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(54) **SYSTEM AND METHOD FOR MEASURING PAYLOAD DOSAGE IN A VAPORIZATION DEVICE**

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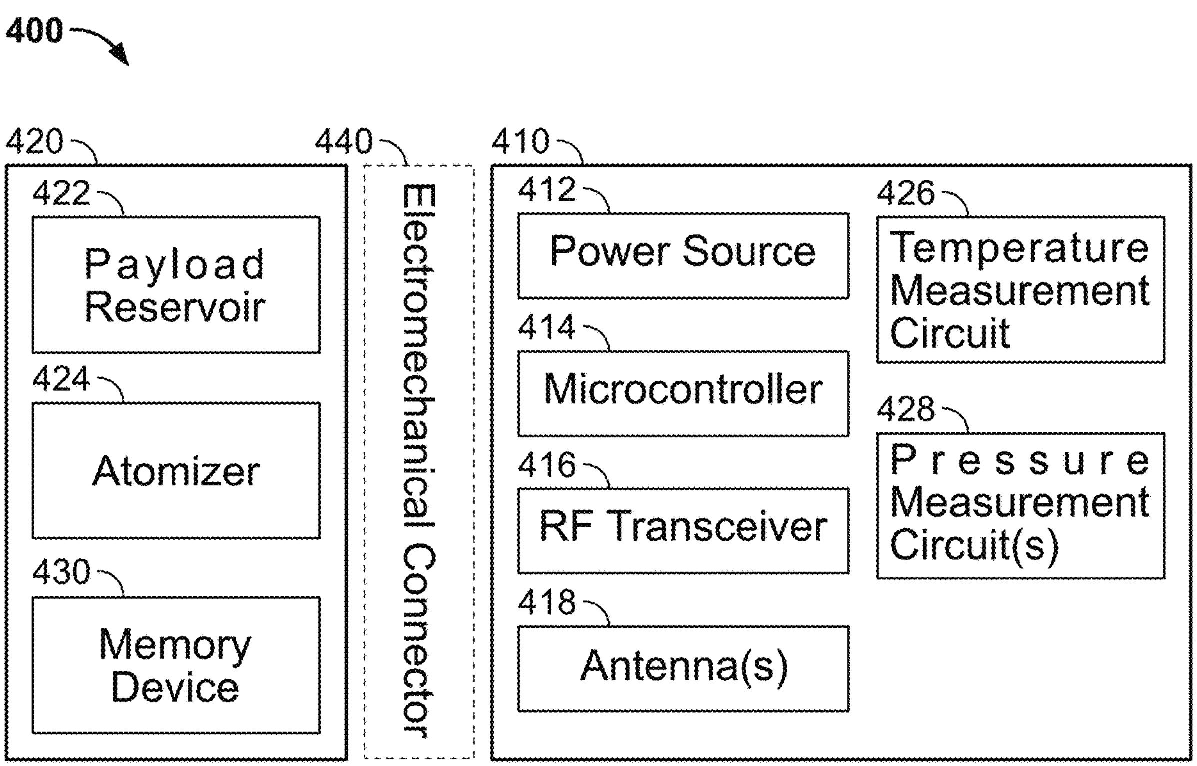
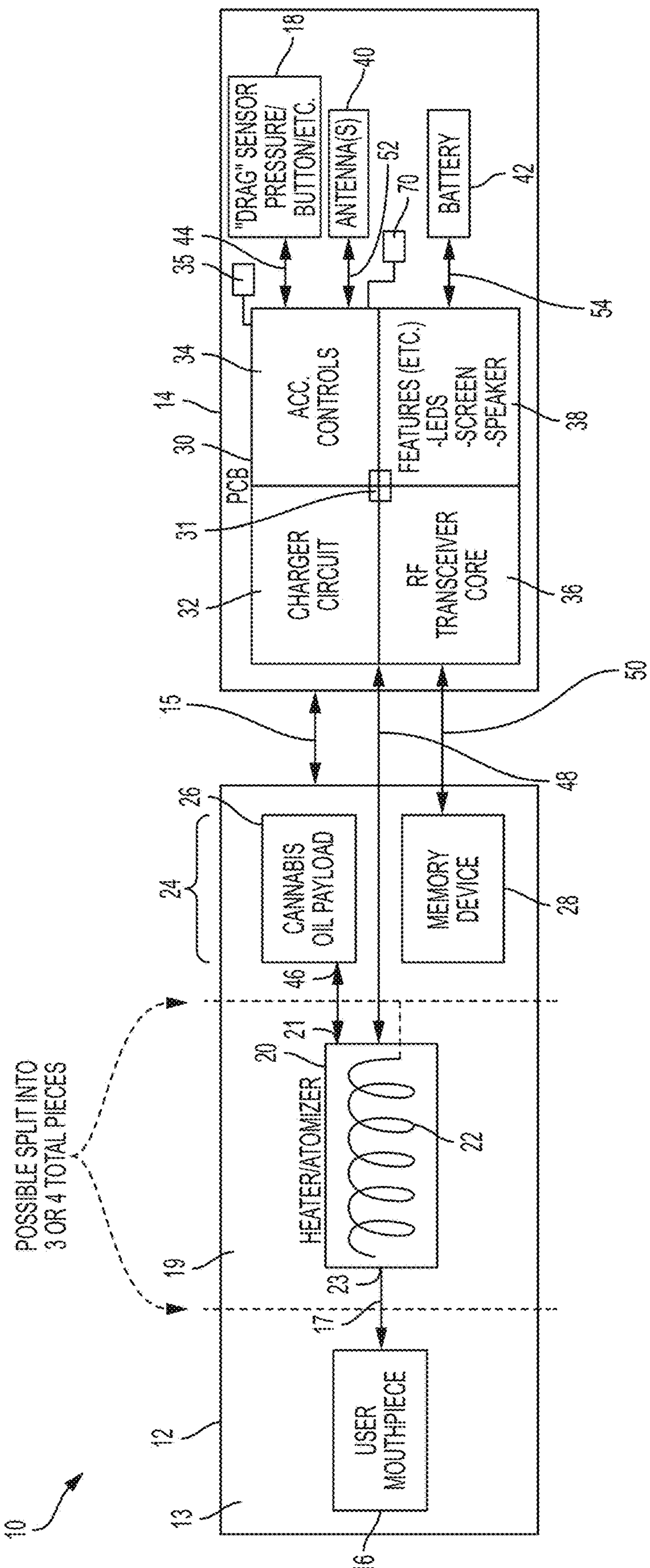
CPC ***A24F 40/57*** (2020.01); *A24F 40/51* (2020.01); ***A24F 40/65*** (2020.01); ***A24F 40/60*** (2020.01)

(57) **ABSTRACT**

The present invention is directed to a vape device configured to determine the dose of a payload delivered to a user during each of a plurality of user inhalations. In a first embodiment, the vape device tracks the energy used to vaporize a portion of the payload during user inhalation to determine the dose. In a second embodiment, the vape device measures the temperature at multiple locations within the air flow chamber during user inhalation to determine the dose. In a third embodiment, the vape device measures the intensity of light that is transmitted through the vaporized payload, reflected off the vaporized payload, or transmitted through a light transmitting medium positioned within the vaporized payload, during user inhalation to determine the dose. In a fourth embodiment, the vape device utilizes hot wire anemometers to determine the mass of the vaporized payload that was delivered to the user during each user inhalation and/or to determine the size and density distribution of the droplets in the vaporized payload and use such distribution to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation. The disclosed methods may be used independently, or in any combination, in accordance with the invention.




"DRAG" SENSOR PRESSURE/ BUTTON/ETC.
ANTENNA(S)
BATTERY
ACC. CONTROLS
FEATURES (ETC.) -LEDS -SCREEN -SPEAKER
PCB
CHARGER CIRCUIT
RF TRANSCEIVER CORE
CANNABIS OIL PAYLOAD
MEMORY DEVICE
HEATER/ATOMIZER
USER MOUTHPIECE
POSSIBLE SPLIT INTO 3 OR 4 TOTAL PIECES
10
12
13
14
15
16
17
18
19
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21
22
23
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54
70

FIG. 1

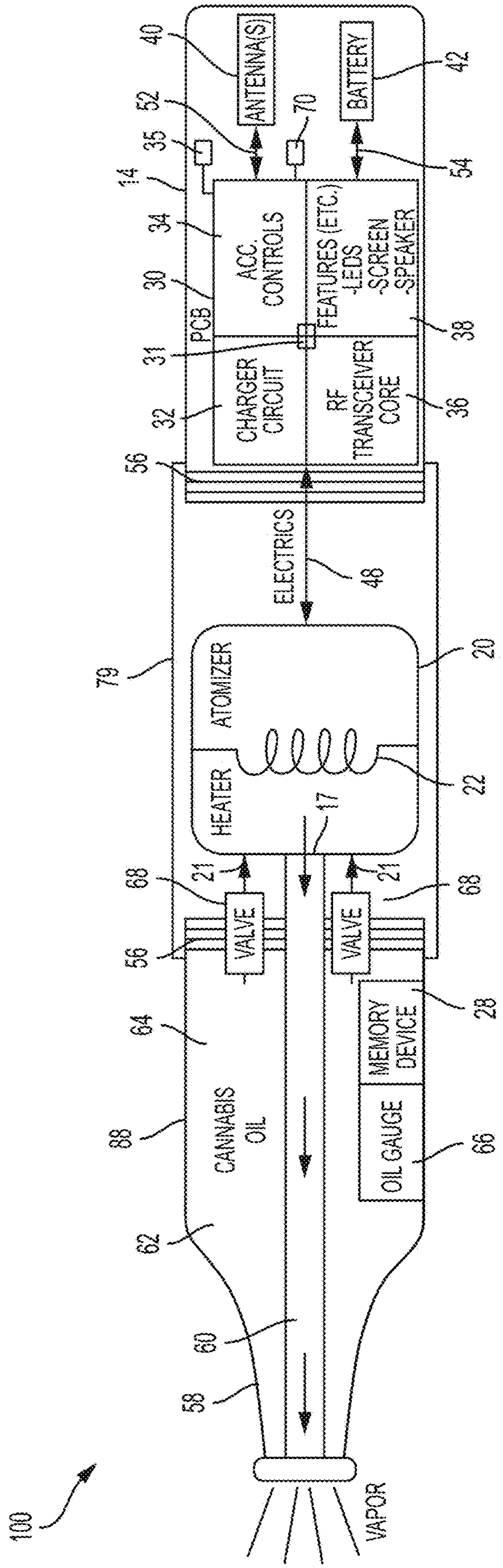
ANTENNA(S)
BATTERY
ACC. CONTROLS
FEATURES (ETC.)
-LEDS
-SCREEN
-SPEAKER
PCB
CHARGER CIRCUIT
RF TRANSCEIVER CORE
ELECTRICS
ATOMIZER
HEATER
VALVE
VALVE
MEMORY DEVICE
OIL GAUGE
CANNABIS OIL
VAPOR
40
52
35
14
34
30
31
32
56
70
42
54
38
36
48
79
20
22
17
21
21
68
68
56
64
28
88
66
62
60
58
100

FIG. 2

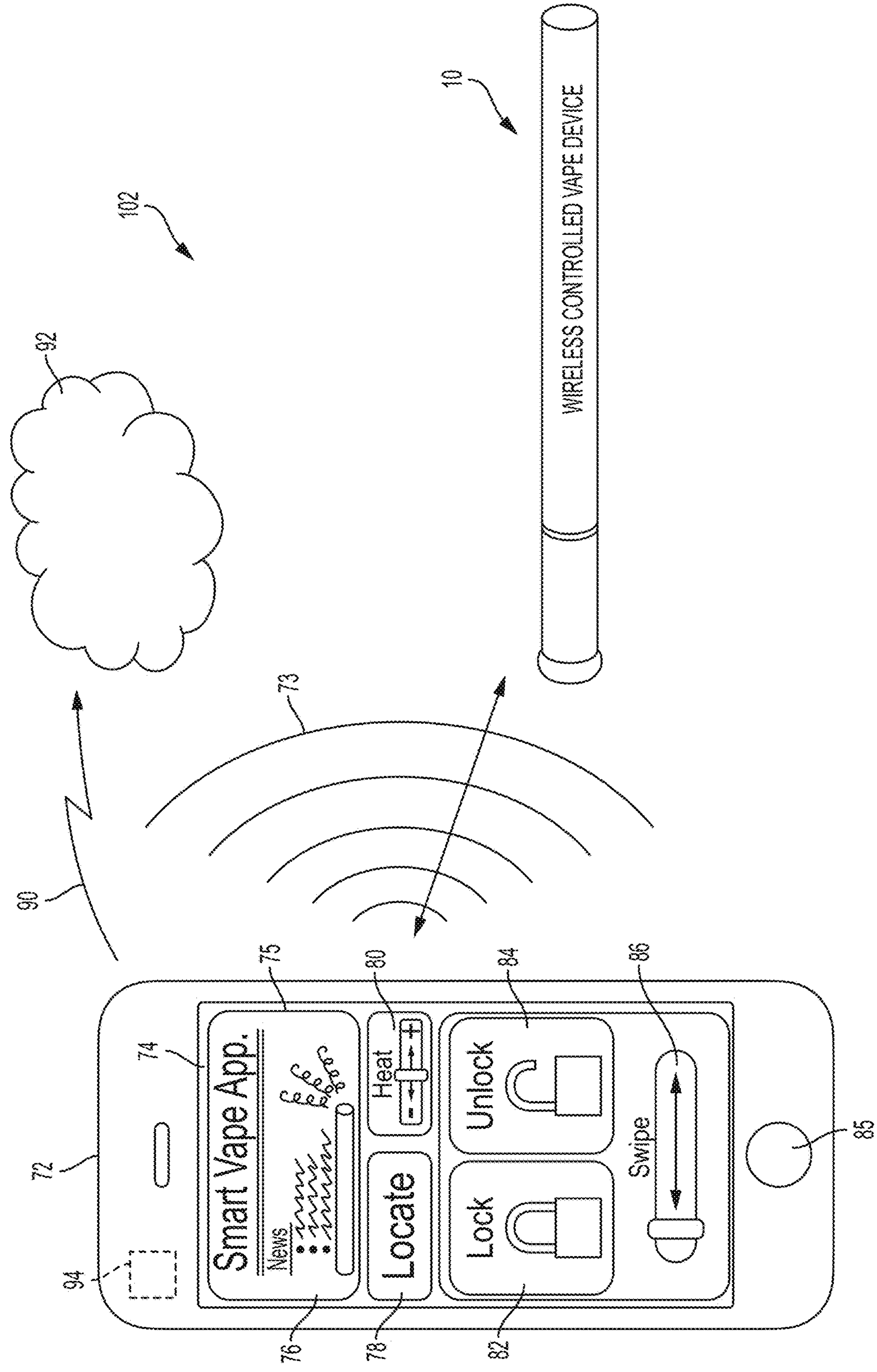
10
WIRELESS CONTROLLED VAPE DEVICE
102
92
73
90
72
74
75
80
84
86
85
94
76
78
82
Smart Vape App.
News
Heat
Locate
Unlock
Lock
Swipe

FIG. 3

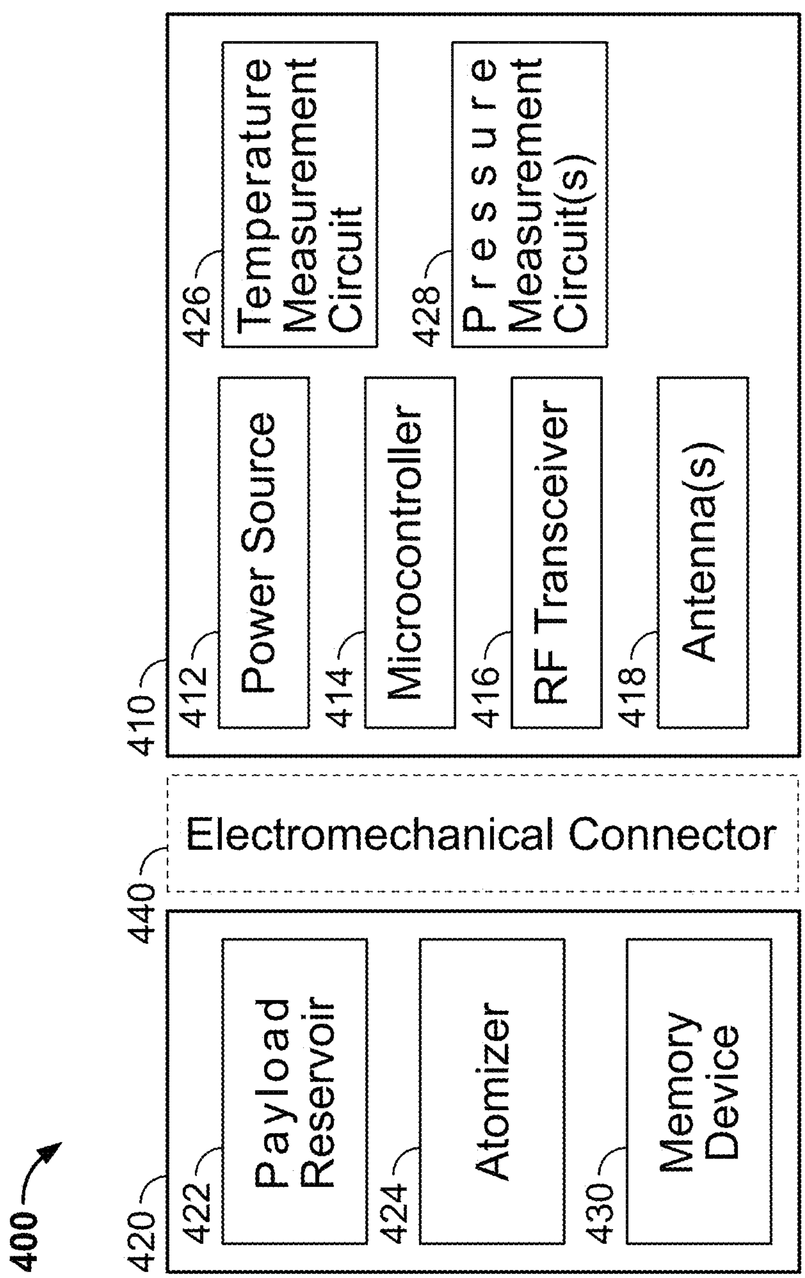
400
410
412
Power Source
414
Microcontroller
416
RF Transceiver
418
Antenna(s)
426
Temperature Measurement Circuit
428
Pressure Measurement Circuit(s)
440
Electromechanical Connector
420
422
Payload Reservoir
424
Atomizer
430
Memory Device

FIG. 4

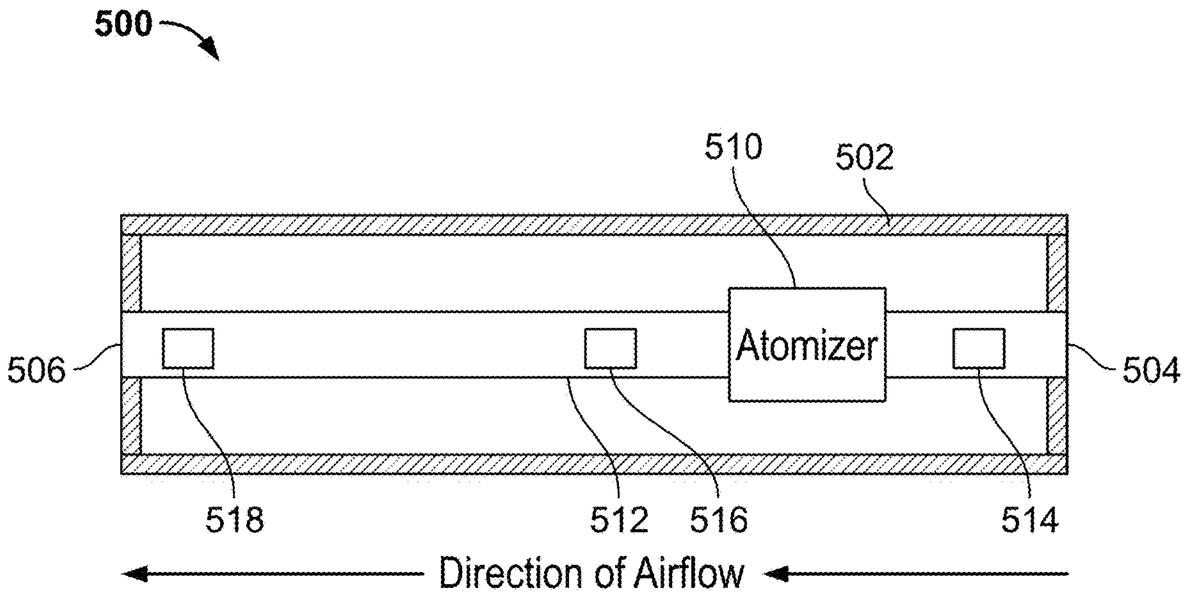
500
510
502
Atomizer
506
504
518
512
516
514
Direction of Airflow

FIG. 5

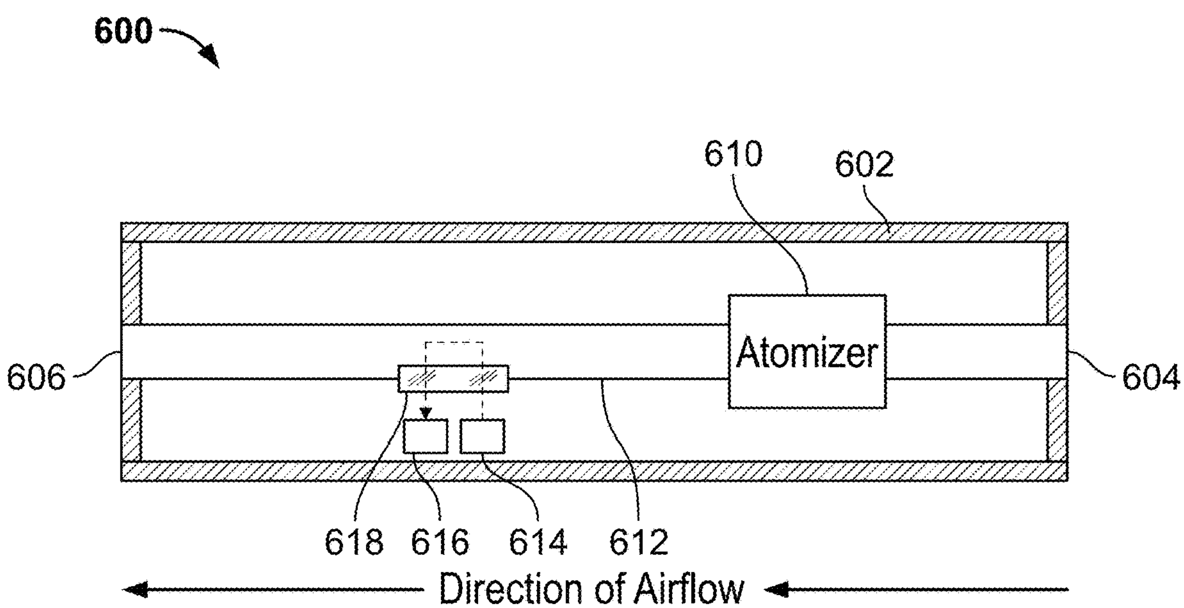
600
610
602
Atomizer
606
604
618
616
614
612
Direction of Airflow

FIG. 6

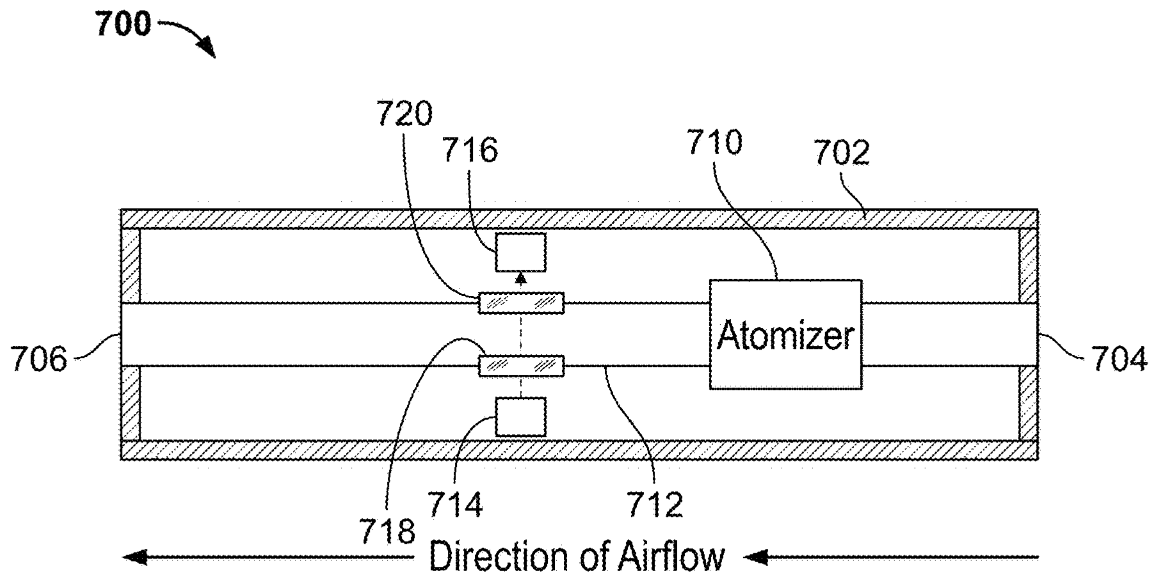
700
720
716
710
702
Atomizer
706
704
718
714
712
Direction of Airflow

FIG. 7

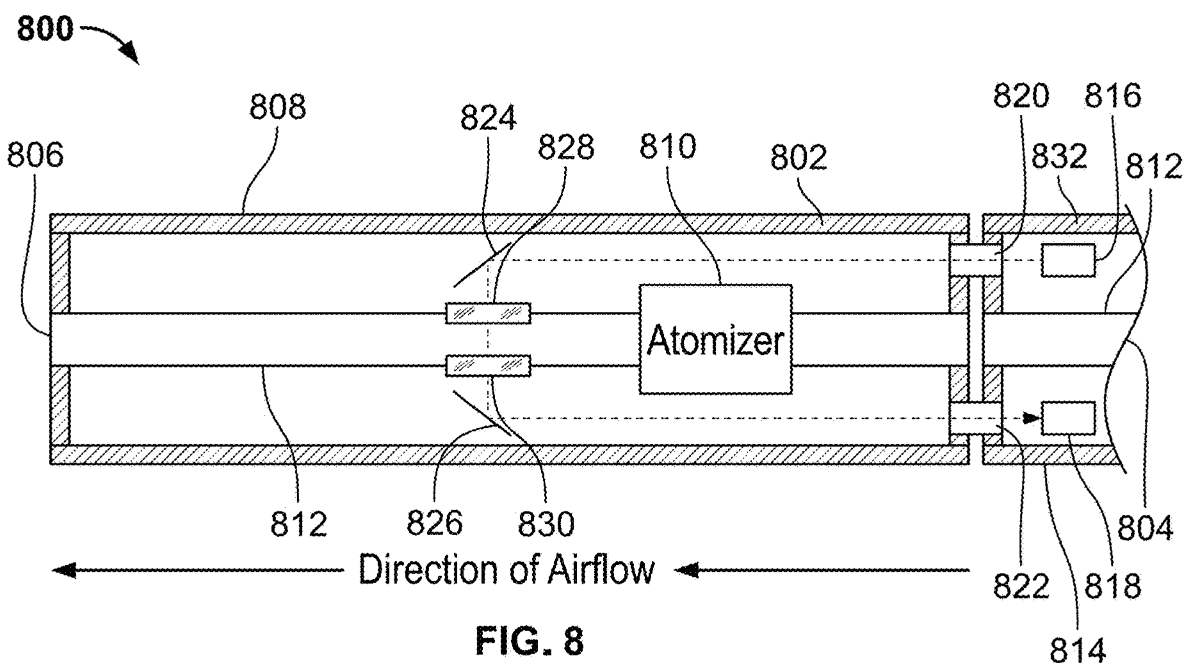
800
808
806
824
828
810
802
820
816
832
812
Atomizer
812
826
830
804
822
818
814
Direction of Airflow

FIG. 8

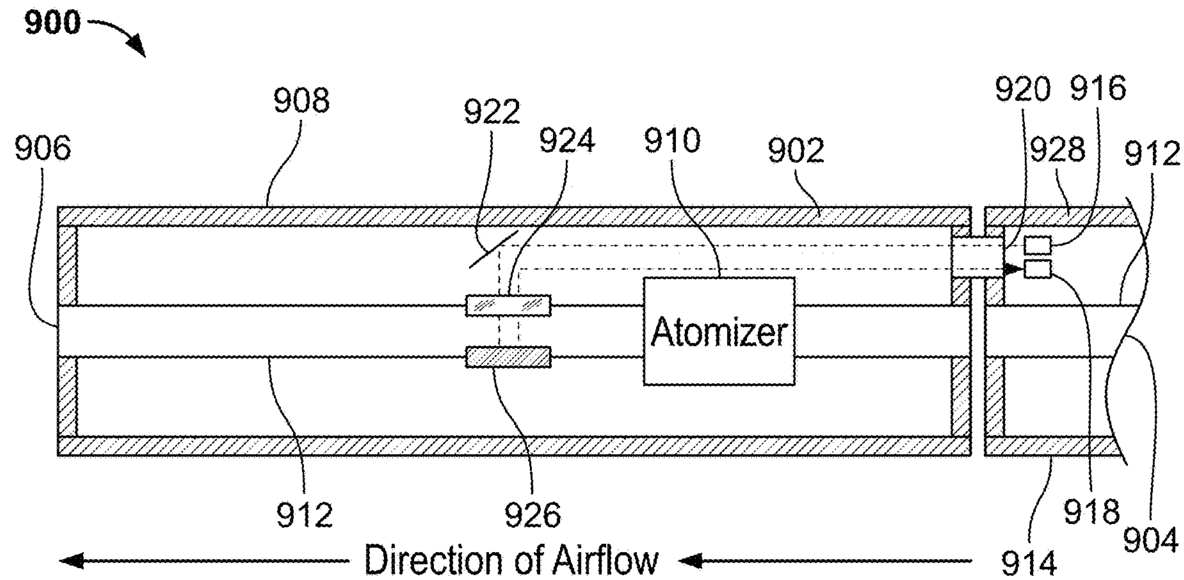
900
908
922
924
910
902
920 916
928
912
906
Atomizer
912
926
918
904
914
Direction of Airflow

FIG. 9

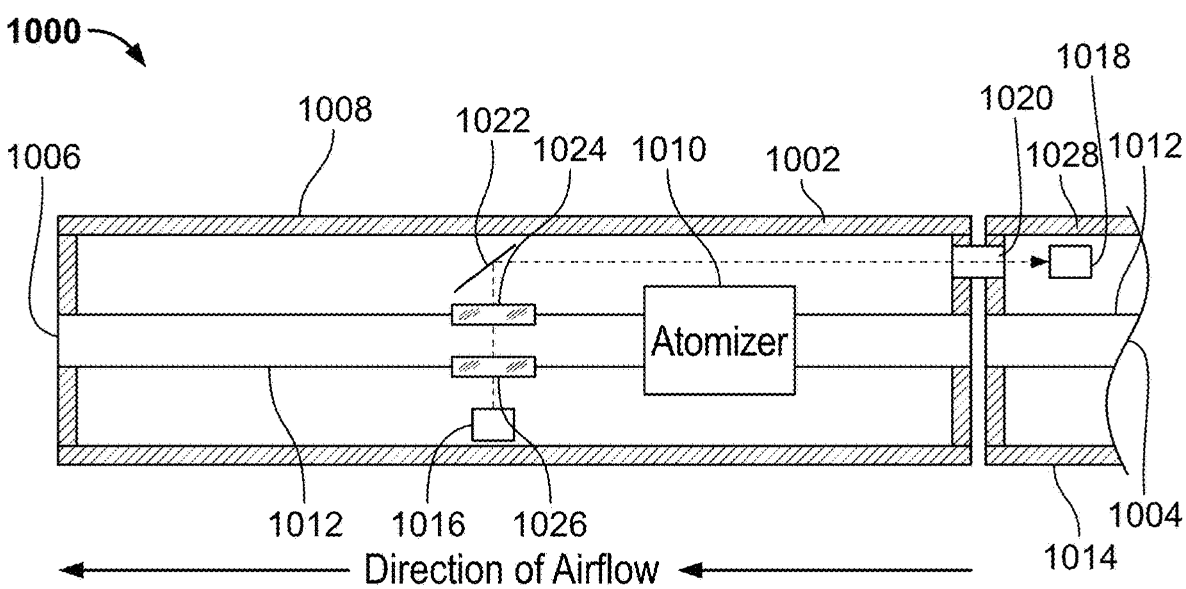
1000
1018
1020
1008
1022
1024
1010
1002
1028
1012
1006
Atomizer
1012
1016
1026
1004
1014
Direction of Airflow

FIG. 10

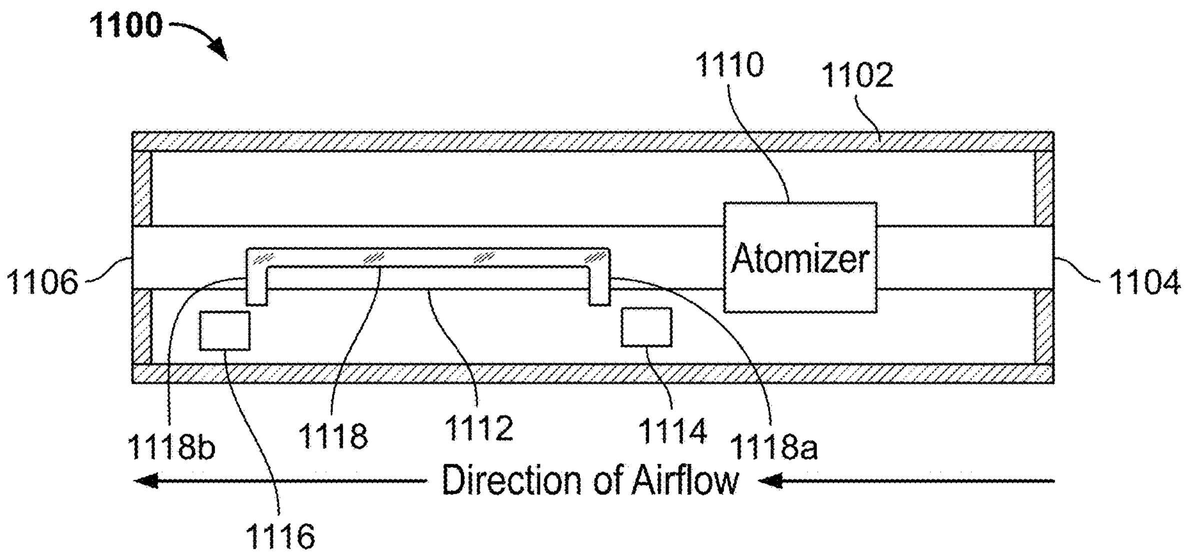

FIG. 11A

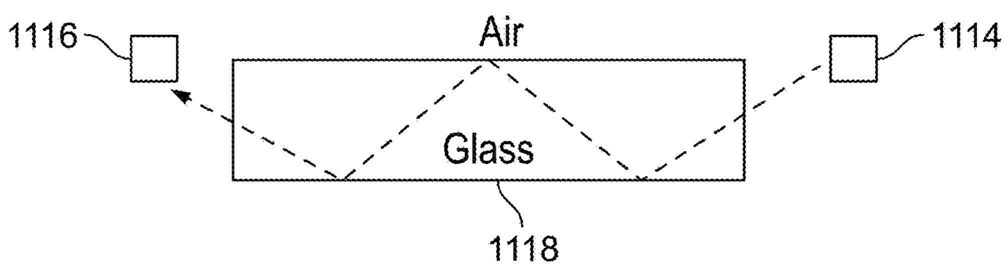

FIG. 11B

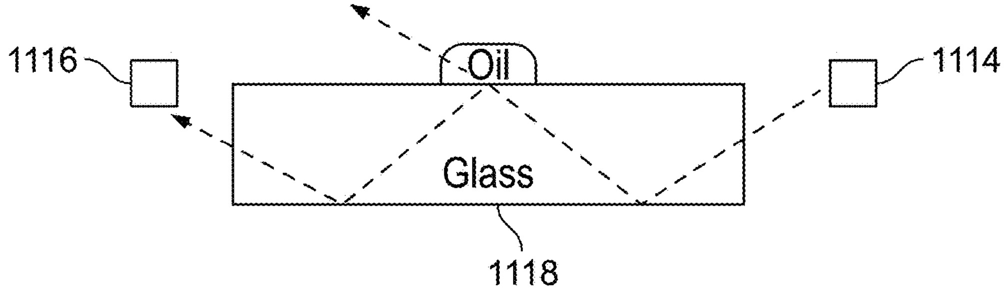

FIG. 11C

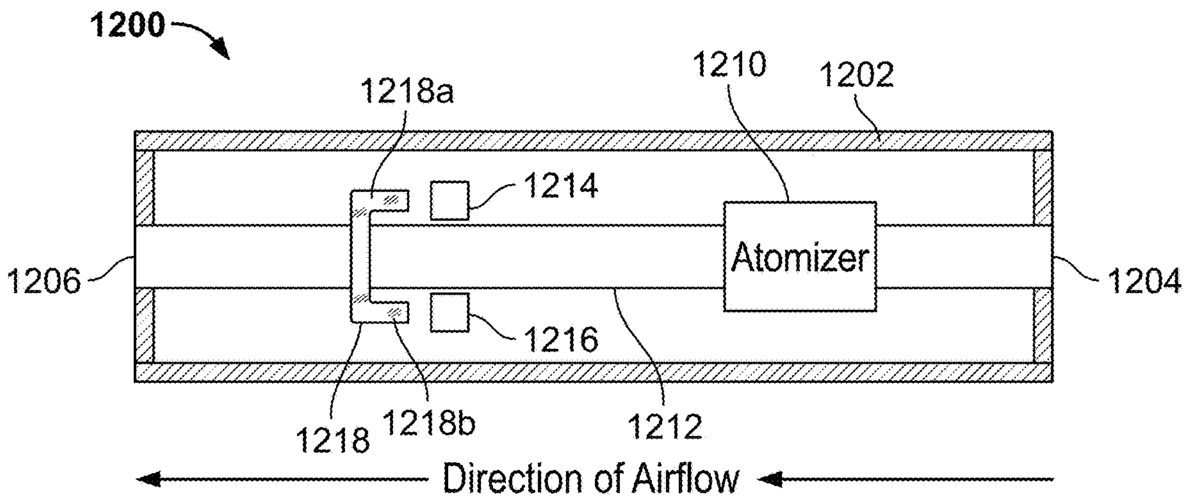
1200
1218a
1210
1202
1214
Atomizer
1206
1204
1216
1218
1218b
1212
Direction of Airflow

FIG. 12

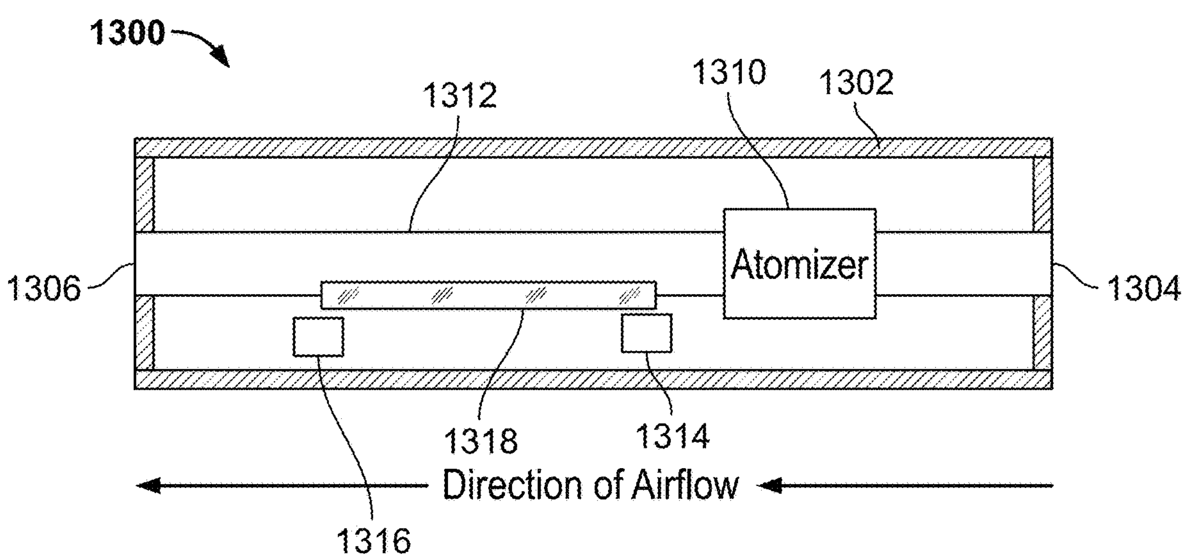
1300
1312
1310
1302
Atomizer
1306
1304
1318
1314
Direction of Airflow
1316

FIG. 13

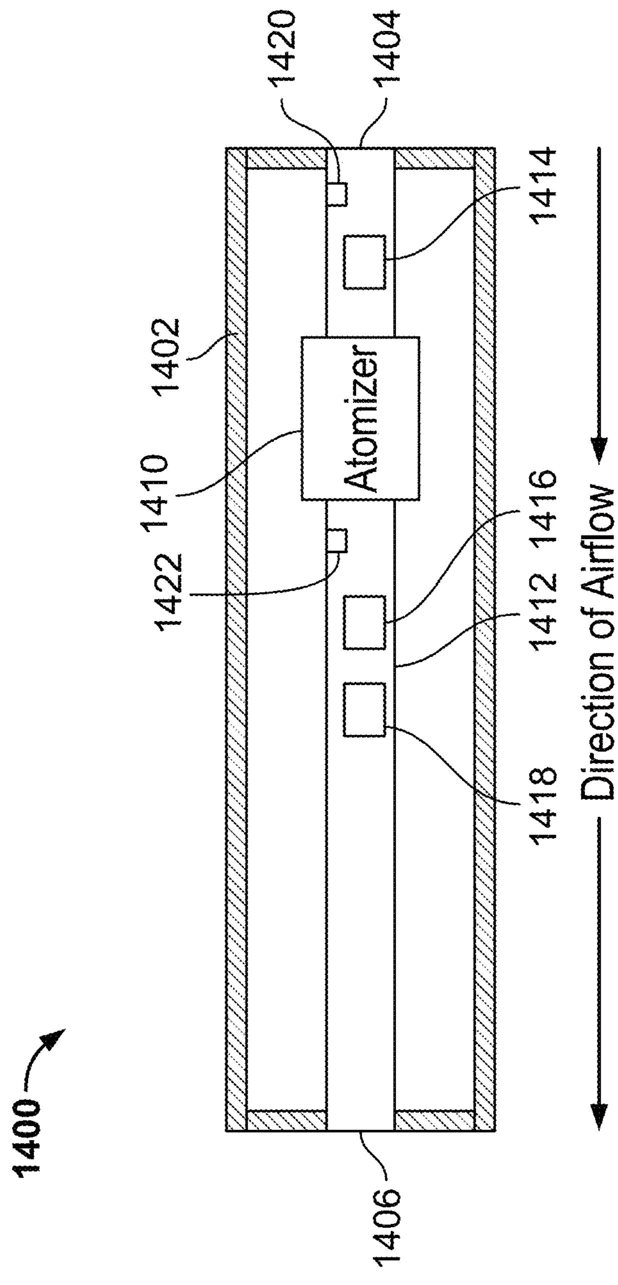
1400
1402
1404
1406
1410
Atomizer
1412
1414
1416
1418
1420
1422
Direction of Airflow

FIG. 14

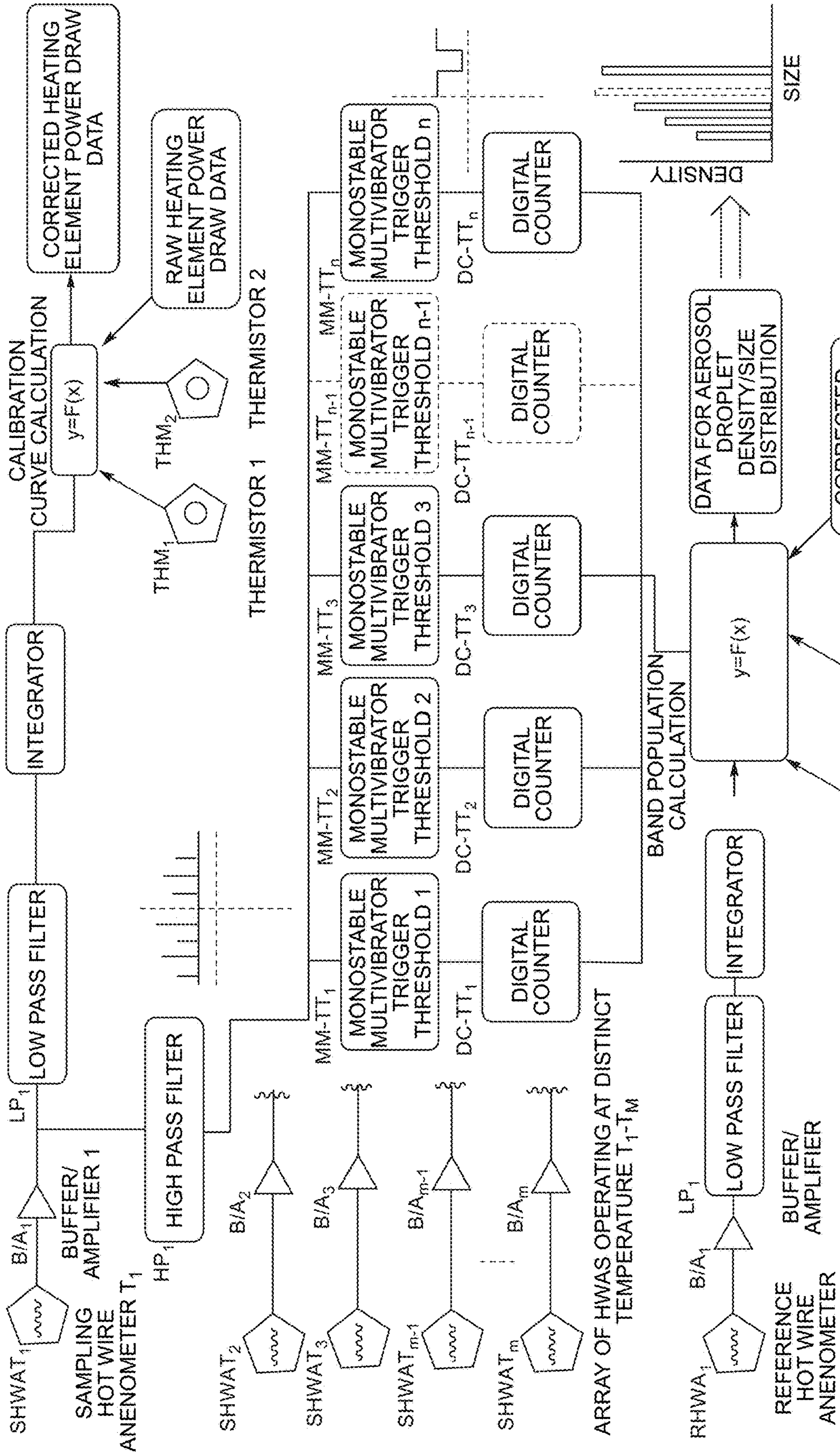
SHWAT1
SAMPLING HOT WIRE ANENOMETER T1
B/A1
BUFFER/ AMPLIFIER 1
LP1
LOW PASS FILTER
INTEGRATOR
CALIBRATION CURVE CALCULATION
y=F(x)
CORRECTED HEATING ELEMENT POWER DRAW DATA
RAW HEATING ELEMENT POWER DRAW DATA
THM1
THM2
THERMISTOR 1
THERMISTOR 2
HP1
HIGH PASS FILTER
SHWAT2
B/A2
SHWAT3
B/A3
SHWATm-1
B/Am-1
SHWATm
B/Am
ARRAY OF HWAS OPERATING AT DISTINCT TEMPERATURE T1-TM
MM-TT1
MONOSTABLE MULTIVIBRATOR TRIGGER THRESHOLD 1
MM-TT2
MONOSTABLE MULTIVIBRATOR TRIGGER THRESHOLD 2
MM-TT3
MONOSTABLE MULTIVIBRATOR TRIGGER THRESHOLD 3
MM-TTn-1
MONOSTABLE MULTIVIBRATOR TRIGGER THRESHOLD n-1
MM-TTn
MONOSTABLE MULTIVIBRATOR TRIGGER THRESHOLD n
DC-TT1
DIGITAL COUNTER
DC-TT2
DIGITAL COUNTER
DC-TT3
DIGITAL COUNTER
DC-TTn-1
DIGITAL COUNTER
DC-TTn
DIGITAL COUNTER
BAND POPULATION CALCULATION
y=F(x)
DATA FOR AEROSOL DROPLET DENSITY/SIZE DISTRIBUTION
CORRECTED HEATING ELEMENT POWER DRAW DATA
THM1
THM2
THERMISTOR 1
THERMISTOR 2
DENSITY
SIZE
RHWA1
REFERENCE HOT WIRE ANENOMETER
B/A1
BUFFER/ AMPLIFIER
LP1
LOW PASS FILTER
INTEGRATOR

FIG. 15

SYSTEM AND METHOD FOR MEASURING PAYLOAD DOSAGE IN A VAPORIZATION DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority to U.S. Provisional Application Ser. No. 62/813,845, filed on Mar. 5, 2019, and U.S. Provisional Application Ser. No. 62/899,828, filed on Sep. 13, 2019, each of which is incorporated herein by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0003] The present disclosure is generally related to the field of personal vaporizer devices and, in particular, to systems and methods for measuring the dosage of a vaporized payload that is delivered to the user of a personal vaporizer device.

2. Description of Related Art

[0004] The use of personal vaporizer devices or "vape devices" for consuming *cannabis*, tobacco products, and other substances has grown significantly. In a basic form, a vape device consists of an atomizer, a battery, a switch for connecting the battery to the atomizer, and a reservoir that contains an amount of payload (e.g., *cannabis* oil) to be vaporized by the atomizer. Controlling the vape device merely entails closing the switch so that current passes from the battery through a coil of the atomizer whereby the atomizer heats up and begins to vaporize a portion of the payload. The vapor—i.e., the cloud-like emission from a vape device that may be some combination of actual gas phase vapor and aerosol—is then inhaled by the user so that the desired components (e.g., THC, CBD, etc.) are delivered for medical or recreational purposes.

[0005] While there are a few conventional vape devices that attempt to determine the dosage of a vaporized payload delivered to a user, they use inaccurate methods that offer poor dose metering performance. It is technically difficult to accurately measure the dose administered by a vape device because, for example, vapor density can be inconsistent and operating conditions will vary. As such, medicinal patients are unsure of the dosage that they have consumed at any given time, which limits the repeatability and efficacy of the drug's effects. Also, recreational users may experience different effects (desirable and undesirable) depending on dosage. Thus, there remains a need in the art for a vape device that accurately measures the dose of a payload delivered to a user and/or that offers other advantages compared to conventional vape devices.

BRIEF SUMMARY OF THE INVENTION

[0006] The present invention is directed to a vape device for determining the dose of a payload delivered to a user during each of a plurality of user inhalations (commonly referred to as a "draw" or "drag" or "puff"). The vape device may use four different methods, independently or in any combination, to measure the portion of the payload that is vaporized during each user inhalation. The first method tracks the energy used to vaporize the payload portion during user inhalation in order to determine the mass of the vaporized payload; the second method measures the temperature at multiple locations within the air flow chamber during the user inhalation (and optionally before and after the user inhalation) to determine the vapor density and by extension the mass of the vaporized payload; the third method measures the intensity of light that is transmitted through the vaporized payload, reflected off the vaporized payload, or transmitted through a light transmitting medium positioned within the vaporized payload, before, during, and after user inhalation to determine the vapor density and by extension the mass of the vaporized payload; and the fourth method utilizes hot wire anemometers to determine the mass of the vaporized payload that was delivered to the user during each user inhalation and/or to determine the size and density distribution of the droplets in the vaporized payload and use such distribution to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation. More accurate dose metering is beneficial to both medicinal and recreational users insofar as they will be able to accurately measure their dosage to obtain the desired effects in a repeatable fashion.

[0007] A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations in accordance with one exemplary embodiment of the invention described herein comprises: a payload reservoir configured to contain a payload to be vaporized; a power source configured to generate a power signal during each respective user inhalation; an atomizer configured to receive the power signal and vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; and a microcontroller programmed to determine a dose of the vaporized payload for each respective user inhalation based on: (a) determining an amount of energy used to vaporize the portion of the payload during the user inhalation; and (b) determining a partial mass of the payload that is vaporized during the user inhalation based on the amount of energy used to vaporize the portion of the payload during the user inhalation.

[0008] A method for determining a dose of a payload delivered to a user of a vape device during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: holding a payload to be vaporized; vaporizing a portion of the payload by transmitting a power signal from a power source to an atomizer to thereby generate a vaporized payload during each respective user inhalation; and determining a dose of the vaporized payload for each respective user inhalation based on: (a) determining an amount of energy used to vaporize the portion of the payload during the user inhalation; and (b) determining a partial mass of the payload that is vaporized during the user inhalation based on the amount of energy used to vaporize the portion of the payload during the user inhalation.

[0009] A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: a payload reservoir configured to contain a payload to be vaporized; an air flow chamber that extends between an inlet and an outlet;

an atomizer positioned between the inlet and the outlet of the air flow chamber, wherein the atomizer is configured to vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; and a microcontroller programmed to determine a dose of the vaporized payload for each respective user inhalation based on: (a) a plurality of temperature measurements obtained within the air flow chamber during the user inhalation; and (b) an air flow rate within the air flow chamber during the user inhalation.

[0010] A method for determining a dose of a payload delivered to a user of a vape device during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: holding a payload to be vaporized; vaporizing a portion of the payload with an atomizer positioned between an inlet and an outlet of an air flow chamber to thereby generate a vaporized payload during each respective user inhalation; and determining a dose of the vaporized payload for each respective user inhalation based on: (a) a plurality of temperature measurements obtained within the air flow chamber during the user inhalation; and (b) an air flow rate within the air flow chamber during the user inhalation.

[0011] A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: a payload reservoir configured to contain a payload to be vaporized; an air flow chamber that extends between an inlet and an outlet; an atomizer positioned between the inlet and the outlet of the air flow chamber, wherein the atomizer is configured to vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; and a microcontroller programmed to determine a dose of the vaporized payload for each respective user inhalation based on a plurality of light intensity measurements obtained during the user inhalation, wherein the light intensity measurements are associated with light that is transmitted through the vaporized payload, reflected off the vaporized payload, or transmitted through a light transmitting medium positioned within the vaporized payload, when the vaporized payload passes through the air flow chamber.

[0012] A method for determining a dose of a payload delivered to a user of a vape device during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: holding a payload to be vaporized; vaporizing a portion of the payload with an atomizer positioned between an inlet and an outlet of an air flow chamber to thereby generate a vaporized payload during each respective user inhalation; and determining a dose of the vaporized payload for each respective user inhalation based on a plurality of light intensity measurements obtained during the user inhalation, wherein the light intensity measurements are associated with light that is transmitted through the vaporized payload, reflected off the vaporized payload, or transmitted through a light transmitting medium positioned within the vaporized payload, when the vaporized payload passes through the air flow chamber.

[0013] A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: a payload reservoir configured to contain a payload to be vaporized; an air flow chamber that extends between an inlet and an outlet; an atomizer located between the inlet and the outlet of the air flow chamber, wherein the atomizer is configured to vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; at least one sampling hot wire anemometer located within the air flow chamber between the atomizer and the outlet, wherein the sampling hot wire anemometer is incorporated into a circuit configured to determine a number of droplets of the vaporized payload passing by the sampling hot wire anemometer during each respective user inhalation; and a microcontroller programmed to determine a dose of the vaporized payload for each respective user inhalation based on the number of droplets of the vaporized payload.

[0014] A method for determining a dose of a payload delivered to a user of a vape device during each of a plurality of user inhalations in accordance with another exemplary embodiment of the invention described herein comprises: holding a payload to be vaporized; vaporizing a portion of the payload with an atomizer positioned between an inlet and an outlet of an air flow chamber to thereby generate a vaporized payload during each respective user inhalation; determining a number of droplets of the vaporized payload passing by at least one sampling hot wire anemometer located within the air flow chamber between the atomizer and the outlet during each respective user inhalation; and determining a dose of the vaporized payload for each respective user inhalation based on the number of droplets of the vaporized payload.

[0015] Various other embodiments and features of the present invention are described in detail below with reference to the attached drawing figures, or will be apparent to those skilled in the art based on the disclosure provided herein, or may be learned from the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a schematic diagram of a first embodiment of a vape device in accordance with the invention described herein.

[0017] FIG. **2** is a schematic diagram of a second embodiment of a vape device in accordance with the invention described herein.

[0018] FIG. **3** is a schematic diagram of an embodiment of a vape device system that includes the vape device of FIG. **1** in wireless communication with a personal computing device.

[0019] FIG. **4** is a schematic diagram of an exemplary vape device that utilizes an energy usage method to determine the dose of vaporized payload delivered to a user.

[0020] FIG. **5** is a schematic diagram of an exemplary vape device that utilizes a temperature measurement method to determine the dose of vaporized payload delivered to a user.

[0021] FIGS. **6-13** are schematic diagrams of exemplary vape devices that utilize various light intensity measurement methods to determine the dose of vaporized payload delivered to a user.

[0022] FIG. **14** is a schematic diagram of an exemplary vape device that utilizes hot wire anemometers to determine the dose of vaporized payload delivered to a user.

[0023] FIG. **15** is a block diagram of exemplary components that may be incorporated into a vape device to determine the dose of vaporized payload delivered to a user and to determine the size and density distribution of the droplets in the vaporized payload.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE INVENTION

[0024] The present invention is directed to a vape device for determining the dose of a payload delivered to a user during each of a plurality of user inhalations. While the invention will be described in detail below with reference to various exemplary embodiments, it should be understood that the invention is not limited to the specific configuration or methodologies of any of these embodiments. In addition, although the exemplary embodiments are described as embodying several different inventive features, those skilled in the art will appreciate that any one of these features could be implemented without the others in accordance with the invention.

[0025] In this description, references to "one embodiment," "an embodiment," "an exemplary embodiment," or "embodiments" mean that the feature or features being described are included in at least one embodiment of the invention. Separate references to "one embodiment," "an embodiment," "an exemplary embodiment," or "embodiments" in this description do not necessarily refer to the same embodiment and are also not mutually exclusive unless so stated and/or except as will be readily apparent to those skilled in the art from the description. For example, a feature, structure, function, etc. described in one embodiment may also be included in other embodiments, but is not necessarily included. Thus, the present invention can include a variety of combinations and/or integrations of the embodiments described herein.

[0026] In this disclosure, the term "payload" refers to any payload suitable for a vape device. Non-limiting examples include a payload comprising nicotine, *cannabis*, a cannabinoid or a *cannabis* concentrate as an ingredient. The payload may include other components such as, without limitation, a viscosity modifying agent, a stabilizer, and a flavorant.

[0027] As used herein, the term "nicotine" can be of plant origin or of synthetic or semi-synthetic origin. For example, it can be extracted from tobacco leaves or obtained by chemical synthesis. Nicotine may also refer to a nicotine substitute, which is typically a molecule that is not addictive but has a sensory effect similar to that of nicotine.

[0028] As used herein, the term "*cannabis*" refers to a genus of flowering plant in the family Cannabaceae. The number of species within the genus is disputed. Three species may be recognized, *Cannabis sativa, Cannabis* indica and *Cannabis ruderalis*. *C. ruderalis* may be included within *C. sativa*; or all three may be treated as subspecies of a single species, *C. sativa*. The genus is indigenous to central Asia and the Indian subcontinent.

[0029] *Cannabis* has long been used for hemp fiber, hemp oils, medicinal purposes, and as a recreational drug. Industrial hemp products are made from *cannabis* plants selected to produce an abundance of fiber. To satisfy the UN Narcotics Convention, some *cannabis* strains have been bred to produce minimal levels of tetrahydrocannabinol (THC), the principal psychoactive constituent. Many additional plants have been selectively bred to produce a maximum level of THC. Various compounds, including hashish and hash oil, may be extracted from the plant.

[0030] Within naturally occurring and manmade hybrids, *cannabis* contains a vast array of compounds. Three compound classes are of interest within the context of the present disclosure, although other compounds can be present or added to the compositions to optimize the experience of a given recreational consumer and medical or medicinal patient or patient population. Those classes include cannabinoids, terpenes and flavonoids.

[0031] There are many ways of growing *cannabis*, some of which are natural, and some are carefully designed by humans, and they will not be recited here. However, one of ordinary skill in the art of *cannabis* production will typically place a *cannabis* seed or cutting into a growth media such as soil, manufactured soil designed for *cannabis* growth or one of many hydroponic growth media. The *cannabis* seed or cutting is then provided with water, light and, optionally, a nutrient supplement. At times, the atmosphere and temperature are manipulated to aid in the growth process. Typically, the humidity, air to carbon dioxide gas ratio and elevated temperature, either by use of a heat source or waste heat produced by artificial light, are used. On many occasions ventilation is carefully controlled to maintain the conditions described above within an optimal range to both increase the rate of growth and, optionally, maximize the plant's production of the compounds, which comprise the compositions of the disclosure. It is possible to control lighting cycles to optimize various growth parameters of the plant.

[0032] Given the number of variables and the complex interaction of the variables, it is possible to develop highly specific formulas for production of *cannabis* which lead to a variety of desired plant characteristics. The present disclosure is applicable to use with such inventive means for growing *cannabis* as well as any of the variety of conventional methods.

[0033] *Cannabis sativa* is an annual herbaceous plant in the *Cannabis* genus. It is a member of a small, but diverse family of flowering plants of the Cannabaceae family. It has been cultivated throughout recorded history, used as a source of industrial fiber, seed oil, food, recreation, religious and spiritual moods and medicine. Each part of the plant is harvested differently, depending on the purpose of its use. The species was first classified by Carl Linnaeus in 1753.

[0034] *Cannabis* indica, formally known as *Cannabis sativa* forma indica, is an annual plant in the Cannabaceae family. A putative species of the genus *Cannabis*.

[0035] *Cannabis ruderalis* is a low-THC species of *Cannabis*, which is native to Central and Eastern Europe and Russia. It is widely debated as to whether *C. ruderalis* is a sub-species of *Cannabis sativa*. Many scholars accept *Cannabis ruderalis* as its own species due to its unique traits and phenotypes that distinguish it from *Cannabis* indica and *Cannabis sativa.*

[0036] As used herein, the term "cannabinoid" refers to a chemical compound belonging to a class of secondary compounds commonly found in plants of genus *cannabis*, but also encompasses synthetic and semi-synthetic cannabinoids.

[0037] The most notable cannabinoid is tetrahydrocannabinol (THC), the primary psychoactive compound in *cannabis*. Cannabidiol (CBD) is another cannabinoid that is a major constituent of the phytocannabinoids. There are at least 113 different cannabinoids isolated from *cannabis*, exhibiting varied effects.

[0038] Synthetic cannabinoids and semi-synthetic cannabinoids encompass a variety of distinct chemical classes, for example and without limitation: the classical cannabinoids structurally related to THC, the non-classical cannabinoids (cannabimimetics) including the aminoalkylindoles, 1,5 diarylpyrazoles, quinolines, and arylsulfonamides as well as eicosanoids related to endocannabinoids.

[0039] In many cases, a cannabinoid can be identified because its chemical name will include the text string "*cannabi*". However, there are a number of cannabinoids that do not use this nomenclature.

[0040] Within the context of this disclosure, where reference is made to a particular cannabinoid, each of the acid and/or decarboxylated forms are contemplated as both single molecules and mixtures. In addition, salts of cannabinoids are also encompassed, such as salts of cannabinoid carboxylic acids.

[0041] As well, any and all isomeric, enantiomeric, or optically active derivatives are also encompassed. In particular, where appropriate, reference to a particular cannabinoid includes both the "A Form" and the "B Form". For example, it is known that THCA has two isomers, THCA-A in which the carboxylic acid group is in the 1 position between the hydroxyl group and the carbon chain (A Form) and THCA-B in which the carboxylic acid group is in the 3 position following the carbon chain (B Form).

[0042] Examples of cannabinoids include, but are not limited to: cannabigerolic acid (CBGA), cannabigerolic acid monomethylether (CBGAM), cannabigerol (CBG), cannabigerol monomethylether (CBGM), cannabigerovarinic acid (CBGVA), cannabigerovarin (CBGV), cannabichromenic Acid (CBCA), cannabichromene (CBC), cannabichromevarinic Acid (CBCVA), cannabichromevarin (CBCV), cannabidiolic acid (CBDA), cannabidiol (CBD), Δ6-cannabidiol (Δ6 CBD), cannabidiol monomethylether (CBDM), cannabidiol-C4 (CBD-C4), cannabidivarinic Acid (CBDVA), cannabidivarin (CBDV), cannabidiorcol (CBD-C1), tetrahydrocannabinolic acid A (THCA-A), tetrahydrocannabinolic acid B (THCA-B), tetrahydrocannabinol (THC or Δ9-THC), Δ8 tetrahydrocannabinol (Δ8-THC), trans-410-tetrahydrocannabinol (trans-Δ10-THC), cis Δ10-tetrahydrocannabinol (cis-Δ10-THC), tetrahydrocannabinolic acid C4 (THCA-C4), tetrahydrocannbinol C4 (THC C4), tetrahydrocannabivarinic acid (THCVA), tetrahydrocannabivarin (THCV), Δ8-tetrahydrocannabivarin (Δ8-THCV), Δ9 tetrahydrocannabivarin (Δ9-THCV), tetrahydrocannabiorcoli c acid (THCA-C1), tetrahydrocannabiorcol (THC-C1), Δ7-cis-iso-tetrahydrocannabivarin, Δ8 tetrahydrocannabinolic acid (Δ8-THCA), Δ9-tetrahydrocannabinolic acid (Δ9-THCA), cannabicyclolic acid (CBLA), cannabicyclol (CBL), cannabicyclovarin (CBLV), cannabielsoic acid A (CBEA-A), cannabielsoic acid B (CBEA-B), cnnabielsoin (CBE), cannabinolic acid (CBNA), cannabinol (CBN), cannabinol methylether (CBNM), cannabinol-C4 (CBN-C4), cannabivarin (CBV), cannabino-C2 (CBN-C2), cannabiorcol (CBN-C1), cannabinodiol (CBND), cannabinodivarin (CBDV), cannabitriol (CBT), 11 hydroxy-Δ9-tetrahydrocannabinol (11-OH-THC), 11 nor 9-carboxy-δ9-tetrahydrocannabinol, ethoxy-cannabitriolvarin (CBTVE), 10 ethoxy-9-hydroxy-δ6a-tetrahydrocannabinol, cannabitriolvarin (CBTV), 8,9 dihydroxy-Δ6a(10a)-tetrahydrocannabinol (8,9-Di-OH-CBT-C5), dehydrocannabifuran (DCBF), cannbifuran (CBF), cannabichromanon (CBCN), cannabicitran (CBT), 10 oxo-Δ6a(10a)-tetrahydrocannabinol (OTHC), Δ9 cis tetrahydrocannabinol (cis THC), cannabiripsol (cbr), 3,4,5,6-tetrahydro-7-hydroxy-alpha-alpha-2-trimethyl-9-n-propyl-2,6-methano-2h-1-benzoxocin-5-methanol (OH-iso-HHCV), trihydroxy-delta-9-tetrahydrocannabinol (triOH-THC), yangonin, epigallocatechin gallate, dodeca-2e, 4e, 8z, 10z-tetraenoic acid isobutylamide, hexahydrocannibinol, and dodeca-2e,4e-dienoic acid isobutylamide.

[0043] In some embodiments of the present disclosure, the cannabinoid is a cannabinoid dimer. The cannabinoid may be a dimer of the same cannabinoid (e.g., THC-THC) or different cannabinoids. In an embodiment of the present disclosure, the cannabinoid may be a dimer of THC, including for example cannabisol.

[0044] As used herein, the term "*cannabis* concentrate" refers to a mixture of compounds that is obtained from a *cannabis* plant, such as for example a mixture of compounds or compositions that have been extracted from *cannabis*. The *cannabis* concentrate may be a concentrated composition of *cannabis*-derived cannabinoids, terpenes, terpenoids, and other naturally occurring compounds found in the *cannabis* plant. Non-limiting embodiments of a *cannabis* concentrate include a *cannabis* distillate, a *cannabis* isolate, a *cannabis* resin, a *cannabis* derived cannabinoid, or any other type of extract containing one or more cannabinoids or terpenes, terpenoids, and other naturally occurring compounds found in the *cannabis* plant.

[0045] As used herein, the term "viscosity control agent" describes a substance for controlling and maintaining the viscosity of the payload. Non-limiting embodiments of a viscosity control agent include propylene glycol (1,2-propanediol), 1,3-propanediol, polyethylene glycol, vegetable glycerin, a terpene, triacetin, diacetin and triethyl citrate.

[0046] As used herein, the term "stabilizer" is any substance used to prevent an unwanted change in state. The stabilizer may be used to improve or maintain the stability of the payload. For example, without a stabilizer, cannabinoids or *cannabis* concentrates may be susceptible to degradation, such as oxidative degradation, cannabinoids may crystallize out of the payload, and/or the payload may undergo color change.

[0047] As used herein, the term "flavorant" is used to describe a compound or combination of compounds that may provide flavor and/or aroma to the payload. The flavorant may include at least one of a natural flavorant or an artificial flavorant. Non-limiting embodiments of a flavorant may be a tobacco flavor, menthol, wintergreen, peppermint, herb flavors, fruit flavors, nut flavors, liquor flavors and terpene flavors.

I. Vape Device

[0048] The present invention is directed to a vape device that measures and preferably controls or meters the dose of vaporized payload inhaled by the user. The dose metering technology may be incorporated into a variety of different types of vape devices available in various sizes in terms of the amount of payload they can contain. In one embodiment, the vape device comprises a self-contained vape device, e.g., a one piece disposable vape device in which all of the components are contained within a single housing. In another embodiment, the vape device comprises a control assembly and cartridge that are formed in separate housings and releasably connected to each other via an electromechanical connection. In this embodiment, the control assembly is provided as a re-useable component that can be used with multiple disposable cartridges. In yet another embodiment, the vape device comprises a tabletop or desktop vaporizer.

[0049] Various embodiments of vape devices that may incorporate the dose metering technology of the present invention are described below in connection with FIGS. **1-3**. In some embodiments, the vape devices can communicate with a personal computing device and work interactively with an application or "app" operating on the personal computing device to provide additional functions and features that enable implementation of certain aspects of the invention. Of course, it should be understood that the present invention is not limited to these embodiments and that other types of vape devices may also be used within the scope of the invention.

[0050] For the sake of simplicity, the vape devices described in connection with FIGS. **1-3** are provided to describe the general structural configuration of the vape devices and do not include all of the various components and circuits required to provide the dose metering technology of the present invention; rather, these components and circuits are described below in connection with the vape devices shown in FIGS. **4-10**.

First Embodiment of Vape Device

[0051] Referring to FIG. **1**, a first embodiment of a vape device is shown generally as reference numeral **10**. Vape device **10** includes a mouthpiece assembly **12**, an atomizer assembly **19**, a payload assembly **24**, and a control assembly **14**. Any of mouthpiece assembly **12**, atomizer assembly **19**, payload assembly **24**, and control assembly **14** may be formed integrally together and included within a common housing suitable for grasping by a user. Further, any of mouthpiece assembly **12**, atomizer assembly **19**, payload assembly **24**, and control assembly **14** may be formed in separate housings that are releasably connected to each other via connecting means **15**, which can comprise, for example, one or more of pressure or friction fit connection means, twist mechanical lock means, magnetic connection means and any other connecting means as well known to those skilled in the art. The connecting means **15** may include a female **510** threaded connector on the control assembly **14** that releasably engages a male **510** threaded connector on the atomizer assembly **19** or payload assembly **24**. A **510** threaded connector, as is known in the art, is a M7-0.5×5 threaded connector, i.e., a threaded connector with a nominal diameter of 7 mm, a pitch of 0.5 mm, and a length of 5 mm. Connecting means **15** may include threaded connectors of other sizes. By way of example, mouthpiece assembly **12** may be releasably connected to atomizer assembly **19**, payload assembly **24** and control assembly **14**, which are either formed integrally together or in separate housings that are releasably connected to each other. Mouthpiece assembly **12** and atomizer assembly **19** may be formed integrally together and releasably connected to payload assembly **24** and control assembly **14**, which are either formed integrally together or in separate housings that are releasably connected to each other. Further, mouthpiece assembly **12**, atomizer assembly **19**, and payload assembly **24** may be formed integrally together and releasably connected to control assembly **14**. The combination of the mouthpiece assembly **12**, atomizer assembly **19**, and payload assembly **24** may be referred to as a cartridge herein. It is also within the scope of the invention for the mouthpiece assembly **12** to be omitted and for the vaporized payload to exit the atomizer assembly **19** directly for inhalation.

[0052] In some embodiments, a heater or atomizer **20** is disposed in atomizer assembly **19**, with atomizer **20** further comprising a heating element **22** disposed therein for heating and vaporizing a payload that may comprise, for example, liquids, oils or other fluids (e.g., *cannabis* oil or nicotine oil). Vape device **10** may also be modified to vaporize a tablet of dry material or dry material that is not in tablet form (e.g., ground *cannabis* bud). Heating element **22** may be a heating coil. Atomizer **20** can comprise an inlet **21** and an outlet **23**, wherein inlet **21** can be in communication, via fluid connector **46**, with payload reservoir **26** disposed in payload assembly **24**, wherein payload reservoir **26** can contain a payload for vaporization or atomization. Outlet **23** can be in communication with a user mouthpiece **16** of mouthpiece assembly **12** via a conduit **17**, which is typically a hollow tube made of stainless steel, aluminum, or other materials known to those skilled in the art. It will be understood to those skilled in the art that an air path will extend through atomizer assembly **19** and mouthpiece assembly **12** allowing ambient air to flow from an air inlet (not shown) of atomizer **20** and through conduit **17** to user mouthpiece **16**.

[0053] In some embodiments, payload assembly **24** contains a memory device **28**. Memory device **28** may be any type of device that includes memory or storage capable of storing a unique payload identifier that identifies payload reservoir **26** and/or other information related to the payload contained in payload reservoir **26**, as discussed below. Memory device **28** also includes means for allowing the stored information to be retrieved by another device. For example, memory device **28** may be wired (e.g., EEPROM or flash memory), wireless (e.g., a radio frequency identification (RFID) tag or near field communications (NFC) tag), or a combination of wired and wireless (e.g., wired through one interface and wireless through another interface). Microcontroller **31** may process the information retrieved from memory device **28** and/or transmit the information to an external computing device via a radio frequency (RF) transceiver circuit **36** and antenna(s) **40**. In one embodiment, memory device **28** comprises an integrated circuit (IC) chip for modulating and demodulating radio frequency signals, such as a galvanically isolated NFC tag that can be read by any NFC-capable device. In one embodiment, the NFC tag is read directly by an external computing device, such as personal computing device **72** described below. Of course, other short-range wireless technologies may also be used in accordance with the present invention.

[0054] In some embodiments, atomizer **20** can be disposed in atomizer assembly **19** that can either be integral to mouthpiece assembly **12**, or a physically separate enclosure that can couple to mouthpiece assembly **12**. Instead of or in addition to including a heating element **22** as disclosed herein, atomizer **20** may include any other structure capable of vaporizing or atomizing a payload in a suitable form for inhalation. For example, atomizer **20** may include a jet nebulizer, an ultrasonic nebulizer, or a mesh nebulizer.

[0055] In some embodiments, payload reservoir **26** and memory device **28** can be disposed in payload assembly **24** that can either be integral to mouthpiece assembly **12** and/or atomizer assembly **19**, or a physically separate enclosure that can couple to mouthpiece assembly **12** and/or atomizer assembly **19**, which can include one or more of connecting means **15** described above. Preferably, memory device **28** is physically coupled to payload reservoir **26** either directly or indirectly (e.g., memory device **28** and payload reservoir **26** are included in a common housing of payload assembly **24**) in a tamper resistant manner.

[0056] In some embodiments, control assembly **14** can comprise one or more antennas **40**, a power source such as battery **42**, and a printed circuit board **30** that can further comprise a microcontroller **31** configured for carrying out one or more electronic functions in respect of the operation of vape device **10**. Having more than one antenna **40** can enable the ability for diversity wireless communications of RF signals, as well known to those skilled in the art. In some embodiments, battery **42** can comprise a lithium ion power cell battery, although other battery technologies can be used as well known to those skilled in the art. As the vape devices are personal use devices, the battery **42** can comprise technology that prevents the advent of an explosion should the battery fail.

[0057] In some embodiments, circuit board **30** can comprise a charger circuit **32** configured for charging battery **42**. Charger circuit **32** can be integral to circuit board **30** or can be disposed on a separate circuit board operatively connected to circuit board **30** and to battery **42** via electrical connection **54**. Charger circuit **32** can be configured to be operatively connected to an external source of power, either via a shared or dedicated electrical connector **35** operatively coupled to circuit board **30** with internal connection to charger circuit **32**, or a wireless connection for power transfer, as well known to those skilled in the art. Charger circuit **32** may also connect to electrical connection **50** as a means of charging.

[0058] In some embodiments, circuit board **30** can comprise user input interface circuit **34** and output interface circuit **38**. Either or both of input interface circuit **34** and output interface circuit **38** can be integral to circuit board **30** or can be disposed on a separate circuit board operatively connected to circuit board **30**. In some embodiments, input interface circuit **34** can provide the electrical interface between user controls and activation mechanisms disposed on vape device **10**, such as buttons, switches, draw sensors, pressure transducers, proximity sensors, flow sensors, touch sensors, voice recognition sensors, haptic controls, saliva and breath biosensors, and the like, and microcontroller **31** and, thus, can provide the means to relay user input commands from the user controls as instructions to microcontroller **31** to operate vape device **10**.

[0059] For example, input interface circuit **34** may be electrically coupled to a draw sensor **18** for receiving an "on" signal from draw sensor **18** when a user draws on mouthpiece **16**. When input interface circuit **34** receives the "on" signal from draw sensor **18**, it may send instructions to microcontroller **31** to cause supply of a controlled current or voltage to heating element **22** and thereby provide vapor through outlet **23**, provided that any other conditions necessary to activate atomizer **20** have been met. In some embodiments, draw sensor **18** comprises a sensor, such as a mass air flow sensor, that can produce an electrical signal in response to when a user inhales or draws on mouthpiece **16**, wherein the electrical signal can cause the power signal to flow from battery **42** through heating element **22**. In some embodiments, draw sensor **18** can be used as a simple "switch" as a means to turn on atomizer **20** to vaporize payload drawn into atomizer **20** from payload reservoir **26** as the user draws on mouthpiece **16**. Draw sensor **18** is one type of activation mechanism that may be used to activate atomizer **20**. Draw sensor **18** may be replaced with or used in connection with another type of activation mechanism that receives an input to switch it from an "off" position, in which atomizer **20** is not activated, and an "on" position, in which atomizer **20** is activated. For example, draw sensor **18** may be replaced with or used in connection with any of the following types of activation mechanisms: a button, switch, pressure transducer, proximity sensor, flow sensor, touch sensor, voice recognition sensor, haptic control, saliva and breath biosensor, and the like.

[0060] In some embodiments, output interface circuit **38** can provide the electrical interface between microcontroller **31** and output display devices, such as indicator lights, alphanumeric display screens, audio speakers, surface heaters, vibration devices, and any other forms of tactile feedback devices as well known to those skilled in the art, and, thus, can provide the means to relay information relating to the operation of vape device **10** from microcontroller **31** to the user.

[0061] In some embodiments, circuit board **30** can comprise an RF transceiver circuit **36** to provide the means for wireless communication of data between vape device **10** and a personal computing device, such as personal computing device **72** as shown in FIG. **3**. In some embodiments, RF transceiver circuit **36** can be integral to circuit board **30** or can be disposed on a separate circuit board operatively connected to circuit board **30**. RF transceiver circuit **36** can be connected to one or more antennas **40** via electrical connection **52**, as well known to those skilled in the art. RF transceiver circuit **36** and the one or more antennas **40** comprise a wireless transceiver of vape device **10**.

[0062] In some embodiments, microcontroller **31** can comprise a microprocessor (which for purposes of this disclosure also incorporates any type of processor) having a central processing unit as well known to those skilled in the art, wherein the microprocessor can further comprise a memory configured for storing a series of instructions for operating the microprocessor in addition to storing data collected from sensors disposed on vape device **10** or data received by vape device **10** to control its operation, such as operational settings. Microcontroller **31** is in electrical communication with charger circuit **32**, user input interface circuit **34**, output interface circuit **38**, and RF transceiver circuit **36** for receiving instructions and/or data from and/or transmitting instructions and/or data to charger circuit **32**, user input interface circuit **34**, output interface circuit **38**, and RF transceiver circuit **36**.

[0063] In some embodiments, atomizer **20** can be operatively and electrically connected to circuit board **30** via electrical connection **48**, which can provide the means to activate atomizer **20** (e.g., deliver electrical current from battery **42** to heating element **22**) when an activation mechanism such as draw sensor **18** sends an "on" signal to microcontroller **31**, as well as receiving data signals from draw sensor **18** and/or atomizer **20**. In this manner, the activation mechanism (i.e., draw sensor **18**) is coupled to the atomizer **20** indirectly through microcontroller **31**, and a direct connection between the activation mechanism and atomizer **20** is not required (i.e., the activation mechanism sends a signal to microcontroller **31** which sends a signal to activate atomizer **20**). In addition to controlling operation of atomizer **20** based on a signal received from the activation mechanism, microcontroller **31** also controls operation of atomizer **20** based on the operational settings described below. In some embodiments, microcontroller **31** can be operatively connected to memory device **28** via electrical connection **50**.

[0064] As used herein, the term "electrical connection" shall include any form of electrical connection via a wired or wireless connection, such as electrical conductors or wires suitable for the transmission of a power signal (e.g., a direct current or pulsed direct current), analog or digital electrical signals or radio frequency signals, as the case may be and as well-known to those skilled in the art.

[0065] The operational settings referred to herein include any type of setting or instruction that instructs the vape device **10** or certain components of the vape device **10** to operate or not operate in a particular manner. Specifically, operational settings of the vape device **10** include one or more of a duty cycle setting, a temperature setting, an operational time duration, a dosage setting, and a security setting. The duty cycle setting preferably corresponds to a pulse width modulation instruction transmitted from microcontroller **31** to battery **42** to send electrical current to heating element **22** in a particular desired manner. The temperature setting preferably corresponds to a temperature instruction transmitted from microcontroller **31** to battery **42** to send electrical current to heating element **22** to maintain heating element **22** at a desired temperature or range of temperatures. A temperature sensor may be coupled to microcontroller **31** to measure the actual temperature of heating element **22** and transmit that information to microcontroller **31** for determination of the amount and duration of electrical current that needs to be sent to heating element **22** to maintain a particular temperature or range of temperatures. The operational time duration preferably corresponds to a time instruction transmitted from microcontroller **31** to battery **42** to maintain heating element **22** at a temperature suitable for vaporization of the contents of payload reservoir **26** for a desired time. The dosage setting preferably corresponds to a dosage instruction transmitted from microcontroller **31** to battery **42** that powers down heating element **22** when a desired volume of vapor passes through atomizer **20**. As described in greater detail below, various dose metering methods may be used to accurately measure the volume of vaporized payload passing through atomizer **20** to mouthpiece **16** for user inhalation, whereby microcontroller **31** compares the actual volume passed through atomizer **20** to the dosage setting to determine when to shut off heating element **22**.

[0066] In some embodiments, memory device **28** and/or microcontroller **31**, along with appropriate sensors, can also be used as part of a system for gathering data relating to the use of vape device **10** by the user by monitoring that can include, without limitation, historical vape device usage information, such as how many times vape device **10** is used during a given period of time (hour, day, week, etc.), the duration of each use of vape device **10**, how many draws the user takes on vape device **10**, the strength of those draws, the amount of payload consumed during each use of vape device **10**, and other information as described herein. The historical vape device usage information may be stored in a database in association with the payload identifier. In some embodiments, the historical vape device usage information can be used as clinical data for determining whether the user is consuming the right amount of medicine to be vaporized and inhaled and at the right times of day. The information can be used to provide feedback to the user in terms of whether the user should consume medicine more frequently or less frequently throughout the day and/or to increase or decrease the amount of medicine consumed per usage overall or per usage at particular times of the day. In some embodiments, the information collected about the user's consumption of a *cannabis* liquid or oil payload with vape device **10** can be used to estimate the user's intoxication or impairment based on the user's physical characteristics and the amount of *cannabis* liquid or oil payload consumed. This estimation can be relayed to the user as a means to inform the user as to whether the user is too intoxicated or impaired to operate a motor vehicle or to operate tools or machinery, as an example.

Second Embodiment of Vape Device

[0067] Referring to FIG. **2**, a second embodiment of a vape device is shown generally as reference numeral **100**. In some embodiments, vape device **100** can comprise control assembly **14**, atomizer assembly **79** and mouthpiece assembly **88** operatively coupled together in that order using mechanical connection means **56** to join the subassemblies together. Mechanical connection means **56** can comprise one or more of threaded connection means, magnetic connection means and friction or press-fit connection means, and any of the connection means **15** described above, including **510** threaded connectors. In some embodiments, mouthpiece assembly **88** can comprise a mouthpiece **58** in communication with the outlet of atomizer **20** via conduit **60**, which is typically a hollow tube made of stainless steel, aluminum, or other materials known to those skilled in the art. Mouthpiece assembly **88** can further comprise a payload reservoir **62** that can be filled with a payload **64** that may be liquid or oil. The payload **64** can flow from payload reservoir **62** to inlet **21** of atomizer **20** via one or more valves **68**. In some embodiments, mouthpiece assembly **88** can comprise memory device **28** and an oil gauge **66**, which can be configured to monitor the volume of payload **64** in payload reservoir **62** and relay that information to microcontroller **31**. In this embodiment, mouthpiece assembly **88** can be a consumable element that can be replaced as a complete subassembly once depleted, or simply interchanged with another mouthpiece assembly **88** containing a different payload **64** for consumption, depending on the needs and wants of the user. In some embodiments, oil gauge **66** can simply be a sight glass disposed on mouthpiece assembly **88** to provide a visual indicator to the user as to the amount of payload remaining therein. Atomizer assembly **79** is preferably configured to prevent air-lock and/or clogging with thick, undiluted payloads. It will be understood to those skilled in the art that an air path will extend through atomizer assembly **79** allowing ambient air to flow from an air inlet (not shown) of atomizer **20** and through conduit **60** to mouthpiece **58**.

[0068] Control assembly **14** of vape device **100** is preferably substantially similar to control assembly **14** of vape device **10**. Atomizer **20** of vape device **100** is preferably substantially similar to atomizer **20** of vape device **10**, and may include alternative means for vaporizing a payload other than a heating element as described above in connection with vape device **10**. It is within the scope of the invention for atomizer assembly **79** and mouthpiece assembly **88** to be formed integrally within a common housing that is releasably connected to control assembly **14**. Further, it is within the scope of the invention for control assembly **14** and atomizer assembly **79** to be formed integrally within a common housing that is releasably connected to mouthpiece assembly **88**. It is also within the scope of the invention for atomizer assembly **79**, mouthpiece assembly **88**, and control assembly **14** to be formed integrally within a common housing.

Vape Device Application

[0069] Referring to FIG. **3**, one embodiment of a vape device system **102** includes vape device **10** and a personal computing device **72** running application **74** thereon. It is understood that personal computing device **72** includes a processor **94** that runs application **74**, and that references herein to personal computing device **72** include its processor **94**. Vape device **100** may also be operated with personal computing device **72** in the same manner as described below with respect to vape device **10**.

[0070] As used herein, the term "personal computing device" is defined as including personal computers, laptop computers, personal digital assistants, personal computing tablets (such as those made by Apple® and Samsung®, and by others as well known to those skilled in the art), smart phones (such as those running on iOS® and Android® operating systems, and others as well known to those skilled in the art), smart watches, fitness tracking wristbands, wearable devices, smart glasses, and any other electronic computing device that comprises means for communication (wireless or wired) with other electronic devices, and with a global telecommunications or computing network.

[0071] In some embodiments, vape device **10** can wirelessly communicate with personal computing device **72** and application **74** via RF communications link **73**. In some embodiments, RF communications link **73** can comprise one or more of Bluetooth™ communications protocol, Wi-Fi™ IEEE 802 communications protocol, Zigbee IEEE 802.15.4-based protocol, and any other RF, short-range, and long-range communications protocol as well known to those skilled in the art. Vape device **10** may also communicate with personal computing device **72** via a wired connection established, for example, between electrical connector **35** of vape device **10** and a communications connector (not shown) of personal computing device **72**.

[0072] Vape device **10** can preferably communicate with personal computing device **72** and operate in conjunction with application **74** to control and monitor the use of vape device **10**. In some embodiments, application **74** can be configured to acquire specific information on the payload being vaporized (described below) based on the serial number of the cartridge. In some embodiments, application **74** can access an online source of data to acquire this information, which can be done periodically and/or automatically, or manually by the user prompting the application to update the information, or a combination of both processes. This information can then be used to control or meter the dose of vapor inhaled by the user, as described below.

[0073] In some embodiments, computing device **72** transmits the unique payload identifier to a remote computing device at a central server or in the cloud. The remote computing device may maintain a database of operational settings that are associated with each unique payload identifier and tailored to the particular substance located in the payload reservoir and/or the particular user using the payload reservoir. The remote computing device may then send the operational settings and identification of the specific substance within the payload reservoir back to the computing device **72**. The historical vape device usage information described above may also be transmitted to and maintained by the remote computing device at the central server or in the cloud.

[0074] In some embodiments, application **74** can present a visual "dashboard" **75** comprising visual information and controls that can be operated by a user. In some embodiments, dashboard **75** can comprise user information window **76** for displaying information regarding the operation of vape device **10** in addition to general information. This general information can include general news as well as information on available updates for vape device **10** or the application **74** from the manufacturer or supplier of the same.

[0075] In some embodiments, dashboard **75** can comprise a locate button **78** as a means for the user to determine the location of vape device **10** should the user misplace it. By pressing locate button **78**, personal computing device **72** can send a signal wirelessly to vape device **10** to operate an audible signal from an audio speaker or buzzer or other like device disposed thereon to assist the user in finding vape device **10**. In other embodiments, pressing locate button **78** can assist the user to determine his or her geographic location (using geographic location capabilities of personal computing device **72**) and whether *cannabis* products can be consumed using vape device **10** in that location (e.g., whether there are any governmental regulations, laws, or rules applicable to or enforceable in the geographic area where vape device **10** is located that may subject the user of vape device **10** to criminal or administrative penalties, fines, or enforcement actions). In some embodiments, dashboard **75** can comprise heat swipe button **80** as a means for the user to manually control the heat used to vaporize payload **64**, wherein the signal transmitted by application **74** to vape device **10** to control the heat can be included in the operational settings. In some embodiments, dashboard **75** can comprise lock indicator **82**, unlock indicator **84** and swipe button **86** as a means to enable and disable vape device **10** by the user swiping swipe button **86** right or left, respectively.

II. Dose Metering Methods

[0076] The vape device as described above may use four different methods, independently or in any combination, to measure the portion of the payload that is vaporized during each user inhalation and thereby determine the dose of vaporized payload delivered to the user. The first method tracks the energy used to vaporize the payload portion during user inhalation in order to determine the mass of the vaporized payload; the second method measures the temperature at multiple locations within the air flow chamber during user inhalation to determine the vapor density and by extension the mass of the vaporized payload; the third method measures the intensity of light that is transmitted through the vaporized payload, reflected off the vaporized payload, or transmitted through a light transmitting medium positioned within the vaporized payload, during user inhalation to determine the vapor density and by extension the mass of the vaporized payload; and the fourth method utilizes hot wire anemometers to determine the mass of the vaporized payload that was delivered to the user during each user inhalation and/or to determine the size and density distribution of the droplets in the vaporized payload and use such distribution to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation. Each of these methods will be described below in connection with the exemplary vape devices shown in FIGS. **4-15**.

[0077] It should be understood that the exemplary vape devices shown in FIGS. **4-15** are illustrated schematically in order to describe the sensors and other components that may be used to implement the various methods. These schematic diagrams and are not intended to illustrate any particular structural configurations for the vape devices, which will vary depending on the type of vape device that implements the disclosed methods. For example, the atomizer of the vape device may be suspended in a conduit and in fluid communication with the payload from a payload reservoir, or, the atomizer of the vape device may be suspended in a portion of the conduit allowing ambient air from the inlet to flow through the atomizer. The conduit may have a cross-section that is circular, rectangular, or any other shape. The various structural configurations for the cartridge, payload reservoir, conduit, etc. will be apparent to those skilled in the art.

[0078] In some embodiments, the vape device is also configured to determine the aggregated amount of payload that has been vaporized during previous user inhalations. This amount may be subtracted from the total amount of payload prior to any vaporization to determine the remaining amount of payload in the payload reservoir. Also, because there will be some residual payload in the payload reservoir, the vape device may also be configured to determine the portion of the remaining amount of payload in the payload reservoir that is useable for vaporization—e.g., based on characterization data or testing of samples to determine a mean and range of useable payload with a specified measure of accuracy. Further, the vape device may be configured to provide a notice to the user (e.g., via personal computing device **72**) when the remaining amount of payload in the payload reservoir is below a minimum level so that the user may take appropriate steps to refill the payload reservoir or obtain a replacement cartridge.

Energy Usage Method

[0079] In some embodiments, the vape device is configured to track the energy used to vaporize a portion of the payload during user inhalation in order to determine the mass of vaporized payload that was delivered to the user during each user inhalation.

[0080] Referring to FIG. **4**, an example of a vape device that relies on the energy usage method to determine the dose of vaporized payload is shown generally as reference numeral **400**. Vape device **400** includes a control assembly **410** and a cartridge **420** that may be formed in separate housings that are releasably connected to each other via an electromechanical connection **440**. In this embodiment, control assembly **410** is provided as a re-useable component that can be used with multiple disposable cartridges, such as cartridge **420**. In other embodiments, control assembly **410** may be disposable, or, the components of control assembly **410** and cartridge **420** may be provided as a self-contained vape device.

[0081] Electromechanical connection **440** is configured to provide a mechanical and electrical connection between control assembly **410** and cartridge **420**. For example, electromechanical connection **440** may comprise a female **510** threaded connector on control assembly **410** that releasably engages a male **510** threaded connector on cartridge **420**. Of course, the invention is not limited to the use of **510** threaded connectors and other types of connectors may also be used, as described above.

[0082] As shown in FIG. **4**, control assembly **410** includes a power source **412**, a microcontroller **414**, an RF transceiver circuit **416**, and one or more antennas **418**. Also, cartridge **420** includes a payload reservoir **422**, an atomizer **424**, one or more temperature measurement circuits **426** (optional), one or more pressure measurement circuits **428** (optional), and a memory device **430** (optional). Of course, it should be understood that all or a portion of temperature measurement circuits **426** and/or pressure measurement circuits **428** may alternatively be located within control assembly **410**. Most of these components (with the exception of the temperature and pressure measurement circuits) are described above in connection with vape devices **10** and **100**. Of course, it should be understood that control assembly **410** and cartridge **420** may include a number of other components that are not specifically shown in FIG. **4**, as also described above in connection with vape devices **10** and **100**.

[0083] With respect to vape device **400**, microcontroller **414** is programmed to control power source **412** (e.g., a battery) so that power source **412** transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **424** in accordance with desired operational settings. When the heating element of atomizer **424** reaches the vaporization temperature of the payload contained in payload reservoir **422**, a portion of the payload is vaporized to thereby generate a vaporized payload for user inhalation. As described below, if the amount of energy required to vaporize the total mass of the payload in payload reservoir **422** is known (i.e., the total mass of the payload prior to any vaporization), microcontroller **414** is able to interpolate from the amount of energy used in each user inhalation the partial mass of payload that has been vaporized during the user inhalation.

[0084] For example, consider a payload having a total mass of 0.5 grams (assuming a density of 1 gram/milliliter) that is known to require 1.240 watt-hours of energy to be fully vaporized. If a particular user inhalation were to use 6.179 milliwatt-hours of energy (e.g., 2 amperes of current at 3.7 volts for 3 seconds), this energy usage would comprise approximately $1/200^{th}$ of the energy required for the total payload. Thus, it is possible to estimate that the partial amount of payload that was vaporized during the user inhalation was 0.0025 grams (i.e., 0.5 grams/200).

[0085] In some embodiments, microcontroller **414** is programmed to determine the dose of payload that is vaporized during each user inhalation by performing the following steps: (1) determining the amount of energy used to vaporize a portion of the payload during each user inhalation; and (2) using the amount of energy to determine the partial mass of the payload that is vaporized during the user inhalation. Each of these steps will be described in greater detail below.

[0086] It should be understood that the amount of energy used to vaporize a portion of the payload may be associated with the partial mass of the payload using characterization data for the particular payload (e.g., data that has been obtained through testing to correlate the amount of energy to the partial mass). In some embodiments, microcontroller

414 acquires this information from memory device **430**, i.e., the characterization data is stored in memory device **430** by the manufacturer of cartridge **420**. In other embodiments, microcontroller **414** acquires a unique payload identifier from memory device **430** and transmits the unique payload identifier to personal computing device **72** via RF transceiver **416** and antenna(s) **418**. The unique serial number may comprise, for example, a serial number of cartridge **420**. The application **74** running on personal computing device **72** may then acquire the characterization data based on the unique payload identifier. In some embodiments, application **74** can access an online source of data to acquire this information. Of course, the payload identifier stored in memory device **430** need not comprise a unique identifier, in which case cartridges containing the same type and amount of payload could all store the same payload identifier in their respective memory devices. In all of these cases, computing device **72** transmits the acquired information back to microcontroller **414** via RF transceiver **416** and antenna(s) **418**. In yet other embodiments in which the vape device comprises a self-contained vape device, the characterization data may be stored on microcontroller **414** itself.

[0087] Microcontroller **414** determines the amount of energy used to vaporize a portion of the payload during each user inhalation by determining the amount of power provided to atomizer **424** during the user inhalation, determining the duration of the user inhalation, and then calculating the total amount of energy based on this information (i.e., $E=P\times t$). In some embodiments, microcontroller **414** is programmed to determine the amount of power provided to atomizer **424** by measuring the output voltage of power source **414**, measuring the current delivered to atomizer **424**, and then calculating the power based on this information (i.e., $P=V\times I$). In other embodiments, microcontroller **414** is programmed to determine the amount of power provided to atomizer **424** by measuring the resistance of the path between power source **412** and atomizer **424**, measuring either the output voltage of power source **414** or the current delivered to atomizer **424**, and then calculating the power based on this information (i.e., $P=I^2\times R=V^2/R$).

[0088] In some embodiments, the step of determining the amount of energy used to vaporize a portion of the payload during each user inhalation may be further refined (optionally) by determining the air flow rate within the air flow chamber, and then adjusting the total amount of energy calculated above to account for the air flow rate and its effect on removing heat from atomizer **424**. The air flow chamber extends between an inlet and an outlet, and atomizer **424** is positioned between the inlet and outlet such that (1) ambient air flows through the air flow chamber from the inlet to atomizer **424** and (2) air mixed with vaporized payload flows through the air flow chamber from atomizer **424** to the outlet (which may be in communication with a mouthpiece). Those skilled in the art will appreciate that increasing the air flow rate will pull more vapor (and by extension heat) away from atomizer **424** thereby causing the control loop to add more energy into the heating element to maintain a constant temperature. Including the effect of the air flow rate using a direct air flow measurement will increase the accuracy of the dose measurement.

[0089] In some embodiments, microcontroller **414** is programmed to determine the air flow rate within the air flow chamber based on a pressure difference across an orifice positioned anywhere in the sealed path between the inlet and outlet of the air flow chamber and the known cross-sectional area of the orifice. As described below, there are different ways to determine the pressure differential across the orifice using one or more pressure sensors incorporated within pressure measurement circuit(s) **428**.

[0090] In one embodiment, a first pressure sensor is located on one side of the orifice and a second pressure sensor is located on the opposing side of the orifice. The first pressure sensor is incorporated into a first pressure measurement circuit configured to obtain a plurality of pressure measurements during user inhalation. Similarly, the second pressure sensor is incorporated into a second pressure measurement circuit configured to obtain a plurality of pressure measurements during user inhalation. Thus, the pressure difference across the orifice during user inhalation is based on the pressure measurements obtained by the first and second pressure measurement circuits during user inhalation.

[0091] In another embodiment, a single pressure sensor is located on one side of the orifice. The pressure sensor is incorporated into a pressure measurement circuit configured to obtain a plurality of pressure measurements before and during user inhalation, e.g., one or more ambient pressure measurements before the draw in which the pressure is equal on either side of the orifice followed by other pressure measurements during the draw in which there is a partial vacuum on the side of the orifice where the pressure sensor is located. Thus, the pressure difference across the orifice during user inhalation is based on the pressure measurements obtained by the pressure measurement circuit before and during user inhalation.

[0092] In another embodiment, a single pressure sensor is located on one side of the orifice. The pressure sensor is incorporated into a pressure measurement circuit configured to obtain a plurality of pressure measurements during and after user inhalation, e.g., pressure measurements during the draw in which there is a partial vacuum on the side of the orifice where the pressure sensor is located followed by one or more ambient pressure measurements after the draw in which the pressure is equal on either side of the orifice. Thus, the pressure difference across the orifice during user inhalation is based on the pressure measurements obtained by the pressure measurement circuit during and after user inhalation.

[0093] In yet another embodiment, a single pressure sensor is located on one side of the orifice. The pressure sensor is incorporated into a pressure measurement circuit configured to obtain a plurality of pressure measurements before, during and after user inhalation, e.g., a combination of the above two embodiments, such that the ambient pressure measurements before and after the draw are used and compared to the partial vacuum measurements during the draw. Thus, the pressure difference across the orifice during user inhalation is based on the pressure measurements obtained by the pressure measurement circuit before, during and after user inhalation.

[0094] In some embodiments, the step of determining the amount of energy used to vaporize a portion of the payload during each user inhalation may be further refined (optionally) by determining the amount of energy used to heat atomizer **424** to the vaporization temperature, and then adjusting the total amount of energy calculated above by subtracting or omitting that portion of the total energy. In order to determine when atomizer **424** has reached the vaporization temperature, a temperature sensor incorporated into temperature measurement circuit **426** may be used to sense the temperature within cartridge **420**. Various examples of temperature sensors that may be used in temperature measurement circuit **426** are described below.

[0095] In general, the temperature sensor may comprise any type of component capable of sensing the temperature within cartridge **420**. For example, temperature sensor **426** may comprise a thermistor, a thermocouple, a bandgap temperature sensor, an analog temperature sensor, a digital temperature sensor (e.g., temperature sensors with I2C interface compatibility), or any other type of temperature sensor known to those skilled in the art. The thermal path between atomizer **424** and the temperature sensor may be implemented with thermal paste, a ceramic thermal bridge (e.g., the Q-Bridge thermal conductor available from American Technical Ceramics), or air and PCB dielectric.

[0096] The temperature sensor may also comprise a light sensor configured to detect light emitted from a material within cartridge **420**, wherein the intensity of the emitted light is proportional to the temperature of the material, as is known to those skilled in the art. The light sensor may comprise, for example, a photodiode or phototransistor that detects light emitted by the heating element and/or light emitted by the vaporized payload (which would typically be in the infrared region of 0.7 microns to 20 microns). The light sensor is preferably able to detect the light through different seals or glass so that the light sensor can be isolated from the vaporized payload.

[0097] The temperature sensor may also comprise a circuit configured to measure the resistance of the heating element and utilize this measurement to determine the temperature within cartridge **420**. As is known in the art, the resistance of the heating element is directly proportional to the resistivity of the material from which the heating element is made (i.e., the resistance is dependent on the resistivity, length, and cross-sectional area of the heating element). The relationship between the resistivity of the heating element and temperature is shown by the following equation (which is a linear approximation for cases in which the temperature variance is not large):

$$\rho=\rho_0(1+\alpha(T-T_0)) \tag{1}$$

where

[0098] ρ=resistivity of heating element at temperature T in ohm meters;

[0099] ρ_0=resistivity of heating element at temperature T_0 in ohm meters;

[0100] α=temperature coefficient of resistivity at T_0;

[0101] T=current temperature in ° K; and

[0102] T_0=fixed reference temperature (e.g., ambient temperature) in ° K.

[0103] It can be seen from equation (1) that the resistivity of the heating element increases with an increase in the current temperature of the heating element. Thus, if the resistance of the heating element is known at any given moment, it is possible to calculate the resistivity of the heating element and, using equation (1), calculate the current temperature of the heating element.

[0104] For example, the following method may be implemented to determine the current temperature of the heating element (and thus the temperature within cartridge **420**): (a) measure the ambient temperature within cartridge **420** (the heating element will be approximately the same temperature provided it has not been activated recently); (b) periodically measure the resistance of the heating element while the heating element is being powered; and (c) calculate the current temperature of the heating element based on the measured resistance (or determine a change in the resistance of the heating element to provide the temperature increase above the ambient temperature value). Thus, the resistance of the heating element as a function of temperature can be used to provide an accurate assessment of the temperature within cartridge **420** at any given moment.

[0105] In addition, in some embodiments, the step of determining the amount of energy used to vaporize a portion of the payload during each user inhalation may be further refined (optionally) by adjusting the total amount of energy calculated above to account for one or more operating conditions, such as those listed in Table 1 below:

TABLE 1

Operating Condition	Impact on Energy
starting temperature of vape device	The starting temperature of the vape device's materials (e.g., the housing, battery, payload reservoir, etc.) will impart a baseline temperature to the volume of air in the vape device.
starting temperature of payload	The payload temperature determines the starting point from which the payload must be heated. The colder the payload, the more energy must be supplied to the atomizer before the payload will begin to vaporize.
temperature of ambient air	The ambient air drawn into the inlet during an inhale will bring with it an amount of heat energy that will offset the air at the outlet. The colder the ambient air, the less it is expected that the air at the outlet will increase. The warmer the ambient air, the more it is expected that the air at the outlet will increase.
relative humidity of ambient air	The ambient relative humidity changes the specific heat capacity of the ambient air, making it require more or less energy to impart the same temperature change.
pressure of ambient air	Ambient pressure is used to determine the flow rate of the air through the orifice. The ambient pressure occurs on one side of the orifice and the inhale pressure occurs on the other side of the orifice. It is the difference between these two that can be used to determine the flow rate.
output voltage of power source	As the battery voltage changes through normal use, the maximum amount of power that can be put into the atomizer is reduced.
temperature ramp rate of atomizer	This operating condition can be used to determine the thermal mass in thermal communication with the heating element. This information can be used to determine how much payload is present and available for vaporization.

[0106] As discussed above, microcontroller **414** uses the amount of energy calculated above to determine the partial mass of the payload that is vaporized during user inhalation. In some embodiments, this step may be further refined (optionally) to determine the mass of each of the components within the payload that are vaporized during user inhalation (assuming that the payload and its constituent components and relative percentages are known). For example, assume that the payload includes known percentages of CBD and THC, wherein CBD vaporizes at 150° C. (i.e., the boiling point of CBD) and THC vaporizes at 178° C. (i.e., the boiling point of THC). Microcontroller **414** can predict the relative amounts of CBD and THC vaporized at temperatures of 140° C., 160° C., 180° C., etc., to provide specific information on the dose of CBD and THC delivered to the user during user inhalation. Further, microcontroller **414** may optionally determine an optimal vaporization temperature for the payload based on the relative percentage and boiling point for each of the components within the payload.

[0107] Finally, it should be understood that all or a portion of the processing steps performed by microcontroller **414**, as described above, could alternatively be performed by one or more other microcontrollers, such as a secondary microcontroller (not shown) positioned in cartridge **420**. For example, in some embodiments, a secondary microcontroller positioned in cartridge **420** is programmed to determine the amount of energy delivered to atomizer **424** during each user inhalation and then transmit this information to microcontroller **414** over the electrical interface between cartridge **420** and control assembly **410**. In this case, microcontroller **414** would perform all of the other steps described above. In other embodiments, a secondary microcontroller positioned in cartridge **420** is programmed to perform all of the steps described above and then transmit the dose of the vaporized payload to microcontroller **414** over the electrical interface between cartridge **420** and control assembly **410**. In yet other embodiments, personal computing device **72** is programmed to perform a portion of the steps described above, assuming that the appropriate information is passed from the vape device to personal computing device **72**. Further, in some embodiments, a secondary microcontroller positioned in cartridge **420** is configured by microcontroller **414** positioned in control assembly **410** or, alternatively, the secondary microcontroller uses operational settings stored in memory device **430** to determine when to stop atomizer **424** so as to deliver a full dose (wherein the full dose may also be stored in memory device **430**). Of course, those skilled in the art will appreciate that the steps performed by microcontroller **414** and any secondary microcontroller will vary between different applications.

Temperature Measurement Method

[0108] In some embodiments, the vape device is configured to measure the temperature at multiple locations within the air flow chamber during user inhalation (and optionally before and after user inhalation) to determine the vapor density and by extension the mass of vaporized payload that was delivered to the user during each user inhalation.

[0109] Referring to FIG. **5**, an example of a vape device that relies on the temperature measurement method to determine the dose of vaporized payload is shown generally as reference numeral **500**. Vape device **500** includes a housing **502**, which may comprise an internal housing or external housing of vape device **500**. Positioned within housing **502** is an air flow chamber which, in this example, comprises a conduit **512** that extends between an inlet **504** and an outlet **506**. It can be appreciated that the inlet and outlet orifices are defined by conduit **512**. An atomizer **510** is positioned anywhere between inlet **504** and outlet **506**. As described above, atomizer **510** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **512** from inlet **504** to atomizer **510**, and ambient air mixed with vaporized payload flows through conduit **512** from atomizer **510** to outlet **506**. Outlet **506** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **500** may include a number of other components that are not specifically shown in FIG. **5**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0110] With respect to vape device **500**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **510** in accordance with desired operational settings. When the heating element of atomizer **510** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described below, the vaporized payload transfers a significant amount of heat from atomizer **510** to the air that is flowing through conduit **512** to outlet **506**—significantly more so than air alone. There are key locations in the air path within conduit **512**—i.e., a location between inlet **504** and atomizer **510** and one or more locations between atomizer **510** and outlet **506**—where temperature measurements can provide valuable information.

[0111] In this example, vape device **500** includes three temperature sensors. Specifically, a first temperature sensor **514** is located within conduit **512** between inlet **504** and atomizer **510**, wherein first temperature sensor **514** is incorporated into a first temperature measurement circuit configured to obtain a plurality of temperature measurements during user inhalation (and optionally before and after user inhalation). Also, a second temperature sensor **516** is located within conduit **512** between atomizer **510** and outlet **506** (relatively close to atomizer **510**), wherein second temperature sensor **516** is incorporated into a second temperature measurement circuit configured to obtain a plurality of temperature measurements during user inhalation (and optionally before and after user inhalation). In addition, a third temperature sensor **518** is located within conduit **512** between atomizer **510** and outlet **506** (close to outlet **506**), wherein third temperature sensor **518** is incorporated into a third temperature measurement circuit configured to obtain a plurality of temperature measurements during user inhalation (and optionally before and after user inhalation).

[0112] Each of temperature sensors **514**, **516** and **518** may comprise any type of component capable of sensing the temperature at the designated locations, such as a thermistor, a thermocouple, an infrared sensor, a bandgap temperature sensor, an analog temperature sensor, or a digital temperature sensor. Of course, those skilled in the art will understand that other types of temperature sensors may be used in accordance with the present invention.

[0113] Using the measured temperatures and the relative temperature changes between temperature sensors **514**, **516** and **518** in conjunction with the air flow rate within conduit **512** (which may be determined using one or more pressure measurement circuits, such as pressure measurement circuit(s) **428** described above in connection with FIG. **4**), it is possible to determine the amount of vaporized payload required to transfer the heat energy throughout the air path. Specifically, the vaporized payload has a specific heat capacity and carries heat away from atomizer **510** and towards outlet **506**. As more vapor is created, more heat energy will be transferred downstream. Given a fixed, non-zero air flow rate, the temperature within conduit **512** between atomizer **510** and outlet **506** will be higher than the temperature within conduit **512** between inlet **504** and atomizer **510**.

Likewise, for a fixed amount of vapor, there will be a lower temperature rise for higher air flow rates because there is more ambient air mixed with the vaporized payload thereby reducing the amount of heat being transferred within conduit **512** from atomizer **510** to outlet **506**. Thus, through characterization over various operating conditions, an accurate estimate of the vapor density of the vaporized payload can be determined. Using the vapor density and the air flow rate over time, it is possible to determine the mass of payload that was vaporized for user inhalation and by extension the dose that the user received.

[0114] Thus, in some embodiments, the microcontroller of vape device **500** is programmed to determine the dose of payload that is vaporized during each user inhalation by performing the following steps: (1) acquiring a plurality of temperature measurements obtained at various locations within the air flow chamber during user inhalation (and optionally before and after user inhalation); (2) determining the air flow rate within the air flow chamber during user inhalation; and (3) using the information from steps 1 and 2 to determine the vapor density of the vaporized payload and by extension the partial mass of the payload that is vaporized during user inhalation.

[0115] In some embodiments, the method may be further refined (optionally) by using a thermistor as part of one or more of the temperature measurement circuits. The thermistor may be biased to a more sensitive operating region by passing current (direct current or pulsed direct current) such that it self-heats the thermistor. By tracking the amount of current increase required to keep the thermistor at the same temperature, an estimate of the air flow rate, vapor density, etc., may be determined using characterization data.

[0116] In some embodiments, the method may be further refined (optionally) by accounting for the air moisture content and atmospheric pressure within the air flow chamber prior to vaporization, e.g., within conduit **512** between inlet **504** and atomizer **510**. These operating conditions will alter the rate at which the temperature changes throughout the air flow path.

[0117] Finally, it should be understood that all or a portion of the processing steps performed by the microcontroller of vape device **500**, as described above, could alternatively be performed by one or more other microcontrollers, such as a secondary microcontroller (not shown) positioned in a cartridge of vape device **500** (for embodiments in which vape device **500** comprises a cartridge releasably connected to a control assembly). Various embodiments will be apparent to those skilled in the art.

Light Intensity Measurement Methods

[0118] Various examples of vape devices that utilize different light intensity measurement methods will be described below. In each of these examples, the vape device includes at least one light sensor comprised of a light source and a light detector. The light source may comprise, for example, a light emitting diode (LED), a laser, or an incandescent lamp, although other types of light sources may also be used. The light detector may comprise, for example, a photo-diode, although other types of light detectors may also be used.

[0119] The characteristics of the light emitted by the light source for detection by the light detector will vary between different applications. The wavelength of the emitted light may fall in the visible or invisible (ultraviolet or infrared) portions of the electromagnetic spectrum. The emitted light may be continuous, or the light may be pulsed, for example, to save power or to take successive light intensity measurements. The pulsing is preferably scaled to reflect the air flow rate.

[0120] As discussed below, the light source and light detector are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of the vape device. Preferably, the characterization data used by the microcontroller to determine the vapor density based on the light intensity measurements will account for the vapor density changing with temperature and air flow rate.

[0121] In some examples, the light sensor is a reflective sensor in which the light source is configured to emit light that is directed toward the path of the vaporized payload and the light detector is configured to detect the light reflection from the vaporized payload (such as the light sensor incorporated into the vape device shown in FIG. **6**). When the vapor density of the vaporized payload increases, the light reflection from the vaporized payload increases. Conversely, when the vapor density of the vaporized payload decreases, the light reflection from the vaporized payload decreases. These properties can be utilized to determine the vapor density of the vaporized payload.

[0122] With a reflective sensor, the wavelength of the emitted light may be selected so that the light is maximally reflected by the vaporized payload. The intensity of the emitted light is preferably low enough so that the reflected light does not overwhelm the light detector. In some embodiments, the light intensity is ramped over a very short time period (but slow enough that the photo-diode is able to track it) in order to identify the point at which the photo-diode begins to saturate. The photo-diode will saturate earlier if the vaporized payload has a higher vapor density and is more reflective. In some embodiments, the light intensity is dynamically modified based on the measured vapor density of the vaporized payload.

[0123] In other examples, the light sensor is a transmissive sensor in which the light source is configured to emit light that is directed toward the path of the vaporized payload and the light detector is configured to detect light transmission through the vaporized payload (such as the light sensors incorporated into the vape devices shown in FIGS. **7-10**). When the vapor density of the vaporized payload increases, the light transmission through the vaporized payload decreases. Conversely, when the vapor density of the vaporized payload decreases, the light transmission through the vaporized payload increases. These properties can be utilized to determine the vapor density of the vaporized payload.

[0124] With a transmissive sensor, the wavelength of the emitted light may be selected so that the light is maximally absorbed by the vaporized payload. The intensity of the emitted light is preferably high enough to result in some light reaching the light detector. In some embodiments, the light intensity is ramped over a very short time period (but slow enough that the photo-diode is able to track it) in order to identify the point at which the photo-diode begins to saturate. The photo-diode will saturate earlier if the vaporized payload has a lower vapor density. In some embodiments, the light intensity is dynamically modified based on the measured vapor density of the vaporized payload.

[0125] In yet other examples, the light source is configured to emit light that is directed toward a light transmitting medium positioned within the path of the vaporized payload and the light detector is configured to detect light transmitted through the medium (such as the light sensors incorporated into the vape devices shown in FIGS. **11-13**). The light transmitting medium is made of glass, plastic or another material with an index of refraction that is sufficiently similar to that of the payload and sufficiently different from that of air.

[0126] When the surface of the light transmitting medium is surrounded entirely by air prior to any use of the vape device, most of the light emitted by the light source will travel through the medium to the light detector. Notably, when the light impacts the medium/air boundary at an angle, the light will totally reflect back into the medium (i.e., total internal reflection) due to the differences between the index of refraction of the medium and the index of refraction of air. Thus, the light detected by the light detector will have substantially the same intensity as the light emitted by the light source.

[0127] However, when vaporized payload, e.g., an oil droplet, is deposited on the surface of the light transmitting medium during use of the vape device, some of the light traveling through the medium will impact the medium/payload boundary at an angle and escape the medium into the deposited payload due to the similarities between the index of refraction of the medium and the index of refraction of the payload. Thus, the level of attenuation of the light received by the light detector will be dependent on the total amount of payload deposited on the surface of the medium.

[0128] It should be understood that the light transmission through the medium will decrease as the medium becomes increasingly fouled (coated) with droplets from the vaporized payload over the lifetime of the medium—i.e., there will be residual payload deposited on the surface of the medium after each user inhalation. Light intensity measurements are preferably obtained before, during, and after each user inhalation, and the rate of decrease of light transmission through the medium indicates the amount of vaporized payload that has passed the medium during that user inhalation. These properties can be utilized to determine the vapor density of the vaporized payload. Because the light transmitting medium has a limited lifetime, it is preferably placed in a replaceable cartridge portion of the vape device.

[0129] With this type of light sensor, the intensity of the emitted light is preferably increased over the lifetime of the light transmitting medium. When the medium is clean, very little of the emitted light will escape the medium due to total internal reflection at the medium/air boundary. As such, the emitted light can have a low intensity and still be detectable at the light detector. However, as droplets from the vaporized payload successively collect on the outside surface of the light transmitting medium throughout the lifetime of the medium, more light will escape the medium at the medium/payload boundary. As such, the emitted light must have a higher intensity to be detectable at the light detector.

[0130] The material of the light transmitting medium may be selected to obtain a desired index of refraction and associated effect. Those skilled in the art will appreciate that the critical angle is the smallest angle of incidence that yields total internal reflection through a light transmitting medium, as shown by the following equation:

$$\theta_c = \arcsin(n_2/n_1) \tag{2}$$

where

[0131] θ_c=critical angle in degrees;

[0132] n_1=index of refraction of light transmitting medium; and

[0133] n_2=index of refraction of material adjacent to light transmitting medium (e.g., the droplets from the vaporized payload).

[0134] The closer the indexes of refraction are between the light transmitting medium and the droplets from the vaporized payload, the more likely it will be that the light escapes the medium into one of the droplets. In some embodiments, the index of refraction of the light transmitting medium is selected so as to be substantially the same as the index of refraction of the vaporized payload so as to maximize the amount of escaped light. In other embodiments, the index of refraction of the light transmitting medium is selected so as to be slightly different than the index of refraction of the vaporized payload so as to limit the amount of escaped light, which may be beneficial in cases where it is desired to limit the amount of attenuation at the light detector. In other embodiments, the payload is modified via the use of additive (s) so as to obtain a desired index of refraction, although this approach is not preferred insofar as any such additive(s) may be inhaled by the user—i.e, it is preferred to modify the index of refraction of the light transmitting medium.

[0135] Of course, other vape devices may include any combination of the foregoing types of light sensors. For example, a vape device may include both a reflective sensor and a transmissive sensor that are used either simultaneously or sequentially to switch between the reflective and transmissive modes (depending on which mode provides better dynamic range).

[0136] Referring to FIG. **6**, a first example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **600**. Vape device **600** includes a housing **602**, which may comprise an internal housing or external housing of vape device **600**. Positioned within housing **602** is an air flow chamber which, in this example, comprises a conduit **612** that extends between an inlet **604** and an outlet **606**. It can be appreciated that the inlet and outlet orifices are defined by conduit **612**. An atomizer **610** is positioned anywhere between inlet **604** and outlet **606**. As described above, atomizer **610** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **612** from inlet **604** to atomizer **610**, and ambient air mixed with vaporized payload flows through conduit **612** from atomizer **610** to outlet **606**. Outlet **606** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **600** may include a number of other components that are not specifically shown in FIG. **6**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0137] With respect to vape device **600**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer

610 in accordance with desired operational settings. When the heating element of atomizer **610** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained during user inhalation (and optionally before and after user inhalation), wherein the light intensity measurements are associated with light reflected from the vaporized payload when the vaporized payload passes through conduit **612** from atomizer **610** to outlet **606**.

[0138] As shown in FIG. **6**, vape device **600** includes a light source **614** and a light detector **616** positioned side-by-side within housing **602** outside of conduit **612** between atomizer **610** and outlet **606**. In this example, conduit **612** includes a transparent section **618** formed on its sidewall that is located adjacent to light source **614** and light detector **616**. Transparent section **618** may be made of glass or any other transparent material known to those skilled in the art. As used herein, the term "transparent" generally means transparency for light and includes both clear transparency as well as translucency. Generally, a material is considered transparent if at least about 50%, preferably about 60%, more preferably about 70%, more preferably about 80% and still more preferably about 90% of the light illuminating the material can pass through the material.

[0139] The light path between light source **614** and light detector **616** is indicated by dashed lines in FIG. **6**. As can be seen, light source **614** is configured to emit light that passes through transparent section **618** and into conduit **612**, whereby some of the light reflects off the vaporized payload within conduit **612** and passes back through transparent section **618** to light detector **616** (noting that some of the emitted light will not be reflected back to light detector **616**). Light detector **616** is then configured to generate a signal representing the intensity of the reflected light. As discussed above, light source **614** and light detector **616** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of vape device **600**.

[0140] It should be understood that various modifications could be made to vape device **600** within the scope of the present invention. For example, in some embodiments, light source **614** and light detector **616** are positioned within conduit **612** (e.g., attached on a sidewall of conduit **612**) so that the vaporized payload can flow past light source **614** and light detector **616**, provided that appropriate steps are taken to protect the integrity of the components within conduit **612**. In this case, transparent section **618** of conduit **612** would not be required. Of course, other modifications will be apparent to those skilled in the art.

[0141] Referring to FIG. **7**, a second example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **700**. Vape device **700** includes a housing **702**, which may comprise an internal housing or external housing of vape device **700**. Positioned within housing **702** is an air flow chamber which, in this example, comprises a conduit **712** that extends between an inlet **704** and an outlet **706**. It can be appreciated that the inlet and outlet orifices are defined by conduit **712**. An atomizer **710** is positioned anywhere between inlet **704** and outlet **706**. As described above, atomizer **710** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **712** from inlet **704** to atomizer **710**, and ambient air mixed with vaporized payload flows through conduit **712** from atomizer **710** to outlet **706**. Outlet **706** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **700** may include a number of other components that are not specifically shown in FIG. **7**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0142] With respect to vape device **700**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **710** in accordance with desired operational settings. When the heating element of atomizer **710** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained during user inhalation (and optionally before and after user inhalation), wherein the light intensity measurements are associated with light transmitted through the vaporized payload when the vaporized payload passes through conduit **712** from atomizer **710** to outlet **706**.

[0143] As shown in FIG. **7**, vape device **700** includes a light source **714** and a light detector **716** positioned within housing **702** outside of conduit **712** between atomizer **710** and outlet **706**, wherein light source **714** is positioned on a first side of conduit **712** and light detector **716** is positioned on a second opposing side of conduit **712**. In this example, conduit **712** includes a first transparent section **718** formed on its sidewall adjacent light source **714** and a second transparent section **720** formed on its sidewall adjacent light detector **716**. Transparent sections **718** and **720** may be made of glass or any other transparent material known to those skilled in the art.

[0144] The light path between light source **714** and light detector **716** is indicated by dashed lines in FIG. **7**. As can be seen, light source **714** is configured to emit light that passes through transparent section **718** and into conduit **712**, whereby the light travels through the vaporized payload within conduit **712** (noting that some of the light is absorbed by the vaporized payload) and passes through transparent section **720** to light detector **716**. Light detector **716** is then configured to generate a signal representing the intensity of the light that is received at light detector **716**. As discussed above, light source **714** and light detector **716** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of vape device **700**.

[0145] It should be understood that various modifications could be made to vape device **700** within the scope of the present invention. For example, in some embodiments, light source **714** and light detector **716** are positioned within conduit **712** (e.g., attached on opposing sidewalls of conduit **712**) so that the vaporized payload can flow past light source **714** and light detector **716**, provided that appropriate steps are taken to protect the integrity of the components within conduit **712**. In this case, transparent sections **718** and **720** of conduit **712** would not be required. Of course, other modifications will be apparent to those skilled in the art.

[0146] Referring to FIG. **8**, a third example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **800**. In this example, vape device **800** includes a cartridge **808** and a control assembly **814** formed in separate housings **802** and **832**, respectively, which are releasably connected to each other via an electromechanical connection, as described above. Housings **802** and **832** may comprise an internal housing or external housing of cartridge **808** and control assembly **814**, respectively. Positioned within housings **802** and **832** is an air flow chamber which, in this example, comprises a conduit **812** that extends between an inlet **804** within control assembly **814** and an outlet **806** within cartridge **808**. It can be appreciated that the inlet and outlet orifices are defined by conduit **812**. An atomizer **810** is positioned anywhere between inlet **804** and outlet **806** within cartridge **808**. As described above, atomizer **810** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **812** from inlet **804** to atomizer **810**, and ambient air mixed with vaporized payload flows through conduit **812** from atomizer **810** to outlet **806**. Outlet **806** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **800** may include a number of other components that are not specifically shown in FIG. **8**, including a power source, a microcontroller, and other electronics positioned in control assembly **814**, as described above in connection with vape devices **10** and **100**. It should also be understood that conduit **812** may be positioned entirely within cartridge **808**, in which case conduit **812** would not extend through control assembly **814** as shown.

[0147] With respect to vape device **800**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) over the electromechanical connection to atomizer **810** in accordance with desired operational settings. When the heating element of atomizer **810** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained during user inhalation (and optionally before and after user inhalation), wherein the light intensity measurements are associated with light transmitted through the vaporized payload when the vaporized payload passes through conduit **812** from atomizer **810** to outlet **806**.

[0148] As shown in FIG. **8**, vape device **800** includes a light source **816** and a light detector **818** positioned within housing **832** of control assembly **814** outside of conduit **812**, wherein light source **816** is positioned on a first side of conduit **812** and light detector **818** is positioned on a second opposing side of conduit **812**. Also, the interface between control assembly **814** and cartridge **808** includes a first transparent window **820** located adjacent light source **816** and a second transparent window **822** located adjacent light detector **818**. In addition, a first reflective surface **824** and a second reflective surface **826** are located within housing **802** of cartridge **808**. As can be seen, first reflective surface **824** and first transparent window **820** are positioned to align with light source **816**, and second reflective surface **826** and second transparent window **822** are positioned to align with light detector **818**. Further, conduit **812** includes a first transparent section **828** formed on its sidewall adjacent first reflective surface **824** and a second transparent section **830** formed on its sidewall adjacent second reflective surface **826**. Transparent sections **828** and **830** may be made of glass or any other transparent material known to those skilled in the art.

[0149] The light path between light source **816** and light detector **818** is indicated by dashed lines in FIG. **8**. As can be seen, light source **816** is configured to emit light that passes through first transparent window **820** to first reflective surface **824**, whereby the light is reflected and redirected though first transparent section **828** and into conduit **812**. The light then travels through the vaporized payload within conduit **812** (noting that some of the light is absorbed by the vaporized payload) and passes through second transparent section **830** to second reflective surface **826**, whereby the light is reflected and redirected through second transparent window **822** to light detector **818**. Light detector **818** is then configured to generate a signal representing the intensity of the light that is received at light detector **818**. As discussed above, light source **816** and light detector **818** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of vape device **800**.

[0150] Referring to FIG. **9**, a fourth example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **900**. In this example, vape device **900** includes a cartridge **908** and a control assembly **914** formed in separate housings **902** and **928**, respectively, which are releasably connected to each other via an electromechanical connection, as described above. Housings **902** and **928** may comprise an internal housing or external housing of cartridge **908** and control assembly **914**, respectively. Positioned within housings **902** and **928** is an air flow chamber which, in this example, comprises a conduit **912** that extends between an inlet **904** within control assembly **914** and an outlet **906** within cartridge **908**. It can be appreciated that the inlet and outlet orifices are defined by conduit **912**. An atomizer **910** is positioned between inlet **904** and outlet **906** within cartridge **908**. As described above, atomizer **910** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **912** from inlet **904** to atomizer **910**, and ambient air mixed with vaporized payload flows through conduit **912** from atomizer **910** to outlet **906**. Outlet **906** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **900** may include a number of other components that are not specifically shown in FIG. **9**, including a power source, a microcontroller, and other electronics positioned in control assembly **914**, as described above in connection with vape devices

10 and **100**. It should also be understood that conduit **912** may be positioned entirely within cartridge **908**, in which case conduit **912** would not extend through control assembly **914** as shown.

[0151] With respect to vape device **900**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **910** in accordance with desired operational settings. When the heating element of atomizer **910** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained during user inhalation (and optionally before and after user inhalation), wherein the light intensity measurements are associated with light transmitted through the vaporized payload when the vaporized payload passes through conduit **912** from atomizer **910** to outlet **906**.

[0152] As shown in FIG. **9**, vape device **900** includes a light source **916** and a light detector **918** positioned in close proximity to each other within housing **928** of control assembly **914** outside of conduit **912**. Also, the interface between control assembly **914** and cartridge **908** includes a transparent window **920** located adjacent light source **916** and light detector **918**. In addition, a reflective surface **922** is located within housing **902** of cartridge **908**. As can be seen, reflective surface **922** and transparent window **920** are positioned to align with light source **916** and light detector **918**. Further, conduit **912** includes a transparent section **924** formed on its sidewall adjacent reflective surface **922** and a reflective section **926** formed on an opposing sidewall. Transparent section **924** may be made of glass or any other transparent material known to those skilled in the art. Reflective section **926** may be made of polished stainless steel or any other reflective material known to those skilled in the art. If the section of conduit **912** opposite transparent section **924** is sufficiently reflective (e.g., if conduit **912** is made of stainless steel), then a separate reflective section **926** would not be required and that section of conduit **912** would serve as the reflective section.

[0153] The light path between light source **916** and light detector **918** is indicated by dashed lines in FIG. **9**. As can be seen, light source **916** is configured to emit light that passes through transparent window **920** to reflective surface **922**, whereby the light is reflected and redirected though transparent section **924** and into conduit **912**. The light then travels through the vaporized payload to reflective section **926**, whereby the light is reflected and redirected back through the vaporized payload (noting that some of the light is absorbed by the vaporized payload). The light then passes through transparent section **924** to reflective surface **922**, whereby the light is reflected and redirected through transparent window **904** to light detector **918**. Light detector **918** is then configured to generate a signal representing the intensity of the light that is received at light detector **918**. As discussed above, light source **916** and light detector **918** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of vape device **900**.

[0154] Referring to FIG. **10**, a fifth example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **1000**. In this example, vape device **1000** includes a cartridge **1008** and a control assembly **1014** formed in separate housings **1002** and **1028**, respectively, which are releasably connected to each other via an electromechanical connection, as described above. Housings **1002** and **1028** may comprise an internal housing or external housing of cartridge **1008** and control assembly **1014**, respectively. Positioned within housings **1002** and **1028** is an air flow chamber which, in this example, comprises a conduit **1012** that extends between an inlet **1004** within control assembly **1014** and an outlet **1006** within cartridge **1008**. It can be appreciated that the inlet and outlet orifices are defined by conduit **1012**. An atomizer **1010** is positioned anywhere between inlet **1004** and outlet **1006** within cartridge **1008**. As described above, atomizer **1010** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **1012** from inlet **1004** to atomizer **1010**, and ambient air mixed with vaporized payload flows through conduit **1012** from atomizer **1010** to outlet **1006**. Outlet **1006** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **1000** may include a number of other components that are not specifically shown in FIG. **10**, including a power source, a microcontroller, and other electronics positioned in control assembly **1014**, as described above in connection with vape devices **10** and **100**. It should also be understood that conduit **1012** may be positioned entirely within cartridge **1008**, in which case conduit **1012** would not extend through control assembly **1014** as shown.

[0155] With respect to vape device **1000**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **1010** in accordance with desired operational settings. When the heating element of atomizer **1010** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained during user inhalation (and optionally before and after user inhalation), wherein the light intensity measurements are associated with light transmitted through the vaporized payload when the vaporized payload passes through conduit **1012** from atomizer **1010** to outlet **1006**.

[0156] As shown in FIG. **10**, vape device **1000** includes a light source **1016** positioned within housing **1002** of cartridge **1008** outside of conduit **1012** and a light detector **1018** positioned within housing **1028** of control assembly **1014** outside of conduit **1012**. Also, the interface between control assembly **1014** and cartridge **1008** includes a transparent window **1020** located adjacent light detector **1018**. In addition, a reflective surface **1022** is located within housing **1002** of cartridge **1008** outside of conduit **1012**. As can be seen, reflective surface **1022** and transparent window **1020** are positioned to align with light detector **1018**. Further, conduit **1012** includes a first transparent section **1024** formed on its sidewall adjacent reflective surface **1022** and a second transparent section **1026** formed on an opposing sidewall. Transparent sections **1024** and **1026** may be made of glass or any other transparent material known to those skilled in the art.

[0157] The light path between light source **1016** and light detector **1018** is indicated by dashed lines in FIG. **10**. As can be seen, light source **1016** is configured to emit light that passes through second transparent section **1026** and into conduit **1012**. The light travels through the vaporized payload within conduit **1012** (noting that some of the light is absorbed by the vaporized payload) and passes through first transparent section **1024** to reflective surface **1022**, whereby the light is reflected and redirected though transparent window **1020** to light detector **1018**. Light detector **1018** is then configured to generate a signal representing the intensity of the light that is received at light detector **1018**. As discussed above, light source **1016** and light detector **1018** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements during each user inhalation (and optionally before and after user inhalation) and provide such measurements to the microcontroller of vape device **1000**.

[0158] Referring to FIG. **11**A, a sixth example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **1100**. Vape device **1100** includes a housing **1102**, which may comprise an internal housing or external housing of vape device **1100**. Positioned within housing **1102** is an air flow chamber which, in this example, comprises a conduit **1112** that extends between an inlet **1104** and an outlet **1106**. It can be appreciated that the inlet and outlet orifices are defined by conduit **1112**. An atomizer **1110** is positioned anywhere between inlet **1104** and outlet **1106**. As described above, atomizer **1110** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **1112** from inlet **1104** to atomizer **1110**, and ambient air mixed with vaporized payload flows through conduit **1112** from atomizer **1110** to outlet **1106**. Outlet **1106** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **1100** may include a number of other components that are not specifically shown in FIG. **11**A, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0159] With respect to vape device **1100**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **1110** in accordance with desired operational settings. When the heating element of atomizer **1110** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained before, during, and after user inhalation, wherein the light intensity measurements in this example are associated with light transmitted through a light transmitting medium positioned parallel to the path of the vaporized payload within conduit **1112**, as described below.

[0160] As shown in FIG. **11**A, vape device **1100** includes a light source **1114** and a light detector **1116** spaced apart from each other within housing **1102** outside of conduit **1112** between atomizer **1110** and outlet **1106**. Also, vape device **1100** includes one or more fibers made of glass, plastic, or another material with an index of refraction that is sufficiently similar to that of the payload and sufficiently different from that of air, as discussed above, which will be referred to herein as a "glass fiber **1118**" for ease of reference. In this example, glass fiber **1118** is positioned substantially inside of conduit **1118** and extends generally parallel to the direction of the airflow. One end **1118***a* of glass fiber **1118** extends through an opening in the sidewall of conduit **1112** so as to be positioned outside of conduit **1112** adjacent light source **1114**. The other end **1118***b* of glass fiber **1118** penetrates through another opening in the sidewall of conduit **1112** so as to be positioned outside of conduit **1112** adjacent light detector **1116**. Any suitable sealant may be used to seal the openings in conduit **1112** so as to prevent the leakage of vaporized payload therethrough.

[0161] The light path between light source **1114** and light detector **1116** through glass fiber **1118** can be understood with reference to the simplified diagrams shown in FIGS. **11**B and **11**C.

[0162] FIG. **11**B shows the surface of glass fiber **1118** surrounded entirely by air, i.e., prior to any use of vape device **1100**. The light emitted by light source **1114** travels through glass fiber **1118** to light detector **1116** in a light path indicated by the dashed lines in FIG. **11**B. As can be seen, when the light impacts each glass/air boundary at an angle, the light totally reflects back into glass fiber **1118** (i.e., total internal reflection) due to the differences between their respective indexes of refraction. Thus, the light detected by light detector **1116** has substantially the same intensity as the light emitted by light source **1114**.

[0163] FIG. **11**C shows the surface of glass fiber **1118** with vaporized payload (an oil droplet in this example) deposited on a portion of the surface. The light emitted by light source **1114** travels through glass fiber **1118** to light detector **1116** in a light path indicated by the dashed lines in FIG. **11**C. As can be seen, when the light impacts the glass/oil boundary at an angle, the light will escape glass fiber **1118** and enter the oil, and some of the light may further escape the oil into the air. However, when the light impacts the glass/air boundary at an angle (i.e., in areas where there are no oil droplets on the surface), the light reflects back into glass fiber **1118**. Thus, the level of attenuation of the light received by light detector **1116** will be dependent on the amount of oil deposited on the surface of glass fiber **1118**.

[0164] It can be appreciated that light detector **1116** is configured to generate a signal representing the intensity of the received light. As discussed above, light source **1114** and light detector **1116** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements before, during, and after each user inhalation and provide such measurements to the microcontroller of vape device **1100**.

[0165] It should be understood that various modifications could be made to vape device **1100** within the scope of the present invention. For example, in some embodiments, glass fiber **1118** is positioned entirely inside of conduit **1112**. In this case, a first transparent section is formed on the sidewall of conduit **1112** adjacent light source **1114** to provide a light path between glass fiber **1118** and light source **1114** and, similarly, a second transparent section is formed on the sidewall of conduit **1112** adjacent light detector **1116** to provide a light path between glass fiber **1118** and light detector **1116**. The transparent sections may be made of glass or any other transparent material known to those skilled in the art. In this case, conduit **1112** would not need openings for the ends of glass fiber **1118**. In yet other embodiments, glass fiber **1118** is replaced with another material having an index of refraction similar to that of the vaporized payload, as discussed above. Of course, other modifications will be apparent to those skilled in the art.

[0166] Referring to FIG. **12**, a seventh example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **1200**. Vape device **1200** includes a housing **1202**, which may comprise an internal housing or external housing of vape device **1200**. Positioned within housing **1202** is an air flow chamber which, in this example, comprises a conduit **1212** that extends between an inlet **1204** and an outlet **1206**. It can be appreciated that the inlet and outlet orifices are defined by conduit **1212**. An atomizer **1210** is positioned anywhere between inlet **1204** and outlet **1206**. As described above, atomizer **1210** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **1212** from inlet **1204** to atomizer **1210**, and ambient air mixed with vaporized payload flows through conduit **1212** from atomizer **1210** to outlet **1206**. Outlet **1206** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **1200** may include a number of other components that are not specifically shown in FIG. **12**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0167] With respect to vape device **1200**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **1210** in accordance with desired operational settings. When the heating element of atomizer **1210** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained before, during, and after user inhalation, wherein the light intensity measurements in this example are associated with light transmitted through a light transmitting medium positioned perpendicular to the path of the vaporized payload within conduit **1212**, as described below.

[0168] As shown in FIG. **12**, vape device **1200** includes a light source **1214** and a light detector **1216** positioned within housing **1202** outside of conduit **1212** between atomizer **1210** and outlet **1206**, wherein light source **1214** is positioned on a first side of conduit **1212** and light detector **1216** is positioned on a second opposing side of conduit **1212**. Also, vape device **1200** includes one or more fibers made of glass, plastic, or another material with an index of refraction that is sufficiently similar to that of the payload and sufficiently different from that of air, as discussed above, which will be referred to herein as a "glass fiber **1218**" for ease of reference. Glass fiber **1218** is positioned substantially inside of conduit **1212** and extends generally perpendicular to the direction of the airflow. One end **1218***a* of glass fiber **1218** extends through an opening in the sidewall of conduit **1212** so as to be positioned outside of conduit **1212** adjacent light source **1214**. The other end **1218***b* of glass fiber **1218** penetrates through another opening in the sidewall of conduit **1212** so as to be positioned outside of conduit **1212** adjacent light detector **1216**. Any suitable sealant may be used to seal the openings in conduit **1212** so as to prevent the leakage of vaporized payload therethrough.

[0169] The light path between light source **1214** and light detector **1216** through glass fiber **1218** can be understood from the description of FIGS. **11**B and **11**C above, wherein light detector **1216** is configured to generate a signal representing the intensity of the received light. As discussed above, light source **1214** and light detector **1216** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements before, during, and after each user inhalation and provide such measurements to the microcontroller of vape device **1200**.

[0170] It should be understood that various modifications could be made to vape device **1200** within the scope of the present invention. For example, in some embodiments, glass fiber **1218** is positioned entirely inside of conduit **1212**. In this case, a first transparent section is formed on the sidewall of conduit **1212** adjacent light source **1214** to provide a light path between glass fiber **1218** and light source **1214** and, similarly, a second transparent section is formed on the sidewall of conduit **1212** adjacent light detector **1216** to provide a light path between glass fiber **1218** and light detector **1216**. The transparent sections may be made of glass or any other transparent material known to those skilled in the art. In this case, conduit **1212** would not need openings for the ends of glass fiber **1218**. In yet other embodiments, glass fiber **1218** is replaced with another material having an index of refraction similar to that of the vaporized payload, as discussed above. Of course, other modifications will be apparent to those skilled in the art.

[0171] Referring to FIG. **13**, an eighth example of a vape device that relies on a light intensity measurement method to determine the dose of vaporized payload is shown generally as reference numeral **1300**. Vape device **1300** includes a housing **1302**, which may comprise an internal housing or external housing of vape device **1300**. Positioned within housing **1302** is an air flow chamber which, in this example, comprises a conduit **1312** that extends between an inlet **1304** and an outlet **1306**. It can be appreciated that the inlet and outlet orifices are defined by conduit **1312**. An atomizer **1310** is positioned anywhere between inlet **1304** and outlet **1306**. As described above, atomizer **1310** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **1312** from inlet **1304** to atomizer **1310**, and ambient air mixed with vaporized payload flows through conduit **1312** from atomizer **1310** to outlet **1306**. Outlet **1306** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **1300** may include a number of other components that are not specifically shown in FIG. **13**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0172] With respect to vape device **1300**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **1310** in accordance with desired operational settings. When the heating element of atomizer **1310** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation. As described above, the microcontroller is programmed to determine the dose of vaporized payload based on a plurality of light intensity measurements obtained before, during and after user inhalation, wherein the light intensity measurements in this example are associated with light transmitted through a glass section of conduit **1312**, as described below.

[0173] As shown in FIG. **13**, vape device **1300** includes a light source **1314** and a light detector **1316** spaced apart from each other within housing **1302** outside of conduit **1312** between atomizer **1310** and outlet **1306**. Also, in this example, conduit **1312** includes a flat or curved section made of glass, plastic, or another material with an index of refraction that is sufficiently similar to that of the payload and sufficiently different from that of air, as discussed above, which will be referred to herein as a "glass section **1318**" for ease of reference. Glass section **1318** extends along the length of conduit **1312** such that one end of glass section **1318** is positioned adjacent light source **1314** and the other end of glass section **1318** is positioned adjacent light detector **1316**.

[0174] The light path between light source **1314** and light detector **1316** through glass section **1318** can be understood from the description of FIGS. **11**B and **11**C above, wherein light detector **1316** is configured to generate a signal representing the intensity of the received light. As discussed above, light source **1314** and light detector **1316** are incorporated into a light intensity measurement circuit configured to obtain a plurality of light intensity measurements before, during and after each user inhalation and provide such measurements to the microcontroller of vape device **1300**.

[0175] It should be understood that various modifications could be made to vape device **1300** within the scope of the present invention. For example, in some embodiments, a mirrored coating may be applied to the non-vapor side of glass section **1318**, i.e., the outside surface of glass section **1318**. In this case, light would still escape glass section **1318** when vaporized payload is deposited on the inside surface of glass section **1318**. In other embodiments, all of conduit **1312** (not just glass section **1318**) may be made of glass—either with or without a mirrored coating on the outside surface of conduit **1312**. In yet other embodiments, glass section **1318** is made of another material having an index of refraction similar to that of the vaporized payload, as discussed above. Of course, other modifications will be apparent to those skilled in the art.

[0176] It should also be understood that any of vape devices **1100**, **1200** and **1300** could be modified by placing a mirrored finish on the far end of the light transmitting medium from the light source so that the light sensor may be co-located with the light source. If the vape device includes a cartridge and a control assembly formed in separate housings that are releasably connected to each other via an electromechanical connection, as described above, this modification would enable the light source and/or the light detector to be positioned within the control assembly while the light transmitting medium is located within the cartridge (similar to the configurations shown in FIGS. **8-10**).

[0177] Of course, other modifications to vape devices **1100**, **1200** and **1300** will be apparent to those skilled in the art. For example, the glass fiber may be oriented at any angle within the conduit and is not limited to being positioned parallel to the direction of airflow (as in the vape device of FIG. **11**A) or perpendicular to the direction of airflow (as in the vape device of FIG. **12**). In addition, the glass fiber may follow the contour of the conduit, either in a direct line or helix.

[0178] Further, in each of the vape devices shown in FIGS. **6-13** above, the light intensity measurement circuit is configured to provide the light intensity measurements obtained during user inhalation (and optionally before and after user inhalation) to the microcontroller of the vape device. In some embodiments, the microcontroller is programmed to determine the dose of payload that is vaporized during each user inhalation by performing the following steps: (1) acquiring a plurality of light intensity measurements from the light intensity measurement circuit during user inhalation (and optionally before and after user inhalation) and (2) using the information from step 1 to determine the vapor density of the vaporized payload and by extension the partial mass of the payload that is vaporized during user inhalation.

[0179] In some embodiments, the method may be further refined (optionally) by varying the intensity of the light signal emitted by the light source and/or the gain of the light detector in order to adjust the sensitivity.

[0180] In some embodiments, the method may be further refined (optionally) by applying an electric field to the air flow chamber so as to orient a plurality of molecules in the vaporized payload when the vaporized payload passes through the conduit in order to improve their reflective properties.

[0181] Finally, it should be understood that all or a portion of the processing steps performed by the microcontroller of the vape device, as described above, could alternatively be performed by one or more other microcontrollers, such as a secondary microcontroller positioned in a cartridge of the vape device (for embodiments in which the vape device comprises a cartridge releasably connected to a control assembly). Various embodiments will be apparent to those skilled in the art.

Dose Determination/Vapor Droplet Counting Method Using Hot Wire Anemometers

[0182] In some embodiments, the vape device utilizes two or more hot wire anemometers to determine the mass of the vaporized payload that was delivered to the user during each user inhalation and/or to determine the size and density distribution of the droplets in the vaporized payload and use such distribution to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation.

[0183] Referring to FIG. **14**, an example of a vape device that relies on this method to determine the dose of vaporized payload is shown generally as reference numeral **1400**. Vape device **1400** includes a housing **1402**, which may comprise an internal housing or external housing of vape device **1400**. Positioned within housing **1402** is an air flow chamber which, in this example, comprises a conduit **1412** that extends between an inlet **1404** and an outlet **1406**. It can be appreciated that the inlet and outlet orifices are defined by conduit **1412**. An atomizer **1410** is positioned anywhere between inlet **1404** and outlet **1406**. As described above, atomizer **1410** is configured to heat and vaporize the payload contained in a payload reservoir (not shown) so as to output a vaporized payload. During a user inhalation, ambient air flows through conduit **1412** from inlet **1404** to atomizer **1410**, and ambient air mixed with vaporized payload flows through conduit **1412** from atomizer **1410** to outlet **1406**. Outlet **1406** may further be in communication with a mouthpiece, as described above. Of course, it should be understood that vape device **1400** may include a number of other components that are not specifically shown in FIG. **14**, including a power source, a microcontroller, and other electronics, as described above in connection with vape devices **10** and **100**.

[0184] With respect to vape device **1400**, the microcontroller is programmed to control the power source (e.g., a battery) so that the power source transmits a power signal (e.g., a direct current or pulsed direct current) to atomizer **1410** in accordance with desired operational settings. When the heating element of atomizer **1410** reaches the vaporization temperature of the payload contained in the payload reservoir, a portion of the payload is vaporized to thereby generate the vaporized payload for user inhalation.

[0185] A rough dose estimate for each user inhalation can be determined by integrating the power draw versus time of the heating element of atomizer **1410** and comparing it with the amount of payload theoretically vaporized based on the specific heat and heat of vaporization of the payload. However, this dose estimate may not be accurate enough for critical pharmaceutical delivery applications, especially in the case of multi-component payloads in which partial fractionation of the mixture may occur at the interface between the wick and heating element of atomizer **1410**. Therefore, in order to provide a more accurate and repeatable measurement of the total mass of the payload vaporized during each user inhalation, vape device **1400** may utilize a number of different components and circuits, as described below.

[0186] In this example, vape device **1400** includes three hot wire anemometers—a reference hot wire anemometer **1414** located within conduit **1412** between inlet **1404** and atomizer **1410** and two sampling hot wire anemometers **1416** and **1418** located within conduit **1412** between atomizer **1410** and outlet **1406**. The wire filament of each of these anemometers may be made of tungsten, platinum or platinum-iridium, although other materials known to those skilled in the art may also be used.

[0187] Vape device **1400** also includes two temperature sensors—a first temperature sensor **1420** located within conduit **1412** between inlet **1404** and atomizer **1410** and a second temperature sensor **1422** located within conduit **1412** between atomizer **1410** and outlet **1406**. Each of temperature sensors **1420** and **1422** may comprise any type of component capable of sensing the temperature at the designated locations, such as a thermistor, a thermocouple, an infrared sensor, a bandgap temperature sensor, an analog temperature sensor, or a digital temperature sensor. Of course, those skilled in the art will understand that other types of temperature sensors may be used in accordance with the present invention.

[0188] Reference hot wire anemometer **1414** is incorporated into a circuit configured to measure the velocity of air flowing over the wire. The circuit may comprise, for example, a constant temperature Wheatstone bridge circuit, as known to those skilled in the art. During each user inhalation, an electric current is sent through the wire, causing the wire to become hot. As air flows over the wire, it cools the wire and removes some of its heat energy. By integrating the instantaneous heat loss from the wire over time, the anemometer provides a baseline reading of the air flow rate through conduit **1412** during user inhalation, which may be used along with the information from sampling hot wire anemometers **1416** and **1418** (discussed below) to determine the dose of the vaporized payload.

[0189] Sampling hot wire anemometer **1416** is incorporated into a circuit configured to measure the mass of vaporized payload passing by the wire during each user inhalation. By passing current through the wire of hot wire anemometer **1416** so that it operates at a temperature that is above the boiling point of each of the components in the payload, individual collisions of the wire with the droplets in the vaporized payload can be measured. Goldschmidt, Victor W. "Measurement of Aerosol Concentrations with a Hot Wire Anemometer," *Journal of Colloid Science* 20, 617-634 (1965). Counting the number of droplets detected over time can serve as input in determining the total mass of vaporized payload delivered during each user inhalation, provided the size distribution of the droplets in the vaporized payload is known, narrow and constant. This enables the accuracy of the dose determination to be significantly improved. It should be understood that sampling hot wire anemometer **1418** operates in the same manner.

[0190] Sampling hot wire anemometers **1416** and **1418** may also be operated at different temperatures to enable detection of different components in the vaporized payload. For example, assume that the vaporized payload contains components A and B, wherein the boiling point of component A is lower than the boiling point of component B. In this case, hot wire anemometer **1416** is operated at a temperature that is higher than the boiling point of component A, but lower than the boiling point of component B. Also, hot wire anemometer **1418** is operated at a temperature that is higher than the boiling points of components A and B. It can be appreciated that this arrangement enables the dose of each of components A and B to be determined.

[0191] It should be noted that sampling hot wire anemometer **1416** may be fouled by deposition of component B. In order to address this issue, the "roles" of sampling hot wire anemometers **1416** and **1418** may be swapped between successive user inhalations (i.e., the operating temperatures of the anemometers are successively swapped) so that component B is vaporized over the course of using vape device **1400**.

[0192] First temperature sensor **1420** is incorporated into a first temperature measurement circuit configured to obtain a plurality of temperature measurements during user inhalation in order to determine the ambient temperature of the incoming air. Second temperature sensor **1422** is incorporated into a second temperature measurement circuit configured to obtain a plurality of temperature measurements during user inhalation in order to determine the temperature of the vaporized payload/air mixture. This data may be used along with the information from reference hot wire anemometer **1414** and sampling hot wire anemometers **1416** and **1418** to determine the dose of the vaporized payload.

[0193] The above implementation is suitable for cases in which the size distribution of the droplets in the vaporized payload is known, narrow and constant. However, if the distribution of droplet sizes is wide and changing over the duration of the user inhalation, the accuracy of the dose determination will suffer. In order to address these issues, it is preferable to utilize a component and circuit arrangement that enables the microcontroller to determine the size and density distribution of the droplets in the vaporized payload and use such distribution to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation.

[0194] FIG. **15** shows an exemplary embodiment of such a component and circuit arrangement that may be incorporated into a vape device. In this example, the vape device includes a reference hot wire anemometer that operates in the same manner as reference hot wire anemometer **1414** described above. The vape device also includes an array of sampling hot wire anemometers ($SHWAT_1$, $SHWAT_2$, $SHWAT_3$ . . . $SHWAT_{m-1}$, $SHWAT_m$) each of which operates at a distinct temperature (T_1, T_2, T_3 . . . T_{m-1}, T_m) in order to enable detection of different components in the vaporized payload, as described above. In addition, the vape device includes two thermistors (Thermistor **1** and Thermistor **2**) that operate in the same manner as temperature sensors **1420** and **1422** described above.

[0195] It can be seen that each of the sampling hot wire anemometers ($SHWAT_1$, $SHWAT_2$, $SHWAT_3$ . . . $SHWAT_{m-1}$, $SHWAT_m$) are connected to an array of monostable multivibrator (one shot) modules with different triggering thresholds (MM-TT_1, MM-TT_2, TT_3 . . . MM-TT_{n-1}, MM-TT_n) and an array of associated digital counters (DC-TT_1, DC-TT_2, DC-TT_3 . . . DC-TT_{n-1}, DC-TT_n,). The triggering thresholds of the monostable multivibrator modules are segmented to cover bands of droplet size detection sensitivity in order to more granularly determine the droplet size distribution and density in the vaporized payload.

[0196] Specifically, each of the monostable multivibrator modules has an individual triggering threshold tailored to be sensitive to a droplet of a minimum size. For example, the most sensitive monostable multivibrator module would count every size droplet, and the second most sensitive monostable multivibrator module would count every size droplet except the smallest size droplet. By subtracting the number of droplets detected by the second most sensitive monostable multivibrator module from the number of droplets detected by the most sensitive monostable multivibrator module, the number of the smallest size droplets within that band can be determined. This scheme can be extended until the desired number of droplet size bands is represented. The size and density distribution of the droplets in the vaporized payload may then be integrated over the time period of the user inhalation in order to calculate the total mass of the vaporized payload that was delivered to the user during each user inhalation.

[0197] In some embodiments, a standardized aerosol generator may be used to calibrate the vape device using various droplet size and density settings.

[0198] Finally, it should be understood that all or a portion of the processing steps performed by the microcontroller of vape device **1400**, as described above, could alternatively be performed by one or more other microcontrollers, such as a secondary microcontroller (not shown) positioned in a cartridge of vape device **1400** (for embodiments in which vape device **1400** comprises a cartridge releasably connected to a control assembly). Various embodiments will be apparent to those skilled in the art.

Dose Control System

[0199] The methods of measuring dosage described above may be used independently, or in any combination, to record the dose administered to the user and report it to personal computing device **72** or an equivalent device. Alternatively, the desired dose can be set in advance by the user through an on-vaporizer input method (e.g., buttons, dial, etc.) or through interaction with application **74** running on personal computing device **72**. The user then inhales until the user-specified dose is administered, at which point the vape device stops vaporizing to thereby provide an accurate means of dose control.

III. General Information

[0200] In this disclosure, the use of any and all examples or exemplary language (e.g., "for example" or "as an example") is intended merely to better describe the invention and does not pose a limitation on the scope of the invention. No language in the disclosure should be construed as indicating any non-claimed element essential to the practice of the invention.

[0201] Also, the use of the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a system, device, or method that comprises a list of elements does not include only those elements, but may include other elements not expressly listed or inherent to such system, device, or method.

[0202] Further, the use of relative relational terms, such as first and second, are used solely to distinguish one unit or action from another unit or action without necessarily requiring or implying any actual such relationship or order between such units or actions.

[0203] Finally, while the present invention has been described and illustrated hereinabove with reference to various exemplary embodiments, it should be understood that various modifications could be made to these embodiments without departing from the scope of the invention. For example, while the methods of measuring dosage are described above for use in a vape device, some of these methods (e.g., the light measurement methods and/or hot wire anemometer methods) could be used in a nebulizer. Therefore, the present invention is not to be limited to the specific structural configurations, circuits or methodologies of the exemplary embodiments, except insofar as such limitations are included in the following claims.

What is claimed and desired to be secured by Letters Patent is as follows:

1. A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations, comprising:

- a payload reservoir configured to contain a payload to be vaporized;
- an air flow chamber that extends between and inlet and an outlet;
- a power source configured to generate a power signal during each respective user inhalation;
- an atomizer located between the inlet and the outlet of the air flow chamber, wherein the atomizer is configured to receive the power signal and vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; and

a microcontroller programmed to determine a dose of the vaporized payload for each respective user inhalation based on: (a) determining an amount of energy used to vaporize the portion of the payload during the user inhalation; and (b) determining a partial mass of the payload that is vaporized during the user inhalation based on the amount of energy used to vaporize the portion of the payload during the user inhalation.

2. The vape device of claim **1**, further comprising a memory device configured to store information that enables the microcontroller to correlate the amount of energy used to vaporize the portion of the payload during the user inhalation to the partial mass of the payload that is vaporized during the user inhalation.

3. The vape device of claim **1**, wherein the vape device comprises a cartridge releasably connected to a control assembly, and wherein the microcontroller is contained within the control assembly.

4. The vape device of claim **1**, wherein the vape device comprises a cartridge releasably connected to a control assembly, and wherein the microcontroller is contained within the cartridge.

5. The vape device of claim **1**, wherein the power source comprises a battery, and wherein the power signal comprises a direct current or a pulsed direct current.

6. The vape device of claim **1**, wherein the microcontroller is programmed to determine the amount of energy used to vaporize the portion of the payload during the user inhalation based on: (a) determining an amount of power provided to the atomizer during the user inhalation; (b) determining a duration of the user inhalation; and (c) determining the amount of energy based on the amount of power provided to the atomizer during the user inhalation and the duration of the user inhalation.

7. The vape device claim **1**, wherein the microcontroller is further programmed to: (a) determine an amount of energy used to heat the atomizer to a vaporization temperature during the user inhalation; and (b) adjust the amount of energy used to vaporize the portion of the payload during the user inhalation by subtracting the amount of energy used to heat the atomizer to the vaporization temperature during the user inhalation.

8. The vape device of claim **1**, wherein the microcontroller is further programmed to adjust the amount of energy used to vaporize the portion of the payload during the user inhalation to account for one or more of the following operating conditions: a starting temperature of the vape device, a starting temperature of the payload, a temperature of ambient air, a relative humidity of ambient air, a pressure of ambient air, an output voltage of the power source, and a temperature ramp rate of the atomizer.

9. The vape device of claim **1**, wherein the microcontroller is further programmed to: (a) determine an air flow rate within the air flow chamber during the user inhalation; and (b) adjust the amount of energy used to vaporize the portion of the payload during the user inhalation to account for the air flow rate.

10. The vape device of claim **1**, further comprising a wireless transceiver configured to transmit the dose of the vaporized payload to an external computing device.

11. The vape device of claim **1**, wherein transmission of the power signal to the atomizer is disabled when the dose of the vaporized payload reaches a specified dose.

12. The vape device of claim **1**, wherein the microcontroller is programmed to determine a remaining amount of the payload in the payload reservoir based on (a) the total amount of the payload and (b) an aggregated amount of the payload that has been vaporized during previous user inhalations.

13. The vape device of claim **12**, wherein the microcontroller is programmed to provide a notice when the remaining amount of the payload in the payload reservoir is below a minimum level.

14. A vape device for determining a dose of a payload delivered to a user during each of a plurality of user inhalations, comprising:

a payload reservoir configured to contain a payload to be vaporized;

an air flow chamber that extends between and inlet and an outlet;

a power source configured to generate a power signal during each respective user inhalation;

an atomizer located between the inlet and the outlet of the air flow chamber, wherein the atomizer is configured to receive the power signal and vaporize a portion of the payload to thereby generate a vaporized payload during each respective user inhalation; and

a microcontroller programmed to:

determine a dose of the vaporized payload for each respective user inhalation based on: (a) determining an amount of energy used to vaporize the portion of the payload during the user inhalation based on an amount of power provided to the atomizer during the user inhalation and a duration of the user inhalation; and (b) determining a partial mass of the payload that is vaporized during the user inhalation based on the amount of energy used to vaporize the portion of the payload during the user inhalation;

disable transmission of the power signal to the atomizer when the dose of the vaporized payload reaches a specified dose.

15. The vape device claim **14**, wherein the microcontroller is further programmed to: (a) determine an amount of energy used to heat the atomizer to a vaporization temperature during the user inhalation; and (b) adjust the amount of energy used to vaporize the portion of the payload during the user inhalation by subtracting the amount of energy used to heat the atomizer to the vaporization temperature during the user inhalation.

16. The vape device of claim **14**, wherein the microcontroller is further programmed to adjust the amount of energy used to vaporize the portion of the payload during the user inhalation to account for one or more of the following operating conditions: a starting temperature of the vape device, a starting temperature of the payload, a temperature of ambient air, a relative humidity of ambient air, a pressure of ambient air, an output voltage of the power source, and a temperature ramp rate of the atomizer.

17. The vape device of claim **14**, wherein the microcontroller is further programmed to: (a) determine an air flow rate within the air flow chamber during the user inhalation; and (b) adjust the amount of energy used to vaporize the portion of the payload during the user inhalation to account for the air flow rate.

18. A method for determining a dose of a payload delivered to a user of a vape device during each of a plurality of user inhalations, comprising:

holding a payload to be vaporized;

vaporizing a portion of the payload by transmitting a power signal from a power source to an atomizer located between and inlet and an outlet of an air flow chamber to thereby generate a vaporized payload during each respective user inhalation; and

determining a dose of the vaporized payload for each respective user inhalation based on: (a) determining an amount of energy used to vaporize the portion of the payload during the user inhalation; and (b) determining a partial mass of the payload that is vaporized during the user inhalation based on the amount of energy used to vaporize the portion of the payload during the user inhalation.

19. The method of claim **18**, further comprising: (a) identifying one or more components within the payload; (b) identifying a relative percentage and a boiling point for each of the components within the payload; and (c) determining a mass of each of the components within the portion of the payload that is vaporized during the user inhalation.

20. The method of claim **19**, further comprising determining an optimal vaporization temperature for the payload based on the relative percentage and the boiling point for each of the components within the payload.

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