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| United States Patent Application Publication | 20250256927 |
| Kind Code | A1 |
| Publication Date | August 14, 2025 |
| Inventor(s) | Wiencek; Joseph Richard et al. |


## DEVICES AND SYSTEMS FOR PNEUMATIC TUBE TRANSPORT

### Abstract


A sample transportation system, in particular embodiments, comprises: a housing; at least one gyroscope sensor disposed within the housing; a substantially linear track disposed within the housing; a sample receptacle slidably coupled to the substantially linear track; and at least one motor in mechanical communication with at least one of the sample receptacle or the substantially linear track. In various embodiments, the at least one motor is configured to cause the sample receptacle to translate parallel to the substantially linear track with respect to the housing. In some embodiments, the system further comprises computing hardware configured to receive velocity data from the at least one gyroscope sensor, and operate the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data.



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**Family ID:** **1000008440130**

**Appl. No.:** **19/049251**

**Filed:** **February 10, 2025**


### Related U.S. Application Data

us-provisional-application US 63551753 20240209

### Publication Classification

**Int. Cl.:** **B65G51/36** (20060101)

**U.S. Cl.:**

CPC **B65G51/36** (20130101); B65G2203/0291 (20130101); B65G2203/042 (20130101)

## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No., 63/551,753, filed Feb. 9, 2024, the disclosure of which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] Blood samples and other items are often transported in pneumatic tube systems, for example, in a hospital setting. Transportation of certain types of samples in a pneumatic tube system, may, for example, have a negative impact on the samples and reduce their viability for the samples' intended use once they reach their destination. Accordingly, there is a need for improved systems and methods for transporting samples and other items while reducing potential negative impact on the samples.

SUMMARY

[0003] In accordance with the purpose(s) of the present disclosure, as embodied and broadly described herein, the disclosure, in one aspect, relates to systems and devices for transporting materials by pneumatic tube transport. The systems can include a device used with a pneumatic tube for transporting materials such as biological specimens (e.g., blood). The device can reduce damage done to materials during transport in a pneumatic tube system.

[0004] Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description and be within the scope of the present disclosure. In addition, all optional and preferred features and modifications of the described embodiments are usable in all aspects of the disclosure taught herein.

[0005] In particular embodiments, a sample transportation system comprises: a housing; at least one gyroscope sensor disposed within the housing; a substantially linear track disposed within the housing; a sample receptacle slidably coupled to the substantially linear track; at least one motor in mechanical communication with at least one of the sample receptacle or the substantially linear track, the at least one motor configured to cause the sample receptacle to translate parallel to the substantially linear track with respect to the housing; and computing hardware disposed within the housing and coupled to the at least one gyroscope sensor. In some embodiments, the substantially linear track is substantially parallel to a longitudinal direction of travel of the housing within the sample transportation system.

[0006] In various embodiments, the computing hardware is configured to: receive velocity data from the at least one gyroscope sensor; and operate the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data.

[0007] In some embodiments, operating the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data comprises operating the at least one motor to translate the sample receptacle antiparallel to a direction of travel identified based on the velocity data. In other embodiments, the sample transportation system further comprises: a second substantially linear track disposed within the housing; and a second motor in mechanical communication with at least one of the sample receptacle or the second substantially linear track. In various embodiments, the second substantially linear track is oriented in a first transverse direction that is substantially perpendicular to the longitudinal direction of travel of the housing within the sample transportation system. In some embodiments, the second motor is configured to cause the sample receptacle to translate parallel to the first transverse direction. In various embodiments, a first end of the substantially linear track is slidably coupled to the second substantially linear track. In particular embodiments, the computing hardware is further configured to operate the second motor to cause the sample receptacle to translate in the transverse direction with respect to the housing based on the velocity data.

[0008] In various embodiments, the sample transportation system further comprises a third substantially linear track disposed within the housing, the third substantially linear track being oriented in a second transverse direction that is substantially perpendicular to both the longitudinal direction and the second longitudinal direction. The sample transportation system may further comprise a third motor in mechanical communication with at least one of the sample receptacle or the third substantially linear track. In some embodiments, the third motor is configured to cause the sample receptacle to translate parallel to the second transverse direction, and the computing hardware is further configured to operate the third motor to cause the sample receptacle to translate in the second transverse direction with respect to the housing based on the velocity data.

[0009] In some embodiments, the sample transportation system is configured for at least one of insertion into a pneumatic tube carrier for use in the sample transportation system or standalone use in the sample transportation system. In particular embodiments, the substantially linear track comprises at least one integrated dampener. In various embodiments, operating the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data comprises causing the sample receptacle to translate in the longitudinal direction at a velocity opposite a velocity determined from the velocity data.

[0010] A pneumatic tube carrier, in various embodiments, comprise: a longitudinal direction support that is substantially parallel to a longitudinal direction of travel of the pneumatic tube carrier when the pneumatic tube carrier is travelling through a pneumatic tube system; a sample housing disposed on the longitudinal direction support; at least one actuator operatively coupled to the sample housing and configured to cause the sample housing to translate substantially parallel along at least a portion of the longitudinal direction support; at least one sensor disposed on or in the pneumatic tube carrier; and computing hardware operatively coupled to the at least one sensor and the at least one actuator, wherein the computing hardware is configured for: receiving sensor data from the at least one sensor; determining a set of actuator instructions based on the sensor data; and operating the at least one actuator according to the set of actuator instructions to at least partially counteract a force, velocity, direction of motion, or acceleration identified based on the sensor data.

[0011] In some embodiments, the longitudinal direction support comprises at least one integrated dampener. In some aspects, the at least one integrated dampener comprise at least one biasing mechanism or at least one dashpot. In some aspects, the sensor data comprises a force on the pneumatic tube carrier. In various aspects, the responsive action comprises causing the at least one actuator to apply a force that is opposing of the force on the pneumatic tube carrier on the sample housing.

[0012] In particular embodiments, the at least one actuator comprises a set of actuators; and the set of actuators are configured to cooperate to at least partially counteract the force, velocity, direction of motion, or acceleration identified by translating the sample housing in three dimensions. In some embodiments, the pneumatic tube carrier further comprises a first transverse direction support substantially perpendicular to the longitudinal direction support. In some embodiments, the at least one actuator is further configured to cause the sample housing to translate substantially parallel along at least a portion of the first transverse direction support. In particular embodiments, the pneumatic tube carrier further comprises a second transverse direction support substantially perpendicular to the longitudinal direction support and the first transverse direction support, wherein the at least one actuator is further configured to cause the sample housing to translate substantially parallel along at least a portion of the second transverse direction support.

[0013] A pneumatic tube insert, in particular embodiments, comprises: a sample housing; at least one actuator operatively coupled to the sample housing and configured to cause the sample housing to translate in a direction substantially parallel to a longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through a pneumatic tube system; at least one sensor disposed on or in the pneumatic tube insert; and computing hardware operatively coupled to the at least one sensor and the at least one actuator. In some embodiments, the computing hardware is configured for: receiving sensor data from the at least one sensor; determining a responsive action based on the sensor data; and causing the responsive action.

[0014] In some embodiments, the sensor data comprises a velocity of the pneumatic tube insert; the responsive action comprises causing the sample housing to translate in the longitudinal direction in a direction opposite the velocity of the pneumatic tube insert at a rate that corresponds to the velocity; and causing the responsive action comprises causing the at least one actuator to translate the sample housing in the longitudinal direction in the direction opposite the velocity of the pneumatic tube insert at the rate that corresponds to the velocity. In various embodiments, the pneumatic tube insert is configured to be selectively inserted into a pneumatic tube carrier for use in the pneumatic tube system.

[0015] In particular embodiment, the at least one sensor comprises at least one of a gyroscope, an accelerometer, or a temperature sensor; and the responsive action comprises at least one of activating the at least one actuator, generating a temperature alert; or generating an excessive force alert.

[0016] In some embodiments, the pneumatic tube insert comprises: a first transverse direction rack; an actuator support defining a linear track, wherein the actuator support is configured to receive the at least one actuator and the linear track is configured to receive at least a portion of the first transverse direction rack such that the first transverse direction rack is slidably disposed within the linear track; and a rotating connector coupled to the at least one actuator, the rotating connector in operable engagement with the first transverse direction rack. In some embodiments, a first end of the sample housing is coupled to the first transverse direction rack. In various embodiments, the responsive action comprises operating the at least one actuator to rotate the rotating connector to cause the first transverse direction rack to translate at least the first end of the sample housing in a transverse direction relative to the longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through the pneumatic tube system.

[0017] In various embodiments, the actuator support comprises a second transverse direction rack substantially perpendicular to the transverse direction rack, and the pneumatic tube insert comprises a second actuator support defining a second linear track. In some embodiments, the second actuator support is configured to receive a second actuator, and the second linear track is configured to receive at least a portion of the second transverse direction rack such that the second transverse direction rack is slidably disposed within the second linear track. In some embodiments, a second rotating connector is coupled to the second actuator, the second rotating connector in operable engagement with the second transverse direction rack; the responsive action comprises operating the second actuator to rotate the second rotating connector to cause the second transverse direction rack to translate at least the actuator support in the second transverse direction relative to the longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through the pneumatic tube system; and the transverse direction is substantially perpendicular to the second transverse direction.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead

being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.
[0019] Drawings are presented in the attachment files accompanying this specification:
[0020] FIG. **1** is a cutaway view of a pneumatic tube transport device in accordance with various embodiments of the present disclosure.
[0021] FIG. **2** is a cutaway view of a pneumatic tube transport device in accordance with various other embodiments of the present disclosure.
[0022] FIG. **3** is a cutaway view of a pneumatic tube transport device in accordance with various other embodiments of the present disclosure.
[0023] FIG. **4** is a pneumatic tube transport device in accordance with still other embodiments of the present disclosure.
[0024] FIG. **5** is a perspective view of the pneumatic tube transport device shown in FIG. **4**.
[0025] FIG. **6** is an exploded view of the pneumatic tube transport device shown in FIG. **4**.
[0026] FIG. **7** is a detail view of an actuator support of the pneumatic tube transport device shown in FIG. **4** in accordance with various embodiments of the present disclosure.
[0027] FIGS. **8-10** are detail views of yet another actuator support of the pneumatic tube transport device shown in FIG. **4** in accordance with various embodiments of the present disclosure.
[0028] FIG. **11** is a detail view of an actuator support and transverse direction rack of the pneumatic tube transport device shown in FIG. **4** in accordance with various embodiments of the present disclosure.
[0029] FIG. **12** is a detail view of a sample housing of the pneumatic tube transport device shown in FIG. **4** in accordance with various embodiments of the present disclosure.
[0030] FIG. **13** is an exploded view of the sample housing shown in FIG. **12** in accordance with various embodiments of the present disclosure.
[0031] FIG. **14** is a detail view of a set of transverse direction sliders of the pneumatic tube transport device shown in FIG. **4** in accordance with various embodiments of the present disclosure.
[0032] FIG. **15** is a detail view of a first transverse direction slider in accordance with various embodiments of the present disclosure.
[0033] FIG. **16** is a detail view of a second transverse direction slider and first transverse direction slider support track in accordance with various embodiments of the present disclosure.
[0034] FIG. **17** is a rear view of the second transverse direction slider shown in FIG. **16**.
[0035] FIG. **18** is a process for controlling pneumatic tube transport device components based on sensor data in accordance with various embodiments of the present disclosure.
[0036] Additional advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or can be learned by practice of the invention. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

## DETAILED DESCRIPTION

[0037] Many modifications and other embodiments disclosed herein will come to mind to one skilled in the art to which the disclosed compositions and methods pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the disclosures are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the disclosure. The skilled artisan will recognize many variants and adaptations of the aspects described herein. These variants and adaptations are intended to be included in the teachings of this disclosure and to be encompassed by the claims herein.
[0038] Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

[0039] As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several embodiments without departing from the scope or spirit of the present disclosure.
[0040] Any recited method and/or process can be carried out in the order of events recited or in any other order that is logically possible. That is, unless otherwise expressly stated, it is in no way intended that any method or aspect set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not specifically state in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that an order be inferred, in any respect. This holds for any possible non-express basis for interpretation, including matters of logic with respect to arrangement of steps or operational flow, plain meaning derived from grammatical organization or punctuation, or the number or type of aspects described in the specification.
[0041] All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited. The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided herein can be different from the actual publication dates, which can require independent confirmation.
[0042] While aspects of the present disclosure can be described and claimed in a particular statutory class, such as the system statutory class, this is for convenience only and one of skill in the art will understand that each aspect of the present disclosure can be described and claimed in any statutory class.
[0043] It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the disclosed compositions and methods belong. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly defined herein.
[0044] Prior to describing the various aspects of the present disclosure, the following definitions are provided and should be used unless otherwise indicated. Additional terms may be defined elsewhere in the present disclosure.

## Definitions

[0045] As used herein, “comprising” is to be interpreted as specifying the presence of the stated features, integers, steps, or components as referred to, but does not preclude the presence or addition of one or more features, integers, steps, or components, or groups thereof. Moreover, each of the terms “by”, “comprising,” “comprises”, “comprised of,” “including,” “includes,” “included,” “involving,” “involves,” “involved,” and “such as” are used in their open, non-limiting sense and may be used interchangeably. Further, the term “comprising” is intended to include examples and aspects encompassed by the terms “consisting essentially of” and “consisting of.” Similarly, the term “consisting essentially of” is intended to include examples encompassed by the term “consisting of.
[0046] As used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a spacer,” “a guide nucleic acid,” or “an miRNA,” including, but not limited to, mixtures or combinations of two or more such spacers, guide nucleic acids, or miRNAs, and the like.
[0047] It should be noted that ratios, concentrations, amounts, and other numerical data can be

expressed herein in a range format. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. It is also understood that there are a number of values disclosed herein, and that each value is also herein disclosed as “about” that particular value in addition to the value itself. For example, if the value “10” is disclosed, then “about 10” is also disclosed. Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms a further aspect. For example, if the value “about 10” is disclosed, then “10” is also disclosed.

[0048] When a range is expressed, a further aspect includes from the one particular value and/or to the other particular value. For example, where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure, e.g. the phrase “x to y” includes the range from ‘x’ to ‘y’ as well as the range greater than ‘x’ and less than ‘y’. The range can also be expressed as an upper limit, e.g. ‘about x, y, z, or less’ and should be interpreted to include the specific ranges of ‘about x’, ‘about y’, and ‘about z’ as well as the ranges of ‘less than x’, less than y’, and ‘less than z’. Likewise, the phrase ‘about x, y, z, or greater’ should be interpreted to include the specific ranges of ‘about x’, ‘about y’, and ‘about z’ as well as the ranges of ‘greater than x’, greater than y’, and ‘greater than z’. In addition, the phrase “about ‘x’ to ‘y’”, where ‘x’ and ‘y’ are numerical values, includes “about ‘x’ to about ‘y’”.

[0049] It is to be understood that such a range format is used for convenience and brevity, and thus, should be interpreted in a flexible manner to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. To illustrate, a numerical range of “about 0.1% to 5%” should be interpreted to include not only the explicitly recited values of about 0.1% to about 5%, but also include individual values (e.g., about 1%, about 2%, about 3%, and about 4%) and the sub-ranges (e.g., about 0.5% to about 1.1%; about 5% to about 2.4%; about 0.5% to about 3.2%, and about 0.5% to about 4.4%, and other possible sub-ranges) within the indicated range.

[0050] As used herein, the terms “about,” “approximate,” “at or about,” and “substantially” mean that the amount or value in question can be the exact value or a value that provides equivalent results or effects as recited in the claims or taught herein. That is, it is understood that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art such that equivalent results or effects are obtained. In some circumstances, the value that provides equivalent results or effects cannot be reasonably determined. In such cases, it is generally understood, as used herein, that “about” and “at or about” mean the nominal value indicated ±10% variation unless otherwise indicated or inferred. In general, an amount, size, formulation, parameter or other quantity or characteristic is “about,” “approximate,” or “at or about” whether or not expressly stated to be such. It is understood that where “about,” “approximate,” or “at or about” is used before a quantitative value, the parameter also includes the specific quantitative value itself, unless specifically stated otherwise.

[0051] As used herein, the terms “optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0052] Unless otherwise specified, temperatures referred to herein are based on atmospheric pressure (i.e. one atmosphere).

Overview

[0053] As noted above, pneumatic tube systems are often utilized to transport blood samples and other materials, particularly in a hospital setting. Such systems may, for example, transport samples from a point of origin to a testing location. When traveling via pneumatic tube system, samples may experience less-than-ideal environmental conditions as a result of forces exerted on the samples during transportation. For example, samples such as blood samples can experience high shock, g-forces, and rapid acceleration changes during transport.

[0054] As a result of such environmental conditions, particular samples may become unsuitable or unviable for a type of testing or other analysis that was to be performed on the samples. For example, in the case of blood samples, hemolysis of red blood cells may occur as a result of forces exerted on the samples during pneumatic tube transportation. Such samples may become unusable or produce unreliable or erroneous test results.

[0055] As a result, caregivers may need to retrieve additional samples from patients, resort to less efficient transportation techniques such as physically carrying the samples to the proper testing facility, etc. In some cases, inefficiencies resulting from a desire to avoid potential sample spoliation from utilizing pneumatic tube systems can affect patient outcomes, waste resources, etc. Various embodiments of a pneumatic tube transportation device described herein may reduce at least some negative impacts resulting from environmental conditions during pneumatic tube transportation.

Pneumatic Tube Carriers and Inserts

[0056] FIG. **1** depicts a pneumatic tube transport device **100** in accordance with various embodiments of the present disclosure. As may be understood from this figure, the pneumatic tube transport device **100** comprises a housing **105**. In various embodiments, the housing **105** is substantially cylindrical. In some embodiments, the housing **105** may comprise an insert for an existing pneumatic tube carrier. In such embodiments, the pneumatic tube transport device **100** may be configured for insertion into an existing pneumatic tube carrier. In still other embodiments, the pneumatic tube transport device **100** may comprise a housing **105** that is sized and structured to function as a stand-alone pneumatic tube carrier (e.g., for use directly within a pneumatic tube system). In this way, in various embodiments, the pneumatic tube transport device **100** may be configured for stand-alone use in a pneumatic tube system. In still other embodiments, the pneumatic tube transport device **100** may be configured for use in a pneumatic tube system as an insert to an existing pneumatic tube carrier.

[0057] As may be further understood from FIG. **1**, the pneumatic tube transport device **100** is sized and shaped to travel through a pneumatic tube system, for example, through insertion into an existing pneumatic tube carrier or directly as a stand-alone pneumatic tube transport device **100**. In particular embodiments, the pneumatic tube transport device **100** comprises at least one longitudinal direction support **110**. In various embodiments, the longitudinal direction support **110** is substantially linear and oriented substantially parallel to a longitudinal direction of travel of the pneumatic tube transport device **100** when the pneumatic tube transport device **100** is traveling through a pneumatic transportation system. In particular embodiments, the pneumatic tube transport device **100** further comprises a sample housing **150** configured to receive and at least temporarily store one or more samples. In some aspects, the one or more samples may include one or more test tubes, vials, or other storage mediums. In particular embodiments, the sample housing **150** is disposed at least partially on and/or around the longitudinal direction support **110** or otherwise coupled to the longitudinal direction support **110**. In various embodiments, the sample housing **150** is slidably coupled to the longitudinal direction support **110** such that the sample housing **150** is at least partially movable along a length of the longitudinal direction support **110** within the pneumatic tube transport device **100**. In this way, the pneumatic tube transport device **100** is configured such that a position of the sample housing **150** within the pneumatic tube transport device **100** (e.g., along the longitudinal direction support **110**) can be altered via operation of one or more motors, one or more linear actuators, one or more dampening mechanisms, one or more biasing mechanisms, or through operation of any other suitable component of the pneumatic tube transport device **100**.

[0058] In various aspects, the longitudinal direction support **110** is supported by at least one first transverse direction support **120**. For example, in the embodiment shown in FIG. **1**, a first end of the longitudinal direction support **110** is coupled to the housing **105** via a first transverse direction support **120**A and a second end of the longitudinal direction support **110** is coupled to the housing **105** via a first transverse direction support **120**B. As shown in FIG. **1**, each of the first transverse direction support **120**A and the first transverse direction support **120**B are substantially perpendicular to a longitudinal axis of the pneumatic tube transport device **100** (e.g., the Z-direction). Each of the first transverse direction support **120**A and the first transverse direction support **120**B may also be substantially perpendicular to the longitudinal direction support **110**. In some aspects, each of the first transverse direction support **120**A and the first transverse direction support **120**B may comprise one or more telescoping rods or other adjustable components. In this way, the first transverse direction support **120**A and/or first transverse direction support **120**B may be configured to expand to fit substantially snugly within an existing pneumatic tube carrier.
[0059] In still other embodiments, the pneumatic tube transport device **100** may comprise any suitable support configuration for maintaining the pneumatic tube transport device **100** in an orientation that is at least substantially parallel to the longitudinal direction of travel of the pneumatic tube transport device **100**. In various embodiments the pneumatic tube transport device **100** comprise at least one first actuator **112**. In the embodiment shown in this figure, the first actuator **112** is disposed adjacent the longitudinal direction support **110**. In still other embodiments, the first actuator **112** may be disposed in any other suitable location. In particular embodiments, the first actuator **112** is configured to cause the sample housing **150** to translate (e.g., and/or rotate) with respect to the longitudinal direction support **110**. In various embodiments, the first actuator **112** may comprise any suitable actuator. For example, in particular embodiments, the first actuator **112** may include one or more suitable actuators that provide force, torque, and/or displacement to one or more other components of the pneumatic tube transport device **100**. In some embodiment, the first actuator **112** includes any suitable actuator configured to translate electrical, pneumatic, hydraulic, or other input into mechanical energy. In some embodiments, the first actuator **112** comprises a linear actuator. In other embodiments, the first actuator **112** comprises a rotational actuator. In various embodiments, the first actuator **112** is configured to convert rotational motion to linear motion in combination with one or more other components. For example, in various embodiments, the first actuator **112** may operate in combination with a rack and pinion or other suitable mechanism for providing linear motion to one or more other aspects of the pneumatic tube transport device **100**, such as the sample housing **150**.
[0060] In a particular embodiment, the pneumatic tube transport device **100** comprises one or more sensors, such as a gyroscope **107** configured to detect an orientation of the pneumatic tube transport device **100**, an angular velocity and/or change in angular velocity of the pneumatic tube transport device **100**, etc. In still other embodiments, the one or more sensors may include any other suitable sensor such as one or more temperature sensors, one or more accelerometers, one or more pressure sensors, one or more inertial sensors, etc. In any embodiment described herein, the one or more sensors (i.e., the gyroscope **107** in particular embodiments) may be disposed in any suitable location on the pneumatic tube transport device **100**. In various embodiments, the one or more sensors are disposed in any suitable location other than the sample housing **150**.
[0061] In various embodiments, the pneumatic tube transport device **100** further comprises a control circuitry **109** configured to receive one or more sensor readings from the one or more sensors. In any embodiment described herein, the control circuitry **109** may comprise any suitable processing circuitry configured to receive and interpret sensor data from the gyroscope **107**, determine opposing force and/or motion data to at least partially counteract a motion and/or force on the sample housing **150**, and cause the first actuator **112** to at least temporarily impart an at least partially counteracting motion and/or force on the sample housing **150**. In a particular embodiment the control circuitry **109** comprises an Arduino Nano.

[0062] The control circuitry **109** may then be configured to operate the first actuator **112** to cause the sample housing **150** to translate along the first actuator **112**, adjust a position or orientation of the sample housing **150** with respect to the pneumatic tube transport device **100**, apply a force to the sample housing **150**, or otherwise modify a velocity and/or acceleration of the sample housing **150** with respect to the pneumatic tube transport device **100**. In some embodiments, the control circuitry **109** is configured to operate the first actuator **112** to modify a position, velocity, and/or acceleration of the sample housing **150** with respect to the pneumatic tube transport device **100** based on one or more readings received from the one or more sensors (e.g., the gyroscope **107**).

[0063] In some embodiments, for example, the control circuitry **109** is configured to cause the first actuator **112** to move the sample housing **150** in a direction opposite a motion detected via the gyroscope **107** (e.g., or other suitable sensor). In this way, the pneumatic tube transport device **100**, in various embodiments, is configured to reduce an amount of force exerted on a sample disposed within the sample housing **150** during transportation. In some embodiments, the sample housing **150** may be further configured to rotate about the longitudinal direction support **110** (e.g., through operation of the first actuator **112** or other suitable motor or actuation device). In such embodiment, the first actuator **112** or other motor may be configured to apply a rotational force to the sample housing **150** with respect to the longitudinal direction support **110**. In such embodiments, the control circuitry **109** may be further configured to cause such a first actuator **112** to apply the rotational force to the sample housing **150** to counteract a rotational force detected by the gyroscope **107** (e.g., or other sensor).

[0064] FIG. **2** depicts another embodiment of a pneumatic tube transport device **100**. As shown in FIG. **2**, in various embodiments, a pneumatic tube transport device **100**, in addition to compensating for forces on the sample housing **150** in the longitudinal direction of motion of the pneumatic tube transport device **100** through a pneumatic tube system, may be configured to counteract one or more forces on the sample housing **150** in at least one transverse direction with respect to the longitudinal direction of motion of the pneumatic tube transport device **100** through the pneumatic tube system. As may be understood from FIG. **2**, the pneumatic tube transport device **100** is substantially structurally similar to the pneumatic tube transport device **100** shown and described with respect to FIG. **1**. In the embodiment shown in FIG. **2**, the longitudinal direction support **110** is slidably coupled to each of the first transverse direction support **120**A and the first transverse direction support **120**B via a respective sliding connector **124** (e.g., a first sliding connector **124**A and a second sliding connector **124**A). In various embodiments, the pneumatic tube transport device **100** further comprises a second actuator **122** in mechanical communication with the longitudinal direction support **110** such that the second actuator **122** is configured to cause the longitudinal direction support **110** to translate in a transverse direction (e.g., the Y-direction) within the pneumatic tube transport device **100** with respect to the longitudinal direction of motion of the pneumatic tube transport device **100** through the pneumatic tube system. As may be understood from FIG. **2**, the transverse direction (Y-direction) is substantially perpendicular to the longitudinal direction of travel (e.g., the Z-direction). In the embodiment shown in FIG. **2**, the control circuitry **109** is configured to operate each of the first actuator **112** and the second actuator **122** to apply motion to the sample housing **150** in a direction that corresponds to the respective longitudinal (e.g., substantially co-linear with the longitudinal direction support **110**) and/or transverse (e.g., substantially co-linear with the first transverse direction support **120**) direction. In some aspects, the control circuitry **109** is configured to operate each of the first actuator **112** and the second actuator **122** in a direction opposite a motion detected via the gyroscope **107** (e.g., or other suitable sensor) in two directions (e.g., the Z-direction and the Y-direction).

[0065] Turning to FIG. **3**, yet another embodiment of a pneumatic tube transport device **100** is shown. In the embodiment shown in this FIG., the pneumatic tube transport device **100** is substantially structurally similar to the pneumatic tube transport device **100** shown in FIG. **2**. In the embodiment shown in FIG. **3**, the pneumatic tube transport device **100** further comprises a second

transverse direction support **130**A that is substantially perpendicular to the first transverse direction support **120**A and coupled to the first transverse direction support **120**A via a sliding connector **124**A. Additionally, the pneumatic tube transport device **100** comprises a second transverse direction support **130**B that is substantially parallel to and spaced apart from the second transverse direction support **130**A. The second transverse direction support **130**B is perpendicular to the first transverse direction support **120**B and coupled to the first transverse direction support **120**B via a sliding connector **124**B. In the embodiment shown in this figure, a first end of the longitudinal direction support **110** is slidably coupled to the second transverse direction support **130**A via a sliding connector **134**A. A second end of the longitudinal direction support **110** is slidably coupled to the second transverse direction support **130**B via a sliding connector **134**B. The pneumatic tube transport device **100** further comprises a third actuator **132** in mechanical communication with the longitudinal direction support **110** such that the third actuator **132** is configured to cause the longitudinal direction support **110** to translate in a second transverse direction (e.g., the X-direction) within the pneumatic tube transport device **100** with respect to the longitudinal direction of motion of the pneumatic tube transport device **100** through the pneumatic tube system. As may be understood from FIG. **3**, the second transverse direction (e.g., X-direction) is substantially perpendicular to the longitudinal direction of travel (e.g., the Z-direction). In some embodiments, the second transverse direction (e.g., X-direction) is substantially perpendicular to a first transverse direction (e.g., the Y-direction, the transverse direction described above with respect to FIG. **2**).
[0066] In the embodiment shown in FIG. **3**, the control circuitry **109** is configured to operate each of the first actuator **112**, the second actuator **122**, and the third actuator **132** to apply motion to the sample housing **150** in a direction that corresponds to the respective longitudinal (e.g., substantially co-linear with the longitudinal direction support **110**) and/or transverse (e.g., substantially co-linear with the first transverse direction support **120** and/or the second transverse direction support **130**) direction. In some aspects, the control circuitry **109** is configured to operate each of the first actuator **112**, the second actuator **122**, and the third actuator **132** in a direction opposite a motion detected via the gyroscope **107** (e.g., or other suitable sensor) in three directions (e.g., the X-direction, the Y-direction, and the Z-direction).
[0067] In any embodiment described herein, any of the longitudinal direction support **110**, the first transverse direction support **120** and/or the second transverse direction support **130** may comprise one or more dampeners (e.g., one or more dashpots, one or more biasing mechanism, etc.). In some aspects, each of the one or more dampeners are configured to reduce an amount of force experienced by the sample housing **150** during an application of force on the sample housing **150** resulting from travel through a pneumatic tube system. In some aspects, the one or more dampeners comprise one or more linear dampeners. In some aspects, the one or more dampeners are disposed parallel to the longitudinal direction support **110**, the first transverse direction support **120**, or the second transverse direction support **130** in which the one or more dampeners are comprised.
[0068] FIGS. **4-17** depict a pneumatic tube insert **200** and various components of a pneumatic tube insert **200** according to yet another embodiment of the present disclosure. In the embodiment shown in FIGS. **4** and **5**, the pneumatic tube insert **200** is configured for at least temporary insertion into a pneumatic tube carrier. As with the sample housing **150** described above with respect to the pneumatic tube transport device **100**, the pneumatic tube insert **200** comprises a sample housing **250**. In various embodiments, the sample housing **250** is configured to receive and at least temporarily store one or more samples, for example, while the pneumatic tube insert **200** is travelling through a pneumatic tube system (e.g., in a pneumatic tube carrier). In some aspects, the one or more samples may include one or more test tubes, vials, or other storage mediums.
[0069] A first end of the sample housing **250** is coupled to (e.g., rotatably coupled to) a first transverse direction rack **220**. As may be understood in light of this disclosure and FIG. **4**, the first transverse direction rack **220** is configured to translate in a transverse direction (e.g., the Y-direction) with respect to a longitudinal direction of travel (e.g., the Z-direction) of the pneumatic

tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system). The first transverse direction rack **220** is slidably coupled to an actuator support **222** that supports an actuator (not pictured) configured to linearly translate the first transverse direction rack **220** in a first transverse direction (e.g., the Y-direction). In some embodiments, the linear translation of the first transverse direction rack **220** causes linear translation of at least the first end of the sample housing **250** (e.g., the sample housing **250**).

[0070] The actuator support **222** is slidably coupled to a second actuator support **232** that supports an actuator (not pictured) configured to linearly translate the actuator support **222** in a second transverse direction (e.g., the X-direction) that is perpendicular to the first transverse direction. In some aspects, the actuator support **232** is at least temporarily coupled to a first hose clamp **262** that is configured to expand within a pneumatic tube carrier in order to engage an inner portion of the pneumatic tube carrier and maintain the pneumatic tube insert **200** in a substantially fixed position within the pneumatic tube carrier. In some aspects, the use of at least one hose clamp to support the pneumatic tube insert **200** within a pneumatic tube may enable a user to quicky and easily insert and remove the insert from the pneumatic tube. Additionally, the use of one or more hose clamps may enable the insert to fit stably within pneumatic tubes of differing sizes. This may, for example, enable a user to utilize the pneumatic tube insert **200** with different pneumatic tube systems at different locations that have different configurations (e.g., size, diameter, etc.). In other embodiments, the pneumatic tube insert **200** may comprise any other mechanism for at least temporarily engaging with an inner portion of the pneumatic tube carrier in order to maintain the pneumatic tube insert **200** in a substantially fixed position within the pneumatic tube carrier (e.g., during transportation in a pneumatic tube system).

[0071] As shown in FIG. **5**, a second end of the sample housing **250** is coupled to (e.g., rotatably coupled to) a first transverse direction slider **226**. As may be understood in light of this disclosure and FIG. **5**, the first transverse direction slider **226** slidably disposed within a first transverse direction slider support track **228** and is configured to translate within the first transverse direction slider support track **228** in a transverse direction (e.g., the Y-direction) with respect to a longitudinal direction of travel (e.g., the Z-direction) of the pneumatic tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system). The first transverse direction slider support track **228** comprises a second transverse direction slider **236** that is substantially perpendicular to a body of the first transverse direction slider support track **228** and slidably disposed within a second transverse direction slider support track **238**. As may be understood from FIGS. **4** and **5**, the second transverse direction slider **236** is configured to translate within the second transverse direction slider support track **238** in a second transverse direction (e.g., the X-direction) with respect to a longitudinal direction of travel (e.g., the Z-direction) of the pneumatic tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system).

[0072] In some aspects, the first transverse direction slider **226** is configured to slide within the first transverse direction slider support track **228** in response to an actuation of the first transverse direction rack **220** (i.e., the first transverse direction slider **226** is configured to substantially freely slide and/or translate within the first transverse direction slider support track **228**). Similarly, the second transverse direction slider **236** may be configured to slide within the second transverse direction slider support track **238** in response to an actuation of the actuator support **222** (e.g., by an actuator supported by the actuator support **232**). In this way, the sample housing **250** may be configured to translate in both a first transverse direction (e.g., the Y-direction) and a second transverse direction (e.g., the X-direction) such that the sample housing **250** remains substantially parallel to the longitudinal direction of travel of the pneumatic tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system. For example, the pneumatic tube insert **200** may comprise one or more actuators configured to actuate the first end of the sample housing **250**, and the second end of the sample housing **250** may translate along with the first end as a result of a sliding and/or translation of the first transverse direction slider **226** and the second transverse direction slider **236**.

[0073] In some aspects, the second transverse direction slider support track **238** is at least temporarily coupled to a second hose clamp **264** that is configured to expand within a pneumatic tube carrier in order to engage an inner portion of the pneumatic tube carrier and maintain the pneumatic tube insert **200** in a substantially fixed position within the pneumatic tube carrier. In other embodiments, the pneumatic tube insert **200** may comprise any other mechanism (e.g., and/or mechanisms) for at least temporarily engaging with an inner portion of the pneumatic tube carrier in order to maintain the pneumatic tube insert **200** in a substantially fixed position within the pneumatic tube carrier (e.g., during transportation in a pneumatic tube system)

[0074] FIG. **6** depicts an exploded view of the pneumatic tube insert **200** shown in FIGS. **4** and **5**. As may be understood from this figure, the actuator support **222** comprises a second transverse direction rack **230** that is substantially perpendicular to the first transverse direction rack **220**. In various embodiments, the second transverse direction rack **230** is configured to interact with a corresponding pinion (e.g., gear) operated by a suitable actuator (not pictured) in order to impart a linear translation on the second transverse direction rack **230** with respect to the actuator support **232**.

[0075] FIG. **7** depicts a detail view of a first end of the pneumatic tube insert **200**. As may be understood from this figure, the actuator support **232** defines an actuator support **233** configured to receive an actuator (e.g., motor). The actuator support **232** further defines a track **235** that is substantially parallel to a transverse axis of the pneumatic tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system. As may be understood from FIG. **7** and FIG. **6**, the track **235** is sized and configured to receive at least a portion of the second transverse direction rack **230** such that opposing portions of the actuator support **232** maintain the second transverse direction rack **230** within the track **235**. The actuator support **232** further comprises a rotating connector **234** disposed at least partially within the track **235**. As may be understood in light of these figures, the rotating connector **234** is configured to maintain the second transverse direction rack **230** within the track **235** and further configured to rotate in response to actuation by an actuator (not pictured). In some embodiments, the rotating connector **234** cooperates with the track **235** to maintain at least a portion of the second transverse direction rack **230** within the track **235**. In this way, the second transverse direction rack **230** is configured to translate within the track **235** in response to a rotation of the rotating connector **234**.

[0076] FIGS. **8-10** depict detail views of the actuator support **222**. As may be understood from these figures, the actuator support **222** comprises a substantially rectangular body defining an actuator receiving recess **223** configured to receive an actuator (e.g., motor). The actuator support **222** further defines a track **225** that is substantially parallel to a transverse axis of the pneumatic tube insert **200** when the pneumatic tube insert **200** is travelling through a pneumatic tube system. As may be understood these figures, the track **225** is sized and configured to receive at least a portion of the actuator support **232** such that opposing portions of the actuator support **222** maintain the first transverse direction rack **220** within the track **225**. The actuator support **222** further comprises a rotating connector **224** disposed at least partially within the track **225**. As may be understood in light of these figures, the rotating connector **224** is configured to maintain the first transverse direction rack **220** within the track **225** and further configured to rotate in response to actuation by an actuator (not pictured). In this way, the first transverse direction rack **220** is configured to translate within the track **225** in response to a rotation of the rotating connector **224**.

[0077] The actuator support **222** further comprises a second transverse direction rack **230** that extends from a rear portion of the actuator support **222**. The second transverse direction rack **230** is substantially perpendicular to the body of the actuator support **222**. FIG. **11** depicts the actuator support **222** with the first transverse direction rack **220**. As may be understood from this figure, the first transverse direction rack **220** is configured to slidably nest within the track **225**, maintained within the track **225** by at least the rotating connector **224**. The first transverse direction rack **220** further comprises a sample housing connector **227** configured to at least temporarily couple the first transverse direction rack **220** to the sample housing **250**.

[0078] FIG. **12** depicts a detail view of the sample housing **250**. As shown in this figure, the sample housing **250** comprises a first connector **257** disposed adjacent the first end of the sample housing **250**. The first connector **257** may be configured to at least temporarily couple (e.g., ratably couple via a suitable pin or other rotating member) to the sample housing connector **227** of the first transverse direction rack **220** (shown in FIG. **11**). The sample housing **250** further comprise a second connector **259** adjacent the second end of the sample housing **250**. The second connector **259** may be configured to couple to at least temporarily couple (e.g., ratably couple via a suitable pin or other rotating member) to a sample housing connector **227** (described more fully below) of the first transverse direction slider **226**. The sample housing **250** further comprise a first housing portion **251** and a second housing portion **252**. The first housing portion **251** and the second housing portion **252** form a substantially cylindrical housing configured to at least temporarily store one or more samples, such as those described herein.

[0079] FIG. **13** depicts an exploded view of the sample housing **250**. The first housing portion **251** may include a suitable casing to receive one or more sample housings such as a test tube. In some embodiments the second housing portion **252** provides a lid of the casing of first housing portion **251** to at least temporarily store one or more samples within the sample housing **250** during transportation.

[0080] As may be understood from this figure, the sample housing **250** further comprises a substantially cylindrical dampener housing portion **256** that is configured to receive at least one linear dampener and/or longitudinal support for the sample housing **250**. In the embodiment shown in this figure, the sample housing **250** comprises a first linear dampener **255**A and a second linear dampener **255**B. In any embodiment described herein, the first linear dampener **255**A and the second linear dampener **255**B may comprise one or more dampeners (e.g., one or more dashpots, one or more biasing mechanism, etc.) configured to reduce an amount of force experienced by the sample housing **250** during transportation. In some embodiments, the linear dampener **255**A and the linear dampener **255**B form part of a longitudinal direction support **110** (e.g., described above with respect to FIGS. **1-3**). In various embodiments, the pneumatic tube insert **200** further comprise at least one actuator (not pictured) configure to cause translation of the sample housing **250** along the longitudinal direction support **110**.

[0081] In still other embodiments, a first linear dampener **255**A and a second linear dampener **255**B (e.g., one or more linear dampeners) may be disposed adjacent to the sample housing **250** rather than at least partially within the sample housing **250**. In such embodiments, one or more linear dampeners may provide a dampening buffer along any suitable axis described herein. In some embodiments, for example, each linear dampener may have a first end and a second end. In such embodiments, a first end of each linear dampener may be coupled to any suitable portion of the sample housing **250**. The second end of each linear dampener may then be coupled any suitable portion of the pneumatic tube insert **200** (e.g., or the pneumatic tube itself). In particular embodiments, each linear dampener is coupled to any suitable portion of the sample housing **250** and/or pneumatic tube insert **200** but is not coupled directly to a second linear dampener.

[0082] FIG. **14** depicts a detail view of a second end of the pneumatic tube insert **200**. As shown in this figure, the first transverse direction slider **226** is slidably disposed within the first transverse direction slider support track **228** and configured to slide and/or translate linearly within a track defined by the first transverse direction slider support track **228**. Similarly, the second transverse direction slider **236** is slidably disposed in the second transverse direction slider support track **238** and configured to slide and/or translate within a track defined by the second transverse direction slider support track **238**. FIG. **15** depicts a detail view of the first transverse direction slider **226**. As shown in this figure, the first transverse direction slider **226** comprises a sample housing connector

**227** extending from a front face of the first transverse direction slider **226** and configured to couple to the second connector **259**. FIGS. **16** and **17** depict detail views of the first transverse direction slider support track **228**. As shown in these figures, the first transverse direction slider support track **228** defines a track configured to receive the first transverse direction slider **226**. The first transverse direction slider support track **228** comprises a substantially rectangular body and a second transverse direction slider **236** extending from a rear portion of the first transverse direction slider support track **228**. The second transverse direction slider **236** is substantially parallel to the first transverse direction slider support track **228** and configured to translate within a track defined by the second transverse direction slider support track **238**.

Pneumatic Tube Transport Device Component Control Process

[0083] FIG. **18** depicts an exemplary process for controlling pneumatic tube transport device components based on sensor data in accordance with various embodiments of the present disclosure. This process may, for example, include operations that computing hardware in the pneumatic tube insert **200** (e.g., the control circuitry **109**) may execute to activate one or more actuators in response to sensor readings received by the computing hardware. In any embodiment described herein, the computing hardware and/or control circuitry **109** may comprise any suitable processing circuitry configured to receive and interpret sensor data from a gyroscope or other sensor, determine opposing force and/or motion data to at least partially counteract a motion and/or force on the sample housing, and cause one or more actuators at least temporarily impart an at least partially counteracting motion and/or force on the sample housing. The computing hardware may, for example, comprise any suitable microcontroller.

[0084] For instance, the flow diagram shown in FIG. **18** may correspond to operations performed by computing hardware found in the pneumatic tube insert **200** that is operatively coupled to both one or more sensors and one or more actuators in the pneumatic tube insert **200**.

[0085] At operation **1802**, the computing hardware (e.g., control circuitry **109**) receives data from one or more sensors disposed in and/or on the pneumatic tube insert **200**. The computing hardware may receive the data while the pneumatic tube insert **200** is travelling through a pneumatic tube system. In some embodiments, the data received from the one or more sensors may include, for example: (1) velocity data (e.g., direction and speed); (2) acceleration data; (3) temperature data; (4) force data; (5) identification data (e.g., from an RFID tag or other unique identifier); (6) etc.

[0086] At operation **1084**, the computing hardware determines, based on the sensor data, a responsive action. In some embodiments, the responsive action is configured to counteract, reduce, or otherwise negate a force, moment, acceleration, change in position, velocity, or other outside force experienced by a sample disposed within the sample housing **250** during transportation. For example, in some embodiments, the computing hardware may determine a responsive action that includes applying an opposing force, velocity, acceleration, etc. to a force, velocity, or acceleration identified from the sensor data. By determining to move the sample housing **250** in a direction opposing a detected direction of movement, the system may reduce an amount of force on a sample housed within the sample housing **250**, and reduce a likelihood that the sample will be damaged or unsuitable for use.

[0087] In still other embodiments, the responsive action may include generating an alert and transmitting the alert to a suitable computing device or otherwise making the alert accessible via a suitable computing device. The responsive action may, for example, include generating and/or modifying a user interface to include the alert. The alert may include, for example, an alert that the pneumatic tube insert **200** has experienced a temperature outside of a desired range, that a sample in the sample housing **250** has experienced a force or rate of travel so great, that the sample is likely unusable despite the use of other potential responsive actions (such as applying counteracting motion to the sample), etc. In some aspects, the pneumatic tube insert **200** may include a suitable indicator (e.g., a light, display screen, etc.) that the computing hardware may activate to provide an indication of an alert.

[0088] In some embodiments, the computing hardware is configured to substantially continuously determine responsive actions as the computing hardware continues to receive sensor data.

[0089] At operations **1806**, the computing hardware may cause the responsive action. In some embodiments, the responsive action may include any suitable responsive action described herein (e.g., applying an opposing movement in any of three dimensions, etc.). Causing the responsive action may, for example, comprise causing operation of any of the set of actuators that make up the pneumatic tube insert **200**.

[0090] Following the responsive action, the computing hardware may optionally revert the pneumatic tube insert **200** to an initial configuration. The initial configuration may include, for example, a default position of the sample housing **250** within the pneumatic tube insert **200**. So, for example, in embodiments in which the computing hardware applies an anti-parallel linear motion to the sample housing **250** (e.g., in the longitudinal direction or one or more transverse directions), the one or more actuators may be configured to, following a particular distance of travel of the sample housing **250**, bias or otherwise translate the sample housing **250** back to a default position (e.g., substantially centrally disposed within the pneumatic tube insert **200** and/or pneumatic tube carrier). For example, the one or more actuators may cooperate to actuate the sample housing **250** back to the default position by translating the sample housing **250** at least partially in a direction and for at least partially a distance opposite the direction and distance by which the one or more actuators translated the sample housing **250** as part of the responsive action.

Pneumatic Tube Transport Device Tracking and Initialization Processes

[0091] In some embodiments a pneumatic tube transport device may include one or more unique identifiers such as an RFID tag, machine-readable indicia (e.g., QR code, barcode, etc.). In some aspects, a pneumatic tube transport system may include one or more unique identifier readers disposed at various locations throughout the system. In this way, the system may be configured to track a location of a particular sample (e.g., through tracking a location of a pneumatic tube in which the sample is disposed) by identifying the unique identifier from a particular pneumatic tube at a particular location in the system. In some aspects, the system may, for example, be configured to track a start and end location, time of transport, and/or other location data for a particular sample. In any embodiment described herein, the system may generate a user interface for display on a suitable computing device that includes an indication of the location information for a particular sample.

[0092] For example, in the context of the Pneumatic Tube Transport Device Component Control Process discussed above, the process may involve receiving location data for the sample based on scanning an RFID tag or suitable machine-readable indicia on the pneumatic tube and/or pneumatic tube insert in which the sample is housed. For example, when a user is utilizing a pneumatic tube system to transport a patient sample, the user may perform an initial RFID scan of the pneumatic tube carrier (e.g., or insert). The user may then access a user interface to provide data related to the sample. This may include, for example, a patient identifier, a sample identifier, a sample destination, etc. The system may then scan the RFID tag as the tube carrier passes particular RFID scanners along the pneumatic tube system in order to update a substantially current location of the sample within the system. The process may then generate and/or update a user interface to include information related to the location data (e.g., start/end location, path of transit through the pneumatic tube system, transportation time, etc.).

[0093] Additionally, the system or process described herein may utilize sample data to determine a maximum threshold of g-forces and other environmental limits for a particular sample. The system may then track environmental factors such as temperature, forces, etc. experienced by the same (e.g., using one or more sensors described herein) to determine whether the sample has experienced environmental conditions that are outside of an acceptable range. In response to determining that a sample has experienced such conditions, the system may generate and/or modify a user interface to include an indication of such experience in association with the sample. The system may then provide the user interface for display on a user computing device.

[0094] It should be emphasized that the above-described examples of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

## Claims

**1**. A sample transportation system comprising: a housing; at least one gyroscope sensor disposed within the housing; a substantially linear track disposed within the housing, the substantially linear track being substantially parallel to a longitudinal direction of travel of the housing within the sample transportation system; a sample receptacle slidably coupled to the substantially linear track; at least one motor in mechanical communication with at least one of the sample receptacle or the substantially linear track, the at least one motor configured to cause the sample receptacle to translate parallel to the substantially linear track with respect to the housing; and computing hardware disposed within the housing and coupled to the at least one gyroscope sensor, wherein the computing hardware is configured to: receive velocity data from the at least one gyroscope sensor; and operate the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data.

**2**. The sample transportation system of claim 1, wherein operating the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data comprises operating the at least one motor to translate the sample receptacle antiparallel to a direction of travel identified based on the velocity data.

**3**. The sample transportation system of claim 1, further comprising: a second substantially linear track disposed within the housing, the second substantially linear track being oriented in a first transverse direction that is substantially perpendicular to the longitudinal direction of travel of the housing within the sample transportation system; a second motor in mechanical communication with at least one of the sample receptacle or the second substantially linear track, the second motor configured to cause the sample receptacle to translate parallel to the first transverse direction, wherein: a first end of the substantially linear track is slidably coupled to the second substantially linear track; and the computing hardware is further configured to operate the second motor to cause the sample receptacle to translate in the transverse direction with respect to the housing based on the velocity data.

**4**. The sample transportation system of claim 1, further comprising: a third substantially linear track disposed within the housing, the third substantially linear track being oriented in a second transverse direction that is substantially perpendicular to both the longitudinal direction and the second longitudinal direction; a third motor in mechanical communication with at least one of the sample receptacle or the third substantially linear track, the third motor configured to cause the sample receptacle to translate parallel to the second transverse direction, wherein: the computing hardware is further configured to operate the third motor to cause the sample receptacle to translate in the second transverse direction with respect to the housing based on the velocity data.

**5**. The sample transportation system of claim 1, wherein the sample transportation system is configured for at least one of insertion into a pneumatic tube carrier for use in the sample transportation system or standalone use in the sample transportation system.

**6**. The sample transportation system of claim 1, wherein the substantially linear track comprises at least one integrated dampener.

**7**. The sample transportation system of claim 1, wherein operating the at least one motor to cause the sample receptacle to translate with respect to the housing based on the velocity data comprises causing the sample receptacle to translate in the longitudinal direction at a velocity opposite a velocity determined from the velocity data.

**8**. A pneumatic tube carrier comprising: a longitudinal direction support that is substantially parallel to a longitudinal direction of travel of the pneumatic tube carrier when the pneumatic tube carrier is travelling through a pneumatic tube system; a sample housing disposed on the longitudinal direction support; at least one actuator operatively coupled to the sample housing and configured to cause the sample housing to translate substantially parallel along at least a portion of the longitudinal direction support; at least one sensor disposed on or in the pneumatic tube carrier; and computing hardware operatively coupled to the at least one sensor and the at least one actuator, wherein the computing hardware is configured for: receiving sensor data from the at least one sensor; determining a set of actuator instructions based on the sensor data; and operating the at least one actuator according to the set of actuator instructions to at least partially counteract a force, velocity, direction of motion, or acceleration identified based on the sensor data.

**9**. The pneumatic tube carrier of claim 8, wherein the longitudinal direction support comprises at least one integrated dampener.

**10**. The pneumatic tube carrier of claim 9, wherein the at least one integrated dampener comprise at least one biasing mechanism or at least one dashpot.

**11**. The pneumatic tube carrier of claim 8, wherein: the sensor data comprises a force on the pneumatic tube carrier; the responsive action comprises causing the at least one actuator to apply a force that is opposing of the force on the pneumatic tube carrier on the sample housing.

**12**. The pneumatic tube carrier of claim 8, wherein: the at least one actuator comprises a set of actuators; and the set of actuators are configured to cooperate to at least partially counteract the force, velocity, direction of motion, or acceleration identified by translating the sample housing in three dimensions.

**13**. The pneumatic tube carrier of claim 8, further comprising: a first transverse direction support substantially perpendicular to the longitudinal direction support, wherein the at least one actuator is further configured to cause the sample housing to translate substantially parallel along at least a portion of the first transverse direction support.

**14**. The pneumatic tube carrier of claim 13, further comprising: a second transverse direction support substantially perpendicular to the longitudinal direction support and the first transverse direction support, wherein the at least one actuator is further configured to cause the sample housing to translate substantially parallel along at least a portion of the second transverse direction support.

**15**. A pneumatic tube insert comprising; a sample housing; at least one actuator operatively coupled to the sample housing and configured to cause the sample housing to translate in a direction substantially parallel to a longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through a pneumatic tube system; at least one sensor disposed on or in the pneumatic tube insert; and computing hardware operatively coupled to the at least one sensor and the at least one actuator, wherein the computing hardware is configured for: receiving sensor data from the at least one sensor; determining a responsive action based on the sensor data; and causing the responsive action.

**16**. The pneumatic tube insert of claim 15, wherein: the sensor data comprises a velocity of the pneumatic tube insert; the responsive action comprises causing the sample housing to translate in the longitudinal direction in a direction opposite the velocity of the pneumatic tube insert at a rate that corresponds to the velocity; and causing the responsive action comprises causing the at least one actuator to translate the sample housing in the longitudinal direction in the direction opposite the velocity of the pneumatic tube insert at the rate that corresponds to the velocity.

**17**. The pneumatic tube insert of claim 15, wherein the pneumatic tube insert is configured to be selectively inserted into a pneumatic tube carrier for use in the pneumatic tube system.

**18**. The pneumatic tube insert of claim 15, wherein: the at least one sensor comprises at least one of a gyroscope, an accelerometer, or a temperature sensor; the responsive action comprises at least one of activating the at least one actuator, generating a temperature alert; or generating an excessive force alert.

**19**. The pneumatic tube insert of claim 15, wherein: the pneumatic tube insert comprises: a first transverse direction rack; an actuator support defining a linear track, wherein the actuator support is configured to receive the at least one actuator and the linear track is configured to receive at least a portion of the first transverse direction rack such that the first transverse direction rack is slidably disposed within the linear track; a rotating connector coupled to the at least one actuator, the rotating connector in operable engagement with the first transverse direction rack; a first end of the sample housing is coupled to the first transverse direction rack; and the responsive action comprises operating the at least one actuator to rotate the rotating connector to cause the first transverse direction rack to translate at least the first end of the sample housing in a transverse direction relative to the longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through the pneumatic tube system.

**20**. The pneumatic tube insert of claim 19, wherein: the actuator support comprises a second transverse direction rack substantially perpendicular to the transverse direction rack; the pneumatic tube insert comprises a second actuator support defining a second linear track, wherein the second actuator support is configured to receive a second actuator, and the second linear track is configured to receive at least a portion of the second transverse direction rack such that the second transverse direction rack is slidably disposed within the second linear track; a second rotating connector coupled to the second actuator, the second rotating connector in operable engagement with the second transverse direction rack; the responsive action comprises operating the second actuator to rotate the second rotating connector to cause the second transverse direction rack to translate at least the actuator support in the second transverse direction relative to the longitudinal direction of travel of the pneumatic tube insert when the pneumatic tube insert is travelling through the pneumatic tube system; and the transverse direction is substantially perpendicular to the second transverse direction.