(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 402 227 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.01.2012 Bulletin 2012/01

(51) Int Cl.:
B61K 9/12 *(2006.01)*

(21) Application number: **11168855.2**

(22) Date of filing: **06.06.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **07.06.2010 IT TO20100479**

(71) Applicant: **DMA S.r.l.**
10129 Torino (IT)

(72) Inventors:
- **Santanera, Cesare**
  10129 Torino (IT)
- **Zingarelli, Angelo**
  10129 Torino (IT)
- **Baronti, Riccardo**
  10129 Torino (IT)

(74) Representative: **Gallarotti, Franco**
Buzzi, Notaro & Antonielli d'Oulx S.r.l.
Via Maria Vittoria, 18
10123 Torino (IT)

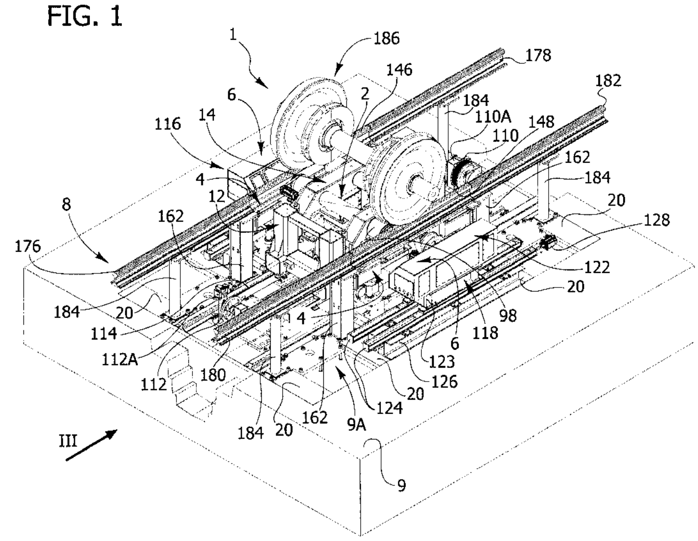
(54) A verification and measurement apparatus for railway axles

(57) Verification apparatus (1) for railway axles, comprising:
- a displacement and support assembly (2, 10),
- a measurement assembly (4),
- a mobile support assembly (6),

wherein:
- said displacement and support assembly (2, 10) comprises support elements (96, 98) arranged to rotatably support a railway axle (186), wherein said displacement and support assembly comprises a motor assembly (100, 102) for the displacement of said support elements (96, 98),
- said measurement assembly (4) comprises optical instruments (122) arranged for the detection of one or more profiles (P1, P2, P3) of a wheel (190) of said railway axle (186),
- said apparatus (1) is configured for supporting said railway axle (186) alternatively by means of said mobile support assembly (6) or said support elements (96, 98) of said displacement and support assembly (2),

wherein when said railway axle is supported by said support elements (96, 98):
- said motor assembly (100, 102) is arranged to bring in rotation said support elements (96, 98) and said railway axle (186),
- said measurement assembly (4) can be actuated to detect said one or more profiles (P1, P2, P3).

FIG. 1



EP 2 402 227 A1

Description

Field of the invention

[0001] The present invention refers to a detection and verification apparatus for railway axles, particularly of the type that can be installed in a railway depot and arranged to perform measurements aimed at determining some characteristic quantities of a railway axle.

General technical problem

[0002] The rolling stock circulating on the railway system is subjected, during use, to a progressive deterioration of the components thereof, which affects the with wheel arrangement elements too. In particular, among the wheel arrangement elements, the railway axles are typically subjected to particularly marked wear phenomena given that they are subjected to particularly heavy operating conditions.

[0003] Such wear phenomena are rarely regular or substantially symmetric between the wheels which form a railway axle, hence potentially leading to unwanted an1d hazardous dynamic phenomena which affect the travel dynamics of the train and the safety of the rolling vehicle and the occupants thereof.

[0004] The wear involving a railway axle occurs markedly on the wheels, which are subjected to variations and/or alterations of the profile thereof due to, for example, impacts during travel, friction of the flange along the side of the railway, and due to the simple rolling on the rails.

[0005] The periodic verification of the railway axles is important given that it allows having an indication regarding the state of wear of a railway axle and hence indications regarding potential criticalities that could arise during the travel of the rolling vehicle. However, in the field of known verification apparatus there still lacks a solution adapted to perform complete and correct verifications in a simple and quick manner on the railway axles without requiring complex operations for disassembling of the axle and installing on a test bench.

[0006] Nevertheless, the measurement apparatus of the known type, generally provide incomplete (e.g. not extended to the entire circumference) and/or poorly accurate data, in particular regarding the diameter and eccentricity)

Object of the invention

[0007] The object of the present invention is to overcome the previously described technical problems.

[0008] In particular, the object of the invention is to provide an apparatus for the measurement and verification of railway axles that allows to perform the measurement operations in a simple, quick and accurate manner without requiring complex operations for disassembling and subsequently reassembling the axle on a bogie of a railway vehicle.

Summary of the invention

[0009] The object of the present invention is achieved by an apparatus having the features forming the subject of the claims that follow, which form an integral part of the technical disclosure provided herein in relation to the invention.

Brief description of the invention

[0010] The invention will now be described with reference to the attached drawings, provided purely by way of non-limiting example, wherein:

- figure 1 is a perspective view of an apparatus according to the present invention in a first operating condition,
- figure 2 is an enlarged view corresponding to figure 1 and with some components removed for the sake of clarity,
- figure 3 is a view according to the arrow III of figure 1 and with some components removed for the sake of clarity,
- figure 4 is a perspective view of a first functional assembly of the apparatus according to the invention,
- figure 5 is a view according to the arrow V of figure 4 with some components removed for the sake of clarity,
- figure 6 is a view according to the arrow VI of figure 4 with some components removed for the sake of clarity,
- figure 7 is an enlarged perspective view corresponding to figure 5 and with some components omitted for the sake of clarity,
- figure 8 is a perspective view of a second functional assembly of the apparatus according to the present invention,
- figure 9 is a view according to the arrow IX of figure 8,
- figure 10 is a perspective view with some components omitted from the functional assemblies of figures 4, 8,
- figure 11 is a perspective view, with some components omitted for the sake of clarity, of a third functional assembly of the apparatus according to the invention,

- figure 12 is a perspective view of the apparatus of figure 1 in a second operating condition,
- figure 12A is a view according to the arrow XII of figure 12,
- figure 13 is an enlarged view corresponding to figure 12 with some components omitted for the sake of clarity,
- figure 14 is a view according to the arrow XIV of figure 12 with some components omitted for the sake of clarity,
- figure 15 is an exemplifying view of a method of operation of the apparatus according to the invention,
- figure 16 schematically illustrates the meaning of some quantities that can be measured by means of the apparatus according to the invention, and
- figure 17 schematically illustrates the meaning of further quantities that can be measured by means of the apparatus according to the invention;
- figure 18 schematically illustrates some procedures implemented by processing means operating in association to the apparatus according to the invention;
- figure 19 is a schematic view of a detail of the apparatus according to the invention;
- figure 20 schematically illustrates the meaning of further quantities that can be measured by means of the apparatus according to the invention;
- figure 21 schematically illustrates a first method for measuring a quantity that can be measured by means of the apparatus according to the invention;
- figures 22 and 23 schematically illustrate a second method for measuring a quantity that can be measured by means of the apparatus according to the invention;
- figure 24 schematically illustrates a module for controlling the apparatus according to the invention.

Detailed description of the invention

[0011] A verification apparatus for railway axles according to the present invention is indicated with 1 in figure 1. With reference to figures 1 to 3, the apparatus 1 comprises a displacement and support assembly 2, a measurement assembly 4 and a mobile support assembly 6. The apparatus 1 is preferably installed in a workshop pit, generally indicated with reference number 8 and represented, in some of the parts thereof, schematically. The pit 8 comprises a floor 9 in which a seat 9A is obtained.

[0012] With reference to figures 4, 5, 6, the displacement and support assembly 2 comprises a bogie 10 having a first frame 12 and a second frame 14. The bogie 10 furthermore comprises four wheels 16 rotatably connected to the first frame 12 and movable along Burback rails indicated with reference number 18 and fixed to plates 20 in turn housed in the seat 9A of the pit 8.

[0013] The first frame 12 comprises two longitudinal beams 22 joined by four crosspieces 24 to form a "ladder-like" structure. Two of the crosspieces 24 are located in proximity of respective opposite ends of the longitudinal beams 22 (at times indicated, in the present description, as "outer crosspieces 24") while the remaining crosspieces 24 (at times indicated, in the present description, as "inner crosspieces") are located between the previously mentioned two cross-pieces 24 thereby defining a quadrangular gap 25 (figure 6). In the present description, the terms "longitudinal" and "transversal" refer to the direction, respectively, of the longitudinal beams 22 and of the crosspieces 24.

[0014] At the ends of each longitudinal beam 22 there are further fixed (preferably by means of welding), substantially orthogonal to the crosspieces 24, four uprights 26, in turn joined in pairs by respective crosspieces 28.

[0015] Preferably, the longitudinal beams 22, the uprights 26 and the crosspieces 24, 28 are provided by means of steel profile beams having hollow cross-section. To each upright 26 there is further fixed a guide 30 positioned so as to face towards all the remaining guides 30. In other words, each guide 30 is positioned in a spatial region comprised between the four uprights 26.

[0016] The guides 30 comprise, each, a fixing plate 32, two clamps 34 fixed at opposite ends of the plate 32 and a cylindrical bar 36, located with axis vertical and orthogonal to the longitudinal beams 22, fastened and secured in position by the clamps 34 (preferably by means of fastening screws).

[0017] On the sides of the longitudinal beams 22, on the same side with respect to the wheels 16 and adjacent thereto, there are arranged four feet 38, rigidly connected to the longitudinal beams 22 and each having a block 40 comprising a recess 41 whose shape is substantially complementary to that of the Burback rail 18. The feet 38 protrude between the wheels 16 and towards the rails 18, when the bogie 10 is positioned thereon.

[0018] With reference to figure 6, illustrating a lower view of the bogie 10, the wheels 16 are in pairs rotatably connected to axles 42, on each of which there are engaged two guide elements 44 fixed in positions substantially corresponding to those of the longitudinal beams 22 with respect to the axles 42.

[0019] Each guide element 44 comprises a lower portion 46 and an upper portion 48 mutually fixed and defining a cylindrical cavity 50 within which there are arranged the axles 42. Furthermore, to each portion 46 there are fixed first ends 51 of leaf springs 52, having second ends 53 fixed to the longitudinal beams 22. Thus, each axle 42 is elastically connected to the longitudinal beams 22.

[0020] Furthermore, each guide element 44 is movable, due to the second portion 48, in respective recesses 54 whose shape is substantially complementary to the portion 48, thus obtaining a prismatic guide. With further reference to figure 7, wherein one of the longitudinal beams 22 was omitted so as to better show the inner details of the structure of the bogie 10, each guide element 44 further carries a pad 56 arranged to cooperate with a stop plate 58 which is further connected to a pin for adjusting the pre-load 60. The pad 56, the plate 58 and the pin for adjusting the pre-load 60 are all housed within the longitudinal beams 22.

[0021] Thus, the guide elements 44, the leaf springs 52 and the axles 42 provide a suspension of the bogie 10 in which the unsprung mass comprises the wheels 16, the axles 42 and the guide elements 44, while the sprung mass substantially comprises the frame 12 and all that is directly or indirectly supported thereby.

[0022] With reference to figures 4 to 7, the second frame 14 is supported by four actuators 62 fixed to the longitudinal beams 22 due to respective fixing plates 64. Each longitudinal beam 22 carries two actuators 62 arranged adjacent to each of the uprights 26.

[0023] Each actuator 62 is of the screw type, preferably with the trapezoidal thread, and comprises a respective threaded stem 66 of the through type. The stem 66 in fact traverses the entire actuator 62 and further also traverses a respective through hole 68 provided on the corresponding longitudinal beam 22.

[0024] With reference to figure 6, between each stem 66 and the frame 14 there is interposed a load cell 70. Furthermore, each actuator 62 is operatively connected, for operation, to a mechanical transmission 72 comprising an electric motor 74 with axis parallel to the longitudinal beams 22 and flanged to a first reducer 76 having three output shafts. In particular, the reducer 76 comprises a first and a second output shaft 78, 80 connected with respective joints 78A, 80A (preferably of the sleeve type) to corresponding pins 81 for the actuation of the actuators 62 (each actuator 62 comprises two mirror-like actuation pins 81, whereby the one not engaged in the joint is observable), and a lay shaft 82 which bring the motion to a second reducer 84 having two output shafts 86, 88 substantially identical to the shafts 78, 80 and also connected by means of joints 86A, 88A to pins 81 for actuating corresponding actuators 62.

[0025] Each of the reducers 76, 84 is fixed to a corresponding inner crosspiece 24.

[0026] With reference to figures 4, 6, 7, the second frame 14 comprises two longitudinal beams 90 substantially arc-shaped and each comprising respective vertical ends 92 substantially parallel to the uprights 26. Furthermore, the two longitudinal beams 90 are transversely joined by two fixed shafts 94 which connect in rotation a first roller 96 to a second roller 98. The rollers 96, 98 lie on opposite sides with respect to the frame 14.

[0027] The first rollers 96 have a larger diameter with respect to the rollers 98 and an electric motor 100 is connected to one of them by means of a toothed belt 102. The rollers 96, 98 each comprise a terminal support stretch 104 (having the same diameter on both rollers) having a conical edge 106 with larger diameter in extreme position with respect to each roller 96, 98. A guide bushing 108 is fixed to each end 92 and it is slidably engaged on a respective cylindrical bar 36 of a guide 30.

[0028] With reference to figure 1, a first and a second pulley 110, 112 rotatably supported by means of respective brackets 110A, 112A fixed to the plates 20 on which there is wound a rope 114 mechanically fixed to the bogie 10, particularly to the first frame 12 are also part of the displacement and support assembly 2.

[0029] With reference to figure 3 and to figures 8 to 10, the measurement assembly 4 comprises a first lateral measurement station 116, a second lateral measurement station 118 and a central measurement station 120. The first and the second lateral measurement stations 116, 118 are identical and positioned mirror-like, in the seat 9A of the pit 8, with respect to the displacement and support assembly 2 (figure 3).

[0030] Each lateral measurement station 116, 118 comprises: an optical acquisition unit 122 supported by an undercarriage 123 slidably mounted on guides 124 carried by profiled beam 126 within the seat 9A of the pit 8. Thus, each optical acquisition unit is slidable in the longitudinal direction along the guides 124.

[0031] The displacement of the optical acquisition unit 122 along the guides 124 is carried out by an electric motor 128 coupled to an angular position transducer, for example an encoder. Each optical acquisition unit 122 comprises a first, a second and a third observation windows 130, 132, 134 associated to respective camera-laser source units connected with an external control unit 250, illustrated in figure 24, comprising a plurality of electronic processor devices. The camera-laser source units perform a detection of the so-called 'light section', or even 'laser line detection' type. The laser sources of the light section unit emit a laser line at a given angle on the objects that should be scanned, which is then detected in reflection by the camera, allowing obtaining the contour of the scanned object.

[0032] The observation window 132, like the respective camera-laser source unit, is in central position with respect to the windows 130, 134 and it shall thus be identified, in the present description, also by the term "central window" and the term "central instrument" shall be similarly used for the camera-laser source unit associated to the window 132.

[0033] Analogously, the windows 130, 134 and the camera-laser source units associated thereto will be at times referred to by the terms "lateral windows" and "lateral instrument/s".

[0034] The central measurement station 120 comprises a third and a fourth optical acquisition unit, each indicated with reference number 136, identical with respect to each other. Each acquisition unit 136 is carried by a plate 138 which develops in a substantially transverse direction, in turn carried by an undercarriage 140 mounted slidably along guides

142 oriented longitudinally parallel to the guides 124.

[0035] Each acquisition unit 136 comprises a respective observation window 144 associated, analogously to the units 122, to a camera-laser source unit.

[0036] With reference to figure 10, the lateral measurement stations 116, 118 and the central measurement station 120 are located on arrays of plates 20 within the pit 8 and in particular the lateral measurement stations are fixed to the plates 20 so that the profiled beams 126 are parallel to the bogie 10 and to the Burback rails 18, while the central measurement station is installed within the first frame 12 essentially so that the undercarriage 140 occupies the quadrangular gap 25 existing between the inner crosspieces 24 and also so that the plate 138 is arranged astride the longitudinal beams 22 between the actuators 62 and the reducers 76, 84, preferably below the lay shaft 82.

[0037] With reference to figure 11, the mobile support assembly 6 comprises a first and a second mobile rails 146, 148 of the Vignoles type commonly used on the European railway system. Each mobile rail 146, 148 is supported by a respective pair of actuators 150 preferably identical to actuators 62. Each actuator 150 comprises a threaded stem 152 rigidly connected to a load cell 154 to which there is in turn fixed a block 156.

[0038] Each rail 146, 148 lies on a pair of blocks 156 aligned in the longitudinal direction and to each block 156 there is further fixed a guide bushing 158 which is slidably engaged on a cylindrical bar 160 with vertical axis fixed within a guide column 162, also vertical. The guide bushing 158 and the cylindrical bar 160 define a guide of type substantially identical to the guide 30.

[0039] Each of the actuators 150 is operatively connected to a mechanical transmission 164 comprising an electric motor 166 mounted with vertical axis and flanged to a reducer 168 comprising two output shafts 170 coaxial with respect to each other and aligned in the longitudinal direction.

[0040] Each output shaft 170 is mechanically connected by means of a joint 170A to an input shaft of a corresponding actuator 150.

[0041] The actuators 150, the mechanical transmissions 164 and the guide columns 162 are carried by plates 172, 174 within the seat 9A of the pit 8.

[0042] In particular, with reference to figure 1, the mobile support assembly 6 is installed in the seat 9A of the pit 8 so that the mobile rails 146, 148 are located, respectively, between the lateral measurement station 116 and the displacement and support assembly 2, particularly the bogie 10, and between the lateral measurement station 118 and the displacement and support assembly 2, particularly the bogie 10.

[0043] The mobile rail 146 is positioned in a spatial region comprised between the lateral measurement station 116 and the rollers 96, while the rails 148 is located between the lateral measurement station 118 and the rollers 98. Furthermore, each mobile rail 146, 148 is located transversely aligned with fixed rails, respectively, 176, 178 and 180, 182 still of the Vignoles type and partly carried by the guide columns 162, partly by columns 184 in turn fixed, similarly to the guide columns 162, to the plates 172. The displacement and support assembly 2 is arranged, evidently, between the pairs of fixed rails 176, 180 and 178, 182, as well as between the mobile rails 146, 148. Furthermore, regarding what has been described previously, the lateral measurement stations 116, 118 are located externally with respect to the fixed rails 176, 178 and 180, 182, while the central measurement station 120 is located between the fixed rails 176, 178 and 180, 182 and between the mobile rails 146, 148, being included within the gap 25 of the frame 12.

[0044] Figure 24 shows a principle block diagram of a system for controlling the measurement of the apparatus. An external control unit 250 of the apparatus, which for example is located in the electrical panel, comprises an actuation control unit 251, comprising a programmable logic, with the task of actuating the motors present in the system and perform the automatic measurement cycle. Such external control unit 250 preferably further comprises a diagnostics processor 252, with the task of monitoring the system, revealing malfunctions and allowing the insertion of some parameters required by the actuation control unit 251 for the displacement. The external control unit 250 also comprises a measurement processor 252, configured to be interfaced with the measurement instruments and with the actuation control unit 251 for coordinating data acquisition. The bogies 116, 118, and 120, carry, as previously described, three camera-laser source units adapted to acquire the external profile of the wheel and each camera-laser source unit comprises a respective microprocessor card 260, for example PowerPC with Linux real-time ELDK operating system and with modules for the profile acquisition, also as indicated in figure 19. A control rack 253, provided with a microprocessor card for synchronising the laser pulses and the camera acquisition on the base of the pulses transmitted by measurement encoders 258 that operate on electric motors 128 is also present in the external control unit 250.

[0045] The various processing modules and microprocessor cards illustrated in figure 24 communicate with each other through TCP/IP protocol and each have a respective IP address.

[0046] The apparatus 1 operates as follows.

[0047] In particular, with reference to figures 1 to 3 and 12 to 15, the mobile support assembly 6 is arranged for displacing mobile rails 146, 148 between a first operating position illustrated in figures 1 to 3 and a second operating position illustrated in figures 12 to 15. In particular, the position illustrated in figures 1 to 3 is a raised position, in which each of the rails 146, 148 is positioned so that a transversal section thereof is aligned and coincident with the transversal section of the rails 176, 178 and 180, 182 so as to provide a rail head substantially continuous and without steps.

[0048] On the contrary, the position illustrated in figures 12 to 15 is a lowered position (same case applying to figure 11, in which the rails are represented in lowered position) in which the rails 146, 148 are aligned transversely to the rails 176, 178 and 180, 182, but the cross-sections thereof are not coincident, thus leading to a vertical offset condition thereof.

[0049] The displacement of each of the rails 146, 148 is controlled by actuating the motors 166 which through the transmissions 164 brings motion to the actuators 150 actuating an extraction or a retraction of the threaded stems 152. In the vertical direction motion thereof the rails 146, 148 are also guided by the guide bushings 158 which are engaged on the cylindrical bars 160.

[0050] Analogously, also the displacement and support assembly 2, particularly the second frame 14, is moveable between a raised position and a lowered position associated respectively, as described hereinafter, to the lowered position and to the raised position of the mobile rails 146, 148.

[0051] The displacement of the second frame 14 with respect to the first frame 12 occurs by controlling the motor 74 which due to the mechanical transmission 72 brings the motion to the actuators 62 controlling an extraction or retraction of the stems 66. It should be observed that, similarly to what occurs regarding the transmission 164, the actuators 62 are all synchronized with respect to each other given that they are mechanically connected to a single kinematic chain.

[0052] The apparatus 1 is arranged to perform measurements and detections on a railway axle 186 which may roll on the section of the track defined by the rails 176, 146, 178 and 180, 148, 182. The railway axle 186 comprises an axle 188 whereon there are fitted two wheels 190. Each wheel 190 comprises a centre 191, a conical rolling surface 192 and a flange 194. Furthermore, each wheel 190 comprises an inner face 195 and an outer face 195a, wherein the inner face 195 of a wheel is in view of the corresponding inner face 195 of the other wheel. The wheels 190 are fitted on the axle 188 so that a portion of the axle projects externally with respect thereto, in particular defining two spindles 196 on which there are fitted bearings of a bushing which connect the railway axle 186 to a frame of a railway bogie (not illustrated) installed on a railway vehicle for which the measurements and verifications are to be carried out.

[0053] In order to be able to perform a measurement or detection on the railway axle 186 it is necessary to move the latter to the level of the mobile rails 146, 148. For such purpose, given and considering that the axle 186 is not dismounted from the frame of the railway bogie to which it is coupled, it is necessary that the railway vehicle be moved using a winch or by means of manoeuvre locomotive so that the axle 186 is moved to the level of the rails 146, 148.

[0054] At this point, an operator in charge of controlling the apparatus 1 by means of the external control unit 250, in particular the actuation unit 251 previously mentioned, controls a motor connected to the pulley 110 so as to move the bogie 10 in proximity to the wheels 190, as illustrated in figures 1 to 3. The positioning of the bogie 10 with respect to the railway axle 186 does not require high accuracy in this phase, given that, as described below, the bogie 10 is capable of being arranged at an optimal position with respect to the axle 186 in an entirely automatic manner.

[0055] In particular, with reference to figures 12 to 15, the operator imparts an actuation, through the actuation unit 251, to the electric motor 74 which by means of the mechanical transmission 72 brings the motion to the actuators 62 controlling an extraction of the stems 66 thereof. Such extraction causes the raising of the second frame 14 and the rollers 96, 98 carried thereby. Thus, the end sections of the support 104 are progressively neared to the flanges 194, with the aim of reaching a position in which the rollers 96, 98 entirely support the axle 186 and the load weighing thereon by supporting the flanges 194.

[0056] During the raising of the second frame 14, in the case in which the bogie 10 is misaligned with respect to the optimal position that should be taken to support the axle 186, the contact between the flanges 194 and the rollers 96, 98 does not occur in a substantially simultaneous manner on each pair of rollers, but evidently the flanges 194 come into contact with a roller 96 and a roller 98 associated to one of the tubular crosspieces 94.

[0057] The force which is exchanged at the interface between the rollers 96, 98 which come into contact with the flanges 194 has a component oriented in the longitudinal direction having a module that is insufficient to displace the axle 186 (in particular a rotation) but sufficient to displace the bogie 10 in the longitudinal direction until it causes the contact of the flanges 194 with the rollers 96, 98 which had been interested by the contact and which are associated to the other tubular crosspiece 94.

[0058] This substantially causes an automatic centring of the rollers 96, 98 with respect to the flange 194 which is at a relative position illustrated in figure 12a, in which the flange 194 is supported by both support end stretches 104 of the rollers 96 or 98.

[0059] Nevertheless, the optimal position thus achieved is maintained due to the feet 38 and the blocks 40. in fact, when the vertical displacement of the second frame 14 is such that the entire weight of the axle 186 is supported by the rollers 96, 98 and no longer by the mobile rails 146, 148 and by the relative actuators 150, the blocks 40 are in contact with the Burback rails 18 given that the stiffness of the leaf springs 52 is chosen so as to have, under the load of the axle 186, such displacement to override the distance existing between the blocks 40 and the Burback rails 18, hence causing the contact therebetween. The recess 41 is shaped according to a substantially complementary shape to that of the rails 18 and it is therewith maintained at contact by the weight of the axle 186 weighing on the bogie 10. The force with which the blocks 40 are pressed on the rails 18 is sufficient due to the fact that the adherence conditions between them and the rails 18 can prevent any further movement, in the longitudinal direction, of the bogie 10 under the action of the forces operating on the bogie 10 itself.

[0060] At the same time, when the entire weight of the axle 186 is supported by the rollers 96, 98, a descent of the mobile rails 146, 148 towards the pit 8 is controlled.

[0061] The modalities with which the descent of the rails 146, 148 is controlled will now be described. Given that the actuators 62 and the actuators 150 are operatively connected to load cells interposed between the respective stems and the load supported thereby (in this case the second frame 14 for the actuators 62 and the mobile rails 146, 148 for the actuators 150), the information coming from the load cells can be used to decide the instant when to stop the vertical ascent of the second frame 14 and hence control the descent of the mobile rails 146, 148.

[0062] Actually, when the entire weight of the axle 186 entirely passes from the rails 146, 148 to the rollers 96, 98 it is observed a reset to zero of the value of the load read by the cells 154 and an ensuing change of the voltage output value provided thereby, which can be used for providing an actuation to the electric motor 74 to stop the motion and hence the interruption of the ascent of the frame 14.

[0063] The descent of the rails 146, 148 can be controlled at this point. Such descent must be such to entirely uncover the profile of the wheel 190 with respect to the windows 130, 132, 134 and with respect to the windows 144, substantially reaching a position illustrated in figures 13, 14. Actually, in the aforementioned figures, it can be simultaneously observed how the rollers 96, 98 support the axle 186 and the final position achieved by the rails 146, 148. In particular, with reference to figure 13, it can be particularly observed how the lateral measurement station 116 (but the same may also apply for the lateral measurement section 118, omitted for the sake of clarity in figure 13) faces the corresponding wheel 190 without interposed obstacles.

[0064] Subsequently, the electric motors 128 are controlled to bring the acquisition unit 122 to a position substantially corresponding to that of the bogie 10 and of the railway axle 186. This occurs by sliding the aforementioned units 122 along the guides 124. Thus, the essential conditions for starting the measurement and the detection on the railway axle 186 are defined.

[0065] For such purpose, the external control unit 250 sends an actuation command to the motor 100 which rotates the roller 96 connected thereto by the belt 102. From the roller 96 connected to the motor 100 the motion is transmitted to the flange 194 of the corresponding wheel 190 and transmitted thereby also to the other roller 96 and to the rollers 98 due to the axle 188 and to the second wheel 190. In other words, with reference to the control system, the actuation control unit 251 positions the inner bogies in axis with the inner bogie and it is kept standing by and awaiting confirmation to start the measurement cycle by the measurement processor 253; the measurement processor 253 communicates to the actuation control unit 251 the duration of the rotation of the wheel and the desired speed of rotation; the unit 251 starts the rotation of the wheels.

[0066] Furthermore, it should be observed that the presence of the conical edge 106 on the support stretches 104 and of the inner shoulder of the rollers facilitates the auto-centring and prevents the possibility that the axle 186 derails from the rollers 96, 98 with ensuing damaging of the apparatus 1 and hazard for the safety of the operator designated to perform the measurements by means of the apparatus 1 itself .

[0067] With reference to figures 15 and 12A, the assembly 4 is arranged to detect at least one profile of each wheel 190. In the present description, the term "profile" referring to the wheel 190 is used to indicate an open curve obtained, at the rolling surface 192, of the flange 194 and of the faces 195, 195A, by intersecting the wheel 190 with a reference plane. The following description and the respective figures will clarify the concept further.

[0068] Each camera-laser source unit is capable of framing a section of the wheel 190 and collimate a laser light beam at said section. More precisely, through each window 130, 132, 134 there is emitted a respective beam F130, F132, F134 which lights various sections of the wheel, corresponding to various diameters of the wheel 190.

[0069] Also the central measurement system 120 is arranged to emit, through the windows 144 due to the respective camera-laser source units, laser light beams F144 which are collimated substantially at the beams F132. Thus, the beams F132 and F144 are capable of detecting a profile P1 on a diameter aligned to the vertical, in which the beam F144 evidently has the function of mapping the area of the profile of the wheel 190 corresponding to part of the flange 194 and to the face 195 which would otherwise be geometrically shielded with respect to the beam F132.

[0070] The beams F130 and F134 emitted by the lateral windows 130, 134 identify, in a manner similar to the beams F132, respective profiles P2, P3 on diameters angularly offset with respect to the diameter on which the profile P1 is detected. Hence the apparatus 1 is capable of detecting three profiles, but generally it can detect one or more profiles of the type analogous to the profiles P1, P2, P3.

[0071] All profiles are framed and memorised by the cameras of each camera-laser source unit and sent to the external control unit for processing.

[0072] In the example illustrated in figure 15, the profiles P2 and P3 are detected symmetrically with respect to the profile P1, but the profiles P2, P3 can also be detected at diameters selected arbitrarily with respect to the reference diameter considered for the detection of the profile P1.

[0073] During such measurement, repeatable for whatever number of rotations of the axle 186, the profiles generated by the camera-laser source unit associated to the central window 132 and those generated by the camera-laser source units associated to the window 144 can be displayed.

[0074] It should be observed that supporting the flanges 194 by means of the rollers 96, 98 is particularly useful in order to be able to measure the profile from the bottom in a vertical transversal plane and hence always radially and independently from the diameter of the wheel.

[0075] The measurement terminates upon stopping rotation of the rollers 96, 98, which is followed by imparting an ascent actuation to the mobile rails 146, 148 so as to return them into contact with the conical rolling surface 192 to free the rollers 96, 98 from the load of the axle 186 (including both the own weight of the axle and the weight fraction of the railway vehicle which is discharged thereon). Then, there is controlled a lowering of the second frame 14 due to the actuators 62 actuated by the motor 74 followed by a displacement of the railway vehicle along the continuous rail head of the rails 176, 146, 178 and 180, 148, 182, during which another axle of the same bogie or axles of a different bogie or even axles of a different railway vehicle can be moved to the level of the apparatus 1.

[0076] In brief, the measurement procedure, starting from the instant in which the wheels are rotated comprises the steps of:

a) collecting by means of the processor 253, while the wheels rotate, the profiles generated by the cameras. The profiles are saved in the original format P and in a linearized format, as described in detail hereinafter with reference to figure 18; during the measurement, it is furthermore possible to display the profiles generated by the central camera and by the inner camera for each wheel. The profiles generated by the external cameras can also be displayed;

b) saving the profiles P1, P2, P3 in binary format, in merged files MP, to allow subsequent post-processing operations to obtain quantity values of the railway axle 186;

c) at the end of the rotation, the measurement encoder 258, with which the measurement processor 253 is in communication, no longer sends pulses and the measurement processor 253 stops the measuring;

d) upon completing the acquisition procedure, the data is processed to produce quantities of the axle 186 as results.

e) upon terminating the measurement, as previously indicated the actuation control unit 251 returns the mobile rails 146, 148 to a rest position and lowers the rollers to return the wheels to rest on the rails.

[0077] The railway vehicle is thus free to be repositioned

[0078] The quantities of the railway axle 186, obtained downstream of the measurement in step b) and of the post-processing in step d), beside the profile of the wheel that is processed using an algorithm to be described hereinafter, comprise eight quantities, all provided as a function of the rotation angle of the axle 186. In particular, such quantities comprise (figures 16, 17) :

- a width S of the flange 194 detected at a distance d by a knee K in turn fixed at a distance D (conventionally fixed at a conventional distance dc equivalent to 70 mm) from the face 195,
- a height H of the flange 194 referred to the knee K
- an inclination angle α of the conical rolling surface 192,
- a width L of the detected profile,
- an internal gauge Si, i.e. a distance between the faces 195 of the two wheels 190,
- a gauge S_{2r} between the faces 195 of the wheel 190 associated to the lateral measurement station 116 and the middle of the bogie 10,
- a gauge S_{21} with meaning identical to the gauge S_{2r} but referring to the wheel 190 associated to the lateral measurement station 118, and
- a diameter D of the wheel 190 calculated as described below.

[0079] The calculation of the diameter of the wheel 190 (of each wheel 190) is carried out by means of the three profiles P1, P2 and P3 detected by the cameras and laser sources associated to the windows 130, 132, 134 and 144. Known the distance between the camera-laser source units associated to the windows 130 132, 134 and selected a measurement plane orthogonal to the axis of the axle 168 and intersecting the conical rolling surface 192, it is possible to calculate the circumference passing through three points P10, P20, P30 resulting from the intersection of the above-mentioned measurement plane with the three profiles P1, P2, P3 measured previously.

[0080] The distance between the camera-laser source units is, in this embodiment of the apparatus 1, fixed at 320 mm so that, assuming that the reference system is centred at the camera-laser source units associated to the central windows 132, a triad of Cartesian coordinates related thereto is assigned to each point of intersection and it is possible to write an equation - in general form - of a circumference passing through the points P10, P20, P30 on the profiles P1, P2, P3 from which, by resolving the resulting system, it is possible to calculate the coefficients of the equation of the circumference and hence all the geometric quantities associated thereto, including the reference diameter described herein and the coordinates of the centre. Such operations are described in detail with reference to a module for calculating the parameters of the wheel 242 indicated in figure 18 and illustrated with reference to figures 21-23.

[0081] Figure 18 illustrates, by way of example, an elaboration processes scheme, in particular software processes, related to the processes of the measurement method of the apparatus according to the invention, in particular in the operations referred to in steps a) to d) described previously. In such figure 18 there are schematically illustrated blocks which represent modules, or software processes, which implement the steps or operations of such procedure.

[0082] The software modules or processes used for the measurement are loaded into the processors of various systems, on a system control card 221, just like in the processors associated to the lateral measurement stations 116 and 118.

[0083] Regarding the lateral measurement stations 116 and 118 there are provided four acquisition modules 224, for acquiring profiles displayed by the respective four cameras, corresponding to the windows 130, 132, 134, 144, which measure a given wheel 190, and for transmitting the measured data of profiles P1, P2, P3, in the original format, towards the linearization modules 225, which provide for locating the original points of the profiles P1, P2, P3 in a homogeneous reference system for all cameras, producing linearized profiles LP1, LP2, LP3. Regarding this, calibration procedures and parameters are adopted.

[0084] The system control module 221 comprises an acquisition module 226 for acquiring the analogue signals coming from distance laser sensors 211, 212 which measure the eccentricity of the wheel as a function of the displacements of the bushing during the rotation of the wheel. Such acquisition module 226 provides - in output - of measured distance data flow MCH which can be represented using a cartesian diagram with the abscissa being the development x of the circumference and the ordinate being distance measured by the sensors 211 and 212; i.e. such measured data is associated to the rotation angle of the wheel, provided for example by the encoder in form of pulses to be counted, and thus these measurements are performed at a known position with respect to the measurements of the profiles performed by the relative laser/camera units.

[0085] Provided for is a storage module 227 which saves in binary files the data transmitted by the cameras i.e. the profiles P1, P2, P3, or by the profile elaboration processes such as the linearization module 225. Correspondingly, a storage module 228 saves in binary files the distance measured data MCH, generated by the acquisition module 226.

[0086] A module for merging the profiles produced by different cameras is indicated with 230. The merged profiles are preferably those of the internal and central cameras.

[0087] Display modules for graphically displaying the acquired profiles LP in real time are indicated with 229. In measurement mode, only the display module 229 for displaying the profile made up of the data acquired by the cameras on the internal 144 and central 132 windows is active.

[0088] A module for collecting and merging the data coming from the various linearization modules 224 i.e. the linearized profiles LP, providing for - in output - merged files MP containing the profile data merging obtained from the lateral measurement stations 116 and 118 is indicated with 231.

[0089] A post-processing module, which receives both the merged files MP regarding the measured profiles and the distance data MCH measured by the sensors 211, 212 is indicated with 240.

[0090] A module 241, on the base of the profiles in the merged files MP and the distance data MCH, provides for the calculation of the quantities of the wheel, like previously illustrated with reference to figure 16.

[0091] A module 242 provides for, still on the base of the profiles in the merged files MP and the distance data MCH, the calculation of the diameter D of the wheel.

[0092] A module 243 further provides for performing calibration operations, to correct the mechanical alignments of the camera and indicate the points of the profiles in a coherent reference system. Considering the mechanical imperfections, in particular in the horizontal and vertical alignment of the guides of the bogies, such procedure is performed preferably in at least three points of the travel of the bogie to adapt the correction parameters to the actual mechanical operation of the system, using "targets" with known dimensions. The calibration parameters are saved in a database 254. Upon starting the measurement, the module 231 updates the tables of the cameras with the correct calibration parameters from the database 254.

[0093] Following is a detailed description, within the post-processing module 240, of the operation of the quantities calculation module 241 of the wheel. Such module 241 is generally configured to calculate the eight quantities, provided as a function of the rotation angle of the axle 186, previously described with reference to the figures 16, 17. Such module 241 is further configured to perform calculations of quantities of the axles 186 or wheels 190 on the base of measurements originating from distance sensors 211, 212, in particular to perform calculations of the eccentricity of the wheels 190.

[0094] Regarding this, figure 19 schematically shows a railway axle 186, which, on the wheels 190, has respective bushings 196 fitted on the spindles 196, not shown here. There are shown two distance sensors 211 and 212, respectively right and left, which are mounted at reference positions, in particular respectively on the lateral measurement stations 116 and 118 and measure a right l_r and left l_l distance, from the relative bushing 214, representing the displacement of the bushing 214 during the measurement. Such distance sensors 211 and 212 perform the detection on the base of a laser triangulation procedure. Measuring the right l_r or left l_l distance between the sensors 211, 212 and the respective bushing 214 allows positioning the profiles in a coherent reference system.

[0095] Measuring the right l_r and left l_l distance at the diameter of the wheel at a preset distance from the inner face of the wheel, which, as previously indicated, is conventionally fixed at a distance dc=70 mm from the inner face in this reference system, obtaining a conventional diameter D70 as shown in figure 20, is provided for. By repeating the procedure for each rotation angle ϑ it is obtained a function of the conventional diameter D70 which corresponds to the calculated diameter at dc=70mm. The measurement of the variation of the value of the conventional diameter D70 provides a measurement of the eccentricity of the wheel. Obviously, such operations can be repeated not only regarding the points at dc=70mm, but also the points at any distance deemed significant.

[0096] More in detail, the eccentricity and of the wheel is defined as:

$$E = \delta D / \delta\vartheta \qquad (1)$$

where D indicates the diameter of the wheel at a preset distance from the inner face of the wheel and ϑ the rotation angle.

[0097] As outlined by figure 20, in which there is represented the profile of the wheel in a manner analogous to figure 16, there is obtained the relation that:

$$P(\vartheta) + D(\vartheta) = k + l(\vartheta) + c \qquad (2)$$

where $P(\vartheta)$ is a distance of the profile from the origin of the reference system, k is a distance of the sensor 211 or 212 from the origin of the reference system and it is constant, $l(\vartheta)$ is the distance of the sensor 211 or 212 from the bushing 214, c is the dimension (diameter) of the bushing 214.

[0098] By processing the previous relations, it is observed that:

$$D(\vartheta) = k + l(\vartheta) + c - P(\vartheta) \qquad (3)$$

$$E = \delta D / \delta\vartheta = \delta l / \delta\vartheta - \delta P / \delta\vartheta \qquad (4)$$

[0099] The last relation (4) shows how the eccentricity E can be calculated having two vectors containing the data of the distances P and D as a function of the rotation angle ϑ.

[0100] It should be observed that the measurement of the eccentricity does not imply the measurement of the diameter, but it is a differential measurement, which can be referred to various distances from the inner face of the wheel, in particular due to the fact that there are accurate profiles measured along the entire circumference.

[0101] Following is a detailed description of the operation of the module 242 which implements a method for the calculation of the diameter of the wheel starting from the measurement of the profiles, positioned in the three-dimensional space, while the eccentricities are measured also using the data measured by the distance laser sensors 211, 212.

[0102] According to a first embodiment of such method, there can be used a three points method, as previously mentioned with reference to figures 16 and 17, i.e. which exploits the fact that one and only one circumference passes through three points in a plane.

[0103] Given three points P10, P20, P30 acquired by the three cameras on the lateral and central bogies one is capable of calculating the circumference and hence the diameter.

[0104] Given the three points P10 (x1, z1) , P20(x2,z2) and P30(x3,z3) where, for example, x1 = 0,x2 = 320, x3 = 320 it is required to solve the system of equations:

$$x^2+z^2+Ax+Bz+C=0 \qquad (5)$$

where A, B, C are the coefficients. Replacing the values of x and z with the values of the points indicated above allows obtaining equations in A, B and C, which provide the values thereof.

[0105] Upon obtaining the values of the coefficients A, B and C the diameter D is obtained through the relation:

$$D=sqr(A^2+B^2-4C) \qquad (6)$$

while the coordinates of the centre are given by

$$x=-A/2 \quad (7)$$

[0106] In order to reduce the error committed when detecting these points, which is amplified by the calculation algorithm and increase the accuracy, a three-point calculation method with error reduction may be applied, such method being illustrated herein with reference to figure 21 and envisaging:

- for each triad of profiles P1, P2, P3 in a plurality of triads of profiles (actually hundreds of triads per wheel are usually considered), calculating the diameter with the three-point method at a preset distance from the inner face of the wheel, obtaining distance data at a plurality of distances (from the inner face), for example d50, d55, d60, d65, d70, d75, d80, d85 and d90 as shown in Figure 21;
- repeating the calculation for each triad of profiles generating data vectors D50, D55, D60, D65, D70, D75, D80, D85 and D90;
- for each series of data, for example D50, calculating the average, maximum and minimum value, i.e. for example dm50, dmin50,dmax50;
- using the average value, for example dm50, to generate the average profile;
- perform smoothing by applying a smoothing algorithm, for example of the third order, on the medium profile;
- calculating the diameter d70, i.e. at the conventional distance dc, of the smoothened profile, which corresponds to the final value of the diameter.

[0107] The use of an "average profile" is useful to reduce the errors, due to the fact that it considers not only the single point at the conventional distance dc equivalent to 70mm but also the various points there around involving them in the measurement algorithm.

[0108] A second embodiment of the method for calculating the diameter of the wheels provides for using the eccentricity data E produced by the laser triangulation sensors 211, 212 which measure the distance of the bushing 214 from the origin of the reference plane during the detection of the profiles, considering that the eccentricity E of the wheel 190 is a function of the variation of the right and left distances l_l and l_r measured during the rotation of the wheel.

[0109] The value of the right and left distances l_l and l_r as a function of the rotation angle ϑ are thus substantially "repeatable" with period 2n, as shown in the diagram of figure 22, which shows the trend of the distance, for example the right, l_r, as a function of the rotation angle ϑ.

[0110] As mentioned previously there are provided angular position transducers, particularly encoders 258, which measure the displacement of the optical acquisition unit 122 along the guides 124.

[0111] Given that the eccentricity E data is correlated with the abscissa provided by the encoder pulses, the detection - therethrough - of a pulse related to the angle θ and a pulse related to the position x+2n will automatically provide the number of encoder pulses required to perform a complete rotation.

[0112] Each encoder 258 is directly fitted on the roller 96 or 98 which rotates the wheel, whose dimensions are known and it is hence possible to calculate the spatial development of the circumference of the flange of the wheel. In fact, it is the flange of the wheel that lies on the rotation roller 96 and not the wheel itself.

[0113] With the aim of correlating a substantially unknown function like that of eccentricity E, which usually has a plurality of relative maximums and minimums, further complicating the correlation with respect to that of the monotone function, it is envisaged to operate by reducing the interval for performing the auto-correlation by using an approximated measurement of the diameter.

[0114] The estimation operation of the diameter of the wheel may envisage to choose between the following options:

- a nominal diameter value introduced by the operator;
- a value introduced in a configuration database;
- a value obtained through the three-point procedure described previously, in the simple form at the sole distance D70, or in the form with error reduction illustrated with reference to figure 21, applied to a single sample profile; in the latter case it should be considered that the algorithm calculates the diameter of the wheel, while the value required herein is an estimation of the diameter of the flange 194; thus the nominal height of the flange 194 should be added to the obtained diameter value.

[0115] The interval to be applied preferably corresponds to an error Δe committed in the operation of estimating the diameter outlined above. There are various possibilities also regarding the choice of such error, for example:

- a preset value;
- a value such as the maximum or minimum distance values (e.g. dmin50 or dmax50) obtained from the procedure of figure 21.

[0116] In figure 23 there is shown the development of the measured distance l_r of the bushing as a function of the rotation angle θ, as in figure 22, where there are however indicated two areas of auto-correlation, around the positions x and x+n d_{est}, (indicated herein as circumference developments, corresponding to respective rotation angles), where:

- d_{est} indicates an estimated diameter
- Δe indicates an error on the estimation of the estimated diameter d_{est}.

[0117] Thus, such method provides for:

- estimating the estimated diameter value d_{est};
- determining the error value Δe associated to the estimation operation of the estimated diameter d_{est};
- considering, within the displacement values l_r or l_l acquired as a function of the rotation angle ϑ, sets of displacement values, l_r or l_l, placed with respect to each other at a distance $d_{est} \pm \Delta e$, i.e. a determined distance, measured in pulses of the encoder 258 - right and left for the right and left wheel respectively, converted to a length measurement, i.e. of circumference developement, by means of the relative scale factor, for example each pulse corresponds to a given number of micrometers - on the basis of the estimated diameter value d_{est} and variable around the estimated diameter value d_{est} within a chosen error value Δe; figure 23 indicates the variation intervals $\pm \Delta e$ around a position x chosen as reference for the calculation and x+ d_{est};
- performing the calculation of a cross-correlation function, more specifically of auto-correlation, on said displacement values l_r, l_l, in particular varying, regarding the auto-correlation calculation, such distance determined starting from d_{est} within the chosen error value Δe; in other words, the auto-correlation is not calculated on the entire domain, but only within a determined neighbourhood (whose amplitude is $\pm \Delta e$) of an estimated diameter value, thus reducing the problem regarding relative minimums and maximums.
- identifying as correct diameter, with respect to such estimated diameter value d_{est}, the value of the determined distance $d_{est} \pm \Delta e$ which maximises the result of said cross-correlation operation, in particular searching the distance at which a given number of points in the two intervals takes consecutively the same value.

[0118] Furthermore, in order to calculate - in the common reference system - a diameter D70 with respect to the conventional distance dc, it is hence provided for:

- calculating the circumference of the flange 194 and hence a diameter d_{flange} thereof using the mechanical parameters of the roller;
- taking a sample profile and, using the diameter d_{flange} for positioning the profile in the common reference system, calculating the diameter D of the wheel at 70mm from the inner face.

[0119] Generally, as mentioned, a measurement of the diameter can be obtained by operating solely a calculation of the pulses of the encoders 258, multiplied by a scale factor, on a wheel rotation. The method described above exploits the eccentricity for identifying a correct wheel rotation (a rotation of 2Π) , so that the count of the pulses of the right and left encoders 258 provides the measurement of the length of the right and left circumference respectively, and hence the diameters. However, the same object can be obtained using another method or the sensor which can determine when a complete revolution is performed. According to one variant embodiment, the used method, for example in the case that it is forecast that the eccentricity be very small, and hence the correlation poorly sensitive, may provide for creating a mark, for example a coloured mark on the side of a wheel (e.g. by means of an ink jet); such notch is then read by a normal photocell, which hence directly generates the circumference length start and end count pulses.

[0120] It is clear that the apparatus 1 according to the invention has a series of indisputable advantages. Firstly, it allows performing sufficiently accurate measurements along the entire circumference, in an entirely simple manner and through a completely automated method and work cycle. Furthermore, operations for dismounting the axle from the frame of the bogie of the railway vehicle are not required given that the system is entirely capable of bearing the weight on the railway axle subject of the measurement independently from the diameter of the wheel.

[0121] Furthermore, using the data obtained from the measurement allows a more accurate evaluation of the actual wear conditions of the wheels and possible damage caused to the axle which irremediably modifies the profile thereof, for example an ovalisation thereof, or local flattening.

[0122] Thanks to the characteristics and advantages listed above the apparatus 1 can be used in various applications, for example including:

- railway vehicle approval/homologation tests,
- verification in normal conditions of operation,
- experimentation
- maintenance

[0123] Regarding the vehicle approval/homologation testing it is possible to verify the specifications conditions thereof for the motion stability tests, verifying the wear of the railway axle thereof, verifying the trend of the wear and the turning intervals and verifying the wear symmetry thereof.

[0124] Regarding verification in normal operating conditions, and the relative maintenance, there can be carried out a verification of the flanges and the profiles and the diameters and the eccentricities, as well as scheduling maintenance on the railway axles.

[0125] Lastly, regarding experimentation, new strategies can be outlined and also new wheel profiles to be used can be studied.

[0126] Obviously, without prejudice to the principle of the invention,, the construction details and the embodiments may widely vary with respect to what has been described and illustrated without departing from the scope of protection of the invention as defined by the attached claims.

[0127] The verification apparatus according to the invention may obviously be a platform adapted to implement other types of measurement and other sensors with respect to the ones described: for example the verification apparatus may be equipped with ultrasonic sensors for verifying the internal status of the metal.

Claims

1. A verification apparatus (1) for railway axles, **characterized in that** it comprises:

- a displacement and support assembly (2, 10),
- a measurement assembly (4),
- a mobile support assembly (6),

wherein:

- said displacement and support assembly (2, 10) comprises support elements (96, 98) arranged to rotatably support a railway axle (186), wherein said displacement and support assembly (2) comprises a motor assembly (100, 102) for the displacement of said support elements (96, 98),
- said measurement assembly (4) comprises optical instruments (122, 136) arranged for the detection of one or more profiles (P1, P2, P3) of a wheel (190) of said railway axle (186),
- said apparatus (1) is configured to support said railway axle (186) alternatively by means of said mobile support assembly (6) or said support elements (96, 98) of said displacement and support assembly (2),

wherein when said railway axle is supported by said support elements (96, 98):

- said motor assembly (100, 102) is arranged to bring in rotation said support elements (96, 98) and said railway axle (186),
- said measurement assembly (4) can be actuated to detect said one or more profiles (P1, P2, P3).

2. The verification apparatus (1) according to Claim 1, **characterized in that** said displacement and support assembly (2) comprises a bogie (10) including a first frame (12), a second frame (14) and actuators (62) arranged for the displacement of said second frame (14) with respect to said first frame (12), wherein on said second frame (14) said support elements (96, 98) are rotatably mounted, wherein said second frame (14) is movable between a raised position in which it is configured to support said railway axle (186) by means of said support elements (96, 98) and a lowered position.

3. The verification apparatus (1) according to Claim 2, **characterized in that** said bogie (10) comprises wheels (16) for the movement along rails (18), and
in that said displacement and support assembly (2) furthermore comprises a first and a second pulley (110, 112) whereon a rope (114) fixed to said bogie (10), in particular to said first frame (12), winds, said first pulley (110) further being connected to a motor that can be actuated for the displacement of said bogie (10).

4. The verification apparatus (1) according to any one of Claims 1 to 3, **characterized in that** said support elements are rollers (96, 98), each comprising a terminal support stretch (104) configured to support the wheels (190) of said railway axle (186), particularly a flange (194) of each of them, in particular in order to be able to measure the profile from the bottom in a vertical transversal plane and hence always radially and independently from the diameter of the wheel.

5. The verification apparatus (1) according to Claim 1, **characterized in that** said mobile support assembly (6) comprises actuators (150) bearing a first and a second mobile rails (146, 148) and configured to displace said first and second mobile rails (146, 148) between a raised position, wherein said first and second mobile rails (146, 148) are arranged to support said railway axle (186), and a lowered position.

6. The verification apparatus (1) according to Claim 5, **characterized in that** said measurement assembly (4) comprises a first and a second lateral measurement station (116, 118) and a central measurement station (120), wherein said first and second lateral measurement stations (116, 118) comprise, each, a respective optical acquisition unit (122) including three camera-laser source units associated to respective observation windows (130, 132, 134) thereof, and wherein said central measurement station (120) comprises two acquisition optical units (136), each comprising a respective camera-laser source unit and arranged to cooperate with a respective optical acquisition unit of said first and second lateral measurement stations (116, 118), said acquisition optical units (122, 136) of said central measurement station (120) and of said lateral measurement stations (116, 118) being configured to detect said one or more profiles (P1, P2, P3) when said first and second mobile rails (146, 148) are in said lowered position.

7. The verification apparatus (1) according to Claim 6, **characterized in that** it is arranged for the installation in a workshop pit (8) comprising fixed rails (176, 178, 180, 182) carried by columns (184), wherein:

- said displacement and support assembly (2) is arranged between said fixed rails (176, 178, 180, 182) and between said first and second mobile rails (146, 148),
- said first and second lateral measurement stations (116, 118) are located externally with respect to said fixed rails (176, 178, 180, 182),
- said central measurement station (120) is located between said fixed rails (176, 178, 180, 182),
- said first and second mobile rails (146, 148) are located, each, between a corresponding lateral measurement station (116, 118) and said displacement and support assembly (2), and are furthermore located between said fixed rails (176, 178, 180, 182),

wherein, furthermore, in said raised position said first and second mobile rails (146, 148) have cross-sections aligned and coincident with respect to each of said fixed rails (176, 178, 180, 182).

8. The verification apparatus (1) according to Claim 3 **characterized in that** said wheels (16) of the bogie (10) are rotatably connected to respective axles (42) on each of which guide elements (44) fixed to springs (52) engage, so as to achieve an elastic connection of each axle (42) to the first frame (12), the stiffness of said springs (52) being chosen so as to have, under the load of the railway axle (186), such a displacement to override the distance existing between feet (38) fixed to said first frame (12) and said rails (18).

9. A method for the verification (1) of railway axles, using a verification apparatus (1) according to one or more of Claims 1 to 8, **characterized in that** it comprises the phases of:

- supporting said railway axle (186) alternatively by said first and second mobile rails (146, 148) or said support elements (96, 98) of said displacement and support assembly (2),
- said phase of supporting a railway axle (186) by said support elements (96, 98) including supporting in a rotatable manner,

said phase of supporting a railway axle (186) in a rotatable manner including a phase of operating in rotation (100, 102) at least one of said support elements (96, 98) to bring in rotation said railway axle (186),
the method further including a detection phase (122) of one or more profiles (P1, P2, P3) of a wheel (190) of said railway axle (186), said detection phase (122) being performed during the operation of at least one of said support elements (96, 98) to bring in rotation said railway axle (186).

10. The method according to Claim 9, **characterized in that** it comprises a post-processing phase (240) to compute on the basis of said one or more profiles (P1, P2, P3) detected in said detection phase (122) one or more quantities of the railway axle (196) selected among:

- a width (S) of a flange (194),
- a height (H) of the flange (194)

- an inclination angle (α) of a conical rolling surface (192) of the wheel,
- a width (L) of the detected profile,
- an internal gauge (Si),
- a gauge (S2r, S21) between the wheel (190) and the middle of the bogie (10) of the displacement and support assembly, and
- a diameter (D) of the wheel (190).

11. The method according to Claim 9 or 10, **characterized in that** said post-processing phase (241) includes computing (241) a diameter (D) of said wheel (190), said computing operation (241) including the steps of:

acquiring at least three profiles (P1, P2, P3) detected by camera-laser sources associated to said observation windows (130, 132, 134),
computing a circumference passing through three points (P10, P20, P30) obtained by the intersection of a measurement plane orthogonal to the axis of the axle (168) and intersecting the conical rolling surface (192) with the three detected profiles (P1, P2, P3).
computing the diameter (D) of said circumference.

12. The method according to one of Claims 9 to 11, **characterized in that** it includes computing the diameter (D) of said circumference of a wheel (190) on the basis of the count of pulses associated to a complete rotation of the wheel given by an angular position transducer, in particular an encoder, multiplied by a scale factor.

13. The method according to Claim 12, **characterized in that** it includes optically detecting a mark applied on the wheel (190) by an optical sensor to generate start and end count pulses of the length of the circumference of the wheel (190).

14. The method according to one of claims 9 to 13, **characterized in that** said operation of detecting includes detecting the displacement of a bushing (214) of the wheel (190) with respect to a reference, in particular with respect to a measurement station (116, 118) by respective distance sensors (211, 212) during said detection phase (122).

15. The method according to claim 14, **characterized in that** said post-processing phase (240) includes acquiring said displacement (l_r, l_l) of a bushing (214) of the wheel (190) detected as a function of the rotation angle (ϑ) of said wheel (190) and measuring an eccentricity (E) of the wheel on the basis of said acquired displacement (l_r, l_l).

16. The method according to claim 14 or 15, **characterized in that** said post-processing phase (240) includes:

- acquiring said displacement (l_r, l_l) of a bushing (214) of the wheel (190) detected at the variation of the rotation angle (ϑ) of said wheel (190),
- estimating an estimated diameter value (d_{est})
- determining an error value (Δe) associated to said estimation operation;
- taking in said acquired displacement (l_r,$l_{l)}$ as a function of the rotation angle (ϑ) displacement values (l_r, l_l) as a function of the rotation angle (ϑ) placed with respect to each other at a distance ($d_{est} \pm \Delta e$) determined on the basis of said estimated diameter value (d_{est}) and variable around said estimated diameter value (d_{est}) within the selected error value (Δe);
- performing the calculation of a cross-correlation or auto-correlation function on said displacement values (l_r, $l_{l)}$, in particular varying said determined distance ($d_{est} \pm \Delta e$) around said estimated diameter value (d_{est}) within the selected error value (Δe) ;
- identifying as correct diameter the value of said determined distance ($d_{est} \pm \Delta e$), in particular measured as encoder pulses by a scale factor, which maximises the result of the cross-correlation or auto-correlation operation, in particular searching for the distance at which a given number of points in the variation intervals takes consecutively the same value.

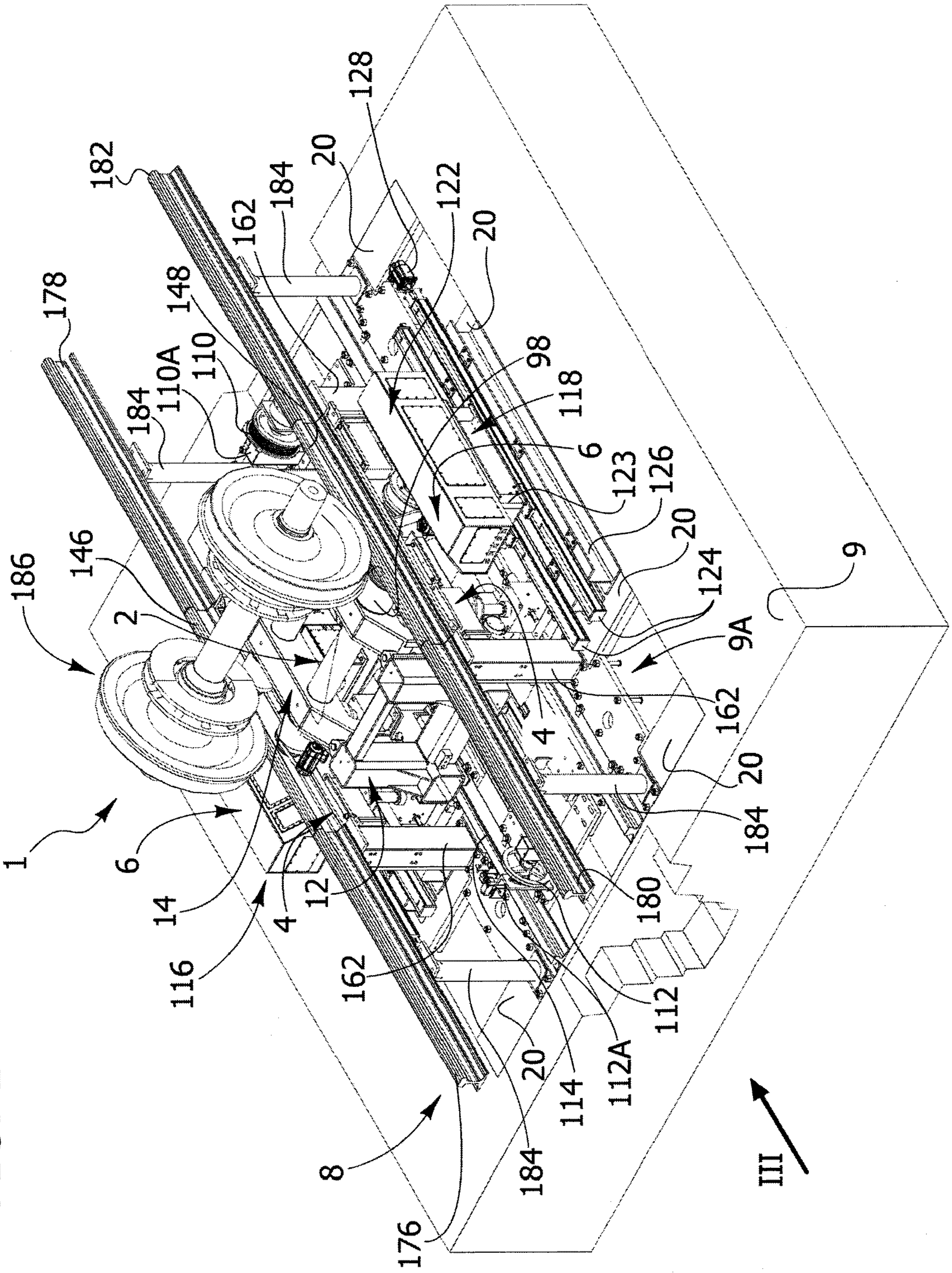

1
2
4
4
6
6
8
9
9A
12
14
20
20
20
20
20
98
110
110A
112
112A
114
116
118
122
123
124
126
128
146
148
162
162
162
176
178
180
182
184
184
184
184
186
III

FIG. 1

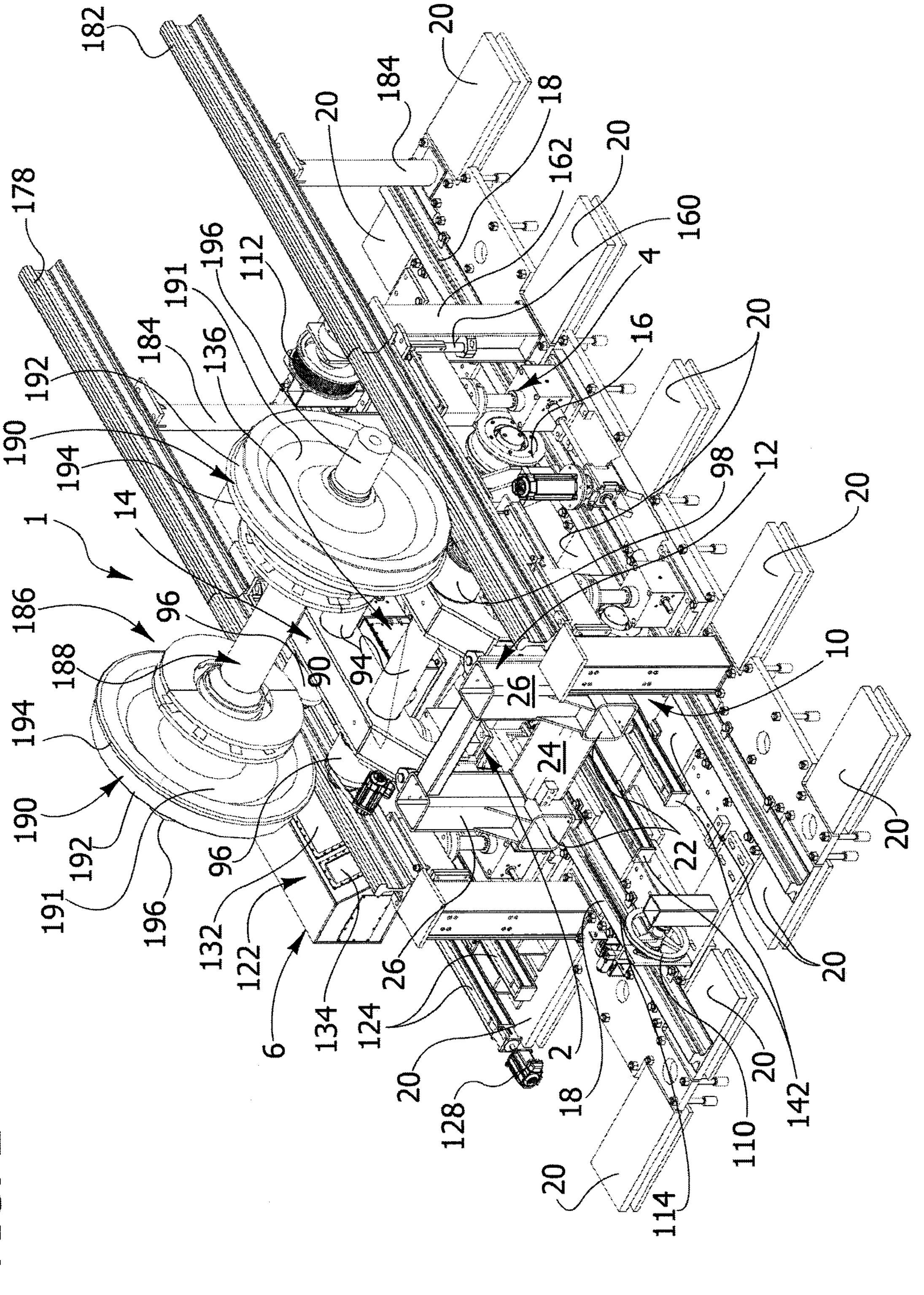

182
20
184
18
178
196
112
191
136
184
192
162
20
160
4
16
20
190
194
1
14
186
96
188
194
190
192
191
196
96
90
94
98
12
26
24
22
10
20
20
132
122
6
134
124
26
20
2
18
128
20
114
110
142
20
20

FIG. 2

FIG. 3

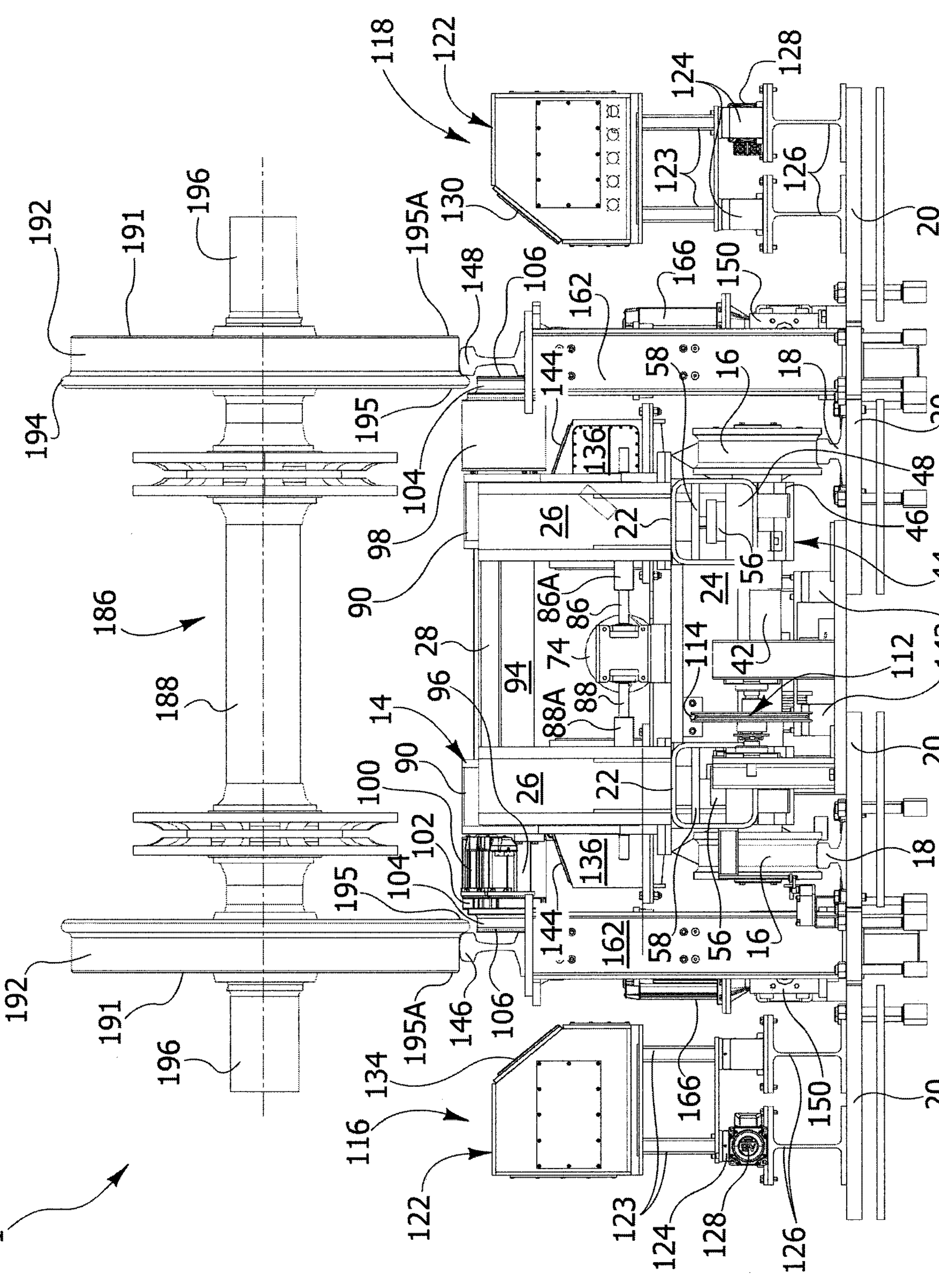
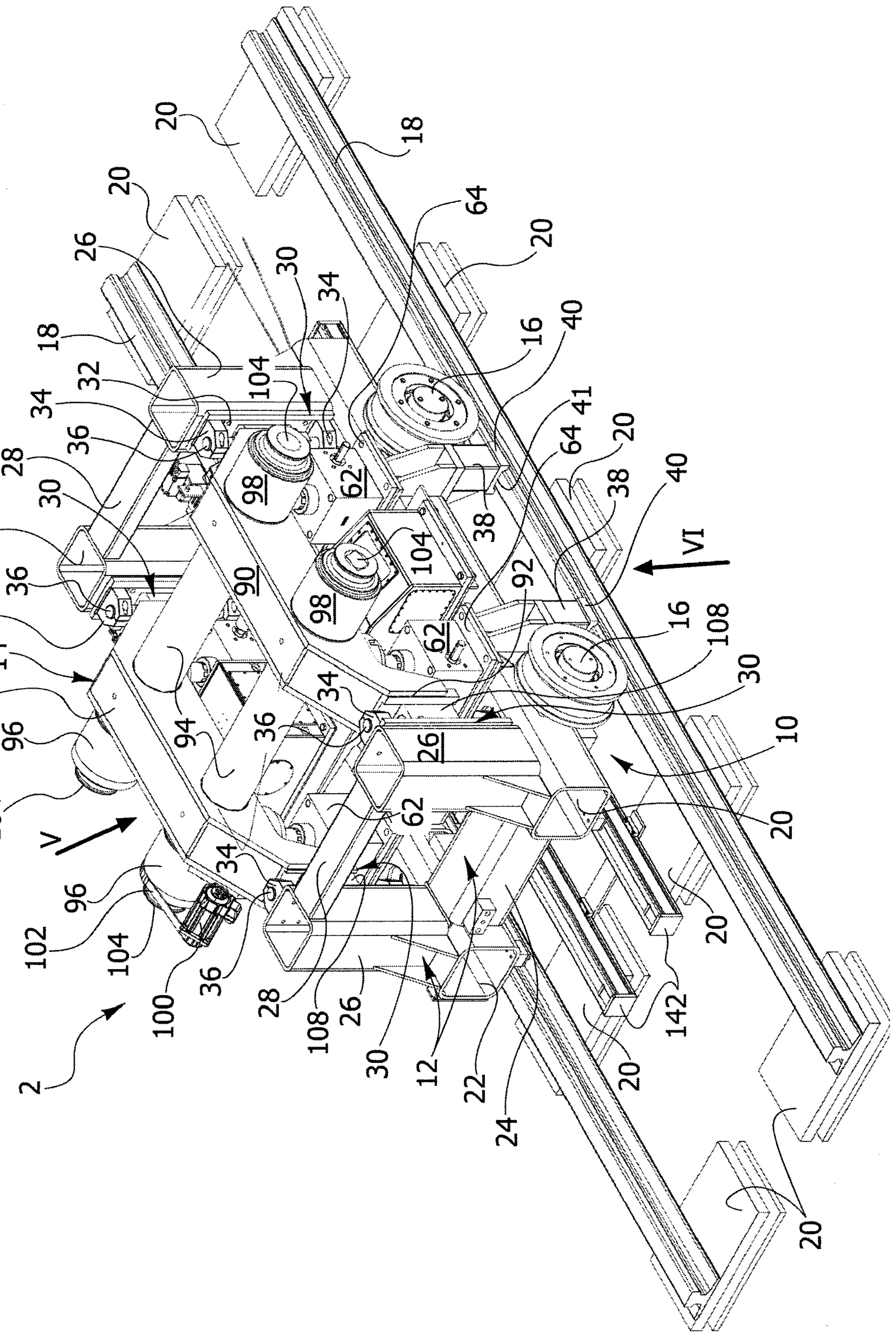


FIG. 4


20
18
20
26
30
34
64
20
18
32
104
34
36
28
16
40
30
62
26
98
41
64
20
36
104
38
38
40
34
90
98
92
VI
14
62
16
108
90
96
94
34
30
36
26
10
30
104
62
20
V
34
96
102
104
36
100
28
108
26
30
12
22
142
20
20
24
2
20
20

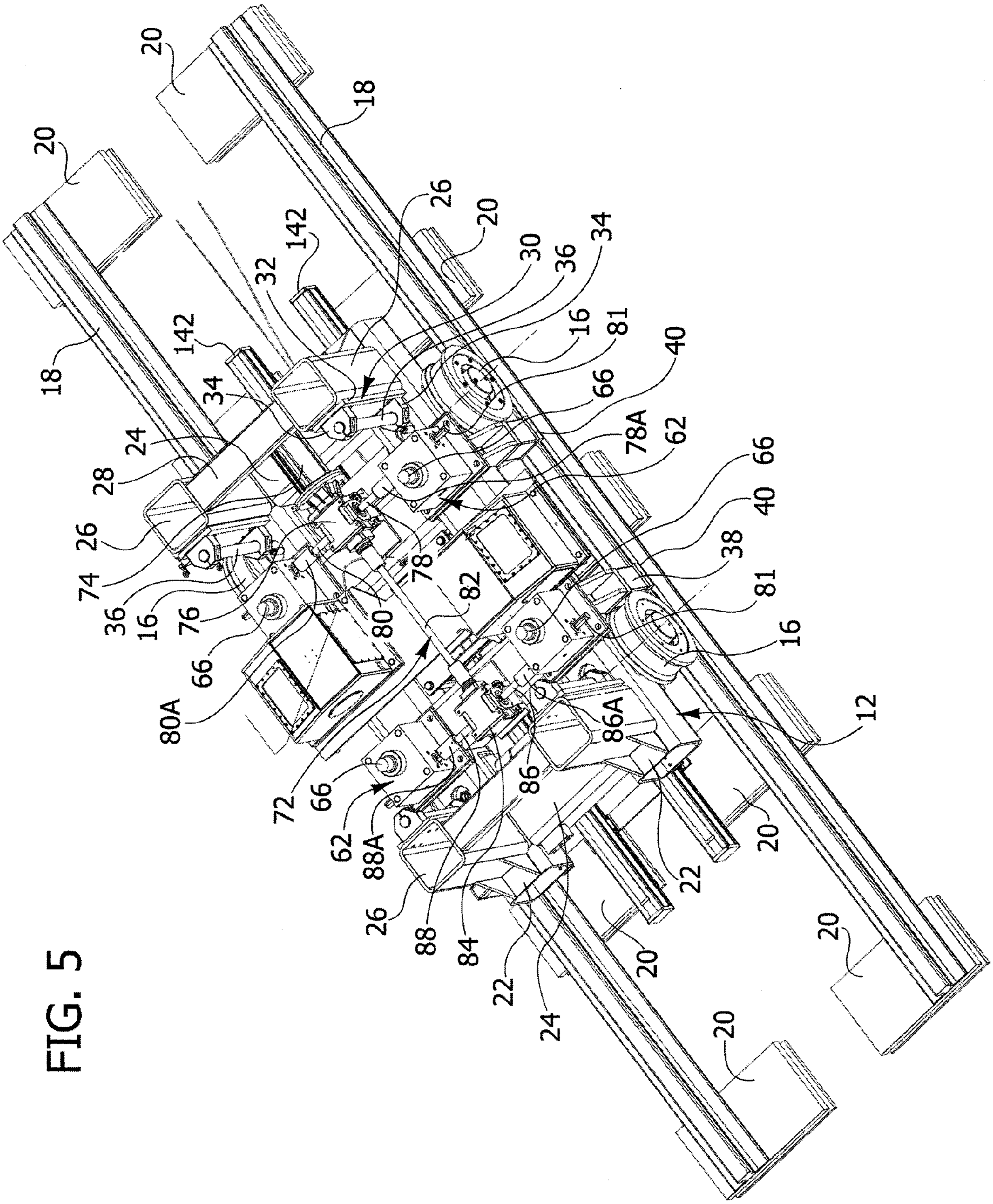

20
20
20
18
18
26
20
142
32
30
36
34
142
16
81
34
40
24
28
66
78A
62
66
26
74
36
16
76
66
80
78
82
40
38
81
16
80A
72
66
62
88A
86A
86
12
20
22
26
88
84
22
24
20
20
20

FIG. 5

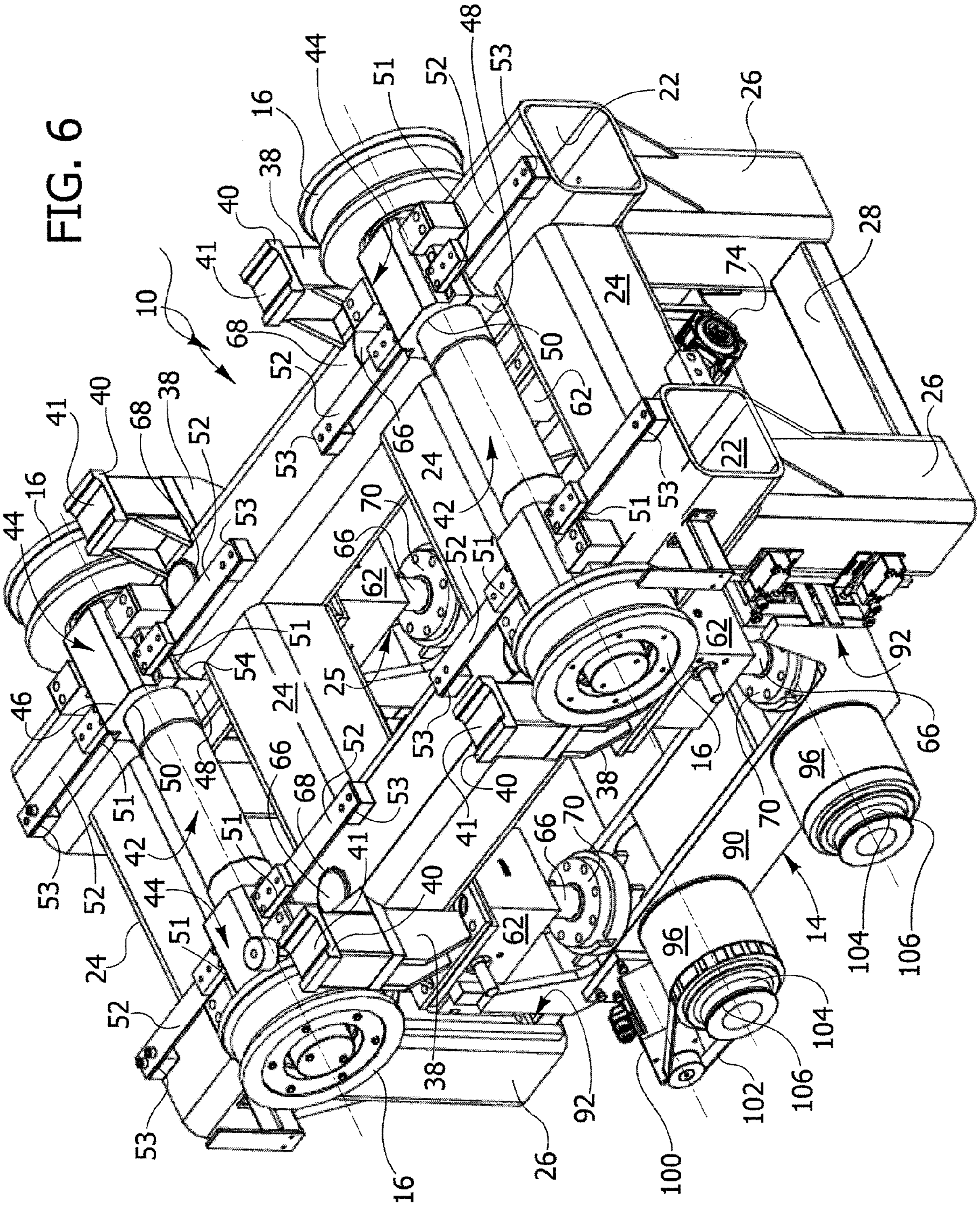


FIG. 6

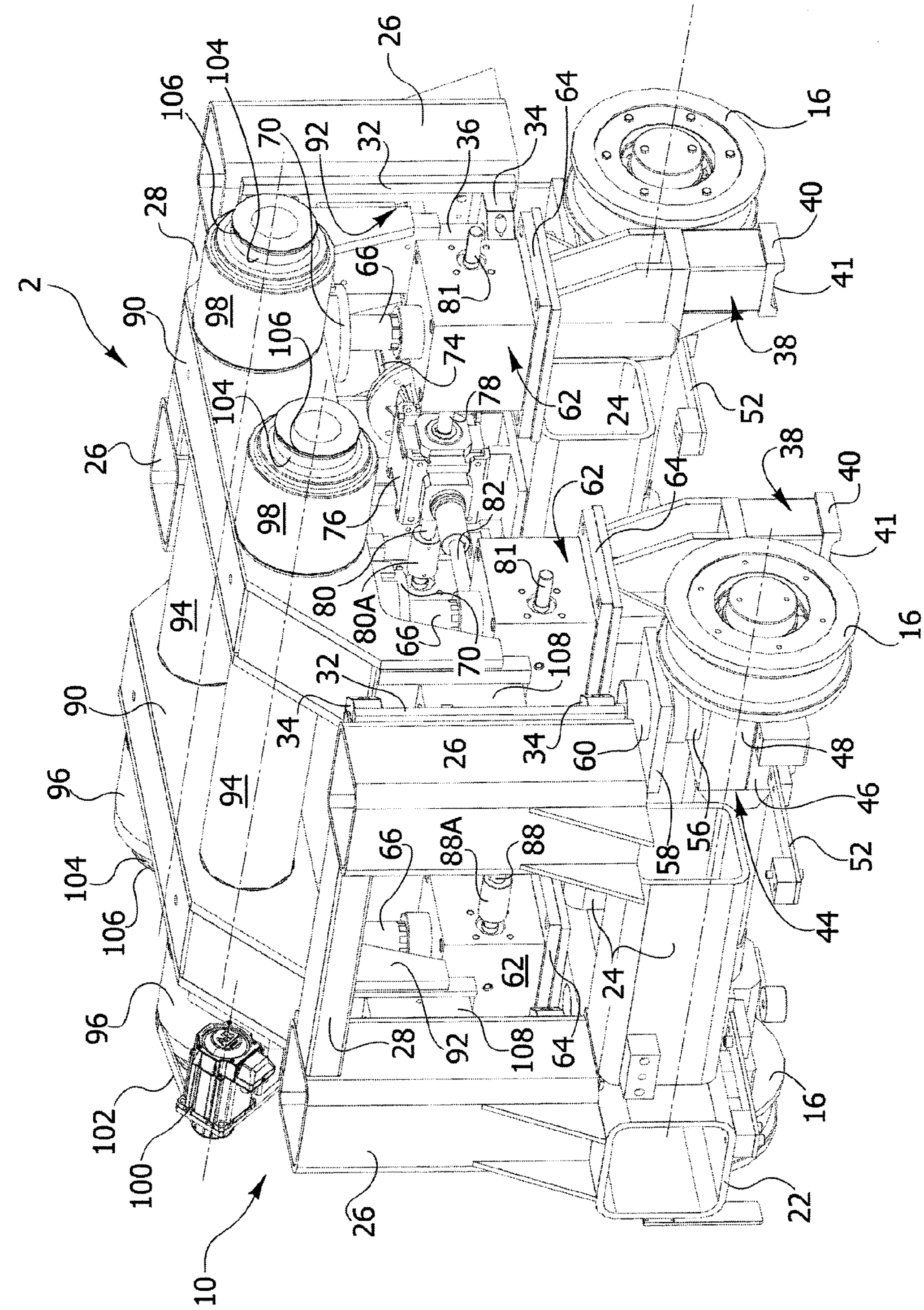

2
10
16
22
24
26
28
32
34
36
38
40
41
44
46
48
52
56
58
60
62
64
66
70
74
76
78
80
80A
81
82
88
88A
90
92
94
96
98
100
102
104
106
108

FIG. 7

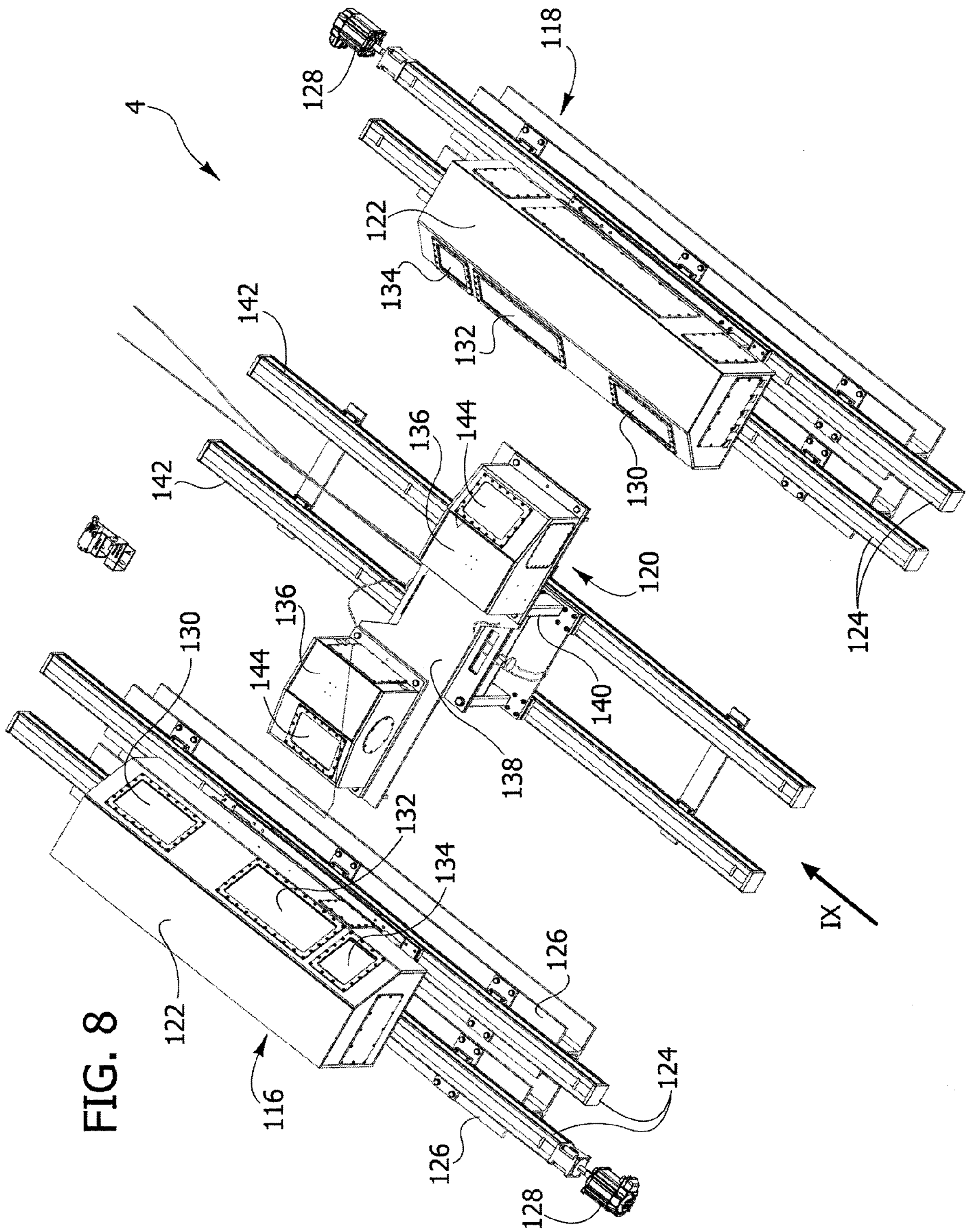

4
118
128
122
134
132
142
136
144
130
142
120
124
130
136
144
140
138
132
134
IX
126
122
116
124
126
128

FIG. 8

FIG. 9

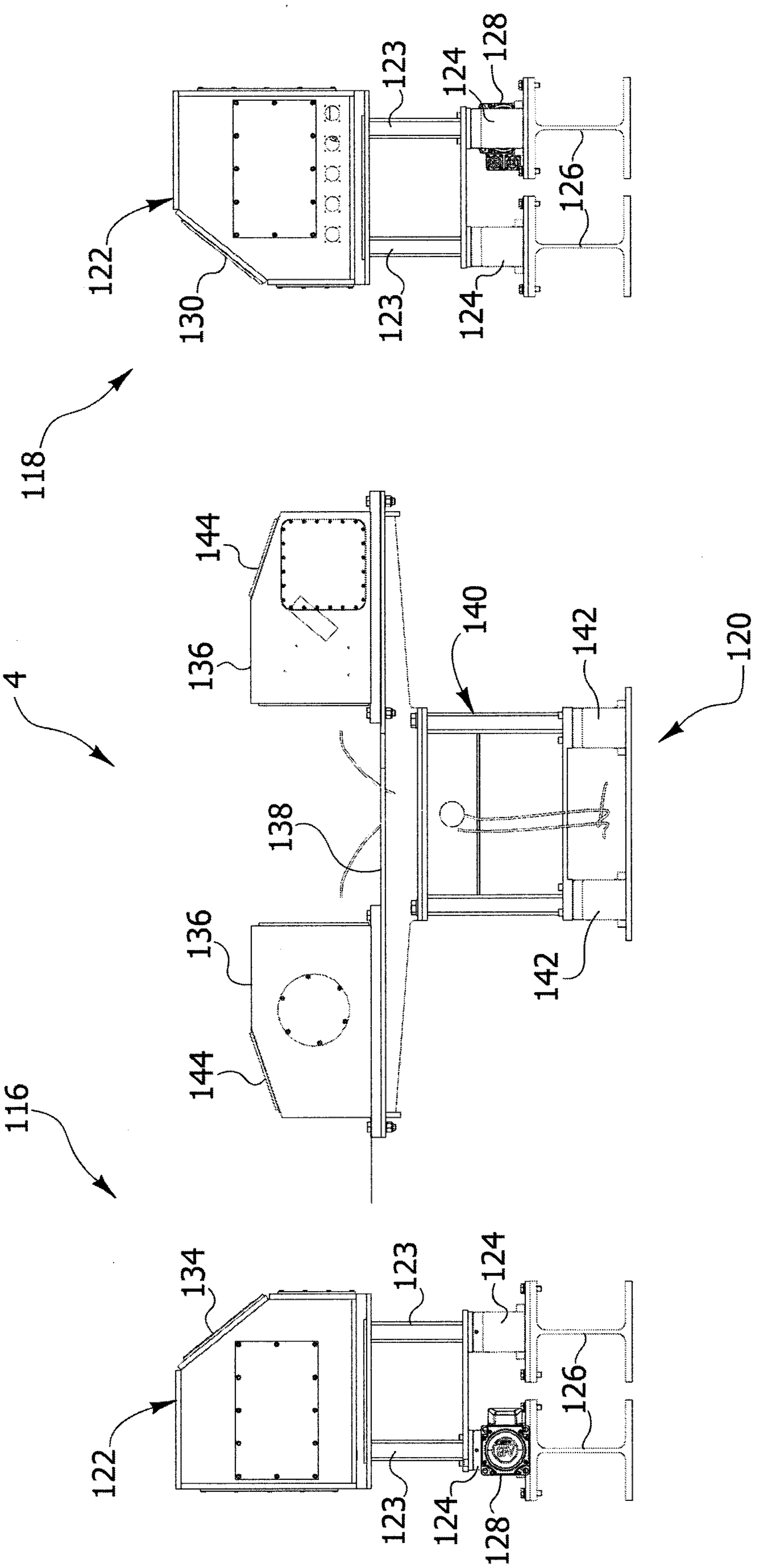


FIG. 10

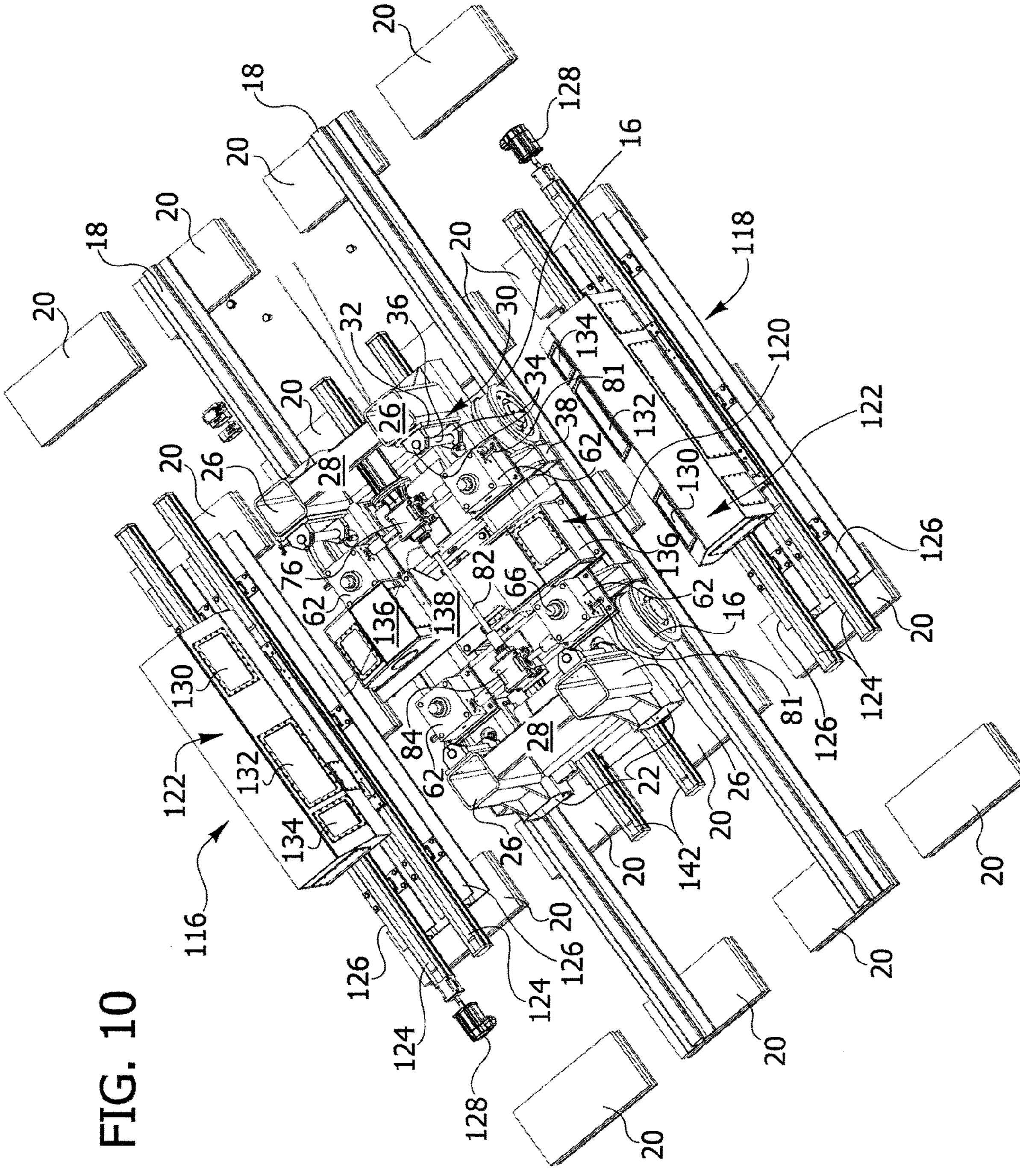
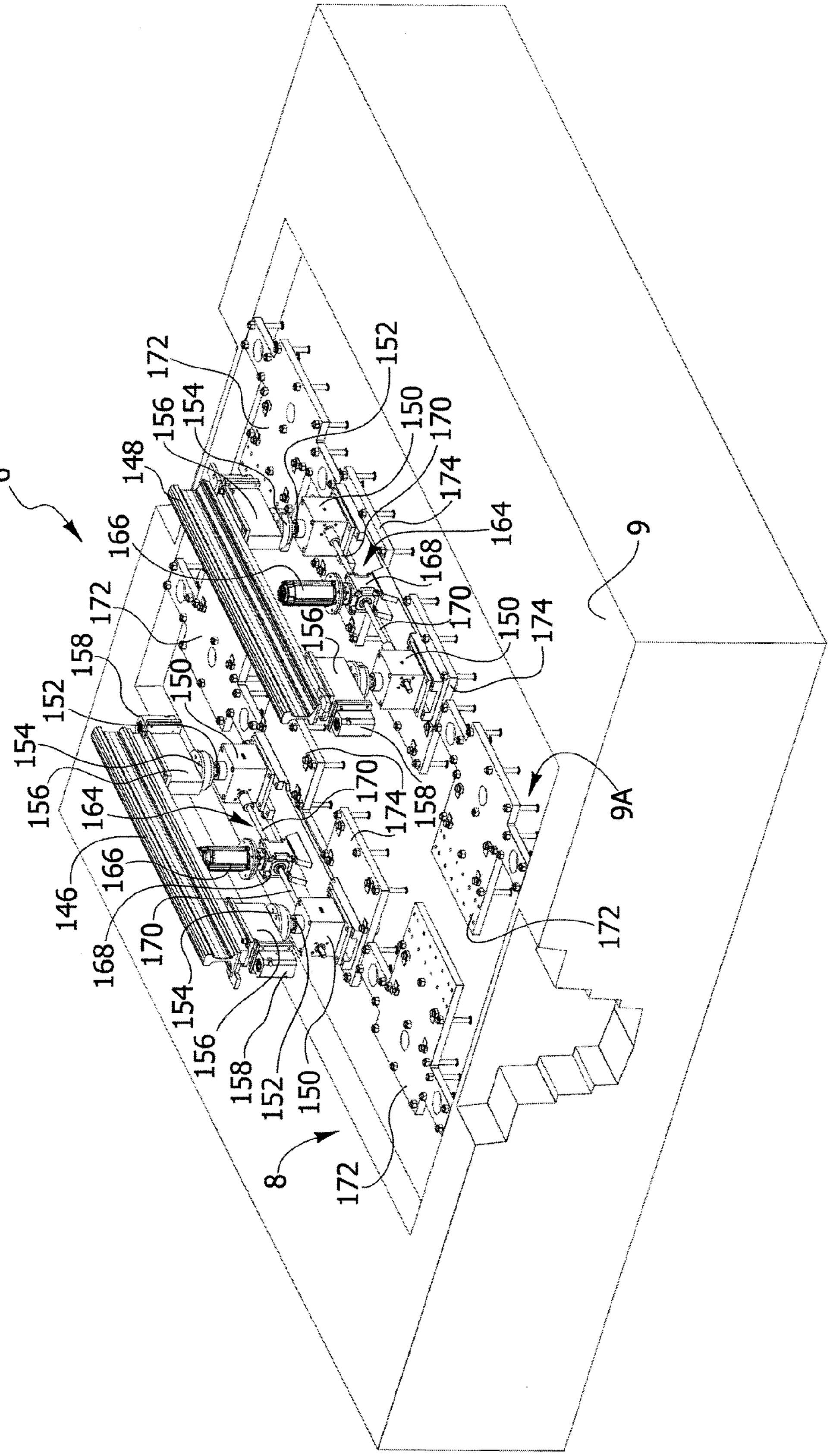

20
18
128
16
118
30
32
36
134
34
120
26
38
81
132
122
28
62
130
136
76
82
66
138
126
124
84
142
22
116

FIG. 11



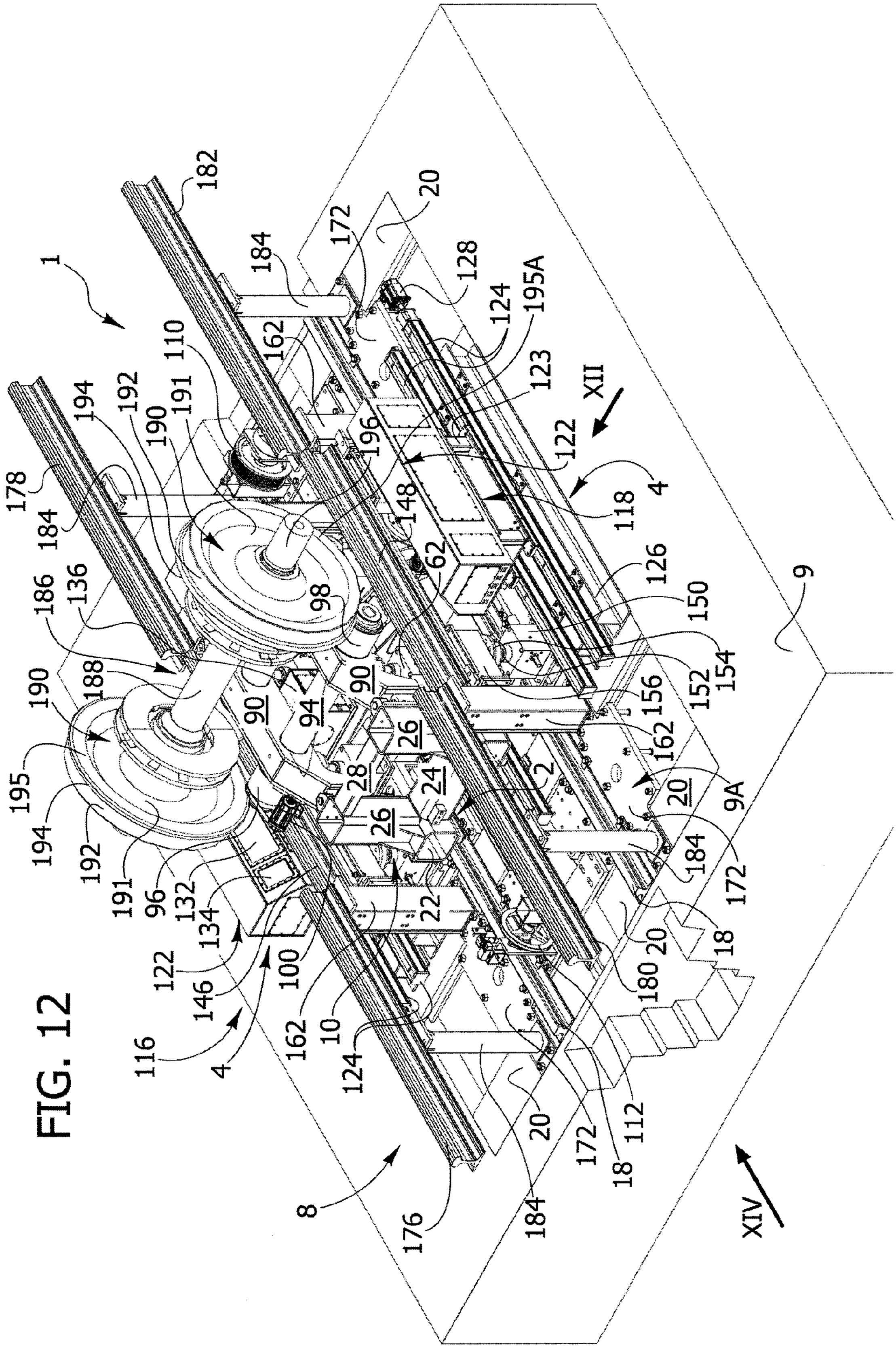

1
182
178
184
172
20
128
124
195A
110
194
192
190
191
162
196
123
XII
122
4
118
148
62
98
126
150
152
154
156
9
186
136
188
90
94
26
28
24
2
20
9A
195
96
132
134
146
116
100
22
10
18
180
112
176
8
XIV

FIG. 12

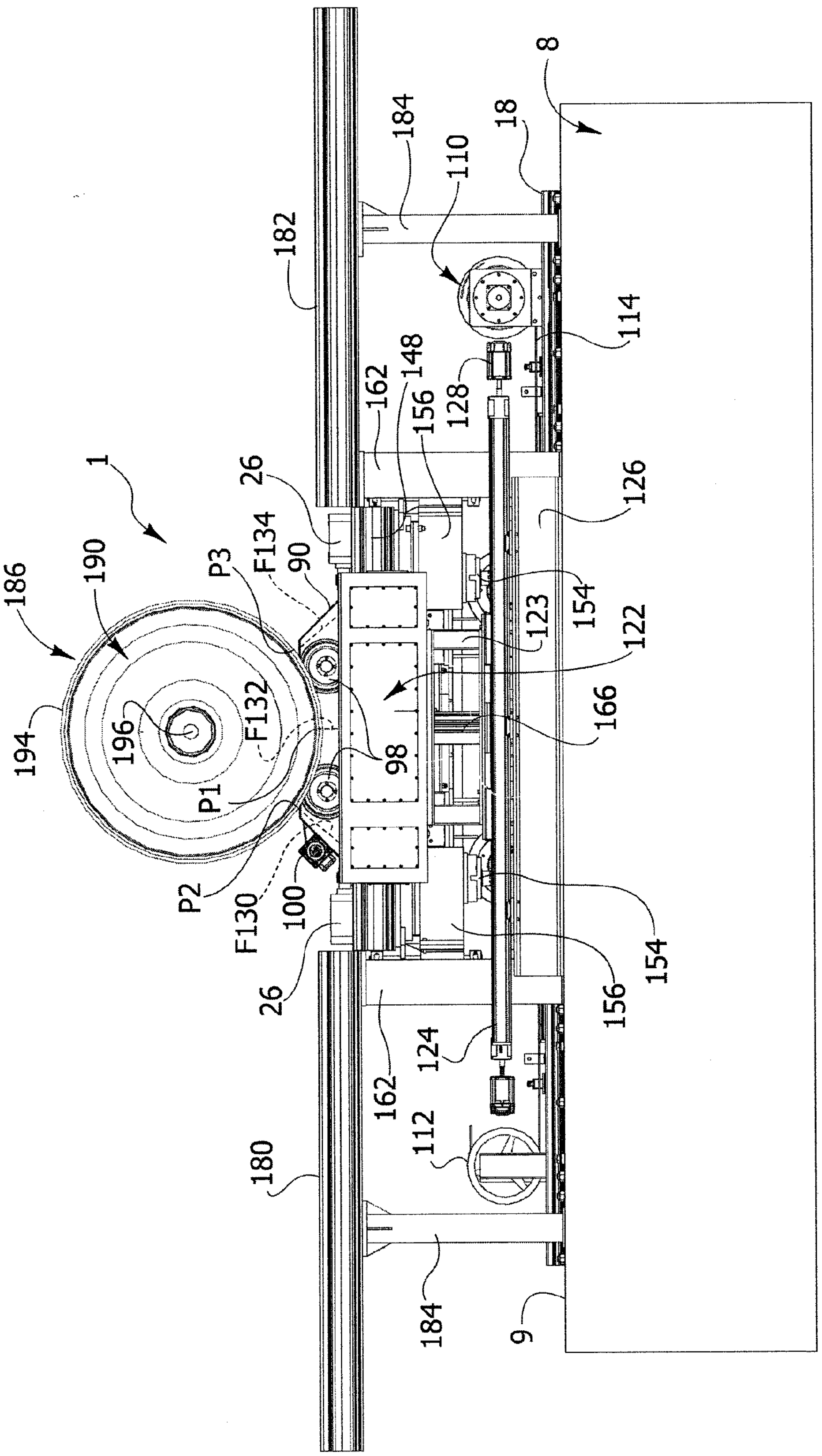

8
18
184
110
182
114
148
162
156
128
1
26
126
F134
P3
90
154
123
122
186
190
166
F132
196
194
98
P1
P2
F130
100
156
154
26
124
162
112
180
184
9

FIG. 12A

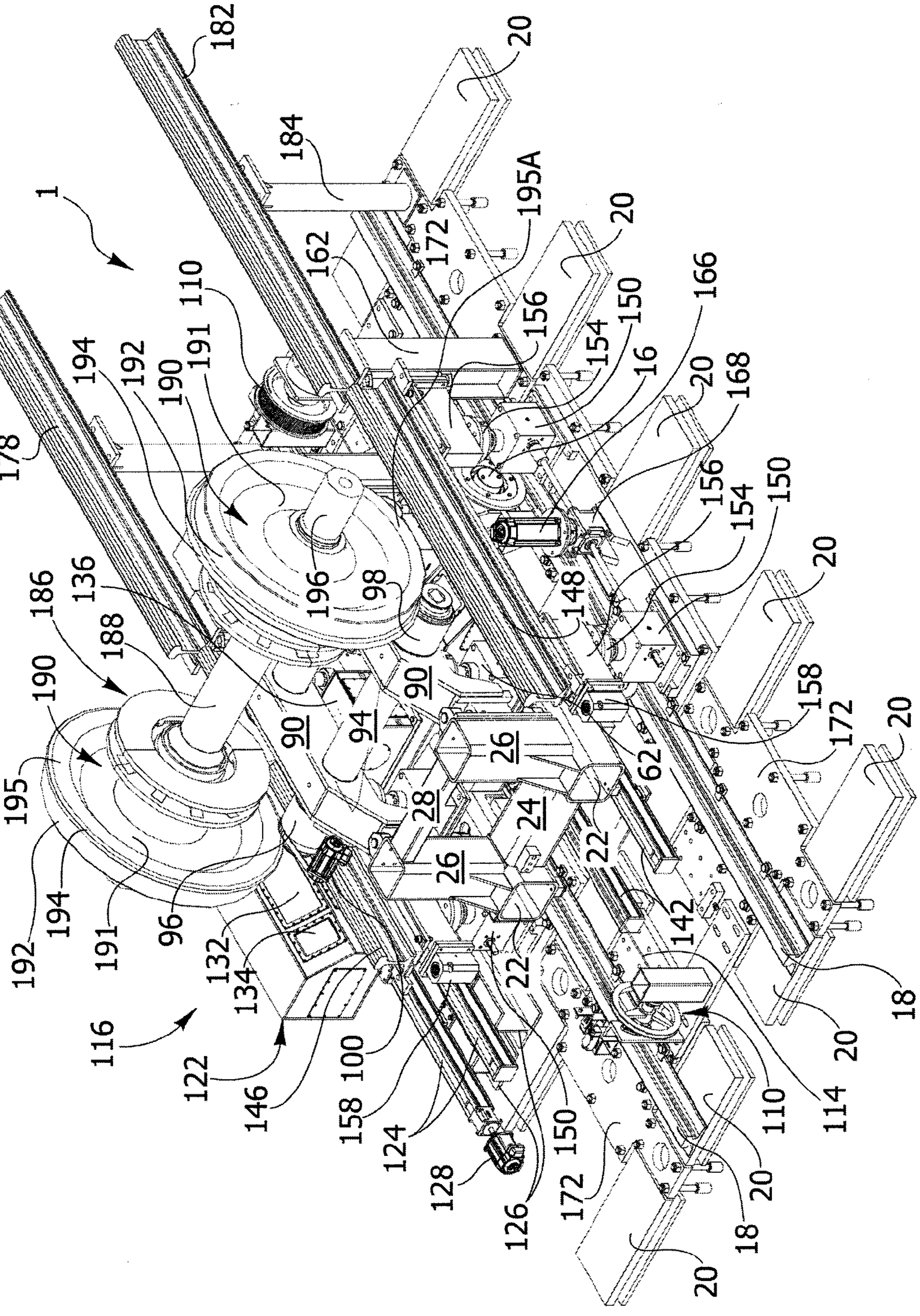


FIG. 13

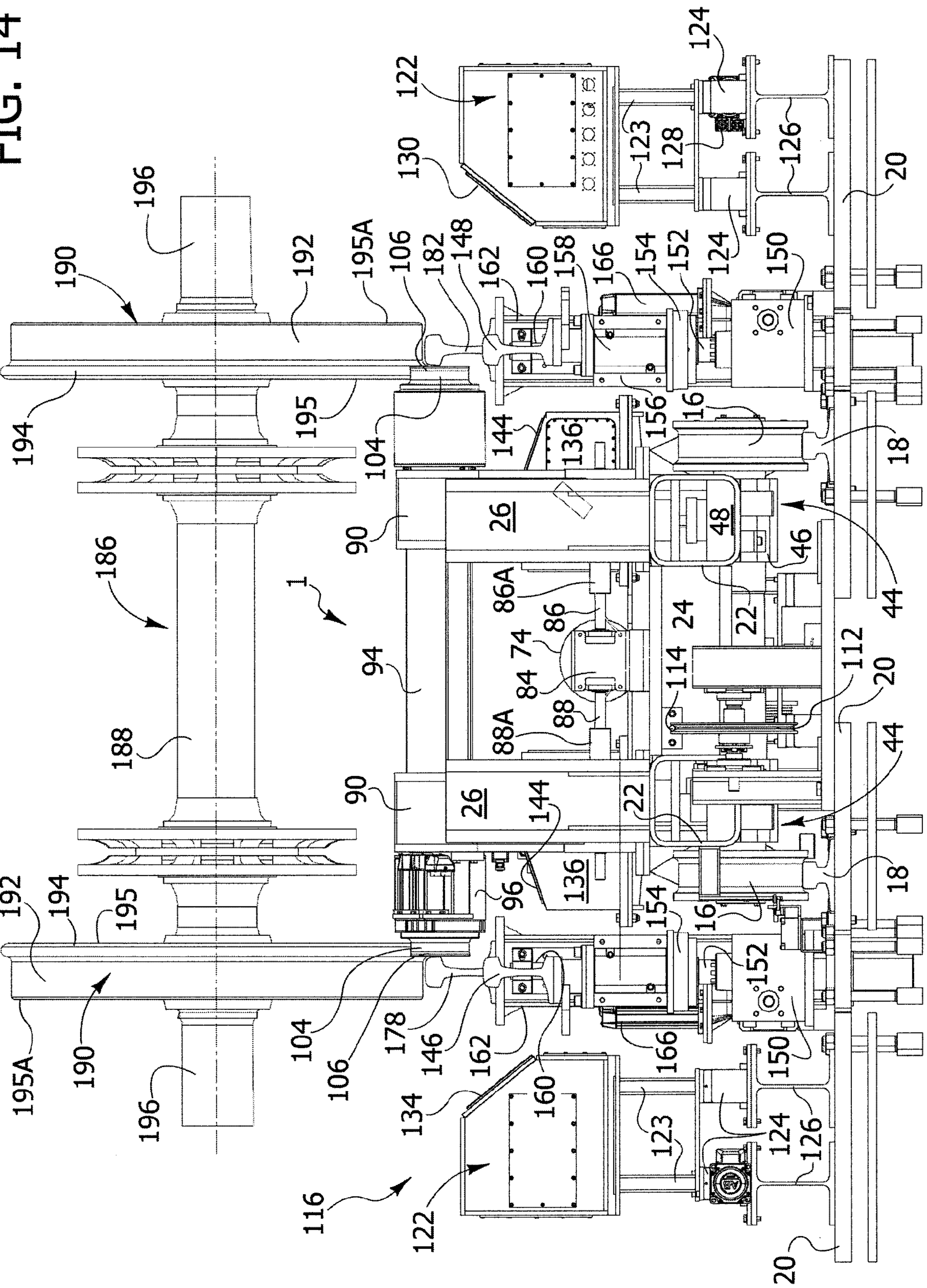

196
190
192
195A
106
182
148
162
160
158
166
154
152
124
150
122
130
123
128
126
20
194
195
104
144
136
156
16
18
90
26
48
46
44
186
1
86A
86
74
84
88A
88
94
114
112
22
24
188
96
178
146
134
116

FIG. 14

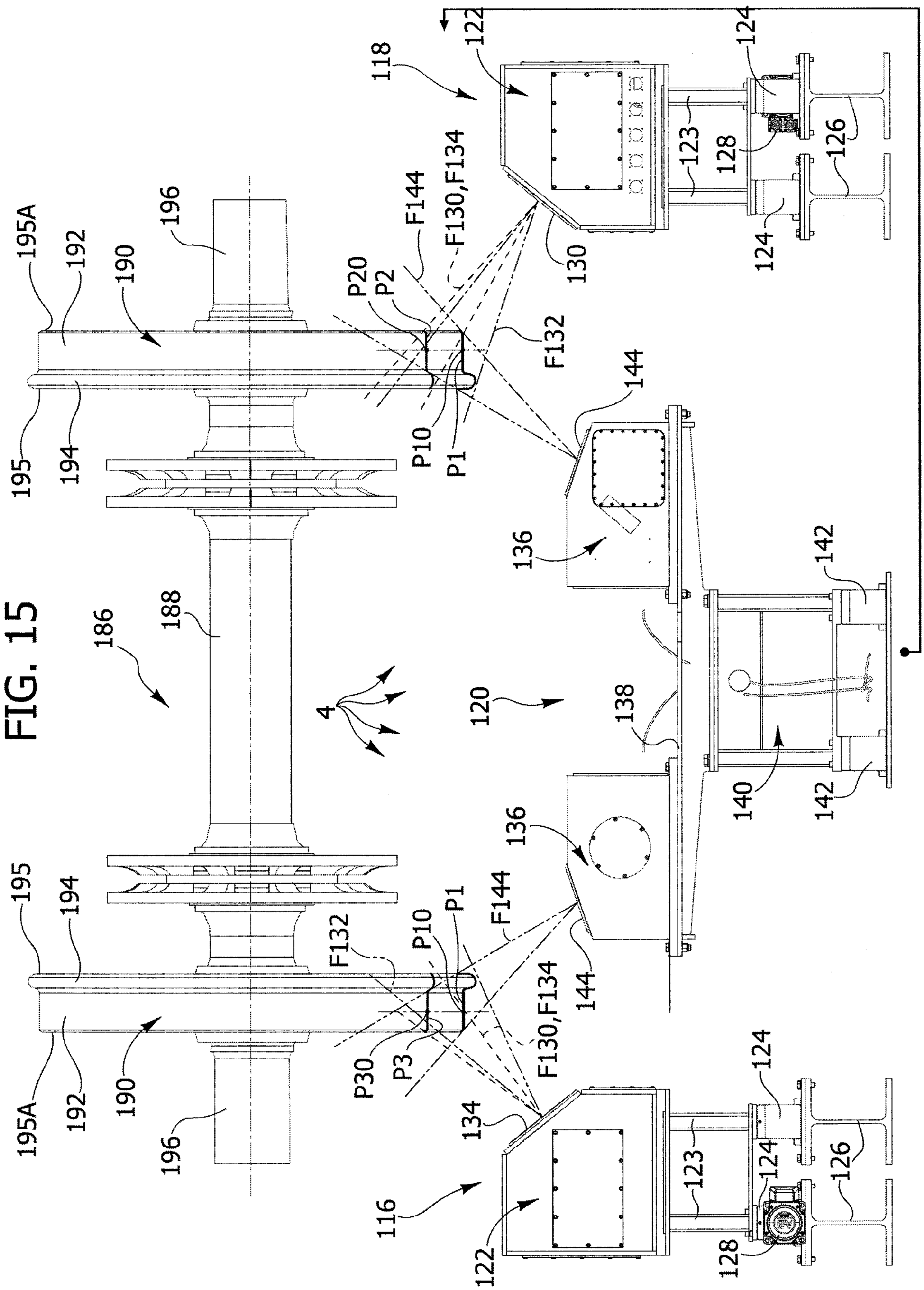

118
122
124
123
128
126
124
130
F144
F130,F134
P20
P2
F132
144
P10
P1
195A
192
190
196
195
194
188
186
4
120
136
138
140
142
F132
P10
P1
F144
F130,F134
P30
P3
134
116
122
123
124
128
126

FIG. 15

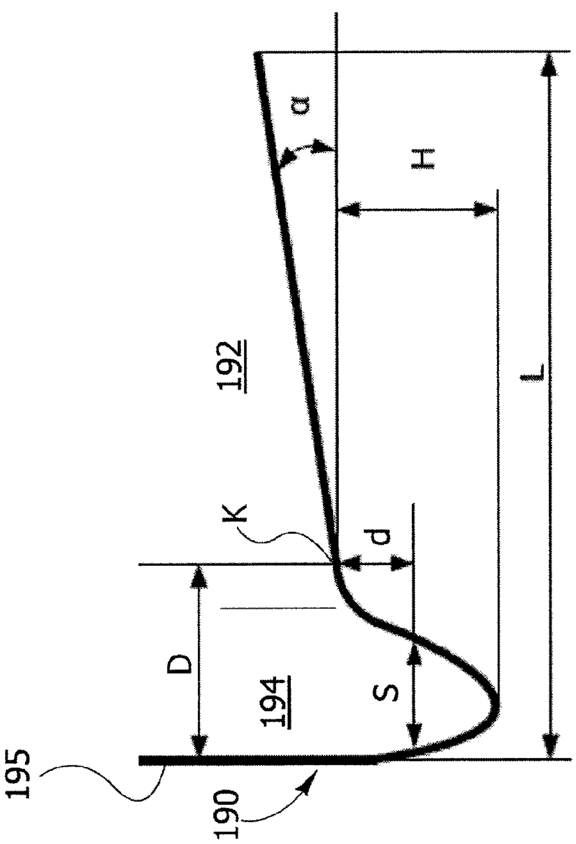


FIG. 16

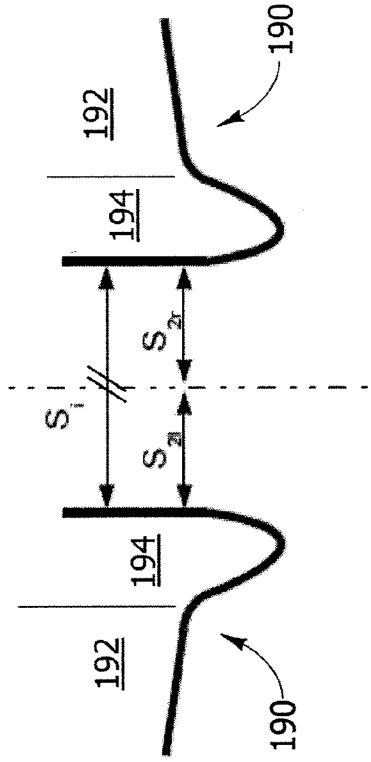
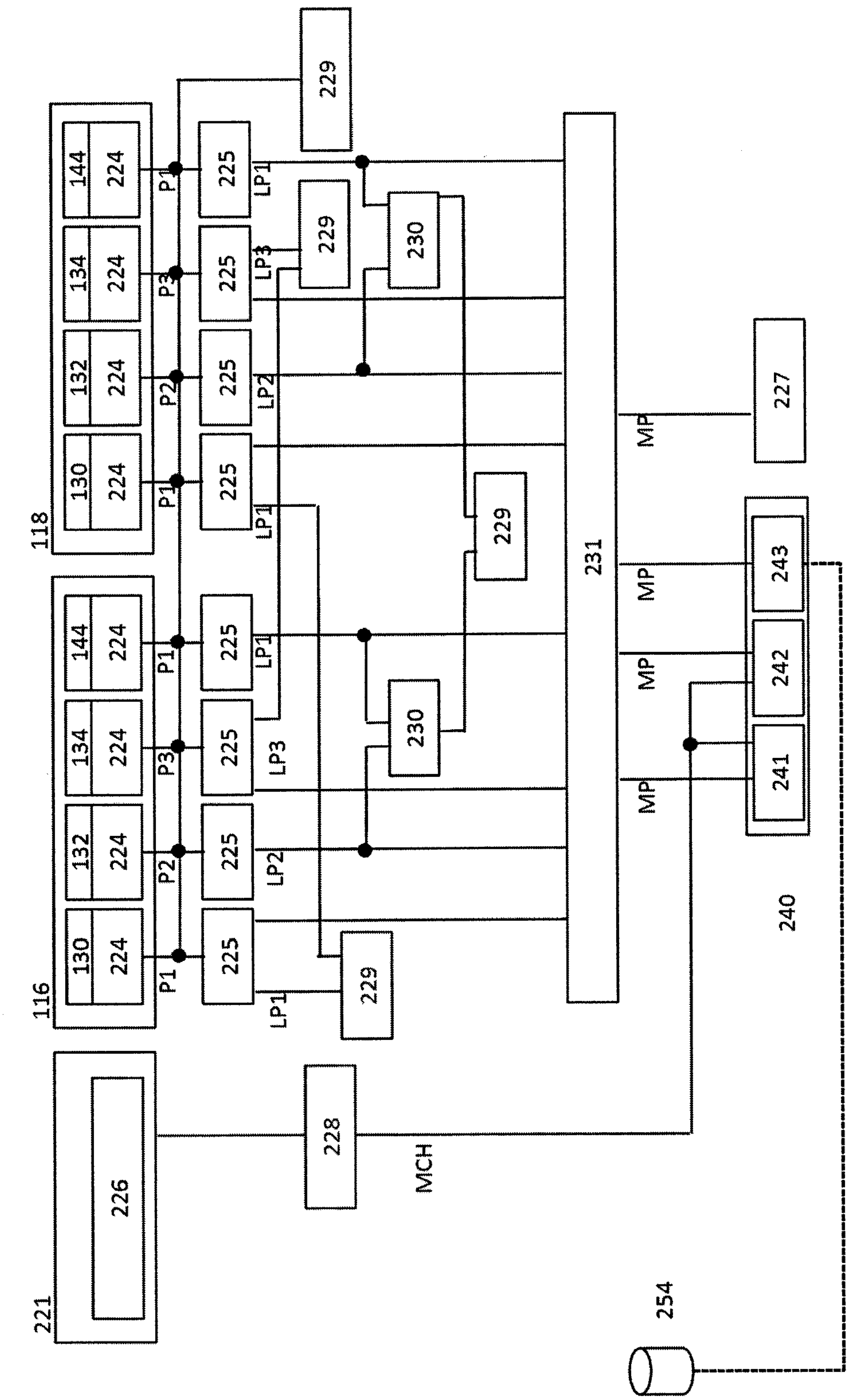


FIG. 17

FIG. 18


118
116
221
130
132
134
144
224
225
226
227
228
229
230
231
240
241
242
243
254
P1
P2
P3
LP1
LP2
LP3
MP
MCH

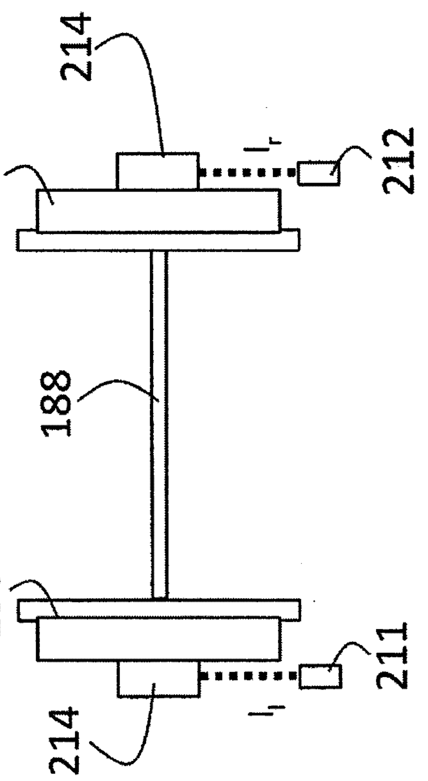


FIG. 19

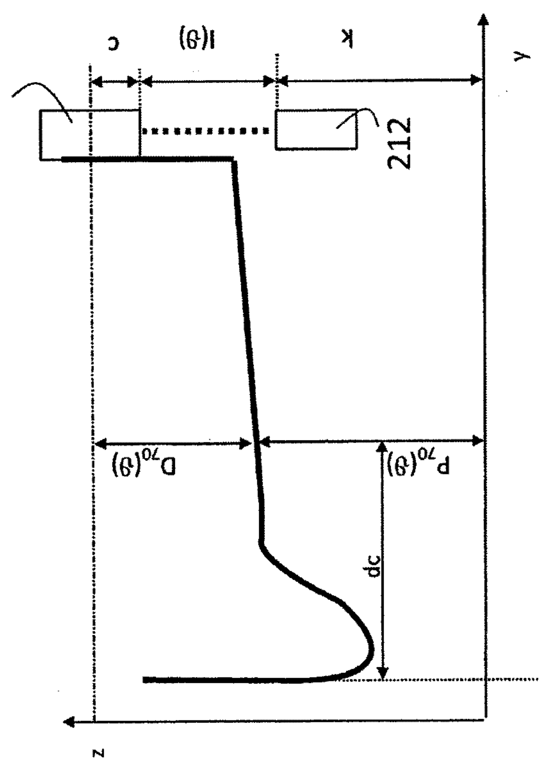


FIG. 20

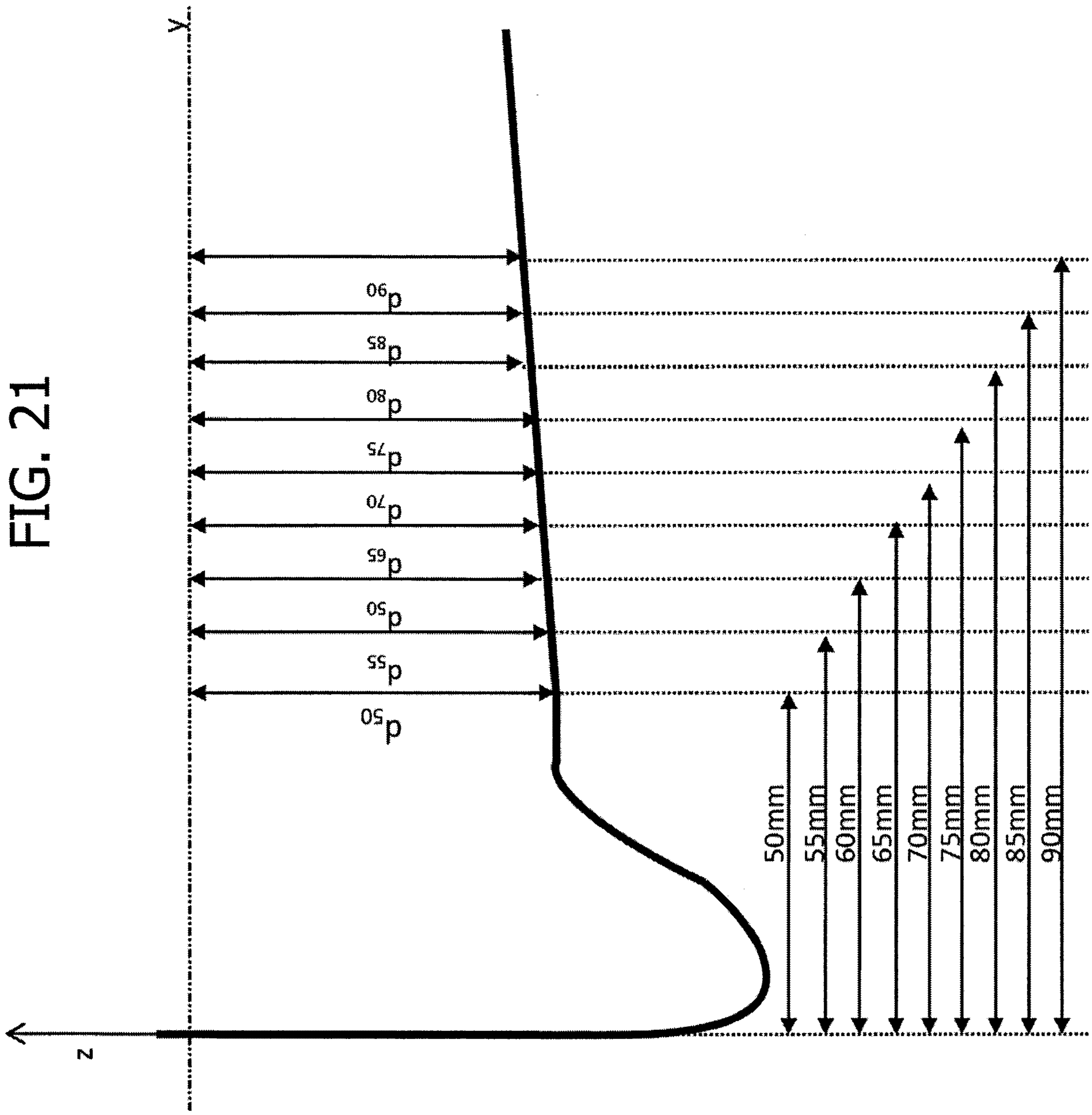

y
z
d90
d85
d80
d75
d70
d65
d50
d55
d50
50mm
55mm
60mm
65mm
70mm
75mm
80mm
85mm
90mm

FIG. 21

FIG. 22

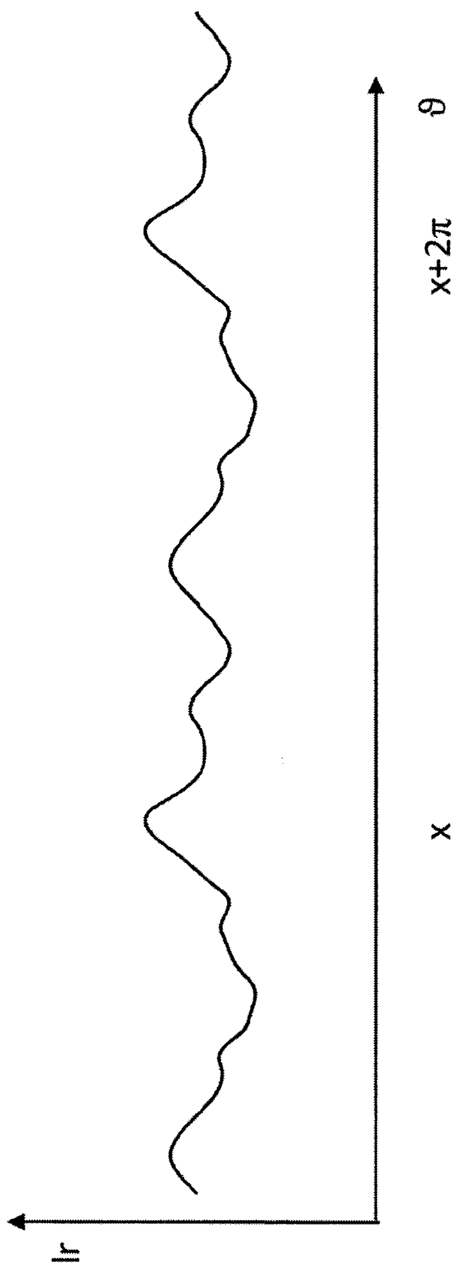


FIG. 23

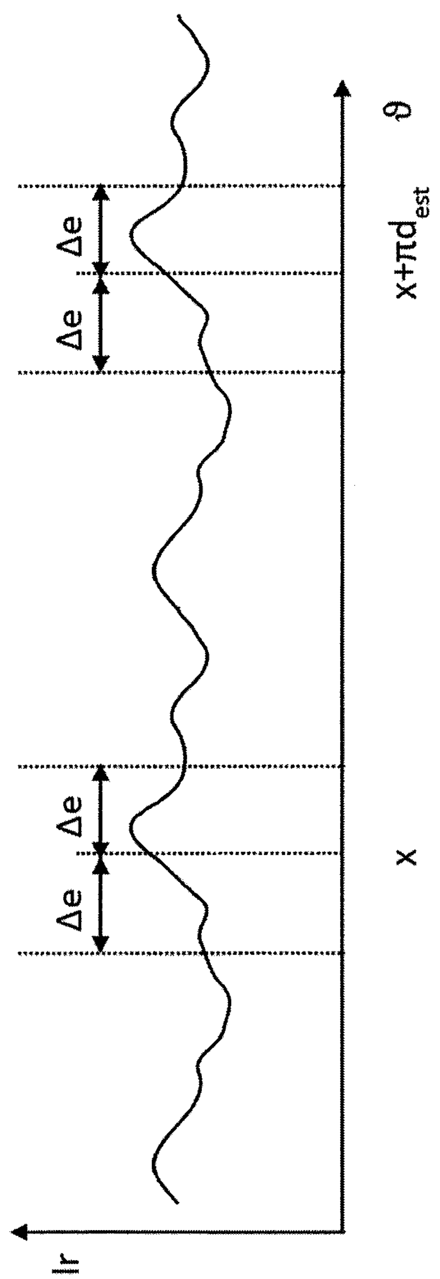
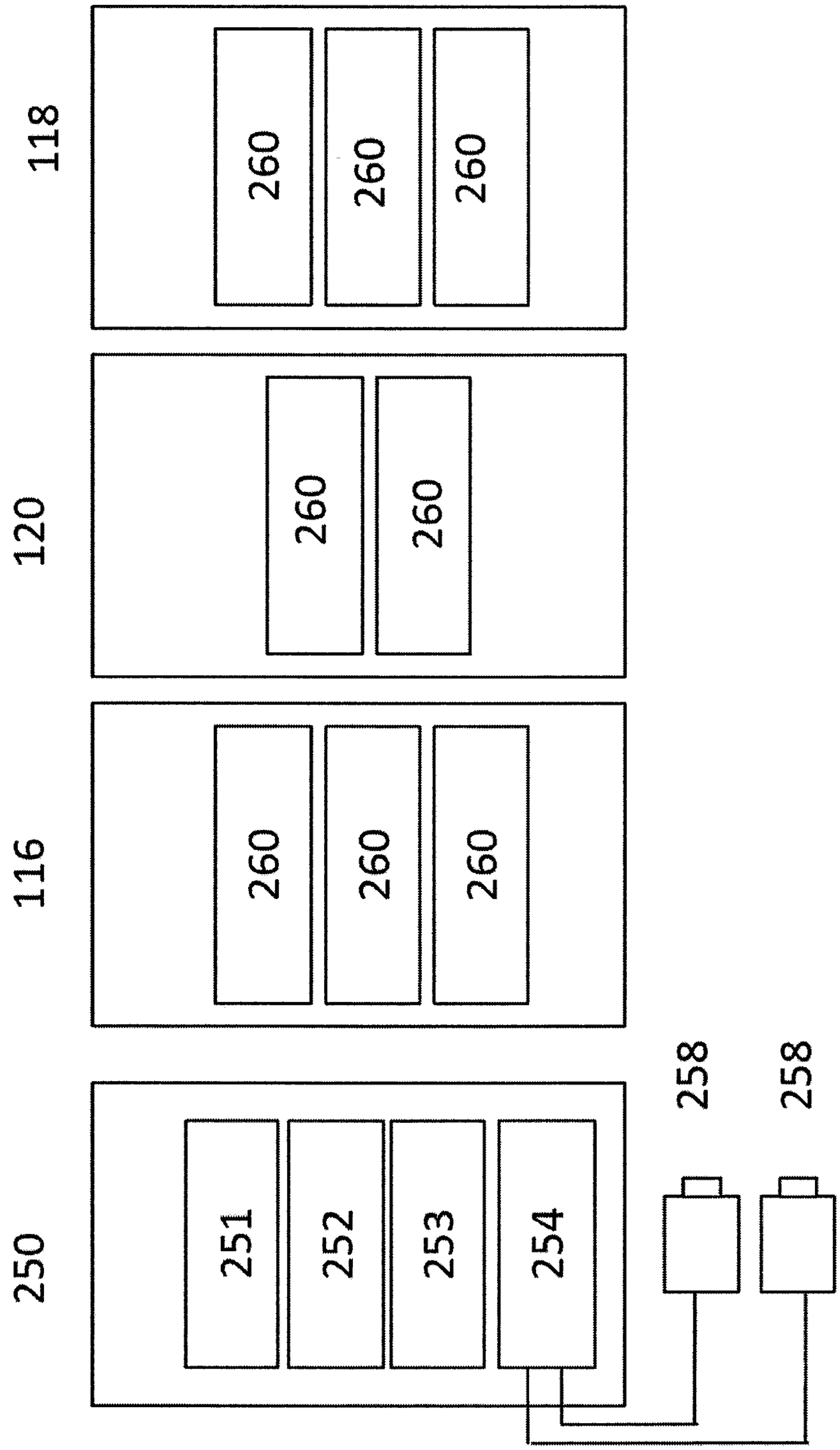


FIG. 24


118
260
260
260
120
260
260
116
260
260
260
250
251
252
253
254
258
258

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 16 8855

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	DE 17 28 624 U (DB BUNDESBAHN ZENTRALAMT [DE]) 23 August 1956 (1956-08-23) * claim 4; figures 1,2 *	16 1-15	INV. B61K9/12
Y	US 2003/160193 A1 (SANCHEZ REVUELTA ANGEL LUIS [ES] ET AL) 28 August 2003 (2003-08-28) * paragraph [0024]; figure 3 *	1-15	
A	DE 103 52 166 B3 (DB CARGO AG [DE]; ZILA ELEKTRONIK GMBH [DE]) 21 April 2005 (2005-04-21) * figure 1 *	1	
A	DE 103 36 042 A1 (WINDHOFF BAHN UND ANLAGENTECHN [DE] WINDHOFF BAHN UND ANLAGENTECHNIK G) 3 March 2005 (2005-03-03) * claim 5; figure 1 *	1	
A	DE 14 73 850 A1 (ERNAULT SOMUA H) 28 November 1968 (1968-11-28) * figure 1 *	1	TECHNICAL FIELDS SEARCHED (IPC) B61K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	30 November 2011	Lorandi, Lorenzo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

2

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 16 8855

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

30-11-2011

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
DE 1728624	U	23-08-1956	NONE			
US 2003160193	A1	28-08-2003	EP	1348931	A2	01-10-2003
			ES	2208055	A1	01-06-2004
			JP	2003254731	A	10-09-2003
			US	2003160193	A1	28-08-2003
DE 10352166	B3	21-04-2005	NONE			
DE 10336042	A1	03-03-2005	NONE			
DE 1473850	A1	28-11-1968	BE	631942	A	30-11-2011
			DE	1473850	A1	28-11-1968
			FR	1295442	A	08-06-1962
			GB	996009	A	23-06-1965
			US	3221412	A	07-12-1965

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82