wearer of the garment, the garment comprising:

a garment body;

garment sleeves; and

a flotation system comprising:

an inflation system including an inflatable bladder and a gas-generating component, the gas-generating component being configured generate gas using a chemical reaction and inject the generated gas into the bladder to inflate it, the gas-generating component comprising a first compartment that contains water, a second compartment that contains a gas-generating compound, a first sacrificial element that separates the water from the gas-generating compound and that is configured to fail when pressure is applied to the element by the water, and a second sacrificial element that separates the second compartment from an interior of the bladder and that is configured to fail when pressure is applied to the element by the generated gas, and

an inflation control system configured to control activation of the gas-generating component.

9. The garment of claim **8**, wherein the garment body and sleeves are made of neoprene.

10. The garment of claim **8**, wherein the inflatable bladder comprises a continuous, elongated, tubular element that extends around a back of a collar of the garment and down a front of the garment.

11. The garment of claim **8**, wherein the inflation control system is configured to activate the gas-generating component when the control system determines that the user is experiencing a seizure.

12. The garment of claim **11**, wherein the inflation control system comprises electrodes configured for application to the user's skin and a central controller that receives electromyography (EMG) signals from the electrodes that are indicative of the user's muscle contractions.

13. The garment of claim **12**, wherein the central controller is configured to analyze the EMG signals and activate the gas-generating component when the amplitude and frequency of the signals exceed predetermined thresholds, which is indicative of the user having a seizure.

14. A method for preventing drowning, the method comprising:

detecting when a person in a body of water is experiencing a medical event that places the person in danger of drowning; and

in response to the detecting, automatically inflating a bladder worn by the person to provide buoyancy that prevents the person from drowning, wherein automatically inflating a bladder comprises inflating the bladder with a gas-generating component, the gas-generating component being configured to generate gas using a chemical reaction and inject the generated gas into the bladder to inflate it, the gas-generating component comprising a first compartment that contains water, a second compartment that contains a gas-generating compound, a first sacrificial element that separates the water from the gas-generating compound that is configured to fail when pressure is applied to the element by the water, and a second sacrificial element that separates the second compartment from an interior of

the bladder that is configured to fail when pressure is applied to the element by the generated gas.

15. The method of claim **14**, wherein detecting when a person is experiencing a medical event comprises detecting when the person is having a seizure and wherein automatically inflating a bladder comprises automatically inflating the bladder with hydrogen gas produced by the chemical reaction between the water and the gas-generating compound.

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