



(51) International Patent Classification:

G01B 11/02 (2006.01) *G01D 5/34* (2006.01)
G01B 11/22 (2006.01)

(21) International Application Number:

PCT/US2014/052229

(22) International Filing Date:

22 August 2014 (22.08.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

14/150,724 8 January 2014 (08.01.2014) US

(71) Applicant: **THE BOEING COMPANY** [US/US]; 5301 Bolsa Avenue, Huntington Beach, California 92647 (US).

(72) Inventors: **BUMGARDNER, Mark, D.**; 100 N. Riverside Plaza, Chicago, Illinois 60606 (US). **SCHWEIGER, Jonathan, A.**; 100 N. Riverside Plaza, Chicago, Illinois 60606 (US). **GORSH, Christopher, M.**; 100 N. Riverside Plaza, Chicago, Illinois 60606 (US).

(74) Agents: **SLENKER, Robert** et al.; 5301 Bolsa Avenue, Huntington Beach, California 92647 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: ELECTRONIC GAGE APPARATUS

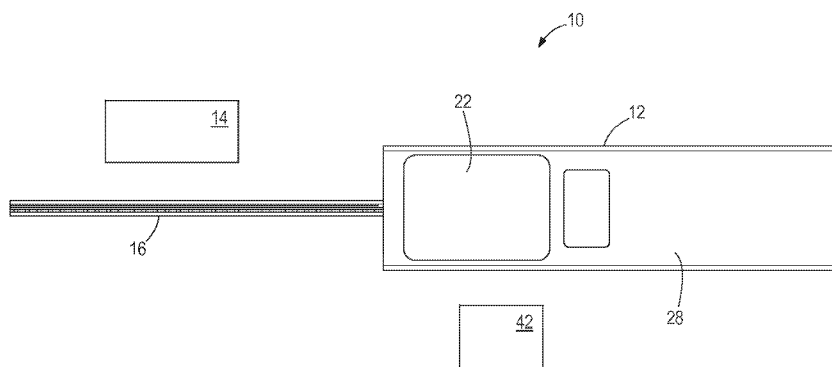


FIG. 1

(57) Abstract: A gage apparatus includes a probe, a processor, and a memory. The probe includes a plurality of transmitters and a plurality of receivers both aligned in an axial direction along the probe. The processor is in electronic communication with the plurality of transmitters and the plurality of receivers. The memory is in electronic communication with the processor. The memory includes programming code for execution by the processor. The programming code is configured to determine a length of a structure disposed adjacent to the probe based on which of the plurality of receivers receive signals transmitted by the plurality of transmitters and reflected off the structure.



ELECTRONIC GAGE APPARATUS

FIELD OF THE DISCLOSURE

This disclosure relates to electronic gage apparatus for measuring lengths.

BACKGROUND

5 Typically gage apparatus for measuring lengths of structures or for determining a length of a fastener to be installed into a structure rely on internal mechanical components requiring physical movement and contact with each other to obtain the measurement. These gage apparatus often require the measuring mechanism to be powered by compression of a human hand or an internal mechanical mechanism. This introduces variables that may lead to fatigue,
10 mechanical wear, break-down, or an increase in error likelihood.

A system and method is needed to measure lengths of structures or for determining a length of a fastener to be installed into a structure while reducing or eliminating one or more issues of the existing gage apparatus.

SUMMARY

15 In one embodiment, a gage apparatus is disclosed. The gage apparatus includes a probe, a processor, and a memory. The probe includes a plurality of transmitters and a plurality of receivers both aligned in an axial direction along the probe. The processor is in electronic communication with the plurality of transmitters and the plurality of receivers. The memory is in electronic communication with the processor. The memory includes programming code for
20 execution by the processor. The programming code is configured to determine a length of a structure disposed adjacent to the probe based on which of the plurality of receivers receive signals transmitted by the plurality of transmitters and reflected off the structure.

In another embodiment, a system for measuring a length of a hole through a structure is disclosed. The system includes a probe, a plurality of transmitters and a plurality of receivers
25 both disposed upon and aligned in an axial direction along the probe, a processor, and a memory. The processor is in electronic communication with the plurality of transmitters, the plurality of receivers, and the memory. The memory includes programming code for execution by the

processor. The programming code is configured to determine a length of the hole through the structure based on which of the plurality of receivers receive signals transmitted by the plurality of transmitters and reflected off the structure.

5 In still another embodiment, a method of measuring a length is disclosed. In one step, a probe is inserted into a hole associated with a structure. In another step, signals are transmitted from a plurality of transmitters aligned along an axial direction of the probe and at least a portion of the transmitted signals are reflected off the structure. In still another step, the signals reflected by the structure are received with a plurality of receivers aligned along the axial direction of the probe. In yet another step, a processor in electronic communication with the plurality of
10 transmitters, the plurality of receivers, and a memory determines, by the processor executing programming code stored in the memory, a length of the hole through the structure based on which of the plurality of receivers receive the reflected signals.

The scope of the present disclosure is defined solely by the appended claims and is not affected by the statements within this summary.

15 **BRIEF DESCRIPTION OF THE DRAWINGS**

The disclosure can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the disclosure.

20 Figure 1 illustrates a perspective view of one embodiment of a system comprising a gage apparatus and a structure;

Figure 2 illustrates an enlarged cross-section view through the system of Figure 1;

Figure 3 illustrates a front view of one embodiment of the gage apparatus of Figure 1 being used to measure a length of a hole of a structure by inserting the probe into the hole;

25 Figure 4 illustrates a front view of another embodiment of the gage apparatus of Figure 1 being used to measure a length of a hole of another structure by inserting the probe into the hole;

Figure 5 illustrates a front view of yet another embodiment of the gage apparatus of Figure 1 being used to measure a grip length of a fastener to be installed into the hole of yet another structure by inserting the probe into the hole;

Figure 6 illustrates a front view of one embodiment of a fastener which may be installed
5 into the hole of the structure of Figure 5;

Figure 7 illustrates a flowchart showing one embodiment of a method of measuring a length;

Figure 8 illustrates a flow diagram showing one embodiment of aircraft production and service methodology; and

10 Figure 9 illustrates one embodiment of a block diagram of an aircraft.

DETAILED DESCRIPTION

Figure 1 illustrates a perspective view of one embodiment of a system 10 comprising a gage apparatus 12 and a structure 14. Figure 2 illustrates an enlarged cross-section view through the system 10 of Figure 1. The gage apparatus 12 may be used to measure the structure 14. The
15 structure 14 may comprise a plate, a stack-up of members, a plate including a hole and a nut or nut plate assembly aligned with the hole, a stack-up of members including a hole aligned with the hole, or another type of structure which may or may not have a hole. In one embodiment, the structure 14 may comprise an aircraft, an aircraft part, or aircraft parts. In other embodiments, the structure 14 may vary. As shown collectively in Figures 1 and 2, the gage apparatus 12
20 includes a probe 16, a processor 18, a memory 20, a display 22, a wireless transmitter 24, a power source 26, an electrical interface port 27, and a handle 28. In other embodiments, the gage apparatus 12 may include varying components. In the embodiment in which the structure 14 comprises a hole, the probe 16 of the gage apparatus 12 may be inserted into the hole of the structure 14 to measure the hole, to determine a length or an identity of a fastener to be inserted
25 into the hole, or to determine other information. In the embodiment in which the structure 14 does not include a hole, the gage apparatus 12 may be used to measure a length of the structure 14 or to determine other information.

The probe 16 includes a plurality of transmitters 30 and a plurality of receivers 32 aligned in an axial direction 34 along the probe 16. The plurality of transmitters 30 are each configured to transmit signals 36. The signals 36a of the plurality of transmitters 30a which are disposed adjacent to the structure 14 will reflect off the structure 14 and be received by the plurality of receivers 32a indicating that the structure 14 is disposed adjacent to those plurality of receivers 32a. The signals 36b of the plurality of transmitters 30b which are disposed apart from the structure 14 will not reflect off the structure 14 and as a result will not be received by the plurality of receivers 32b indicating that the structure 14 is not disposed adjacent to those plurality of receivers 32b. In one embodiment, the plurality of transmitters 30 comprise optical transmitters and the plurality of receivers 32 comprise optical receivers. In other embodiments, the plurality of transmitters 30 and the plurality of receivers 32 may vary in type, in number, in configuration, or in location.

The processor 18 is in electronic communication with the plurality of transmitters 30, the plurality of receivers 32, the memory 20, the display 22, and the wireless transmitter 24. The memory 20 comprises programming code 38 for execution by the processor 18. The programming code 38 is configured to determine a length 40 of the structure 14 disposed adjacent to the probe 16 based on which of the plurality of receivers 32 receive signals 36 transmitted by the plurality of transmitters 30 and reflected off the structure 14. In other embodiments, the programming code 38 may be configured to determine a variety of differing items.

The programming code 38 is configured to display on the display 22 the determined length 40 of the structure 14, or to display on the display 22 an identity or a grip length of a fastener which is to be installed into the structure 14 as determined by the programming code 38 based on the determined length of the structure 14. In other embodiments, the programming code 38 may be configured to display on the display 22 a variety of different information.

The programming code 38 is configured to have the wireless transmitter 24 wirelessly transmit to a device 42 the determined length 40 of the structure 14, or the identity or a grip length of a fastener which is to be installed into the structure 14 as determined by the programming code 38 based on the determined length 40 of the structure 14. The device 42 may comprise a computer, another display, or another type of device. In other embodiments, the

programming code 38 may be configured to have the wireless transmitter 24 wirelessly transmit varying information to other devices.

The power source 26 is configured to power the gage apparatus 12. In one embodiment, the power source 26 may comprise a battery. In other embodiments, the power source 26 may vary. The electrical interface port 27 may be configured to charge the power source 26, or to interface with the processor 18. In other embodiments, the electrical interface port 27 may be used for varying functions. The handle 28 is used to grip the gage apparatus 12. In other embodiments, the grip 12 may further vary.

Figure 3 illustrates a front view of one embodiment of the gage apparatus 12 of Figure 1 being used to measure a length 40a of a hole 44a of a structure 14a by inserting the probe 16 into the hole 44a. Figure 4 illustrates a front view of another embodiment of the gage apparatus 12 of Figure 1 being used to measure a length 40b of a hole 44b of another structure 14b by inserting the probe 16 into the hole 44b. The another structure 14b comprises a stack-up of members 46 and 48. The gage apparatus 12 is configured to additionally detect the length 40c and location 50 of a gap 52 in-between members 46 and 48.

Figure 5 illustrates a front view of yet another embodiment of the gage apparatus 12 of Figure 1 being used to measure a grip length of a fastener to be installed into the hole 44c of yet another structure 14c by inserting the probe 16 into the hole 44c. Structure 14c comprises a stack-up of members 54 and 56 with a nut plate assembly 58 attached to member 54. The nut plate assembly 58 comprises a plate 60 attached to member 54. A nut 62 may either be fixed or may float within the plate 60. Gage apparatus 12 operates to determine a total length as defined by hole 44c plus a hole associated with nut plate assembly 58.

Figure 6 illustrates a front view of one embodiment of a fastener 64 which may be installed into the hole 44c of the structure 14c of Figure 5. The fastener 64 includes a head 66, threads 68, a transition or run-out 70, and grip length 72. The grip length 72 (or shank) is defined as the length from the underside 74 of the head 66 to the transition or run-out 70 where the threads 68 begin. As discussed above with respect to Figure 5, the gage apparatus 12 may be used to determine the grip length 72 of the fastener 64 to be installed into the hole 44c of the structure 14c of Figure 5. In other embodiments, the gage apparatus 12 of Figure 1 may be used to measure or determine varying items.

Figure 7 illustrates a flowchart showing one embodiment of a method 80 of measuring a length. The method 80 may utilize the gage apparatus of Figure 1 or any of the embodiments disclosed herein. In step 82, a probe of a gage apparatus is inserted into a hole of a structure. The structure may comprise a plate or a stack-up of members. A nut or nut plate assembly may be aligned with the hole of the structure. In other embodiments, the structure may vary. In step 84, a plurality of transmitters, a plurality of receivers, a processor, a display, and a wireless transmitter of the gage apparatus are powered with a power source of the gage apparatus. The power source may comprise a battery. In other embodiments, the power source may vary. In step 86, the power source is charged through an electrical port interface of the gage apparatus, or another device interfaces with the processor through the electrical port interface.

In step 88, signals are transmitted from the plurality of transmitters aligned along an axial direction of the probe and the signals are reflected off the structure. In one embodiment, the signals may comprise optical signals. In other embodiments, the signals may vary. In step 90, the reflected signals are received with the plurality of receivers aligned along the axial direction of the probe. In step 92, the processor determines a length of the structure based on which of the plurality of receivers receive the reflected signals. The processor is in electronic communication with the plurality of transmitters, the plurality of receivers, and a memory. The processor determines the length of the structure by executing programming code stored in the memory.

In step 94, the determined length of the structure or an identity or a grip length of a fastener to be installed into the hole of the structure is displayed on the display. The display is in electronic communication with the processor. The programming code determines the length of the structure or the identity or the grip length of the fastener to be installed into the hole of the structure based on the determined length of the structure. In step 96, the programming code causes the wireless transmitter to wirelessly transmit to a device the determined length, or the identity or a grip length of a fastener to be installed into the hole of the structure as determined by the programming code based on the determined length of the structure. In one embodiment, step 94, step 96, or a subsequent step may further include a user selecting the particular fastener identified by the gage apparatus and installing the particular fastener into the hole of a structure which may comprise an aircraft or another type of structure. In other embodiments, one or more steps of the method 80 may be modified in substance or in order, may not be followed, or one or more additional steps may be added.

Embodiments of the disclosure may find use in a variety of potential applications, particularly in the transportation industry, including for example, aerospace, marine, automotive applications, and other applications where automated layup equipment may be used. Thus, referring now to Figures 8 and 9, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method 100 as shown in Figure 8 and an aircraft 102 as shown in Figure 9. Aircraft applications of the disclosed embodiments may include, for example, without limitation, layup of stiffener members such as, without limitation beams, spars and stringers, to name only a few. During pre-production, exemplary method 100 may include specification and design 104 of the aircraft 102 and material procurement 106. During production, component and subassembly manufacturing 108 and system integration 110 of the aircraft 102 takes place. Thereafter, the aircraft 102 may go through certification and delivery 112 in order to be placed in service 114. While in service by a customer, the aircraft 102 is scheduled for routine maintenance and service 116, which may also include modification, reconfiguration, refurbishment, and so on.

Each of the processes of method 100 may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in Figure 9, the aircraft 102 produced by exemplary method 100 may include an airframe 118 with a plurality of systems 120 and an interior 122. Examples of high-level systems 120 include one or more of a propulsion system 124, an electrical system 126, a hydraulic system 128, and an environmental system 130. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the marine and automotive industries.

Systems and methods embodied herein may be employed during any one or more of the stages of the production and service method 100. For example, components or subassemblies corresponding to production process 108 may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft 102 is in service. Also, one or more apparatus embodiments, method embodiments, or a combination thereof

may be utilized during the production stages 108 and 110, for example, by substantially expediting assembly of or reducing the cost of an aircraft 102. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while the aircraft 102 is in service, for example and without limitation, to maintenance and service
5 116.

One or more embodiments of the gage apparatus of the disclosure eliminates internal mechanical components which need to be compressed with a human hand thereby reducing or eliminating the likelihood for fatigue, for mechanical wear, for break-down, or for error in measurements of a structure or of a fastener to be installed into the structure.

10 Further, the disclosure comprises embodiments according to the following clauses:

Clause 1. A gage apparatus comprising: a probe comprising a plurality of transmitters and a plurality of receivers both aligned in an axial direction along the probe; a processor in electronic communication with the plurality of transmitters and the plurality of receivers; and a memory in electronic communication with the processor, wherein the memory
15 comprises programming code for execution by the processor, and the programming code is configured to determine a length of a structure disposed adjacent to the probe based on which of the plurality of receivers receive signals transmitted by the plurality of transmitters and reflected off the structure.

Clause 2. The gage apparatus of claim 1 wherein the plurality of transmitters
20 comprise optical transmitters and the plurality of receivers comprise optical receivers.

Clause 3. The gage apparatus of claim 1 further comprising a display in electronic communication with the processor, wherein the programming code is configured to display on the display the determined length of the structure, or to display on the display an identity or a grip length of a fastener which is to be installed into the structure as determined by the
25 programming code based on the determined length of the structure.

Clause 4. The gage apparatus of claim 1 further comprising a wireless transmitter in electronic communication with the processor, wherein the programming code is configured to have the wireless transmitter wirelessly transmit to a device the determined length, or the identity

or a grip length of a fastener which is to be installed into the structure as determined by the programming code based on the determined length of the structure.

Clause 5. The gage apparatus of claim 1 wherein said probe is configured for insertion into a hole formed through the structure, the programming code configured to
5 determine a length of the hole through the structure.

Clause 6. The gage apparatus of claim 1 further comprising an electrical interface port configured to charge a battery of the gage apparatus, or to interface with the processor.

Clause 7. The gage apparatus of claim 1 further comprising a handle from which said probe extends.

10 Clause 8. A system for measuring a length of a hole through a structure, said system comprising: a probe configured for insertion through the hole of the structure; a plurality of transmitters and a plurality of receivers both disposed upon and aligned in an axial direction along the probe; a memory; and a processor in electronic communication with the plurality of transmitters, the plurality of receivers, and the memory, the memory comprising programming
15 code for execution by the processor, and the programming code is configured to determine a length of the hole through the structure based on which of the plurality of receivers receive signals transmitted by the plurality of transmitters and reflected off the structure.

Clause 9. The system of claim 8 wherein the plurality of transmitters comprise optical transmitters and the plurality of receivers comprise optical receivers.

20 Clause 10. The system of claim 8 further comprising a display in electronic communication with the processor, wherein the programming code is configured to display on the display the determined length of the hole through the structure, or to display on the display an identity or a grip length of a fastener which is to be installed into the hole through the structure as determined by the programming code based on the determined length of the hole through the
25 structure.

Clause 11. The system of claim 8 further comprising a wireless transmitter in electronic communication with the processor, wherein the programming code is configured to have the wireless transmitter wirelessly transmit to a device the determined length, or the identity or a grip length of a fastener which is to be installed into the hole through the structure as

determined by the programming code based on the determined length of the hole through the structure.

Clause 12. The system of claim 8 further comprising a battery configured to power the system.

5 Clause 13. The system of claim 8 further comprising an electrical interface port configured to charge a battery of the system, or to interface with the processor.

Clause 14. The system of claim 8 further comprising a handle from which the probe is configured to extend.

10 Clause 15. The system of claim 8 wherein the system is configured to determine a total hole length for the hole through the structure and a nut or nut plate assembly disposed in alignment with the hole.

15 Clause 16. A method of measuring a length comprising: inserting a probe into a hole associated with a structure; transmitting signals from a plurality of transmitters aligned along an axial direction of the probe to reflect at least a portion of the transmitted signals off the structure; receiving the signals reflected by the structure with a plurality of receivers aligned along the axial direction of the probe; and determining, with a processor in electronic communication with the plurality of transmitters, the plurality of receivers, and a memory, a length of the hole through the structure based on which of the plurality of receivers receive the reflected signals by the processor executing programming code stored in the memory.

20 Clause 17. The method of claim 16 wherein transmitting signals comprises transmitting optical signals.

25 Clause 18. The method of claim 16 further comprising displaying, with a display in electronic communication with the processor, the determined length of the structure, or an identity or a grip length of a fastener to be installed into the hole of the structure as determined by the programming code based on the determined length of the structure.

Clause 19. The method of claim 16 further comprising the programming code causing a wireless transmitter to wirelessly transmit to a device the determined length, or the identity or a

grip length of a fastener which is to be installed into the hole of the structure as determined by the programming code based on the determined length of the structure.

Clause 20. The method of claim 16 further comprising charging a battery powering the plurality of transmitters, the plurality of receivers, and the processor through an electrical interface port, or interfacing with the processor through the electrical interface port.

Clause 21. The method of claim 16 wherein the structure comprises a nut or nut plate assembly aligned with the hole, said determining comprising determining a total length of a hole extending through the structure and the nut or nut plate assembly.

The Abstract is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

While particular aspects of the present subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true scope of the subject matter described herein. Furthermore, it is to be understood that the disclosure is defined by the appended claims. Accordingly, the disclosure is not to be restricted except in light of the appended claims and their equivalents.

CLAIMS

1. A gage apparatus (12) comprising:

a probe (16) comprising a plurality of transmitters (30) and a plurality of receivers (32) both aligned in an axial direction (34) along the probe;

5 a processor (18) in electronic communication with the plurality of transmitters and the plurality of receivers; and

a memory (20) in electronic communication with the processor, wherein the memory comprises programming code (38) for execution by the processor, and the programming code is configured to determine a length (40) of a structure (14) disposed adjacent to the probe based on
10 which of the plurality of receivers receive signals (36) transmitted by the plurality of transmitters and reflected off the structure.

2. The gage apparatus (12) of claim 1 wherein the plurality of transmitters (30) comprise optical transmitters and the plurality of receivers (32) comprise optical receivers.

3. The gage apparatus (12) of claim 1 or 2 further comprising a display (22) in electronic
15 communication with the processor (18), wherein the programming code (38) is configured to display on the display the determined length (40) of the structure (14), or to display on the display an identity or a grip length (72) of a fastener (64) which is to be installed into the structure as determined by the programming code based on the determined length of the structure.

20 4. The gage apparatus (12) of any of claims 1 to 3 further comprising a wireless transmitter (24) in electronic communication with the processor (18), wherein the programming code (38) is configured to have the wireless transmitter wirelessly transmit to a device (42) the determined length (40), or the identity or a grip length (72) of a fastener (64) which is to be installed into the structure (14) as determined by the programming code based on the determined length of the
25 structure.

5. The gage apparatus (12) of any of claims 1 to 4 wherein said probe (16) is configured for insertion into a hole (44) formed through the structure (14), the programming code (38) configured to determine a length (40) of the hole through the structure.

6. The gage apparatus (12) of any of claims 1 to 5 further comprising an electrical interface port (27) configured to charge a battery of the gage apparatus, or to interface with the processor (18).

7. The gage apparatus (12) of any of claims 1 to 6 further comprising a handle (28) from which said probe (16) extends.

8. The gage apparatus (12) of any of claims 1 to 7 further comprising a battery configured to power the apparatus.

9. The gage apparatus (12) of claim 5 wherein the programming code (38) is configured to determine a total hole length for the hole (44) through the structure (14) and a nut (62) or a nut plate assembly (58) disposed in alignment with the hole.

10. A method (80) of measuring a length, the method comprising:

inserting (82) a probe (16) into a hole (44) associated with a structure (14);

transmitting (88) signals (36) from a plurality of transmitters (30) aligned along an axial direction (34) of the probe to reflect at least a portion of the transmitted signals off the structure;

receiving (90) the signals reflected by the structure with a plurality of receivers (32) aligned along the axial direction of the probe; and

determining (92), with a processor (18) in electronic communication with the plurality of transmitters, the plurality of receivers, and a memory (20), a length (40) of the hole through the structure based on which of the plurality of receivers receive the reflected signals by the processor executing programming code (38) stored in the memory.

11. The method (80) of claim 10 wherein transmitting (88) signals (36) comprises transmitting optical signals.

12. The method (80) of claim 10 or 11 further comprising displaying (94), with a display (22) in electronic communication with the processor (18), the determined length (40) of the hole (44), or an identity or a grip length (72) of a fastener (64) to be installed into the hole of the structure (14) as determined by the programming code (38) based on the determined length of the hole.

13. The method (80) of any of claims 10 to 12 further comprising the programming code (38) causing (96) a wireless transmitter (24) to wirelessly transmit to a device (42) the determined length (40), or the identity or the grip length (72) of the fastener (64) which is to be installed into the hole (44) of the structure (14) as determined by the programming code based on the

5 determined length of the hole.

14. The method (80) of any of claims 10 to 13 further comprising charging (86) a battery powering the plurality of transmitters (30), the plurality of receivers (32), and the processor (18) through an electrical interface port (27), or interfacing with the processor through the electrical interface port.

10 15. The method (80) of any of claims 10 to 14 wherein the structure (14) comprises a nut (62) or a nut plate assembly (58) aligned with the hole (44), said determining (92) comprising determining a total length of the hole extending through the structure and the nut or the nut plate assembly.

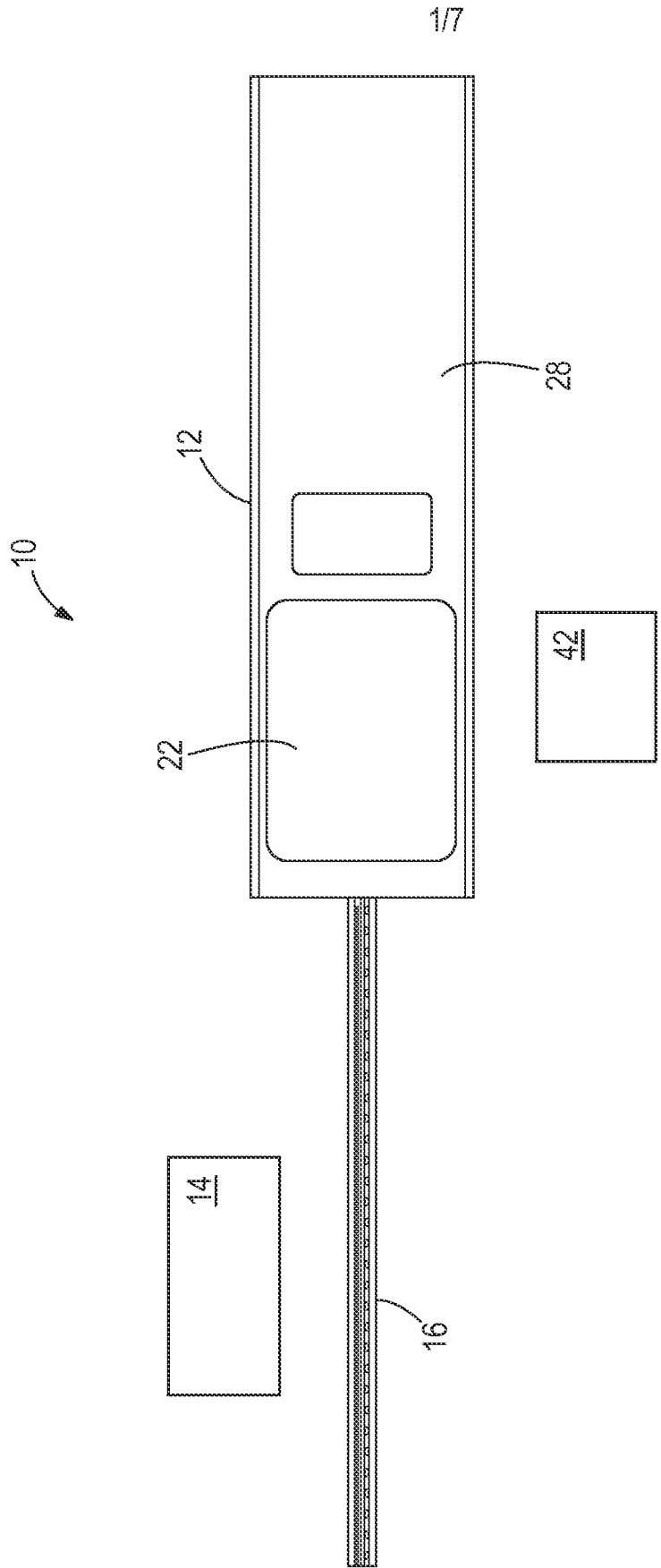
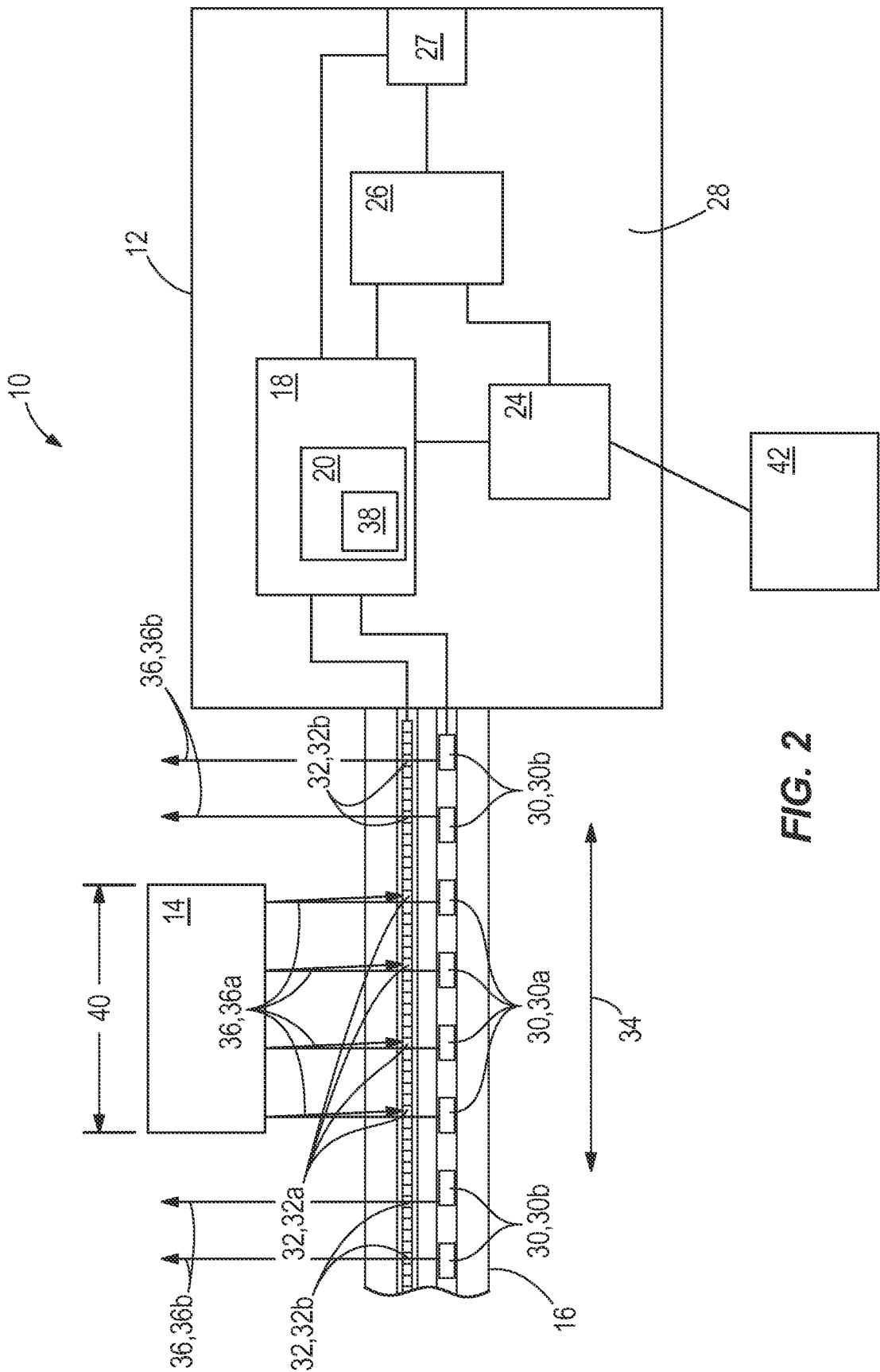
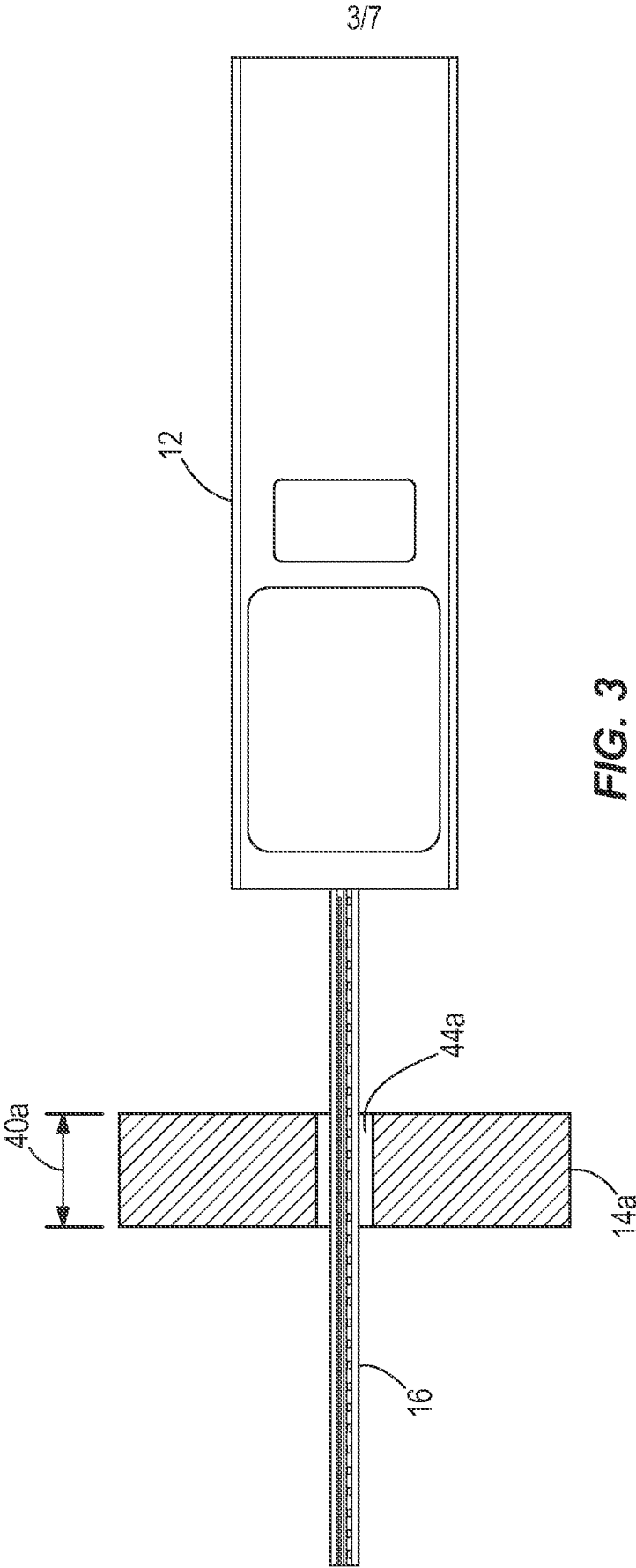
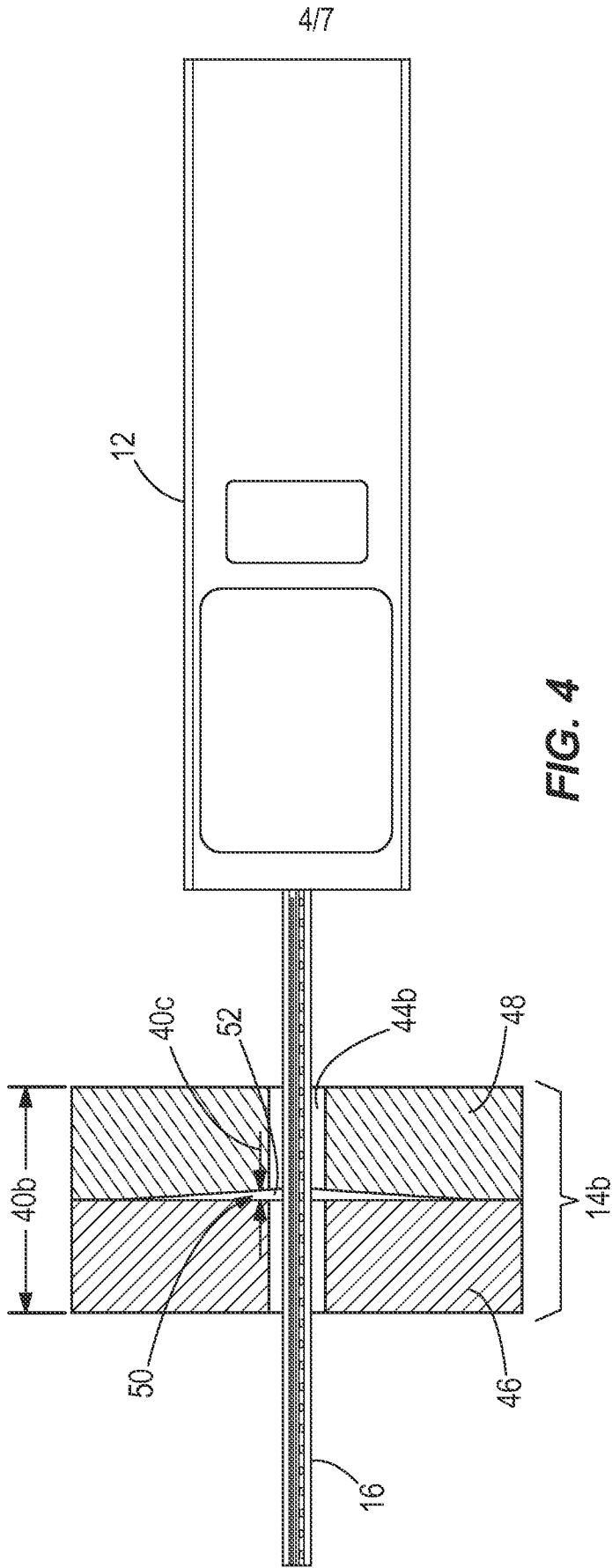
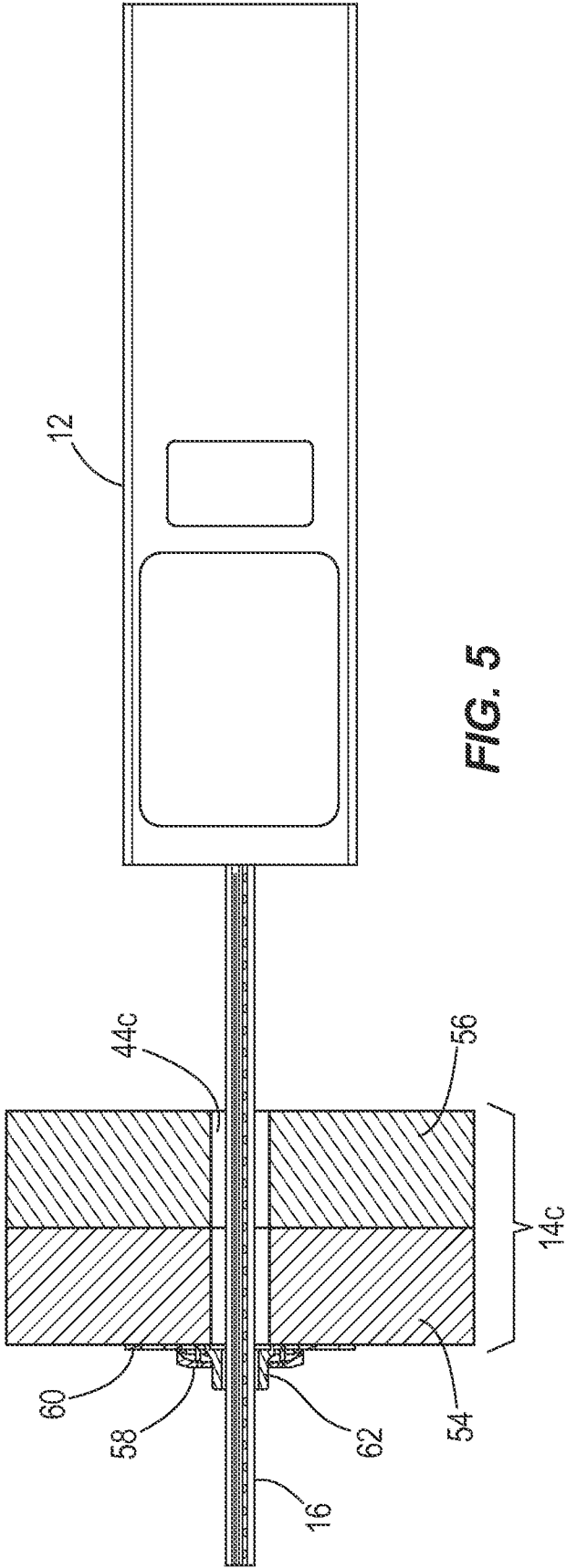
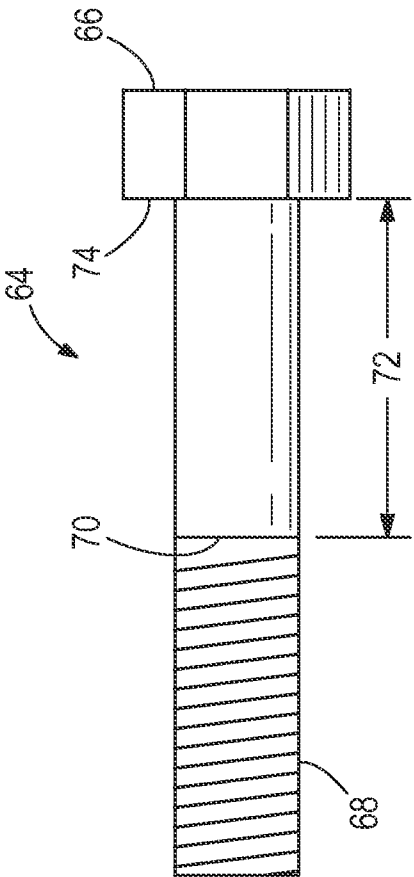


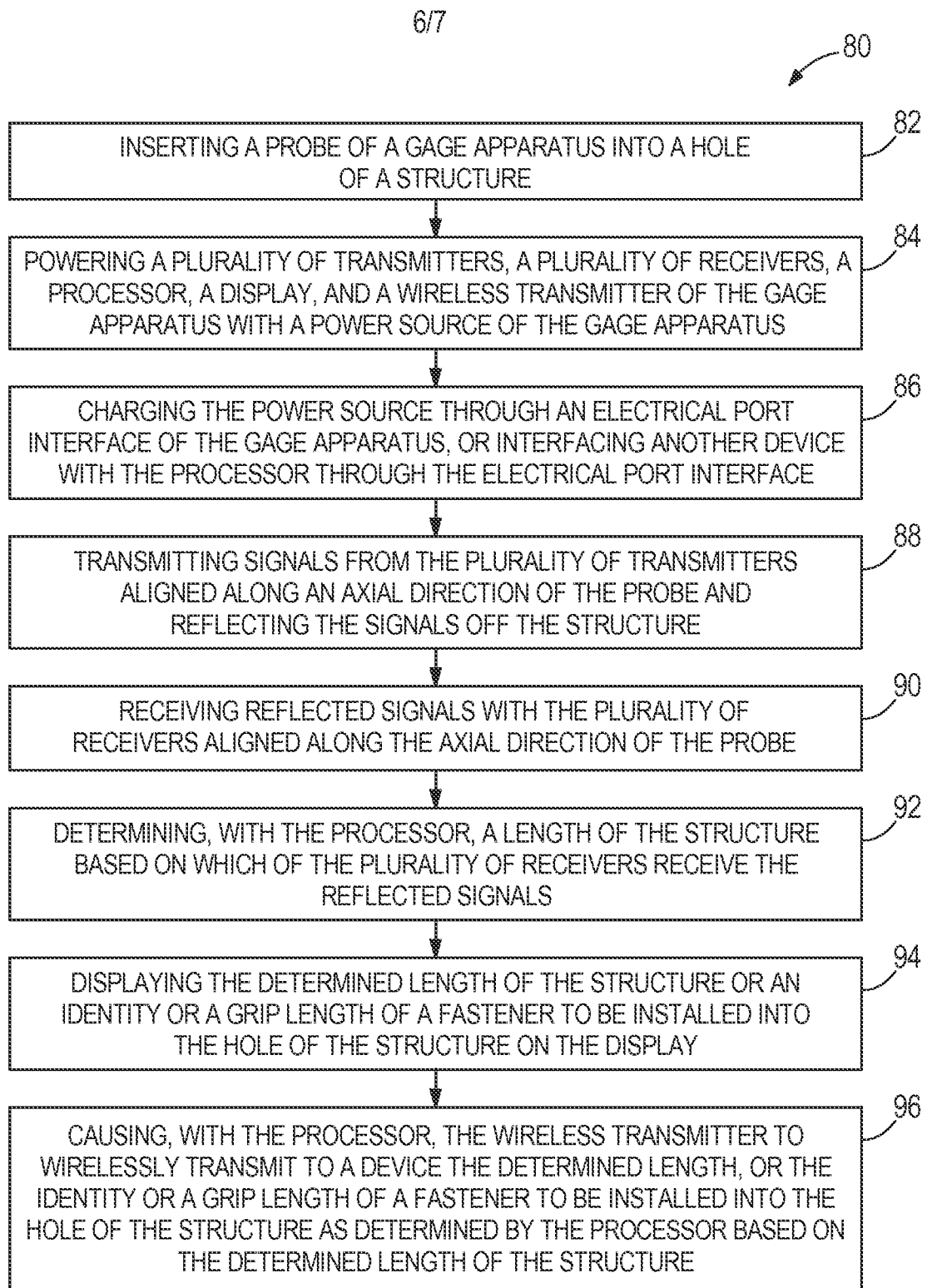
FIG. 1



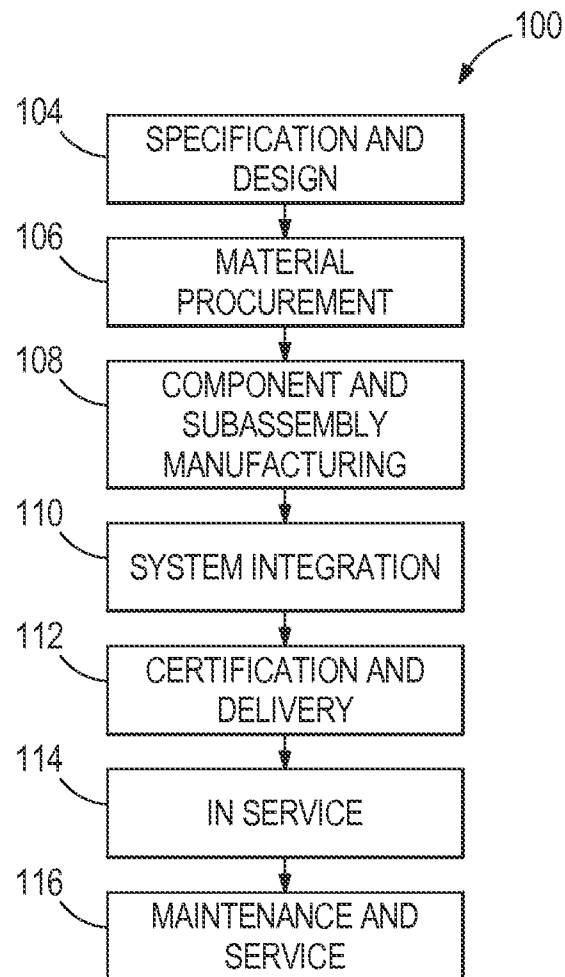
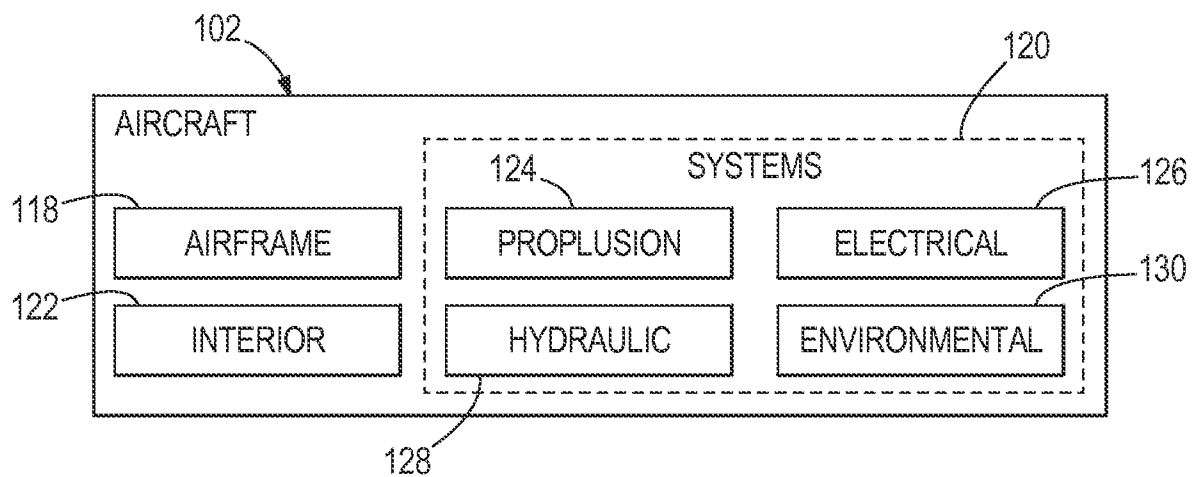






**FIG. 7**

7/7

**FIG. 8****FIG. 9**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2014/052229

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01B11/02 G01B11/22 G01D5/34
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01B G01D

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/092300 A2 (MAHLO GMBH & CO KG [DE]; SCHMIDL KARL-HEINZ [DE]) 8 September 2006 (2006-09-08) abstract page 8, line 29 - page 10, line 16 figure 3	1-15
X	GB 1 033 811 A (DAVY AND UNITED INSTR LTD) 22 June 1966 (1966-06-22) page 2, line 6 - page 3, line 10 claims 1,5-7 figures 1-4	1-15
X	FR 2 635 382 A1 (AEROSPATIALE [FR]) 16 February 1990 (1990-02-16) abstract page 5, line 3 - page 8, line 15 figures 1-7	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

16 December 2014

Date of mailing of the international search report

22/12/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kokkonen, Jukka

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/052229

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006092300 A2	08-09-2006	EP 1859227 A2	28-11-2007
		HK 1095007 A2	20-04-2007
		WO 2006092300 A2	08-09-2006
GB 1033811 A	22-06-1966	DE 1448394 A1	06-02-1969
		GB 1033811 A	22-06-1966
		SE 301882 B	24-06-1968
FR 2635382 A1	16-02-1990	NONE	