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(54) **Title**: DEVICES, SYSTEMS, AND METHODS FOR VOLUMETRICALLY MEASURING SYRINGE FLUID

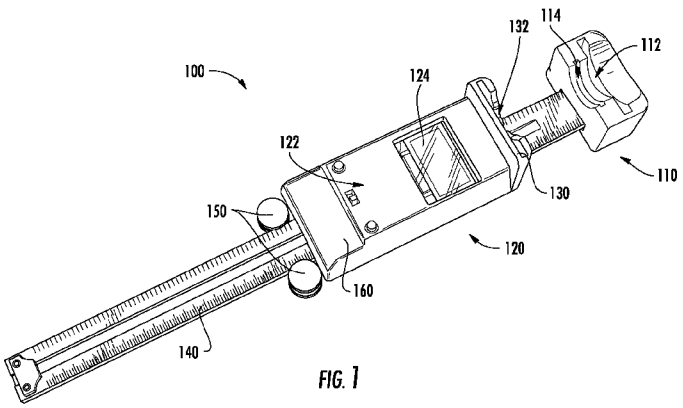

FIG. 1

(57) **Abstract**: Devices, systems, and methods for volumetrically measuring syringe fluid are disclosed. In one aspect, a device for volumetrically measuring syringe fluid includes a reference plate, a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe, a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate, a displacement sensor disposed in the housing and configured to measure a displacement of the plunger adapter in relation to the flange adapter base as the plunger adapter is slid along the length of the reference plate, and a displacement conversion mechanism disposed in the housing and configured to convert the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in.

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DESCRIPTION

DEVICES, SYSTEMS, AND METHODS FOR VOLUMETRICALLY MEASURING SYRINGE FLUID

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application Serial No. 61/988,972 filed May 6, 2014, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

The presently disclosed subject matter generally relates to fluid measurement and transfer. More particularly, the presently disclosed subject matter relates to devices, systems, and methods for volumetrically measuring syringe fluids.

BACKGROUND

Cancer is the second most common cause of death in the United States. Treatments for this disease involve the administration of toxic chemicals to the body, which can be harmful in excessive doses and ineffective in inadequate doses. One method of cancer treatment is chemotherapy. Chemotherapy involves injectable drugs that target rapidly dividing cells for destruction. Rapidly dividing cells in the body are affected by the toxicity of the drug, and overexposure to the drug can lead to widespread tissue damage with a variety of symptoms. Thus, a goal of oncologists is to prescribe medications that are potent enough to significantly reduce the number of malignant cells without causing significant systemic damage to a patient.

In practice, chemotherapy doses are prepared by pharmacy technicians who transfer drugs from vials to patient-specific IV bags with syringes. The volumes that are required for each dose are calculated from the prescriptions and measured with a volumetric scale on a barrel of the syringe. However, preparing doses in this manner is notoriously imprecise

and inaccurate. For example, one study concluded that only 86% of doses prepared in this manner are accurate to within 10% of the prescription, and only 72% of doses are accurate to within 5% of the prescription. The magnitude of this error is primarily a result of estimations made by the technicians who are using potentially inaccurate volumetric measurements on the syringes, themselves. Although, error may also be attributed to residual fluid left in the syringes after dispensing, and potentially other practices in the preparation of the dose. Thus, it is desirable to reduce error in the process of dose preparation by automating the dosage process, thereby removing the element of human estimation. While some automated dose-measuring systems exist, they are both expensive and too large for use in a fume hood or crowded laboratory setting.

Accordingly, a need exists for devices, systems, and methods for volumetrically measuring syringe fluids that provide users the ability to transfer prescribed drugs, in particular chemotherapy drugs, with greater precision and accuracy, without adding significant preparation time or cost, and while minimizing risk of contamination.

SUMMARY

Devices, systems, and methods for volumetrically measuring fluid are described herein. In one aspect, a device for volumetrically measuring fluid can comprise a reference plate, a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe, a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate, a displacement sensor disposed in the housing and configured to measure a displacement of the plunger adapter in relation to the flange adapter base as the plunger adapter is slid along the length of the reference plate, and a displacement conversion mechanism disposed in the housing and configured to convert the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in.

In another aspect, a system for volumetrically measuring fluid can comprise a device and a server or memory connected with the device. The device can comprise a reference plate, a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe, a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate, a displacement sensor disposed in the housing and configured to measure a displacement of the plunger adapter in relation to the flange adapter base as the plunger adapter is slid along the length of the reference plate, and a displacement conversion mechanism disposed in the housing and configured to convert the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in. The volume measurement is then recorded on the server or memory.

In still another aspect, a method for volumetrically measuring syringe fluid can comprise a barcode scanner to identify and/or record the type of liquid drawn with a device. The device can comprise a reference plate, a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe, a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate, a displacement sensor disposed in the housing, and a displacement conversion mechanism disposed in the housing. The method can further comprise securing the flange of the syringe to the flange adapter base and the plunger of the syringe to the plunger adapter, measuring, by the displacement sensor, a displacement of the plunger adapter in relation to the flange adapter base, as the plunger adapter is slidingly moved along the length of the reference plate, and converting, by the displacement conversion mechanism, the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present subject matter will be more readily understood from the following detailed description which should be read in conjunction with the accompanying drawings that are given merely by way of explanatory and non-limiting example, and in which:

Figure 1 is a perspective view of an exemplary device for volumetrically measuring syringe fluid according to a first embodiment of the subject matter described herein;

Figure 2 is an elevation view of an exemplary device for volumetrically measuring syringe fluid according to a first embodiment of the subject matter described herein;

Figure 3 is a side view of an exemplary device for volumetrically measuring syringe fluid according to a first embodiment of the subject matter described herein;

Figure 4 is a cross-sectional view of the exemplary device of Figure 3;

Figure 5A is an elevation view of an exemplary device for volumetrically measuring syringe fluid using, for example, a 60 mL syringe according to a first embodiment of the subject matter described herein;

Figure 5B is an elevation view of an exemplary device for volumetrically measuring syringe fluid using, for example, a 10 mL syringe according to a first embodiment of the subject matter described herein;

Figure 6A is an elevation view of an exemplary device for volumetrically measuring syringe fluid using, for example, a 60 mL syringe according to a second embodiment of the subject matter described herein;

Figure 6B is an elevation view of an exemplary device for volumetrically measuring syringe fluid using, for example, a 10 mL syringe according to a second embodiment of the subject matter described herein;

Figure 7A is an elevation view of an exemplary device for volumetrically measuring syringe fluid using, for example, a 30 mL syringe in an initial position according to a first embodiment of the subject matter described herein;

Figure 7B is an elevation view of the exemplary device of Figure 7B in a displacement position;

Figure 8 is a schematic of an exemplary system for volumetrically measuring syringe fluid according to some embodiments of the subject matter described herein; and

Figure 9 is a flow diagram of an exemplary method for volumetrically measuring syringe fluid according to some embodiments of the subject matter described herein.

DETAILED DESCRIPTION

Devices, systems, and methods for volumetrically measuring syringe fluid are provided herein. In some aspects, the presently disclosed subject matter relates to the field of chemotherapy drug preparation for patient treatments. In other aspects, the presently disclosed subject matter relates to the field of general fluid measurement and transfer for clinical and research use, as well as for use in veterinary or other medicine. Accordingly, the present subject matter is in no way limited to use in preparation of chemotherapy drugs.

Figures 1-4 illustrate a first embodiment of device **100** for volumetrically measuring syringe fluids. Device generally designated **100** is configured to hold at least one syringe and to measure an amount of fluid drawn in by the at least one syringe with high accuracy and precision. In the field of chemotherapy, where there is a narrow therapeutic index between a toxic dose and a therapeutic dose, it is especially important to have improved accuracy and precision in determining an amount of chemotherapy drug that has been drawn into the syringe. Although it is known in the art to use automated dose-measuring systems for this exact reason, such systems can be expensive and too large for use in a fume hood or crowded laboratory setting. Thus, device **100** can advantageously provide a user (e.g., a pharmacy technician) with an ability to measure chemotherapy volumes from drug vials with greater precision and accuracy than current methods, without adding significant time to the technician's workload. Additionally, device **100** can minimize the risk of contact between the drug and the technician to prevent both contamination of the medicine and chemical harm to the technician, since device **100** is small enough to fit

within a fume hood. Device **100** can also advantageously be durable enough to withstand multiple uses each day, but still be inexpensive to produce.

In some aspects, device **100** can comprise a flange adapter base generally designated **110** and a housing generally designated **120** in which a syringe generally designated **200** can be resiliently received and manipulated. Adapter base **110** and housing **120** can be composed of materials durable enough to withstand hundreds of uses (e.g., 200 uses) per day, while still being flexible enough to resiliently secure components of a syringe to device **100**. For example, adapter base **110** and housing **120** can be composed of or comprise stainless steel, plastic, rubber, ceramic, or any other suitable material.

In some aspects, device **100** can be configured as a device that can comfortably fit in a user's hand. For example, device **100** can be approximately between one inch and two feet in length. Alternatively, device **100** can be configured for use primarily on a surface. For example, device **100** can be approximately two feet or larger in length.

In some aspects, adapter base **110** and/or housing **120** can comprise a plurality of slots for holding differently sized syringes. As is known in the art, syringes can come in different sizes according to various needs and a volume of medication needed to be dispensed by the syringe. Thus, device **100** can be provided with a plurality of slots that are configured to hold a plurality of differently sized syringes. In one such aspect, adapter base **110** can be configured to resiliently receive a flange of a syringe (e.g., **220**, Figs. 5A-5B) to device **100**. As illustrated in Figure 1, a first adapter slot generally designated **112** and a second adapter slot generally designated **114** can be disposed on a top surface of adapter base **110**. However, in other aspects, slots **112**, **114** can be disposed on a different surface or each slot on different surfaces of base **110**. Slot **112** and slot **114** can also comprise two differently sized slots each being configured to resiliently hold varying sizes of syringe flanges, which increase and/or decrease in size depending on a size of the syringe. For example, first adapter slot **112** can be configured to resiliently accommodate 20 mL, 30 mL, and 60 mL syringes, while second

adapter slot **114** can be configured to resiliently accommodate 1 mL, 2 mL, 3 mL, 5 mL, and 10 mL syringes. In some aspects, a slot can be configured to accommodate 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL syringes (see, e.g., **316**, Figures 6A-6B).

Housing **120** can be configured to resiliently receive a plunger of a syringe (e.g., **210**, Figs. 5A-5B) to device **100**. As illustrated in Figure 1, housing **120** can comprise a plunger head adapter **130** at one end. Plunger head adapter **130** can be separate from or integral with housing **120** and can be composed of or comprise a same or a different material. Plunger head adapter **130** can comprise a slot or a plurality of slots for resiliently securing a plunger of the syringe. For example, plunger head adapter **130** can comprise one resilient slot **132** for accommodating variously sized plungers of differently sized syringes (e.g., 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL syringe). Resilient slot generally designated **132** can be disposed on a top surface of plunger head adapter **130**, such that slot **132** is in a plane substantially parallel to slots **112** and **114**. Accordingly, a plunger of a syringe can be resiliently received by slot **132** and a flange of a syringe can be resiliently received by one of slots **112** or **114** depending on a size of the syringe.

Housing **120** can further comprise a user interface generally designated **122** for user interaction with device **100**. User interface **122** can comprise a plurality of buttons and/or switches **122A-E** (shown in Figure 2) corresponding to particular device functionality and a display **124**. In some aspects, as illustrated in Figure 2, the plurality of buttons and/or switches **122A-E** can comprise, for example, a syringe size selection button **122A**, button **122B** for zeroing device **100**, a measurement repetition mode button **122C**, a button **122D** for mechanically locking motion of device **100** and saving a measurement, and a button **122E** for transmitting a saved measurement to a server. Plurality of buttons and/or switches **122A-E** can also comprise a switch for connecting a power supply to a rest of a circuit of device **100**. Additionally, device **100** may be provisioned with a button and/or switch for translating a sensor signal to displacement data, converting displacement data to volume data, transferring data to a wireless transmitter,

displaying certain data on display **124** (e.g., volume of the measurement, syringe size, battery life, indicator for measurement repeating mode, indicator for remote server connection, etc.).

Display **124** can be a digital display that is configured to display, for example and without limitation, syringe size, volume of fluid that has been collected or expelled, a saved measurement if device **100** has been locked, an indicator for measurement repeating mode, a state of a wireless connection, and/or remaining battery life. Other information can also be displayed on display **124** relevant to use of device **100**. In some aspects, display **124** can be disposed adjacent to plurality of buttons and/or switches **122A-E** for quick visual reference of any selections made by user interaction with buttons **122A-E**.

Base **110** and plunger adapter **130** can be displaceable in regard to one another via a reference sensor plate **140**. Reference sensor plate **140** can be configured to be fixedly attached to base **110**. For example, as illustrated in Figure 1, base **110** is fixedly attached to one end of reference sensor plate **140**. Reference sensor plate **140** can be configured to be movably to plunger adapter **130** via housing **120**. For example, as illustrated in Figure 1, housing **120** is slidingly moved at a bottom surface to reference sensor plate **140** and can be slid along an axial length of reference sensor plate **140** until locked into place via clamping mechanism **126** (see, Figure 4). Clamping mechanism **126** can comprise an electromagnetic clamp or other electrically-engaged mechanism for preventing motion of plunger adapter **130** on reference sensor plate **140** with respect to base **110**, and can be actuated by device **100**. For example, clamping mechanism **126** can be actuated by a user interfacing with button **122D** for mechanically locking displacement of plunger adapter **130** via preventing housing **120** from sliding on reference plate **140**, and also saving a displacement measurement. In this example, after clamping mechanism **126** is actuated, mechanism **126** can be configured to lock housing **120** at its current position along axial length of reference sensor plate **140** and then temporarily store (e.g., in local storage, **186**, Figure 8) a displacement measurement **Δx** (see, Figs. 7A-7B) as measured between base **110** and plunger adapter **130**.

In some aspects, clamping mechanism **126** can be utilized by specific functionality of device **100**. The clamping mechanism can be a friction type connection, a screw fastener, a tab fastener or any other clamping type fastener. For example, a repeating mode of device **100** can be activated to repeat volume measurements by a user interfacing with button **122C**, which can disengage clamping mechanism **126** and can reset temporarily stored measurements to zero. In this example, clamping mechanism **126** can automatically reengage when a subsequent volumetric measurement is again equal to the temporarily stored value.

In this manner, reference sensor plate **140** can be composed of or comprise a material that enables substantially frictionless movement along its length. For example, reference sensor plate **140** can be composed of or comprise stainless steel, plastic, rubber, ceramic, or any other suitable material. In some aspects, oil, grease, and/or any other lubricant can be used so that housing **120** can slide smoothly on plate **140**. Reference sensor plate **140** can comprise a plurality of demarcations or indicators (not shown) along its axial length to visually denote displacement of plunger adapter **130** from base **110**. In some aspects, the demarcations or indicators denote a displacement measurement in millimeters (mm), inches (in), and/or any other measurement standard.

In some aspects, axial movement of housing **120** along reference sensor plate **140** can be accomplished through two types of adjustments: coarse adjustment and fine adjustment. Coarse adjustment of housing **120** along reference sensor plate **140** can be accomplished through a user manually grasping housing **120** and moving it along the axial length of sensor plate **140**. However, for finer adjustments of housing **120** in relation to sensor plate **140**, fine adjustments using a fine adjustment mechanism **150** can be utilized. Fine adjustment mechanism **150** can be rotatably attached to housing **120** (e.g., disposed within displacement sensor housing **170**) at an end opposing the end at which plunger head adapter **130** is positioned. Fine adjustment mechanism **150** can comprise, for example, two friction-based cylindrical wheels, one being disposed on either side of reference sensor plate **140**. The wheels of fine adjustment mechanism **150**

can comprise for example stainless steel, plastic, rubber, ceramic, or any other suitable material. Housing **120** can be configured to fixedly hold fine adjustment mechanism **150** against the sides of sensor plate **140**, such that pressing and rotating either a left or right wheel of fine adjustment mechanism **150** can use friction to incrementally slide housing **120** an axial distance along plate **140**. In some aspects, fine adjustment mechanism **150** can slide housing along plate **140** by smaller increments than by coarse adjustment. Accordingly, larger adjustments of housing **120** can be made through coarse adjustment of housing **120** in relation to sensor plate **140**, whereas fine adjustment mechanism **150** can be utilized for making smaller adjustments at smaller increments.

Notably, displacement of housing **120** along sensor plate **140** results in a plunger of a syringe resiliently received in plunger adapter **130** also being displaced in relation to a flange of the syringe received in base **110**, which will be discussed in more detail below. Thus, more or less medicine may be aspirated from a vial of medicine based on a distance that plunger adapter **130** is displaced from base **110**.

Housing **120** can further comprise, for example, a distance measurement system, a displacement-to-volume conversion system, and/or a data transmission system. In particular, electronics and circuitry, as well as a circuitry power supply, needed for each of these individual systems can be stored in housing **120**. The embodiment of device **100** illustrated in Figures 1-4 provide for a battery (not shown) to provide power to device **100**. However, other types of providing power (e.g., replaceable battery(s), rechargeable battery(s), wall adapter, etc.) to device **100** are also contemplated. Where device **100** is powered by a battery, battery can be disposed in housing **160** accessible from a top surface of housing **120**. A power switch can be disposed in user interface **122** so that power to device **100** can be controlled by a user.

A distance measurement system can be used by device **100** in order to measure displacement of a syringe plunger within a syringe barrel from a syringe flange. In this regard, the distance measurement system can use reference plate **140** as a reference for measuring the distance between the

syringe plunger and the syringe flange. For example, a distance between a first position of plunger adapter **130** and a second position of plunger adapter **130** on sensor plate **140** can be a displacement distance **Δx**. Where a syringe (e.g., **200**) is secured to device **100** in a manner described above, displacement of adapter **130** from base **110** corresponds to a displacement distance **Δx** of a syringe plunger within a barrel of the syringe. As such, the displacement-to-volume system can convert a displacement of the syringe plunger within the barrel of the syringe to a volume of material (e.g., air, fluid, etc.) that has been drawn in or expelled from the syringe. This converted value can be displayed on a user interface associated with device **100** and/or transmitted to a remotely located computing platform for electronic storage, verification of dosage, etc.

In some aspects, the distance measurement system can use at least one distance or displacement mechanism housed in displacement sensor housing **170** for determining a displacement of adapter **130** from base **110**. For example, the at least one distance reference mechanism can comprise: at least one capacitive sensor, at least one laser sensor, at least one drop line sensor, at least one inductive sensor, at least one rod capacitive sensor, at least one sonic sensor, at least one linear variable differential transformer (LVDT) whose distance measurement points are attached to the plunger head adapter **130** and the flange adapter base **110**, or any combination thereof. Additional distance reference mechanisms can also be utilized. In the embodiment of device **100** illustrated in these figures, however, a capacitive sensor **172** (see, Fig. 8) is used. Capacitive sensor **172** can be fixedly attached to plunger head attachment **130** of device **100**. Sensor **172** can be configured to measure the distance between an initial position and a second, displacement position of a plunger of a syringe in reference to a flange of the syringe as housing **120** is slid along plate **140**. For example, as housing **120**, to which plunger head adapter **130** is attached, is slid along reference plate **140**, sensor **172** can measure in real-time a distance between plunger head adapter **130** and flange adapter base **110**.

In some aspects, capacitive sensor **172** can transmit this measurement in the form of a signal, pulse, or other electronic

communication to circuitry **182** for application of a filter(s), adjustment, amplification, and/or other signal processing. Circuitry **182** can be a component of the displacement-to-volume conversion system, which can be housed within an electronics housing **180**. Circuitry **182** of the volume-to-displacement conversion system can comprise capacitive plates, a signal generator, a signal interpreter, a microprocessor (e.g., **184**, Fig. 8), an amplification stage for sensor output signal, a stage which delivers the amplified sensor signal to a microprocessor, a display (e.g., **124** stored on housing **120** as a component of user interface **122**), a stage which relays real-time volume measurement from the microprocessor to the display, a stage that relays user input to the microprocessor, and a stage for wireless transmission of measurement data to a server (e.g., **402**, Fig. 8) for converting the displacement measurement into a volume measurement. Other components of circuitry **182** can also be utilized.

In some aspects, the displacement measurement signal can be transmitted to a microprocessor of the volume-to-displacement conversion system for scalar conversion to a volume measurement. For example, the microprocessor can be configured as a microprocessor **184** comprising a programmable integrated circuit configured to convert the displacement measurement to a volumetric measurement based on a syringe size. In particular, a calibration function or coefficient corresponding to each syringe size (e.g., 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL) can be stored in a local database (e.g., data storage **196**) for computation by microprocessor **184** with the displacement measurement signal. In some aspects, device **100** can be provisioned with a user interface for selecting syringe size. For example, a user can select a syringe size using syringe size selection button **122A** at user interface **122**. Microprocessor **184** can thereby be provided with data regarding each syringe size, so that upon selection of syringe size, microprocessor **184** need only locate and access such data from a local database (e.g., data storage **196**). Once the appropriate syringe size has been selected, microprocessor **184** can be configured to apply the distance measurement and input the measurement into the appropriate conversion mathematics in order to output a volumetric

measurement of fluid drawn in by the syringe. In some aspects, the volumetric measurement can be displayed on user interface **122** (e.g., display **124**) in real-time. In other aspects, for example, the volumetric measurement can be transmitted to a remote computing platform for remote storage, verification, etc.

In some aspects, the programmable integrated circuit of microprocessor **184** can be configured to perform specific device functions associated with converting a displacement measurement into a volumetric measurement. To achieve this functionality, the programmable integrated circuit can comprise an algorithm to provide device **100** with functionality for reading a sensor signal, converting the sensor signal to displacement data, converting displacement data to a volume measurement, resetting volume measurements to zero, sending converted volume measurements to digital display (e.g., display **124**), recording locked data, sending a signal to locking mechanism (e.g., clamping mechanism **126**), and including a measurement repeating mode. Other functionality not listed is also contemplated to be included. An exemplary algorithm for performing such functionality associated with device **100** is set forth below:

```
#include <16F1829.h>
#device icd=true #use delay (clock = 16000000)
#include <oled_16F1829_i2c.h>
#include <MATH.H>
#include <interrupt_control.h>
#fuses INTRC_IO, NOWDT, PUT
#define DATA PIN_C3  unsigned int idx = 0;
unsigned int rupt = 0;  float num_out = 0;
float pwr_exp = 0;  float num_total = 0;
float measurment_MM = 0;
unsigned long int Num = 0; unsigned int num_in = 0;
unsigned int min_in = 0;
unsigned int mode = 0;
unsigned int syringe = 0;
#int_EXT
void  EXT_isr(void) {
        num_in = input(PIN_C3);
        rupt = 1;
        Num = 0;
}
void main (){
// display on OLED
        SETUP_OSCILLATOR(OSC_16MHZ|OSC_INTRC);
```

```
                delay_us(10);

        output_low(ress);
                delay_us(20);
                output_high(ress);
                delay_us(20);
        initialise_screen();
                delay_us(10);
                clear_screen();
                delay_us(10);
                fill_screen();
                delay_us(10);
                clear_screen();
                delay_us(10);
        oled_write_command(0xb0);
        oled_write_command(0x00);
        oled_write_command(0x10);
        oled_zoom();

                disable_interrupts(GLOBAL);
                setup_timer_1(T1_INTERNAL|T1_DIV_BY_1);
        setup_comparator(NC_NC_NC_NC);
                enable_interrupts(INT_EXT);
                ext_int_edge(0,L_TO_H);
                enable_interrupts(GLOBAL);
                while (true){
                        Num = Num +1;
                        if (Num >= 15000){
                                idx = 0;
                                Num = 0;
                        } //if
                        if (input(PIN_C4)){
                                delay_ms(10);
                                if (input(PIN_C4)==1){
                                        while (input(PIN_C4)){
                                        delay_ms(1);
                                        }
                                        mode=mode +1;
                                }
                        }
                        if (rupt == 1){
                                if (idx == 0){
                                        num_out = num_in;
                                        num_total = num_total + num_out;
                                        }
                                if (idx == 1){
                                        num_out = num_in * 2;
                                        num_total = num_total + num_out;
                                        }
                                if (idx == 2){
```

```
                num_out = num_in * 4;
                num_total = num_total + num_out;
                }
            if (idx == 3){
                num_out = num_in * 8;
                num_total = num_total + num_out;
                }
            if (idx == 4){
                num_out = num_in * 16;
                num_total = num_total + num_out;
                }
            if (idx == 5){
                num_out = num_in * 32;
                num_total = num_total + num_out;
                }
            if (idx == 6){
                num_out = num_in * 64;
                num_total = num_total + num_out;
                }
            if (idx == 7){
                num_out = num_in * 128;
                num_total = num_total + num_out;
                }
            if (idx == 8){
                num_out = num_in * 256;
                num_total = num_total + num_out;
                }
            if (idx == 9){
                num_out = num_in * 512;
                num_total = num_total + num_out;
                }
            if (idx == 10){
                num_out = num_in * 1024;
                num_total = num_total + num_out;
                }
            if (idx == 11){
                num_out = num_in * 2048;
                num_total = num_total + num_out;
                }
            if (idx == 12){
                num_out = num_in * 4096;
                num_total = num_total + num_out;
                }
            if (idx == 13){
                num_out = num_in * 8192;
                num_total = num_total + num_out;
                }
            if (idx == 14){
                num_out = num_in * 16384;
                num_total = num_total + num_out;
```

```
        }
    if (idx == 15){
        num_out = num_in * 32768;
        num_total = num_total + num_out;
        }
    if (idx == 16){
        num_out = num_in * 65536;
        num_total = num_total + num_out;
        }
        if (idx >= 23){
            if (num_in == 1){
                num_total = num_total * -1;
                }
            //Store measurement, print to screen and RESET idx
            //      measurment_MM = num_total / 100;
            if (mode == 0) {          // 1ml y = 0.0172x - 0.0113
            //      measurment_MM = ((0.0172 * num_total)) / 100 ;
            syringe = 1;
            }
            if (mode == 1) {          // 3ml y = 0.0565x - 0.001
            //      measurment_MM = ((0.0565 * num_total)) / 100 ;
            syringe = 3;
            }
            if (mode == 2) {          // 5ml y = 0.1103x + 0.0033
            //      measurment_MM = ((0.1103 * num_total)) / 100 ;
            syringe = 5;
            }
            if (mode == 3) {          // 10ml y = 0.1618x - 0.0189
            //      measurment_MM = ((0.1618 * num_total)) / 100 ;
            syringe = 10;
            }
            if (mode == 4) {          // 20ml y = 0.2794x + 0.0015
            //      measurment_MM = ((0.2794 * num_total)) / 100 ;
            syringe = 20;
            }
            if (mode == 5) {          // 30ml y = 0.3606x - 0.008
```

```
                                        //      measurment_MM = ((0.3606 *
                                        num_total)) / 100 ;
                                        syringe = 30;
                                        }
                                        if (mode == 6) {        // 60ml y =
                                        0.5472x - 0.003
                                        //      measurment_MM = ((0.5472 *
                                        num_total)) / 100 ;
                                        syringe = 60;
                                        }
                                        if (mode >= 7) {            // Clear
                                        mode = 0;
                                        }
                                                num_total = 0;
                                                num_out = 0;

                                                 oled_gotoxy(0,0);
                                                 printf(oled_printchar,"Syring
                                                 e  %2.0u", syringe );
                                                 printf(oled_printchar,"mL");
                                                 oled_gotoxy(2,0);
                                                 printf(oled_printchar,"  mL =
                                                 %2.3g", measurment_MM );
                                                 idx = 0;
                                }
                                rupt = 0;
                                idx = idx+1;
                                }
                                } //while
                                }//main
```

Hardware and/or software for relaying data to an external server can be stored in a housing **190**. For example, a wireless transmitter **192** (see, Fig. 8) can be stored in a wireless transmitter housing **190**. Transmitter **192** can be functionally connected with a wireless connector **194** (see, Fig. 8) that can relay data (e.g., volumetric measurements) to an electronic interface of a server **402** that is configured to store electronic medical records and/or verify dosage amounts. A local repository, storage or database **196** (see, Fig. 8) associated with device **100** can temporarily store data until data is transmitted to the electronic interface. Exemplary data storage may include non-transitory computer readable media, such as flash memory, random access memory, or other storage devices. For example, where there is no wireless connection, battery is low, etc., device **100** can

temporarily store volumetric measurement records in local database **196**. In some aspects, data storage may be external.

In some aspects, a scanner (not shown) for reading dosages that are to be dispensed can also be included in device **100**. The scanner may comprise a bar code scanner, a QR code scanner, or any other scanner known in the art. Upon scanning a bar code using the scanner, information regarding a particular dosage can be displayed at display **124** of device **100**. Additionally, the scanner can be configured to provide a warning on display **124** if an amount displayed and an amount of medicine withdrawn by device **100** are not within a specified, acceptable threshold of one another. Circuitry and other electronics and/or components associated with the scanner can be housed in housing **120** of device **100**.

Now referring to Figures 5A-5B, a first embodiment of device **100** is illustrated with a syringe, generally designated **200**, with two different size syringes secured into adaptor base **110** and plunger adapter **130**. In Figure 5A, a 60 mL syringe **200A** is secured to device **100**. In particular, a plunger **210** of syringe **200A** is resiliently secured to slot **132** while a flange **220** of syringe **200A** is secured in slot **112** of base **110**. Since syringe **200A** is a 60 mL syringe, flange **220** is secured to the larger of the two resilient slots, which is slot **112**. By comparison, in Figure 5B a 10 mL syringe **200B** is secured to device **100**. Notably, while plunger **210** is still resiliently secured to slot **132**, flange **220** is resiliently secured in slot **114** of base **110**. This is because slot **114** is configured to resiliently receive syringes of smaller sizes than slot **112**. Accordingly, regardless of the size of syringe **200**, as plunger adapter **130** is slid along reference plate **140** via housing **120**, plunger **210** can be configured to slide in and out of barrel **230** of the syringe.

Figures 6A-6B illustrate a second embodiment of the device, generally designated **300**. Device **300** can provide the same functionality and materials as device **100**, but can comprise three separate slots for receiving differently sized flanges of a syringe, as well as three separate slots for receiving accompanying sized syringe plungers. Notably, device **300** can hold up to three differently or similarly sized syringes at one time for volumetric measurement thereof. As a result, it will be understood by one of

skill in the art that the subject matter disclosed herein can be configured in any manner in which multiple sized syringes can be securely received either at one time or individually.

In particular, device **300** can comprise a flange adapter base generally designated **310** configured to resiliently secure a flange of a syringe (e.g., **220**) to device **300**. As illustrated in Figures 6A-6B, a first adapter slot generally designated **312** and a second adapter slot generally designated **314** can be disposed on a top surface of adapter base **310**, while a third adapter slot **316** can be disposed on an opposing bottom surface of adapter base **310**. Slots **312** and **314** can be disposed adjacent to one another such that two syringes may be securely received in each of the slots at a same time. Since third adapter slot **316** is disposed at an opposing surface of base **310**, a third syringe may be simultaneously securely received in third adapter slot **316**. First adapter slot **312**, second adapter slot **314**, and third adapter slot **316** can comprise a same or differently sized slots each being configured to resiliently receive varying sizes of syringe flanges, which increase and/or decrease in size depending on a size of the syringe. For example, first adapter slot **312** can be configured to resiliently accommodate 20 mL, 30 mL, and 60 mL syringes, while second adapter slot **314** can be configured to resiliently accommodate 1 mL, 2 mL, 3 mL, 5 mL, and 10 mL syringes. In some aspects, each of slots **312** and **314** can accommodate syringes of a same size. Third adapter slot **316** can be configured to accommodate 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL syringes.

Device **300** can also comprise a housing **320** configured to resiliently receive a plunger of a syringe. Housing **320** can comprise a plunger head adapter **330** at one end. Plunger head adapter **330** can be separate from or integral with housing **320** and can be composed of or comprise a same or a different material. Plunger head adapter **330** can comprise a slot or a plurality of slots for resiliently securing a plunger of the syringe. For example, plunger head adapter **330** can comprise three resilient slots, a first resilient slot generally designated **332**, a second resilient slot generally designated **334**, and a third resilient slot **336** for accommodating variously

sized plungers of differently sized syringes (e.g., 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL syringe). For example, first slot **332** can be configured to resiliently accommodate 20 mL, 30 mL, and 60 mL syringe plungers, while second slot **334** can be configured to resiliently accommodate 1 mL, 2 mL, 3 mL, 5 mL, and 10 mL syringe plungers. In some aspects, each of slots **332** and **334** can accommodate syringe plungers of a same size. Third adapter slot **336** can be configured to accommodate 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL syringe plungers. In some aspects, for example, resilient slots **332** and **334** can be disposed on a top surface of plunger head adapter **330**, such that slots **332** and **334** are in a plane substantially parallel to slots **312** and **314**. In this aspect, third resilient slot **336** can be disposed on an opposing bottom surface of plunger head adapter **330**, such that third resilient slot **336** is in a plane substantially parallel to third slot **316** disposed on the opposing bottom surface of base **310**. Accordingly, a plunger of a syringe can be resiliently received by any one of first resilient slot **332**, second resilient slot **334**, or third resilient slot **336**, and a flange of a syringe can be resiliently received by a corresponding one of first slot **312**, second slot **314**, or third slot **336**, depending on a size of the syringe.

As illustrated in Figure 6A, a 60 mL syringe **200A** is illustrated as being securely received in device **300**. In particular, a plunger of syringe **200A** is received in a third resilient slot **336** disposed on a plunger adapter **330**, while a flange of syringe **200A** is received in a third resilient slot **316** disposed on a flange adapter base **310**. By comparison, as illustrated in Figure 6B, a 10 mL syringe **200B** is illustrated as being securely received in device **300**. In particular, a plunger of syringe **200B** is received in slot **334** while a flange of syringe **200B** is received in slot **314**.

Now referring to Figures 7A-7B, a first embodiment of device **100** is illustrated securely receiving a 30 mL syringe **200C** aspirating a fluid from a vial **250**. However, as described above, a syringe between the sizes of 1 mL and 60 mL may be securely held by device **100**. In Figure 7A, syringe **200C** is illustrated prior to aspirating any fluid from vial **250**, while in Figure 7B syringe **200C** is illustrated in the process of aspirating fluid from vial **250**.

Specifically, in Figure 7A, device **100** securely holds syringe **200C** at an initial position, where a plunger **210** and a flange **220** of syringe **200C** are disposed proximate to one another. Plunger **210** of syringe **200C** may be resiliently secured in slot **132** of plunger head adapter **130**, while flange **220** of syringe **200C** may be resiliently secured in slot **112** of base **110**. When syringe **200C** is secured in an initial position, no liquid or fluid can be aspirated into a barrel **230** of the syringe. Opposing flange **220** is an open end **232** of barrel **230**. At open end **232**, a hypodermic needle **240** may be attached using any suitable method. Needle **240** may be inserted into vial **250** for aspirating medicine therefrom.

In Figure 7B, device **100** has been manipulated by a user using either coarse adjustments or fine adjustment knobs **150** to displace or slidingly adjust housing **120** from a first position to a second position with regard to reference plate **140**. Thus, housing **120** is displaced an amount equivalent to **Δx**. Since plunger **210** is secured to adapter **130** and flange **220** is secured to base **110**, plunger **210** can also be displaced from base **110** an amount equivalent to **Δx**. In other words, as housing **120** is moved along reference plate **140**, plunger **210** of syringe **200C** is simultaneously moved a corresponding amount. By grasping and moving housing **120** along with plunger **210**, a corresponding volume of fluid may be aspirated into barrel **230** of syringe **200C** until a desired dosage amount is acquired. Although not illustrated in Figure 7B, a reference mechanism (e.g., capacitive sensor **172**) can be utilized by device **100** for determining a displacement of syringe plunger **210** in relation to a barrel **230** of syringe **200C**. The reference mechanism can be configured to transmit this measurement in the form of a signal, pulse, or other electronic communication to circuitry **182** for application of a filter(s), adjustment, amplification, and/or other signal processing. The processed displacement measurement can be converted to a volumetric measurement using a stored calibration function or coefficient corresponding to the syringe size. The volumetric measurement can then be displayed on user interface (e.g., display **124**). In one exemplary embodiment, device **100** is configured to draw more fluid than desired into

barrel **230** of syringe **200C**, such that fine adjustments using fine adjustment knobs **150** can be made until the exact dosage amount is attained.

Accordingly, device **100** can be used to measure a displacement of plunger of syringe **200** and convert said displacement measurement to a volume measurement as a way to more precisely and accurately measure fluid intake of a syringe. Device **100** can be accurate between approximately at least ±5% to ±0.01% by weight. Preferably, device **100** is accurate to at least approximately ±0.3% by weight.. This is in stark contrast to conventional practices where only 86% of doses are accurate to within 10% of a dosage amount and only 72% are accurate to within 5% of the dosage amount. Such a device **100** is advantageous in the dose preparation process of chemotherapy drugs due to the narrow therapeutic range such drugs have.

Referring to Figure 8, a system generally designated **400** for increased precision and accuracy of fluid transfer from a syringe can in some aspects comprise a device **100** and a server **402** communicatively connected to device **100**. In some aspects, device **100** can be a device of either the first or second embodiment described above, although other configurations of device **100** are also contemplated.

Device **100** may be configured to securely hold a syringe, which may be provided by a user of the device. For example, a user may interface with device **100** by securing a flange of a syringe (e.g., syringe **200**) to a flange adapter base **110** and a plunger of the syringe to a plunger adapter **130** of the device. In addition, device **100** may be configured to be manipulated by the user in order to draw in or expel fluids from a syringe secured to the device. For example, the user may grasp and move a housing **120** including plunger adapter **130** along a reference plate **140** in order to draw in or expel a quantity of liquid into or from a barrel of the syringe.

In some aspects, device **100** can comprise a user interface allowing a user to interface with device **100**. For example, a user can press one of a plurality of buttons and/or switches that can be disposed on user interface **122**, such as, a syringe size selection button **122A**, button **122B** for zeroing device **100**, a measurement repetition mode button **122C**, a button **122D** for

mechanically locking the motion and saving a measurement, and/or a button **122E** for transmitting a saved measurement to a server. Selections made by the user at user interface **122** may be transmitted as input to a microprocessor **184**.

Device **100** may also comprise a displacement reference mechanism for measuring a displacement between a flange of a syringe in reference to a plunger of the syringe in order to determine a volumetric measurement of fluid drawn into a barrel of the syringe. For example, the displacement reference mechanism can comprise at least one displacement sensor **172**. In some aspects, at least one displacement sensor **172** can be at least one capacitive sensor, at least one laser sensor, at least one drop line sensor, at least one inductive sensor, at least one rod capacitive sensor, at least one sonic sensor, at least one linear variable differential transformer (LVDT) whose distance measurement points are attached to plunger head adapter **130** and flange adapter base **110**, or any combination thereof. In this example, displacement sensor **172** can be configured to measure a displacement **Δx** between an initial position and a second, displacement position of a flange of a syringe in reference to a plunger of the syringe as housing **120** is slid along plate **140**.

In some aspects, capacitive sensor **172** can transmit this measurement in the form of a signal, pulse, or other electronic communication to circuitry **182** for application of a filter(s), adjustment, amplification, and/or other signal processing. Circuitry **182** can be a component of the displacement-to-volume conversion system, which can be housed within an electronics housing **180** of device **100**.

In some aspects, circuitry **182** can transmit the processed signal to microprocessor **184** for conversion to a volumetric measurement. Microprocessor **184** can comprise a programmable integrated circuit configured to convert the displacement measurement to a volumetric measurement based on a syringe size. In particular, a calibration function or coefficient corresponding to each syringe size (e.g., 1 mL, 2 mL, 3 mL, 5 mL, 10 mL, 20 mL, 30 mL, and 60 mL) can be stored in a local database (e.g., data storage **196**) for computation by microprocessor **184** with the

displacement measurement signal. For example, a user can select a syringe size using syringe size selection button **122A** at user interface **122**. Microprocessor **184** can be provided with data regarding each syringe size, so that upon selection of syringe size, microprocessor **184** need only locate and access such data from a local database (e.g., data storage **196**). Once the appropriate syringe size has been selected, microprocessor **184** can be configured to apply the distance measurement and input the measurement into the appropriate conversion mathematics in order to output a volumetric measurement of fluid drawn in by the syringe.

In some aspects, microprocessor **184** can transmit the volumetric measurement to a local storage and/or recording device **196**. Exemplary data storage may include non-transitory computer readable media, such as flash memory, random access memory, or other storage devices. For example, where there is no wireless connection, battery is low, etc., device **100** can temporarily store measurement records in local database **196**. In some aspects, data storage may be external.

In some aspects, microprocessor **184** can also transmit the volumetric measurement for display at user interface **122**. User interface **122** can comprise a display **124** on which the volumetric measurement can be displayed. Display **124** can be a digital display that can be configured to display syringe size, volume of fluid that has been collected or expelled, a saved measurement if device **100** has been locked, an indicator for measurement repeating mode, a state of a wireless connection, and remaining battery life. Other information can also be displayed on display **124** relevant to use of device **100**. In some aspects, display **124** can be disposed adjacent to plurality of buttons and/or switches **122A-E** for quick visual reference of any selections made by user interaction with buttons **122A-E**.

In some aspects, microprocessor can also transmit the volumetric measurement to a wireless transmitter or communicator **192** and a wireless connector **194** stored in a housing **190** of device **100**. Transmitter **192** can be functionally connected with a wireless connector **194**, which can relay data (e.g., stored measurements) to an electronic interface of a server **402**

that is configured to store electronic medical records and/or verify dosage amounts.

Once the volumetric measurement has been transmitted to server **402**, server **402** can store electronic medical records and/or verify dosage amounts. This information can then be used to provide a feedback mechanism for ensuring that the right dosage and medication was made. The information my also be used for tracking what medication was given to a patient by a specific user. In addition, it can accurately bill the patient for the exact medication received by the patient and allow for the ability to determine which patient got which medication, if needed during a recall of the medication. Server **402** can comprise any server, node, computer, or unit that is configured to store electronic medical records, verify dosage amounts, track medication, bill the patient, etc. Server **402** may include at least one processor (not shown), and modules (not shown) configured to store electronic medical records, verify dosage amounts, track medication, bill the patient, etc. In some aspects, the processor of server **402** may include a microprocessor, a central processing unit (CPU), or any other like hardware-based processor unit that is configured to execute and/or utilize the modules of server **402** (e.g., a software based algorithm). In some embodiments, the modules of server **402** may be stored in memory (not shown), such as random access memory (RAM), read only memory (ROM), optical read/write memory, cache memory, magnetic read/write memory, flash memory, or any other non-transitory storage media.

Figure 9 is a flow chart depicting an exemplary method, generally designated **500**, for volumetrically measuring syringe fluid according to an embodiment of the subject matter described herein.

Referring to Figure 9, in block **502**, a device **100** for volumetrically measuring syringe fluid is provided. In some aspects, device **100** can comprise a reference plate **140**, a flange adapter base **110** attached at a first end of reference plate **140** for receiving a flange **220** of a syringe **200**, a plunger adapter **130** configured to slidingly move along a length of reference plate **140** and disposed adjacent to a housing **120** for receiving a plunger **210** of syringe **200**, a displacement sensor **172** disposed in housing **120** and

configured to measure a displacement **Δx** of plunger adapter **130** in relation to flange adapter base **110** as plunger adapter **130** is slid along the length of reference plate **140**, and a displacement conversion mechanism **184** disposed in housing **120** and configured to convert displacement **Δx** of plunger adapter **130** to a volumetric measurement in order to determine a volume of fluid syringe **200** has drawn in.

In some aspects, displacement sensor **172** can comprise at least one of: a capacitive sensor; a laser sensor, a drop line sensor, an inductive sensor, a rod capacitive sensor, a sonic sensor, a linear variable differential transformer (LVDT) with distance measurement points attached to plunger adapter **130** and flange adapter base **110**, or any combination thereof.

In some aspects, a user interface **122** can be disposed on a top surface of housing **120** of device **100**. User interface **122** can comprise functionality including, for example, at least one of selecting a size of the syringe, zeroing the device, activating and deactivating a measurement repetition mode, mechanically locking motion of the device and saving the displacement measurement, and/or transmitting the displacement measurement.

In some aspects, flange adapter base **110** and/or the plunger adapter **130** can be configured to resiliently receive syringes sized approximately between 1 mL and 60 mL.

In block **504**, flange **220** of syringe **200** can be secured to flange adapter base **110** and plunger **210** of syringe **200** can be secured to plunger adapter **130**.

In block **506**, displacement **Δx** of plunger adapter **130** in relation to flange adapter base **110** can be measured. For example, as plunger adapter **130** is slidingly moved along the length of reference plate **140**, displacement sensor **172** can measure displacement **Δx**.

In block **508**, displacement measurement **Δx** can be converted to a volumetric measurement. For example, displacement conversion mechanism **184** can use conversion mathematics to convert displacement measurement **Δx** to a volumetric measurement.

In some aspects, a calibration function corresponding to a size of syringe **200** for converting displacement measurement **Δx** of plunger adapter **130** to the volumetric measurement can be applied.

In some aspects, method **500** can transmit the volumetric measurement to at least one of a display **124** on the device, a storage database **196**, and a server **402**.

In some aspects, method **500** can automatically repeat, by the measurement repetition mode, volume measurements by storing the volumetric measurement, disengaging a clamping mechanism **126** disposed in housing **120**, where the clamping mechanism **126** can be for preventing sliding movement of plunger adapter **130** along the length of reference plate **140**, zeroing device **100**, and automatically reengaging clamping mechanism **126** when at least one subsequent volumetric measurement is equal to the previously stored volumetric measurement.

In some aspects, method **500** determines the volumetric measurement of the volume of fluid syringe **200** has drawn in is at least approximately ±0.3% accurate.

It will be appreciated that exemplary process **500** is for illustrative purposes and that different and/or additional actions may be used. It will also be appreciated that various actions described herein may occur in a different order or sequence.

Accordingly, while the devices, systems, and methods have been described herein in reference to specific embodiments, features, and illustrative embodiments, it will be appreciated that the utility of the subject matter is not thus limited, but rather extends to and encompasses numerous other variations, modifications and alternative embodiments, as will suggest themselves to those of ordinary skill in the field of the present subject matter, based on the disclosure herein.

Various combinations and sub-combinations of the structures and features described herein are contemplated and will be apparent to a skilled person having knowledge of this disclosure. Any of the various features and elements as disclosed herein may be combined with one or more other disclosed features and elements unless indicated to the contrary herein.

Correspondingly, the subject matter as hereinafter claimed is intended to be broadly construed and interpreted, as including all such variations, modifications and alternative embodiments, within its scope and including equivalents of the claims. It is understood that various details of the presently disclosed subject matter may be changed without departing from the scope of the presently disclosed subject matter. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation.

CLAIMS

What is claimed is:

1. A device for volumetrically measuring syringe fluid, the device comprising:

a reference plate;

a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe;

a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate;

a displacement sensor disposed in the housing and configured to measure a displacement of the plunger adapter in relation to the flange adapter base as the plunger adapter is slid along the length of the reference plate; and

a displacement conversion mechanism disposed in the housing and configured to convert the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in.

2. The device of claim 1, wherein the device is configured to determine the volumetric measurement of the volume of fluid the syringe has drawn in to at least approximately ±0.3 % accuracy.

3. The device of claim 1, wherein the displacement sensor comprises at least one of a capacitive sensor; a laser sensor, a drop line sensor, an inductive sensor, a rod capacitive sensor, a sonic sensor, a linear variable differential transformer (LVDT) with distance measurement points attached to the plunger adapter and the flange adapter base, or any combination thereof.

4. The device of claim 1, wherein the device is configured to transmit volumetric measurement to at least one of a display on the device, a storage database, and a server.

5. The device of claim 1, further comprising a user interface disposed on a top surface of the housing of the device, the user interface comprising functionality including at least one of selecting a size of the syringe, zeroing the device, activating and deactivating a measurement repetition mode, mechanically locking motion of the device and saving the displacement measurement, and/or transmitting the displacement measurement.

6. The device of claim 5, wherein the measurement repetition mode is configured to automatically repeat volume measurements by storing the volumetric measurement, disengaging a clamping mechanism disposed in the housing, the clamping mechanism for preventing sliding movement of the plunger adapter along the length of the reference plate, zeroing the device, and automatically reengaging the clamping mechanism when at least one subsequent volumetric measurement is equal to the previously stored volumetric measurement.

7. The device of claim 1, wherein the displacement conversion mechanism is configured to apply a calibration function or coefficient corresponding to a size of the syringe to convert the displacement of the plunger adapter to the volumetric measurement.

8. The device of claim 1, wherein the flange adapter base and/or the plunger adapter are configured to resiliently receive syringes sized between approximately 1 mL and 60 mL.

9. A system for volumetrically measuring syringe fluid, the system comprising:

a device comprising:

a reference plate,

a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe,

a plunger adapter disposed adjacent to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate,

a displacement sensor disposed in the housing and configured to measure a displacement of the plunger adapter in relation to the flange adapter base as the plunger adapter is slid along the length of the reference plate, and

a displacement conversion mechanism disposed in the housing and configured to convert the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in; and

a server connected with the device.

10. The system of claim 9, wherein the device is configured to determine the volumetric measurement of the volume of fluid the syringe has drawn in to at least approximately ±0.3% accuracy.

11. The system of claim 9, wherein the displacement sensor comprises at least one of: a capacitive sensor; a laser sensor, a drop line sensor, an inductive sensor, a rod capacitive sensor, a sonic sensor, a linear variable differential transformer (LVDT) with distance measurement points attached to the plunger adapter and the flange adapter base, or any combination thereof.

12. The system of claim 9, wherein the device is configured to transmit the volumetric measurement to at least one of a display on the device, a storage database, and the server.

13. The system of claim 9, further comprising a user interface disposed on a surface of the housing of the device, the user interface comprising functionality including at least one of selecting a size of the syringe, zeroing the device, activating and deactivating a measurement repetition mode, mechanically locking motion of the device and saving the displacement measurement, and/or transmitting the displacement measurement.

14. The system of claim 13, wherein the measurement repetition mode is configured to automatically repeat volume measurements by storing the volumetric measurement, disengaging a clamping mechanism disposed in the housing, the clamping mechanism for preventing sliding movement of the plunger adapter along the length of the reference plate, zeroing the device, and automatically reengaging the clamping mechanism when at least one subsequent volumetric measurement is equal to the previously stored volumetric measurement.

15. The system of claim 9, wherein the displacement conversion mechanism is configured to apply a calibration function or coefficient corresponding to a size of the syringe to convert the displacement of the plunger adapter to the volumetric measurement.

16. The system of claim 9, wherein the flange adapter base and/or the plunger adapter are configured to resiliently receive syringes sized between approximately 1 mL and 60 mL.

17. A method for volumetrically measuring syringe fluid, the method comprising:

providing a device comprising a reference plate, a flange adapter base attached at a first end of the reference plate for receiving a flange of a syringe, a plunger adapter disposed adjacent

to a housing for receiving a plunger of the syringe, the plunger adapter being configured to slidingly move along a length of the reference plate, a displacement sensor disposed in the housing, and a displacement conversion mechanism disposed in the housing;

securing the flange of the syringe to the flange adapter base and the plunger of the syringe to the plunger adapter;

measuring, by the displacement sensor, a displacement of the plunger adapter in relation to the flange adapter base, as the plunger adapter is slidingly moved along the length of the reference plate; and

converting, by the displacement conversion mechanism, the displacement measurement of the plunger adapter to a volumetric measurement in order to determine a volume of fluid the syringe has drawn in.

18. The method of claim 17, further comprising interfacing with a user interface disposed on a top surface of the housing of the device, the interface comprising functionality including at least one of selecting a size of the syringe, zeroing the device, activating and deactivating a measurement repetition mode, mechanically locking motion of the device and saving the displacement measurement, and transmitting the displacement measurement.

19. The method of claim 18, further comprising automatically repeating, by the measurement repetition mode, volume measurements by storing the volumetric measurement, disengaging a clamping mechanism disposed in the housing, the clamping mechanism for preventing sliding movement of the plunger adapter along the length of the reference plate, zeroing the device, and automatically reengaging the clamping mechanism when at least one subsequent volumetric measurement is equal to the previously stored volumetric measurement.

20. The method of claim 17, further comprising applying a calibration function or coefficient corresponding to a size of the syringe for converting the displacement of the plunger adapter to the volumetric measurement.

21. The method of claim 17, further comprising transmitting the volumetric measurement to at least one of a display on the device, a storage database, and a server.

22. The method of claim 17, wherein the volumetric measurement of the volume of fluid the syringe has drawn in is at least approximately ±0.3% accurate.

23. The method of claim 17, wherein the flange adapter base and/or the plunger adapter of the device are configured to resiliently receive syringes sized between approximately 1 mL and 60 mL.

24. The method of claim 17, wherein the displacement sensor of the device comprises at least one of: a capacitive sensor; a laser sensor, a drop line sensor, an inductive sensor, a rod capacitive sensor, a sonic sensor, a linear variable differential transformer (LVDT) with distance measurement points attached to the plunger adapter and the flange adapter base, or any combination thereof.

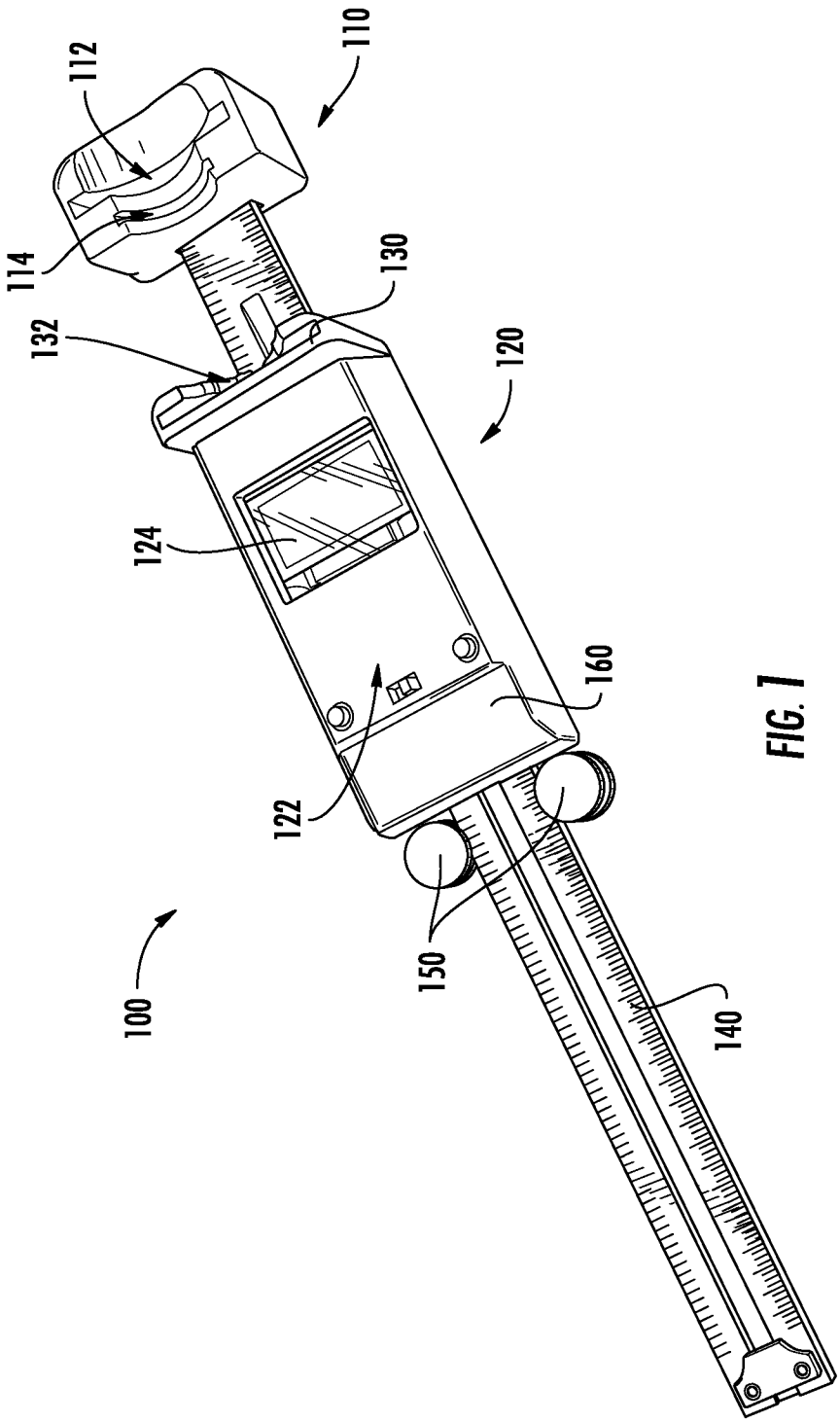

FIG. 1

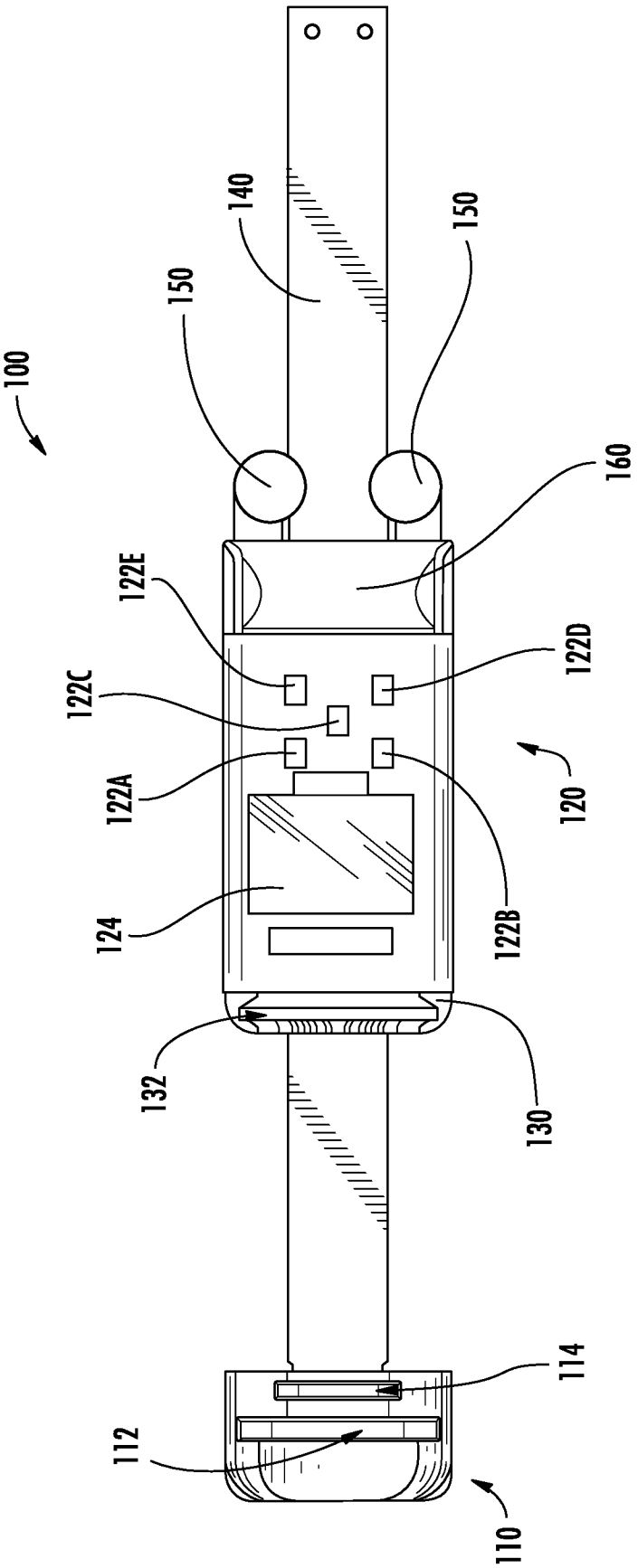
100
140
150
150
160
122E
122D
122C
122A
120
124
122B
132
130
114
112
110

FIG. 2

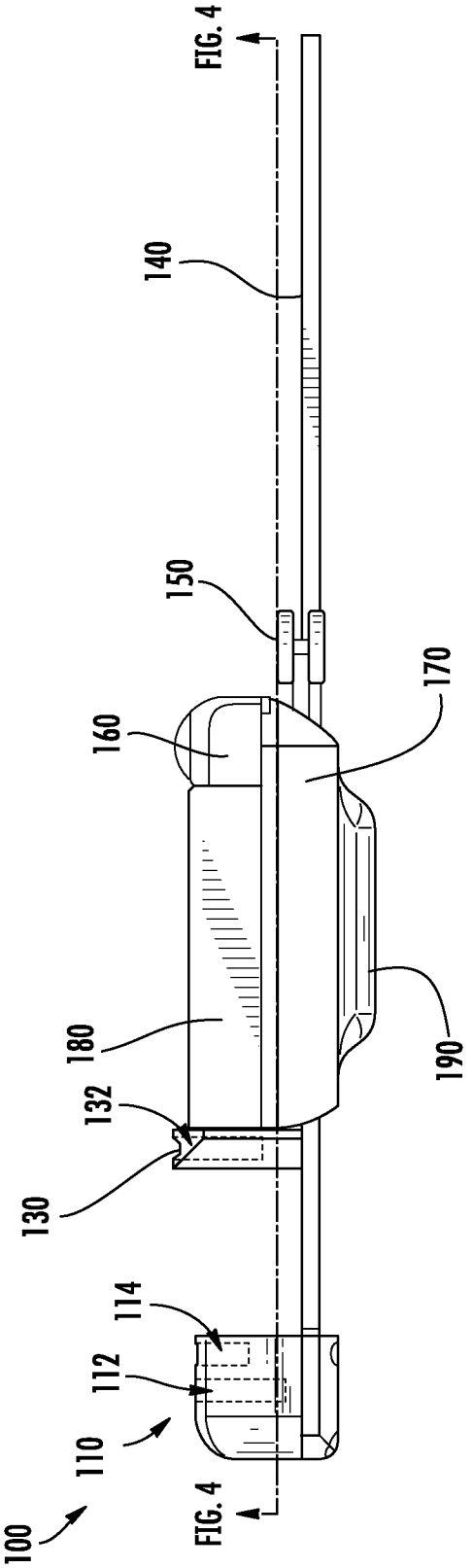

FIG. 3

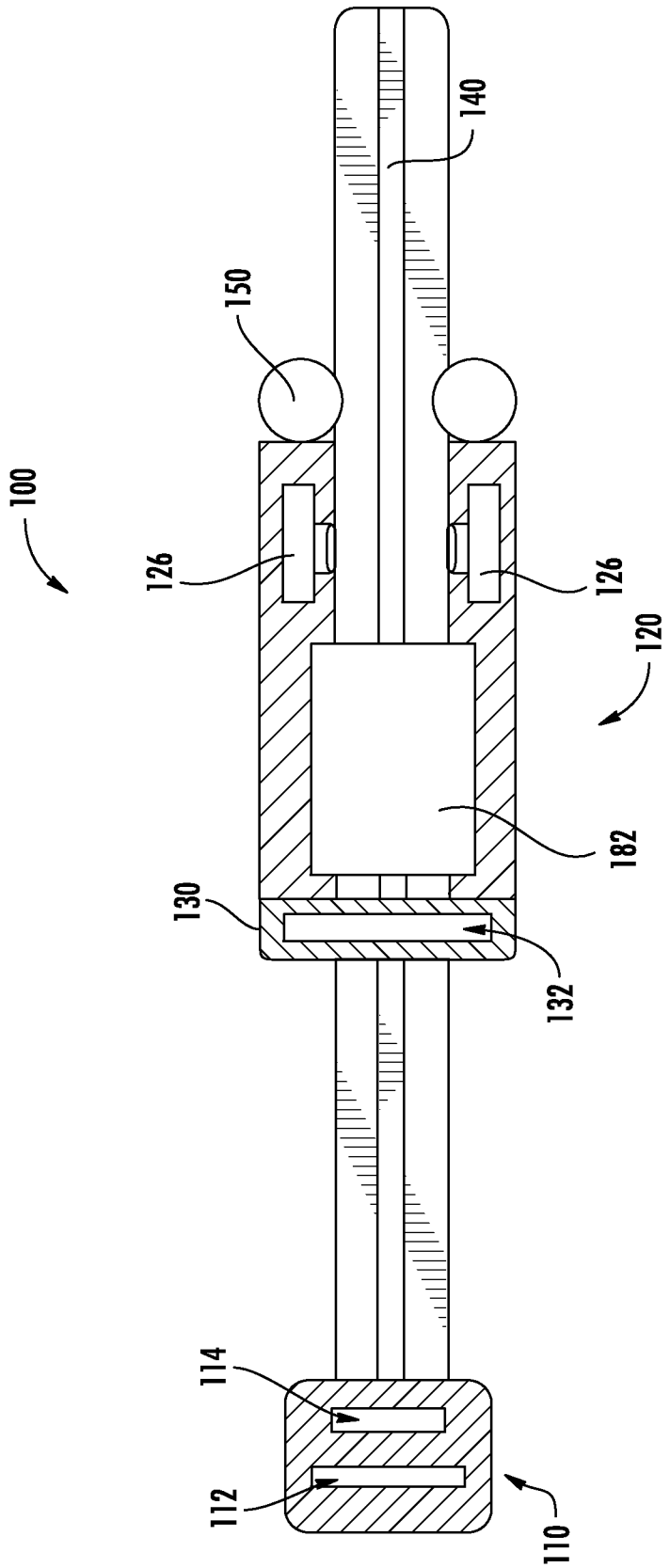

FIG. 4

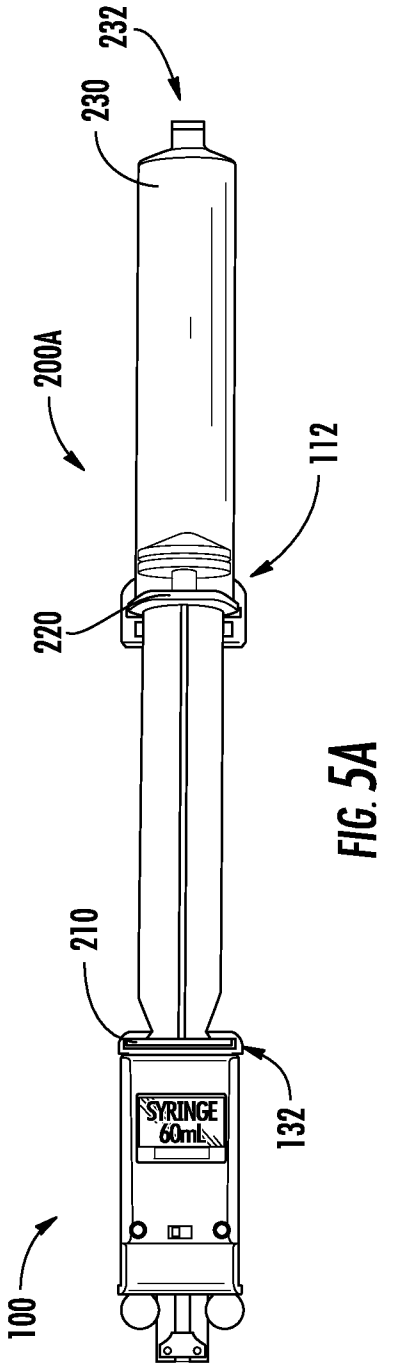
232
230
200A
112
220
210
SYRINGE
60mL
132
100

FIG. 5A

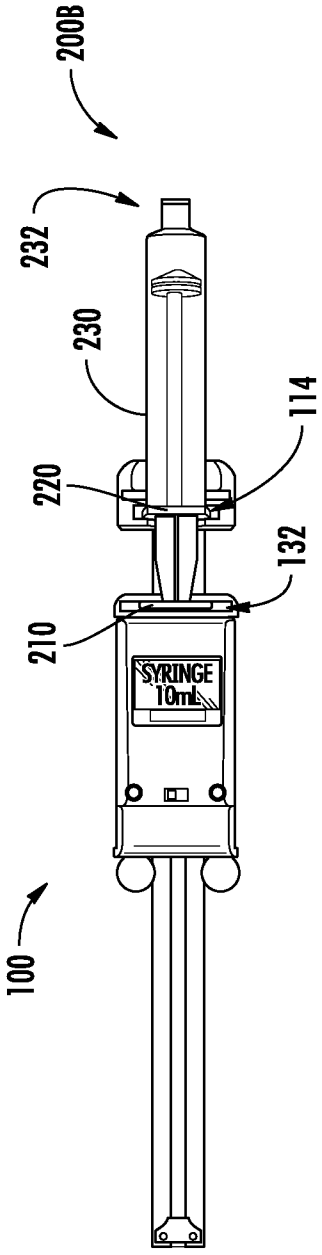
200B
232
230
114
220
132
210
SYRINGE
10mL
100

FIG. 5B

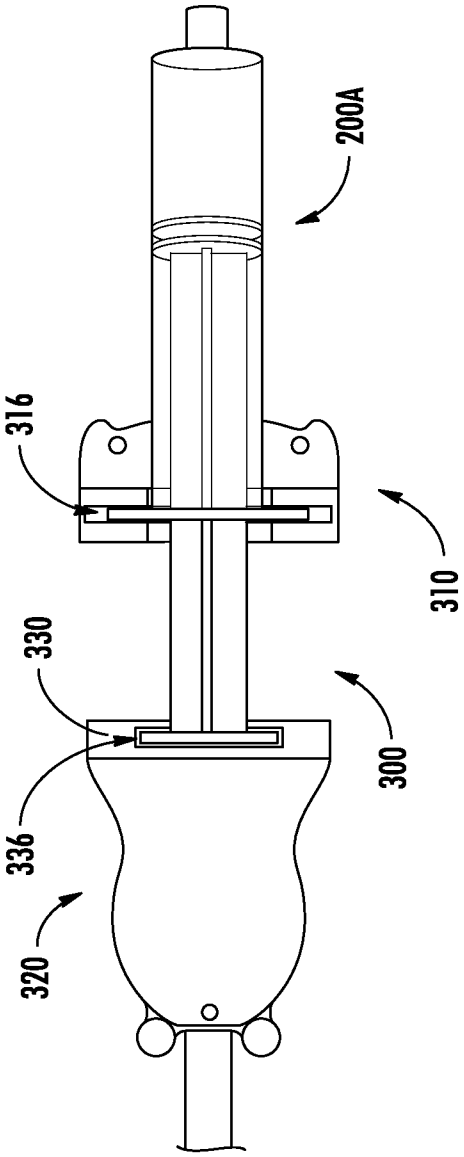
200A
316
310
330
300
336
320

FIG. 6A

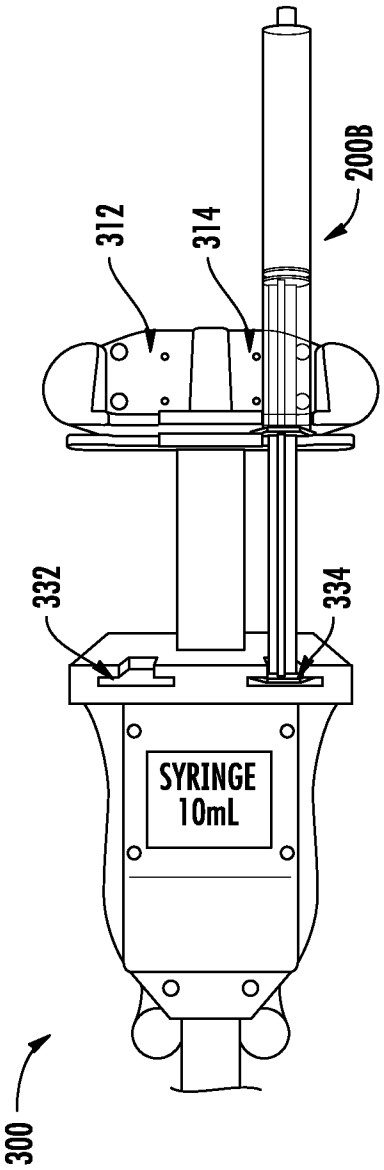
200B
312
314
332
334
SYRINGE
10mL
300

FIG. 6B

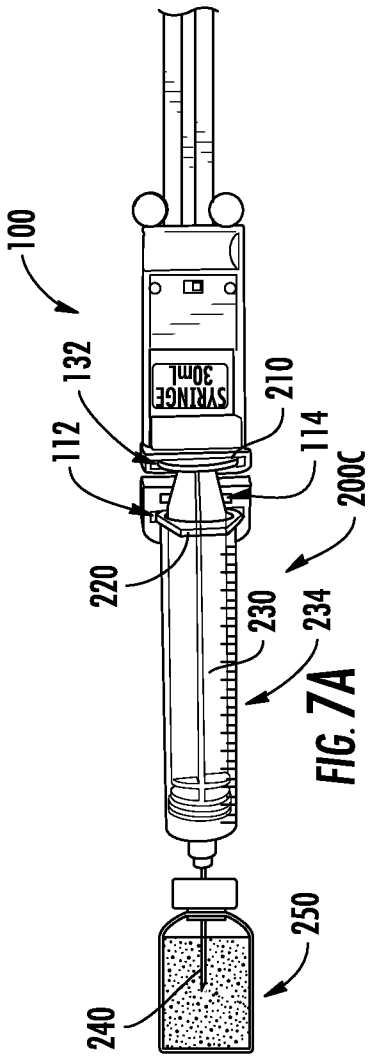
100
132
112
220
SYRINGE 30mL
210
114
200C
230
234
250
240

FIG. 7A

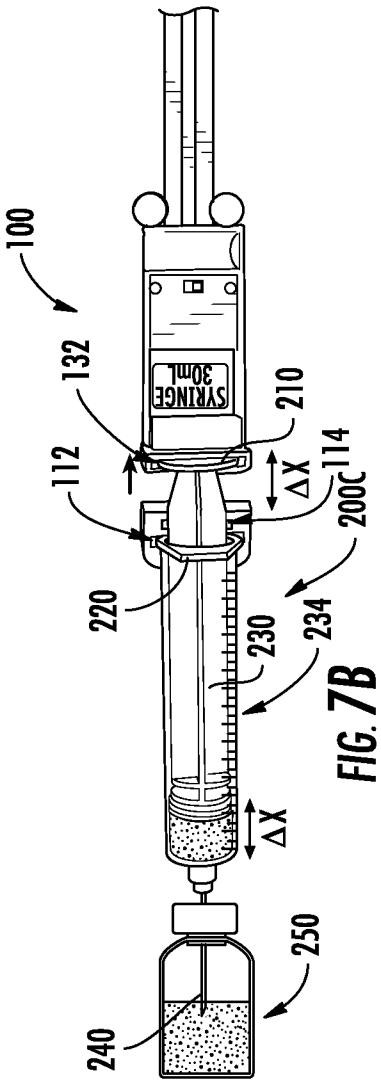
100
132
112
220
SYRINGE 30mL
210
ΔX
114
200C
230
234
ΔX
250
240

FIG. 7B

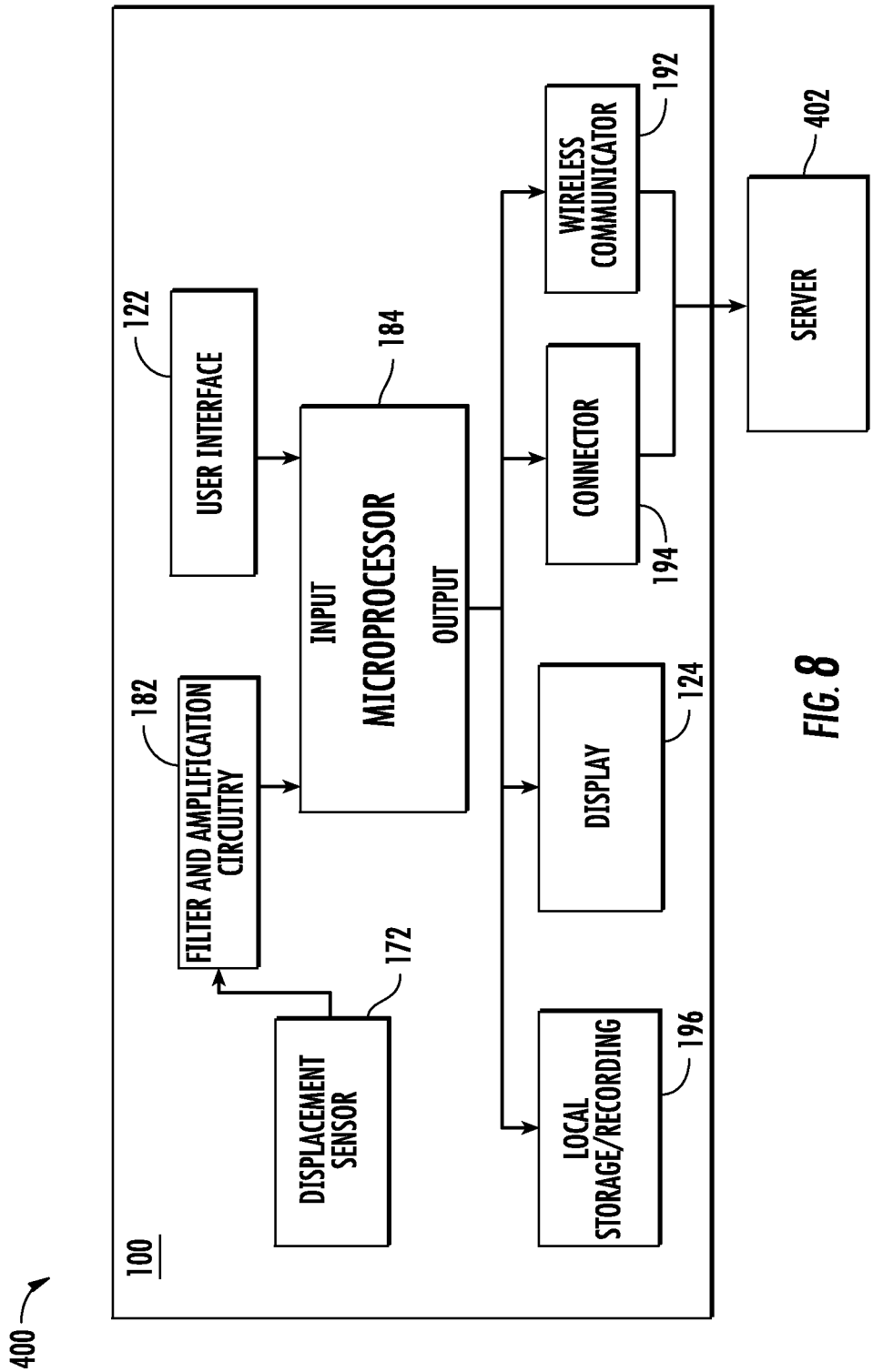
400
100
USER INTERFACE
122
MICROPROCESSOR
INPUT
OUTPUT
184
FILTER AND AMPLIFICATION CIRCUITRY
182
DISPLACEMENT SENSOR
172
WIRELESS COMMUNICATOR
192
CONNECTOR
194
DISPLAY
124
LOCAL STORAGE/RECORDING
196
SERVER
402

FIG. 8

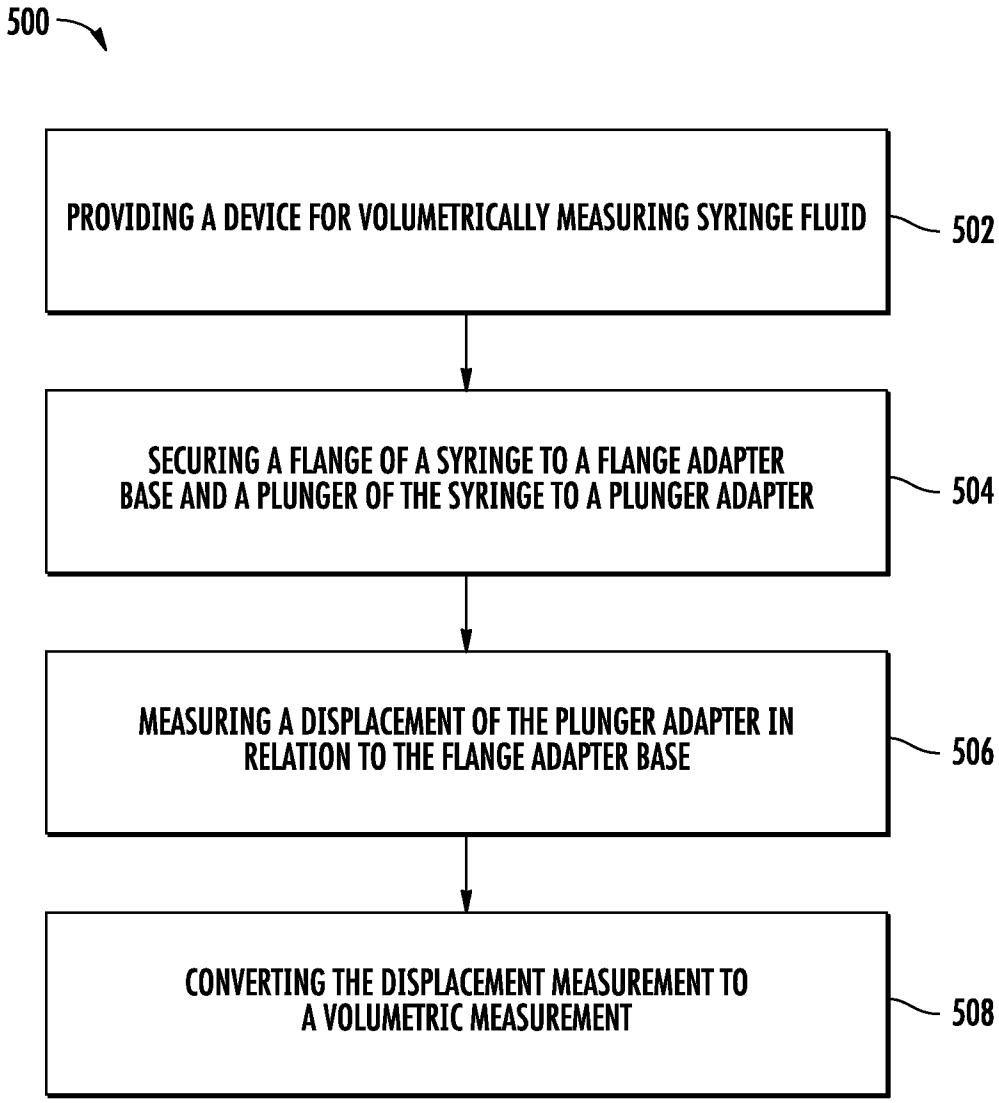
500
PROVIDING A DEVICE FOR VOLUMETRICALLY MEASURING SYRINGE FLUID
502
SECURING A FLANGE OF A SYRINGE TO A FLANGE ADAPTER BASE AND A PLUNGER OF THE SYRINGE TO A PLUNGER ADAPTER
504
MEASURING A DISPLACEMENT OF THE PLUNGER ADAPTER IN RELATION TO THE FLANGE ADAPTER BASE
506
CONVERTING THE DISPLACEMENT MEASUREMENT TO A VOLUMETRIC MEASUREMENT
508

FIG. 9

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 421/368 PCT	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 2015/029488	International filing date *(day/month/year)* 06 May 2015 (06.05.2015)	(Earliest) Priority Date *(day/month/year)* 06 May 2014 (06.05.2014)
Applicant THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title,**

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings,**

a. the figure of the drawings to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2015/029488

A. CLASSIFICATION OF SUBJECT MATTER

A61M 5/315 *(2006.01)*
G01F 22/00 *(2006.01)*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61M 5/00, 5/14-5/52, 31/00, 37/00, G01F 19/00, 22/00, A61B 17/00, 17/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7879025 B2 (BAXTER INTERNATIONAL INC.) 01.02.2011	1-24
A	US 8672886 B2 (STRYKER CORPORATION) 18.03.2014	1-24
A	US 8535268 B2 (ALCON RESEARCH, LTD.) 17.09.2013	1-24
A	EP 2179758 A2 (TEMA SINERGIE S.R.L.) 28.04.2010	1-24
A	US 5611784 A (HAMILTON COMPANY) 18.03.1997	1-24

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2015 (27.08.2015)	17 September 2015 (17.09.2015)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer O. Pakhomenko Telephone No. 499-240-25-91