IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Utility Patent Application (Provisional)

TITLE: APPARATUS, SYSTEM, AND METHOD FOR NON-DESTRUCTIVE TESTING OF WOODEN UTILITY POLES USING AIR-COUPLED ULTRASONIC TRANSDUCERS

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FIELD OF THE INVENTION

[0001] The present invention relates to the field of energy inspections. Specifically, the present invention relates to the non-destructive internal testing of wooden utility poles using two (transmitter and receiver) air-coupled ultrasonic transducers.

BACKGROUND OF THE INVENTION

[0002] In the U.S., there are an estimated 150-180 million wooden utility poles in use for electric utility and communication systems. Most poles are 30-60 feet tall and 50-60 years old. Of the 150-180 million wooden poles, approximately 135 million of them are chemically treated to protect and enhance the life of the wood with chemicals including penta, creosote, and arsenicals. An estimated three percent of these poles are replaced annually. The use of utility poles made of alternative materials, such as recycled steel, concrete, composite materials, or the burying of lines, are alternatives to the installation of wooden poles.

[0003] Typically, wooden poles decay as a result of the pole being in contact with the soil and insect infestations and decay can be either internal or external in nature, with the extent of decay partly a result of the type of wood used for the pole (e.g., southern yellow pine, Douglas-fir), ground conditions (e.g., moisture content), and the type of chemical used for treatment. To ensure the integrity of electrical and communication infrastructure, wooden utility poles are inspected on a periodic and recurring basis to identify defective, worn, or damaged poles for removal and replacement. Regular inspections are conducted on each pole every 3-10 years by a qualified inspector. Pole inspection procedures are divided into destructive and non-destructive procedures and include above visual ground inspection, subsurface visual inspection after excavating around the base of the pole, mechanical/hammering on the surface of the pole to assess pole density, manual or automated drilling/boring to evaluate the condition of internal wood particles/cuttings, and use of test devices such as a sonic, ultrasonic, electrical, and refractometer testing equipment. Utility companies or utility pole inspection companies evaluate poles either through spot-checking or through more rigorous pole sampling programs which evaluate a more representative sample of poles. Well, thought-out pole inspection/maintenance operations carried out by trained workers are critical in ensuring the integrity of electrical and communication infrastructure to provide reliable services to customers. Inspection/maintenance programs are a costly undertaking typically required by regulatory bodies and can represent an operational safety hazard to the lineman/technicians conducting the inspections.

[0004] Visual- Exterior pole condition is visually assessed either above ground and/or near-sub-surface after excavation to identify external damage (e.g., wood coating anomalies, charring, insect boreholes, pitting, etc.). Visual inspection can be performed either on a limited, spot check basis or over a larger number of poles. Visual inspection does not require the use of any specialized equipment; workers need minimal training/skill and is generally low in cost. Visual procedures are limited to external damage assessment and do not detect internal wood pole damage.

[0005] Hammer Test/Mechanical Sounding - This technique is the most frequently used procedure for wooden pole inspections. Hammering involves striking the pole with a hammer and listening to the sound produced from the impact to detect internal wood anomalies. Damaged wood pockets internal to the pole will typically produce a duller sound as compared to that of a non-defective, denser pole. This technique is subjective, with its accuracy determined by the experience of the lineman and yields no quantitative data regarding the internal structure of the pole in question. The resulting information can result in increased maintenance/replacement costs by the utility company as poles may be replaced, which do need replacement.

[0006] Drilling- This technique can be used to assess internal pole damage through an evaluation of the condition of the acquired wood drill cuttings. Manual drilling can be performed by lineman/service workers to acquire wood cuttings, or use of an automated, digital drilling inspection tool can be used to drill holes along the entire vertical profile of a pole with drilling resistance and drilling speed evaluated using software to determine if any internal decay was detected. Manual drilling is cost-effective but only provides an evaluation of the pole's integrity at the location of the boring site. Manual drilling requires the use of semi-skilled technicians capable of identifying wood damage by visually assessing the acquired drill cuttings. Automated drilling systems, if fully implemented along with the entire vertical profile of a pole, can yield a complete internal picture of the pole but can be costly and time-consuming to implement and requires technicians with specialized training. Both manual and automated drilling techniques cause physical damage to the utility pole, which could degrade its integrity.

[0007] Ultrasound - A non-destructive test method employed as a substitute for visual, hammer testing, or destructive drilling/boring evaluation methods. The U.S. uses a sound wave sent by a transmitter (electronic or manual rasping with a hammer) through the pole to a receiver to identify wood decay/damage. This technology is time-consuming to implement in the field, requires direct contact and a coupling medium, multiple readings are required in multiple quadrants of the pole to give accurate readings, and excessive pole cracks/damage and vegetation can affect device accuracy. The U.S. is less invasive than destructive techniques (e.g., boring/drilling) but requires the use of specialty-trained workers.

[0008] Electrical Resistance - A non-destructive test method to measure the electrical resistance of the pole using a probe with two wires attached to its tip. Probes are inserted into holes drilled into the pole (e.g., one inch in length) which can detect resistivity changes inside the wood that are associated with early stages of decay. The electrical resistance/conductivity technique is affected by pole moisture and temperature and can provide an indication of the presence of decay within a pole but not the location of the decay. As with other non-destructive test techniques, operational personnel need specialized training to fully understand the equipment and test results/data.

[0009] X-Ray - In this method, x-ray waves are sent through the pole producing a two-dimensional tomographic image that details how the mass inside the pole is distributed, this is called computed tomography (CT). The CT produced from x-ray waves can detect large areas of decay and degradation, however, it is unable to identify small pockets of decay inside the pole. Due to the high-cost, large size, need for a highly trained operator, and inefficient defect detection, x-ray scans are not an ideal choice for identifying defects inside wooden poles.

[00010] Impulse Radar - Impulse radar uses electromagnetic waves to send and receive signals. The waves are usually in the form of microwaves. Reflections are identified through wood’s low dielectric constant, which would generate important reflections when encountering an area of decay. The radar technique produces varied results, often proving to be difficult in interpreting and identifying defects.

[00011] Refractometer- This destructive test method measures the mechanical bending fracture strength of cores removed from wooden poles through mechanical drilling to assess decayed wood by measuring the stiffness and fracture strength of the core samples. Acquired data is analyzed by a computer to compare the core's fracture strength to a sample of the same wood that has no decay. Specialized training is required by workers, and the coring device requires a high amount of maintenance to maintain its functionality. Acquired core data is limited and only provides localized wood damage information.

[0012] Therefore, what is needed in the field of wooden utility pole inspections are techniques or methods that overcome the above-mentioned disadvantages.

BRIEF SUMMARY OF THE INVENTION

[00013] The present invention involves using non-contact ultrasonic transducers for use by wooden utility pole inspectors to identify degradation or non-serviceability of poles. The technology can evaluate the condition of wooden utility poles, including their interior structure, in a non-invasive and non-destructive manner. The technology utilizes air-coupled ultrasonic wave transmission to penetrate the woods interior to detect rot, holes, cracks, and other anomalies/defects without damaging/changing the integrity of the wood structure. The device will record a continuous readout of internal wood condition as the device travels in a vertical direction across the entire vertical profile of a utility pole.

BRIEF DESCRIPTION OF THE DRAWINGS

[00014] The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

[00015] **FIG. 1 -** Figure **1** illustrates a top-down view of the overall system including all its components according to various embodiments of the present invention.

[00016] **FIG. 2 -** Figure **2** illustrates a side view of the transducers placed co-linear across the diameter of the supporting structure and the receiving transducers connection to the resistor termination box according to various embodiments of the present invention.

[00017] **FIG. 3 -** Figure **3** illustrates a top-down view of the transducers placed co-linear across the diameter of the supporting structure with identification of the elbow BNC connection to the transducer according to various embodiments of the present invention.

[00018] **FIG. 4 -** Figure **4** illustrates the side view of the transducer that highlights some components of the transducer holder according to various embodiments of the present invention.

[00019] **FIG. 5 -** Figure **5** illustrates the top-down view of the transducer holder with the cylindrical plates extended 180° according to various embodiments of the present invention.

[00020] **FIG. 6 -** Figure **6** illustrates the transducer holder with the cylindrical plates extended 180° with the transducer placed inside the holder according to various embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[00021] Various embodiments and aspects of the inventions will be described with reference to details discussed below, and the accompanying drawings will illustrate the various embodiments. The following description and drawings are illustrative of the invention and are not to be construed as limiting the invention. Numerous specific details are described to provide a thorough understanding of various embodiments of the present invention. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present inventions.

[00022] Reference in the specification to “one embodiment” or “an embodiment” or “another embodiment” means that a particular feature, structure, or characteristic described in conjunction with the embodiment can be included in at least one embodiment of the invention. The appearances of the phrase “in one embodiment” in various places in the specification do not necessarily all refer to the same embodiment.

[00023] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one having ordinary skill in the art to which this invention belongs. 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 relevant art and the present disclosure and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[00024] In describing the invention, it will be understood that several techniques and steps are disclosed. Each of these has individual benefit and each can also be used in conjunction with one or more, or in some cases all, of the other disclosed techniques. Accordingly, for the sake of clarity, this description will refrain from repeating every possible combination of the individual steps in an unnecessary fashion. Nevertheless, the specification and claims should be read with the understanding that such combinations are entirely within the scope of the invention and the claims.

[00025] **FIG. 1** illustrates a top-down diagram of an embodiment of the overall system including all its components. The main foundational structure of the system (**1**) is responsible for supporting the receiving transducer (**5**) and the transmitting transducer (**4**), as well as the other components specific to the transducer operation, which are the oscilloscope (**2**), and pulser/receiver (**3**). The foundational structure of the system adheres to two main functions, to provide a stable platform for which the transducers can operate, and to traverse in the vertical direction along the pole. The pulser/receiver functions to support the transducer operation including the voltage and tone bursts necessary to drive the transmitting transducer, and the components noted in a broadband receiver capable of capturing the propagation wave from the receiving transducer.

[00026] **FIG. 2** illustrates an embodiment of the transducers, transducer holders (**6**), and resistor-termination box (**7**). The figure illustrates the arrangement of the transducers and their co-linear locations towards one another. This arrangement is necessary to initiate in "through-transmission propagation" in which the wave propagated from the transmitting unit is sent across the diameter of the pole to be captured by the receiving unit. The supporting structure, detailed in **FIG.1**, will be able to rotate the transducers in a perimeter around the pole to send ultrasonic waves at multiple diameter points, which enables the capture of data from various locations. Vital parameters from the capture of the through-transmission waves are time-of-flight, acoustic impedance, frequency, attenuation coefficient, and modulus of elasticity. This data is interpreted and analyzed on the oscilloscope by a skilled technician who will identify and determine the defect and subsequently, if the pole is serviceable given the defect severity. These parameters are essential to identifying the defects that may be in the pole's internal structure. Time-of-flight will be the main data point in which to capture and is defined as the time required by the wave to travel from the transmitter to the receiver. The standard baseline and establishment for a non-defective pole will be measured first by observing the earliest peak of the cross-correlation between the two units. This measurement will then be compared to the readings from an initial inspection and any deviations in the peak amplitude will be cause for further identification to receive more information about the defect. The resister-termination box is specific to the system operation and reduces the reflections caused by the toneburst as well as providing more control of the voltage amplitude.

[00027] **FIG. 3** illustrates a diagram of an embodiment of a top-down view of the transducer holders and the BNC elbow connection (**10.A**) to the receiving transducer. The BNC elbow allows a subsequent BNC cable (**11.A**) to connect the receiving transducer to the resistor-termination box which is then sent to a broadband receiver.

[00028] **FIG. 4** illustrates a diagram of an embodiment of a side view of the transducer and transducer holder with some of its components. The transducer holder plays an important role in allowing placement of the transducer unit and providing a stable non-motion platform for which the transducers can conduct their main functions. The main holding structure of the holder, the cylindrical plate mechanism (**12**) is the focus point of the holder and allows for a specific and secure placement of the transducer. The clamp screw mechanism (**8**) secures the two cylindrical aluminum plates in place by containing two matching, threaded, and extended screw inserts at opposite sides along the cylindrical plate separation. The screw is inserted rotationally inside the screw holders by a knob at the bottom of the screw. The action of "unscrewing" the screw will allow the cylindrical plates to rotate in an outward angle. This action is described in detail in **FIG. 6**. The rotational axis point mechanism (**13**) incorporates three circular and threaded "rings" with a fitted screw to provide a full 180° of the transducer holder (except for the base) allowing the holder to be placed at any angle along the 180° for access or pitch-echo transmission. The base mechanism (**9**) is complete with a cylindrical copper base with a threaded insert to provide another 180° horizontal rotation point for the holder. The screw is placed in the threaded insert in the cylindrical base by a rotational knob that secures and un-secures the holder from horizontal rotation.

[00029] **FIG. 5** illustrates a diagram of an embodiment of a top-down view of the transducer holder highlighting the neoprene inserts (**14**) along the side of the cylindrical plate mechanism. These neoprene inserts negate the aluminum-to-aluminum contact between the transducer and the cylindrical plate mechanism. This eliminates any scratches or abrasion that may occur from the above-mentioned contact.

[00030] **FIG. 6** illustrates a diagram of an embodiment of the transducer holder at full opening rotation with the transducer placed inside. The rotational hinge mechanism (**15**) describes the action of rotating the cylindrical plates in an outward angle to provide an access point for the transducer to be placed. This mechanism is of copper material and functions like a common door hinge.

CLAIMS

1. An air-coupled ultrasonic inspection system, method, and apparatus capable of identifying internal defects or degradation such as rot, voids, holes, etc. inside the entirety of wooden utility/energy poles.

2. A determination of serviceability in wooden utility/energy poles based on the system, method, and apparatus stated in claim

3. A method, system, or apparatus using the subject matter and techniques described herein that were not otherwise stated in the above claims.

FIG. 1

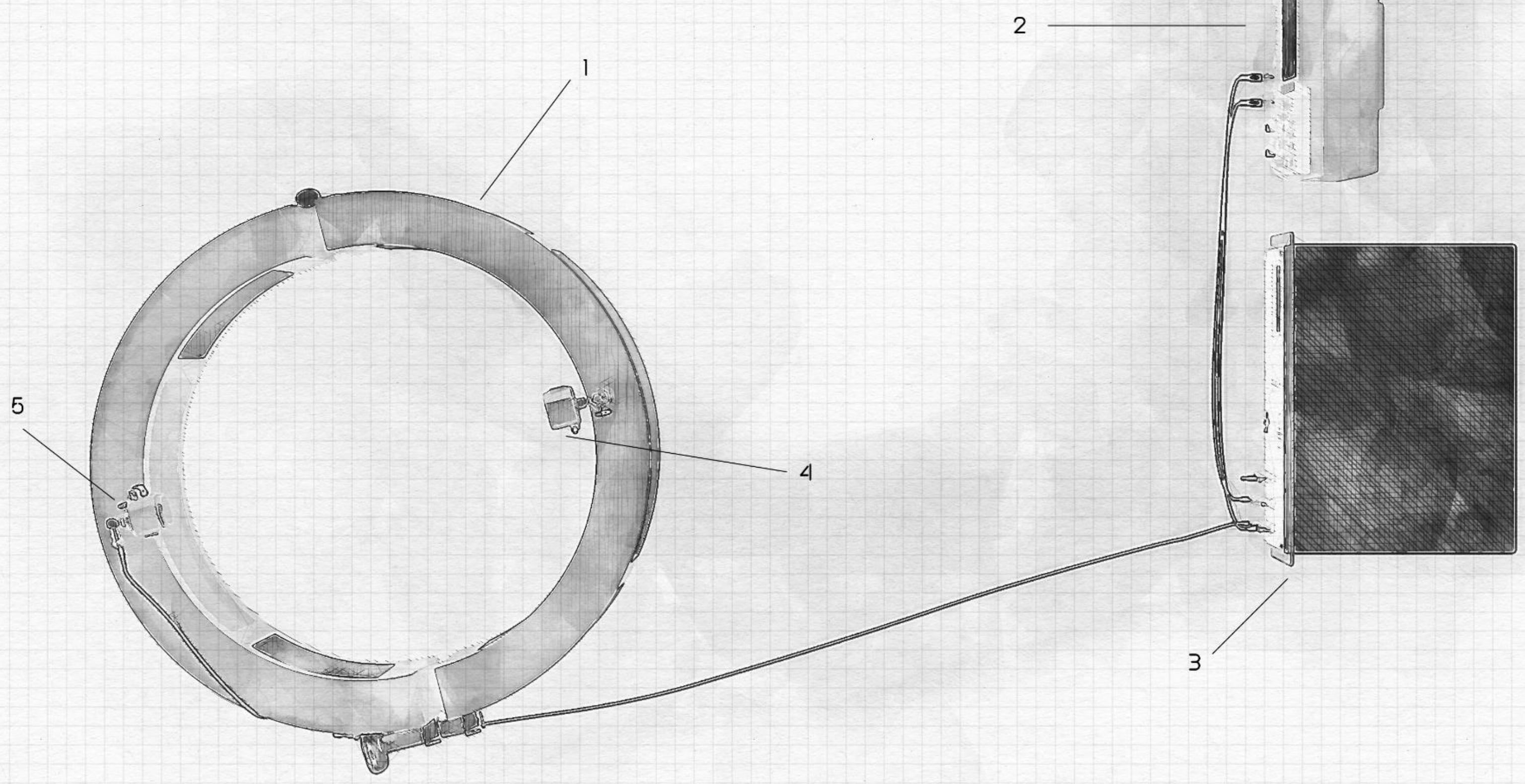

FIG. 2

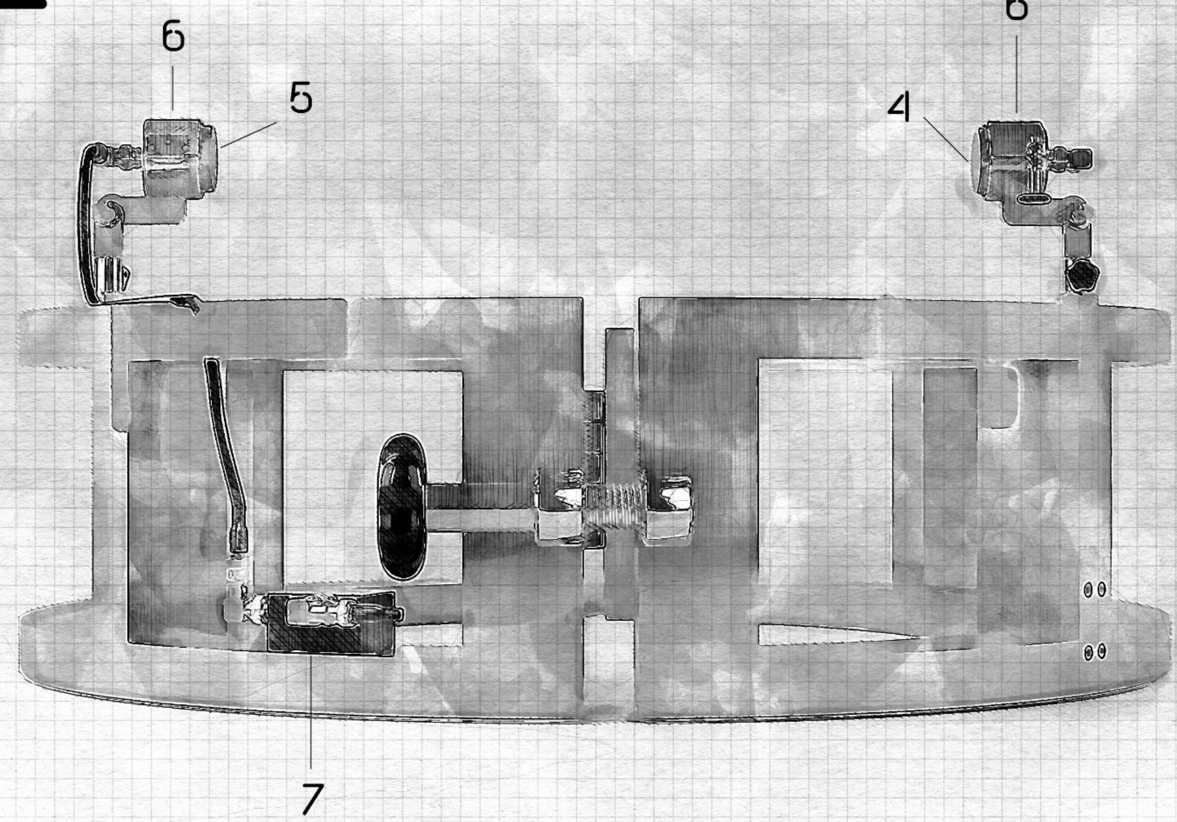

FIG. 3

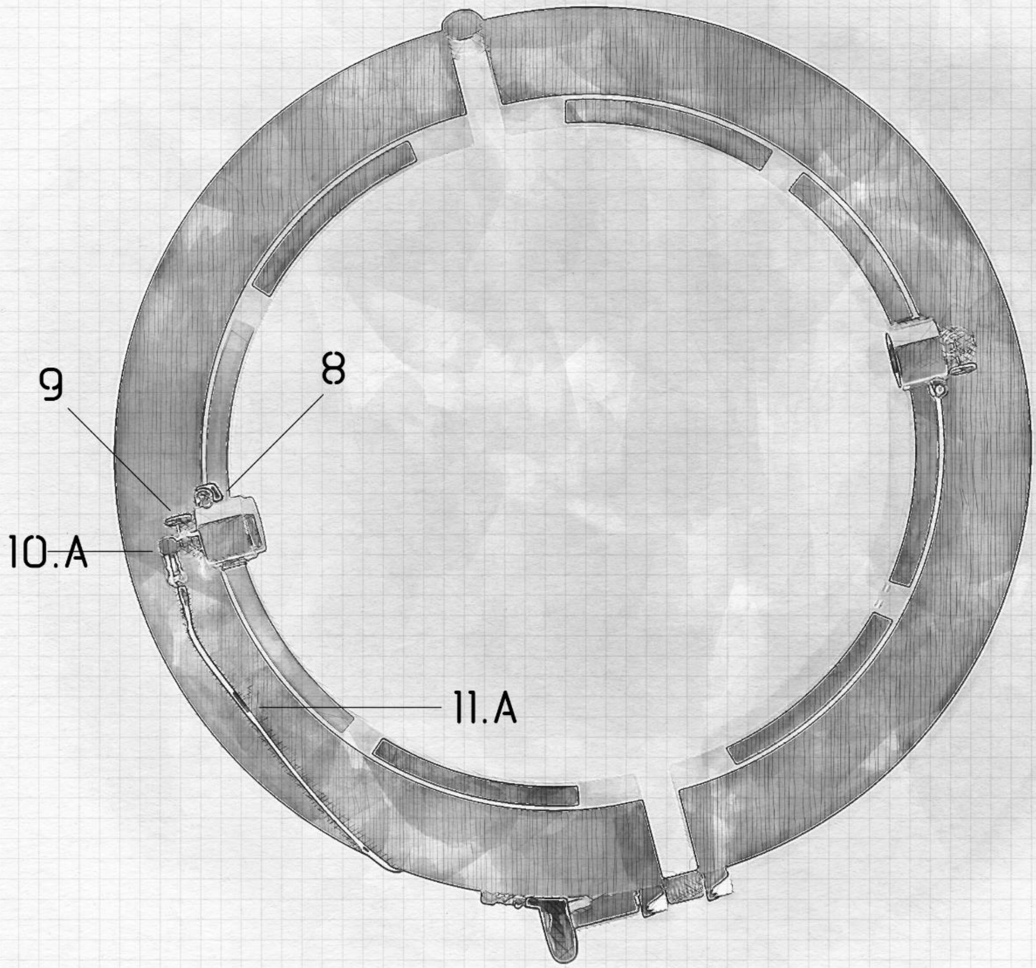

FIG. 4

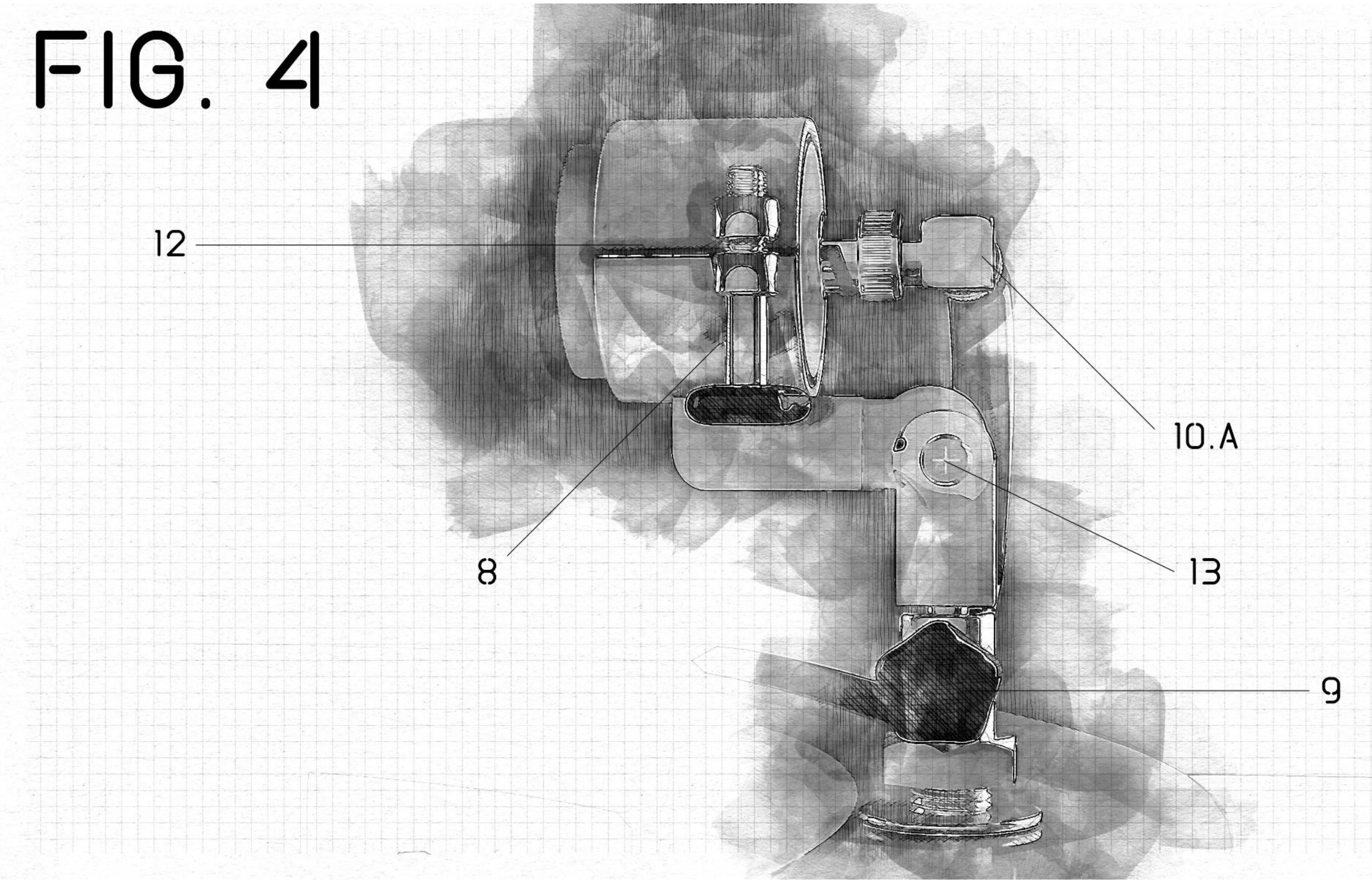

FIG. 5

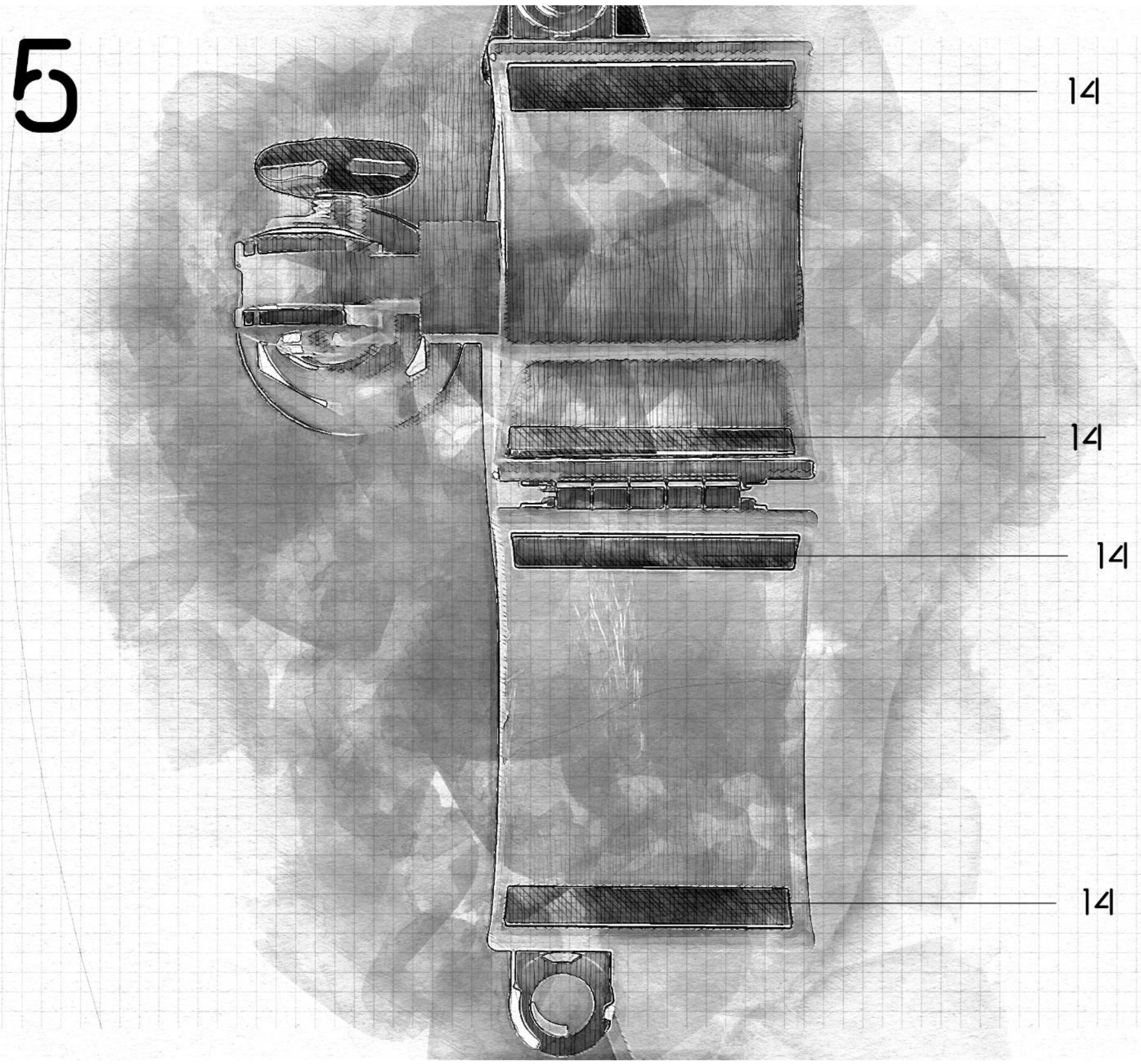

FIG. 6