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Jacobson et al.

(54) **SYSTEMS AND METHODS FOR CONTROLLED SUBSTANCE DISTRIBUTION NETWORK**

(76) Inventors: **Andrew D. Jacobson**, San Antonio, TX (US); **Jeft Sommers**, San Antonio, TX (US); **Rasmus T. Kolln**, Kiel (DE); **Kenneth R. Rose**, San Antonio, TX (US)

Correspondence Address:
MEYERTONS, HOOD, KIVLIN, KOWERT & GOETZEL, P.C.
P.O. BOX 398
AUSTIN, TX 78767-0398 (US)

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(60) Provisional application No. 60/925,881, filed on Apr. 23, 2007.

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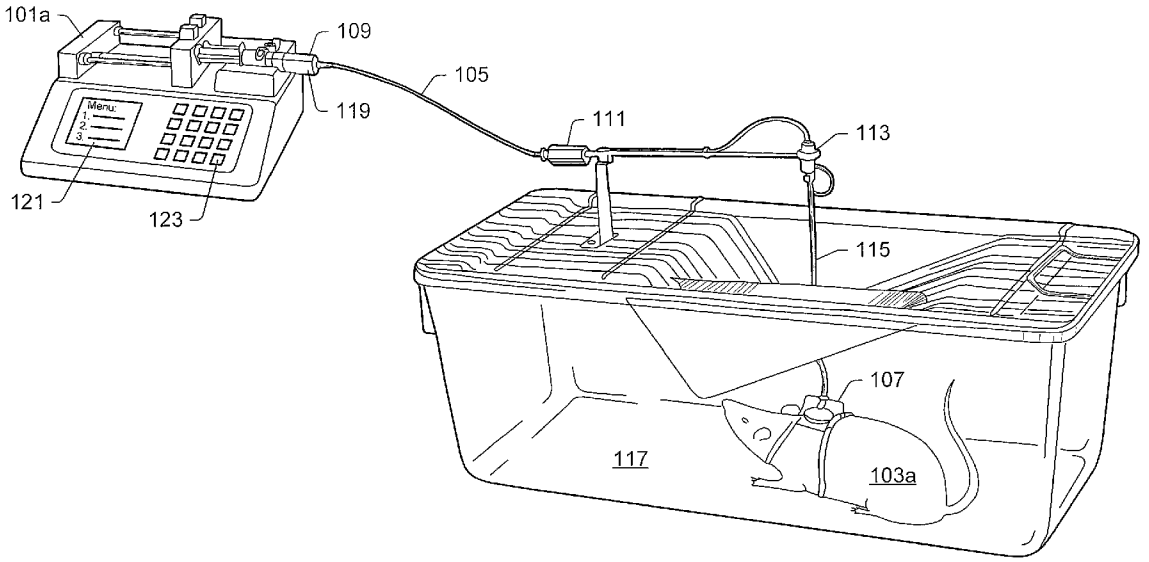
A61M 5/142 (2006.01)

(52) **U.S. Cl.** **604/111**; 604/65

(57) **ABSTRACT**

In various embodiments, multiple pumps may be used to deliver substances to multiple respective animals. A computer system may send/receive information to/from the pumps (e.g., to control and monitor various aspects of the pumps and/or store information associated with the pump). In some embodiments, the computer system may determine respective controlled delivery rates for the pumps (e.g., based in part on a weight of an animal receiving the substance from the respective pump) and send the determined controlled delivery rates to the respective pumps. The computer system may also receive user identifications from operators controlling a pump (e.g., in response to a pump alarm) and documentation indicators entered by the operator and/or pump to use in documenting pump activity.



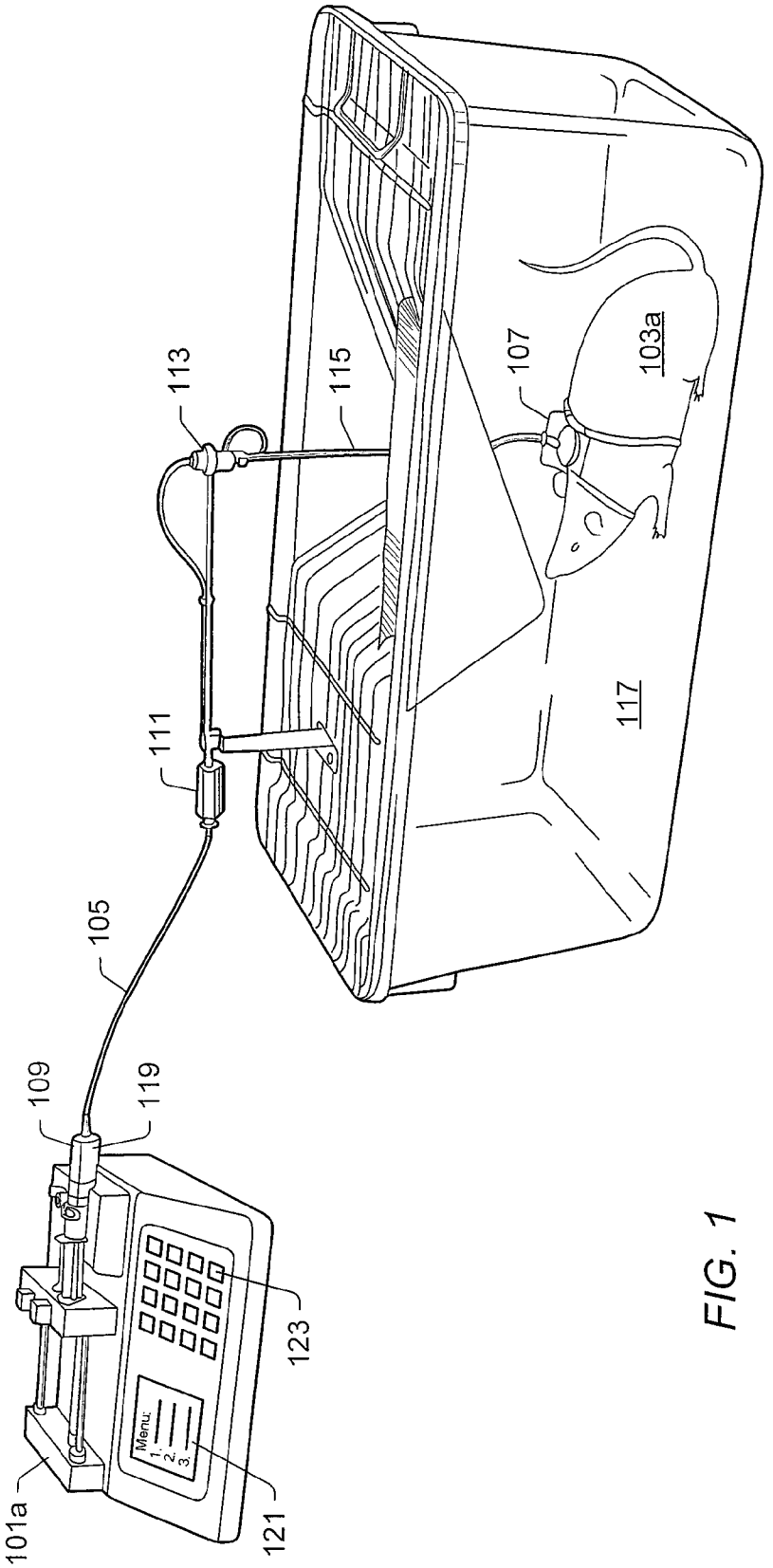


FIG. 1

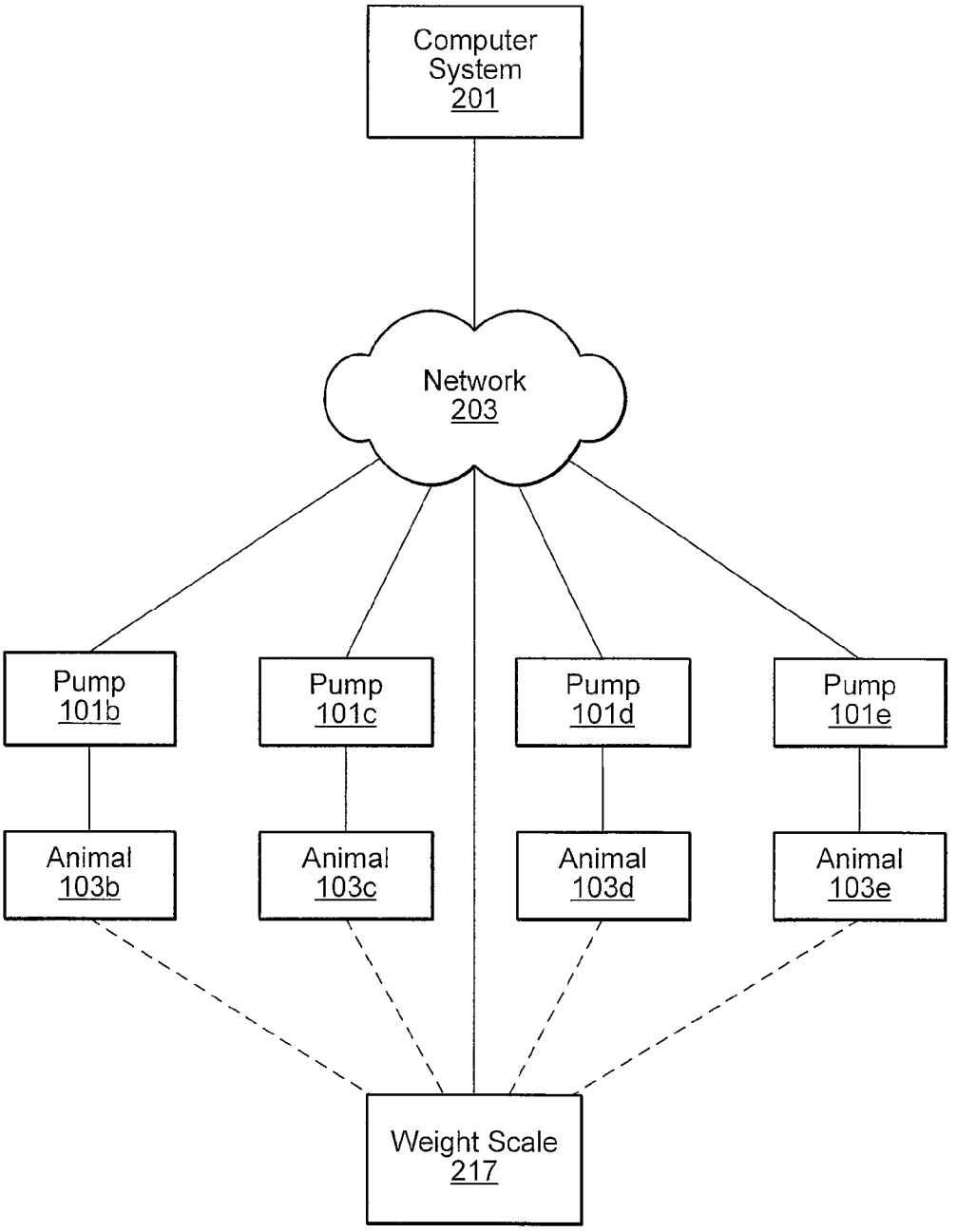

Computer System 201
Network 203
Pump 101b
Pump 101c
Pump 101d
Pump 101e
Animal 103b
Animal 103c
Animal 103d
Animal 103e
Weight Scale 217

FIG. 2A

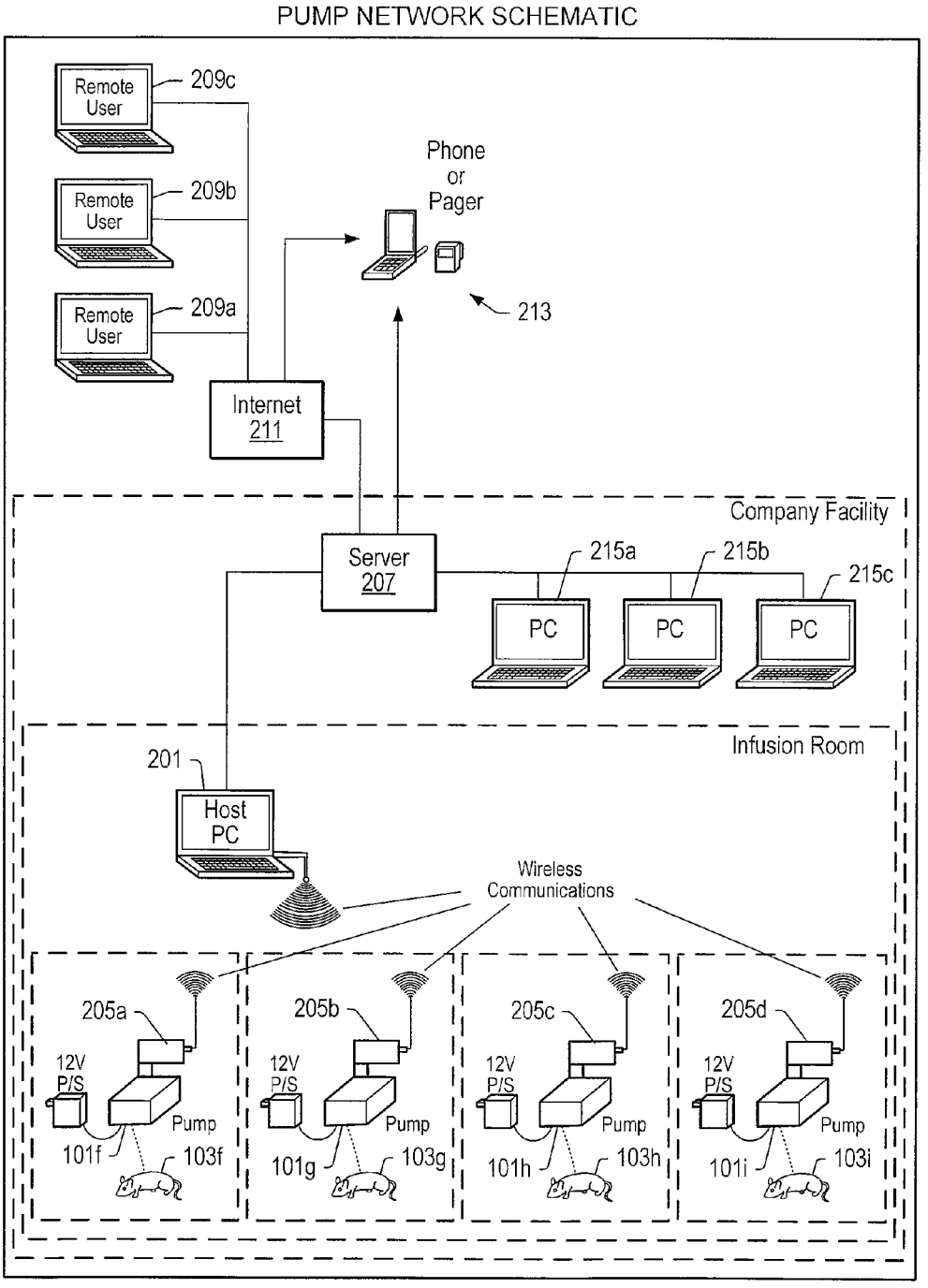

PUMP NETWORK SCHEMATIC
Remote User
209c
Remote User
209b
Remote User
209a
Phone or Pager
213
Internet 211
Company Facility
Server 207
215a
215b
215c
PC
PC
PC
Infusion Room
201
Host PC
Wireless Communications
205a
205b
205c
205d
12V P/S
Pump
101f
103f
101g
103g
101h
103h
101i
103i

FIG. 2B

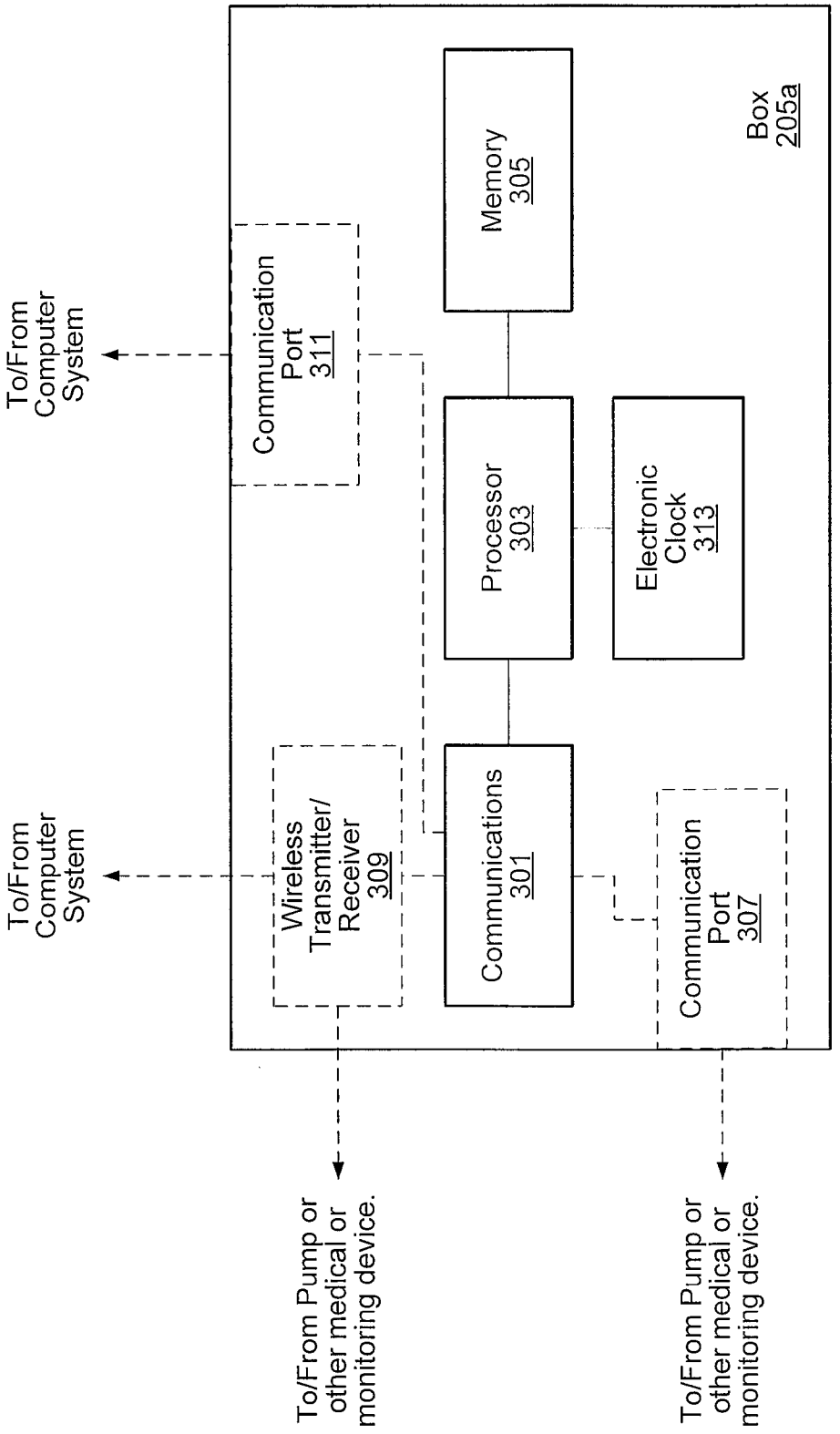

Box 205a
Memory 305
Communication Port 311
Processor 303
Electronic Clock 313
Communications 301
Wireless Transmitter/ Receiver 309
Communication Port 307
To/From Computer System
To/From Computer System
To/From Pump or other medical or monitoring device.
To/From Pump or other medical or monitoring device.

FIG. 3

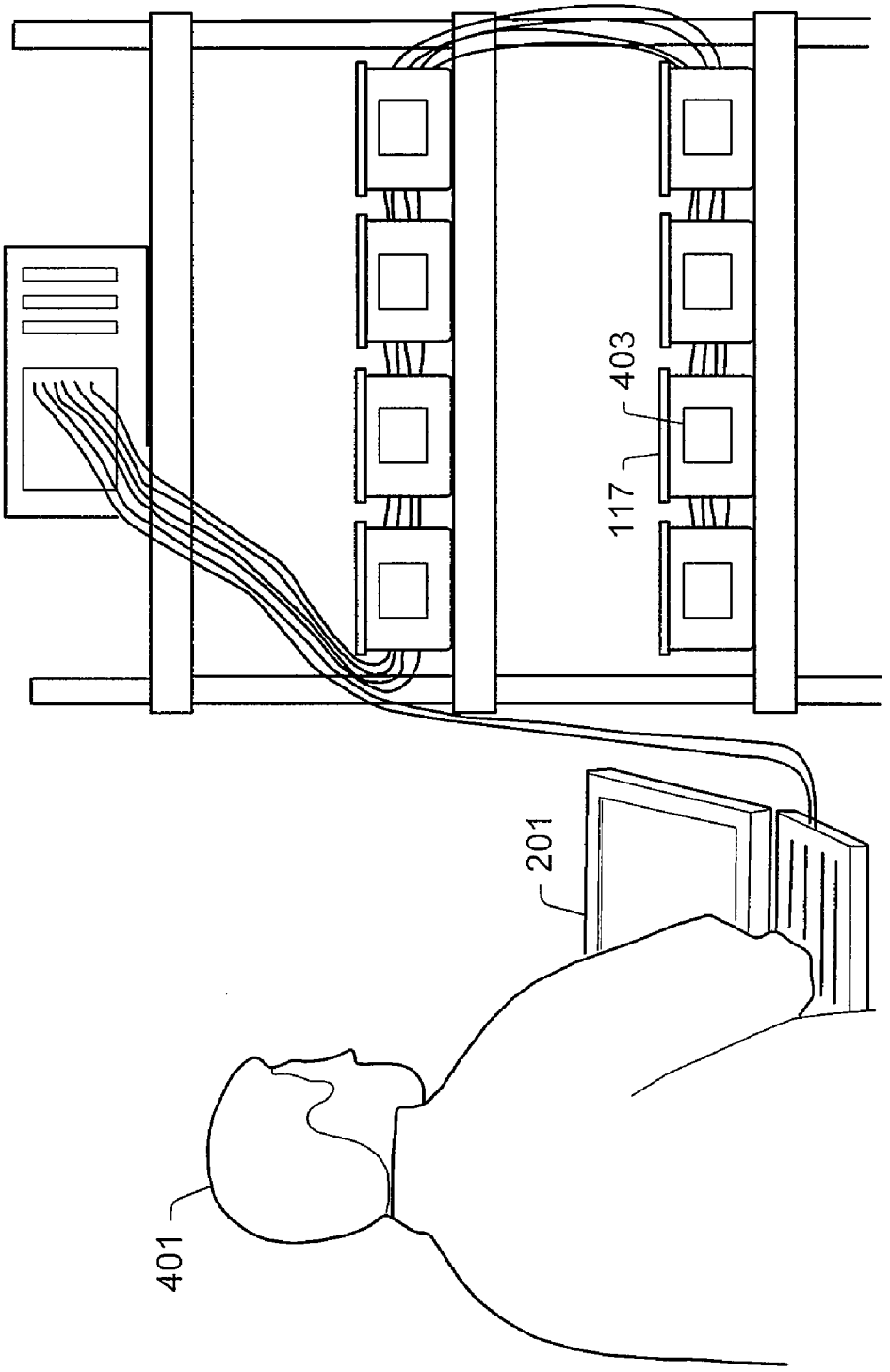
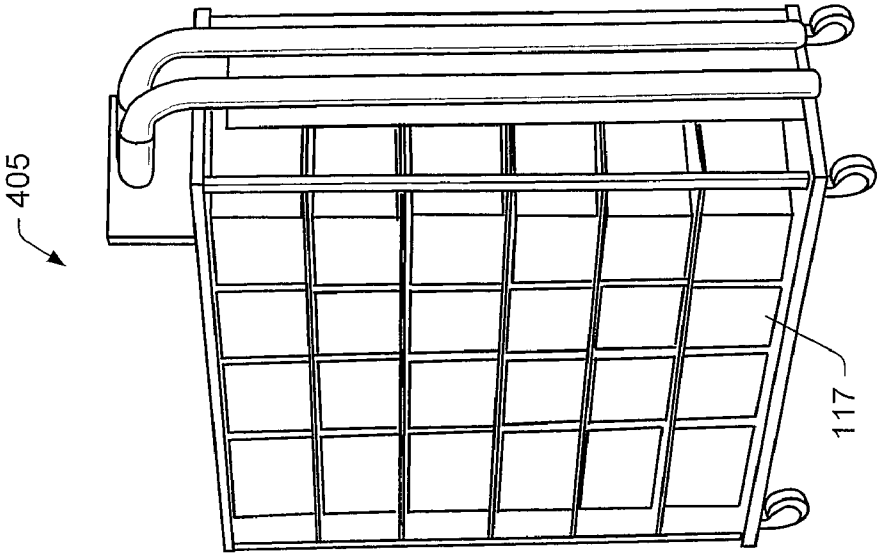


FIG. 4



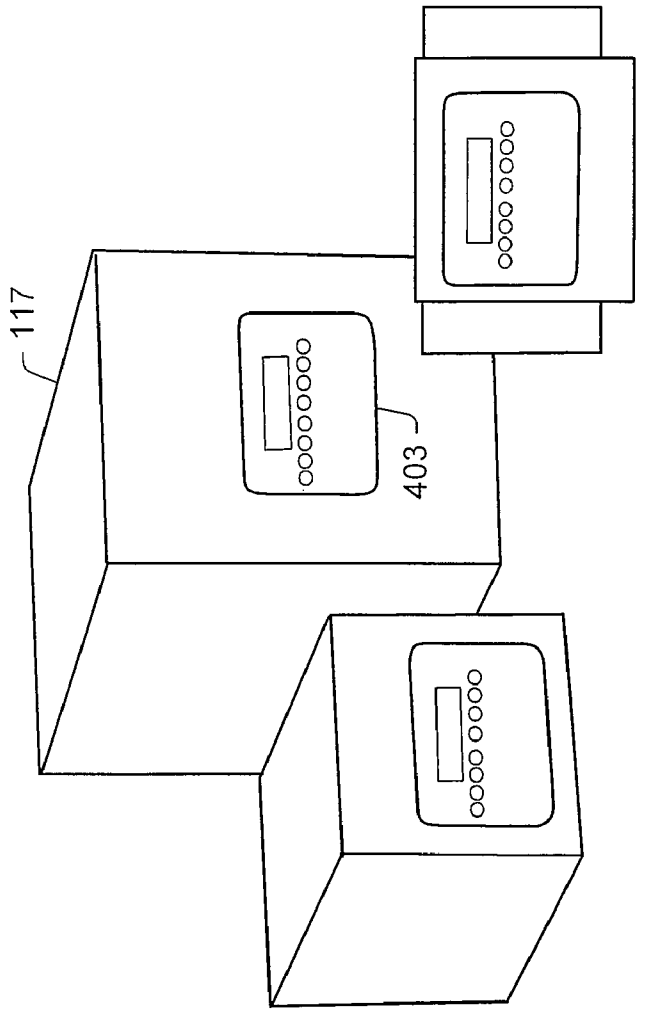


FIG. 5

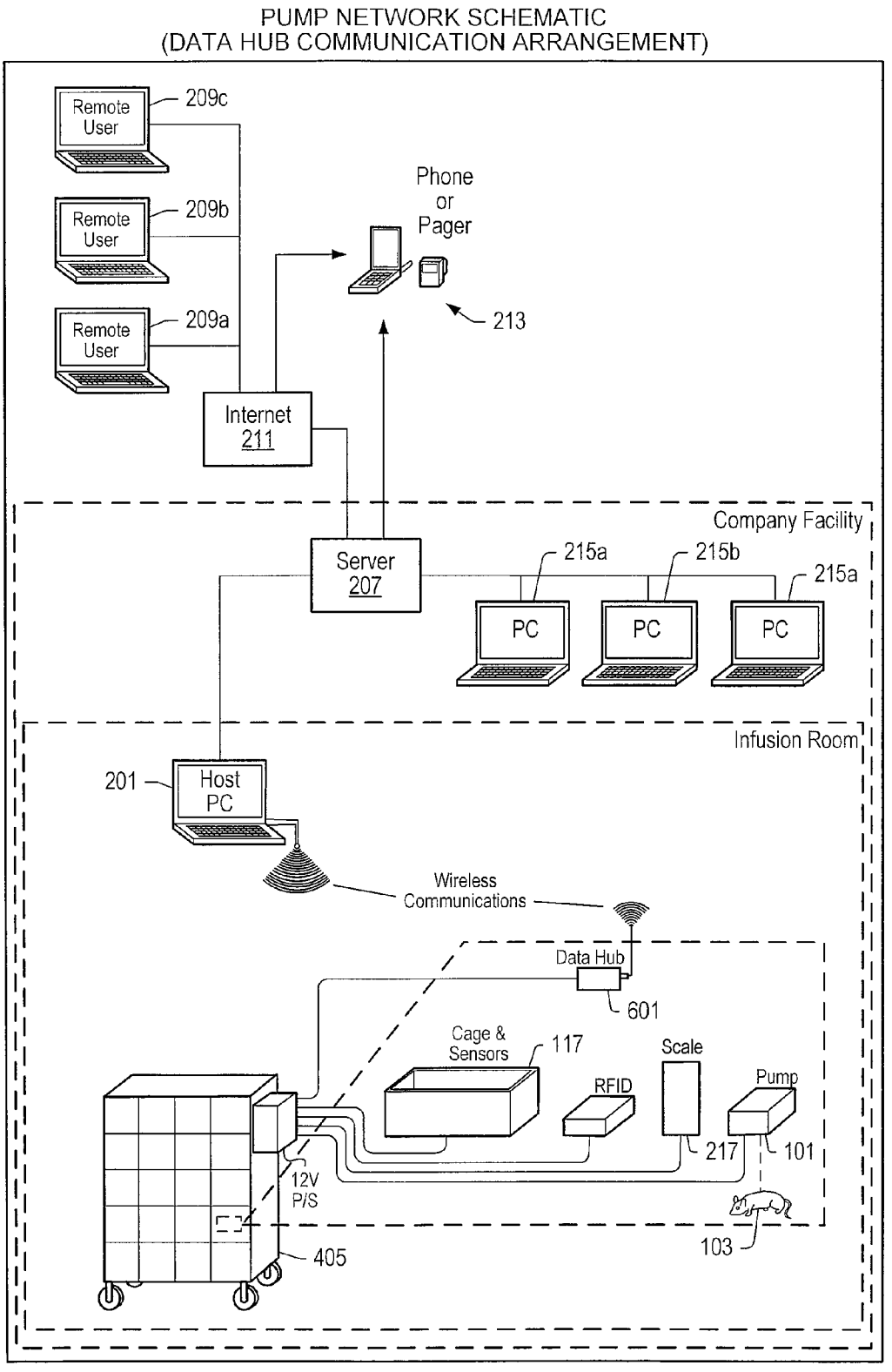

PUMP NETWORK SCHEMATIC
(DATA HUB COMMUNICATION ARRANGEMENT)
Remote User
209c
Remote User
209b
Remote User
209a
Phone or Pager
213
Internet 211
Company Facility
Server 207
215a
215b
215a
PC
PC
PC
Infusion Room
201
Host PC
Wireless Communications
Data Hub
601
Cage & Sensors
117
Scale
RFID
Pump
217
101
12V P/S
405
103

FIG. 6

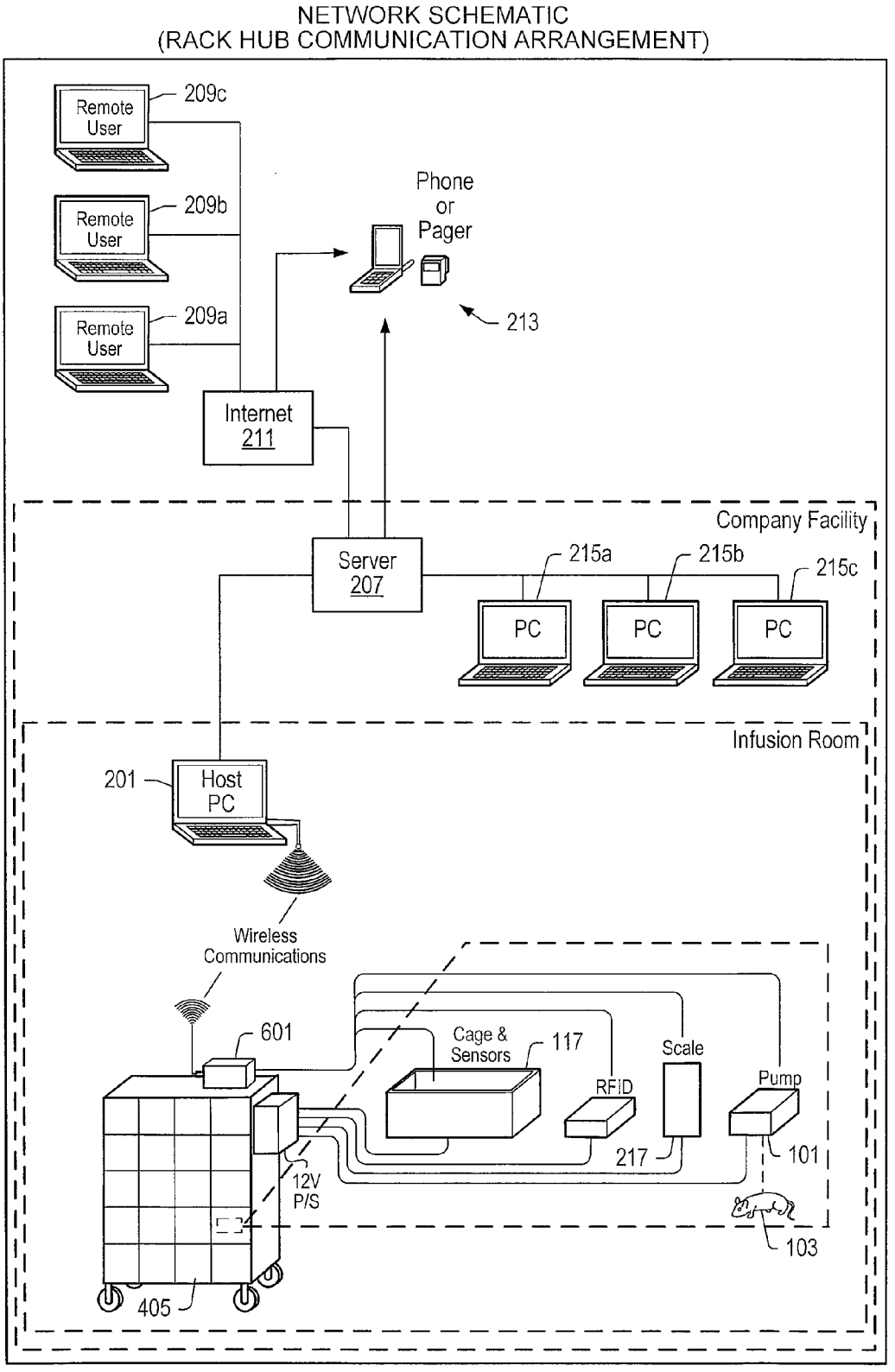

NETWORK SCHEMATIC
(RACK HUB COMMUNICATION ARRANGEMENT)
Remote User
209c
Remote User
209b
Remote User
209a
Phone or Pager
213
Internet 211
Company Facility
Server 207
215a
215b
215c
PC
PC
PC
Infusion Room
201
Host PC
Wireless Communications
601
Cage & Sensors
117
RFID
Scale
Pump
217
101
12V P/S
103
405

FIG. 7

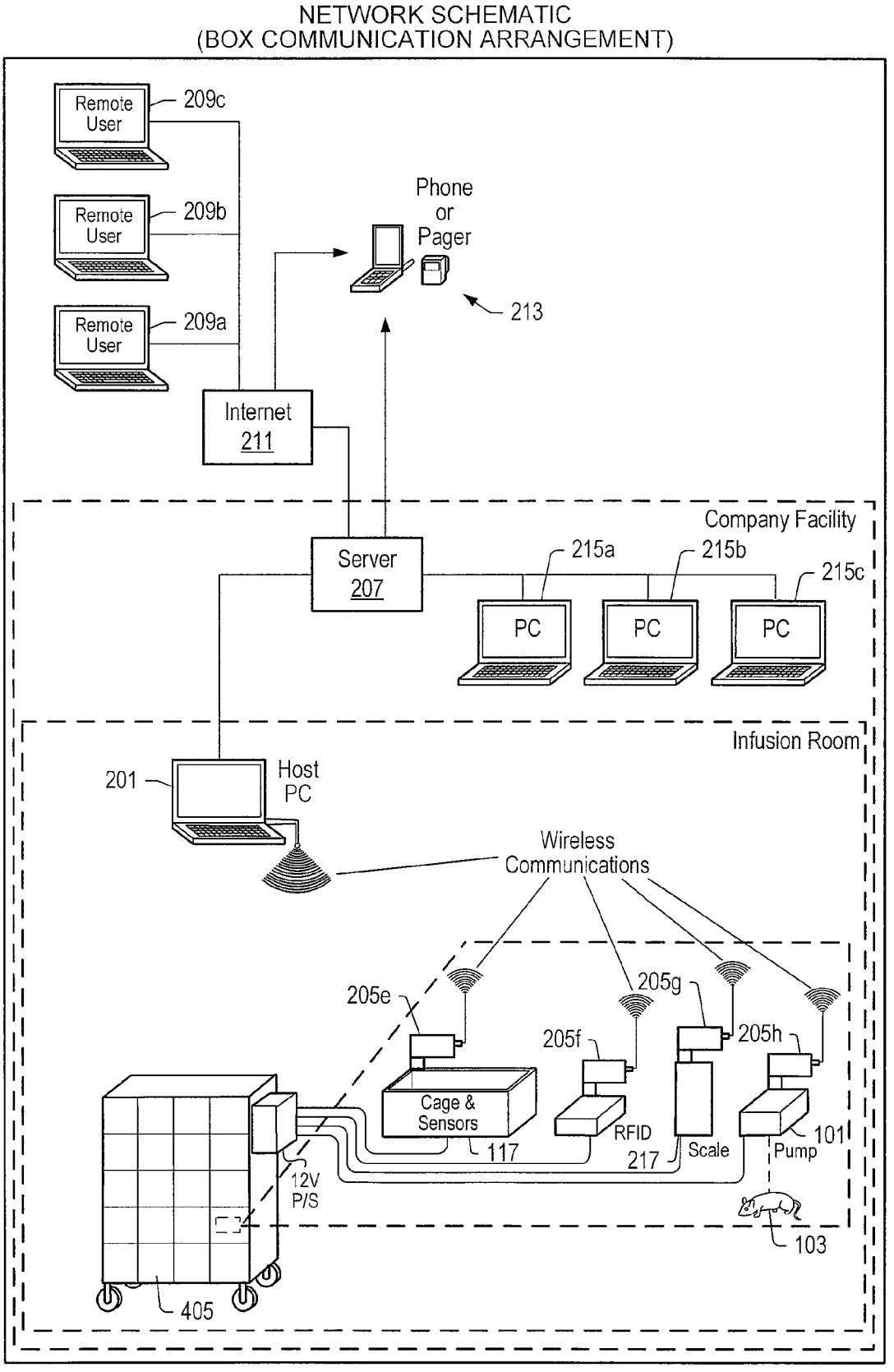

NETWORK SCHEMATIC
(BOX COMMUNICATION ARRANGEMENT)
Remote User
209c
Remote User
209b
Remote User
209a
Phone or Pager
213
Internet 211
Company Facility
Server 207
215a
215b
215c
PC
PC
PC
Infusion Room
201
Host PC
Wireless Communications
205e
205g
205f
205h
Cage & Sensors
117
RFID
217
Scale
Pump
101
12V P/S
103
405

FIG. 8

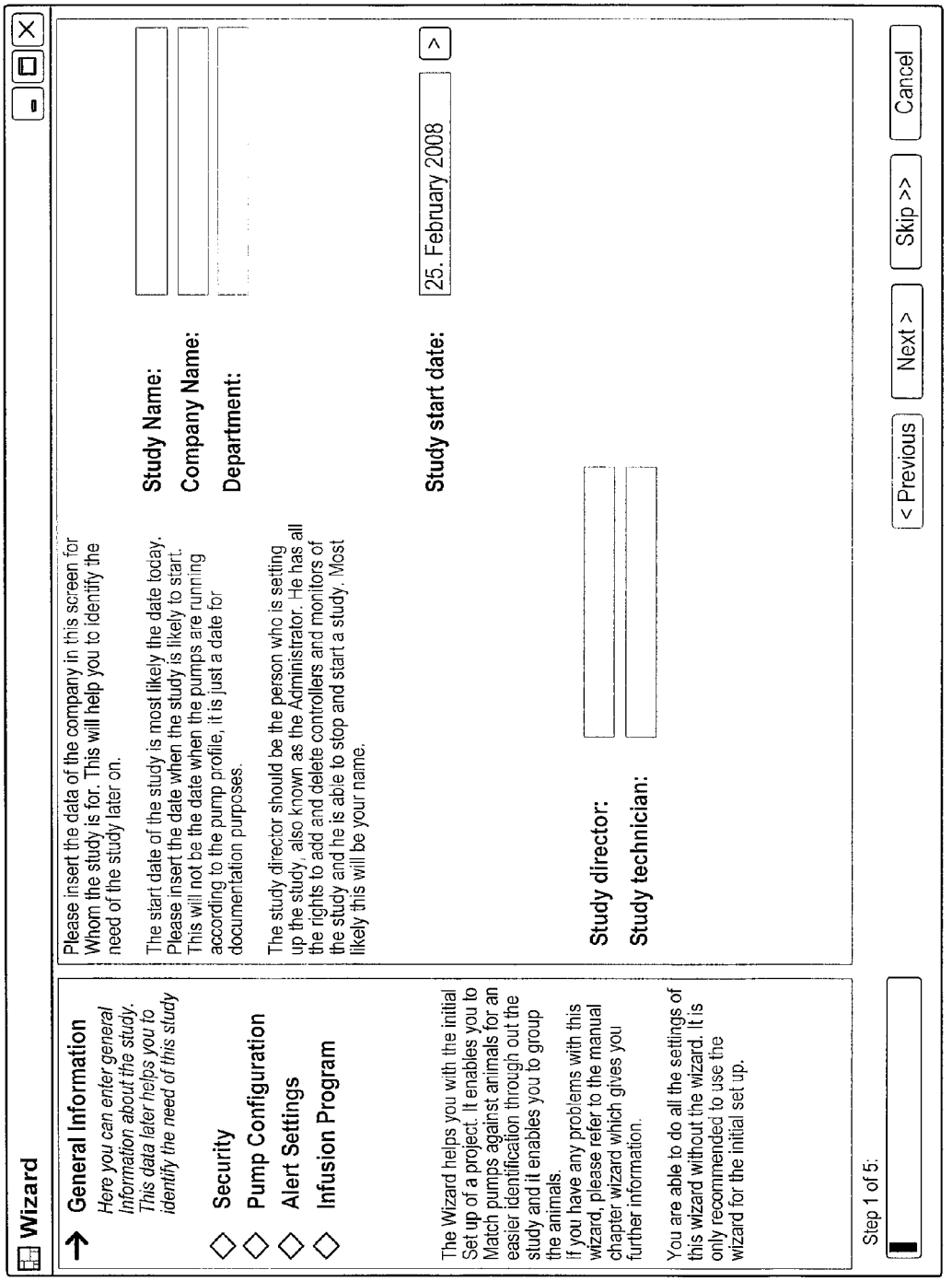

Wizard
General Information
Here you can enter general Information about the study. This data later helps you to identify the need of this study
Security
Pump Configuration
Alert Settings
Infusion Program
The Wizard helps you with the initial Set up of a project. It enables you to Match pumps against animals for an easier identification through out the study and it enables you to group the animals.
If you have any problems with this wizard, please refer to the manual chapter wizard which gives you further information.
You are able to do all the settings of this wizard without the wizard. It is only recommended to use the wizard for the initial set up.
Step 1 of 5:
Please insert the data of the company in this screen for Whom the study is for. This will help you to identify the need of the study later on.
The start date of the study is most likely the date today. Please insert the date when the study is likely to start. This will not be the date when the pumps are running according to the pump profile, it is just a date for documentation purposes.
The study director should be the person who is setting up the study, also known as the Administrator. He has all the rights to add and delete controllers and monitors of the study and he is able to stop and start a study. Most likely this will be your name.
Study Name:
Company Name:
Department:
Study start date:
25. February 2008
Study director:
Study technician:
< Previous
Next >
Skip >>
Cancel

FIG. 9

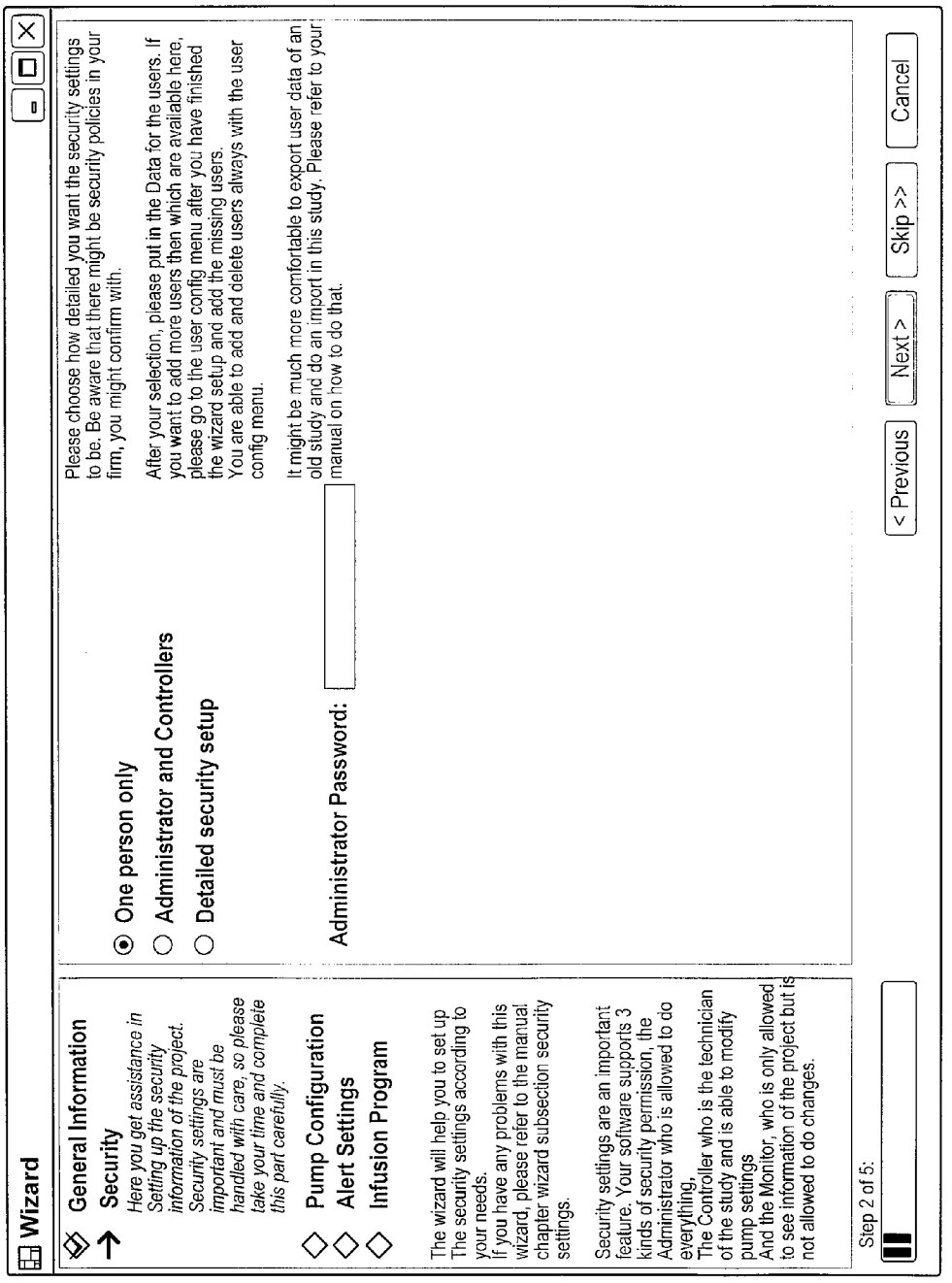

Wizard
General Information
Security
Here you get assistance in Setting up the security information of the project. Security settings are important and must be handled with care, so please take your time and complete this part carefully.
Pump Configuration
Alert Settings
Infusion Program
The wizard will help you to set up The security settings according to your needs.
If you have any problems with this wizard, please refer to the manual chapter wizard subsection security settings.
Security settings are an important feature. Your software supports 3 kinds of security permission, the Administrator who is allowed to do everything,
The Controller who is the technician of the study and is able to modify pump settings
And the Monitor, who is only allowed to see information of the project but is not allowed to do changes.
Step 2 of 5:
One person only
Administrator and Controllers
Detailed security setup
Please choose how detailed you want the security settings to be. Be aware that there might be security policies in your firm, you might confirm with.
After your selection, please put in the Data for the users. If you want to add more users then which are available here, please go to the user config menu after you have finished the wizard setup and add the missing users.
You are able to add and delete users always with the user config menu.
It might be much more comfortable to export user data of an old study and do an import in this study. Please refer to your manual on how to do that.
Administrator Password:
< Previous
Next >
Skip >>
Cancel

FIG. 10

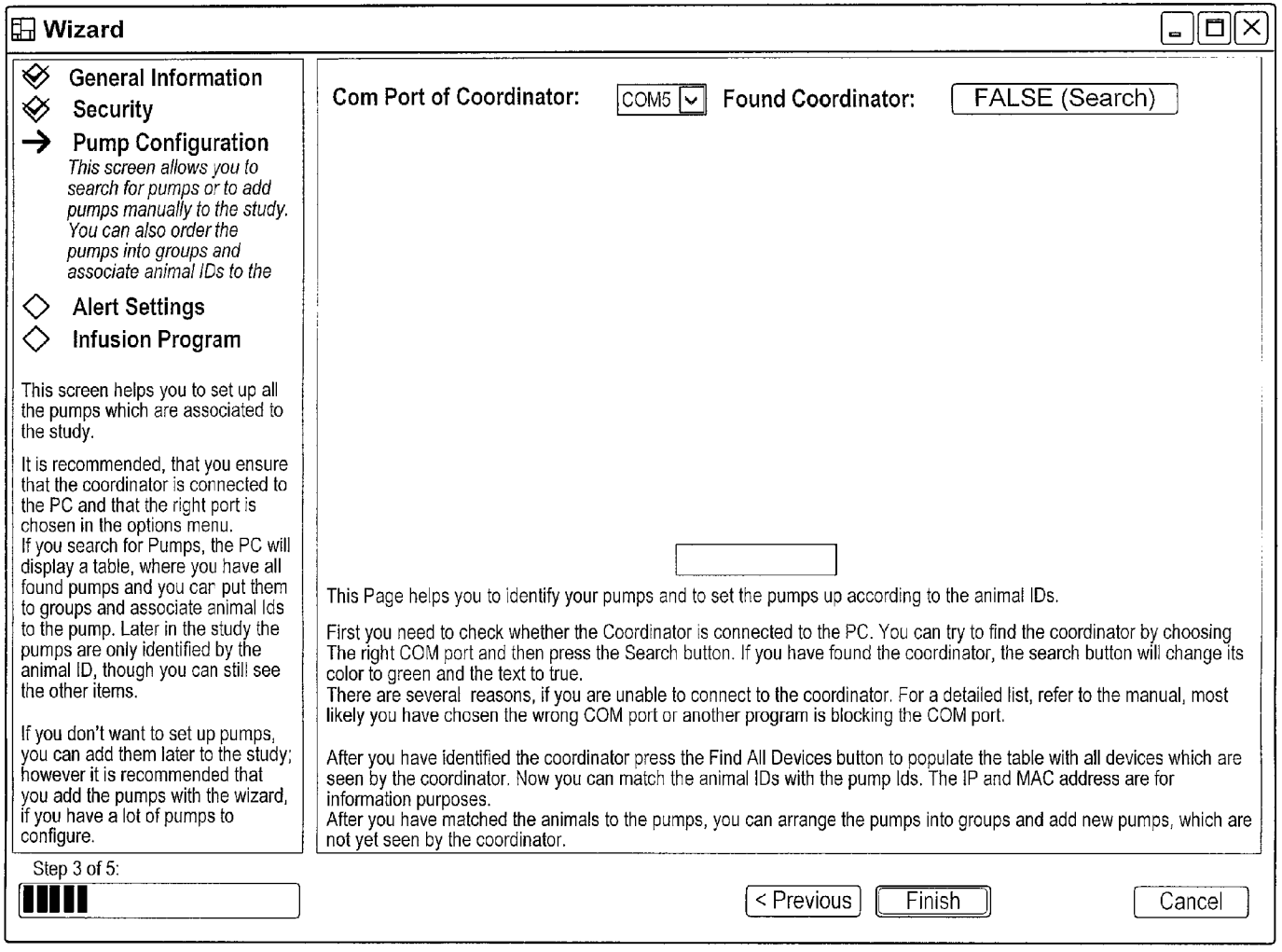

Wizard
General Information
Security
Pump Configuration
This screen allows you to search for pumps or to add pumps manually to the study. You can also order the pumps into groups and associate animal IDs to the
Alert Settings
Infusion Program
This screen helps you to set up all the pumps which are associated to the study.
It is recommended, that you ensure that the coordinator is connected to the PC and that the right port is chosen in the options menu.
If you search for Pumps, the PC will display a table, where you have all found pumps and you can put them to groups and associate animal Ids to the pump. Later in the study the pumps are only identified by the animal ID, though you can still see the other items.
If you don't want to set up pumps, you can add them later to the study; however it is recommended that you add the pumps with the wizard, if you have a lot of pumps to configure.
Com Port of Coordinator:
COM5
Found Coordinator:
FALSE (Search)
This Page helps you to identify your pumps and to set the pumps up according to the animal IDs.
First you need to check whether the Coordinator is connected to the PC. You can try to find the coordinator by choosing The right COM port and then press the Search button. If you have found the coordinator, the search button will change its color to green and the text to true.
There are several reasons, if you are unable to connect to the coordinator. For a detailed list, refer to the manual, most likely you have chosen the wrong COM port or another program is blocking the COM port.
After you have identified the coordinator press the Find All Devices button to populate the table with all devices which are seen by the coordinator. Now you can match the animal IDs with the pump Ids. The IP and MAC address are for information purposes.
After you have matched the animals to the pumps, you can arrange the pumps into groups and add new pumps, which are not yet seen by the coordinator.
Step 3 of 5:
< Previous
Finish
Cancel

FIG. 11

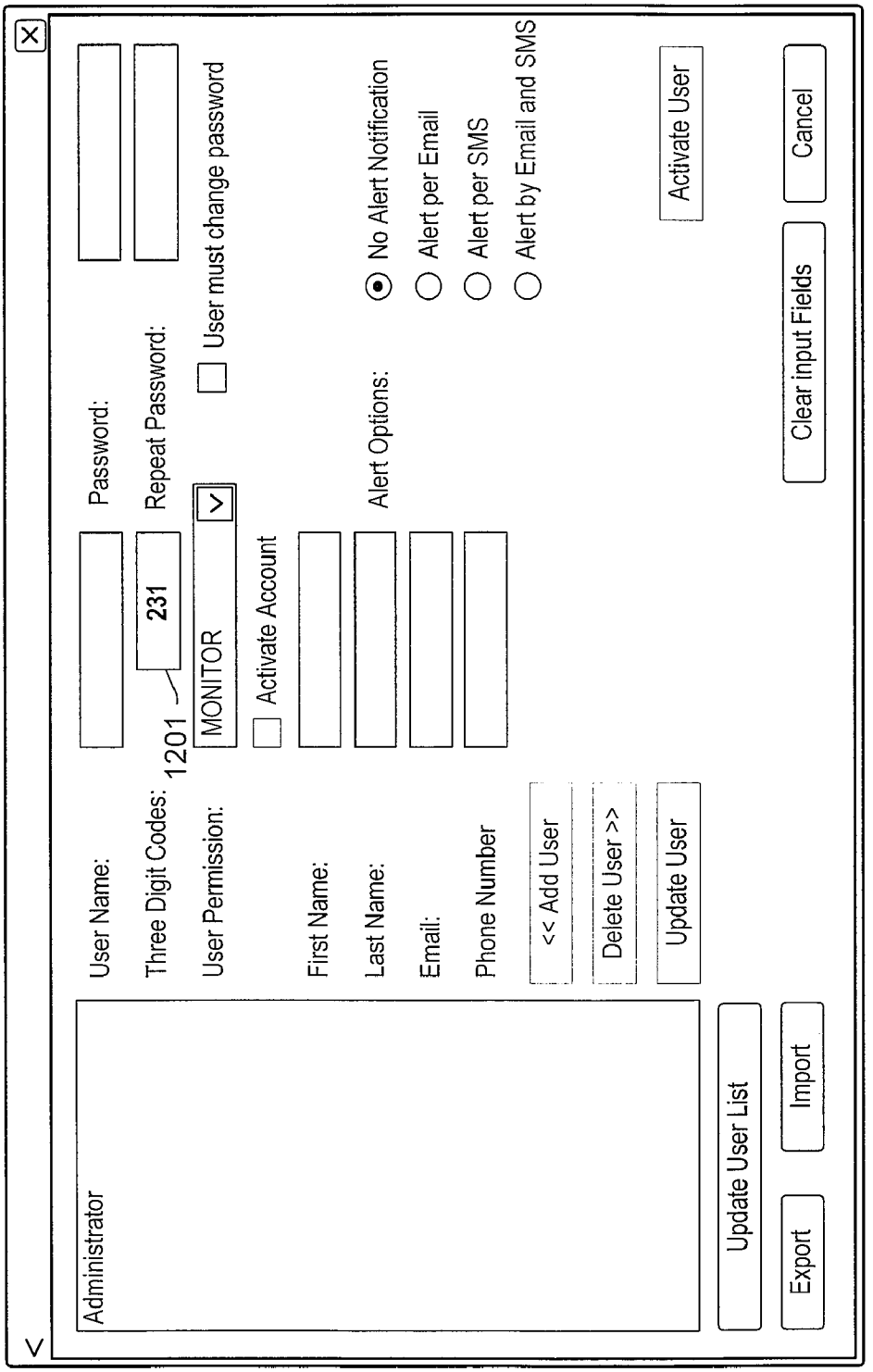

Administrator
User Name:
Password:
Three Digit Codes:
1201
231
Repeat Password:
User Permission:
MONITOR
User must change password
Activate Account
First Name:
Last Name:
Alert Options:
No Alert Notification
Alert per Email
Alert per SMS
Alert by Email and SMS
Email:
Phone Number
<< Add User
Delete User >>
Update User
Activate User
Clear input Fields
Cancel
Update User List
Export
Import

FIG. 12

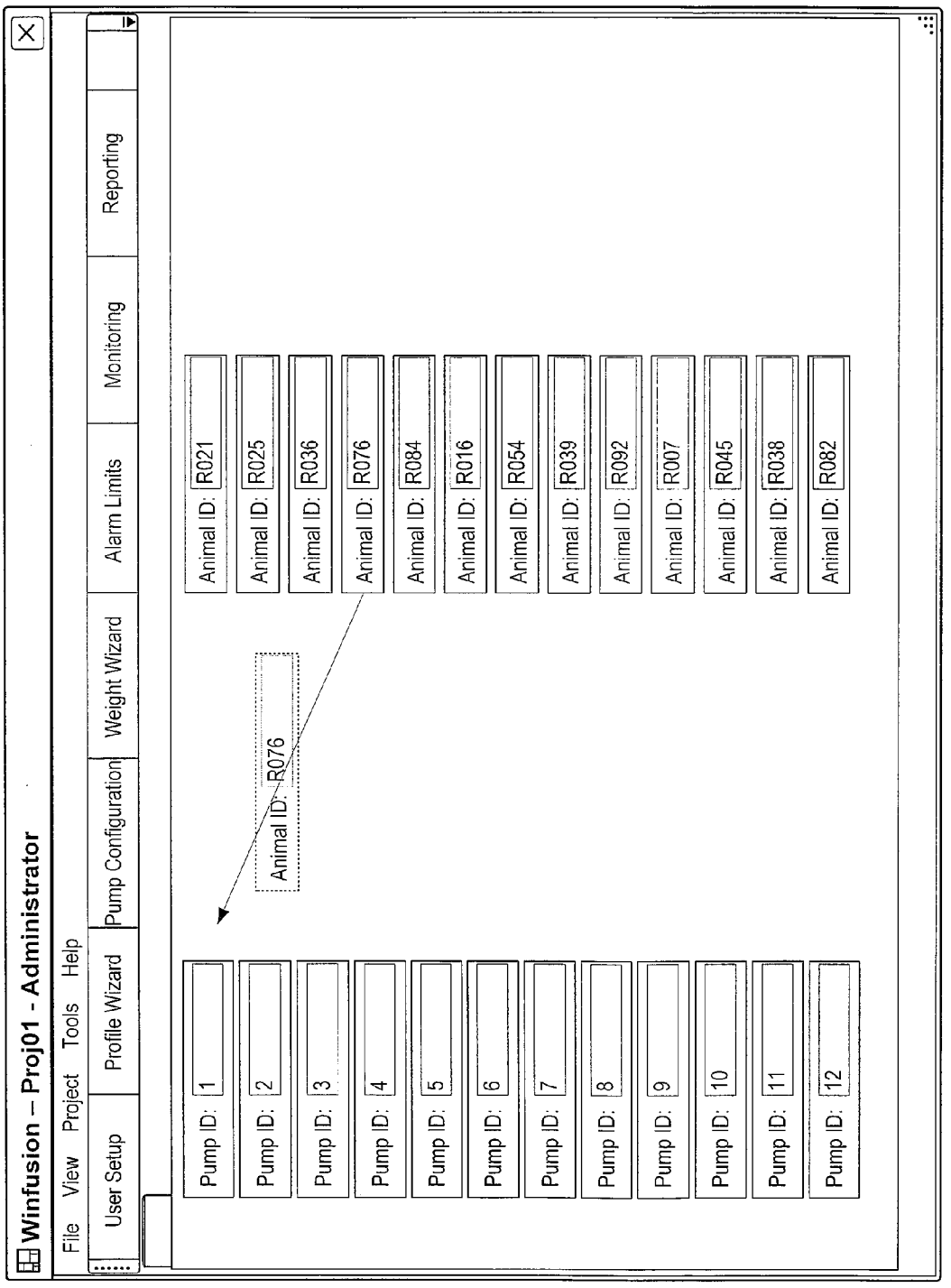

Winfusion – Proj01 - Administrator
File View Project Tools Help
User Setup
Profile Wizard
Pump Configuration
Weight Wizard
Alarm Limits
Monitoring
Reporting
Pump ID: 1
Pump ID: 2
Pump ID: 3
Pump ID: 4
Pump ID: 5
Pump ID: 6
Pump ID: 7
Pump ID: 8
Pump ID: 9
Pump ID: 10
Pump ID: 11
Pump ID: 12
Animal ID: R076
Animal ID: R021
Animal ID: R025
Animal ID: R036
Animal ID: R076
Animal ID: R084
Animal ID: R016
Animal ID: R054
Animal ID: R039
Animal ID: R092
Animal ID: R007
Animal ID: R045
Animal ID: R038
Animal ID: R082

FIG. 13A

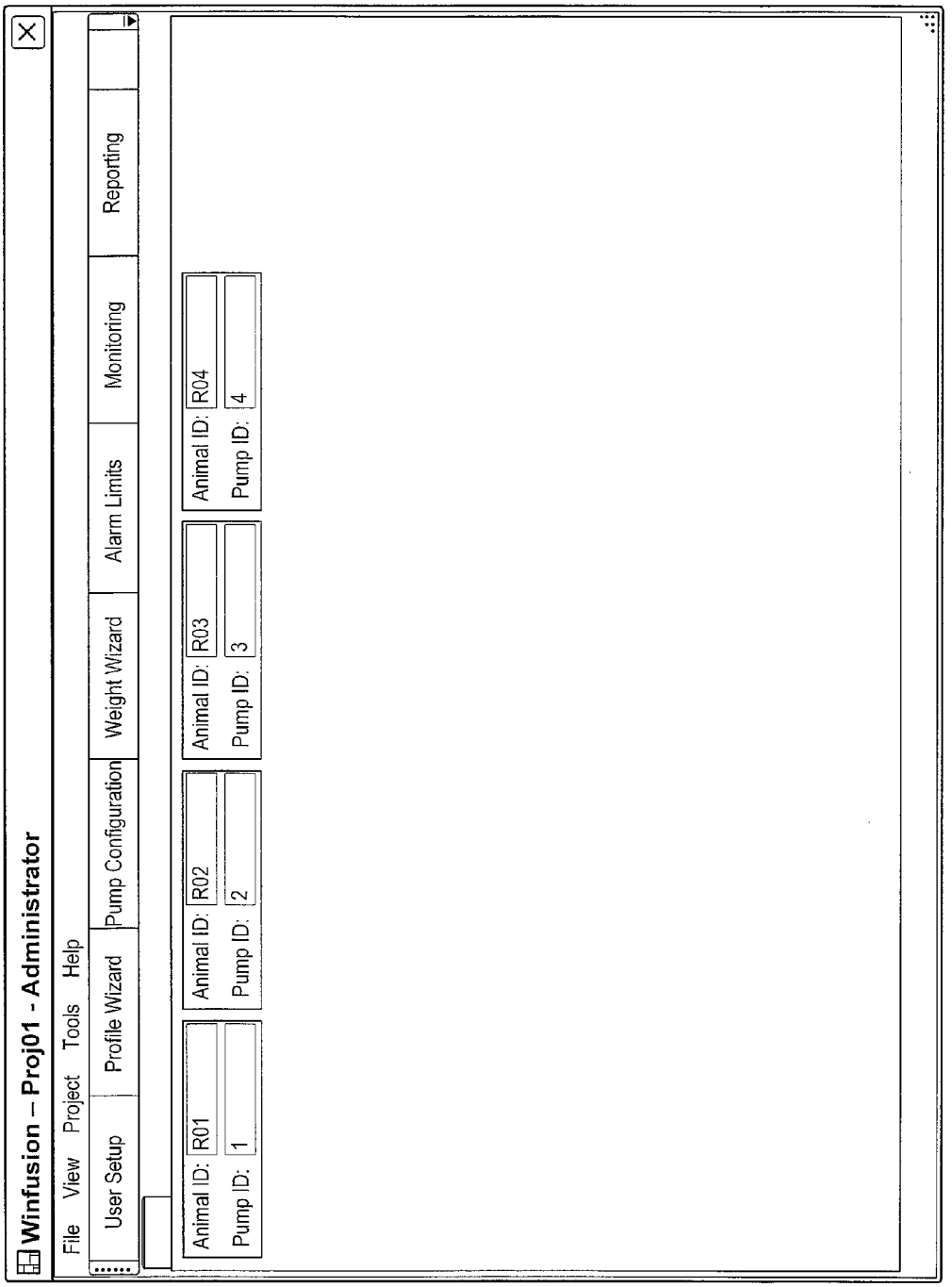

Winfusion – Proj01 - Administrator
File View Project Tools Help
User Setup
Profile Wizard
Pump Configuration
Weight Wizard
Alarm Limits
Monitoring
Reporting
Animal ID: R01
Pump ID: 1
Animal ID: R02
Pump ID: 2
Animal ID: R03
Pump ID: 3
Animal ID: R04
Pump ID: 4

FIG. 13B

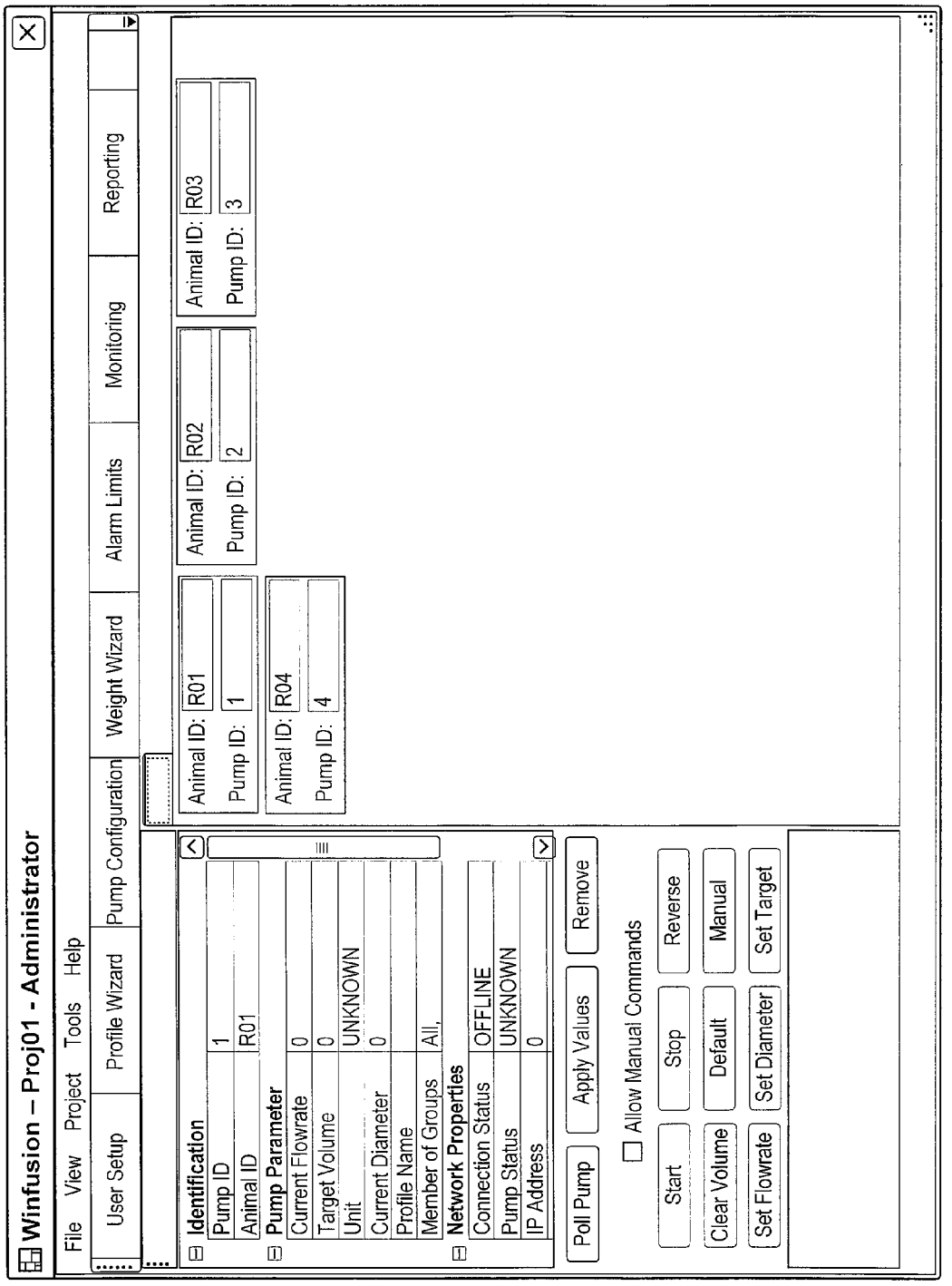

Winfusion – Proj01 - Administrator
File View Project Tools Help
User Setup
Profile Wizard
Pump Configuration
Weight Wizard
Alarm Limits
Monitoring
Reporting
Identification
Pump ID 1
Animal ID R01
Pump Parameter
Current Flowrate 0
Target Volume 0
Unit UNKNOWN
Current Diameter 0
Profile Name
Member of Groups All,
Network Properties
Connection Status OFFLINE
Pump Status UNKNOWN
IP Address 0
Animal ID: R01
Pump ID: 1
Animal ID: R02
Pump ID: 2
Animal ID: R03
Pump ID: 3
Animal ID: R04
Pump ID: 4
Poll Pump
Apply Values
Remove
Allow Manual Commands
Start
Stop
Reverse
Clear Volume
Default
Manual
Set Flowrate
Set Diameter
Set Target

FIG. 14

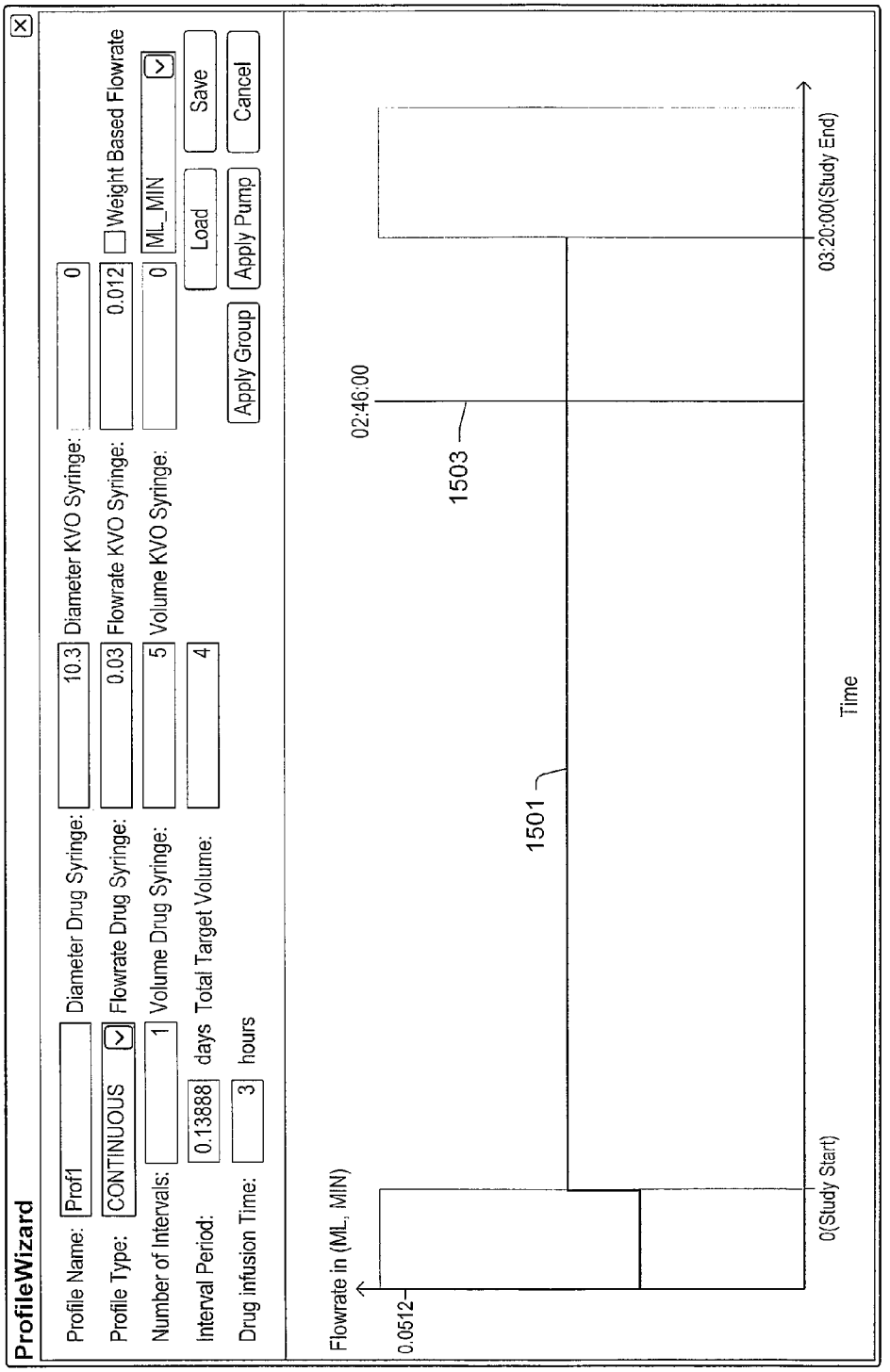

ProfileWizard
Profile Name: Prof1
Profile Type: CONTINUOUS
Number of Intervals: 1
Interval Period: 0.13888 days
Drug infusion Time: 3 hours
Diameter Drug Syringe: 10.3
Flowrate Drug Syringe: 0.03
Volume Drug Syringe: 5
Total Target Volume: 4
Diameter KVO Syringe: 0
Flowrate KVO Syringe: 0.012
Volume KVO Syringe: 0
Weight Based Flowrate
ML_MIN
Load
Save
Apply Group
Apply Pump
Cancel
Flowrate in (ML, MIN)
0.0512
02:46:00
1503
1501
0(Study Start)
Time
03:20:00(Study End)

FIG. 15A

To be loaded at 2:00 pm Thursday December 3

Future Dose	Syringe ID
20 ml	#356
30 ml	#245
23 ml	#785
10 ml	#754
14 ml	#748
34 ml	#934

1505

FIG. 15B

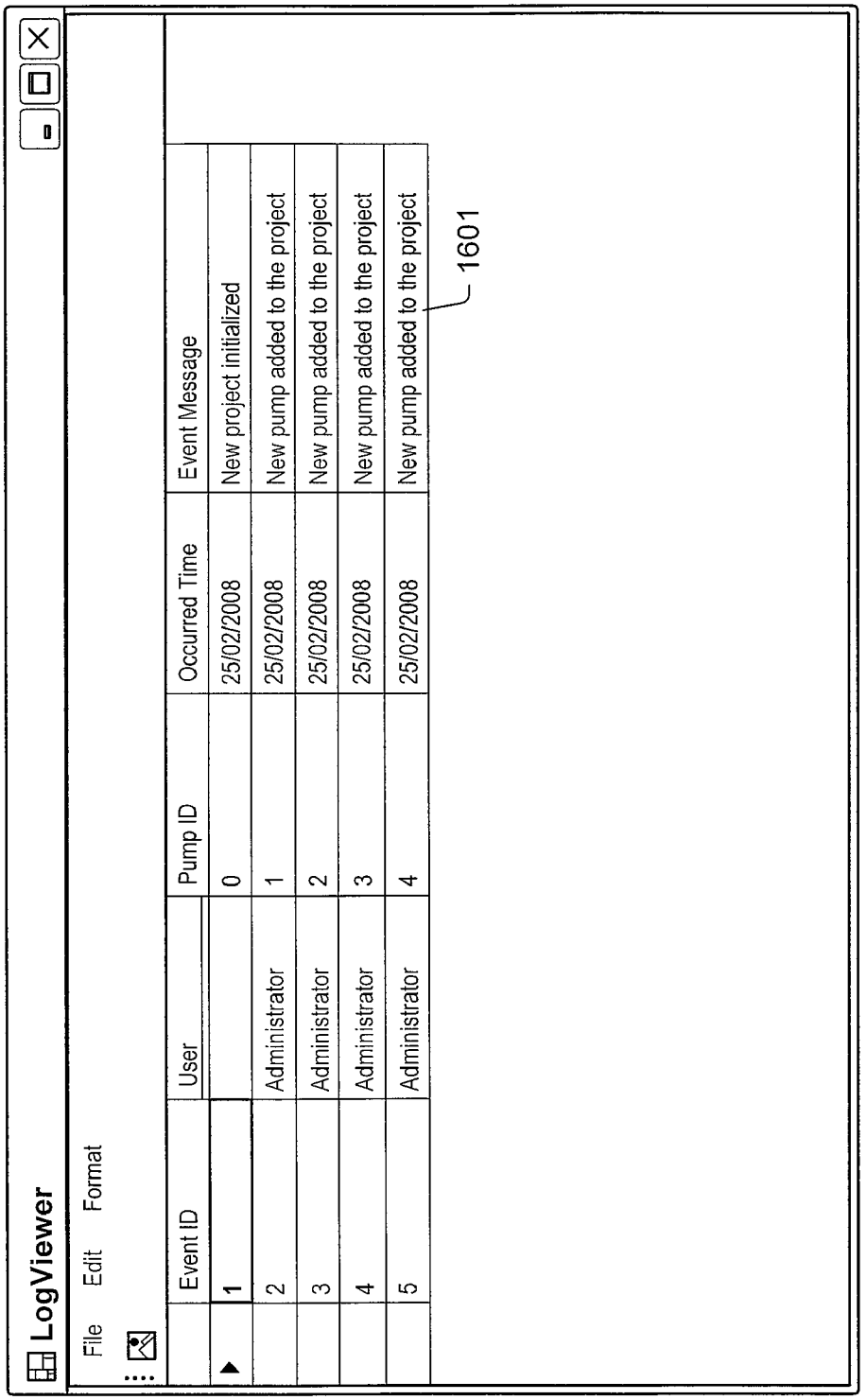

LogViewer
File
Edit
Format
Event ID
User
Pump ID
Occurred Time
Event Message
1
0
25/02/2008
New project initialized
2
Administrator
1
25/02/2008
New pump added to the project
3
Administrator
2
25/02/2008
New pump added to the project
4
Administrator
3
25/02/2008
New pump added to the project
5
Administrator
4
25/02/2008
New pump added to the project
1601

FIG. 16

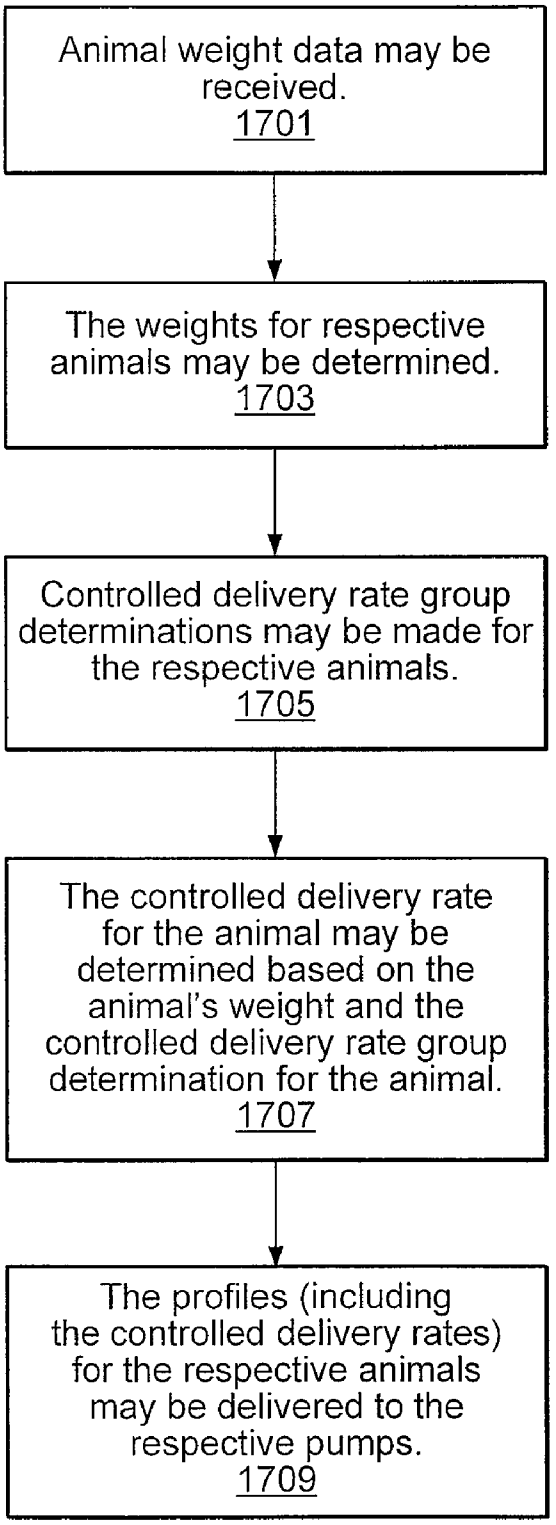

Animal weight data may be received.
1701
The weights for respective animals may be determined.
1703
Controlled delivery rate group determinations may be made for the respective animals.
1705
The controlled delivery rate for the animal may be determined based on the animal's weight and the controlled delivery rate group determination for the animal.
1707
The profiles (including the controlled delivery rates) for the respective animals may be delivered to the respective pumps.
1709

FIG. 17

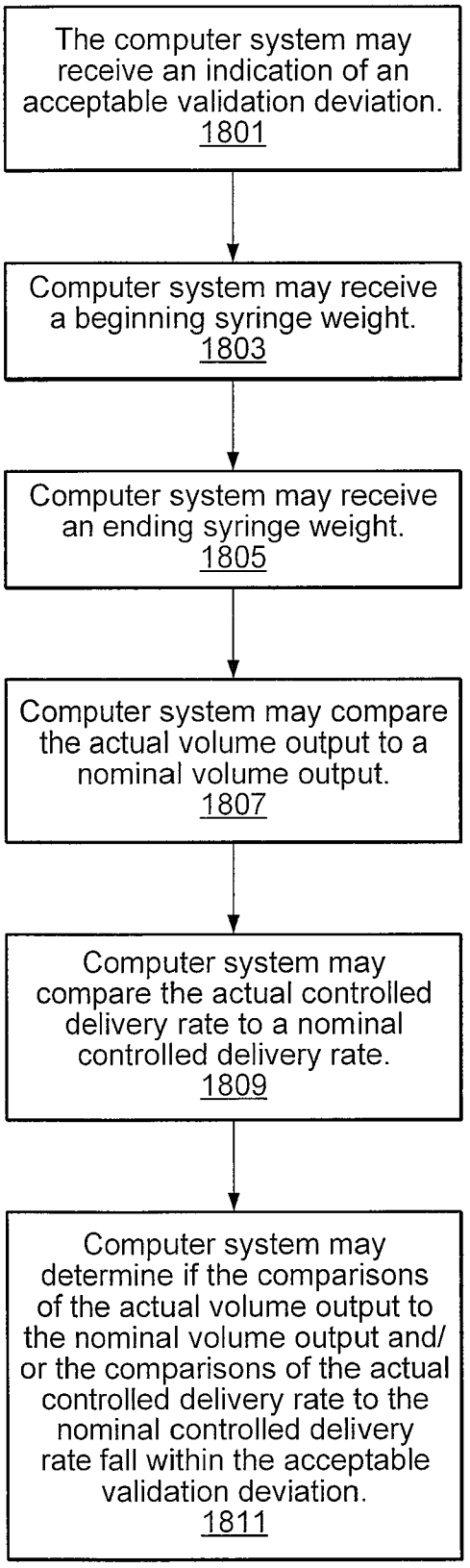

The computer system may receive an indication of an acceptable validation deviation. 1801
Computer system may receive a beginning syringe weight. 1803
Computer system may receive an ending syringe weight. 1805
Computer system may compare the actual volume output to a nominal volume output. 1807
Computer system may compare the actual controlled delivery rate to a nominal controlled delivery rate. 1809
Computer system may determine if the comparisons of the actual volume output to the nominal volume output and/or the comparisons of the actual controlled delivery rate to the nominal controlled delivery rate fall within the acceptable validation deviation. 1811

FIG. 18

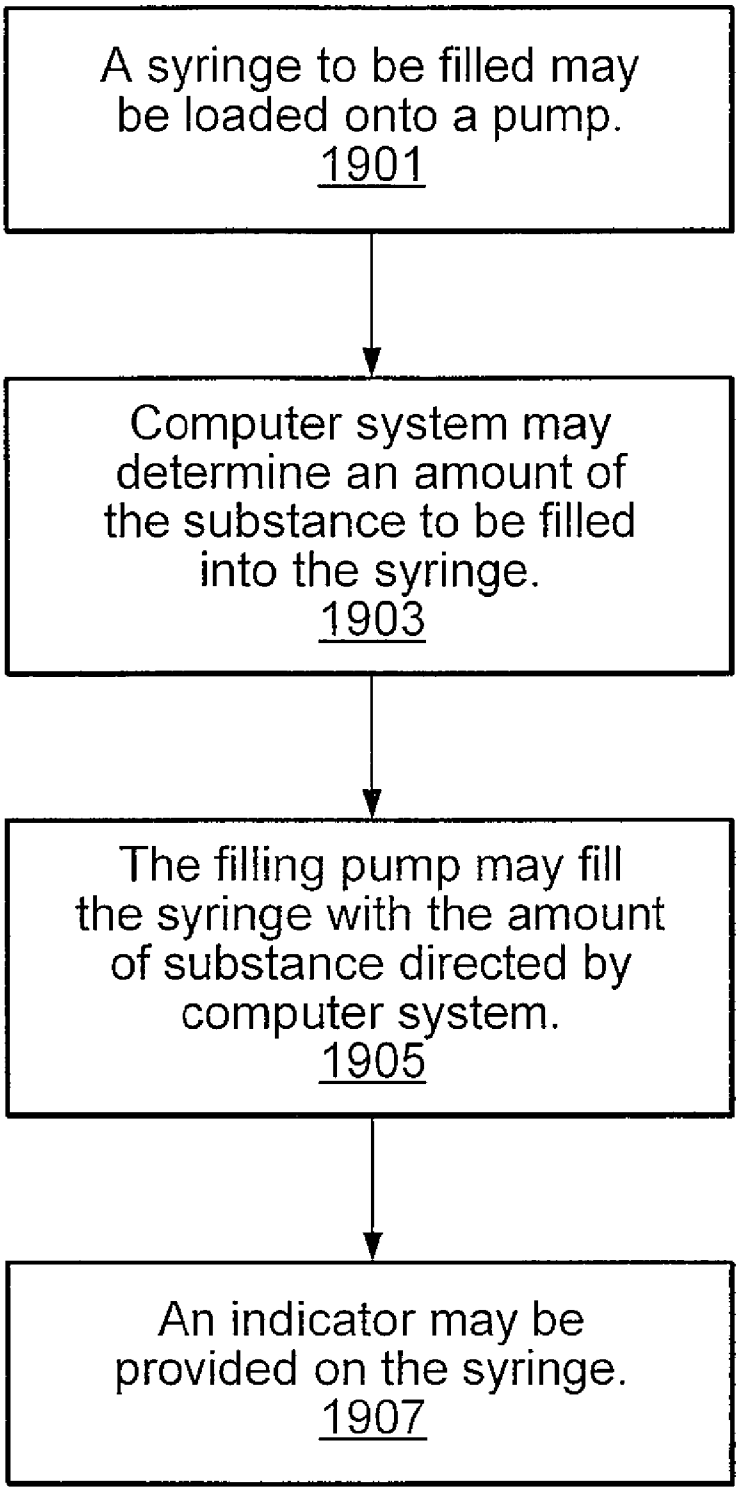

A syringe to be filled may be loaded onto a pump.
1901
Computer system may determine an amount of the substance to be filled into the syringe.
1903
The filling pump may fill the syringe with the amount of substance directed by computer system.
1905
An indicator may be provided on the syringe.
1907

FIG. 19

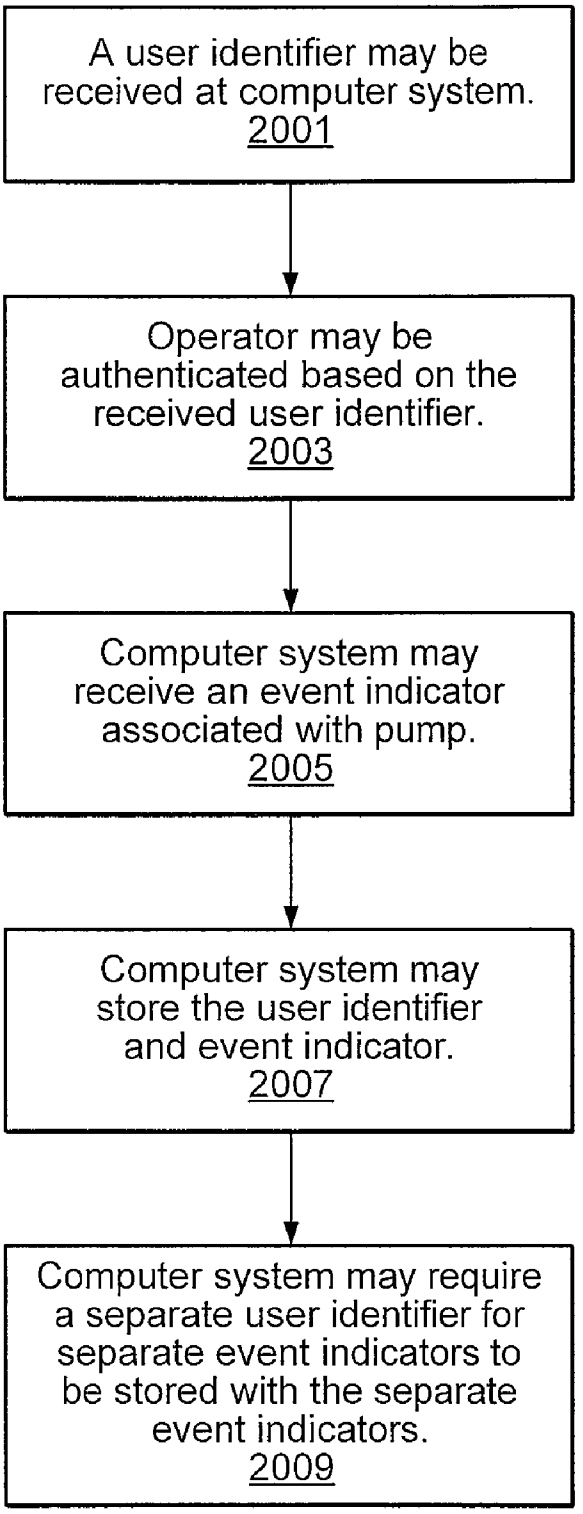

A user identifier may be received at computer system.
2001
Operator may be authenticated based on the received user identifier.
2003
Computer system may receive an event indicator associated with pump.
2005
Computer system may store the user identifier and event indicator.
2007
Computer system may require a separate user identifier for separate event indicators to be stored with the separate event indicators.
2009

FIG. 20

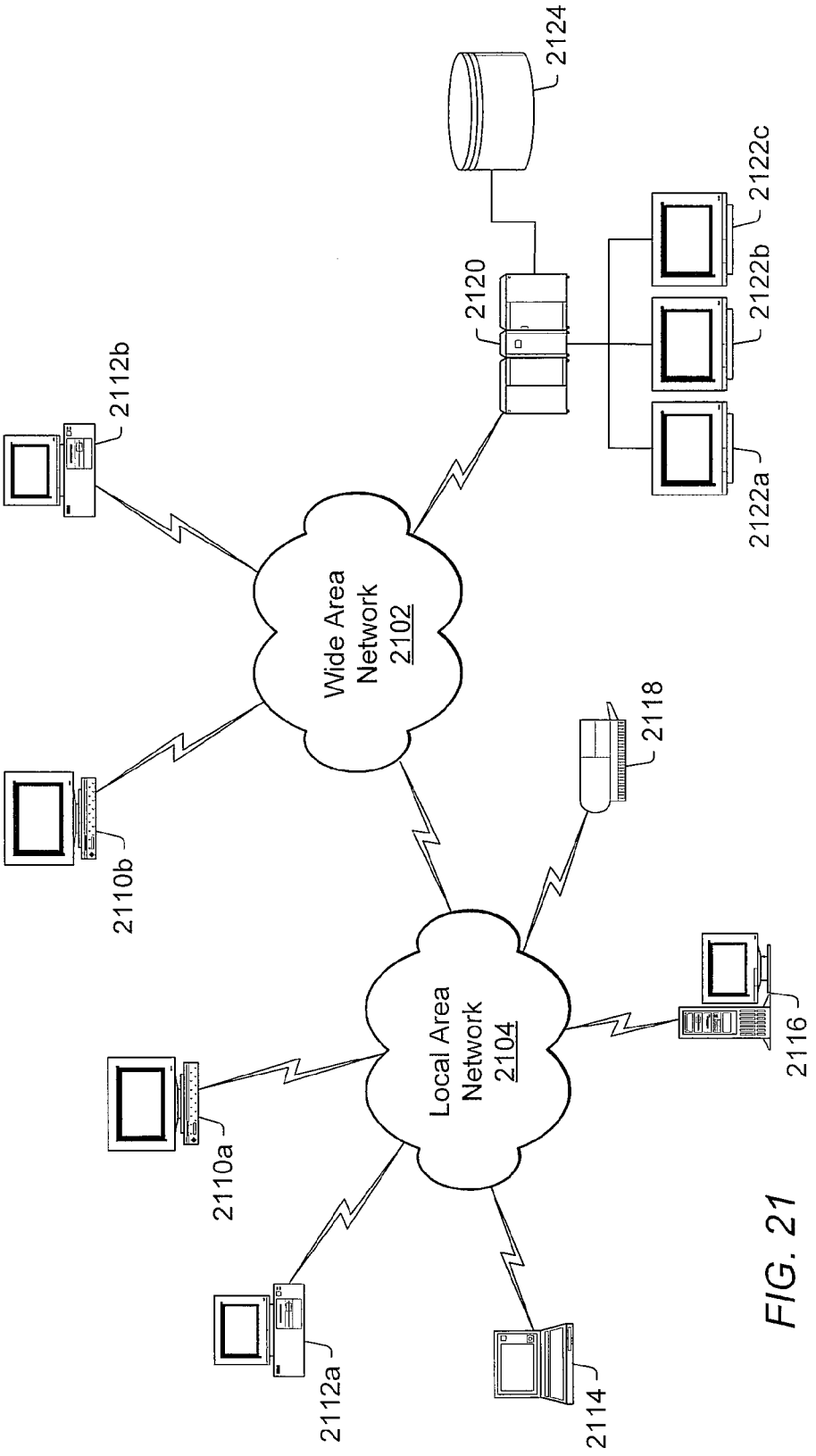

2124
2120
2122c
2122b
2122a
2112b
Wide Area Network 2102
2110b
2118
Local Area Network 2104
2116
2110a
2112a
2114

FIG. 21

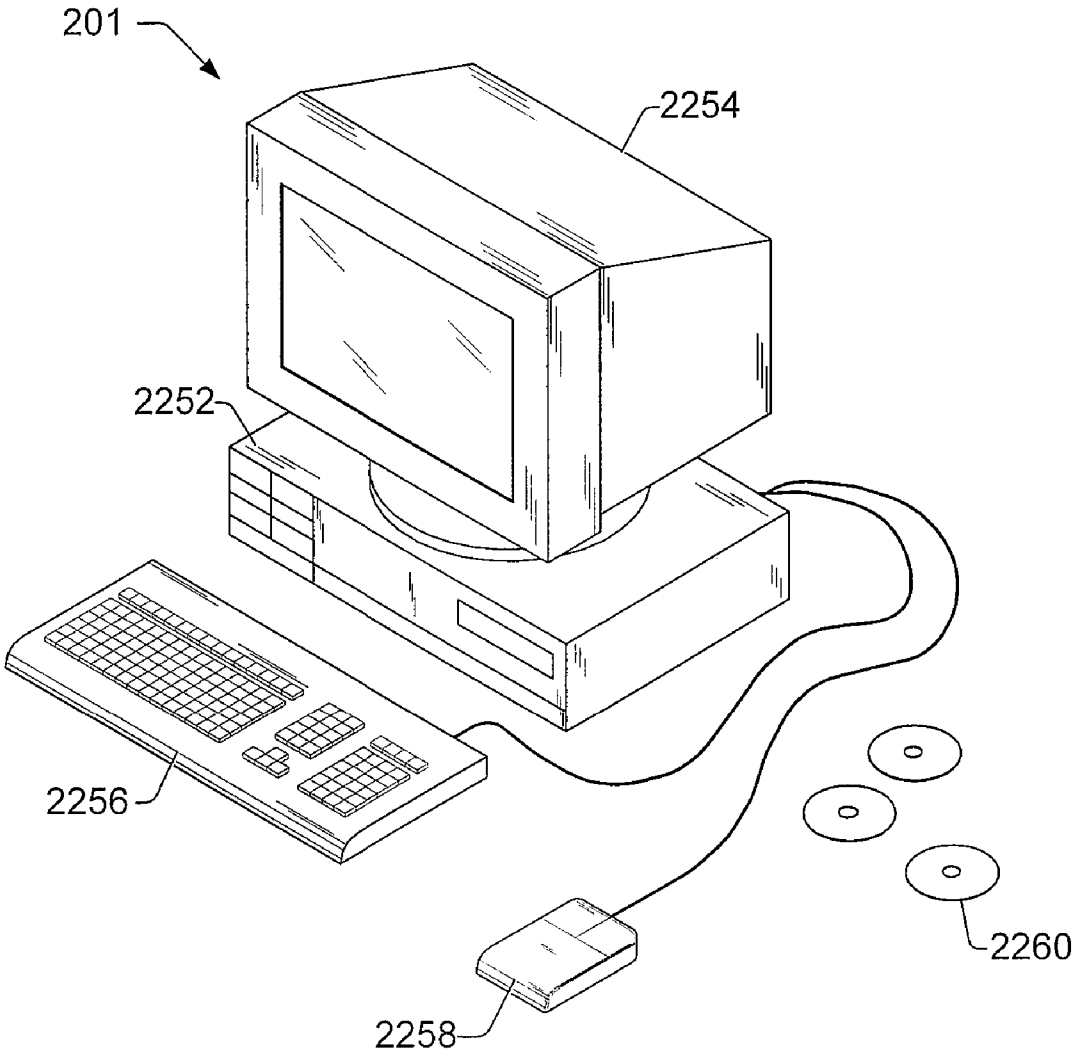


FIG. 22

SYSTEMS AND METHODS FOR CONTROLLED SUBSTANCE DISTRIBUTION NETWORK

PRIORITY CLAIM

[0001] This is a continuation application of, and claims the benefit of priority under 35 USC §120, to co-pending U.S. patent application Ser. No. 12/107,470 titled "Systems and Methods for Controlled Substance Delivery Network", filed Apr. 22, 2008, which claims the benefit of priority under USC §119(e), to U.S. Provisional Patent Application Ser. No. 60/925,881 titled "Information network including medical infusion pumps and other medical devices", filed on Apr. 23, 2007, the disclosures of which are hereby incorporated by reference in their entirety as though fully and completely set forth herein.

BACKGROUND

[0002] The pharmaceutical industry, contract research organizations, academia, and government entities routinely test the efficacy and safety of new chemical entities using intravenous (usually) infusion in lab animals including, for example, rats, dogs and nonhuman primates. While some acute infusion studies may be performed in a small number of lab animals (e.g., ≦10) over several minutes or hours, large-scale "toxicology" infusion studies of, for example, several hundred rats or, for example, 10's of larger animals such as dogs or nonhuman primates for periods lasting, for example, from 30-90 days may also be performed.

[0003] Medical infusion pumps (e.g., electromechanical medical infusion pumps) may be used during these studies (as well as in other veterinary and/or human medical applications). There are numerous types of electromechanical medical infusion pumps including syringe, peristaltic, diaphragm, large volume, stationary ("pole mount"), and portable ("ambulatory"). These pumps may be used to deliver a substance (such as a drug) at a controlled delivery rate to, for example, a laboratory test animal. Lab animal infusion and human-use infusion may share similar pump technology. The methods of use in each field may differ in that human-use infusion (e.g., in a healthcare application) may be tailored to a single patient's needs while lab animal infusion (e.g., in an industrial application) may apply common parameters to multiple animals.

[0004] Animals may be connected to a medical infusion pump (for example, a syringe pump, though other pumping mechanisms may also be used) through a catheter, tubing, tether, fluid swivel, etc. Usually, one pump is used per animal and operators may program and monitor each pump manually. Operators may manually enter a delivery rate into a pump, load a substance-filled syringe for the pump, and then activate the pump (e.g., by pressing a start button). Operators may also interact with numerous medical and monitoring devices involved in the study. The process of loading, starting, and stopping the pump, recording data from medical and monitoring devices, and, for example, responding to pump alarms may be manually documented by the operator (e.g., on a clipboard). Because studies often involve large numbers of animals, manually setting up numerous pumps may be time consuming and tedious. In addition, Good Laboratory Practices (GLP's) (including documentation of processes, data collection, and study results) are required by regulatory agencies such as the Food and Drug Administration (FDA). Manually documenting the processes, data collection, and study results may also be time consuming, tedious and subject to human error.

SUMMARY

[0005] In various embodiments, a pump may receive a controlled delivery rate (e.g., from a computer system) to be used to deliver a substance to an animal (e.g., to study the effects of the substance on the respective animal). In some embodiments, multiple pumps may communicate with the computer system and may be used to deliver substances at respective received controlled delivery rates to respective animals (e.g., one animal per pump). In some embodiments, the computer system may also send/receive other information to/from the pumps (e.g., to control various aspects of the pumps and/or store information associated with the pumps). In some embodiments, the computer system may determine respective controlled delivery rates for the pumps based in part on a weight of a respective animal receiving the substance from the respective pump and/or for example, a study group the animal is in. For example, a study may involve testing one group of animals with a high dose of a substance, one group with a mid dose of the substance, one group with a low dose of the substance, and one group with a control substance (other study configurations are also contemplated). In some embodiments, the computer system may calculate and then send the determined controlled delivery rates to the respective pumps in response to a global command (e.g., received from an operator). The pumps may use the received determined controlled delivery rates to control the rate of substance delivery to a respective animal that is receiving the substance from the respective pump (e.g., through an intravenous (IV) connection to a syringe with the substance being controlled by the pump). In some embodiments, the computer system may display respective graphical profiles of the controlled delivery rates over time for the respective pumps. The graphical profiles may also include indicators marking the graphical profile at the current time point in the study.

[0006] In some embodiments, pumps and other equipment (e.g., medical or monitoring devices) may communicate with the computer system through wired and/or wireless connections. For example, the connections may form a mesh network allowing the computer system to send and receive information to the pumps and other equipment. In some embodiments, the computer system may communicate with the pumps and other equipment through a data hub. In some embodiments, the pumps and other equipment may be coupled to a box operable to send/receive communications to/from the network. The boxes may also include memory for storing information such as instructions (e.g., for the pump), a controlled delivery rate, a start time, a stop time, a duration, a target volume, etc. to allow the box to provide the instructions, etc. in the event of a computer system failure and/or to allow the box to be placed on a different pump if the original pump should fail (or for some other reason need to be disconnected from the study).

[0007] In some embodiments, the computer system may receive information such as weights (e.g., from a weight scale, file, or remote computer), sensor data (e.g., from monitoring sensors either implanted in the animals or coupled to cages holding the animals), documentation (e.g., including user identifiers and documentation identifiers for respective events occurring in the network such as pump starting, pump stopping, alarm, alarm cleared, how alarm was cleared, etc).

User identifiers (e.g., personal identification numbers (PINs)) may be used to authenticate an operator prior to allowing the operator to perform an action on the pump (or other equipment). The user identifier may also be stored with a received documentation identifier to indicate which operator performed the respective action. In some embodiments, user identifiers and documentation indicators (e.g., when clearing an alarm) may be required prior to continued system access and/or prior to restarting pump operation (e.g., if stopped after an alarm).

[0008] In some embodiments, the computer system may communicate with the pumps and/or weight scales associated with the pumps for in process pump validation. For example, an operator may weigh a syringe before a pump pumps a substance and after the pump pumps the substance according to a received controlled delivery rate. The weights (and, for example, start and stop times) may be used to validate the pump (e.g., determine if the expected delivery rate is within an acceptable range of the actual delivery rate (output volumes may also be used in the validation)). The computer system may also track calibration dates for the pumps and may warn an operator (or, for example, inhibit pump operation) of pumps that have gone past their calibration intervals (or will go past their calibration intervals during the study).

[0009] In some embodiments, the computer system may communicate with a filling pump (either coupled or not coupled to an animal) to fill syringes with an amount of substance needed for a next phase of a study. For example, after determining a controlled delivery rate for a pump (and a duration of pumping at the determined controlled delivery rate), the computer system may determine and communicate an amount of substance needed in a respective syringe (or, for example, a syringe plunger displacement indication, etc.) to a filling pump and the filling pump may fill the respective syringe with the indicated amount of substance (the syringe and a vat of the substance to be used to fill the syringe may be coupled to the filling pump by an operator). An indicator (e.g., printed directly on the syringe or on a label to be coupled to the syringe) may be placed on the syringe to assist the operator in placing the syringe on the respective pump (in some embodiments, the same pump may fill the syringe and deliver the substance to the respective animal). In some embodiments, the computer system may calculate several syringe amounts and may display (or, for example, print) the list for an operator to use in preparing syringes for future phases of the study (e.g., the list may include entries with a pump indicator, a time indicator, an amount indicator, an animal indicator, etc. along with the substance amount to fill the respective syringe with). In some embodiments, when a syringe is placed into a pump, the pump (e.g., using information stored in the box and/or received from the computer system) may check a diameter of the received syringe to make sure the received syringe diameter corresponds to the expected syringe diameter (different sized syringes may be used at different times in the study). In some embodiments, the pump may indicate an error and/or not pump the syringe if the diameters do not match.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A better understanding of the present invention may be obtained when the following detailed description is considered in conjunction with the following drawings, in which:

[0011] FIG. **1** illustrates a pump and an animal cage, according to an embodiment.

[0012] FIG. **2***a* illustrates multiple pumps communicating with a computer system, according to an embodiment.

[0013] FIG. **2***b* illustrates multiple pumps communicating with a computer system through respective boxes, according to an embodiment.

[0014] FIG. **3** illustrates a box, according to an embodiment.

[0015] FIG. **4** illustrates a food consumption monitoring device, according to an embodiment.

[0016] FIG. **5** illustrates an embodiment of monitoring devices for monitoring the micro-environments of multiple animal cages in a rack and cage system.

[0017] FIG. **6** illustrates a data hub communication arrangement including a pump and medical and monitoring devices wired to an external stand-alone data hub, according to an embodiment.

[0018] FIG. **7** illustrates a rack hub communication arrangement with multiple pumps and medical and monitoring devices in a rack wired to an external stand-alone data hub, according to an embodiment.

[0019] FIG. **8** illustrates a box communication arrangement with a pump and medical and monitoring devices respectively coupled to a removable piece of wireless communications hardware, according to an embodiment.

[0020] FIG. **9** illustrates a set-up screen for a study, according to an embodiment.

[0021] FIG. **10** illustrates a security set-up screen, according to an embodiment.

[0022] FIG. **11** illustrates a communications port set-up screen, according to an embodiment.

[0023] FIG. **12** illustrates a user set-up screen, according to an embodiment.

[0024] FIG. **13***a* illustrates a graphical user interface for pump/animal assignment, according to an embodiment.

[0025] FIG. **13***b* illustrates graphical user interface for equipment access, according to an embodiment.

[0026] FIG. **14** illustrates a pump set-up screen, according to an embodiment.

[0027] FIG. **15***a* illustrates a graphical profile for a substance delivery, according to an embodiment.

[0028] FIG. **15***b* illustrates a listing of future syringes, according to an embodiment.

[0029] FIG. **16** illustrates an electronic log, according to an embodiment.

[0030] FIG. **17** illustrates a flowchart of a method for controlled delivery rate determination and global command rate distribution, according to an embodiment.

[0031] FIG. **18** illustrates a flowchart of a method for pump validation, according to an embodiment.

[0032] FIG. **19** illustrates a flowchart of a method for automated syringe filling, according to an embodiment.

[0033] FIG. **20** illustrates a flowchart of an embodiment for study documentation.

[0034] FIG. **21** illustrates an embodiment of a wide area network (WAN) and a local area network (LAN).

[0035] FIG. **22** illustrates an embodiment of computer system that may be suitable for implementing various embodiments of a system and method for substance delivery and monitoring.

[0036] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended

to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present invention as defined by the appended claims. Note, the headings are for organizational purposes only and are not meant to be used to limit or interpret the description or claims. Furthermore, note that the word "may" is used throughout this application in a permissive sense (i.e., having the potential to, being able to), not a mandatory sense (i.e., must). The term "include", and derivations thereof, mean "including, but not limited to". The term "coupled" means "directly or indirectly connected".

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0037] FIG. **1** illustrates an embodiment of pump **101***a* (e.g., a medical infusion pump) and a laboratory animal cage **117** for animal **103***a*. In various embodiments, pump **101** ("pump **101**" used generally herein to refer to pumps **101***a*, **101***b*, **101***c*, etc.) may be used to deliver substance **119** to animal **103** ("animal **103**" used generally herein to refer to animals **103***a*, **103***b*, **103***c*, etc.) at a controlled delivery rate (e.g., to study the effects of substance **119** on respective animal **103**). In some embodiments, the controlled delivery rate may be calculated, for example, by computer system **201** (e.g., see FIG. **2**) and communicated to pump **101** for use in delivering substance **119** to animal **103**. As discussed herein, other information may also be communicated between computer system **201**, pumps **101**, and other equipment in an animal drug study. While embodiments described herein include animal applications (e.g., laboratory/veterinary research applications), other applications are also contemplated (e.g., human study applications).

[0038] In some embodiments, pump **101** may include a stepper motor to push a plunger on syringe **109** to deliver substance **119** in syringe **109** at the controlled delivery rate (or pull the plunger to load substance **119** into syringe **109**). While syringe **109** is used throughout, other delivery containers (e.g., a holding tank) are also contemplated. Other pump types are also contemplated (e.g., peristaltic, diaphragm, large volume, stationary ("pole mount"), and portable ("ambulatory")). Animals **103** may include rodents, pigs, rabbits, dogs, cats, nonhuman primates, etc. Substances **119** may include a saline solution, a drug solution, or a control solution (which may be a saline solution). Other substances **119** are also contemplated. In some embodiments, substance **119** may be a liquid delivered through tube **105** on animal **103** which may deliver substance **119** intravenously (through a catheter **107**) to animal **103**. Other routes of administration are also contemplated. For example, substance **119** may be an airborne particle that is pumped into an animal's breathing space or a solid/liquid substance that is pumped into the animal's digestive system. Substance **119** may also be applied to the animal's eyes, ears, skin, etc. (e.g., by a spray pump). In some embodiments, counter balance **111**, swivel **113**, and spring tether **115** may be used to guide and stabilize tube **105** transporting substance **119** to animal **103** in animal cage **117**. Other configurations are also contemplated.

[0039] FIG. **2***a* illustrates multiple pumps **101** communicating with computer system **201**, according to an embodiment. In some embodiments, multiple pumps **101** (e.g., pumps **101***b*, **101***c*, **101***d*, and **101***e*) may be used to deliver substances **119** to multiple respective animals **103** (e.g., animals **103***b*, **103***c*, **103***d*, and **103***e*). For example, a toxicity study may include delivering different respective amounts of a drug to different animals (e.g., one animal **103** per pump **101**) to determine the toxic effects (if any) of the drug and to determine ideal drug amount/body weight ratios. Other study types and study characteristics (e.g., effects of the drug on different genders, age groups, etc.) are also contemplated. Studies may require testing tens, hundreds, or thousands of animals over a few hours, days, weeks, etc. Animal studies may be preliminary to human studies (e.g., for obtaining FDA approval). For example, animal studies may be used in researching new formulations for drugs to treat diseases (e.g., heart disease, diabetes, etc.)

[0040] In some embodiments, pumps **101** may communicate with computer system **201** through network **203** (e.g., through wired and/or wireless communications). Computer system **201** may be a personal computer (such as a desktop or laptop), mainframe, etc. Other computer system types are also contemplated. In some embodiments, computer system **201** may include several computer systems communicatively coupled together. In some embodiments, computer system **201** may send/receive information to/from pumps **101** and other equipment involved in the study (e.g., medical or monitoring devices such as weight scale **217**). For example, computer system **201** may receive weight data from weight scales **217** to determine, for a respective pump **101**, a respective controlled delivery rate for delivering substance **119** to animal **103**. Computer system **101** may then send the determined controlled delivery rate to the respective pump **101**. Each animal **103** may have an individual weight scale **217** (e.g., incorporated in respective animal cage **117**) or multiple animal cages **117** may share a weight scale **217**. In some embodiments, weight scale **217** may communicate (e.g., measured animal weights) with computer system **201** through network **203**.

[0041] In some embodiments, computer system **201** may provide an interface for operator **401** (e.g., see FIG. **4**) to automate control of pumps **101** and the other equipment involved in the study. Information may also be received at computer system **201** from pumps **101** and other equipment (e.g., other medical or monitoring devices) communicatively coupled to computer system **201**. For example, information may be entered at pump **101** through an operator interface **123** (e.g., an alpha/numerical keypad, a full Qwerty keyboard, etc). In some embodiments, information may also be displayed on pump display **121** (e.g., see menu displayed on display **121** in FIG. **1**). Other pump configurations are also contemplated. Computer system **201**, pumps **101**, and/or other medical or monitoring devices may also be operable to communicate (e.g., send and receive data and instructions) with personal digital assistants (PDAs), cell phones, smart cards, etc. For example, operator **401** may send information to computer system **201** through a PDA (e.g., an animal weight, documentation of a study event, etc). As another example, operator **401** may send information to pump **101** by entering the information into a PDA; the PDA sending the information to computer system **201**, and the information being transmitted to pump **101** from computer system **201** over network **203**. As another example, operator **401** may send information to computer system **201** by entering the information into a PDA; the PDA sending the information to pump **101**, and the information being transmitted to computer system **201** from pump **101** over network **203**. Computer system **201** may be used by operator **401** to set-up a study (e.g., by calculating respective controlled delivery rates) and

automate documentation for the study (e.g., associated with pumps **101** and the other equipment involved in the study). Automating control may save substantial time over manual pump set-ups. In addition, automating documentation may result in more accurate and complete study documentation (often required by the FDA and other regulatory bodies) and may force operators **401**, etc. to enter documentation at the appropriate times (e.g., during a pump alarm).

[0042] In some embodiments, computer system **201** may determine respective controlled delivery rates for substance delivery for pumps **101** (e.g., based in part on a weight of animal **103** receiving substance **119** from respective pump **101**) and send the determined controlled delivery rates to respective pumps **101**. In some embodiments, controlled delivery rates may include [dose/time]/animal weight ([ml/hr]/kg) where dose may indicate a substance concentration. Other controlled delivery rates are also contemplated (e.g., non-weight based controlled delivery rates may include dose/time (ml/hr)). Pumps **101** may use the received determined controlled delivery rate to control the rate of substance delivery to animal **103** that is receiving substance **119** from respective pump **101**.

[0043] In some embodiments, studies may involve testing groups of animals with different levels of drug doses. For example, a study may involve testing one group of animals with a high dose of substance **119**, one group with a mid dose of substance **119**, one group with a low dose of substance **119**, and one group with a control (other study configurations are also contemplated). In some embodiments, computer system **201** may also use the study group criteria in determining the respective controlled delivery rate for pump **101** (e.g., in addition to the determined animal weight). Pumps **101** in the high dose group may be provided a controlled delivery rate with an increased dose of the drug per unit of body weight than the mid or low dose group pumps **101**. In some embodiments, study ratios (of substance amount per unit body weight) may be provided to computer system **201** (e.g., by operator **401**) for each group along with a number of animals **103** to test in each dose group (or a respective percentage of the total number of animals to include in each group). For example, operator **401** may provide a spreadsheet with the ratios (and, for example, other test parameters such as animal type, gender, age, etc.) to computer system **201**. Other information may also be received (e.g., time periods for administering the drugs). Other sources of the study information are also contemplated (e.g., downloaded from a remote computer). Computer system **201** may use this information to set up which pumps **101** will provide which dose levels. The respective weights of the animals may also be received by computer system **201** (e.g., on a spreadsheet, through manual entry on a pump interface **123**, through a weight received from weight scale **217** associated with pump **101**, etc). Computer system **201** may arrange pump groupings (e.g., by assigning pumps **101** to respective groups), pump controlled delivery rates, etc. and communicate the resulting respective controlled delivery rates to respective pumps **101** throughout the study.

[0044] In some embodiments, pumps **101** and/or other medical or monitoring devices may communicate over network **203** with computer system **201** through wired and/or wireless communications. For example, pumps **101** (e.g., pumps **101***f*, **101***g*, **101***h*, and **101***i*) and/or other medical or monitoring devices may include and/or be coupled to wireless communication devices such as Wireless Fidelity (IEEE 802.11b wireless networking) (Wi-Fi) transmitter/receiver, Bluetooth transmitter/receiver), etc. for communication with computer system **201**. In some embodiments, pumps **101** and/or other medical or monitoring devices (e.g., as seen in FIG. **2***b*) may communicate with computer system **201** through boxes **205** (e.g., see boxes **205***a*, **205***b*, **205***c*, and **205***d* (referred to generally herein as boxes **205**)). In some embodiments, box **205** attached to a communication port of pump **101** and/or other medical or monitoring devices (e.g., through communication port **307** as seen in FIG. **3**) may send/receive information to/from pump **101** (and/or other medical or monitoring devices) and computer system **201** (e.g., wirelessly through wireless transmitter/receiver **309** or through a wired connection through communication port **311**). In some embodiments, box **205** may not be physically attached to pump **101** and/or other medical or monitoring devices, but may communicate with pump **101** and/or other medical or monitoring devices through wireless transmitter/receiver **309** (which may include a separate transmitter and receiver or a transceiver). Other communication configurations are also contemplated. As seen in FIG. **2***b*, pumps **101***f*, **101***g*, **101***h*, and **101***i* may use respective controlled delivery rates received from computer system **201** to pump the determined respective amounts of substance **119** into animals **103***f*, **103***g*, **103***h*, and **103***i*.

[0045] In some embodiments, pumps **101** and/or other medical or monitoring devices may also be coupled to computer system **201** through wired connections (in some embodiments, boxes **205** may provide wired and/or wireless connections). In some embodiments, pumps **101** and/or other medical or monitoring devices may have communication ports (e.g., serial RS-232, Universal Serial Bus (USB), Ethernet, other communications (COM) port, etc). Connections may be made through the communication ports directly to computer system **201** (e.g., through a wired connection) or indirectly to computer system **201** (e.g., box **205** may be coupled to the communication port and may send/receive communications to/from computer system **201** through a wired and/or wireless connection). Other connections are also contemplated.

[0046] In some embodiments, network **203** may be a mesh network. Through the mesh network, pumps **101** (and, for example, other medical or monitoring devices) in network **203** may communicate directly with each other and/or communicate with each other via computer system **201**. For example, computer system **201**, boxes **205**, etc. may use a ZigBee™ wireless protocol for peer-to-peer communication (which may provide alternate communication paths in the network **203** if a direct path is not available). In some embodiments, computer system **201**, boxes **205**, etc. may communicate with each other through a router. In some embodiments, the router may be external or internal to computer system **201**. Other network configurations and protocols are also contemplated.

[0047] In some embodiments, pump **101** may access memory **305**. Memory **305** may be internal to pump **101** or may be external to pump **101** (e.g., memory **305** may be in box **205** communicatively coupled to pump **101**). Memory **305** may include a non-volatile memory (e.g., flash memory) or volatile memory (e.g., Random Access Memory (RAM)). Other memory types are also contemplated. In some embodiments, memory **305** may store information such as instructions (e.g., for pump **101**), a controlled delivery rate, a start time, a stop time, a duration, a target volume, etc. for pump

101 from computer system **201**. For example, memory **305** may store the received controlled delivery rate, a start time, and a duration from computer system **201** for pump **101** to use in pumping substance **119** to animal **103**. Other combinations are also contemplated (e.g., memory **305** may store controlled delivery rate and target volume or controlled delivery rate and a start and stop time). Memory **305** may also include program instructions (e.g., received from computer system **201**) to control pump **101**. For example, the programming instructions may be stored as firmware on memory **305**. Because instructions for pump **101** may be stored on memory **305**, if computer system **201** fails (or, for example, is restarted, disconnected, etc.), pumps **101** may continue operation per the instructions stored on memory **305**. In some embodiments, programming instructions for determining the controlled delivery rate for pump **101** may be stored in memory **305**. The controlled delivery rate may be determined based on information collected at pump **101** and corresponding information may be sent to computer system **201** for storage (e.g., the animal's weight, the controlled delivery rate, etc). In some embodiments, computer system **201** may communicate information needed for the calculation to pump **101** and/or box **205** (e.g., a dose ratio assigned to respective pump **101**) to be used with the programming instructions on memory **305** and/or other data in memory **305** for the calculation. Memory **305** may also include, for example, alarm codes, menu options for indicating how alarms were solved, etc. Memory **305** may also store information sent to and received from computer system **201** (e.g., as serve as a back-up for computer system **201**). In some embodiments, memory **305** may be accessible to other medical or monitoring devices (e.g., internal to the devices or externally accessible to the devices) for storing information (e.g., information sent/received to/from computer system **201**) and/or instructions for these devices. For example, box **205** with memory **305** may be coupled to a medical or monitoring device's communications port. In addition to memory **305**, box **205** may include processor **303** to access memory **305**, electronic clock **313**, and communications circuitry **301**. In some embodiments, the memory **305** and wireless transmitter/receiver **309** may be on the same printed circuit board (PCB). Other configurations are also contemplated. In some embodiments, memory **305** may be included in a router (e.g., external to computer system **201**) to allow continued operation of pumps **101**, medical and monitoring devices, network **203**, etc. if computer system **201** fails (or, for example, is restarted, disconnected, etc).

[0048] In some embodiments, box **205** may be replaced on pump **101** (and/or other medical or monitoring device) (e.g., if box **205** fails, is not functioning properly, is being updated, etc). For example, an external box **205** may be replaced without replacing or repairing pump **101** (and/or other medical or monitoring device). If the memory **305** and/or communications circuitry **301** is on box **205** instead of an interior of pump **101**, the memory **305** and communications circuitry **301** may be easier to repair/replace by replacing box **205** (as opposed to accessing the interior of pump **101**). In some embodiments, if pump **101** (or other medical or monitoring device) fails, is not functioning properly or, for example, is being updated, box **205** may be placed on a different pump **101** (or other medical or monitoring device). In some embodiments, box **205** may not need to be reprogrammed after the switch (e.g., box **205** may interact with the new pump to perform the functionality expected of the previous pump (e.g., controlled delivery rate, delivery schedule, etc)). In some embodiments, box **205** may be configured to interface with different types of pumps **101** (and/or other medical or monitoring device). Box **205** may include dedicated programming instructions specific to the pump style (or style of other medical or monitoring device). In some embodiments, the pump **101** (and/or other medical or monitoring device) may include programming instructions to be compatible with box **205**. In some embodiments, box **205** may be internal to pump **101** (and/or medical or monitoring device) and pump **101** (and/or medical or monitoring device) may be repaired or replaced if the internal box **205** is not functioning properly (or, for example, to update box **205**). In some embodiments, box **205** may include a wireless communications device with one or more communication port connectors (e.g., serial RS-232, USB, Ethernet, etc) to configure box **205** to communicate with a specific pump **101**. In some embodiments, communications circuitry **301** (and, for example, wireless transmitter/receiver **309**, communication ports **307**/**311**) processor **303**, memory **305**, and/or electronic clock **313** may be internal to pump **101** (and/or medical or monitoring device). Other placements are also contemplated.

[0049] In some embodiments, other medical or monitoring devices (e.g., used to treat or monitor humans or animals **103**) may communicate with computer system **201**. For example, the medical or monitoring devices (e.g., sensors) may monitor physiologic parameters (e.g., animal temperature, activity, pulse oxymetry, heart rate, blood pressure, metabolic function, etc) and animal cage conditions (e.g., a micro-environment monitoring apparatus may measure animal cage temperature, humidity, ammonia level, etc)). As seen in FIG. **4**, a monitoring device may include a food and/or water consumption monitoring device **403** (e.g., for one animal cage **117** of a collection of animal cages). In some embodiments, network **203** may include individual laboratory animal cages **117** with respective devices for monitoring the weight of feed dispensed (and, in some embodiments, consumed) (e.g., food consumption monitoring device **403**) by animal **103** (e.g., a rat) in the respective animal cages **117** (e.g., separate monitoring devices for each of the respective animal cages **117**). FIG. **5** illustrates an embodiment of monitoring devices for monitoring the micro-environments of multiple animal cages **117** in a rack and cage system **405**. The medical or monitoring device may include a rack and cage system **405** including multiple laboratory animal cages **117** and micro-environment monitoring devices attached to respective animal cages **117** to measure conditions within each animal cage **117** (e.g., temperature, humidity, etc). This micro-environment data may be transmitted to computer system **201** (e.g., wirelessly through communications circuitry in the monitoring devices or box **205** coupled to the monitoring devices).

[0050] In some embodiments, medical or monitoring devices may include weight scale **217** used to determine a weight of animal **103**, cage **117**, etc. Other weight determinations are also contemplated (e.g., the weight of a syringe for pump **101** may be weighed in weight scale **217** for transmission to computer system **201**). In some embodiments, computer system **201**, weight scale **217** (and/or other medical or monitoring devices), and pump **101** may form a closed information loop. Other information arrangements are also contemplated. Other medical or monitoring devices are also contemplated (e.g., a Wireless Information Device (WID) reader for animal identification based on an implanted, external, and/or wearable Radio Frequency Identification (RFID) chips) may be used to identify specific animals associated

with a specific animal cage **117** (e.g., with the reader). Medical or monitoring devices may thus include monitoring sensors either implanted in animals **103** or coupled to cages **117** holding animals **103**. Medical or monitoring devices may transmit and receive information to/from computer system **201** (e.g., through wired and/or wireless communications). In some embodiments, pumps **101** (and/or medical or monitoring devices) in network **203** may have unique addresses (e.g., unique Internet protocol (IP) addresses). Other unique address types are also contemplated (e.g., Media Access Control (MAC) addresses). In some embodiments, computer system **201** may use the unique addresses to send/receive information to/from pumps **101** (and/or medical or monitoring devices) to control, monitor, and/or store information associated with pumps **101** (and/or medical or monitoring devices).

[0051] In some embodiments, computer system **201**, pumps **101** (and/or other medical or monitoring devices) may communicate with other computers (e.g., via an intranet or Internet **211**). For example, information from computer system **201** may be sent to server **207** in communication with remote personal computers **209** (e.g., computers **209***a*, **209***b*, and **209***c*) over Internet **211**. In some embodiments, a network of remote computers may communicate with computer system **201** for remote access to data in computer system **201** (e.g., remote computers **209** may communicate with computer system **201** via Internet **211** and/or via server **207** coupled to and/or including computer system **201**). In some embodiments, other remote computers **215** (e.g., computers **215***a*, **215***b*, and **215***c*) may access computer system **201** through server **207**. Remote access may allow operators **401** (e.g., remote operators) to monitor and/or control equipment in the study, access documentation, etc. Other uses for remote access are also contemplated. In some embodiments, computer system **201** may notify an entity (e.g., operator **401**) of the status (e.g., normal or abnormal) of pumps **101** and/or medical or monitoring devices and may allow the entity to control pumps **101** and/or medical or monitoring devices communicating through network **203**. In some embodiments, computer system **201** may notify operator **401** via electronic mail messages, text messages, paging, voice messaging, etc. of a status and, for example, may receive control instructions through operator mobile device **213** (e.g., a phone, PDA, etc).

[0052] In some embodiments, computer system **201** may communicate through wired, wireless, or a combination of wired and wireless network hardware to pumps **101** and/or medical or monitoring devices to program, monitor, and collect data from the pump **101** and/or medical or monitoring devices. The network combinations may include, for example, a data hub communication arrangement (e.g., see FIG. **6**), a rack hub communication arrangement (e.g., see FIG. **7**), a box communication arrangement (e.g., see FIG. **8**), or various subsets and/or combinations of these communication arrangements (other network configurations are also contemplated).

[0053] FIG. **6** illustrates an embodiment of the data hub communication arrangement including pump **101** and/or medical or monitoring devices wired (or wirelessly connected) to data hub **601** (e.g., an external stand-alone data hub). FIG. **6** illustrates an embodiment including rack **405** with multiple cages **117**, integrated direct current (DC) power ports, and a universal, removable power supply (other configurations are also contemplated). FIG. **7** illustrates an embodiment of a rack hub communication arrangement with multiple pumps **101** and/or medical or monitoring devices in rack **405** wired or wirelessly connected to data hub **601** (e.g., an external stand-alone data hub mounted to rack **405**). FIG. **7** illustrates an embodiment of rack **405** with multiple cages **117** and a mounted data hub **601** operable to handle the infusion groups within the single rack **405** (other configurations are also contemplated). In some embodiments, cage rack **405** may also include integrated washable DC power ports and a Universal, removable power supply. Other data hub types and placements are also contemplated. The data hub hardware may include embedded programming instructions operable to allow data input to/from multiple devices (e.g., pump **101** and/or medical or monitoring devices (such as sensors and weight scales), etc.) and to/from computer system **201**. Data hub **601** (e.g., a universal data hub) may be placed on, in or proximate to animal cage **117**, pump **101**, and/or medical or monitoring device (e.g., one data hub **601** per animal cage **117**, one data hub **601** per pump **101**, one data hub **601** supporting multiple animal cages **117** in rack **405**, etc). In some embodiments, a single data hub **601** may be located at each of one or more animal cages **117**. In some embodiments, a single data hub **601** may be coupled to multiple animal cages **117** (e.g., coupled to rack **405**). Other configurations are also contemplated. In some embodiments, pump **101** and/or medical or monitoring devices dedicated to animal cage **117** may communicate bi-directionally with data hub **601** and to computer system **201** (e.g., through data hub **601**).

[0054] In some embodiments, data hub **601** may accommodate multiple wired and/or wireless data platforms and protocols used in pumps **101**, and/or medical or monitoring devices (e.g., Ethernet, RS232, USB, Wi-Fi, Bluetooth, etc). For example, data hub **601** may pass through (and/or convert) communications to/from pumps **101** and/or medical or monitoring devices to/from computer system **201**. In some embodiments, data hub **601** may integrate multiple data sources from pumps **101** and/or medical or monitoring devices into a data stream for transmission to computer system **201** (e.g., wirelessly). In some embodiments, data hub **601** may multiplex various communications from pump **101** and/or medical or monitoring devices to computer system **201**. Computer system **201** may separate the data streams (e.g., using a pre-arranged template shared with data hub **601** and/or a demultiplexer). Other communication formats are also contemplated (e.g., data to/from pump **101** and/or medical or monitoring devices may be transmitted/received as single serial streams). Computer system **201** may transmit information intended for pump **101** and/or medical or monitoring devices to data hub **601** for delivery to the intended pump **101** and/or medical or monitoring devices (these streams may also be combined/multiplexed streams or separate streams). In some embodiments, data hub **601** may support a generic platform to transmit and receive data to/from several different types of platforms (e.g., different pump types, different computer systems, etc). In some embodiments, data hub **601** may include programming instructions to convert data in one platform to another platform prior to sending the data to an intended device.

[0055] In some embodiments, data hub **601** may transmit bi-directional data for a single animal cage **117** to computer system **201** (e.g., via wired or wireless hardware) or data hub **601** may transmit bi-directional data for animal cages **117** in rack **405** to computer system **201** (e.g., via wired or wireless hardware). In various embodiments, a lab animal cage rack **405** (other rack types are also contemplated) may hold mul-

tiple animal cages **117** (e.g., 10, 100, 1000, etc). The cage rack **405** may include power sources **603** (which may be integrated in the cage rack **405**) and wires as well as data communication devices and wires for pumps **101** and/or medical or monitoring devices on animal cages **117**. In some embodiments, power sources **603**, wires, communication devices, etc. may be removable and/or replaceable (in some embodiments, one or more of these devices may be permanently affixed to animal cage **117**). Removable and replaceable power and data components may allow for racks **405** to integrate with pumps **101** and/or medical or monitoring devices while, when removed, allowing for cleaning and, when replaced, reuse of racks **405** and the power and data communication components. Data hubs **601** may reduce workspace clutter (wired and/or wireless) and may reduce the risk of data transmission interference between various devices.

[0056] FIG. **8** illustrates an embodiment of a box communication arrangement with pump **101** and/or medical or monitoring devices respectively connected (e.g., directly connected or connected through a separate piece of hardware) to a removable piece of wireless communications hardware (e.g., box **205**) allowing for wireless bi-directional communication between pump **101** and/or medical or monitoring devices on animal cages **117** and computer system **201**. In some embodiments, boxes **205** (e.g., boxes **205***e*, **205***f*, **205***g*, and **205***h*) may be distributed to several devices. In some embodiments, one or more boxes **205** may be shared by multiple devices. In some embodiments, rack **405** may include multiple cages **117** with integrated DC power ports and a universal, removable power supply (other configurations are also contemplated).

[0057] In some embodiments, a graphical user interface (GUI) (e.g., a browser-based GUI) may be used to allow operator **401** to configure pumps **101** and/or medical or monitoring equipment (e.g., see FIGS. **9-14**) through computer system **201** (or, for example, through remote computers **209***a,b,c* or **215***a,b,c*). The GUI may also allow configuration of the network which may include pumps **101**, communications hardware (e.g., wireless communications hardware for networking pumps **101** to computer system **201**), computer system **201** (e.g., including programming and data collection software), and a network of remote computers (e.g., computers **209***a,b,c*) linked to computer system **201** via Internet **211** and, for example, a network of remote computers (e.g., computers **215***a,b,c*) linked to computer system **201** via server **207**. Other network configurations are also contemplated. As seen in FIG. **9**, a GUI may be provided to assist operator **401** (e.g., a study director, technician, etc.) to set up a study. Information entered into the GUI may be used, for example, by computer system **201** to store information about the study, control the study, etc. As seen in FIG. **10**, operator **401** may set up a password and specify other security parameters for the study. As seen in FIG. **11**, various pumps used in the study may be set-up (e.g., communication paths may be established and/or tested between the pumps **101** and computer system **201**). As seen in FIG. **12**, different operators **401** may be added to a study (e.g., granted access to perform actions on pumps **101** and other equipment, document actions performed, etc). User identifiers **1201** may also be assigned to respective operators **401**. As seen in FIG. **13***a*, operator **401** may assign respective pumps **101** to respective animals **103** (or vice versa). For example, computer system **201** may poll pumps **101** coupled to network **203** and pumps **101** may respond, for example, with a pump ID (see, for example, pump IDs on the left side of FIG. **13***a*). In some embodiments, computer system **201** may access respective animal IDs (e.g., from a data file, from animal RF identification chips scanned from animals **103**, manually from operators **401** (e.g., reading animal tattooed IDs), etc). The animal IDs may also be listed (e.g., see the right side of FIG. **13***a*). In some embodiments, operator **401** may assign the animal IDs to their respective pumps **101**. For example, the animal ID on the right side of the screen may be dragged and dropped onto the corresponding pump ID of respective pump **101** from which respective animal **103** is receiving substance **119**. In some embodiments, pump IDs and/or animal IDs may be related to each other by operator **401** (e.g., by entering respective IDs in text boxes of the graphical user interface). In some embodiments, RFID readers assigned to respective cages **117** may scan RF animal ID chips and send the animal ID back to computer system **201** along with the respective pump ID for respective pump **101** providing substance **119** to cage **117** with animal **103** having the respective animal ID. Other assignment processes are also contemplated. As seen in FIGS. **13***b*-**14**, operator **401** may navigate the GUI to check on a status of pumps **101** and other equipment in the study, send instructions to pumps **101** and other equipment in the study, etc.

[0058] FIG. **17** illustrates a flowchart of a method for controlled delivery rate determination and global command rate distribution, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0059] At **1701**, animal weight data may be received (e.g., by computer system **201**, box **205**, etc). In some embodiments, weight data may be received from weight scale **217**. Weight scale **217** may be integrated into animal cage **117** (e.g., coupled to animal cage **117** or to tether **115** for passive automatic weight data collection) or may be external (e.g., animal cage **117** may be placed on top of (or hung from) weight scale **217** by operator **401**). In some embodiments, multiple pumps **101** may be associated with a specific weight scale **217** (e.g., 10 pumps **101** assigned to one weight scale **217** physically located nearby). For example, operator **401** may place each animal **103** (e.g., in turn) associated with the pumps **101** on the weight scale **217** for measurement (or may place respective animal **103** from pump **101** on weight scale **217**). In some embodiments, weight data from weight scale **217** may be communicated to computer system **201**. For example, computer system **201** may receive weight data from weight scale **217** through data hub **601** and/or box **205** coupled to weight scale **217**. As another example, weight scale **217** may be coupled to pump **101** and weight data from weight scale **217** may be sent to pump **101** (or box **205** coupled to pump **101**) for communication to computer system **201**. In some embodiments, the weight data may be automatically communicated to computer system **201** and stored in a database (e.g., an operator's project software database). In some embodiments, the weight data may be sent to computer system **201** when an instruction is received by weight scale **217** or pump **101** (e.g., from operator **401**). As another example, in some embodiments, the weight data may be sent in response to a query from computer system **201**. Other weight data sources are also contemplated. For example, animal weight data may be received from a customer database on a server, from a database in a computer hosting infusion

system, etc. Computer system **201** may query a database for the weight data to be imported into computer system **201**. In some embodiments, operators **401** may load the data directly into computer system **201** (e.g., by inserting a Compact Disc (CD) with the weight data, manually entering the weight data, etc). In some embodiments, new weight data may be received as new animal weights are determined. For example, animals **103** may be weighed continuously or at intervals (e.g., animal **103** may be weighed daily, weekly, monthly, etc). In some embodiments, animal weights and respective animal weights may not be determined (e.g., if the controlled delivery rates are not weight based).

[0060] At **1703**, the weights for respective animals **103** may be determined. Animals **103** may be associated with specific pumps **101** and computer system **201** may associate weight data with respective pumps **101**. For example, if weight scale **217** is coupled to or assigned to one respective pump **101**, the weight data received from that weight scale **217** may be associated (e.g., in a database) with animal **103** at that respective pump **101**. In some embodiments, (e.g., if multiple pumps **101**/cages **117** are assigned to weight scale **217**) identifiers (e.g., entered by operator **401** into weight scale **217**, scanned by an RFID scanner when animal **103** with an embedded RFID chip containing the identifier is placed on weight scale **217**, etc.) may be sent with the weight data to computer system **201** as the animals **103** (or cages **117**, etc.) are weighed to associate the received weight data with the respective animal **103**/pump **101**. In some embodiments, identifiers may be stored in the database with the weight data to associate the weight data with respective animals **103** and/or pumps **101** (respectively assigned to animals **103**). In some embodiments, identifiers may not be used. For example, weight data may be associated with respective animals **103** according to an order the weights were entered (which may correspond to a predetermined order of pumps **101** in relationship to the weight scale **217**). For example, 10 pumps **101** may be assigned to a weight scale at the end of the row of pumps **101**. When the animals **103**/cages **117** are weighed, operator **401** may always start with the cage farthest from weight scale **217** and proceed down the line of cages **117** to the cage nearest weight scale **217** (computer system **201** may be aware of the order of cages **117** and may assign the weights to respective animals **103** according to the order the weights were received. Other weight associations are also contemplated. The animal **103** may be weighed on weight scale **217** directly or, for example, cage **117** and be weighed and the animal's weight may be derived (e.g., by subtracting a predetermined weight of the empty cage). Other weight data sources are also contemplated (e.g., the weight data may be imported from a separate software program or database, manually entered, etc).

[0061] At **1705**, controlled delivery rate group determinations may be made for the respective animals **103**. In some embodiments, animals **103** may be assigned to different study groups (e.g., high dose group, mid-dose group, low dose group, and control, etc). Group assignments may be downloaded to computer system **201** (e.g., from an external computer), manually entered (e.g., by operator **401**), or determined according to criteria (e.g., entered by operator **401**). For example, operator **401** may specify **1000** cages will be used in the study and 25% are to be assigned to a high dose group, 25% to a mid dose group, 25% to a low dose group and 25% to a control group. This criteria may also be downloaded from an external source. Computer system **201** may have access to (or may determine) which pumps **101** are currently communicatively coupled to computer system **201** (e.g., through a broadcast query and subsequent pump responses) and the pumps **101** may be initially assigned to different respective groups (e.g., computer system **201** may determine and store assignments in a database for later access). In some embodiments, respective controlled delivery rates (e.g., [dose/time]/kg×animal weight ([ml/hr]/kg×kg of animal weight)) may be associated with respective groups of animals. For example, the respective controlled delivery rates may be downloaded from an external source, manually entered by operator **401**, etc. Additional study parameters may also be received and/or determined. For example, an amount of time to deliver the respective doses may also be received (e.g., downloaded from an external source, manually entered by operator **401**, etc). For example, computer system **201** may receive and store an indication that the specified controlled delivery rates are to be delivered for one hour a day. Computer system **201** may also receive the total trial length (e.g., 30 days). In some embodiments, complex profiles may be received (e.g., controlled delivery rate for one hour per day for 15 days and 2 hours per day for 15 days). Other profiles are also contemplated. Computer system **201** may store controlled delivery rates, time periods, profiles, etc. to be used in determining controlled delivery rate for respective animals **103** in the study.

[0062] At **1707**, the controlled delivery rate for animal **103** may be determined based, for example, on the animal's weight and the controlled delivery rate group determination (e.g., the controlled delivery rate assigned to the animal's group). For example, for a specific animal **103** in a high dose group, a predetermined controlled delivery rate of [100 ml/hr]/kg×kg of body weight may be assigned (e.g., by computer system **201** based on received data). In this example, if the weight data for the specific animal **103** indicates the specific animal **103** weighs 0.7 kg, the controlled delivery rate for a pump **101** pumping substance **119** to the specific animal **103** is [100 ml/hr]/kg * 0.7 kg=70 ml/hr. Computer system **201** may also use the received time periods to determine a dose per time period of delivery. For example, study parameters may specify the high dose group should receive the specified controlled delivery rate for 1 hour a day. In the above example, computer system **201** may then prepare a profile with instructions for respective pump **101** to deliver 70 ml of substance **119** to respective animal **103** for one hour every 24 hours. Study parameters may also specify the animals **103** are to receive saline solution during the hours animals **103** are not receiving substance **119** in order that the positive saline flow reduces the risk of catheter clotting. Other controlled delivery rate calculations are also contemplated for the other groups (e.g., mid dose, low dose, etc). Other time periods may also be used (e.g., 2 hrs/day, 2 min/day, 1 hour every 3 days, etc). In some embodiments, computer system **201** may determine multiple respective profiles with instructions for respective animals in the study according to their respective weights and their respective dose groups.

[0063] At **1709**, the profiles for respective animals **103** may be delivered to the respective pumps **101**. In some embodiments, the profiles may include respective controlled delivery rates, relevant time periods for delivery (e.g., indicating number of hours every 24 hours for delivery and total study period), start/stop times, etc. In some embodiments, a global command may instruct computer system **201** to send the multiple profiles to their respective pumps **101** (e.g., in some

embodiments, all of the pumps **101** in the study may receive their specific profile from computer system **101**). In some embodiments, a subset of pumps **101** may be sent their respective profiles in response to the global command (e.g., the global command may instruct computer system **201** to send profiles to pumps **101** in the high dose group). As another example, the global command may instruct computer system **201** to send profiles to pumps **101** with animals in a certain weight group (e.g., with animals **103** having weights between 0.5 kg and 0.6 kg) or to animals of a certain gender (e.g., all male animals). Other groups are also contemplated. In some embodiments, multiple groups may be specified (e.g., profiles may be sent to the low dose group and the placebo group in response to receiving the global command). In some embodiments, multiple profiles may be pushed to their respective pumps **101** after performing a sequence of calculations (e.g., by computer system **201**) to generate the multiple profiles. In some embodiments, operator **401** may indicate when to send the profiles (e.g., by pressing a button (or by some other input) on computer system **201** (e.g., to select an on screen menu item), sending a command to computer system **201** from a remote device, etc). As part of the global command, operator **401** may also specify which groups (or, for example, all of the pumps **101**) to send profiles. In some embodiments, computer system **201** may deliver infusion rate commands (e.g., including controlled delivery rates based on the animals weight and determined group weight-based controlled infusion rates) to pumps **101** individually instead of in groups.

[0064] Other global commands are also contemplated. For example, a global command may instruct computer system **201** to send other instructions to multiple pumps **101** and/or medical or monitoring devices on the network. For example, the global command may cause computer system **201** to send other instructions to pumps **101** instead of or in addition to inputting commands (e.g., by operator **401**) to pumps **101** on a one-by-one basis. In some embodiments, the global command may instruct computer system **201** to send inquiries to pump **101**, a group of pumps **101**, or all of pumps **101** in the study. For example, upon receiving an indication from operator **401**, computer system **201** may request information from a group of pumps **101** (such as current amount of delivery time remaining, last calibration date, etc). In some embodiments, the global command may reduce the manpower needed to perform and send the calculations, reduce manual calculation errors, and reduce manual data input errors. In some embodiments, the global command may be used to automate scheduling to reduce scheduling errors by including start/stop times with the profiles delivered to respective pumps.

[0065] In some embodiments, the instructions for determining a controlled delivery rate may be included in box **205** (or, for example, internally to pump **101**). Pumps **101** may determine their respective controlled delivery rate based on the stored instructions, the animal weight (e.g., received at pump **101** from weight scale **217**), and other information (e.g., the dose/body weight for animal **103** associated with respective pump **101**, times for delivery, etc). In some embodiments, pumps **101** may perform the calculations to determine their own controlled delivery rates (e.g., computer system **201** may send a global command to pumps **101** to calculate their controlled delivery rates). In some embodiments, the calculated controlled delivery rates (and, for example, animal weight data) may be sent by pumps **101** to computer system **201** (e.g., for storage and/or validation). Other locations for controlled delivery rate determination are also contemplated.

[0066] FIG. **18** illustrates a flowchart of a method for pump validation, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0067] At **1801**, computer system **201** may receive an indication of an acceptable validation deviation. For example, operator **401** may indicate that an acceptable validation deviation of +/−1% of actual syringe weight difference (before and after substance delivery) compared to calculated syringe weight difference (based on pump determined substance delivery and substance density) is acceptable. In some embodiments, the acceptable validation deviation may be received from other sources (e.g., downloaded from a remote computer). Acceptable validation deviations may also be specified in other terms. For example, an acceptable validation deviation may include +/−X % of actual controlled delivery rate (e.g., determined using the difference in syringe weights, density of substance **119**, and start/stop times from pump **101**) compared to provided/calculated controlled delivery rate (e.g., the controlled delivery rate provided to pump **101**). Other acceptable validation deviations are also contemplated. Acceptable validation deviations may be provided in non-percent indicators. For example, operator **401** may be prompted to enter an acceptable validation deviation as a difference in weight (e.g., +/−X ml) between the actual volume output and the provided/calculated volume output (e.g., X=actual volume−volume provided to pump **101** in profile instructions). Other sources of acceptable validation deviations are also contemplated. In some embodiments, a range of acceptable validation deviations may be received.

[0068] At **1803**, computer system **201** may receive a beginning syringe weight. In some embodiments, operator **401** may place syringe **109** on weight scale **217** prior to delivering substance **119**. For example, operator **401** may place syringe **109** for pump **101** on a shared weight scale **217** (e.g., shared with other pumps **101**). In some embodiments, the weight (and, for example, a pump identifier) may be sent to computer system **201** by weight scale **217**. In some embodiments, weight scale **217** may be built into pump **101** to weigh syringe **109** without syringe **109** having to be removed from pump **101** (the weights (and/or weight difference) may be sent to computer system **201** by pump **101**).

[0069] In some embodiments, operator **401** may be prompted to enter a beginning syringe weight. For example, operator **401** may enter the weight into computer system **201** or into pump **101** (e.g., for delivery to computer system **201**). For example, operator **401** may place syringe **109** on weight scale **217**, see weight of syringe **109** (e.g., on a display of weight scale **217**), and may enter the weight in, for example, pump **101** associated with animal **103** or computer system **201**. Other sources of the beginning syringe weight are also contemplated. In some embodiments, weight scale **217** on, in, or proximate to animal cage **117** or pump **101** (e.g., one weight scale **217** per pump **101** or animal cage **117** or one weight scale **217** per a group of pumps **101** or animal cages **117**) may communicate weights of syringe **109** to computer system **201** (e.g., through box **205** coupled to the weight scale

217). For example, weight scale **217** may determine a weight of syringe **109** prior to delivering substance **119** to animal **103**.

[0070] At **1805**, computer system **201** may receive an ending syringe weight. In some embodiments, weight scale **217** may determine a weight of syringe **109** after delivering substance **119** to animal **103** (e.g., operator **401** may place syringe **109** on weight scale **217** after the delivery time period or weight scale **217** may be built into pump **101**). In some embodiments, operator **401** may be prompted to enter ending syringe weight. For example, operator **401** may place syringe **109** on weight scale **217**, see weight of syringe **109** (e.g., on a display of weight scale **217**), and may enter the weight in, for example, pump **101** associated with animal **103** or computer system **201**. Other sources of the ending syringe weight are also contemplated.

[0071] At **1807**, computer system **201** may compare the actual volume output (determined using the substance density and the difference in the beginning syringe weight and the ending syringe weight) to a nominal volume output (e.g., an expected volume output based on the calculated controlled delivery rate delivered to pump **101** by computer system **201** prior to delivery).

[0072] At **1809**, computer system **201** may compare the actual controlled delivery rate (e.g., using substance density, difference in the beginning syringe weight and the ending syringe weight and a received actual start time and end time from pump **101**) to a nominal controlled delivery rate (e.g., based on the calculated controlled delivery rate delivered to pump **101** by computer system **201**). In some embodiments, computer system **201** may receive a start and stop time (or, for example, a total time of delivery) to use with the received weights to calculate the pump's actual controlled delivery rate. In some embodiments, computer system **201** may compare an actual controlled delivery rate (e.g., ((beginning syringe weight−ending syringe weight)/substance density/(stop time−start time)) to a calculated/provided delivery controlled delivery rate (e.g., calculated by computer system **201** prior to substance delivery and provided to pump **101** as the respective controlled delivery rate for respective animal **103**) to determine an accuracy of pump **101**. Other information may also be sent to computer system **201** (e.g., a controlled delivery rate determined locally by pump **101**). Other controlled delivery rate determination calculations are also contemplated. For example, computer system **201** or pump **101** may use a displacement volume and delivery time to determine an actual controlled delivery rate. The displacement volume may be determined using dimensions of syringe **109** (e.g., radius of a cylindrical syringe) and, for example, the amount of plunger displacement (e.g., indicated by a sensor on pump **101**) (where displaced volume may equal the amount of displacement * internal area (e.g., π * radius^2). The actual controlled delivery rate may be represented by the displaced volume over time of displacement (e.g., as determined by start and stop times). In some embodiments, information such as the dimensions of syringe **109** may be received by computer system **201** (e.g., from pump **101** detecting a diameter of syringe **109**, operator **401**, or other external source).

[0073] At **1811**, computer system **201** may determine if the comparisons of the actual volume output to the nominal volume output and/or the comparisons of the actual controlled delivery rate to the nominal controlled delivery rate fall within the acceptable validation deviation (e.g., as determined/received at **1801**). For example, the actual controlled delivery rate may be compared to the nominal controlled delivery rate (e.g., the controlled delivery rate provided to pump **101** by computer system **201** for the corresponding time period (or, for example, the controlled delivery rate calculated by pump **101** for the corresponding time period)). In some embodiments, comparison may include subtracting the actual volume output from the nominal volume output (or vice versa) and comparing the difference to an acceptable validation deviation (which may include a range of acceptable differences between the actual volume output and the nominal volume output). In some embodiments, comparison may include subtracting the actual controlled delivery rate from the nominal controlled delivery rate (or vice versa) and comparing the difference to an acceptable validation deviation (which may include a range of acceptable differences between the actual controlled delivery rate and the nominal controlled delivery rate). Other statistical comparisons are also contemplated. As another example, the weight (or, for example, volume) of actual substance **119** delivered (collected infusate) may be plotted versus time along with a plot of the weight (or, for example, volume) of substance **119** that would be delivered versus time according to the nominal controlled delivery rate. In some embodiments, operator **401** may review the plots for semi-automatic validation. In some embodiments, accuracy may be provided as a +/−X % accuracy (e.g., representative of the difference between the actual controlled delivery rate and the nominal controlled delivery rate). In some embodiments, the validation may be fully automatic (e.g., computer system **201** may compare statistics of the validation against acceptable validation ranges). In some embodiments, indications of the success or failure of validation may be presented to operator **401**. For example, accuracies falling out of the acceptable ranges may be reported (e.g., to operator **401**) as pump **101** failing validation. Validation may be performed prior to (e.g., with a dummy substance **119**), during (e.g., with the actual substance **119** delivered to animal **103**), and/or after a lab animal infusion study. In some embodiments, each pump **101** may be validated or a sampling of pumps **101** may be validated. In some embodiments, if pump **101** fails validation, pump **101** may not be used until successfully validated. In some embodiments, automated validation may reduce the manpower needed to perform and send the calculations, reduce manual calculation errors, and reduce manual data input errors. In some embodiments, the validations may be performed according to an automated schedule to reduce scheduling errors. In addition, automated validations may allow for an increased validation frequency (e.g., pumps **101** may be validated before a study, one or more times during the study, and after the study).

[0074] In some embodiments, pumps **101** may be calibrated (e.g., on a regular basis such as once a year). Calibration may include testing controlled delivery rate accuracy over a period of time (e.g., comparing actual pump controlled delivery rate to instructed pump controlled delivery rate). Calibration may further include comprehensive periodic checks to confirm proper pump functioning (e.g., several aspects of pump **101** may be checked with sensors, etc. to insure proper functioning). In some embodiments, information related to the next calibration may be stored, for example, on computer system **201**, pump **101**, box **205**, etc. Calibration information may include a date pump **101** was last calibrated, a next date pump **101** should be calibrated by, etc. Calibration

information may be stored, for example, in firmware in pump **101** (or, for example, coupled to pump **101** (such as in memory **305**)). Calibration information may also be included on an outside of pump **101** (e.g., written on a pump label). Computer system **201** (or executable instructions on box **205**, etc.) may check the calibration information (e.g., prior to the beginning of a study) and may indicate (e.g., to operator **401**) pumps **101** that have surpassed their calibration interval (or will surpass their calibration interval during the study). For example, if the calibration dates are stored at pumps **101**, computer system **201** may poll pumps **101** in the network for their calibration dates to determine if any of pumps **101** are outside of their calibration period or will be outside the calibration period at any time during the next study. In some embodiments, computer system **201** (or, for example, box **205**) may prevent use of pump **101** until pump **101** is calibrated and the information stored for pump **101** indicates that the calibration is current. In some embodiments, a calibration database may include pump identifiers and respective calibration dates for pumps **101** (e.g., the calibration dates may not be stored in the pumps **101**). In some embodiments, operators **401** may read calibration information on pump **101** (e.g., on an outer label) and may enter the calibration information into an interface on pump **101** and/or computer system **201** to be stored. Computer system **201** may poll pumps **101** to determine pump identifiers (indicating which pumps **101** are currently coupled to the network) and compare this list of pumps **101** to the calibration database to determine if the current pumps **101** have current calibration dates. Computer system **201** may alert operator **401** as to which pumps **101** have calibration problems to allow operator **401** to replace and/or calibrate the problem pumps **101**. In some embodiments, computer system **201** (or, for example, box **205**) may calibrate pump **101** (e.g., using techniques described above). Other calibration techniques are also contemplated. Automating the calibration check may save time, assure compliance with documentation requirements, and reduce the risk of human error.

[0075] FIG. **19** illustrates a flowchart of a method for automated syringe filling, according to an embodiment. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0076] At **1901**, syringe **109** to be filled may be loaded onto pump **101**. For example, computer system **201** may instruct operator **401** to load syringe **109** onto a filling pump (which may be a pump **101**). In some embodiments, computer system **201** may instruct operator **401** to attach a vat holding substance **119** to be loaded into syringe **109** to pump **101** (or the vat may already be attached to syringe **109** on pump **101**). In some embodiments, pumps **101** at animal cages **117** may fill syringe **109** (e.g., operator **401** may carry the vessel from pump **101** to pump **101** and the filling instructions may be sent by computer system **201** to respective pump **101**). For example, pump **101** may be a bi-directional pump **101** capable of pulling the appropriate fluid volume into syringe **109** (e.g., by pulling plunger of syringe **109** to fill syringe **109**). In some embodiments, pump **101** for filling syringe **109** may be located next to respective animal cage **117** or may be a separate pump **101** (e.g., communicatively coupled to computer system **201** but not necessarily at animal cage **117**).

[0077] At **1903**, computer system **201** may determine an amount of substance **119** to be filled into syringe **109**. For example, computer system **201** may determine an amount of substance **119** needed for a next round of delivery for a respective animal **103** (e.g., based on a controlled delivery rate assigned to animal **103**). In some embodiments, computer system **201** may determine an amount of substance **119** to be delivered by pump **101** during a next phase of the study and the amount may be communicated to pump **101**.

[0078] At **1905**, filling pump **101** may fill syringe **109** with the amount of substance **119** directed by computer system **201**. For example, pump **101** may pull the syringe plunger backward to aspirate fluid (e.g., substance **119**) from a vessel into syringe **109** until the directed amount is in syringe **109**. In some embodiments, the filling pump **101** may operate in a reverse direction of pumps **101** delivering substance **119** to animal **103** (e.g., at the animal cages **117**). Pump **101** may aspirate an appropriate volume of substance **119** on an animal-by-animal (pump-by-pump) basis (e.g., for different syringes **109**). In some embodiments, operator **401** may instruct pump **101** (e.g., at animal cage **117**) to enter a filling mode and pump **101** may receive data from computer system **201** for the proper fill amount. In some embodiments, pump **101** may be controlled by computer system **201** (or, for example, box **205** coupled to pump **101**) to load syringe **109** with a predetermined amount of substance **119**. Pump **101** and/or computer system **201** may also specify to operator **401** what type of substance **119** to load into syringe **109** (and operator **401** may attach the appropriate vat of substance **119**). In some embodiments, operator **401** may receive an indicator such as "Vat A" instead of or in addition to the specific type of substance **119** to load into syringe **109** (e.g., in a blind study). In some embodiments, syringe **109** may be loaded several times a day.

[0079] At **1907**, an indicator may be provided on syringe **109**. For example, operator **401** may write the animal identification (ID) (e.g., of the respective animal to receive the substance) and sequence of use data on syringe **109**. As another example, an attached printhead may apply the data onto syringe **109** (e.g., automatically and/or by operator **401**) (which may be printed directly on the syringe **109** or on a label to be coupled to the syringe **109**). In some embodiments, operator **401** may apply a label generated by an attached label printer. In some embodiments, a printer (e.g., coupled to computer system **201**, pump **101**, etc.) may print a label for syringe **109** (e.g., with a pump identifier, the substance type, amount, animal identifier, etc.) Other information may also be printed onto the label. The label may be attached to syringe **109** (e.g., by operator **401**). In some embodiments, a separate pump **101** may be used to fill syringes **109** (e.g., at a dedicated filling station (which may also have a printer)). Other filling techniques are also contemplated. Automating filling the syringe may decrease manpower needed to fill the syringe, reduce manual calculation errors and reduce manual data input errors.

[0080] In some embodiments, computer system **201** may display and/or print out a list (e.g., list **1505** in FIG. **15***b*) of dosages for future syringes **109**. For example, computer system **201** may determine a dosage amount needed for multiple syringes **109** based on the respective animal weights, dosage ratios, etc. The dosage (e.g., a substance volume) for each syringe **109** may be displayed and/or printed with an identifier for pump ID, animal ID **103**, dosage, approximate time/day for next syringe change, syringe type (e.g., syringe vol-

ume), etc. The displayed or printed list **1505** may allow operator **401** to pre-load syringes **109** in advance (e.g., without performing additional calculations). In some embodiments, animals **103** may be reweighed weekly (or other time interval) and the future syringes **109** for a week may be displayed (beyond a week, computer system **201** may need a new weight for animal **103** and therefore, may not be able to provide a listing past the current week). Other weigh in times (e.g., continuous, once a day, once a month, etc.) are also contemplated. The future syringe print outs may reduce manpower needed to perform the calculations, reduce manual calculation errors, and reduce manual data input errors.

[0081] In some embodiments, pump **101** may measure a size of syringe **109** (e.g., may detect a diameter of syringe **109**). Pumps **101** may include a mechanism for determining a diameter of a loaded syringe **109** (e.g., a lever arm coupled to a gear to measure the diameter of syringe **109**). In the lever arm example, the gear may detect a displacement of the lever arm when syringe **109** is placed between the lever arm and pump **101**. Other diameter detections are also contemplated. A study may use a syringe of saline solution in an intermittent infusion profile (or a KVO (Keep Vein Open) solution to prevent catheter clotting) and a different sized syringe for a test article (TA) solution (e.g., the new chemical entity to be tested). Syringe **109** with the KVO solution may have a larger diameter than syringe **109** for the test solution. For example, the KVO solution syringe may be a 20 cubic centimeter (cc) syringe used to deliver saline solution to animal **103** for 23 hours and the test solution syringe may be a 5 cc syringe used to deliver a test solution to animal **103** for one hour. Other sizes and times are also contemplated. In some embodiments, pump **101** may detect the size (e.g., diameter and/or length) of syringe **109** in pump **101** and, if syringe **109** size does not correspond to syringe **109** that pump **101** is assigned to be pumping (e.g., as noted by instructions from computer system **201** stored, for example, in the box memory), pump **101** may give operator **401** an indicator, sound an alarm, and/or not pump syringe **109**. Pump **101** may reduce human loading error to insure compliance with the provided infusion profile. In some embodiments, operator **401** may input information about syringe **109** (e.g., type of syringe, brand of syringe, size of syringe, syringe identifier, etc.) into pump **101** and/or computer system **201**. The information may be stored and/or used to verify that the correct syringe **109** has been loaded.

[0082] FIG. **20** illustrates a flowchart of an embodiment for study documentation. Computer system **201** may communicate with pumps **101** and/or other medical or monitoring devices involved in the study to document events occurring in the study (e.g., start times, stop times, alarms, how alarms were cleared, animal weights, amount of feed/water consumed, etc). These events may also be stored with respective user identifiers **1201** to identify operators **401** associated with the events (e.g., to identify operator **401** who cleared an alarm). The documentation may be used to support the validity of the study. It should be noted that in various embodiments of the methods described below, one or more of the elements described may be performed concurrently, in a different order than shown, or may be omitted entirely. Other additional elements may also be performed as desired.

[0083] At **2001**, user identifier **1201** may be received at computer system **201**. In some embodiments, operator **401** may enter user identifier **1201** (e.g., an identifier such as a PIN code or, for example, a pre-assigned (by computer system **201**) alpha numeric user code unique to operator **401**) into pump **101** and/or medical or monitoring device. Other user identifiers **1201** are also contemplated (e.g., operator **401** may enter their name as user identifier **1201**, scan a bar code (e.g., on the operator's uniform), swipe a magnetic card with user identifier **1201**, biometric scan (e.g., scanning an user's thumbprint or retina), Radio Frequency Identification (e.g., transmitted from a PDA, etc)). User identifier **1201** may be sent to computer system **201** for storage relative to the actions performed by (or other documentation submitted by) operator **401**. For example, in responding to an alarm, operator **401** may enter user identifier **1201** (e.g., into the pump interface or into computer system **201**) assigned to that operator **401** prior to taking action to correct the alarm. The alarm may be indicated on computer system **201** and/or a communication (such as an email, short message service (SMS), etc.) may be sent to operator **401**. The communication may include a pump identifier and an alarm type indicator (e.g., indicating why the alarm sounded). For example, if a pressure transducer on pump **101** detects an occlusion in the delivery tube, pump **101** may indicate an alarm and send a communication.

[0084] At **2003**, operator **401** may be authenticated based on the received user identifier **1201**. In some embodiments, user identifier **1201** may be used by pump **101** (or, for example, computer system **201**, etc.) to authenticate operator **401** prior to allowing operator **401** to take action on pump **101**. User identifier **1201** may thus act as user stamp/e-signature for the actions taken by operator **401**. In some embodiments, operator **401** may be authenticated prior to taking action on other devices (e.g., computer system **201**, medical devices, monitoring devices, animal cage **117**, etc). In some embodiments, authentication may include comparing the received user identifier **1201** to user identifiers **1201** stored in an authentication database. Other authentication is also contemplated. In some embodiments, user identifiers **1201** may be changed for each study (e.g., by a study administrator who may set up which operators **401** are authorized to interact with the study equipment).

[0085] At **2005**, computer system **201** may receive a documentation indicator associated with pump **101** (or other equipment). For example, documentation indicators (e.g., see documentation indicator **1601** in FIG. **16**) may correspond to events (such as starting pump **101**, responding to an alarm, stopping pump **101**, etc.) and actions taken by operators **401** in response to the events. Documentation indicators **1601** may also correspond to information related to general and/or specific observations by operator **401** (e.g., animal **103** is sick) which may or may not be event specific. Documentation indicators **1601** may include a cause of an alarm. Alarms (e.g., as discussed above) may occur when equipment (e.g., pump **101**) or other variables (e.g., health conditions of animal **103**) in the study encounter a problem. For example, pump **101** may encounter a problem such as occlusion in delivery tube **105**, low battery, no power, empty syringe, etc. When problems occur, an alarm may sound (or in some way be indicated to operator **401**). Actions taken to clear an alarm may be entered (e.g., by operator **401** into a graphical interface on pump **101** or computer system **201**) and a corresponding documentation indicator **1601** may be assigned. In some embodiments, operator **401** may be presented with menu (e.g., a drop down menu) and other options at computer system **201** and/or pump **101** (operator may have flexibility to document the event and/or enter other information (e.g., observations and/or non-event related information) at pump **101** or computer system **201**). The menu may be specific to

the type of alarm encountered. For example, if an alarm is triggered because of a kinked delivery tube, the alarm menu provided to operator **401** may include options for how the kinked delivery tube was fixed (e.g., "1: Tube unkinked"; "2: Tube replaced"; "3: Other"). In some embodiments, pump **101** may determine what caused the alarm, the actions taken by operator **401** to fix the alarm, etc. and may transmit appropriate documentation indicators **1601** to computer system **201**. In some embodiments, operators **401** may enter documentation indicators **1601** indicative of what caused the alarm, the actions taken to clear the alarm, etc. into a pump interface (and/or computer system interface). Other interfaces are also contemplated (e.g., operators **401** may enter documentation indicators into a PDA which may transmit the documentation indicators **1601** to computer system **201** and/or pump **101** (e.g., to be transmitted to computer system **201**)). Documentation indicators **1601** may also be stored relative to events not corresponding to an operator's actions (e.g., documentation indicator **1601** may be stored to indicate the occurrence of the alarm). Documentation indicators **1601** may be textual descriptions (e.g., "Alarm cleared by refilling syringe"). Documentation indicators **1601** may also be numerical or alpha-numerical (e.g., numbers or alpha numeric entries linked to textual description, for example, through a look-up table). Other documentation indicators **1601** are also contemplated. In some embodiments, operators **401** may define menus and menu selections for receiving documentation indicators. For example, operators **401** may define a menu for a specific type of alarm and the menu may be provided to pump **101** for presentation the next time that alarm is triggered. Operator **401** may respond to the alarm by entering appropriate menu selections and the information may be stored in computer system **201** as documentation indicators (e.g., along with the respective user identifiers **1201**).

[0086] At **2007**, computer system **201** may store user identifier **1201** and documentation indicator **1601**. In some embodiments, computer system **201** may store corresponding documentation indicators **1601** for the operator's actions. Operator **401** may respond to the alarm and indicate on pump **101** (e.g., using a pump keypad and menu options presented on the pump display) the cause of the problem and/or how the problem was fixed. Information about the alarm, the technician identification (e.g., user identifier **1201**), how the alarm was fixed, etc. may be entered into computer system **201** by operator **401** or may be entered into pump **101** and relayed to computer system **201** to be stored (e.g., in an electronic log) (see, for example, FIG. **16**). Computer system **201** may store user identifiers **1201** with the corresponding documentation indicators **1601** (and, for example, a pump identifier or other device identifier).

[0087] At **2009**, computer system **201** (and/or pump **101** or other equipment) may require a separate user identifier **1201** for separate documentation indicators **1601** to be stored with the separate documentation indicators **1601**. In some embodiments, operator **401** may enter their user identifier **1201** prior to each action operator **401** takes on pump **101** (or in relationship to animal cage **117**, medical, and/or monitoring device). In some embodiments, operator **401** may be required to enter user identifier **1201** prior to any intervention with pump **101** (or other equipment). For example, if user identifier **1201** for operator **401** is "231" and operator **401** starts and stops pump **101**, operator **401** may be required to enter "231" prior to pressing a button to start pump **101** and enter "231" again prior to stopping pump **101**. Computer system **201** may log documentation indicators **1601** with user identifiers **1201** (e.g., "231 start pump; **231** stop pump"). In some embodiments, computer system **201** may store a time and/or date with documentation indicators **1601**. In some embodiments, computer system **201** may prompt operator **401** for additional documentation at computer system **201**. For example, in clearing an alarm, operator **401** may indicate at pump **101** "other" for how alarm was cleared (e.g., using menu options provided at pump **101**). Computer system **201** may then blink a screen of computer system **201**, provide an alert indicator, or in some other fashion request additional description from the operator **401** as to how the pump alarm was cleared (or for other prior pump or equipment interactions). Operator **401** may enter one or more phrases, sentences, etc. in a text box that may be saved with log information for the respective pump **101**. Other documentation may also be required of operator **401** (e.g., documentation may be requested for why pump **101** was stopped, why animal **103** was removed from animal cage **117**, etc). In some embodiments, pump **101** may require operator **401** to enter information about the alarm (e.g., cause of problem, how the problem was fixed, etc.) prior to allowing operator **401** to continue pump operations (e.g., restart pump **101**). This may force documentation of the alarm and the solution. In some embodiments, operator **401** may select "Other" in the menu options of the alarm. Operator **401** may then be prompted (e.g., at computer system **201**) to enter additional information (e.g., a written statement of the problem solution) at computer system **201**. In some embodiments, operator **401** may be required to enter the additional documentation before the pump **101** will be allowed to resume. In some embodiments, computer system **201** may prevent operator's future access to computer system **201** or pump **101** until the required documentation is entered. This may improve documentation by reducing human error (intentional and inadvertent) and enforcing compliance with protocols for documentation including documentation requirements.

[0088] In some embodiments, a graphical profile of a substance delivery for a respective pump **101** may be displayed by computer system **201**. For example, as seen in FIG. **15**, the amount of the substance delivered (Y axis) over time (X axis) may be plotted as graphical profile line **1501**. The Y axis may also be substance volume/body weight and the graphical profile may represent substance volume per weight per time unit. The graphical profile may make it easier for operator **401** to see when the syringe changes occur, what types of syringes are being exchanged (e.g., size of syringes being exchanged), etc. The profile may present a preview (e.g., which may be printed out) for one or more pumps for the study. The graphical profile may assist operator **401** in confirming proper infusion profile input and better visualize a sequence of future pump activities.

[0089] In some embodiments, indicator **1503** may be displayed on the graphical profile to indicate a current status of the substance delivery (e.g., where in the profile the current pump **101** is in the study (e.g., see line **1503**)). Line **1503** may be in a different color (e.g., red) than graphical profile line **1501**. Other graphical indicators **1503** are also contemplated (e.g., asterisk, arrow, etc). In some embodiments, by viewing indicator **1503**, operator **401** may be able to graphically determine a current controlled delivery rate and substance type being delivered by the selected pump **101** (operator **401** may also select other respective pumps **101** to view their respec-

tive profiles). In some embodiments, indicator **1503** may assist operator **401** in determining what point in the infusion profile pump **101** is current operating. For example, operator **401**, upon viewing indicator **1503**, may determine whether pump **101** is at a point in the infusion profile for a KVO syringe or a TA syringe.

[0090] FIG. **21** illustrates an embodiment of a WAN **2102** and a LAN **2104**. WAN **2102** may be a network that spans a relatively large geographical area. Internet **211** is an example of a WAN **2102**. WAN **2102** typically includes a plurality of computer systems that may be interconnected through one or more networks. Although one particular configuration is shown in FIG. **21**, WAN **2102** may include a variety of heterogeneous computer systems and networks that may be interconnected in a variety of ways and that may run a variety of software applications.

[0091] One or more LANs **2104** may be coupled to WAN **2102**. LAN **2104** may be a network that spans a relatively small area. Typically, LAN **2104** may be confined to a single building or group of buildings. Each node (i.e., individual computer system or device) on LAN **2104** may have its own Central Processing Unit (CPU) with which it may execute programs. Each node may also be able to access data and devices anywhere on LAN **2104**. LAN **2104**, thus, may allow many users to share devices (e.g., printers) and data stored on file servers. LAN **2104** may be characterized by a variety of types of topology (i.e., the geometric arrangement of devices on the network), of protocols (i.e., the rules and encoding specifications for sending data, and whether the network uses a peer-to-peer or client/server architecture), and of media (e.g., twisted-pair wire, coaxial cables, fiber optic cables, and/or radio waves).

[0092] Each LAN **2104** may include a plurality of interconnected computer systems (e.g., computers **201**, **215***a*, **215***b*, **215***c*, etc.) and optionally one or more other devices. For example, LAN **2104** may include one or more workstations **2110***a*, one or more personal computers **2112***a*, one or more laptop or notebook computer systems **2114**, one or more server computer systems **2116** (e.g., server **207**), and one or more network printers **2118**. As illustrated in FIG. **21**, an example LAN **2104** may include one of each computer systems **2110***a*, **2112***a*, **2114**, and **2116**, and one printer **2118**. LAN **2104** may be coupled to other computer systems and/or other devices and/or other LANs through WAN **2102**.

[0093] One or more mainframe computer systems **2120** may be coupled to WAN **2102**. As shown, mainframe **2120** may be coupled to a storage device or file server **2124** and mainframe terminals **2122***a*, **2122***b*, and **2122***c*. Mainframe terminals **2122***a*, **2122***b*, and **2122***c* may access data stored in the storage device or file server **2124** coupled to or included in mainframe computer system **2120**.

[0094] WAN **2102** may also include computer systems connected to WAN **2102** individually and not through LAN **2104**. For example, workstation **2110***b* and personal computer **2112***b* may be connected to WAN **2102**. For example, WAN **2102** may include computer systems that may be geographically remote and connected to each other through the Internet.

[0095] FIG. **22** illustrates an embodiment of computer system **201** that may be suitable for implementing various embodiments of a system and method for test animal substance delivery and monitoring. Each computer system **201** typically includes components such as CPU **2252** with an associated memory medium such as Compact Disc Read Only Memories (CD-ROMs) **2260**. The memory medium may store program instructions for computer programs. The program instructions may be executable by CPU **2252**. Computer system **201** may further include a display device such as monitor **2254**, an alphanumeric input device such as keyboard **2256**, and a directional input device such as mouse **2258**. Computer system **201** may be operable to execute the computer programs to implement computer-implemented systems and methods for test animal substance delivery and monitoring.

[0096] Computer system **201** may include a memory medium on which computer programs according to various embodiments may be stored. The term "memory medium" is intended to include an installation medium, e.g., floppy disks or Compact Disc Read Only Memories (CD-ROMs) **2260**, a computer system memory such as Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM), Extended Data Out Random Access Memory (EDO RAM), Double Data Rate Random Access Memory (DDR RAM), Rambus Random Access Memory (RAM), etc., or a non-volatile memory such as a magnetic media, e.g., a hard drive or optical storage. The memory medium may also include other types of memory or combinations thereof. In addition, the memory medium may be located in a first computer, which executes the programs or may be located in a second different computer, which connects to the first computer over a network. In the latter instance, the second computer may provide the program instructions to the first computer for execution. Computer system **201** may take various forms such as a personal computer system, mainframe computer system, workstation, network appliance, Internet appliance, PDA, television system or other device. In general, the term "computer system" may refer to any device having a processor that executes instructions from a memory medium.

[0097] The memory medium may store a software program or programs operable to implement a method for test animal substance delivery and monitoring. The software program(s) may be implemented in various ways, including, but not limited to, procedure-based techniques, component-based techniques, and/or object-oriented techniques, among others. For example, the software programs may be implemented using ActiveX controls, C++ objects, JavaBeans, Microsoft Foundation Classes (MFC), browser-based applications (e.g., Java applets), traditional programs, or other technologies or methodologies, as desired. A CPU such as host CPU **2252** executing code and data from the memory medium may include a means for creating and executing the software program or programs according to the embodiments described herein.

[0098] Various embodiments may also include receiving or storing instructions and/or data implemented in accordance with the foregoing description upon a carrier medium. Suitable carrier media may include storage media or memory media such as magnetic or optical media, e.g., disk or CD-ROM, as well as signals such as electrical, electromagnetic, or digital signals, may be conveyed via a communication medium such as a network and/or a wireless link.

[0099] Embodiments of a subset or all (and portions or all) of the above may be implemented by program instructions stored in a memory medium or carrier medium and executed by a processor. A memory medium may include any of various types of memory devices or storage devices. The term "memory medium" is intended to include an installation medium, e.g., a Compact Disc Read Only Memory (CD-ROM), floppy disks, or tape device; a computer system

memory or random access memory such as Dynamic Random Access Memory (DRAM), Double Data Rate Random Access Memory (DDR RAM), Static Random Access Memory (SRAM), Extended Data Out Random Access Memory (EDO RAM), Rambus Random Access Memory (RAM), etc.; or a non-volatile memory such as a magnetic media, e.g., a hard drive, or optical storage. The memory medium may comprise other types of memory as well, or combinations thereof. In addition, the memory medium may be located in a first computer in which the programs are executed, or may be located in a second different computer that connects to the first computer over a network, such as the Internet. In the latter instance, the second computer may provide program instructions to the first computer for execution. The term "memory medium" may include two or more memory mediums that may reside in different locations, e.g., in different computers that are connected over a network.

[0100] In some embodiments, a computer system at a respective participant location may include a memory medium(s) on which one or more computer programs or software components according to one embodiment of the present invention may be stored. For example, the memory medium may store one or more programs that are executable to perform the methods described herein. The memory medium may also store operating system software, as well as other software for operation of the computer system.

[0101] In this patent, certain U.S. patents, U.S. patent applications, and other materials (e.g., articles) have been incorporated by reference. The text of such U.S. patents, U.S. patent applications, and other materials is, however, only incorporated by reference to the extent that no conflict exists between such text and the other statements and drawings set forth herein. In the event of such conflict, then any such conflicting text in such incorporated by reference U.S. patents, U.S. patent applications, and other materials is specifically not incorporated by reference in this patent.

[0102] Further modifications and alternative embodiments of various aspects of the invention may be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.

1-161. (canceled)

162. A method of validating a pump, comprising:

receiving, at a computer system, a beginning syringe weight of a syringe coupled to the pump, wherein the beginning syringe weight comprises a weight of a syringe with a substance for delivery to an animal;

receiving, at the computer system, an ending syringe weight of the syringe coupled to the pump, wherein the ending syringe weight is determined after delivering at least a portion of the substance in the syringe;

automatically determining an actual volume output, wherein the actual volume output is at least partially determined using the beginning syringe weight and the ending syringe weight;

automatically comparing the actual volume output to an expected volume output, wherein the expected volume output is determined from a calculated controlled delivery rate delivered to the pump; and

automatically determining if the comparison of the actual volume output to the expected volume output is approximately within an acceptable validation deviation.

163. The method of claim **162**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual volume output and the expected volume output.

164. The method of claim **162**, wherein the beginning syringe weight and/or ending syringe weight is received, at the computer system, from a weight scale integrated into the pump.

165. The method of claim **162**, further comprising:

determining an actual controlled delivery rate based at least partially on the actual volume output;

comparing the actual controlled delivery rate to the calculated controlled delivery rate delivered to the pump; and

determining if the comparison of the actual controlled delivery rate to the calculated controlled delivery rate is approximately within an acceptable validation deviation.

166. The method of claim **165**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual controlled delivery rate and the calculated controlled delivery rate.

167. A system, comprising:

one or more pumps,

a computer system communicatively coupled to one or more pumps, wherein the computer system comprises:

a processor;

a memory coupled to the processor and configured to store program instructions executable by the processor to validate one or more of the pumps:

receive a beginning syringe weight, wherein the beginning syringe weight comprises a weight of a syringe with a substance for delivery to an animal;

receive an ending syringe weight, wherein the ending syringe weight is determined after delivering a portion of the substance in the syringe;

determine an actual volume output, wherein the actual volume output is at least partially determined using the beginning syringe weight and the ending syringe weight;

compare the actual volume output to an expected volume output, wherein the expected volume output is determined from a calculated controlled delivery rate delivered to the one or more pumps; and

determine if the comparison of the actual volume output to the expected volume output is approximately within an acceptable validation deviation.

168. The system of claim **167**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual volume output and the expected volume output.

169. The system of claim **167**, wherein the one or more pumps comprise a weight scale integrated into the pump,

wherein a beginning syringe weight and/or ending syringe weight is received from the weight scale.

170. The system of claim **167**, wherein the program instructions are further executable to:

determine an actual controlled delivery rate based at least partially on the actual volume output;

compare the actual controlled delivery rate to the calculated controlled delivery rate delivered to the pump; and

determine if the comparison of the actual controlled delivery rate to the calculated controlled delivery rate is approximately within an acceptable validation deviation.

171. The system of claim **170**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual controlled delivery rate and the calculated controlled delivery rate.

172. A computer-readable storage medium, comprising program instructions for validating a pump, wherein the program instructions are computer-executable to:

receive, at a computer system, a beginning syringe weight of a syringe coupled to the pump, wherein the beginning syringe weight comprises a weight of a syringe with a substance for delivery to an animal;

receive, at the computer system, an ending syringe weight, wherein the ending syringe weight is determined after delivering a portion of the substance in the syringe;

automatically determine an actual volume output, wherein the actual volume output is at least partially determined using the beginning syringe weight and the ending syringe weight;

automatically compare the actual volume output to an expected volume output, wherein the expected volume output is determined from a calculated controlled delivery rate delivered to the pump; and

automatically determine if the comparison of the actual volume output to the expected volume output is approximately within an acceptable validation deviation.

173. The computer-readable storage medium of claim **172**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual volume output and the expected volume output.

174. The computer-readable storage medium of claim **172**, wherein the beginning syringe weight and/or ending syringe weight is received, at the computer system, from a weight scale integrated into the pump.

175. The computer-readable storage medium of claim **172**, wherein the program instructions are further executable to:

determine an actual controlled delivery rate based at least partially on the actual volume output;

compare the actual controlled delivery rate to the calculated controlled delivery rate delivered to the pump; and

determine if the comparison of the actual controlled delivery rate to the calculated controlled delivery rate is approximately within an acceptable validation deviation.

176. The computer-readable storage medium of claim **175**, wherein the acceptable validation deviation is an acceptable difference or an acceptable percentage comparison between the actual controlled delivery rate and the calculated controlled delivery rate.

177-428. (canceled)

429. The method of claim **162**, further comprising:

receiving an intermediate syringe weight at predetermined time intervals as the substance is being delivered;

determining an actual intermediate volume output at predetermined time intervals as the substance is being delivered, wherein the actual intermediate volume output is at least partially determined using the beginning syringe weight and the intermediate syringe weight;

comparing the actual intermediate volume output to an expected intermediate volume output at predetermined time intervals as the substance is being delivered, wherein the expected intermediate volume output is determined from the calculated controlled delivery rate delivered to the pump; and

determining if the comparison of the actual intermediate volume output to the expected intermediate volume output is approximately within an acceptable validation deviation at predetermined time intervals as the substance is being delivered.

430. The method of claim **429**, further comprising providing an indication if the comparison of the actual intermediate volume output to the expected intermediate volume output is not approximately within an acceptable validation deviation.

431. The method of claim **430**, wherein the indicator is an audible alarm.

432. The method of claim **430**, wherein the indicator is a graphic display.

433. The method of claim **430**, further comprising inhibiting substance delivery if the comparison of the actual intermediate volume output to the expected intermediate volume output is not approximately within an acceptable validation deviation.

434. The method of claim **162**, further comprising:

determining an actual intermediate controlled delivery rate at predetermined time intervals as the substance is being delivered, wherein the actual intermediate controlled delivery rate is based at least partially on the actual intermediate volume output;

comparing the actual intermediate controlled delivery rate to the calculated controlled delivery rate delivered to the pump at predetermined time intervals as the substance is being delivered; and

determining if the comparison of the actual intermediate controlled delivery rate to the calculated controlled delivery rate is approximately within an acceptable validation deviation at predetermined time intervals as the substance is being delivered.

435. The method of claim **434**, further comprising providing an indication if the comparison of the actual intermediate controlled delivery rate to the expected controlled delivery rate is not approximately within an acceptable validation deviation.

435. The method of claim **434**, further comprising inhibiting substance delivery if the comparison of the actual intermediate controlled delivery rate to the expected controlled delivery rate is not approximately within an acceptable validation deviation.

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