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(54) **SOLID INSTRUMENTED SPHERICAL BLAST IMPULSE RECORDING DEVICE (SISBIRD)**

(71) Applicant: **US Gov't as represented by Secretary of Air Force**, Wright-Patterson AFB, OH (US)

(72) Inventors: **Charles M. Jenkins**, Ft Walton Beach, FL (US); **Alain L. Beliveau**, Niceville, FL (US)

(73) Assignee: **United States of America as represented by the Secretary of the Air Force**, Wright-Patterson AFB, OH (US)

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This patent is subject to a terminal disclaimer.

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CPC **G01L 5/14** (2013.01)

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CPC . G01L 5/14; G01L 5/00; G01L 5/0004; G01L 5/0009; G01L 23/00; G01L 1/00
See application file for complete search history.

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Primary Examiner — Michael P Nghiem

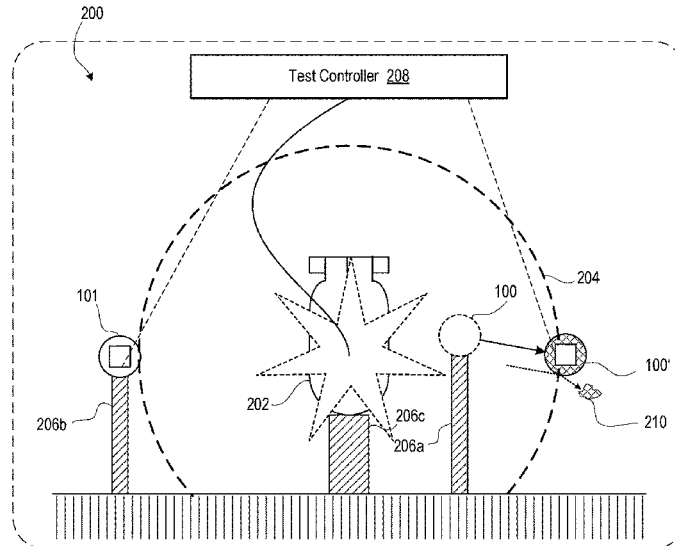
Assistant Examiner — Dachhang P Ngo

(74) *Attorney, Agent, or Firm* — AFMCLO/JAZ; David E. Franklin

(57) **ABSTRACT**

A Solid Instrumented Spherical Blast Impulse Recording Device (SISBIRD) includes a spherical housing formed of material that is resistant to an explosive blast wave from a test weapon. A test payload bore shaft is accessible through an opening in the spherical housing. A door is fastened over the opening in the spherical housing. A test data module is received in the test payload bore shaft. The test data module includes: (i) a three-axis acceleration sensor; (ii) a memory; and (iii) a controller. The controller is communicatively coupled to the three-axis acceleration sensor and the memory. The controller executes a data acquisition utility to record, in the memory, acceleration data in three-dimensions from the three-axis acceleration sensor during exposure of the spherical housing to the explosive blast wave.

6 Claims, 2 Drawing Sheets



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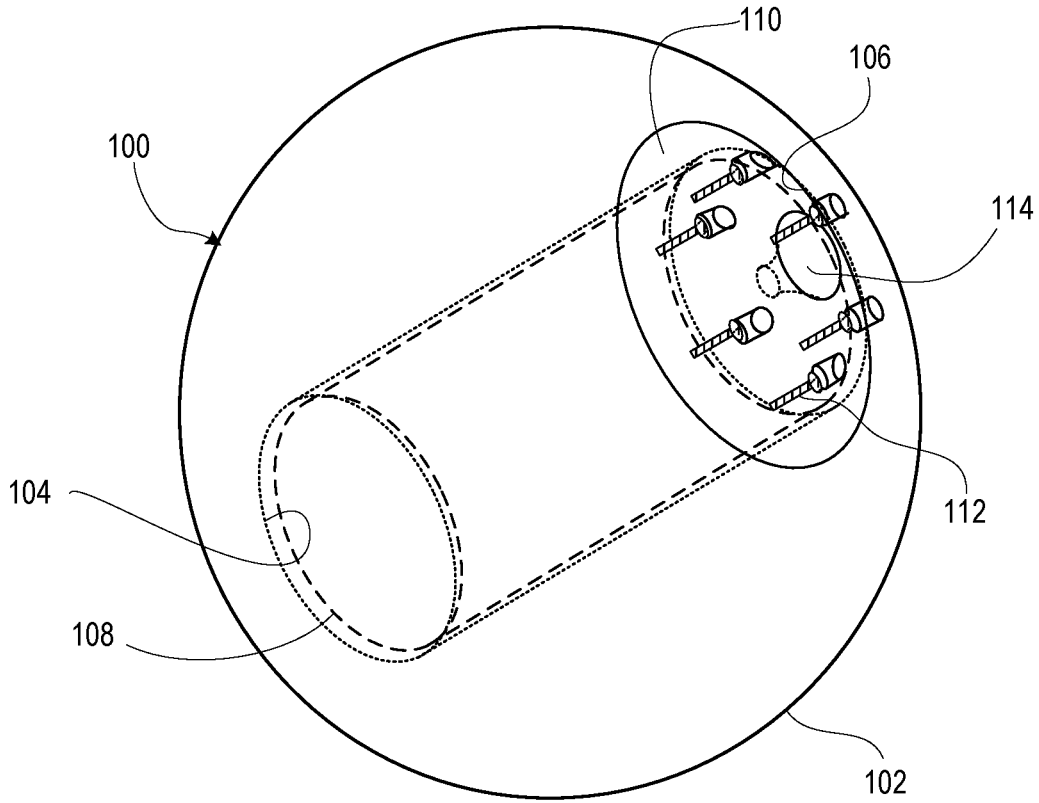


FIG. 1

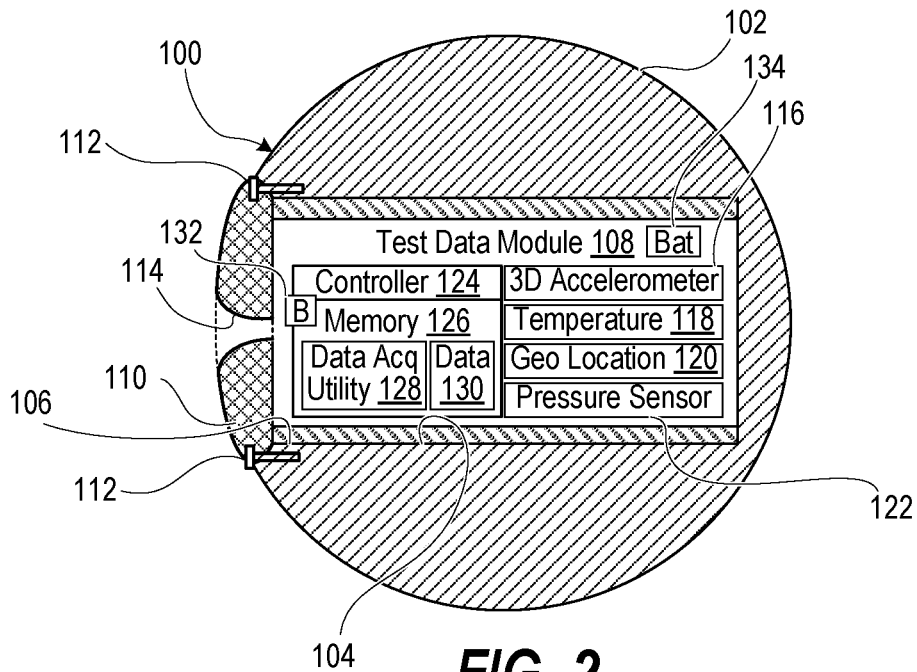


FIG. 2

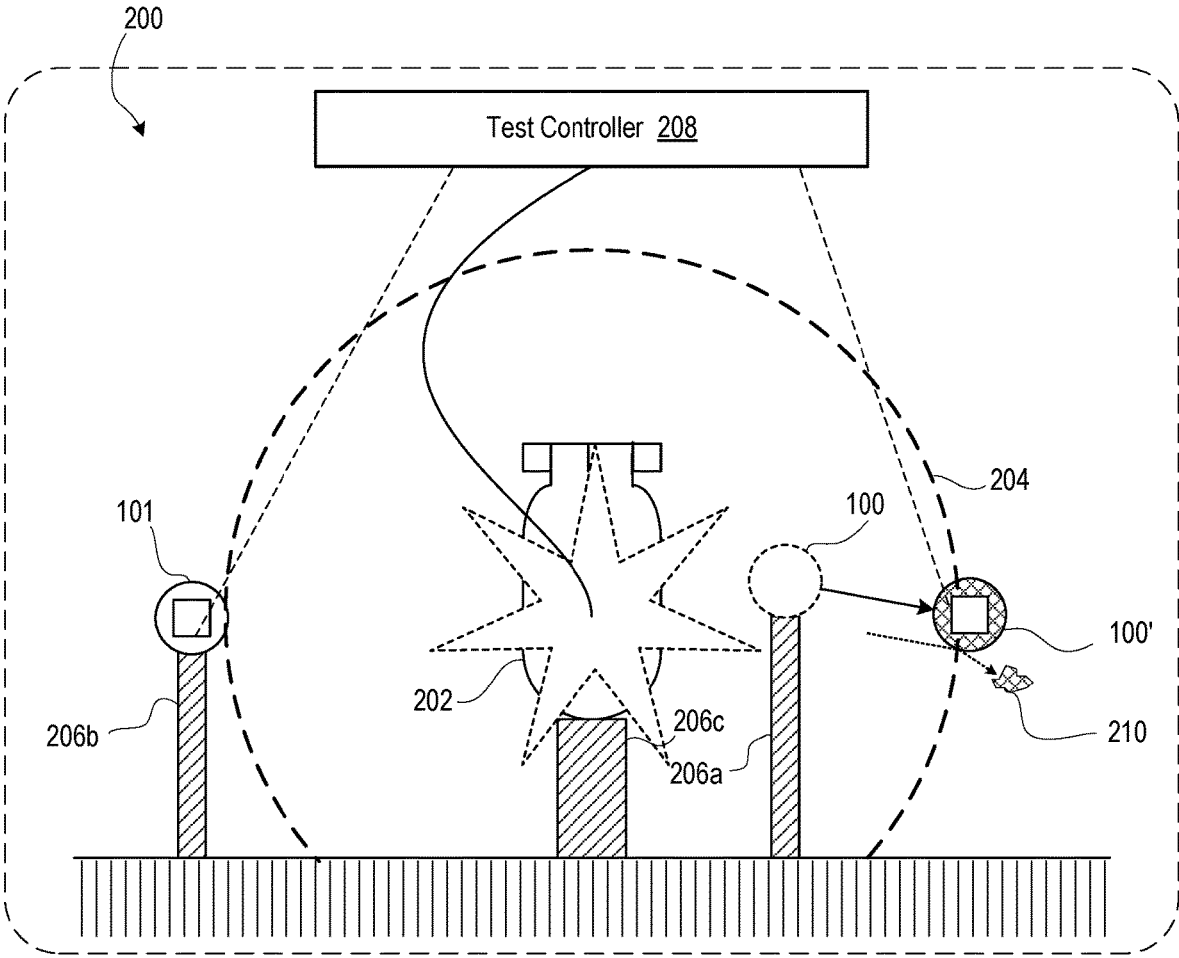


FIG. 3

SOLID INSTRUMENTED SPHERICAL BLAST IMPULSE RECORDING DEVICE (SISBIRD)

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority under 35 U.S.C. § 119(e) to U.S. Provisional Application Ser. No. 62/838,471 entitled "Solid Instrumented Spherical Blast Impulse Recording Device (SISBIRD)", filed 25 Apr. 2019, the contents of which are incorporated herein by reference in their entirety.

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

BACKGROUND

1. Technical Field

The present disclosure generally relates to acceleration measurement devices, and more particularly relates to acceleration measurement devices that have are survivable in an explosive blast wave environment.

2. Description of the Related Art

Explosive devices are tested to determine blast characteristics, such as by placing various targets at varying distances to be accelerated by a blast wave. More accurate empirical data regarding blast impulse is obtained by positioning impulse measurement devices, generally referred to as unconfined momentum traps (UMTs), with proximity to explosive device. Generally-known UMTs have block shape that is positioned to receive the blast impulse against a reinforced side. Physical forces exerted on the UMT are measured as acceleration.

While able to collect information related to the blast impulse, generally-known UMTs can be less than accurate or reliable in gathering test data. UMTs have limits to the magnitude of blast impulse that is survivable. Orienting the UMT relative to the direction of the blast is important in order for the UMT to survive and to collect useful data. Explosive devices can have different secondary effects, such as shrapnel and projectile that can adversely interact with the UMD during the blast. Even if correctly placed and not degraded by impacts, extracting test results from generally-known UMDs can be difficult or time consuming.

For example, the disk UMT is a circular flat metal disks 3-4 inches in diameter with a ½ to ¼ inch thickness or they can be another shaped block such as a cone or hemisphere that a shape factor is applied to in order to adjust the drag coefficient from that of a sphere. The mass and distance the UMT is thrown and the height above ground provides parameters used to calculate the total impulse applied to the UMT. An inverted ballistic pendulum (IBP) is a pivoting wall that is placed face on to the explosive charge and rotates about the hinged point at the top edge of the plate and stand, the height of the plate movement from a baseline is a measurement for total impulse. Cantilever Plates, provide a plastic deformation angle of a metal rod which in-turn provides the value to calculate the total impulse value.

All of these older methods can suffer from large measurement uncertainty from coefficients of material restitution between the particle and sensing material device based on collision elastic response and energy transmittance. Unusual drag effects do to a changing projected area of the UMT to the blast wave is also a factor. Energy losses from mechanical connections to the IBP and material anomalies in the Cantilever Plate poles also contribute to uncertainty in the impulse calculation. Also, most of these devices have an upper limit to the impulse they can take and still function, whereas the present innovation as described herein does not.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the illustrative embodiments can be read in conjunction with the accompanying figures. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein, in which:

FIG. 1 illustrates an isometric diagram view of an Instrumented Spherical Blast Impulse Recording Device (ISBIRD) with interior components shown in phantom lines, according to one or more embodiments;

FIG. 2 illustrates a simplified functional block diagram of an ISBIRD of FIG. 1, according to one or more embodiments;

FIG. 3 illustrates a simplified side view diagram of an ISBIRD positioned in a testing scenario for an explosive device, according to one or more embodiments.

DETAILED DESCRIPTION

In one or more embodiments, FIGS. 1-2 illustrate Solid Instrumented Spherical Blast Impulse Recording Device (SISBIRD) 100. Spherical housing 102 of SISBIRD 100 is formed of a metal, ceramic, polymer or other strong material that is survivable from an explosive blast wave from a test weapon. Test payload bore shaft 104 is accessible through opening 106 in spherical housing 102. Test data module 108 is received in test payload bore shaft 104. Door 110 is attached with fasteners 112 to spherical housing 102 over opening 106 in spherical housing 102. Vent port 114 through door 110 enables pressure and temperature readings of an ambient environment to be made by test data module 108.

With reference to FIG. 2, test data module 108 has one or more sensors related to explosive blast testing, such as: (i) three-axis acceleration sensor (accelerometer) 116; (ii) temperature sensor 118; (iii) geographic location sensor 120; and (iv) pressure sensor 122. Examples of geographic location sensor 120 include global positioning satellite (GPS) receiver or an automatic direction finder (ADF). Controller 124 is communicatively coupled to memory 126 and three-axis accelerometer 116, temperature sensor 118, geographic location sensor 120, and pressure sensor 122. Controller 124 executes data acquisition utility 128 to record, in memory 126, test data 130 such as acceleration data in three-dimensions, temperature, location and pressure during exposure of spherical housing 102 to an explosive blast wave.

In one or more embodiments, SISBIRD 100 includes beacon 132 that emits visible light, infrared light, acoustic output, or radio frequency (RF) to assist in locating SISBIRD 100. Controller 124 is communicatively is coupled to beacon 132 to activate beacon 132 in response to exposure

of spherical housing **102** to the explosive blast wave. Electrical power for SISBIRD **100** is provided by replaceable or rechargeable battery **134**.

According to one or more embodiments, FIG. **3** illustrates SISBIRD **100** positioned in testing scenario **200** for explosive device **202**. Instrumented Spherical Blast Impulse Recording Device (ISBIRD) **101** is positioned farther away from explosive device **202** than SISBIRD **100**. ISBIRD **101** is described in greater detail in U.S. Patent Application Ser. 62/837,003 filed 22 Apr. 2019, the disclosure of which is hereby incorporated by reference in its entirety. Explosive device **202** can be a bomb, warhead, mine, missile, cannon shell or ordnance, or other assembly that includes explosive material capable of producing an explosive blast impulse or wave **204**. SISBIRD **100** is not sensitive to orientation with respect to explosive device **202**. Pedestals **206a-c** preposition respectively SISBIRD **100**, ISBIRD **101**, and explosive device **202**. As depicted in FIG. **3**, explosive impulse **204** has thrown SISBIRD **100** to a new position (SISBIRD **100'**). At this instant, explosive impulse **204** has just encountered ISBIRD **101**. As a largely solid object, in one or more embodiments SISBIRD **100** can absorb a greater blast force than ISBIRD **101**, which can enable positioning SISBIRD **100** closer to explosive device **202** or can enable withstanding projectiles or shrapnel **210** of higher energy and momentum. The additional density of SISBIRD **100** can result in a slower acceleration than ISBIRD **101**, allowing use of accelerometers that operate in a lower range. The slower acceleration can also keep the SISBIRD **100** within a smaller radius from explosive device **202**.

Test controller **208** triggers detonation of explosive device **202** and wirelessly receives test data from SISBIRD **100**. Test data can also be manually extracted from SISBIRDs **100**. The spherical shape of SISBIRD **100** provides for a predictable aerodynamic response to explosive impulse **204** that is not sensitive relative rotation with respect to explosive device **202**. The spherical shape also mitigates impact by shrapnel or projectiles **210** that originate from explosive device **202**. Most of the spherical shape presents a tangential impact surface to projectile **210**, which absorbs less impact and presents a stronger surface than a perpendicular impact.

The present innovation differs from previous mass block only UMTs and other instrumented shapes by using a state of the art machined reusable metallic spherical shaped container with a reusable on-board high resolution 3-axis commercially available accelerometer, additional instrumentation for temperature, pressure and position (GPS) could be added. This major improvement in a spherical shape maintains the same presented surface area to the blast wave regardless of the device's rotation or spatial orientation ensuring simplification of the applicable drag law equations and a higher breakthrough accuracy in the determination of the blast impulse and applied forces on the measurement device. The device's improvement in impulse calculation will support the accuracy needed to compare changes in experimental blast impulse measurement for variations in explosive device designs, orientation and radial distance from the explosive event. The device's measured data will provide a level of accuracy and repeatability not currently available. The present innovation ensures high quality data for validation and verification of high resolution computational models used in design and optimization of new explosives currently being developed for the Department of Defense and specifically the United States Air Force. The specific design of the device and its instrumented package could be applied by commercial industry in applications involving the measurement of fluid flows in large

volume chemical reactors and mass flow transport systems (pipelines) in oil and gas refineries, fluidized bed reactors, and air/gas stripping columns. Further development is in progress to instrument the device with an accelerometer capable of 10× the data rate currently available and to adjust the specific material type of the sphere to the demands of the environment in which the device is being used. Thus the aluminum material identified in the patent could be changed depending on the corrosive environment to a composite material, stainless steel or tantalum to enhance the survivability of ISBIRD **100**.

As a proof of concept, testing was conducted to compare instrumented spheres and disk-shaped UMTs. Each prototype was exposed to explosively driven blast waves to determine the effect of shape on different UMT accelerations. The spherical UMTs were successfully tested. The present disclosure provides that is a state-of-the-art machined reusable metallic spherical shaped protective container with a reusable on-board, high-resolution 3-axis commercially available accelerometer that is resistant to high impulse loading and shock. Additional sensors for measuring temperature, pressure and local position via GPS can be accommodated. The spherical shape maintains the same presented surface area to the blast wave regardless of the rotation or spatial orientation of the spherical UMT. The continuity in response simplifies the applicable drag law equations and provides a greater accuracy in the determination of the blast impulse and applied forces on the measurement device. The device's improvement in acceleration measurement will support the accuracy needed to compare changes in experimental blast impulse for variations in explosive device designs and explosive type at different target orientation and radial distance from the explosive event.

The present innovation supports test operations for explosive testing and possibly in the commercial industry in applications involving the measurement of fluid flows in large volume unit operations such as reactors and mass flow transport systems such as oil and gas refineries, fluidized bed plug flow reactors and air/gas stripping columns. The aluminum material identified in the patent for the instrument outer shell could be changed for increased survivability in corrosive environments by using stainless steel or tantalum to enhance survivability or reduce weight by using a composite material in less corrosive environments.

The present innovation is highly responsive to the blast wave and has a capability to provide more accurate impulse measurements than an instrumented disk momentum UMT due to the same presented surface area and shape at all time during the blast event. Standard solid UMTs only provides a single impulse data point as opposed to ten (10) or more from an instrumented UMT. ISBIRD **100** enables quick analysis and graphing capability of the acceleration versus time data to determine total impulse with provided software used on any compatible laptop. ISBIRD **100** is durable and can be used multiple times with a spherical housing that can be made of different materials for different strength requirements and corrosive environments. Additionally, reset time is faster than traditional impulse measuring devices, alignment is quicker and the entire blast field can be instrumented with several of these instruments at any azimuth, height or radius for a detailed mapping of the blast field at the same time. All parts of ISBIRD **100** are serviceable or replaceable commercially.

ISBIRD **100** is designed to accurately record the acceleration of a known shape when accelerated by a blast wave generated by a high explosive detonation or by other dis-

placing fluid bodies. By measuring the acceleration of an object of known mass and shape it is possible to then calculate the applied impulse to the sphere. ISBIRD 100 is designed to survive the extreme pressures and shock environment in near proximity of the detonation event. ISBIRD 100 records the acceleration of the sphere and saves the data until the sphere stops moving and is later downloaded to a data base such as a laptop computer where the data can then be processed into a meaningful format and displayed. ISBIRD 100 is designed to also survive a violent impact with the ground after it has been carried by the blast wave. Outer shell of ISBIRD 100 can be metallic to resist particulate and ground impact during the event. The metallic shell is uniquely designed as a two piece shell enclosure to house the sensor package in which the material has been machined from a solid single billet of material for increased strength and durability. In one or more embodiments, the two halves are held together along a fitted surface under compression using the accelerometer case located in the center and six machine screws on each end to pull the halves together in place along the fitted surface to form a sphere. Different materials can be used on the outer spherical shell depending on the shock, temperature, impact or corrosion resistance that is needed. The seam along the fitted surface can also be fitted with a gasket to seal the ISBIRD 100 for gas or liquid immersions.

The instrumented package contains an accelerometer, recorder and battery package, it is contained within the spherical protective shell which has been designed to withstand very high G force acceleration events and vibrations; it is a commercial off the shelf (COS) item separately produced. The instrument package electronics can be accessed via a cable system that leads to the exterior of the shell, making it possible to arm the instrument package while the item is being set on the test stand saving the onboard battery life until the test is ready to begin.

ISBIRD 100 is designed to sit on a "golf tee" like support of high density polyurethane foam or of a similar material and positioned to a height by a light structure such as wood table stand. ISBIRD 100 is deliberately launched when a blast wave strikes ISBIRD 100. Later, ISBIRD 100 is retrieved and the data downloaded. The instrumented package is then provided with a freshly charged battery sealed up in the sphere and armed when ready and placed on a new support for the next test.

The spherical case may be modified to fit the application of the specific operating environment. There are two primary reasons to choose the correct case material; durability in the operating environment and weight of the material as it relates to the expected applied forces. Durability covers the resistance to damage in the extreme environment of the blast wave and weight of the case as it applies to the size or distance of the explosive charge in order to push the invention a long enough distance to generate good usable data.

The specific design of the device and its instrumented package could be applied by to commercial industry in applications involving the measurement of fluid flows in large volume reactors and mass flow transport systems such as oil and gas refineries, fluidized bed reactors, air/gas stripping columns and other large mass flow unit operations both enclosed and in the open environment.

While the disclosure has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the disclosure. In addition, many modifications may be made to adapt a particular system,

device or component thereof to the teachings of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiments disclosed for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

In the preceding detailed description of exemplary embodiments of the disclosure, specific exemplary embodiments in which the disclosure may be practiced are described in sufficient detail to enable those skilled in the art to practice the disclosed embodiments. For example, specific details such as specific method orders, structures, elements, and connections have been presented herein. However, it is to be understood that the specific details presented need not be utilized to practice embodiments of the present disclosure. It is also to be understood that other embodiments may be utilized and that logical, architectural, programmatic, mechanical, electrical and other changes may be made without departing from general scope of the disclosure. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims and equivalents thereof.

References within the specification to "one embodiment," "an embodiment," "embodiments," or "one or more embodiments" are intended to indicate that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. The appearance of such phrases in various places within the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Further, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not other embodiments.

It is understood that the use of specific component, device and/or parameter names and/or corresponding acronyms thereof, such as those of the executing utility, logic, and/or firmware described herein, are for example only and not meant to imply any limitations on the described embodiments. The embodiments may thus be described with different nomenclature and/or terminology utilized to describe the components, devices, parameters, methods and/or functions herein, without limitation. References to any specific protocol or proprietary name in describing one or more elements, features or concepts of the embodiments are provided solely as examples of one implementation, and such references do not limit the extension of the claimed embodiments to embodiments in which different element, feature, protocol, or concept names are utilized. Thus, each term utilized herein is to be given its broadest interpretation given the context in which that term is utilized.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence

or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope of the disclosure. The described embodiments were chosen and described in order to best explain the principles of the disclosure and the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. An explosive testing system comprising:

at least one Solid Instrumented Spherical Blast Impulse Recording Device (SISBIRD) comprising:

a spherical housing formed of material that is resistant to an explosive blast wave from a test weapon and having a test payload bore shaft accessible through an opening in the spherical housing;

a test data module received in the test payload bore shaft and comprising:

a three-axis acceleration sensor;

a memory;

a controller communicatively coupled to the three-axis acceleration sensor and the memory and that executes a data acquisition utility to record, in the memory, acceleration data in three-dimensions from the three-axis acceleration sensor during exposure of the spherical housing to the explosive blast wave; and

a door fastened over the opening in the spherical housing;

at least one pedestal at a respective predefined location from an explosive device and that supports one of the at least one SISBIRD;

a test controller that triggers the explosive device to produce a blast impulse that propels each of the at least one SISBIRD from their respective at least one pedestal through the air; and

a computer that analyzes the acceleration data caused by the blast impulse and retrieved from the at least one SISBIRD.

2. The SISBIRD explosive testing system of claim 1, wherein:

the test data module comprises a pressure sensor that communicates to an exterior of the spherical housing; and

the controller communicatively is coupled to the pressure sensor and the memory and that executes the data acquisition utility to record, in the memory, pressure data from the pressure sensor during the exposure of the spherical housing to the explosive blast wave.

3. The explosive testing system of claim 1, wherein:

the test data module comprises a temperature sensor that communicates to an exterior of the spherical housing; and

the controller communicatively is coupled to the temperature sensor and the memory and that executes the data acquisition utility to record, in the memory, temperature data from the temperature sensor during the exposure of the spherical housing to the explosive blast wave.

4. The explosive testing system of claim 1, wherein:

the test data module comprises a geographic location sensor; and

the controller communicatively is coupled to the geographic location sensor and the memory and that executes the data acquisition utility to record, in the memory, geographic location data from the geographic location sensor during the exposure of the spherical housing to the explosive blast wave.

5. The explosive testing system of claim 1, wherein:

the test data module comprises a beacon; and the controller communicatively is coupled to the beacon and the memory and that executes the data acquisition utility to activate the beacon in response to the exposure of the spherical housing to the explosive blast wave.

6. The explosive testing system of claim 1, wherein the test controller wirelessly receives test data from the at least one SISBIRD.

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