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Slezak et al.

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(54) **DIGITAL CREEL SYSTEM**

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(73) Assignee: **RJS CORPORATION**, Akron, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/754,913**

(22) PCT Filed: **Oct. 19, 2020**

(86) PCT No.: **PCT/US2020/056331**

§ 371 (c)(1),
(2) Date: **Apr. 15, 2022**

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PCT Pub. Date: **Apr. 22, 2021**

(65) **Prior Publication Data**

US 2024/0125014 A1 Apr. 18, 2024

Related U.S. Application Data

(60) Provisional application No. 62/916,375, filed on Oct. 17, 2019.

(51) **Int. Cl.**

D02H 1/00	(2006.01)
B65H 49/26	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***D02H 1/00*** (2013.01); ***B65H 49/26*** (2013.01); ***B65H 49/32*** (2013.01); ***B65H 59/04*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC B65H 49/20; B65H 49/26; B65H 49/32; B65H 49/34; B65H 59/02; B65H 59/04;

(Continued)

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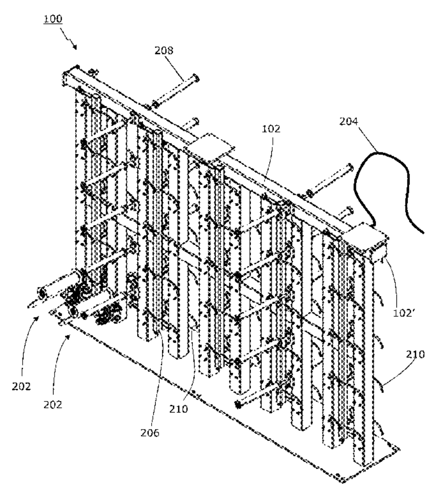
Assistant Examiner — Raveen J Dias
(74) *Attorney, Agent, or Firm* — Vorys, Sater, Seymour and Pease LLP; Rex W. Miller, II

(57) **ABSTRACT**

A creel system includes a plurality of tension controller apparatuses that hold spools of wire. The tension controller apparatuses apply tension to the wire and may be manipulated to fine-tune or control the tension applied to the wire. The creel system may further include a plurality of sensors

(Continued)



that measure operation of the creel system as well as the condition of the wire. In such embodiments, the creel system may include a user-interface that provides data to the operator in real time and with which the operator may interact to control operation of the creel system.

11 Claims, 30 Drawing Sheets

(51) **Int. Cl.**
B65H 49/32 (2006.01)
B65H 59/04 (2006.01)
B65H 59/26 (2006.01)
B65H 59/38 (2006.01)
B65H 63/024 (2006.01)
B65H 63/04 (2006.01)
D02H 13/24 (2006.01)

(52) **U.S. Cl.**
CPC ***B65H 59/26*** (2013.01); ***B65H 59/381*** (2013.01); ***B65H 63/024*** (2013.01); ***B65H 63/04*** (2013.01); ***D02H 13/24*** (2013.01)

(58) **Field of Classification Search**
CPC B65H 59/043; B65H 59/38; B65H 59/381; B65H 59/382; B65H 59/40; B65H 59/12; B65H 59/24; B65H 59/26; B65H 59/30; B65H 59/34; B65H 59/36; B65H 63/02; B65H 63/024; B65H 63/04; D02H 1/00; D02H 13/22; D02H 13/24
See application file for complete search history.

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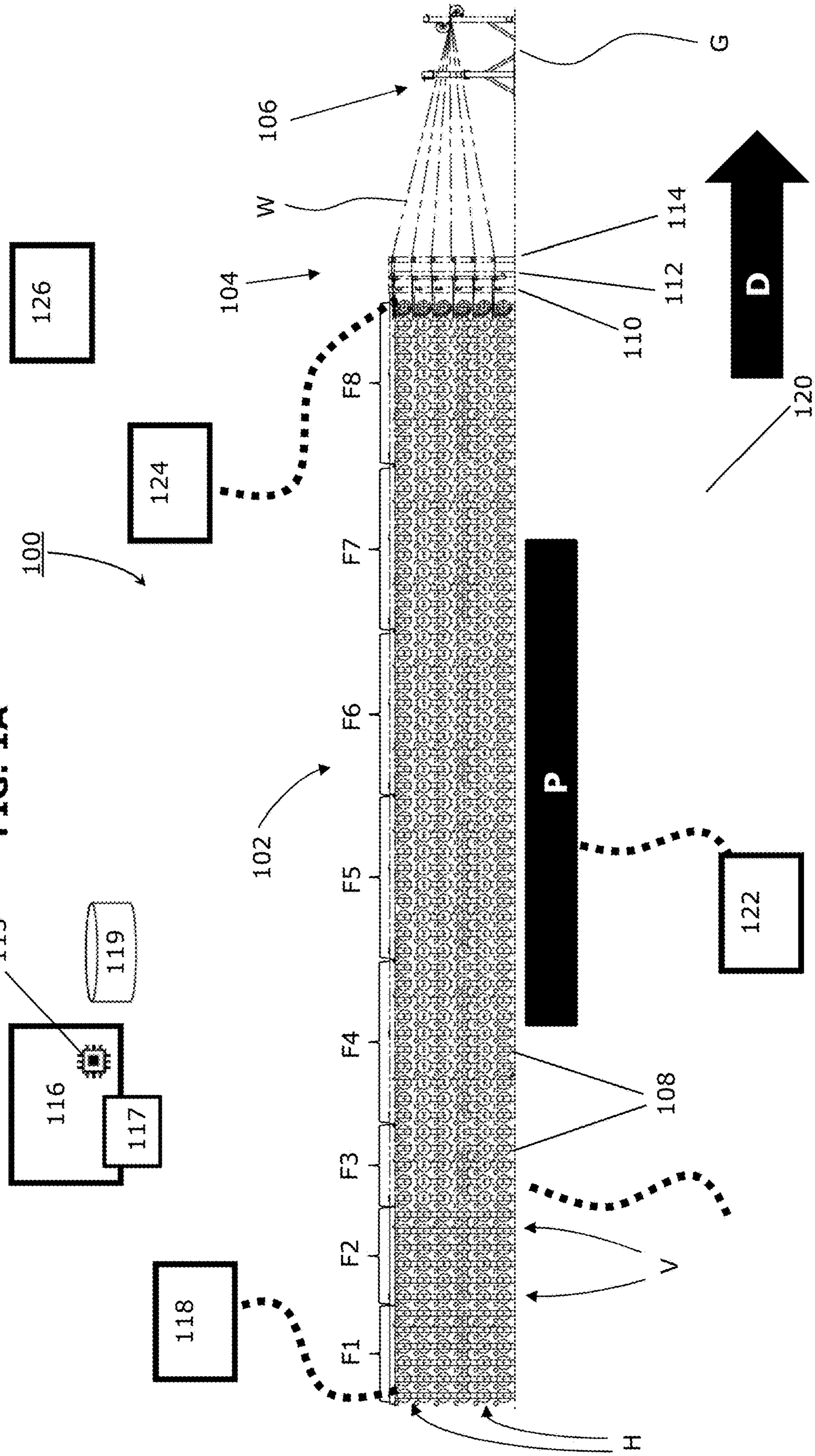

100
102
104
106
108
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112
114
115
116
117
118
119
120
122
124
126
F1
F2
F3
F4
F5
F6
F7
F8
G
W
D
P
V
H

FIG. 1A

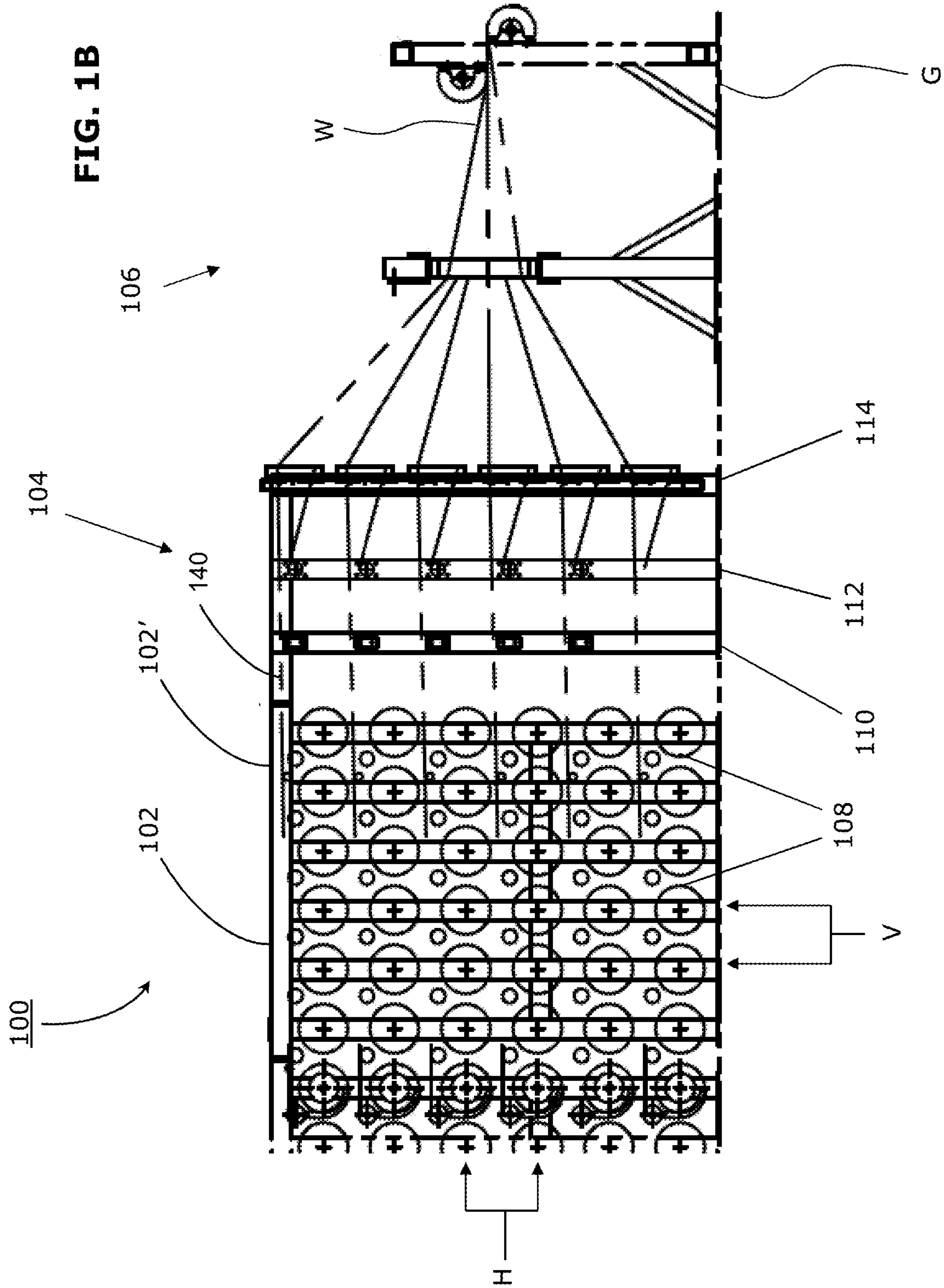
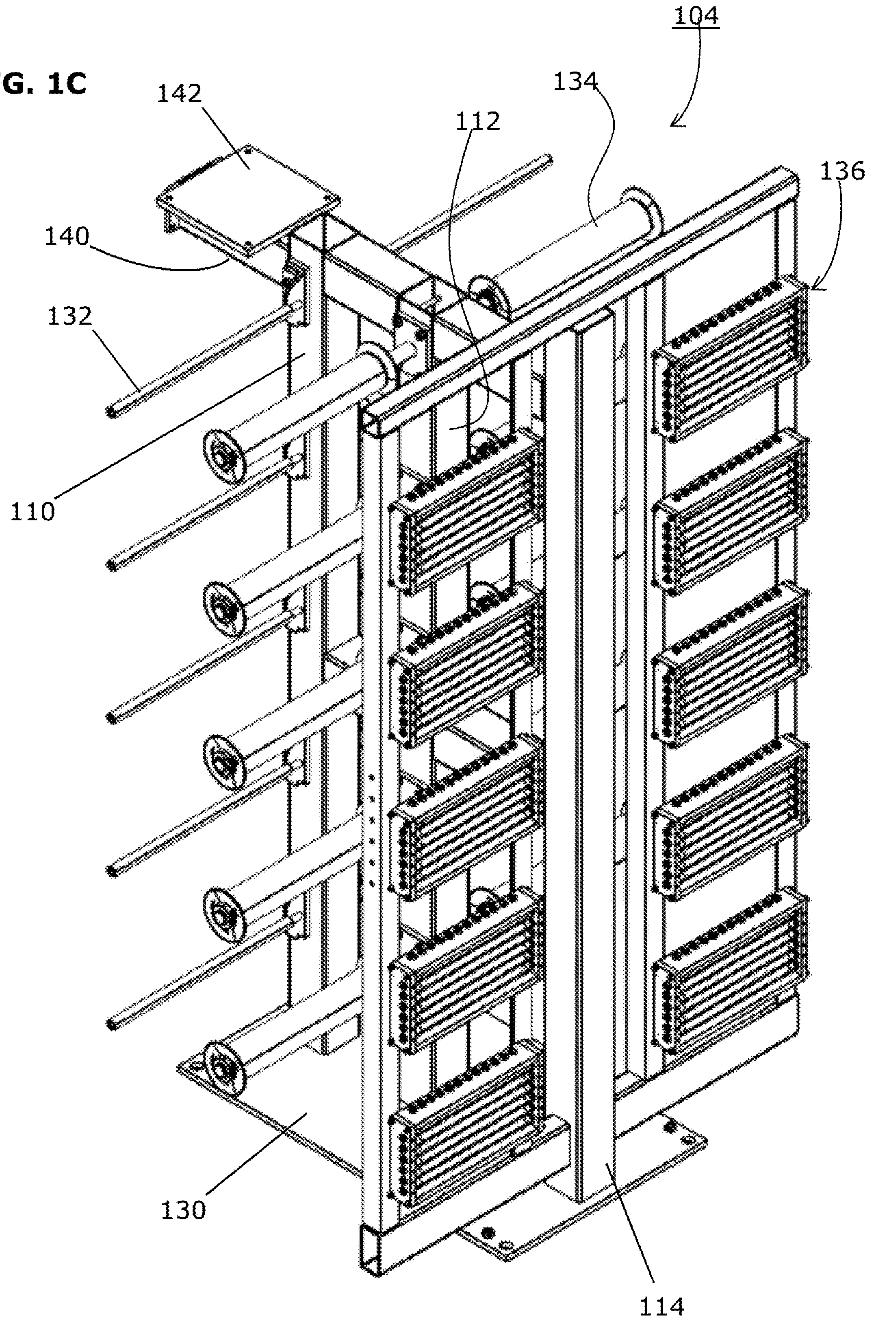


FIG. 1B

FG. 1C



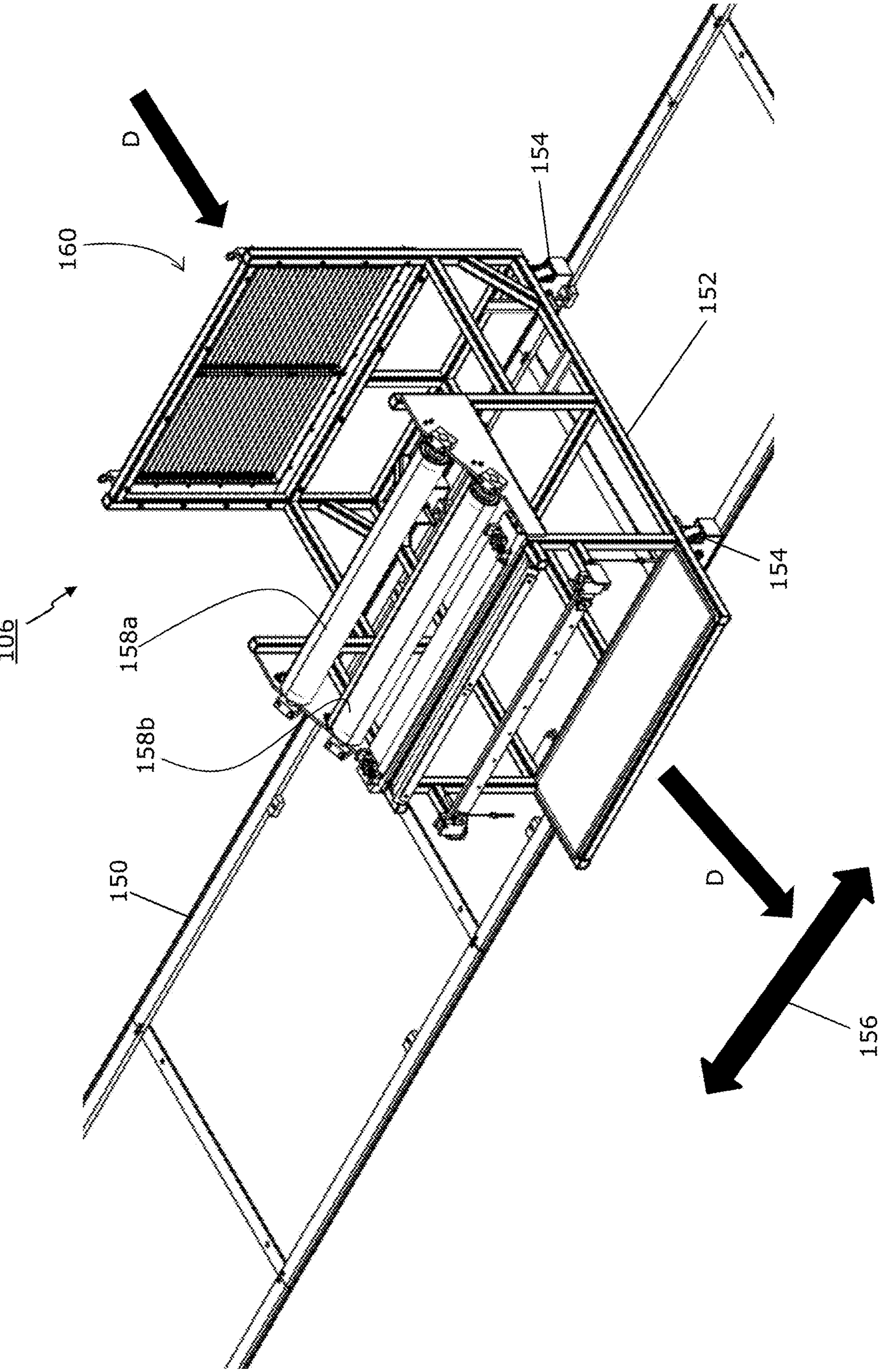


FIG. 1D

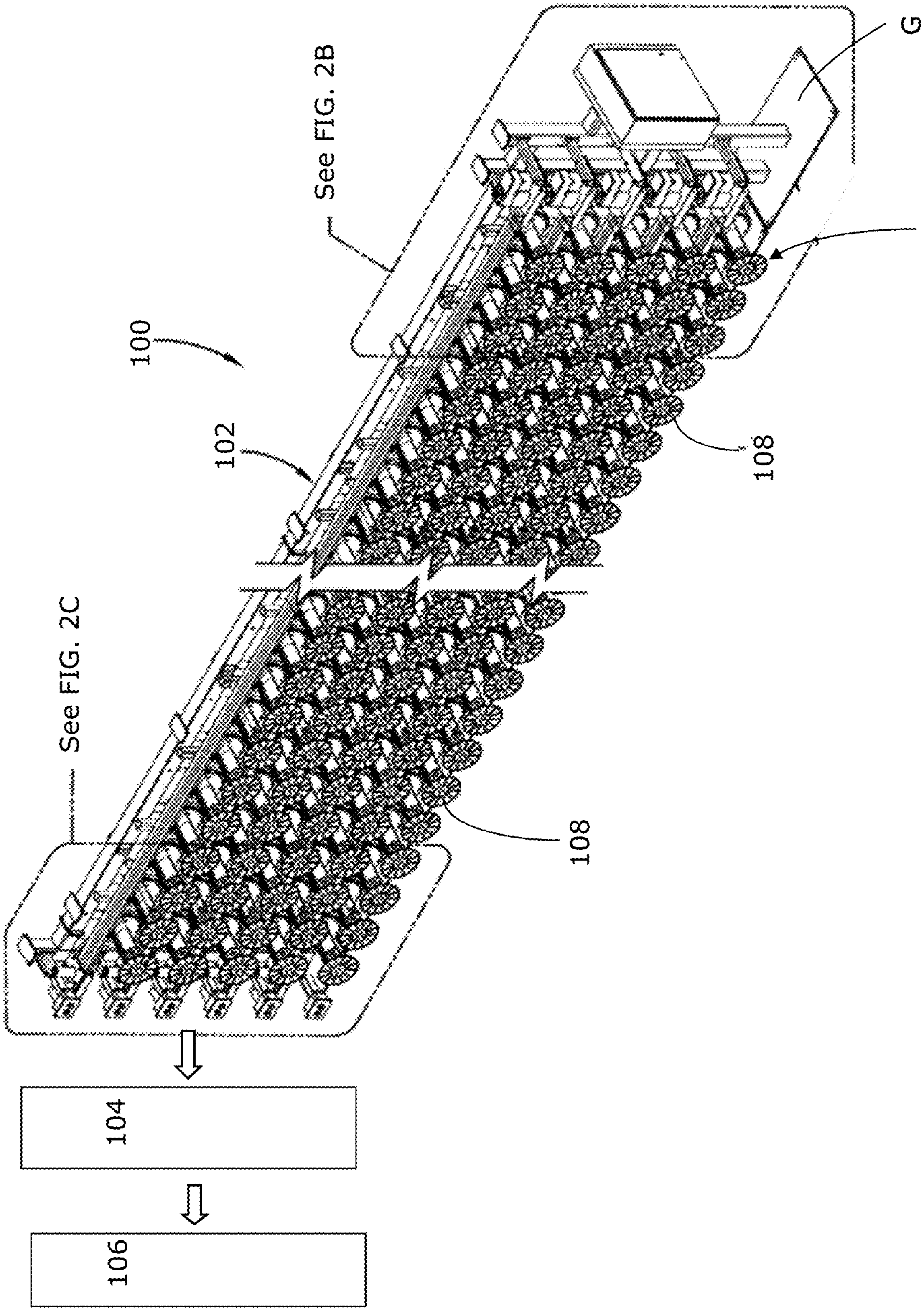


FIG. 2A

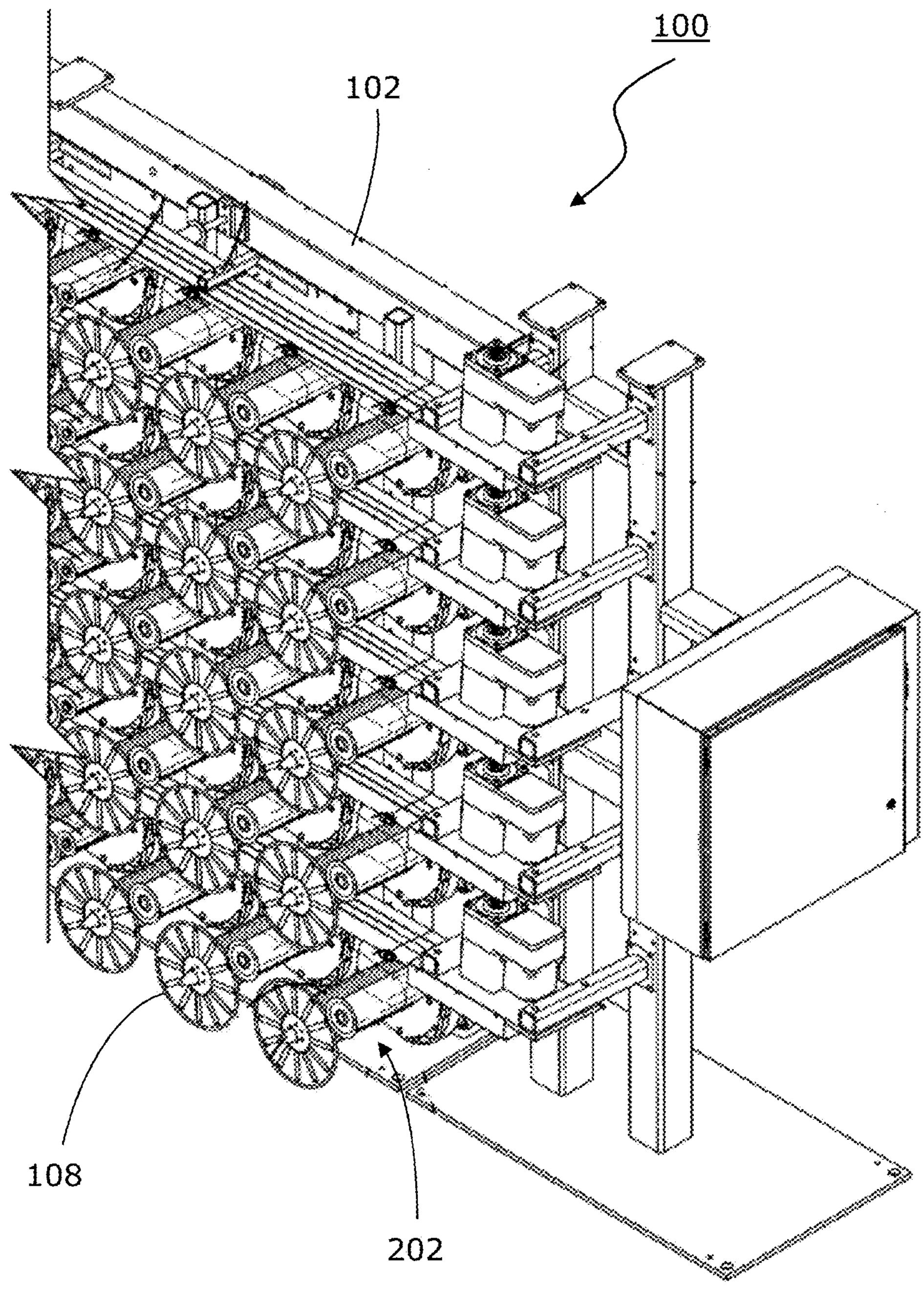


FIG. 2B

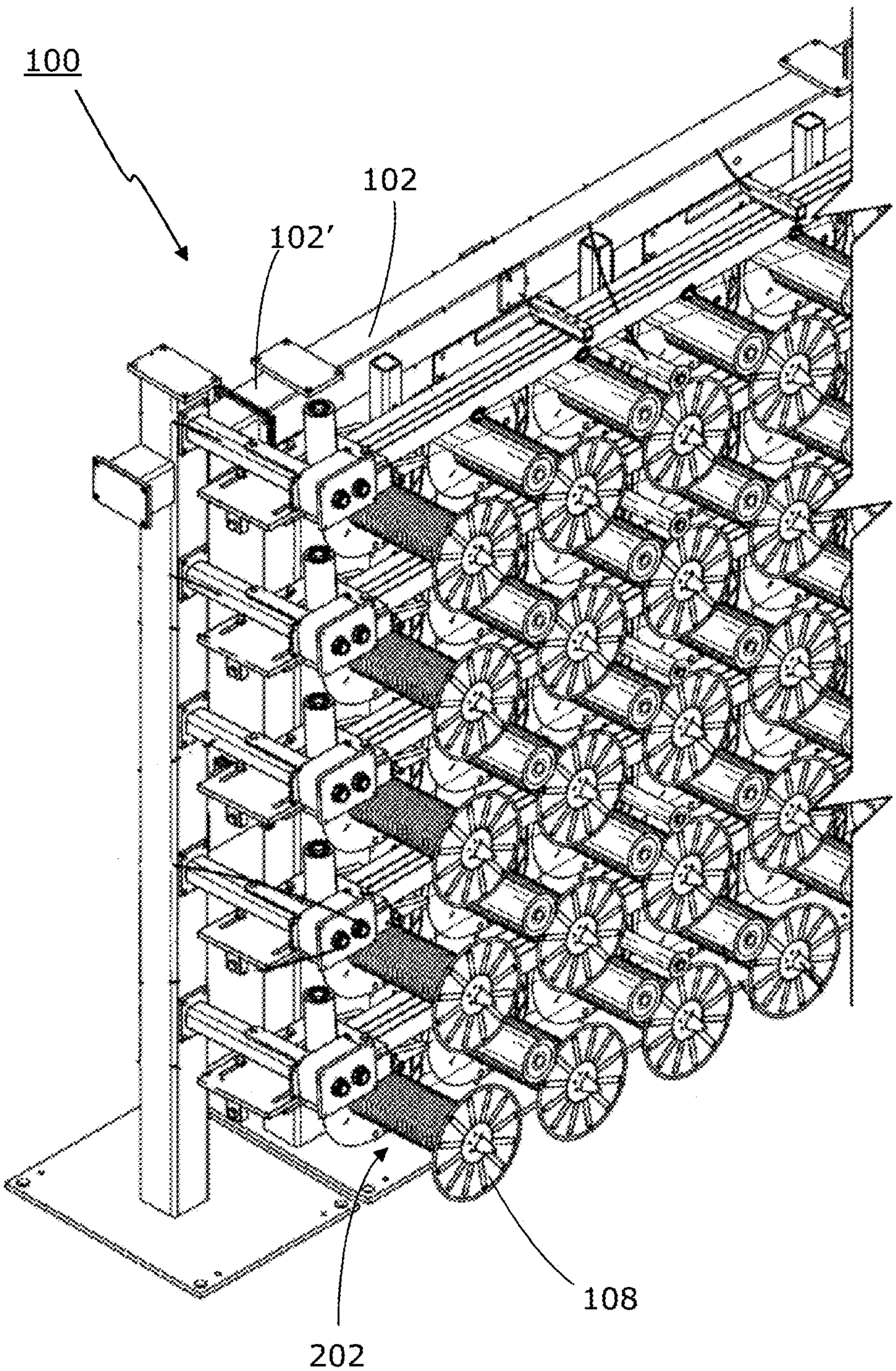
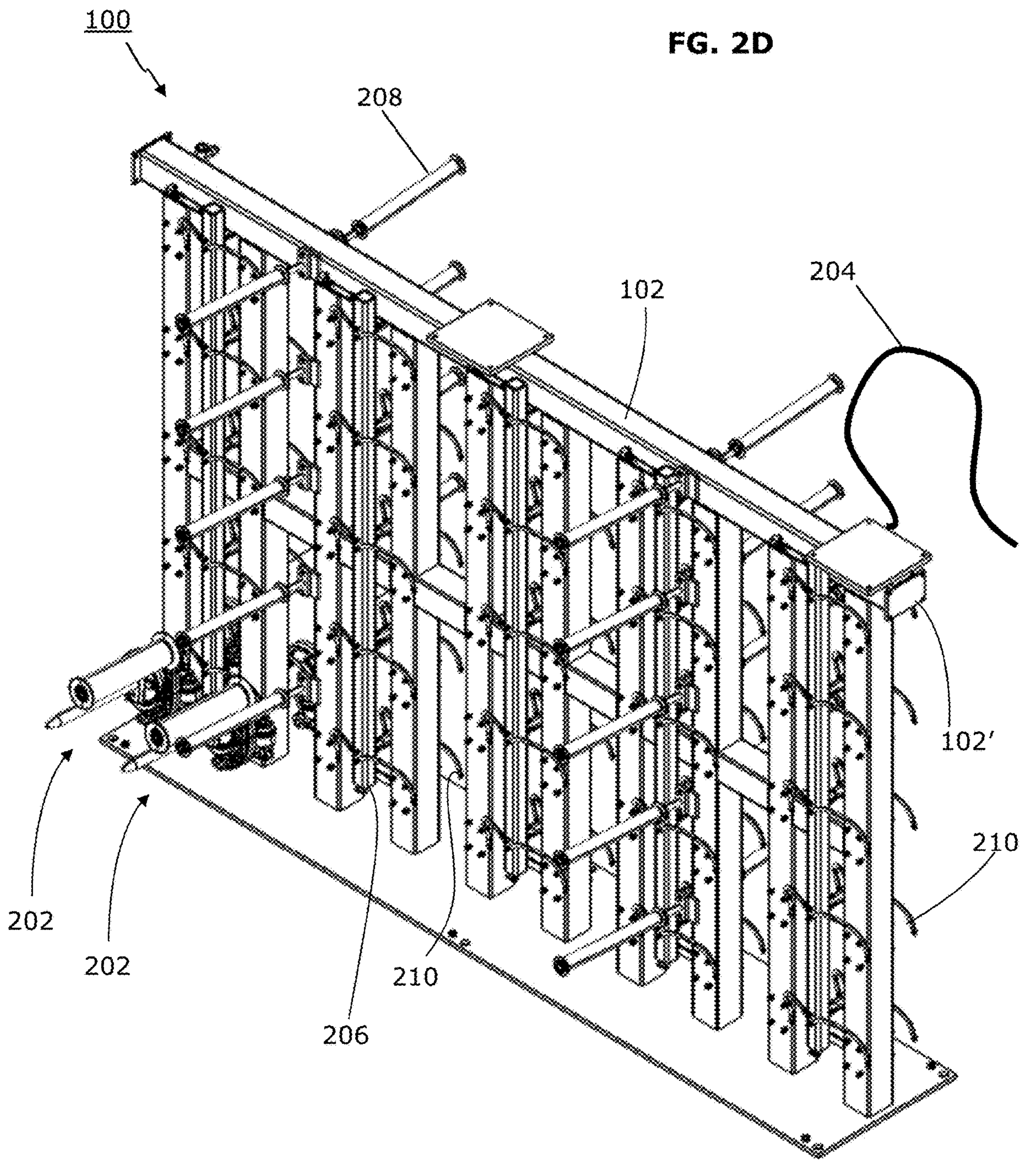


FIG. 2C

FG. 2D



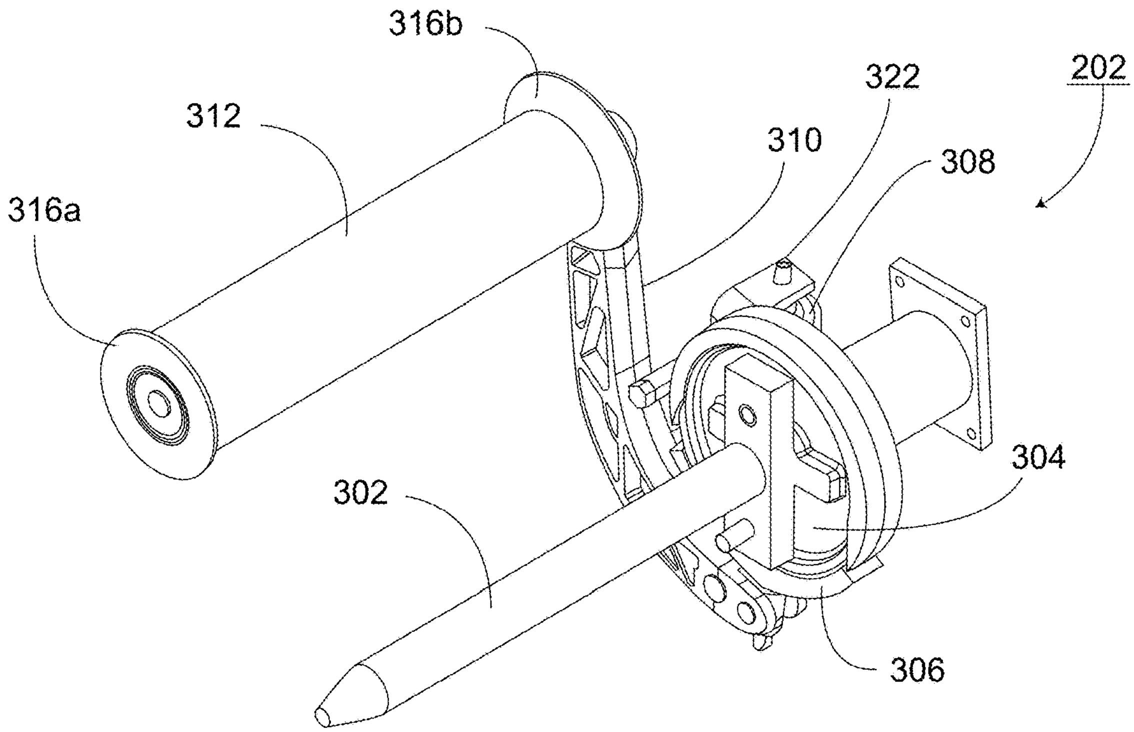
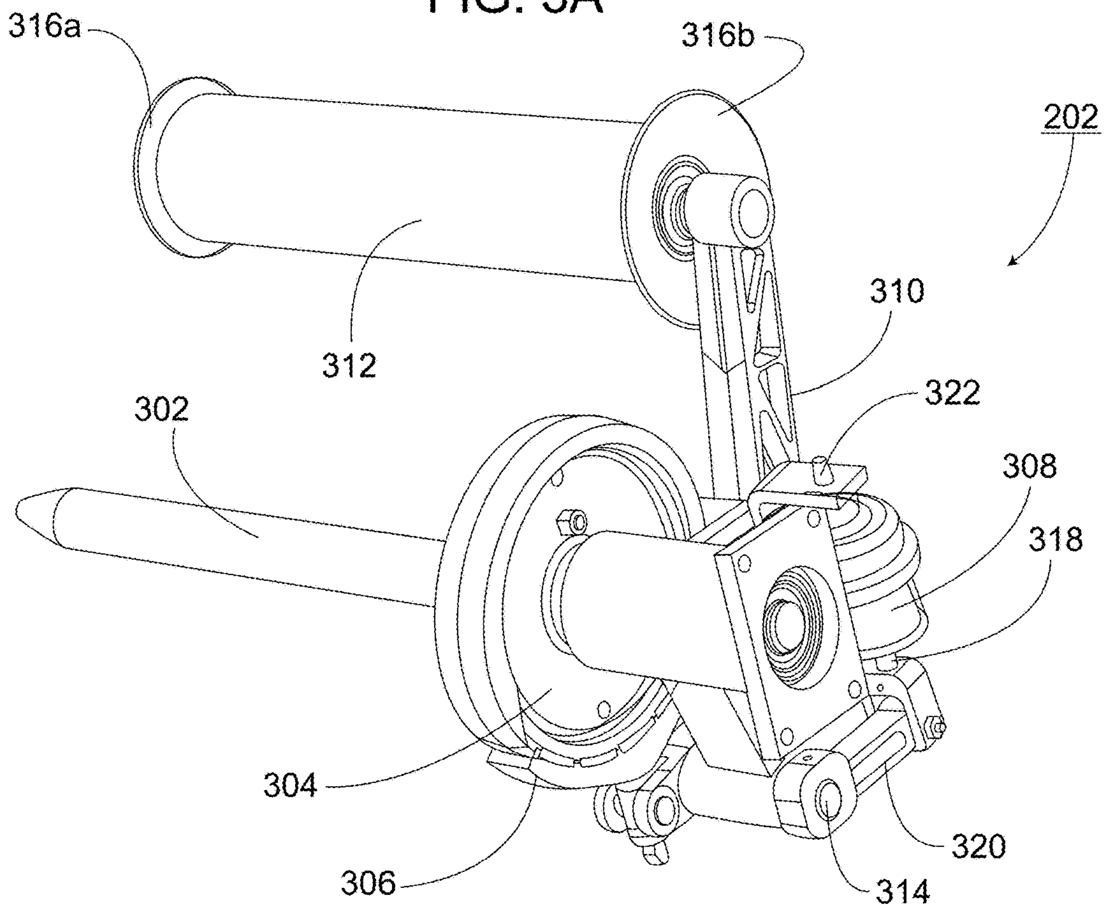

316b
322
202
312
310
308
316a
304
302
306

FIG. 3A


316a
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320
306
314

FIG. 3B

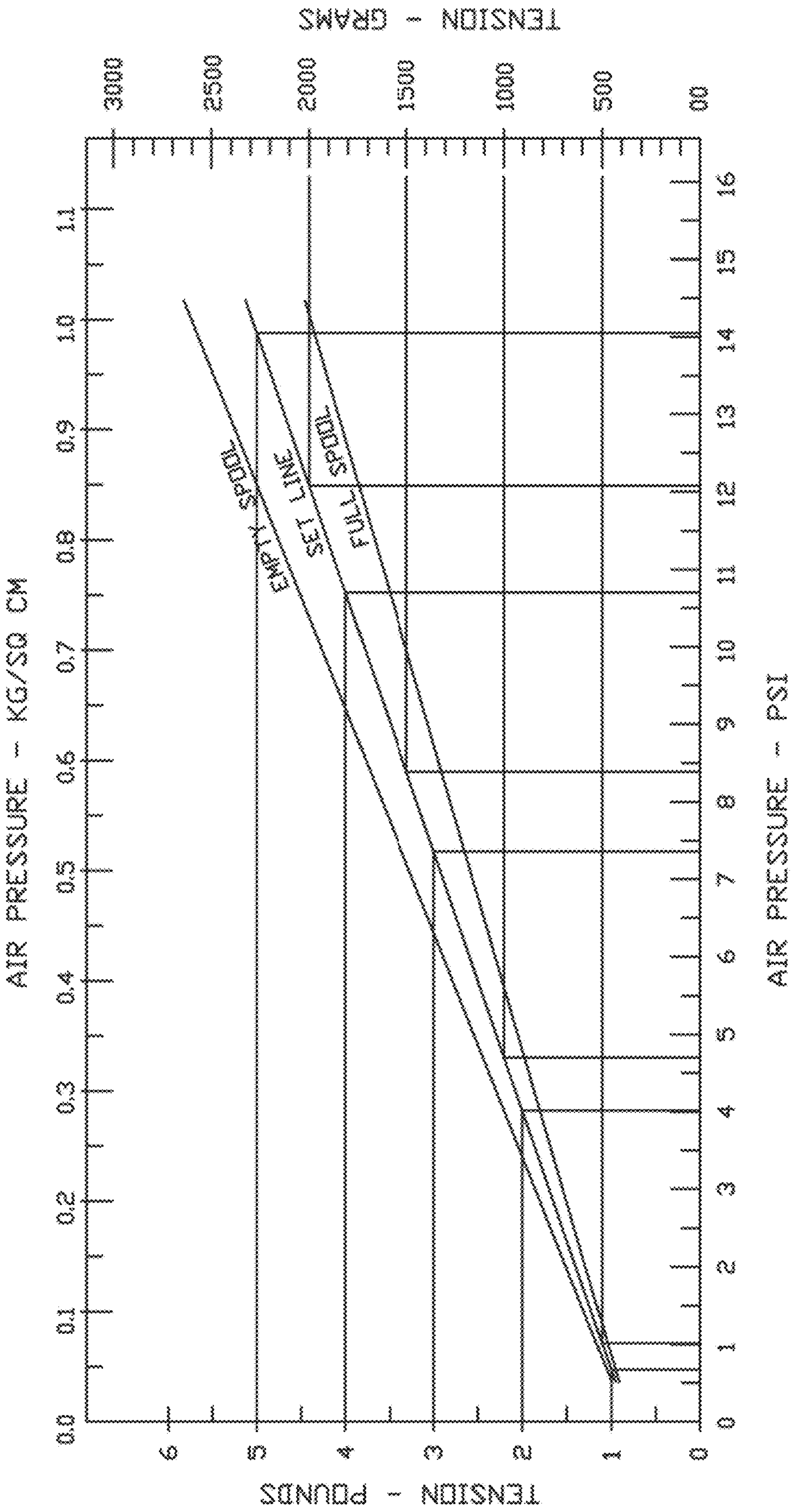

TENSION - GRAMS
3000
2500
2000
1500
1000
500
00
AIR PRESSURE - KG/SQ CM
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
EMPTY SPOOL
SET LINE
FULL SPOOL
AIR PRESSURE - PSI
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TENSION - POUNDS
0
1
2
3
4
5
6

FIG. 4

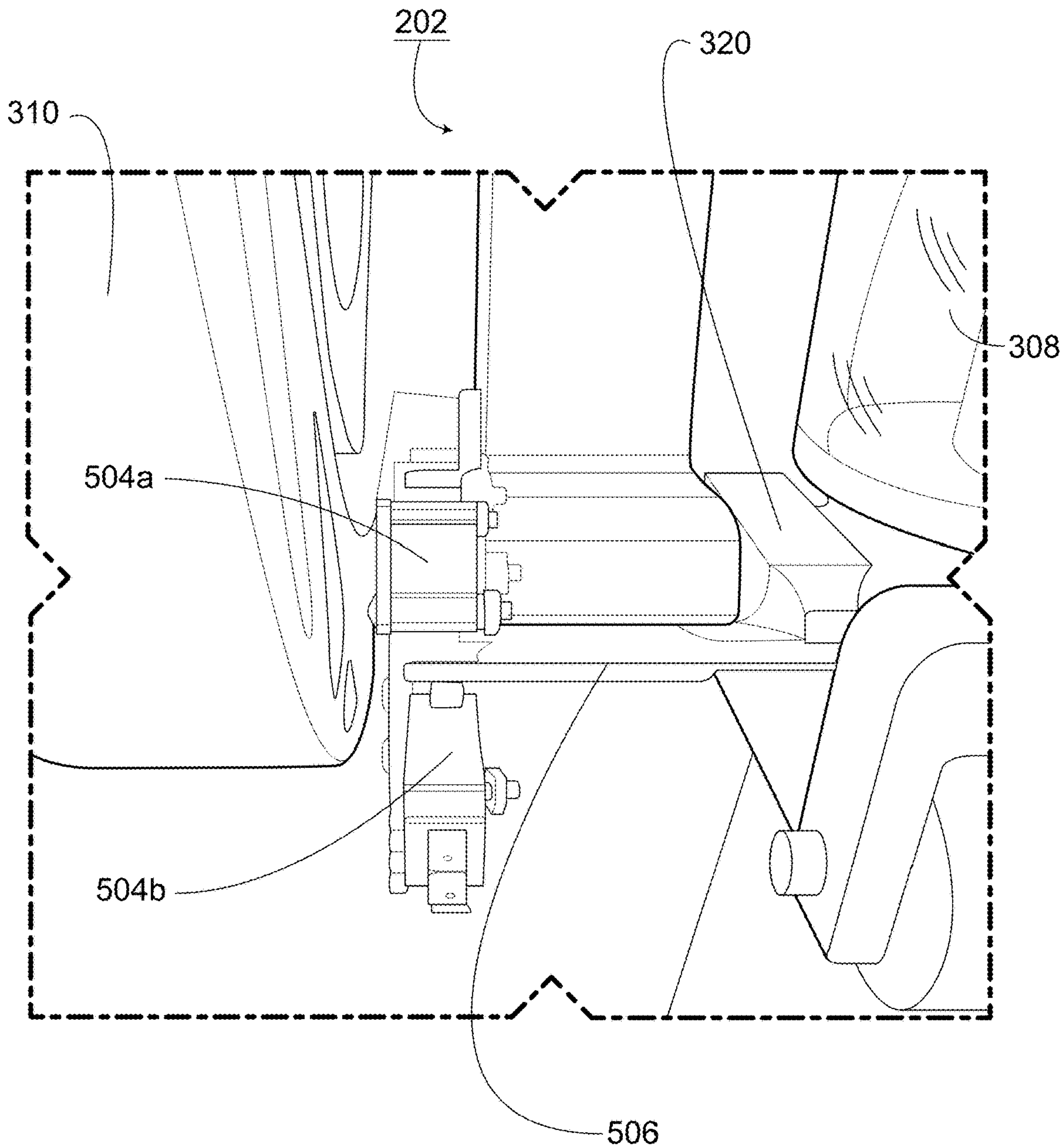


FIG. 5

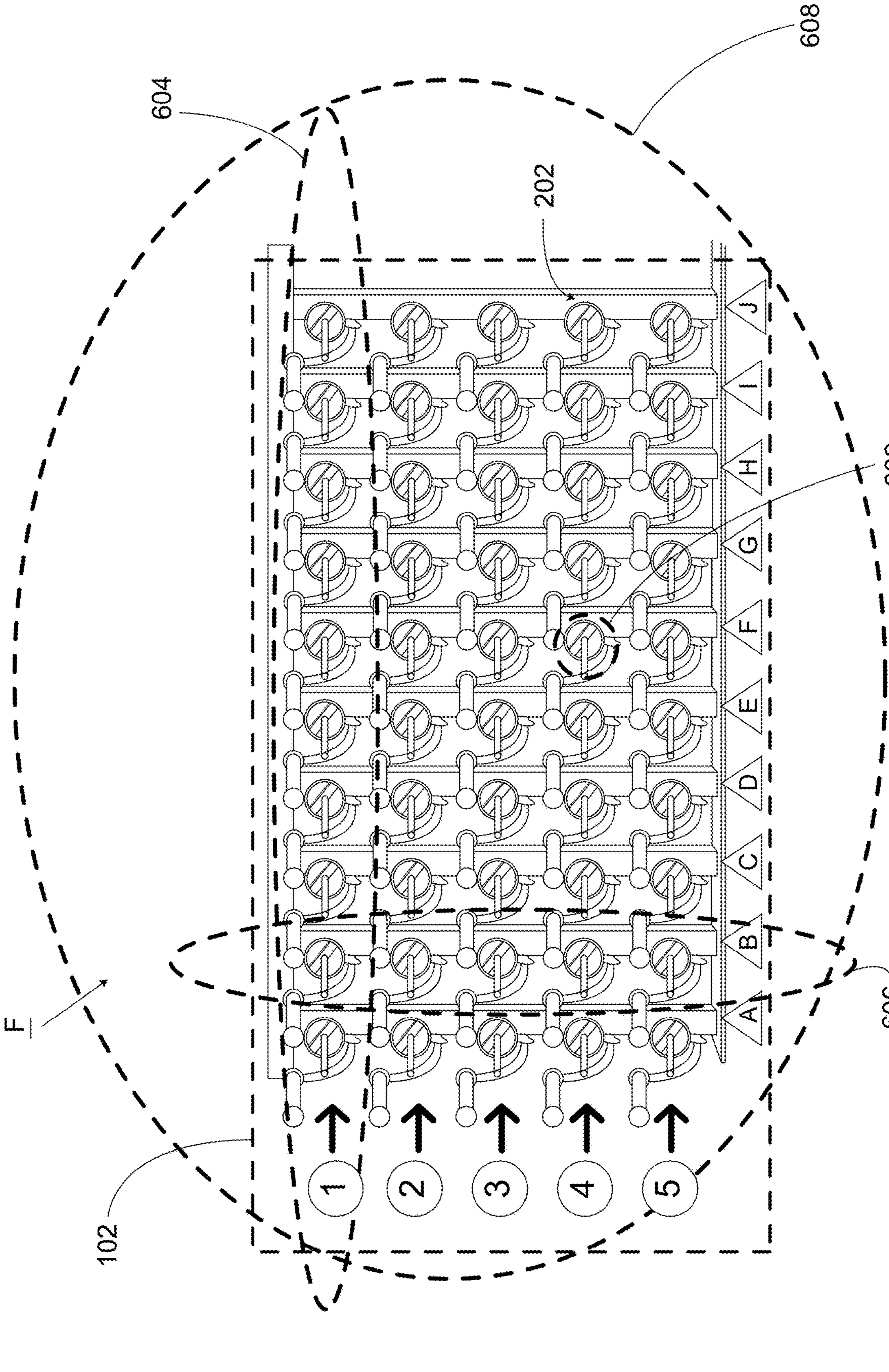


FIG. 6

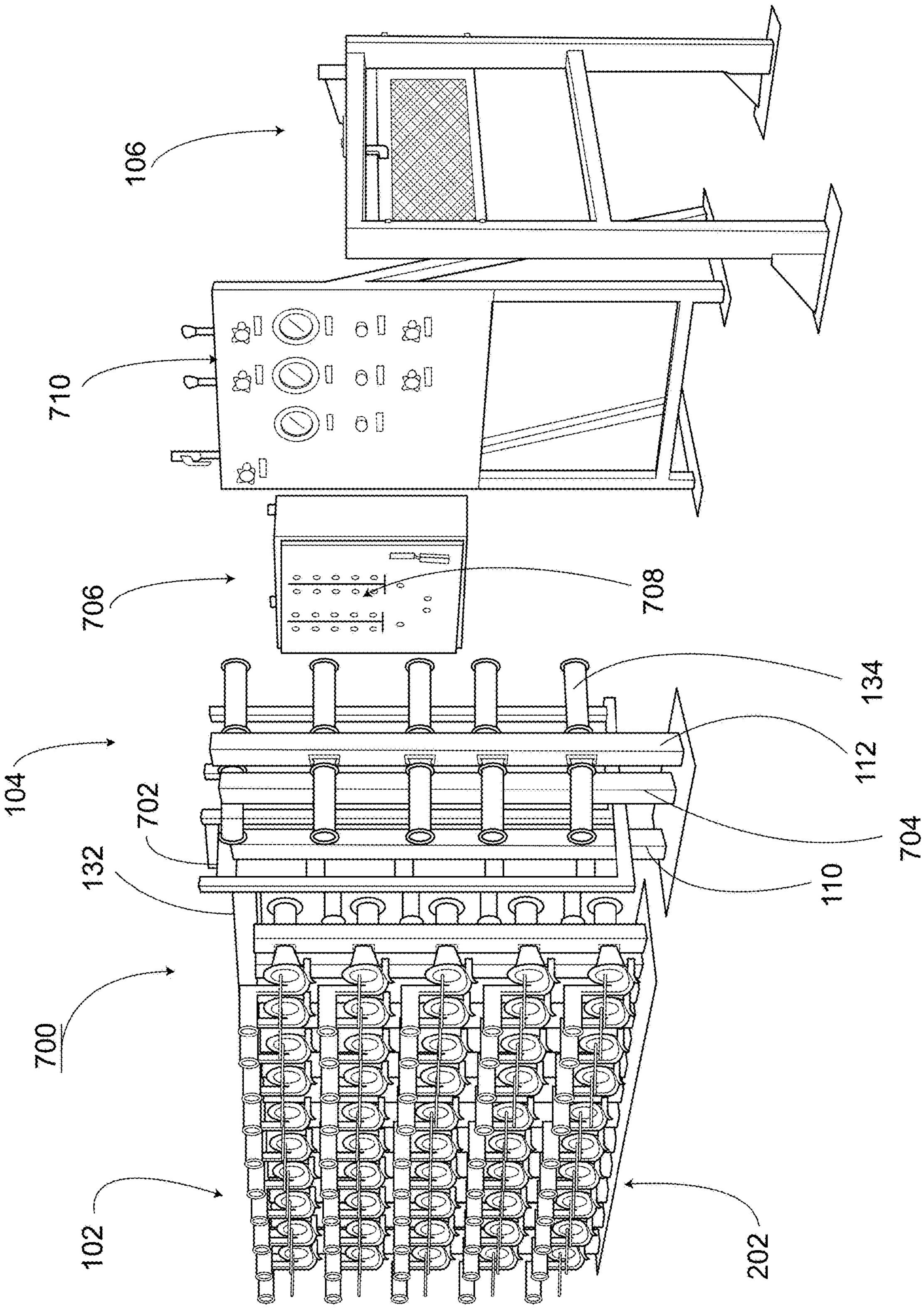
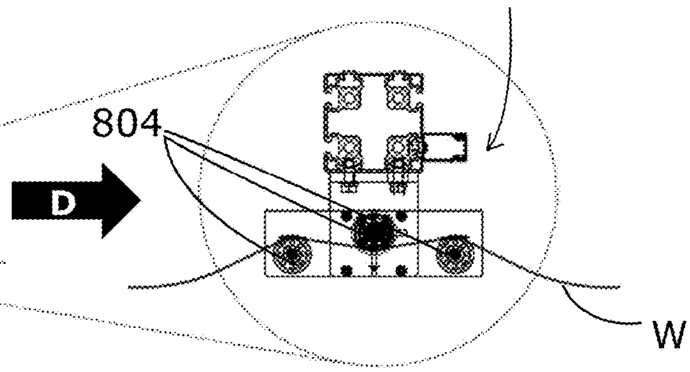
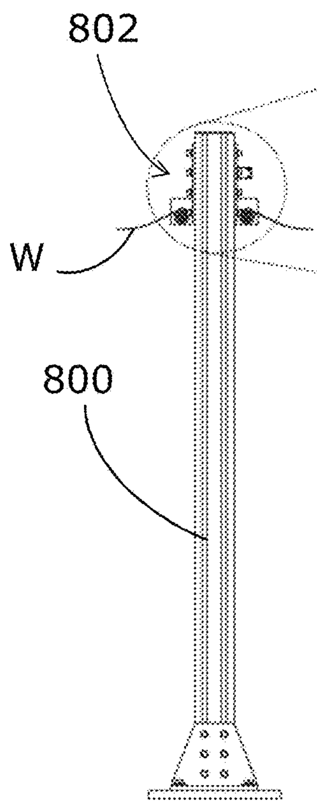


FIG. 7

FIG. 8D





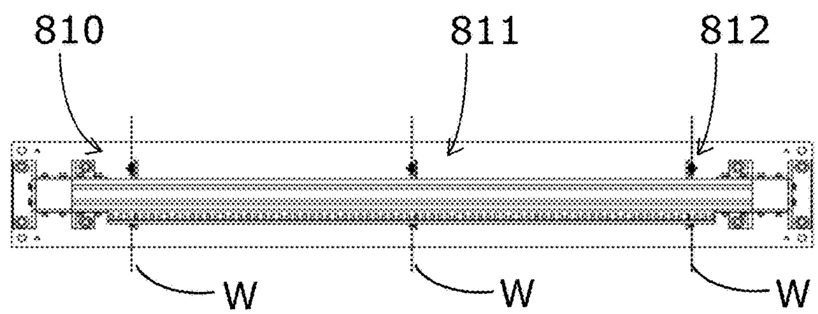


FIG. 8C

FIG. 8A

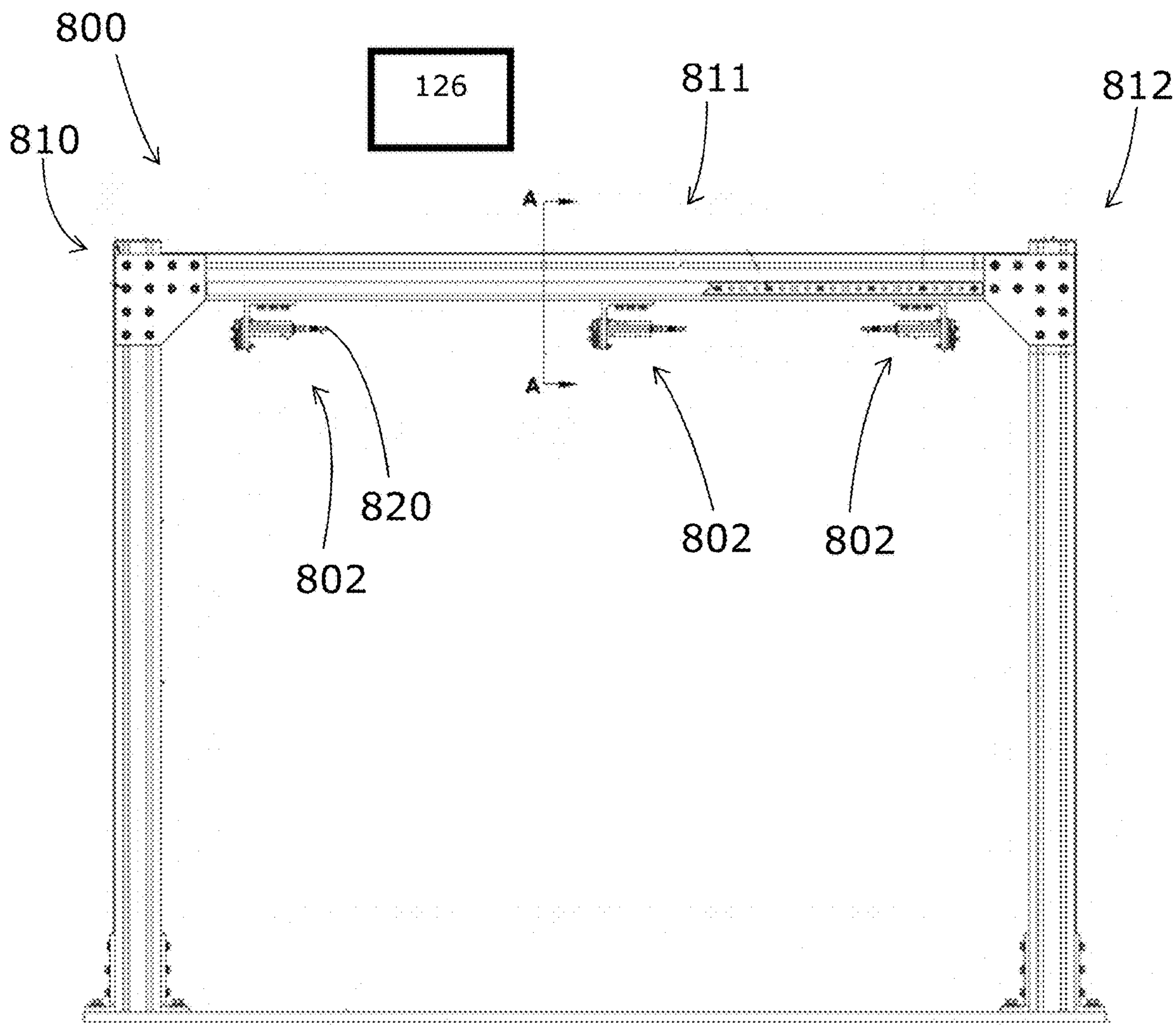


FIG. 8B

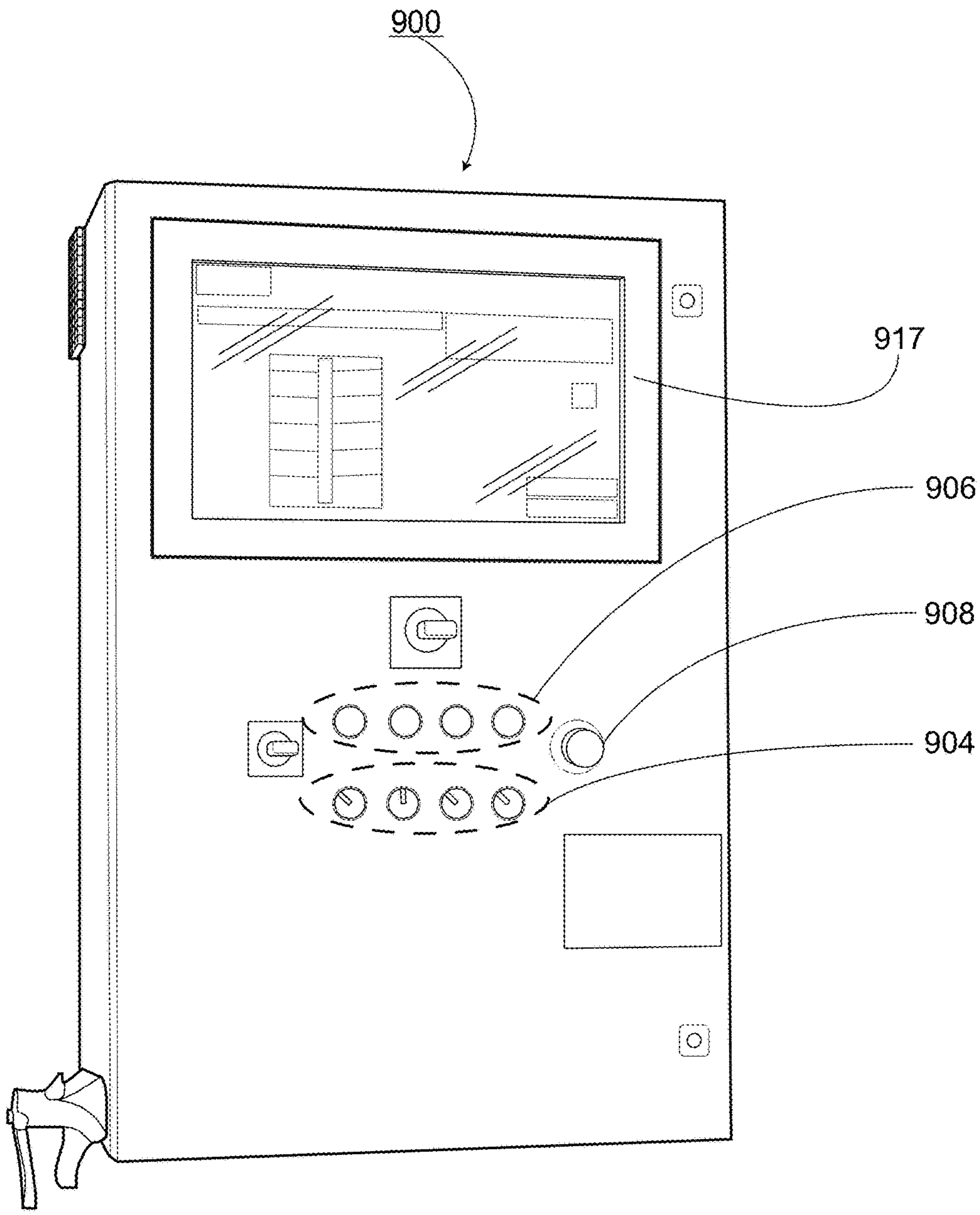
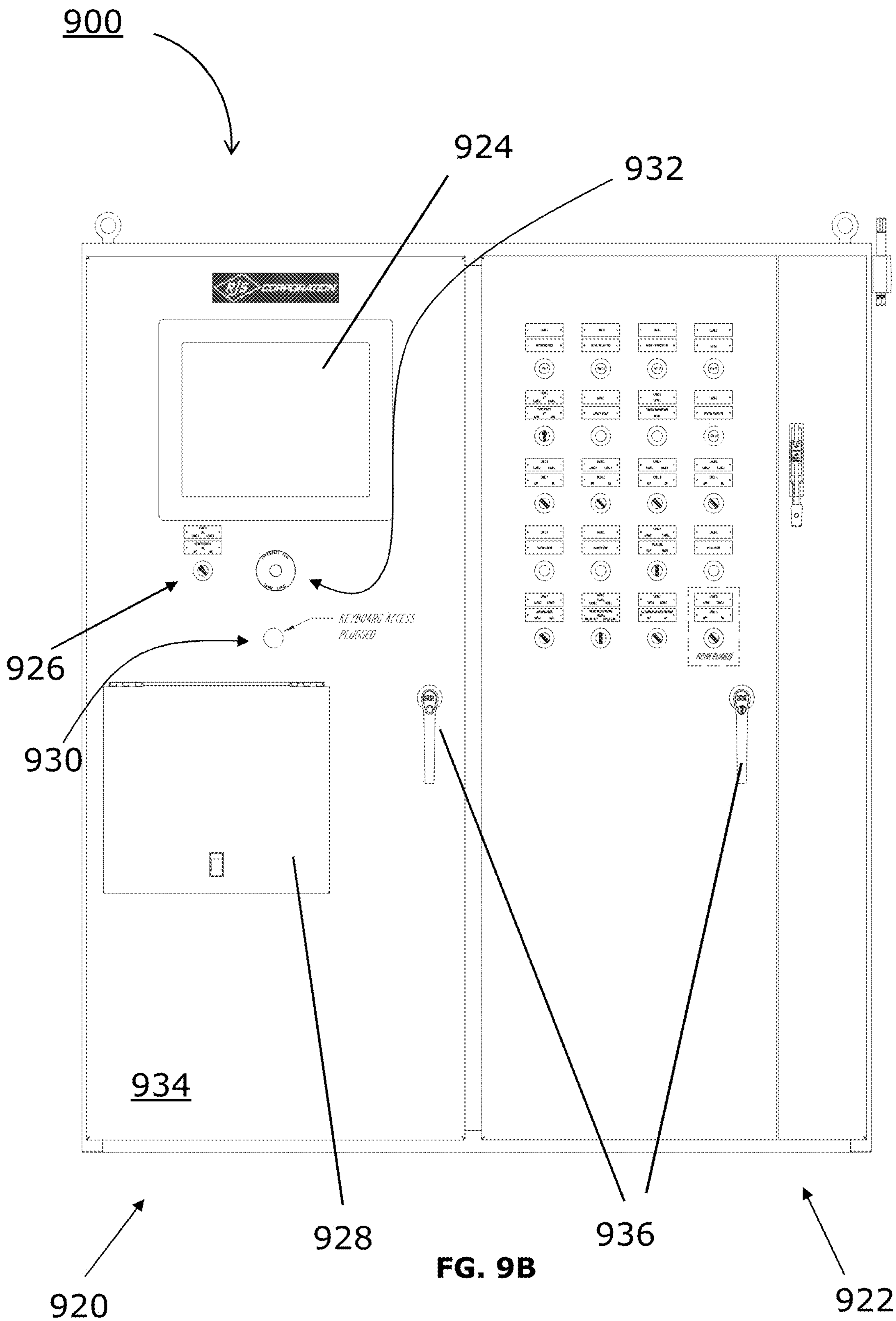
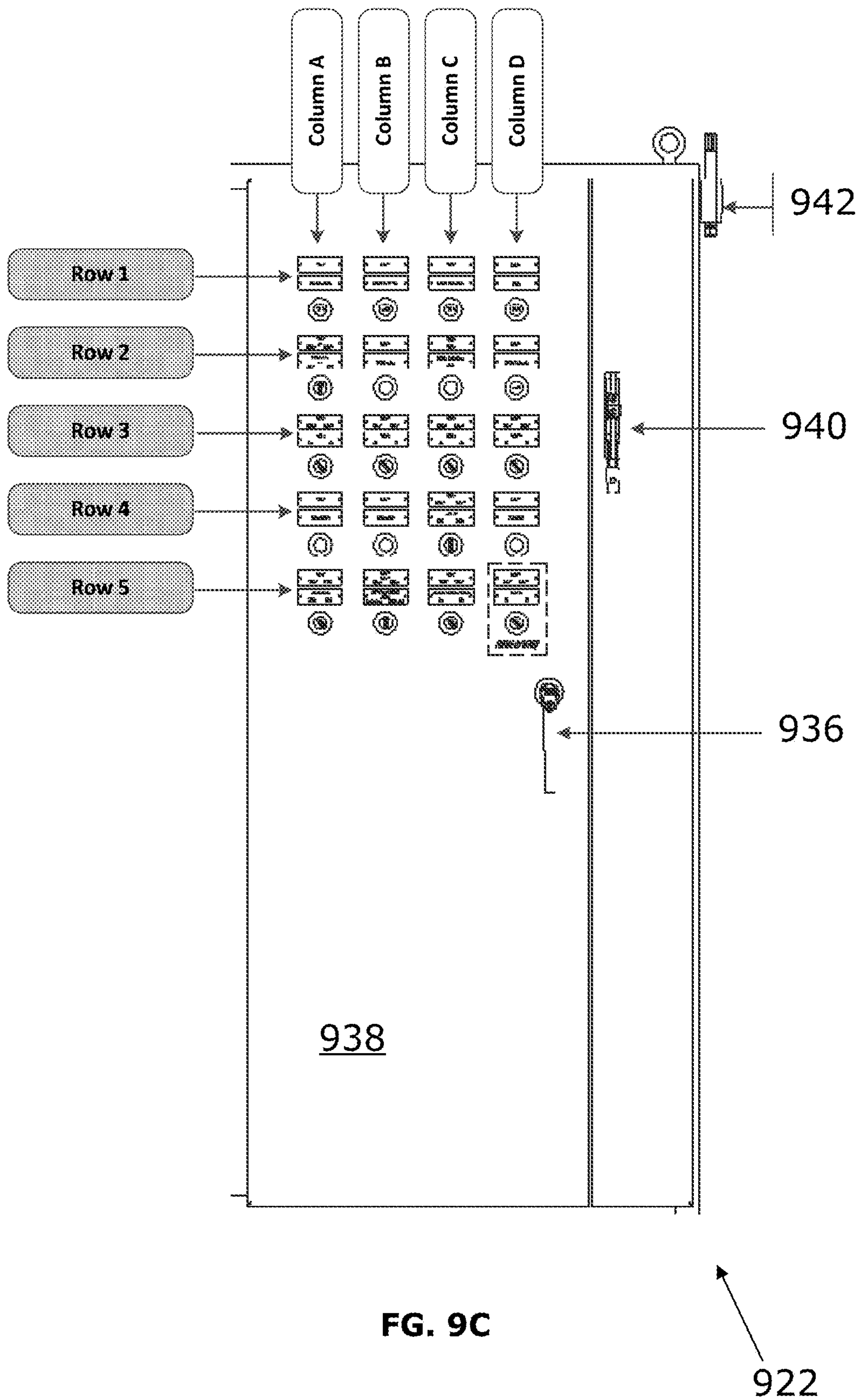


FIG. 9A


900
924
932
926
930
KEYBOARD ACCESS
PLUGGED
934
920
928
936
922

FG. 9B



Column A
Column B
Column C
Column D
Row 1
Row 2
Row 3
Row 4
Row 5
942
940
936
938
922

FG. 9C

FIG. 10A

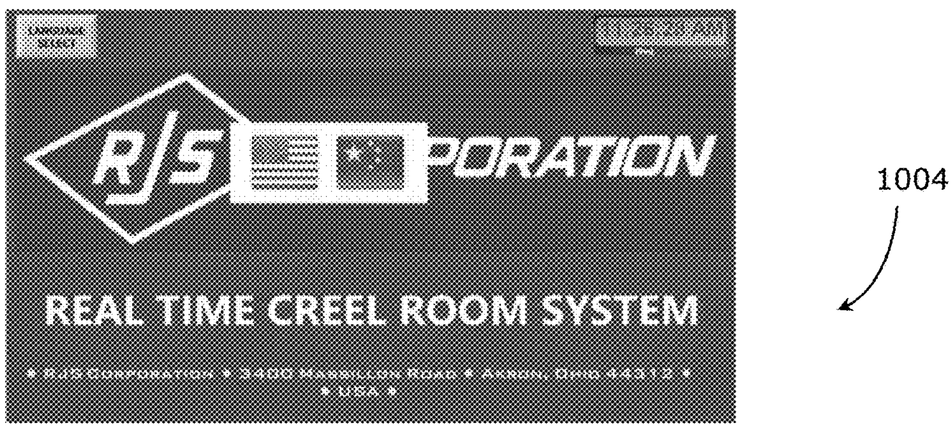


FIG. 10B

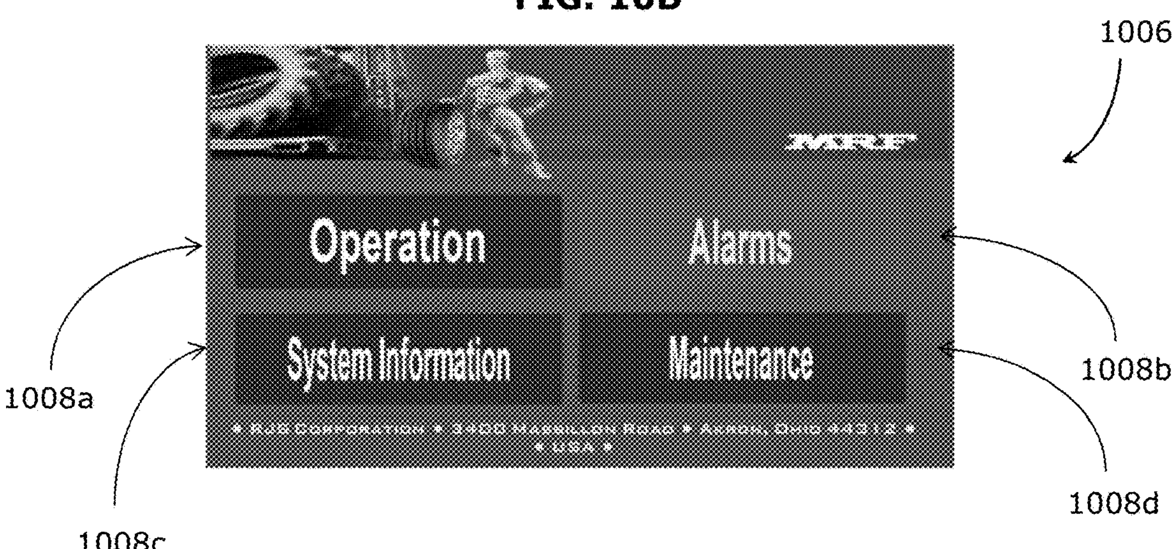


FIG. 10C

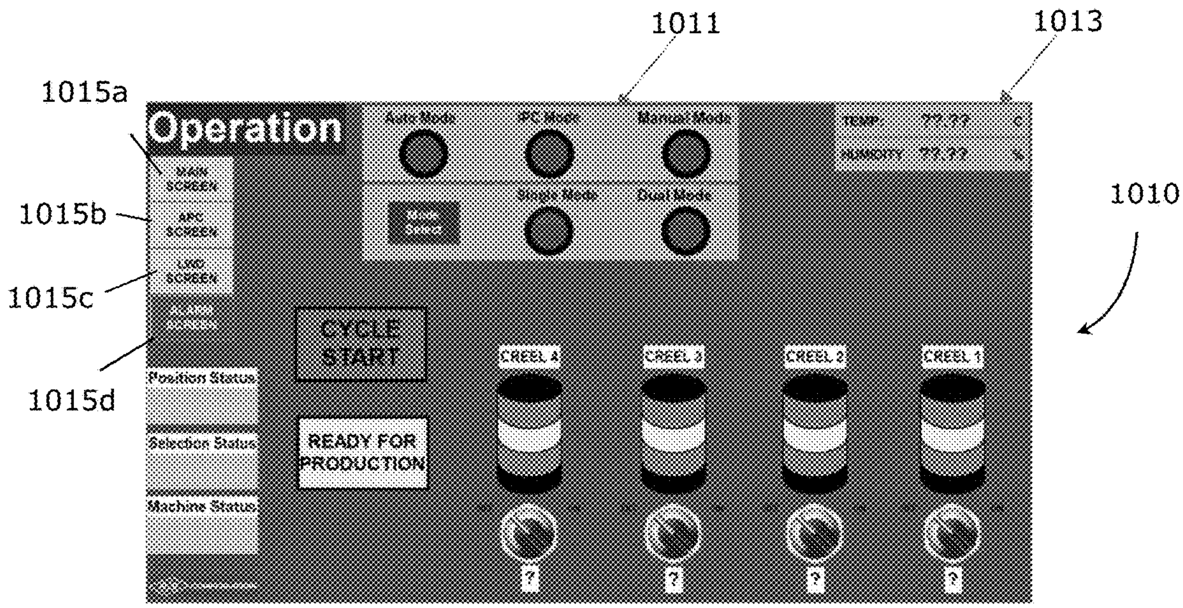


FIG. 10D

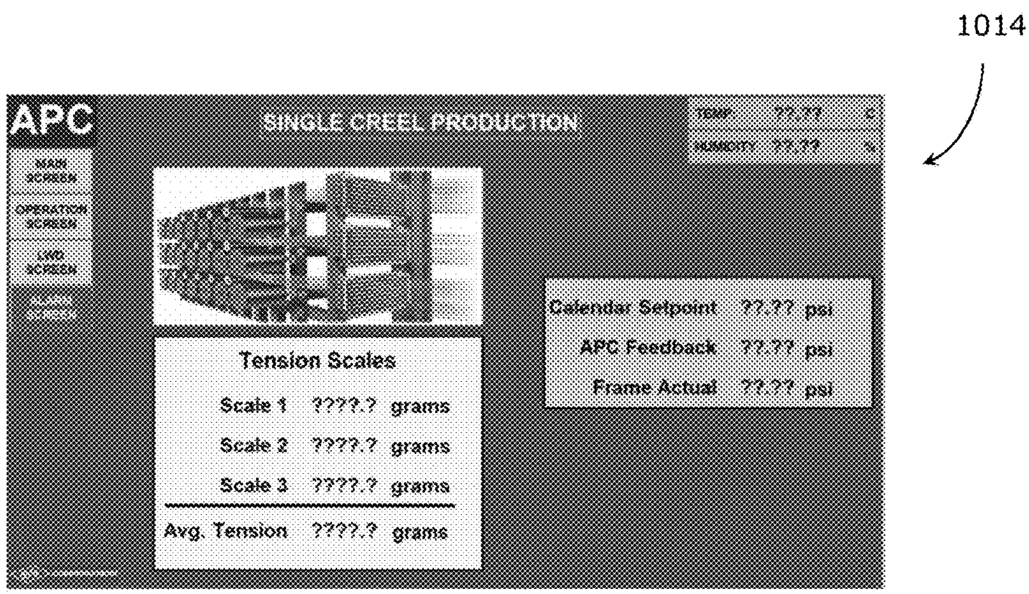


FIG. 10E

1016

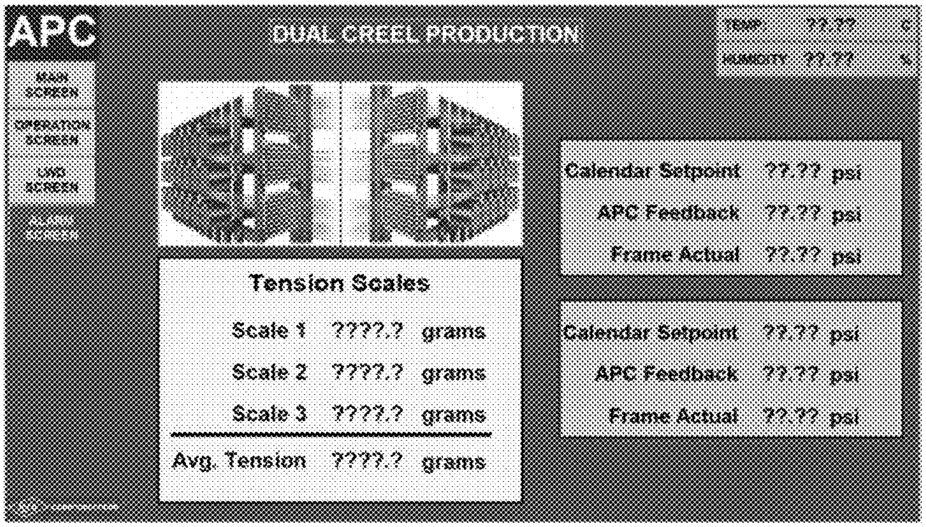


FIG. 10F

1018

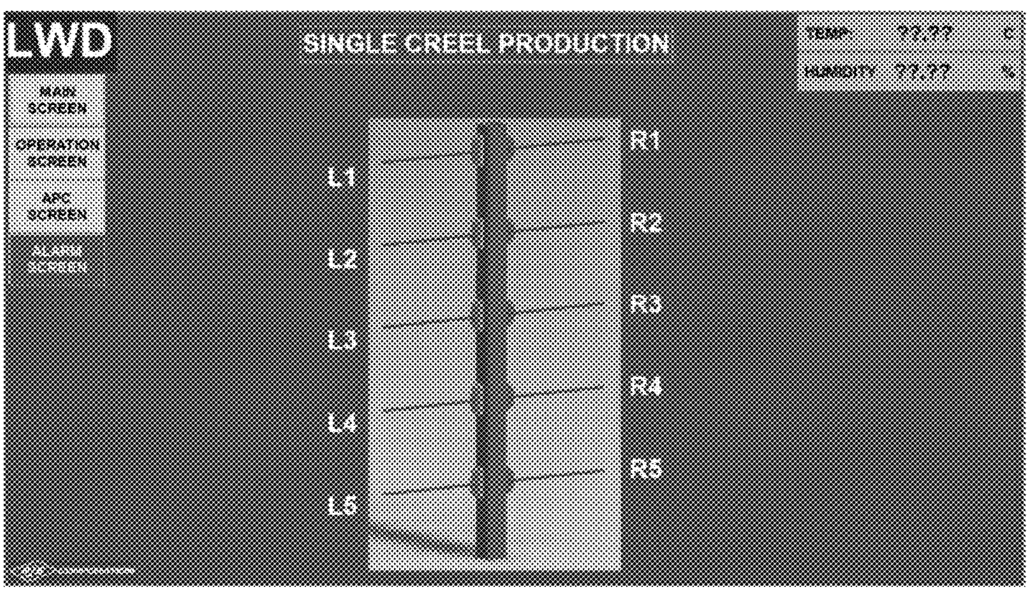


FIG. 10G

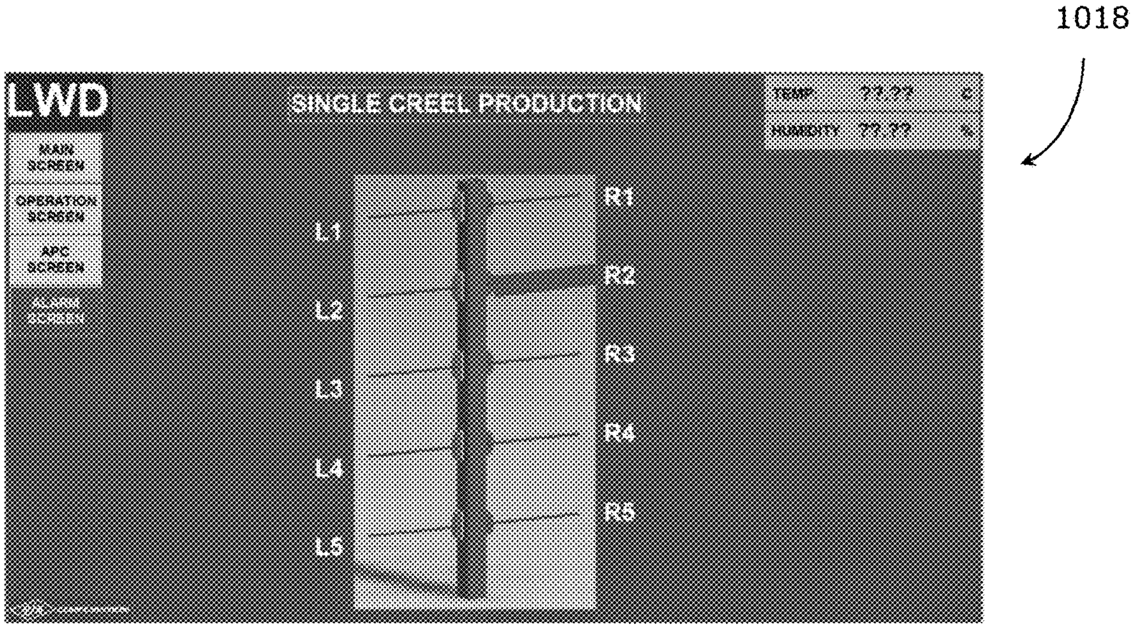


FIG. 10H

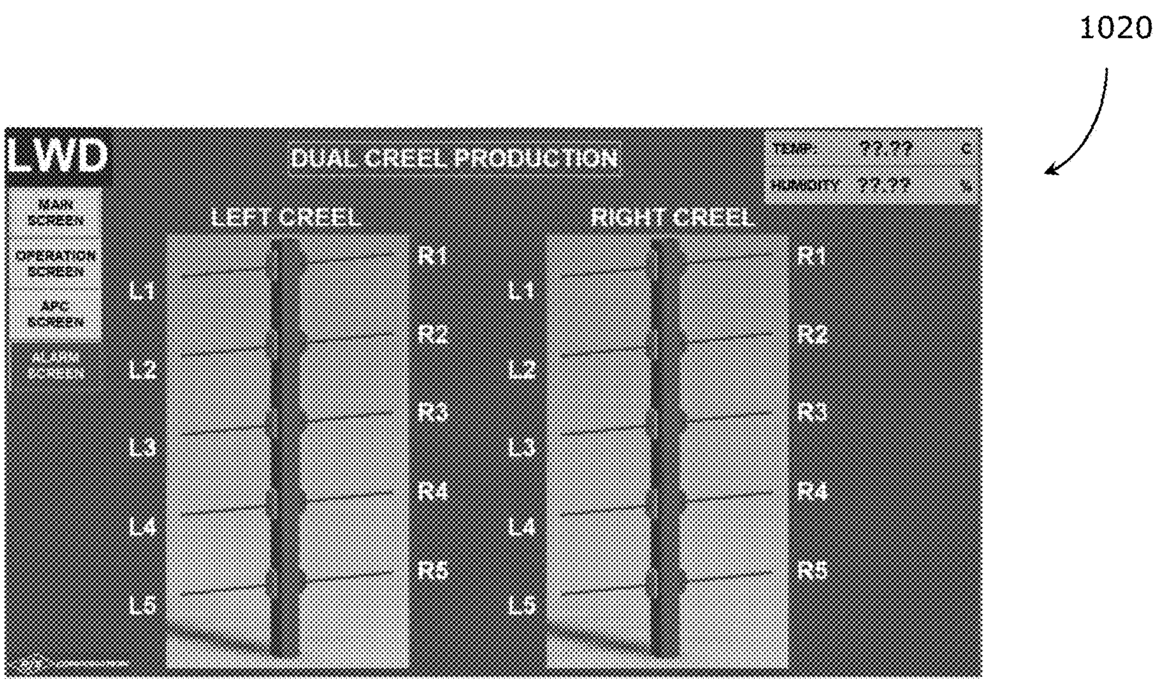


FIG. 10I

1020

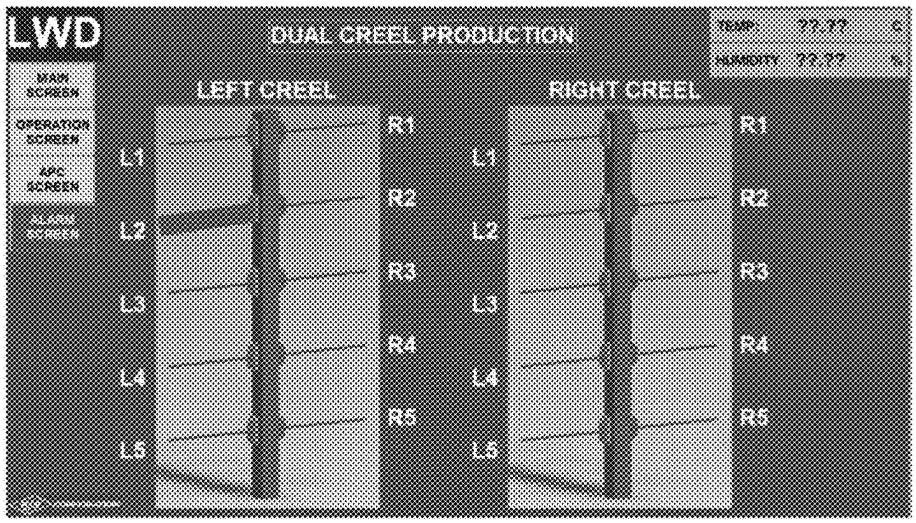


FIG. 10J

1022

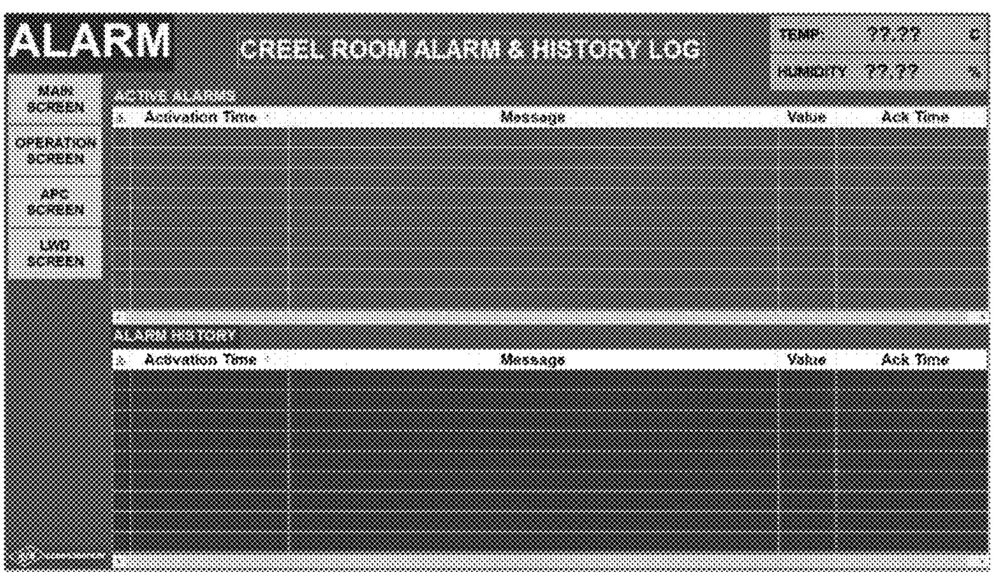


FIG. 10K

ERROR MESSAGE TEXT
MAIN AIR SUPPLY NOT PRESENT
COLLISION AVOIDANCE SYTEM OVERRIDE ACTIVE
INVALID CREEL COMBINATION/SELECTION
BROKEN OR LOOSE WIRE CREEL # L#
BROKEN OR LOOSE WIRE CREEL # R#
VFD (VARIABLE FREQUENCY DRIVE) FAULT VFD #
ACTIVE CREEL SAFETY ROPE TRIP CREEL #
COLLISION AVOIDANCE CREEL # LEFT SIDE
COLLISION AVOIDANCE CREEL # RIGHT SIDE
MAX TRAVEL RIGHT CREEL 1
MAX TRAVEL LEFT CREEL 4

KEY
= **CREEL** ROW NUMBER RIGHT TO LEFT (1 - 4)
L# = LEFT **WIRE** ROW NUMBER (1 - 5, TOP TO BOTTOM)
R# = RIGHT **WIRE** ROW NUMBER (1 - 5, TOP TO BOTTOM)

FIG. 10L

1024

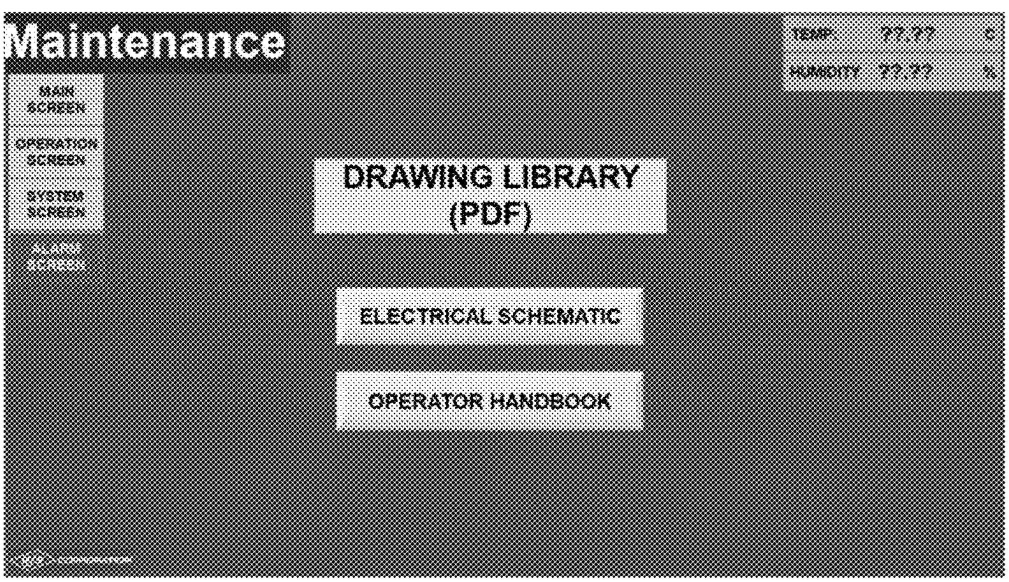


FIG. 10M

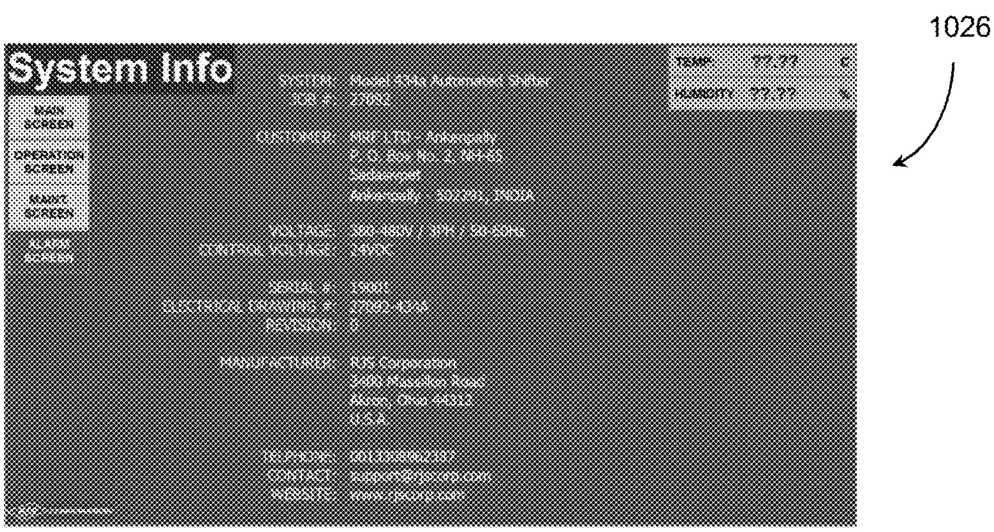

1026
System Info
MAIN SCREEN
OPERATION SCREEN
TEMP
HUMIDITY
SYSTEM:
JOB #:
CUSTOMER:
VOLTAGE:
CONTROL VOLTAGE:
SERIAL #:
ELECTRICAL DRAWING #:
REVISION:
MANUFACTURER:
RJS Corporation
U.S.A
TELEPHONE:
CONTACT:
WEBSITE:

FIG. 10N

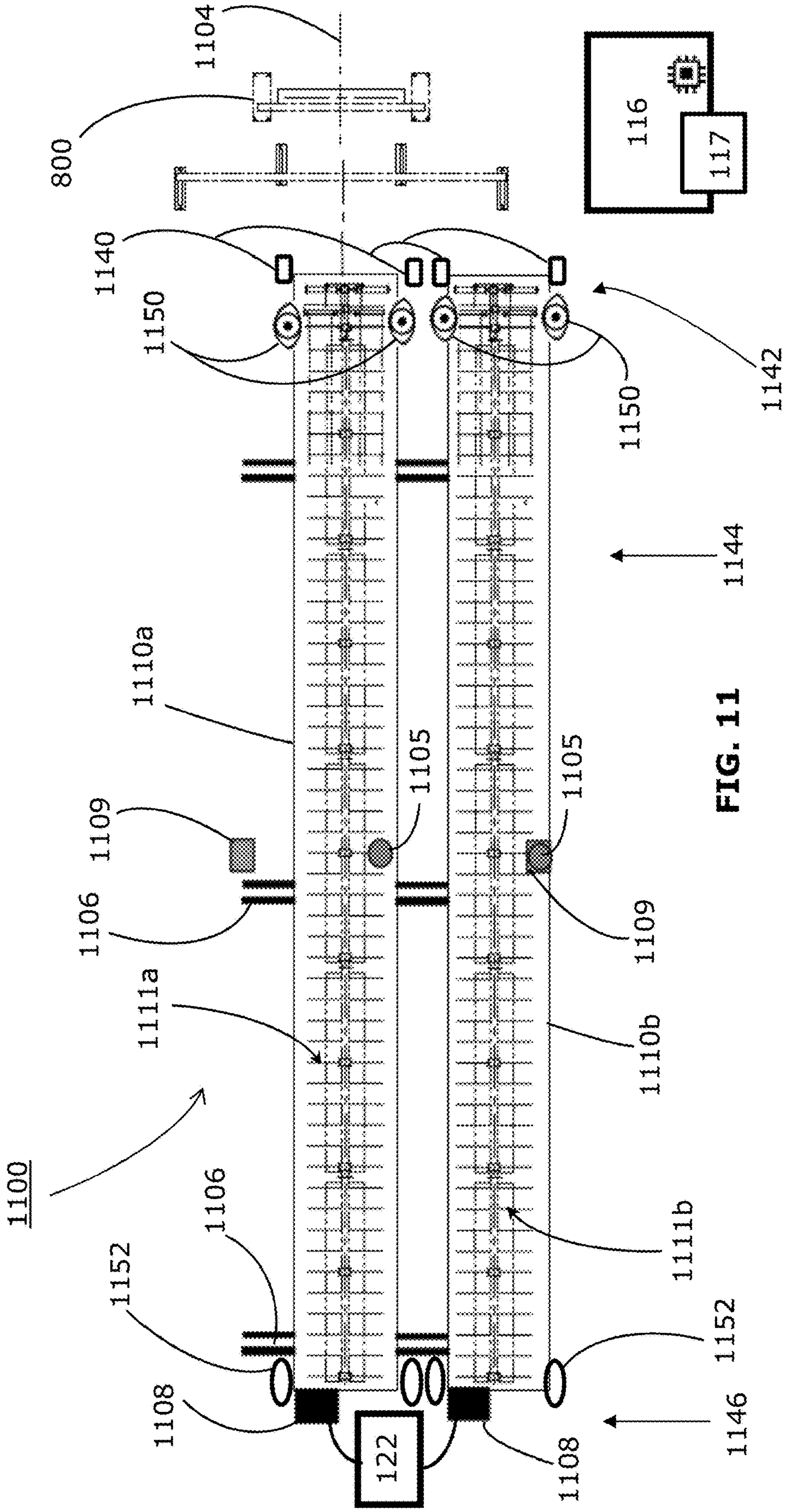
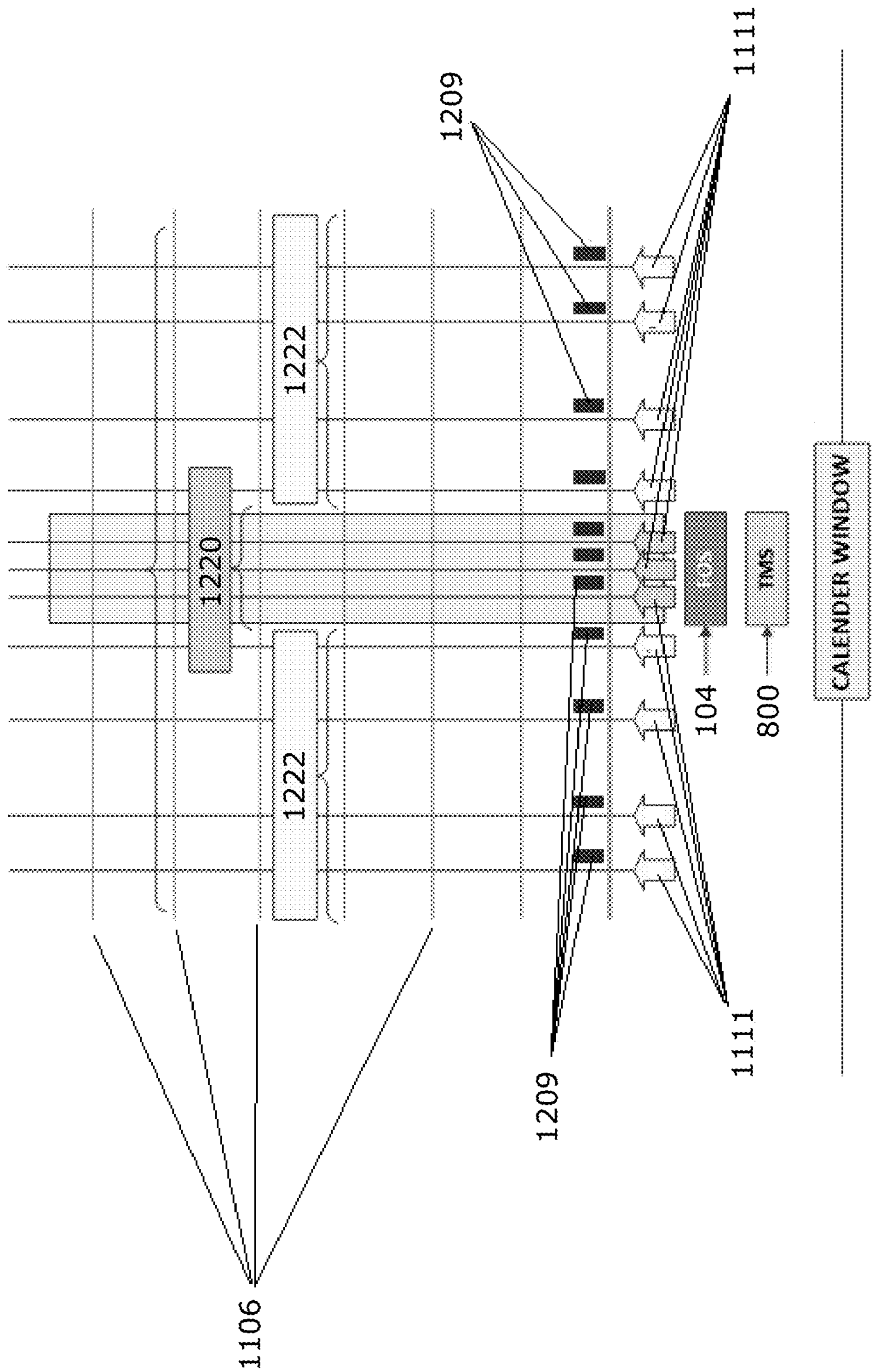

1100
1104
800
116
117
1140
1142
1144
1146
1150
1110a
1110b
1111a
1111b
1105
1106
1108
1109
1152
122

FIG. 11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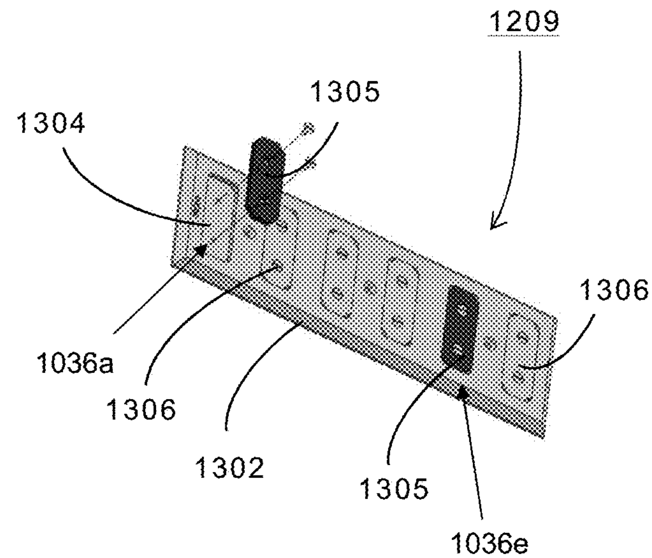
1111
1222
1220
1222
104
800
TMS
CALENDER WINDOW
1209
1111
1106

FIG. 12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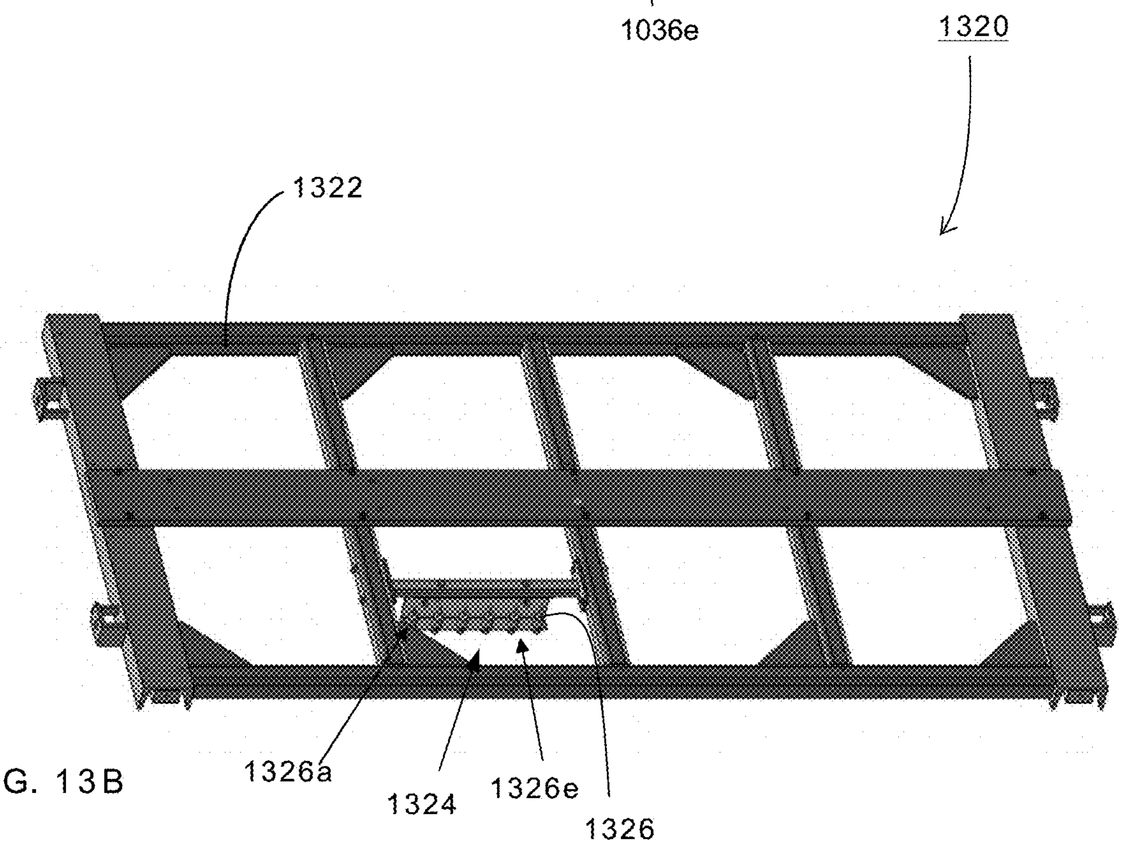
1306
1036a
1306
1302
1305
1036e

FG. 13A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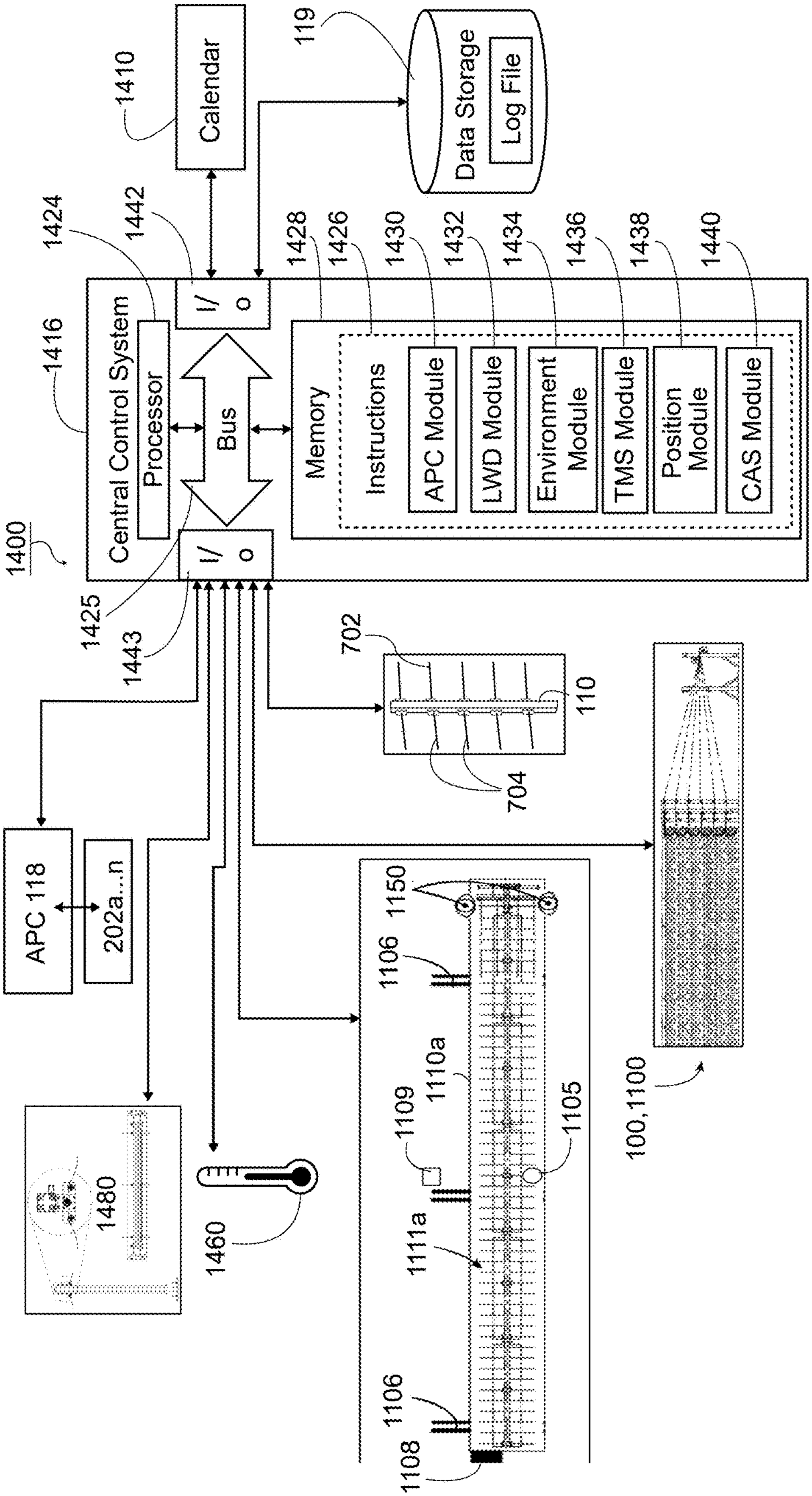
1326a
1324
1326e
1326

FG. 13B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Central Control System
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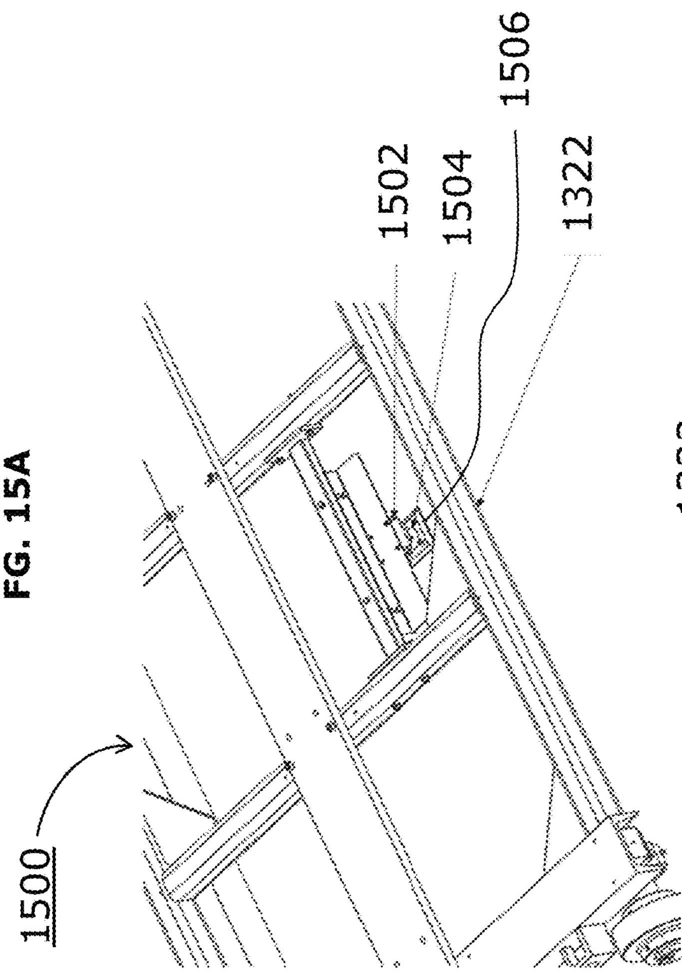
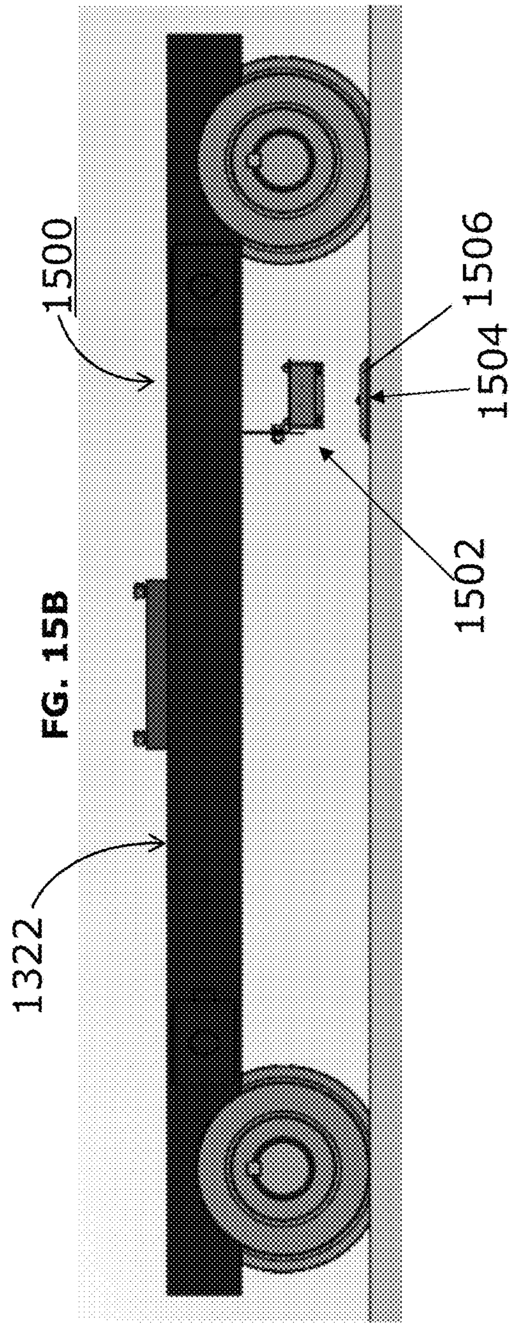
Processor
1425
Bus
1442
I/O
1443
I/O
1428
Memory
1426
Instructions
1430
APC Module
1432
LWD Module
1434
Environment Module
1436
TMS Module
1438
Position Module
1440
CAS Module
1410
Calendar
119
Data Storage
Log File
APC 118
202a...n
1480
1460
702
704
110
1150
1106
1110a
1109
1105
1111a
1108
100,1100

FIG. 14

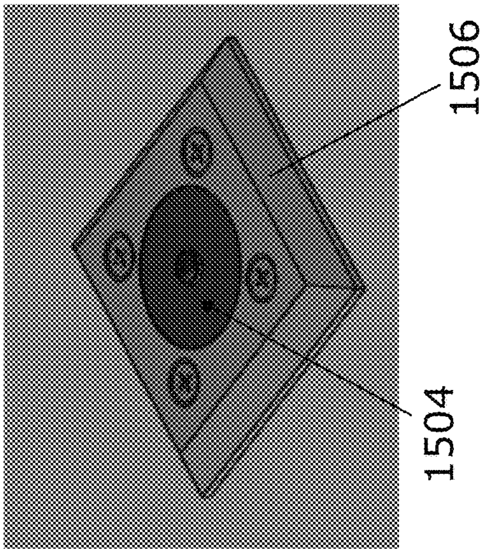
FG. 15A



FG. 15B



FG. 15C



DIGITAL CREEL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of pending International Patent Application PCT/US2020/056331, International File Date Oct. 19, 2020, which claims priority to U.S. Provisional Application No. 62/916,375, filed Oct. 17, 2019, which are incorporated by reference herein in their entirety.

BACKGROUND

Filamentary materials are commonly utilized as reinforcements for plastic or elastomeric compounds or may themselves be fabricated into integral arrangements as utilized in the textile, hose, and tire industries. These filamentary materials, often referred to as wires, are stored on (wrapped around) spools. In addition, these wires may include, without limitation, fibers in single and multiple strands, flat bands, or tubing produced in long lengths and wound on spools. The various wires may be either natural or synthetic fibers, glass or metal.

Creel systems are utilized to pull the wires from its spools and manipulate them into final form. Creel systems include a plurality of tension controller systems that each have a spindle that permit the spools to rotate as the wire is withdrawn therefrom. These tension controller systems have control arms and rollers that are utilized to provide tension to the wire and may be adjusted via compressed air. Creel systems may further comprise a front organizing stand into which wires are fed from the spools. Front organizing stands often include sub-systems, including a broken/loose wire detector sensor, direction change roller, and a front roller or eyelet board.

Conventional creel systems, however, are not able to measure and automatically adjust wire tension. Rather, conventional creel systems will sound an alarm if a wire is broken/loose wire contacts the conductive sensor rod on the front organizing stand and, if enough broken/loose wires are detected, production will be shut down and the suspect wires addressed. Moreover, conventional creel systems provide little feedback or operational feedback to the operator in real time.

In view of the shortcomings of the conventional creel systems, there is a need for a creel system that measures operating characteristics and displays the same to a user in real time so that the operator may take corrective action, and there is a need for a creel system that automatically controls and optimizes wire tension based on those measured operating characteristics.

SUMMARY

Embodiments herein are directed towards a creel system. The creel system may comprise a frame having a plurality of tension controller apparatuses for paying out a wire under tension, each of the tension controller apparatuses having a brake shoe that is engageable with a spindle and a control arm that that is rotatable towards the spindle to move the brake shoe away from the spindle and rotatable away from the spindle to move the brake shoe towards the spindle, an air pressure control system operatively connected to each of the tension controller apparatuses and actuatable to move the brake shoe towards the spindle, the tension control apparatus in communication with at least one apparatus sensor disposed on at least one of the control arms, and a central control system in communication with the air pressure control system, wherein the central control system ascertains a wire tension based on data from the apparatus sensor and the air pressure control system, and wherein the central control system is configured to actuate the air pressure control system in response to the wire tension. In a further embodiment, the creel system further comprises a loose wire detection system in communication with the central control system, the loose wire detection system comprising a wire tree positioned downstream from the frame and including a plurality of vertically spaced sensor bars configured to generate a loose wire detection signal upon contact between a wire and at least one sensor bar. In a further embodiment, the creel system further comprises a tension monitoring system in communication with the central control system, the tension monitoring system comprising a tension monitoring stand positioned downstream from the frame, the tension monitoring stand including at least one tension sensor that receives a wire from the frame, wherein the at least one tension sensor measures the tension of the received wire and generates a tension output signal that is sent to the central control system, wherein the central control system changes the air pressure of the air pressure control system based on the tension output signal. In another further embodiment, the tension monitoring stand comprises a left tension sensor, a center tension sensor, and a right tension sensor, each configured to receive a wire from a left portion of a plane of wires, a wire from a central portion of the plane of wires, and a wire from a right portion of the plane of wires. In a further embodiment, the creel system further comprises a plurality of platforms, wherein a frame having a plurality of tension controller apparatuses for paying out a wire under tension is mounted to each platform, each platform includes a set of wheels that are driven by a motor, the motor of each platform is in communication with the central control system which directs the motor to drive the associated platform to a target position. In another further embodiment, each platform includes a proximity sensor configured to generate a position signal in response to reading at least one feature plate located at a predetermined position on the creel room floor. In another further embodiment, the feature plate comprises a plate body having a plurality of pockets, each pocket is configured to receive one of a steel and nylon pad, an order of steel and nylon pads creating a unique code read by the proximity sensor relating to the position of the platform within the creel room. In another further embodiment, each platform includes at least one photo eye sensor configured to measure a distance between adjacent platforms, wherein the central control system generates a stop motion signal based on a predetermined threshold distance measured by the at least one photo eye sensor. In a further embodiment, the creel system further comprises at least one mechanical travel limit switch in communication with the central control system configured to prevent over-travel of a platform beyond a predetermined location. In a further embodiment, the creel system further comprises at least one pull switch comprising a rope mounted at a front end of a creel row, the pull switch generates a stop signal when the rope is pulled, the stop signal readable by the central control system to cease operation of the creel system. In another further embodiment, the central control system is configured to shut down the creel system based on a stop signal generated from a creel row based and determined position of the creel row in the creel room. In a further embodiment, the creel system further comprises a data storage in communication with the central control system, the data storage configured to storage a log file.

Embodiments herein are directed towards a method of operating a creel system, comprising: with a APC module, controlling the tension of at least one wire by directing an air pressure to at least one tension control apparatus having a brake shoe that is engageable with a spindle and a control arm that that is rotatable towards the spindle to move the brake shoe away from the spindle and rotatable away from the spindle to move the brake shoe towards the spindle; with LWD module, receiving sensor bar data from a plurality of sensor bars disposed on a wire tree a and determining a location on the wire tree where at least one wire contracts a sensor bar of the plurality of sensor bars; and with a Position module, tracking a position of a creel row with respect to a creel room based on location data received from at least one proximity sensor or other sensing technology device associated with each creel row and controlling a motor associated with each creel row to move a creel row to a target position. In a further embodiment, the method further comprises positioning a plurality of feature plates, each plate comprising a plate body having a plurality of pockets, each pocket is configured to receive one of a steel and nylon pad, wherein an order of steel and nylon pads creates a unique code readable by the proximity sensor and used by the position module to determine a location of the creel row. In a further embodiment, the method further comprises with an environment module, receiving environment data from at least one environment sensor and controlling the operation of the creel system based on data received by the at least one environment sensor. In a further embodiment, the method further comprises with a TMS module, receiving wire tension data from at least one tension sensor located between a creel row and a calender and/or; adjusting the air pressure delivered to at least one tension control apparatus based on a measured tension. In a further embodiment, the method further comprises with at least one mechanical travel limit switch in communication with the central control system, generate a limit switch signal and stop the motion of an associated creel row based on the generated limit switch signal. In a further embodiment, the method further comprises with a CAS module, receiving collision data from at least one eye sensor associated with each creel row and determining a distance between a creel row in motion and adjacent creel row, and controlling the motion of a moving creel row based on the determined distance between the creel row in motion and adjacent creel row. In a further embodiment, the method further comprises with at least one pull switch comprising a rope mounted at a front end of a creel row, generating a stop signal when the rope is pulled, and shutting down the operation of the creel system based on the pull switch signal. In another further embodiment, shutting down the creel system is based on both the stop signal generated from a creel row based on a determined position of the associated creel row in the creel room.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures are included to illustrate certain aspects of the present disclosure and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, without departing from the scope of this disclosure.

FIGS. **1**A-**1**B are side views of an example creel system that may incorporate the principles of the present disclosure, and FIGS. **1**C-**1**D are isometric perspective views of example creel system components.

FIGS. **2**A-**2**D are perspective views of the creel system of FIG. **1**A.

FIGS. **3**A-**3**B are front and rear perspective views of the tension controller apparatuses that may be utilized in FIGS. **1**-**2**.

FIG. **4** is a curve showing the relationship between air pressure and wire tension in the tension controller apparatus of FIGS. **3**A-**3**B.

FIG. **5** is a close-up view of the tension controller apparatuses of FIGS. **3**A-**3**B.

FIG. **6** is an exemplary frame of the creel system that illustrates example zones of tension controller apparatuses that may be controlled as a group.

FIG. **7** is a perspective view of an alternate exemplary creel system that may incorporate the principles of the present disclosure.

FIGS. **8**A-**8**D are front, top, side, and cross-sectional views of a tension monitoring stand in accordance with the present disclosure.

FIG. **9**C illustrates a close up of a side of the user interface of FIG. **9**B.

FIGS. **9**A and **9**B illustrate various exemplary user interfaces.

FIGS. **10**A-**10**N are screen-shots of the touch screen display of FIG. **9** that illustrate various aspects of a software platform that may be utilized to monitor and control the creel system.

FIG. **11** is a plan view of a creel system having multiple creel rows in accordance with the present disclosure.

FIG. **12** is a diagram of multiple creel rows in a creel room in accordance with the present disclosure.

FIG. **13**A is an exemplary floor plate in accordance with the present disclosure, and FIG. **13**B is an exemplary unit for detecting floor plates in accordance with the present disclosure.

FIG. **14** is an exemplary control system diagram for a creel system in accordance with the present disclosure.

FIGS. **15**A-**15**C illustrate an alternate system for sensing or tracking position of the shifting creel rows, in accordance with the present disclosure.

DETAILED DESCRIPTION

The present disclosure is related to creel systems and, more particularly, to digital creel systems that provide real-time optimized feedback, automatic control and increased efficiency.

The embodiments described herein provide a control system for a creel system. The control system is a digital control system integrating multiple creel room processes, which previously functioned independently of each other. In some embodiments, the digital control system integrates together one or more of the following separate functions: (i) servo valve operated air pressure control console (i.e., an APC), (ii) a loose wire detection system (i.e., an LWD), (iii) a shifting platform control (i.e., SPC), (iv) a tension monitoring system (a TMS), and (v) one or more shifting platform safety devices. The digital control system may include one or more sensors for monitoring various parameters of the creel system, such as ambient temperature and/or humidity within the creel room. The digital control system integrates signals associated with the foregoing functions and/or parameters and system controls into a common Industrial Personal Computer (IPC), which may include a touch screen user interface. The digital control system may also allow for user input parameters which are not required for creel room function, but may be desirable for the end user, for example, the size of wire currently being run on the creel system. The IPC may be programmed to include a series of data display screens and control screens navigable by the operator. The IPC may communicate wirelessly or over cables/wires (e.g., Ethernet) and the IPC may include an internal Programmable Logic Controller (PLC) accessible by other customer PLCs. For example, the IPC PLC may be accessible by a calender PLC which sends signals commands to adjust air pressure modifying wire tension in the creel room in addition to monitoring other creel room data. Accordingly, the digital control system permits real-time monitoring of wire characteristics as the wire is un-spooled and fed from the creel system. Other embodiments described herein provide tension control systems utilizable in a creel system that include a sensor that measures the tension in a wire, which the tension control system utilizes to control the rotation of a spool of wire, and thus eliminate or minimize strain or breaking of the wire unspooled therefrom. The digital control system may also be configured to self-adjust based on measured data taken during a creel run, for example, logic may be programmed (e.g., on the IPC) such that a user-specified target tension is maintained throughout the creel run by measuring tension via the TMS, and adjusting the air pressure as required to maintain that tension.

Creel systems provide the mechanism for delivery to a calender or conveyor of cords, typically fabric or steel. The creel system is the first step in the manufacture of textiles or tires because it is important to the quality of the product that the cords be organized and brought together with even tension.

FIG. **1**A is a side view of an example creel system **100** that may incorporate the principles of the present disclosure. The depicted creel system **100** is just one example creel system that can suitably incorporate the principles of the present disclosure. Indeed, many alternative designs and configurations of the creel system **100** may be employed, without departing from the scope of this disclosure.

The creel system **100** may be utilized to deliver a plurality of cords, filaments, or wires W, for example, to a calender or conveyor machine (not illustrated). The wires W may comprise various materials, such as, for example, fabric or steel. As illustrated, the creel system **100** may include a creel frame **102**, a front organizing stand (FOS) **104**, and a main organizing stand (MOS) **106**, which are secured on a factory floor or ground G. In some embodiments, the creel frame **102**, the FOS **104**, and the MOS **106** are installed in a dedicated room commonly referred to as a creel room (not illustrated). The creel system **100** delivers wire W in direction D towards a calendering operation/process (not illustrated) which processes the wire W into a form utilizable in the final product (i.e., tires). In some applications, the frame **102** is comprised of multiple frame segments, side by side, that each operate (one after the other, or in unison) to deliver the wire downstream to the same calendering process, and in such application each side by side frame **102** is referred to as a creel row. FIG. **1**A illustrates the creel system **100** comprising a single creel row, however, one or more additional creel rows (with the same and/or different configuration than the first creel row) may be implanted in the system **100**. Each of the FOS **104** and MOS **106** provide organization for wires W in a system **100**. Eventually, each layer of wires W may be oriented in one flat plane for entry into the calender. The FOS **104** and MOS **106** are utilizable to gradually move the wires W into this position before they leave the creel room.

In some embodiments, the creel frames **102** are mounted on one or more platforms P that are movable and carry the creel frames **102** mounted thereon as they are moved relative to the ground G (i.e., of a creel room). The platforms P may have wheels (e.g., that ride along rails embedded in the ground G of the creel room. The platforms P may be motor driven and controllable, for example, by a shifting platform control (SPC) drive system **122**. With multiple creel rows in one system, one creel row can be positioned on the calender centerline while running, and the other creel row (or creel rows) may be positioned off to the side out of the way while being loaded with spools of wire W, such that, when the first creel row completes its run, it may be moved to the side and the next creel row takes its place minimizing calender downtime, and then, the creels rows may be switched again when the second row has finished (and so on). In some embodiments, multiple rows (for example, 2 rows) are positioned in a run position symmetric to the calender center line, in close lateral proximity to one another and, in this example, both creel rows would pay off wire W to the calender in unison; though, in some embodiments a single row is run from a position offset from the calender centerline.

The wires W are provided on reels or spools **108**. The creel frame **102** carries the spools **108** and may group or organize them in a series of rows that are vertically spaced (relative to the ground G) from each other. Thus, the wires W are payed-out from the spools **108** in a series of rows, where each such row comprises a bundle wires W. The wire W may be fed downstream in direction D to the FOS **104** and the MOS **106**, and then further downstream for calendering. FIG. **1**A illustrates an example where the FOS **104** includes a wire tree **110**, which may be configured detect loose wires in each row of wires W as they are fed further downstream. The wire tree **110** includes a plurality of detector rods or sensors arranged as branches that each correspond (or align) with a respective one of the rows of wires W, and the detector rods/sensors may be integrated within of a loose wire detection system (LWD System) and placed on either or both sides of the creel frame **102** for detecting the presence of a loose or sagging wire W in the wire rows. Also in the illustrated example, the FOS **104** includes a direction change apparatus **112** for receiving each row of wire W as they pass through the wire tree **110**. The direction change apparatus **112** may include a plurality of rollers configured to facilitate change of vertical direction of the wire W and facilitate its downstream delivery to the MOS **106** and any other downstream operations, for example, a downstream calendering operation. In addition, the illustrated example illustrates the FOS **104** includes an organizing board apparatus **114**, which may be either an "Eyelet Board" consisting of individual ceramic eyelets arranged in a steel plate, and/or a "Roller Board" comprised of a plurality of vertical and horizontal rollers, which define "Openings" through which the individual (or bundles) of wire W may be directed, and which further facilitates directing the wire W downstream in a particular vector depending on the end use application. Together, the direction change apparatus **112** and roller board apparatus **114** re-direct each row of wires W so that they may be received by the MOS **106**. In some examples, the wire tree **110**, the direction change apparatus **112**, and/or the roller board apparatus **114** are separate (stand-alone) components and/or any one of them may be integral with either the creel frame **102**. However, as described below with reference to FIGS. **1**B and **1**C, the wire tree **110**, the direction change apparatus **112**, and the organizing board apparatus **114** may be integrated together as a single structure, such as the FOS **104**.

In some examples, element **110** of FIG. **1**A may be a LWD Upright, element **112** of FIG. **1**A may be the Eyelet Board Upright, and element **114** of FIG. **1**A may be the DCR Upright. In some examples, element **110** of FIG. **1**B may be the LWD upright, but element **112** of FIG. **1**B may be the DCR Upright, and element **114** of FIG. **1**B may be the Roller Board Upright. In some examples, the LWD Upright, the Eyelet Board Upright, and the DCR Upright may be positioned in that order, rear to front (i.e., DCR being closest to calender). In other examples, for example, where utilizing rollers for the organizing, the LWD Upright, the-DCR upright, and the roller may be positioned in that order, rear to front (i.e., Roller being closest to calender).

In the illustrated embodiments, the creel frame **102** is a structure comprising a plurality of horizontal members H and vertical members V configured to array the spools **108** in a rectangular grid. In other embodiments, however, the creel frame **102** may be differently configured without departing from the present disclosure. Thus, the creel frame **102** may carry the spools **108** in various arrangements or organizations, rectangular or otherwise.

Here, for example, the creel frame **102** carries six rows and sixty-seven columns of spools **108**. It will be appreciated, however, that the creel frame **102** may include more or less rows and/or columns of spools **108** without departing from the present disclosure. For example, the creel frame **102** may be taller and include one or more additional rows of spools **108**, or may be shorter and include fewer rows of spools **108**.

Similarly, the creel frame **102** may be longer or shorter and include more or less columns of spools **108**. In embodiments comprising a multitude of columns of spools **108**, the creel frame **102** may include discrete frame sections or segments F. As will be appreciated, providing the creel frame **102** in discrete frame sections facilitates shipping and installation of creel frames **102** and provides the end-user the ability to scale creel operations up or down as needed. Here, for example, the creel frame **102** includes eight frame segments F1-F8 that together define an individual creel row, with frame segments F1 and F2 having six rows and six columns of spools **108**, frame segment F3 having six rows and five columns of spools **108**, and frame segments F4-F8 having six rows and ten columns of spools **108**. Accordingly, the exemplary creel system **100** of FIG. **1**A includes a single creel row of multiple frames supporting a total of four-hundred and two spools **108**. However, the creel system **100** may have various other set-ups without departing from the present disclosure.

FIG. **1**B is a close up view of the front portion of the creel system **100**, according to one or more embodiments of the present disclosure. In particular, FIG. **1**B illustrates the FOS **104** when installed proximate to a front portion (or flanged end pad) **102'** of the creel frame **102**, such as a mating flanged end pads. FIG. **1**C illustrates the FOS **104** without the creel frame **102**. Here, the FOS **104** includes a base **130** on which the wire tree **110**, the direction change apparatus **112**, and the organizing board apparatus **114** are mounted such that they together define an individual unit.

The wire tree **110** may include a plurality of detector rods **132** extending from the wire tree **110** and configured detect the presence of a loose or sagging wire W. Here, the detector rods **132** are organized to correspond to each row of wire W output from the creel frame **102**, and are utilizable with a loose wire detection (LWD) system **124**. A sleeve may be provided on any one or more of the detector rods **132** to thereby cover or insulate at least a portion of each particular detector rod **132**. For example, insulator sleeves may be provided around a portion (or length) of the detector rods **132** at which they may interact or engage (or be engaged by) the wire W.

The direction change apparatus **112** may include a plurality of direction changing roller assemblies **134** and the organizing board apparatus **114** may include a roller board assembly **136**. With this arrangement, the FOS **104** facilitates re-directing (or re-direction of) the rows of wires W into a new (vertical and/or horizontal) direction. In the illustrated example, the FOS **104** also includes a frame extension **140** configured to mount or attach to the creel frame **102**, such that the FOS **104** may be secured to the creel frame **102**. In some examples, a mounting pad **142** may be included on the top of the FOS **104** frame, which may be utilized in some embodiments to support additional overhead structure. This mounting pad **142** may be provided in multiple sizes and configurations.

The creel system **100** may further include a control system **116** for controlling operation of the various sub-systems of the creel system **100**. The control system **116** may comprise a IPC that may be installed at various locations proximate to the creel system **100**, for example, in the creel room, or may instead be provided at another location segregated or spaced away therefrom (e.g., outside of the creel room and/or in a separate control room). As mentioned below, the creel system may further include an air pressure control (APC) system **118** that, in the illustrated embodiment, supplies pneumatic power to the creel frame **102** via one or more conduits or hoses **120**; however, other types of power may be utilized instead or in combination with pneumatic power, such as hydraulic power. The APC system **118** may be provided at various locations relative to the creel system **100** and, in one embodiment, is disposed in the creel room, proximate to the creel frame **102**.

The central control system **116** may communicate with various sub-systems, sensors, or devices. For example, the central control system **116** may monitor and control the APC system **118**, the SPC drive system **122**, the LWD system **124**, a tension monitoring system (TMS) **126**, and/or various other systems or sensors and aggregate data about overall operation. The central control system **116** may be variously embodied without delineating from the scope of the present disclosure, for example, as an internal Programmable Logic Controller (PLC), personal computer, tablet, smartphone, etc. The central control system **116** may include a processor **115** that may be any of various commercially available processors including, without limitation, a single-core processor, a dual-core processor (or more generally by a multiple-core processor), a digital processor and cooperating math coprocessor, a digital controller, or the like. The central control system **116** may include at least one user interface **117** and/or display configured to present data related to the operation of creel system **100** to a user. The user interface **117** may also allow a user to input commands into the central control system **116** for the monitoring and controlling the various components. In some embodiments, the central control system **116** may be located in a creel room and/or at locations proximate to other control equipment (e.g., calender equipment control interfaces). In other embodiments, the central control system **116** may be mounted on a portion of the creel system **100** itself, such as a portion of the frame **102**. In even other embodiments, the central control system **116** is a remote device capable of operating the creel system from a distance, e.g., the central control system **116** is a device located in a room other than the creel room, or is a device held by an operator at a facility where the digital creel is installed or remotely.

The central control system **116** may also include a data storage **119**. Implementation of the associated data storage **119** is capable of occurring on any mass storage device(s), for example, magnetic storage drives, a hard disk drive, optical storage devices, flash memory devices, or a suitable combination thereof. The associated data storage **119** may be implemented as a component of the central control system **116**, e.g., resident in memory, or the like. The central control system **116** may then save data obtained during operation in a database or log file (event log) within the data storage **119** which may be utilized by operators, for example, to ensure efficient operation of the creel system and/or address logged errors, creating reports, etc.

FIG. **1**D illustrates an alternate MOS **106** that is utilizable with the creel system **100**, according to one or more embodiments of the present disclosure. In the illustrated example, the MOS **106** is provided on a track **150** to be movable in a path defined by the track **150**. Here, the MOS **106** includes a frame **152** and a plurality of wheels **154**. The wheels **152** are provided on the frame **152** to ride along the track **150**, and thereby constrain movement of the MOS **106** to a path **156** defined by the track **150**. Here, the track **150** extends in a direction that is substantially perpendicular to the direction D, such that the path **156** traveled on by the MOS **106** is also substantially perpendicular to direction D as indicated by the arrowheads of the path **156**. It will be appreciated, however, that the track **150** may have different geometries for positioning the MOS **106** as may be needed or beneficial in a particular creel setup. For example, the track **150** may be at least partially arcuate. Also, a drive system may be provided for moving the MOS **106** along the track **150**. For example, the MOS **106** may include an onboard motor assembly configured to drive one or more of the wheels **154**. Thus, the MOS **106** is movable such that it may be selectively aligned with various creel rows. When the MOS **106** is provided as a movable MOS, multiple such MOSs **106** may be utilized and each provided on the tracks, so that while one MOS **106** is running on center with the calender, another one or more MOS **106** is off to the side being loaded in front of another creel row that is not actively running; then, when the run is complete, the loaded MOS **106** can slide over to the center and be ready to run.

The MOS **106** includes a pair of guide roller assemblies **158***a*, **158***b*. In some embodiments, the guide roller assemblies **158***a*, **158***b* include flattening rollers. The guide roller assemblies **158***a*, **158***b* are arranged to take the grid pattern of wires coming through the main roller board, and level them into a flat plane when it exits the stand such that a flat plane of wires is provided as input to the calendering process. Thus, at some point, the wires W may be guided to a flat sheet/plane, either by rollers assemblies **158***a*, **158***b* integrated in the exemplary MOS **106** of FIG. **1**D, and/or as a separate roller prior to the calender intake. In some examples, the calender may include a guide roller at the intake to accomplish this. In some examples, the MOS **106** may include one or more additional roller assemblies in addition to the rollers **158***a*, **158***b*, or the MOS **106** may include a single roller assembly.

The MOS also includes a main organizing board assembly **160**. The main organizing board assembly **160** may be either a "Main Eyelet Board" comprised of ceramic eyelets in a steel plate, or a "Main Roller Board" comprised of a plurality of vertically oriented rollers and a plurality of horizontally oriented rollers. Accordingly, the wire W may be routed through the main organizing board assembly **160**, under (or over) the first guide roller assemblies **158***a* and over (or under) the second guide roller assemblies **158***b*, and then routed out therefrom for further downstream processing (i.e., to the calendar). Depending on which corresponding opening in the front organizing board a given wire W comes from before passing through the main organizing board assembly **160**, the wire W may be re-directed downward by a roller in the main organizing board toward the guide rollers **158***a* and **158***b*, or may be re-directed updward by a roller in the main organizing board toward the guide rollers **158***a* and **158***b*, or the wire may pass substantially horizontally through the main organizing board toward the guide rollers **158***a* and **158***b* (e.g., without being re-directed).

FIGS. **2**A-**2**D are perspective views of the creel system **100** of FIG. **1**A, according to one or more embodiments of the present disclosure. More specifically, FIG. **2**B is a partial perspective view of a rear end of the creel system **100** of FIG. **2**A, whereas FIG. **2**C is a partial perspective view of a front or output end of the creel system **100** of FIG. **2**A. Furthermore, FIG. **2**D illustrates a partial perspective view of a front or output end of the creel system **100** when partially assembled utilizing an alternate creel frame **102**, according to one or more embodiments.

As illustrated, the creel system **100** further includes a plurality of tension controller apparatuses **202** that are actuated by the APC system **118**. FIGS. **2**B and **2**C illustrate the frame **102** supporting a plurality of tension controllers **202**, whereas FIG. **2**D illustrates just two tension controllers **202** installed on the frame **102** (and without spools **108** thereon) to illustrate remaining locations at which tension controllers may be installed/mounted and how input air may be supplied to the tension controllers **202**. The tension controller apparatuses **202** are mounted on the creel frame **102** and carry (or hold) the spools **108** such that the wire W may be unwound therefrom for downstream operations and/or processing. The APC system **118** integrates with the tension controller apparatuses **202** and may be used to adjust (i.e., increase or decrease) the tension (or speed) on the wires as the spools **108** unwind (or rotate). Thus, the APC system **118** may cause the tension controller apparatuses **202** to increase friction applied to the spools **108** as they unwind, which provides greater resistance to rotation of the spools **108** and adds tension to the wire W as it is unwound therefrom. A plurality of intermediate support rollers **208** may be provided for helping support and/or direct the wire W.

The APC system **118** may be provided at various locations about the creel system **100**. For example, the APC system **118** may be provided in a console that is mounted to a part of the creel system **100**, such as the creel frame **102**, or, the APC system **118** may be differently provided, such as a stand-alone console that is positionable at various locations.

The APC **118** may be supplied with air regulated to a desired pressure, for example and without limitation, about 10 pounds per square inch (psi) to about 30 psi, including about 30 psi, and including about 25 psi. One or more input lines **204** may be provided for supplying the input air. In some embodiments, a single input line **204** is utilized to feed all tension controller apparatuses **202** in the creel system **100**. In other embodiments, a plurality of input lines **204** are utilized, with each such input line **204** supplying input air to a group of tension controller apparatuses **202**. In some examples, a network of hoses and lines may be routed throughout the frame to supply the various tension controller apparatuses **202** (or groups of tension controllers **202**). For example, the input line **204** may be connected to (and supply input air to) a plurality of manifolds **206**, where each of the manifolds **206** is connected to a group of tension controllers **202**. Here, each of the manifolds **206** is oriented vertically to supply columns of tension controllers **202** on opposing sides of the manifold **206**, where each tension controller **202** in a particular column is fed with supply air through an individual input line **210** extending from the manifold **206**.

The APC **118** may include at least one electronically operated valve (servo valve) associated/controlling at least one tension controller apparatus **202**. In some embodiments, an electrical signal for actuating each servo valve originates from the calender. In some embodiments, the central control system **116** is configured to actuate each servo valve. In some embodiments, a servo valve is associated/controls a single row of tension controller apparatus **202**, e.g., row **604** or column **606** of FIG. **6**. By adjusting the output air pressure to each row **604**, the central control system **116** can change the tension output of the tension controller apparatus **202**, thereby setting the desired tension of the wires W. In some embodiments, the valves are located in a pneumatic panel enclosure that may be positioned adjacent to the main electrical enclosure.

In some embodiments, the central control system **116** receives signals from the calender to set the target air pressure for at least one tension controller apparatus **202**. For example, the calender may send an input signal to the control system **116** to govern a pilot-operated regulator, in and, based on the value of that input signal, the control system **116** may then send an appropriate 4-20 mA signal to the servo valve driving the pilot regulator to a target pressure (e.g., determinable via a pressure to tension curve). Thus, the central control system **116** receives and analyzes input signals from the calender and then sends an appropriate electrical signal to the servo valves based on the input signals from the calender.

The central control system **116** may also be configured to send a digital signal back to the calender. The digital signal sent back to the calender may be indicative of a plurality of different parameters, such as, for example the set pressure point received, and/or the actual pressure reading from the servo valve. In some embodiments, the digital signal to the calender also includes the actual pressure reading at each creel row, which may be accomplished through the installation of a sensor and a slave PLC at each creel row to send the data to the central control system **116**. The additional data points provide the calender a more accurate representation of the actual realized pressure output based on the input target permitting the calender to be programmed to adjust target pressure based on this downstream feedback. Thus, the control system **116** is beneficial in that, compared to other systems that utilize just one-way communication between the calender and the air pressure control, the control system **116** is able to provide digital signal feedback to the calender as well as providing visual feedback to an operator via the user interface **117**.

The control system **116** may display information (e.g., the target pressure, actual valve pressure, and actual creel frame pressure) on the user interface **117**. The user interface **117** may comprise one or more touchscreen displays that may be provided at various locations, for example, in a creel room. Upper and lower pressure thresholds may be set/stored in the control system **116** to trigger an alarm state if the pressure deviates outside the acceptable operating limit. The control system **116** may be configured to maintain an event log, accessible to the creel room operator via the IPC touchscreen display, and which log may include a record of air pressure alarm state and activity.

FIGS. **3**A and **3**B are perspective views of an exemplary tension controller apparatus **202** utilizable with the creel system **100** of FIGS. **1-2**, according to one or more embodiments of the present disclosure. As illustrated, the tension controller apparatus **202** includes a spindle **302** that carries the spool **108** (FIGS. **1-2**), a brake drum **304**, a brake shoe **306**, a diaphragm actuator **308**, a control arm **310**, and a control arm roller **312**. The control arm **310** is connected to a pivot shaft **314** and configured to pivot towards and away from the spindle **302**. The control arm **310** is also connected to the brake shoe **306** such that the brake shoe **306** is urged into contact with the brake drum **304** as the control arm **310** pivots away from the spindle **302**.

The control arm roller **312** is connected to the control arm **310** and thus pivotable toward and away from the spindle **302**. The control arm roller **312** extends substantially perpendicular to the control arm **310** and substantially parallel with the spindle **302** and the spool **108** mounted thereon. Here, the control arm roller **312** is configured as a smooth cylindrical drum over which the wire W may pass, and is dimensioned to be at least as long as an axial length of the spool **108** to insure the smooth and uniform withdrawal of the wire W from the spool **108** without fouling or substantial deflection. As the wire W is payed out from the spool **108** and passes over the control arm roller **312**, the wire W may be maintained thereon by a pair of lateral flanges **316***a*, **316***b*.

The diaphragm actuator **308** is connected to the APC system **118** and is configured for pneumatic operation as hereinafter described. A piston **318** extends from a lower end of the diaphragm actuator **308**. The piston **318** is pivotally fixed to a brake arm **320**, and the brake arm **320** is fixed to the pivot shaft **314** such that rotation of the brake arm **320** rotates the pivot shaft **314** and the control arm **310** attached thereto. The diaphragm actuator **308** is supplied with fluid (e.g., air) at its upper end via a port **322** that may receive a hose (not illustrated) or other conduit leading from the APC system **118**. As will be appreciated, the port **322** may be interconnected to a manifold (not illustrated) which services a plurality of tension controller apparatus **202**, and application of the fluid via the APC system **118** causes actuation of the piston **318** relative to the diaphragm actuator **308**.

In operation, the spool **108** of wire W is mounted on the spindle **302**, and an end of the wire W is led from the top of the spool **108**, under and around the control arm roller **312** in a clockwise direction (in FIG. **3**A) and to a downstream take-up mechanism (not illustrated). Prior to actuating the downstream take-up mechanism, the control arm **310** and the control arm roller **312** will repose, displaced from the spool **108**. At this time, the brake shoe **306** is urged into engagement with the braking surface of the brake drum **304**, thereby arresting rotation of the brake drum **304** and the spindle **302** connected thereto, so that the wire W cannot be payed-out from the spool **108** that is mounted on the spindle **302**.

As the wire W is taken up, the control arm **310** and control arm roller **312** will rotate toward the spool **108** and, in so doing, will move the brake shoe **306** away from the brake drum **304**. Such movement of the brake shoe **306** relative to the brake drum **304** will reduce the friction force between the brake shoe **306** and the braking surface of the brake drum **304**, thereby permitting rotation of the brake drum **304**, the spindle **302**, and the spool **108** mounted on the spindle **302**. The force exerted on the control arm **310** by the wire W (when engaging the control arm roller **312**) is balanced against the friction between the brake shoe **306** and the braking surface of the brake drum **304** to maintain a constant tension in the wire W. The tension from this force-balance system is, within normal operating limits, independent of the coefficient of friction between the braking surfaces of the brake drum **304** and the brake shoe **306**. In the event the take-up decreases in rate or ceases, the requisite amount of braking is immediately applied so there is never any undesirable slack created in the wire W. Likewise, upon an increase in the rate of take-up, the balance between the braking force and the force applied by the diaphragm actuator **308**, permits a smooth and uniform rate of payout without stretching or jerking of the wire W.

Application of air pressure to the diaphragm actuator **308** via the APC system **118** actuates the piston **318** extending therefrom, thereby urging the brake arm **320** to rotate (counter-clockwise in FIG. **3**A and clockwise in FIG. **3**B). Such rotation of the brake arm **320** produces a torsional force about the pivot shaft **314** that in turn urges the brake shoe **306** into engagement with the braking surface of the brake drum **304**, thereby producing a desired tension force in the wire W. Since this torsional force must be overcome by the force exerted on the control arm **310** by the control arm roller **312**, as produced by the tension in wire W, before the control arm **310** rotates (clockwise in FIG. **3**A and counter-clockwise in FIG. **3**B), it constitutes a biasing force substantially proportional to the tension in the wire W.

Thus, the tension in the wire W may be adjusted by controlling the air pressure in the diaphragm actuator **308**. FIG. **4** is a curve showing the relationship between air pressure and wire tension (i.e., tension of a wire W) in an exemplary tension controller apparatus **202**, according to one or more embodiments. More specifically, FIG. **4** is an air pressure verses wire tension operating curve that may be utilized to control the tension in a wire W by adjusting the air pressure supplied to the diaphragm actuator **308**. The operating curve of FIG. **4**, however, may vary depending on a number of factors, including but not limited to, the amount of wire W on the spool **108** (i.e., whether the spool **108** is full or empty), the weight of the spool **108**, the operating speed, and the tension controller apparatus **202** utilized.

The creel system **100** may include various sensors and/or detection systems that monitor the wires W and the environmental conditions present in the creel room during operation. For example, the creel system **100** may include a wire W detection system that detects broken or loose wires W encountered in each row of wires W (i.e., the "LWD System"). In addition, the creel system **100** may include a tension monitoring system ("TMS") **126** for detecting and measuring tension in the wire W. The creel system **100** may include one or more additional sensors for measuring various other aspects of the creel system **100**, including environmental parameters and/or operational parameters associated with the creel system **100**. For example, the creel system **100** may include an environmental monitoring system (not illustrated) that includes one or more sensors for measuring conditions of the creel room such as temperature, humidity or moisture, and/or atmospheric pressure. As hereinafter discussed, the control system **116** may include software that permits the operator thereof to modify or control various operating parameters of the creel system **100** in response to the information gathered via the foregoing sensors and/or detection systems. Thus, the operator may fine-tune the tension of the wire W and/or fine-tune the environmental conditions experienced within the creel room.

FIG. **5** is a close-up view of the tension controller apparatus **202** of FIGS. **3**A-**3**B configured with limit switches, according to one or more embodiments of the present disclosure. The depicted arrangement of switches is just one example arrangement that can suitably incorporate the principles of the present disclosure. Indeed, many alternative designs and configurations of switches may be employed, without departing from the scope of this disclosure.

Here, a pair of limit switches **504***a*, **504***b* is provided on the tension controller apparatus **202**, and a switch blade **506** that is connected to the brake arm **320** of the tension controller apparatus **202**. The limit switches **504***a*, **504***b* may comprise various types of limit switch, such as the MICRO-SWITCH V3-1101-D8 or V7-2617D8. As the brake arm **320** rotates (with the control arm **310**) about the pivot shaft **314** (FIGS. **3**A-**3**B) in response to a change in the tension imparted by the wire W on the control arm roller **312** (FIGS. **3**A-**3**B), the switch blade **506** may reciprocate between the limit switches **504***a*, **504***b*. When the brake arm **320** rotates a sufficient degree clockwise or counter-counter-clockwise to the bounds of the normal operating range (e.g., to either the lower or upper bound of the range 0-35°), the switch blade **506** engages one of the limit switches **504***a*, **504***b* thereby indicating that either tension in the wire W is too high or tension in the wire W is too low indicating that the wire W is loose or broken. In other embodiments, a single limit switch (not illustrated) may be utilized to measure whether the tension is too high or whether the wire W is loose or broken. The single limit switch, for example, could be engaged by the brake arm **320** as the brake arm **320** rotates within normal operating limits (e.g., between the range 0-35°), but become disengaged when the brake arm **320** rotates in either direction outside of the normal operating limits. These embodiments, however, do not provide wire W tension measurements between the limits defined by the limit switches **504***a*, **504***b* (e.g., between the upper and lower bounds of the range 0-35°).

The limit switches **504***a*, **504***b* (or the single limit switch) may comprise various types of switches or sensors, as known in the art. Regardless of type, however, they may be configured to communicate with the user interface **117** (FIG. **1**) as hereinafter described. When engaged, for example, the limit switches **504***a*, **504***b* may supply a signal to actuate a transmitter (not illustrated) provided on the creel frame **102**. The transmitter communicates with a remote receiver (not illustrated) disposed in the user interface **117**, which may in turn produce an audio or video indication (or both) to remotely indicate that the tension in the wire W is too great or that the wire W is too loose or broken. The signal transmitted from the transmitter to the remote receiver may be coded to uniquely identify signals from a plurality of tension controller apparatuses **202**.

Various other devices or tension sensors may be utilized to monitor tension in the wire W instead of, or in addition to, the limit switches **504***a*, **504***b*. For example, one or more additional tension sensors may be utilized, such as a TE-24 Check-Line® heavy-duty tension sensor manufactured by Electromatic Equipment Company, Inc. (each, a "TE-24 sensor"). In one such embodiment, one TE-24 sensor is utilized for each of the tension controller apparatuses **202**. In other embodiments, however, one or more TE-24 sensors are utilized to monitor the tension of wires W of a group of tension controller apparatuses **202** (e.g., a row of tension controller apparatuses **202**). Thus, the TE-24 sensor may be utilized to measure a group of wires W, though the TE-24 sensors may locally influence the wire W tension as they are routed through its wheeled measurement mechanism. The TE-24 sensor, or any of them, may be provided at various locations about the creel system **100**, for example, at the front of the creel frame **102** and/or proximate to the FOS **104**. As mentioned above, the TE-24 sensor(s) may be utilized in addition to, or instead of, the limit switches detailed above. Also, it will be appreciated that tension sensors other than the TE-24 sensor may be utilized without departing from the present disclosure.

In another example, one or more tension sensing rollers may be utilized, such as the TSR-3 or TSR-4 Tension Sensing Roller manufactured by The Montalvo Corporation (each, a "tension-sensing roller"). In one such embodiment, a single tension-sensing roller is utilized for each row of tension controller apparatuses **202**. In this manner, each tension-sensing roller would provide an average reading of the tension of all wires W in the row rather than providing unique tension readings of the individual wires W in the particular row, and thus might not provide feedback of a variance in tension that would necessitate a shutdown (e.g., where 1 to 3 wires W are loose). As mentioned above, the tension-sensing roller(s) may be utilized in addition to, or instead of, the TE-24 sensor(s) and/or the limit switches detailed above. Also, it will be appreciated that tension-sensing rollers other than the TSR-3 or TSR-4 Tension Sensing Rollers may be utilized without departing from the present disclosure. For example, a tension-sensing roller that may measure each individual wire passing there over may be utilized.

In even other embodiments, tension of a wire W may be determined based on the position of the control arm **310** (or control arm roller **312**) associated with that wire W via a position sensor (the "Position Sensor"). In some of these embodiments, the Position Sensor is an instrument that measures angles of slope and inclination with respect to gravity. Accordingly, the Position Sensor may comprise various types of instruments, including but not limited to inclinometers, tilt sensors, accelerometers, gyroscopes, and combinations thereof, and may take measurements in one, two, or three axes. In one example, the Position Sensor is an inclinometer that is mounted to the control arm **310** (or the control arm roller **312**) and configured to determine the angular position thereof within its full range of motion (e.g., 0-35°). In even other embodiments, the Position Sensor is an inductive sensor that may determine the distance that the control arm **310** (or the control arm roller **312**) has traveled relative to a stationary reference point (e.g., on the tension controller apparatus **202**) to determine its angular position within the full range of motion. Moreover, a rotational encoder/sensor or similar device may be provided on any or each of the tension controller apparatuses **202**, in addition to or instead of any of the above, to carry out the same measurements.

After determining the position of the control arm **310** (or control arm roller **312**) via the Position Sensor, that information may be utilized to extrapolate a corresponding wire W tension from an operating curve such as that provided in FIG. **4**. For example, knowing the full range of motion of the control arm **310** (e.g., 0-35°), it may be determined that the wire W is broken when the control arm **310** is fully forward or that the wire W is overly tight when the control arm **310** is fully rearward, and intermediate wire W tension conditions may be determined by correlating an intermediate angular position there-between (i.e., when the control arm **310** is between the fully forward and fully rearward positions) with a tension obtained from an operating curve (e.g., FIG. **4**) based on air pressure. With this information (i.e., feedback), the creel system **100** may automatically adjust the air pressure provided to any individual or groups of tension controller apparatuses **202** as needed via the APC system **118** to optimize operation. In other embodiments, an operator of the creel system **100** may utilize this information to manually adjust the air pressure provided to any individual or groups of tension controller apparatuses **202** as needed via the APC system **118**.

Moreover, when paired with either or both of the tension-sensing roller(s) and the TE-24 sensor(s) detailed above, the Position Sensor's measurements may be correlated to obtain tension feedback from one or more tension controller apparatuses **202**, independently (see FIG. **6**); and then a table incorporating appropriate values (e.g., for tension, wire type, spool package, feed rate, etc.) at a set air pressure may be used to check the tension controller apparatuses **202** individually, in pre-determined zones (e.g., rows or columns), or in the entire creel system **100**, as described below with reference to FIG. **6**.

The creel system **100** may, thus, be modified to control automatically any or all of the tension control apparatuses **202** and thereby fine-tune the tension of the wires W. FIG. **6** illustrates a single frame F that may be incorporated into the creel frame **102** and the various zones of the frame F that may be independently controlled, according to one or more embodiments. In some embodiments, for example, each tension control apparatus **202** is provided in an individual zone **602** such that the creel system **100** may automatically controls each tension controller apparatus **202** individually. In other embodiments, each row of tension controller apparatuses **202** are organized as a zone **604** such that the creel system **100** may automatically control each row of tension controller apparatuses **202** as a group. Similarly, each column of tension controller apparatuses **202** may be organized as a zone **606** such that the creel system **100** may control automatically each column of tension controller apparatuses **202** as a group. In even other embodiments, all tension controller apparatuses on the frame are organized as a zone **608** so that the creel system **100** may control automatically the tension controller apparatuses **202** on each frame F (e.g., on frame F1) as a group independently from the tension controller apparatuses **202** on the other frames F (e.g., frames F2-F8); and in even other embodiments, all tension controller apparatuses **202** on the creel frame **102** are organized as a single zone (not illustrated) such that the creel system **100** may control automatically all of the tension controller apparatuses **202** on the creel frame **102** as a group. As mentioned above, in these or other embodiments, the creel system **100** may provide an operator thereof the ability to manually control the tension controller apparatuses **202** individually or in any number of groupings.

LWD systems may be integrated within various types of creel systems. As described herein, creel systems may comprise one or more creel rows, with each such creel row being a frame structure and a number of rows of tension controllers (e.g., four to six) mounted on both sides (i.e., the left-hand and right-hand) of the frame structure. All wires for a given row of tension controllers on a particular side of the frame are routed through an organizing board at the front of the creel row. In the course of operation of the creel, all the wires in each row and side will flow through a similar path.

FIG. **7** illustrates an alternate example creel system **700** incorporating the LWD system, according to one or more embodiments. It should be appreciated that, while the FOS **104** illustrated in FIG. **7** is different than the FOS **104** described with reference to FIG. **1**C, the FOS **104** of FIG. **1**C may be integrated within the system of FIG. **7** and vice versa, as the subject matter of the present disclosure may be utilized with various types of FOS designs. The LWD system is integrated within the creel system **700** illustrated in FIG. **7**, with all wires W for a given row of tension control apparatuses **202** on a side of the frame **102** being routed through an organizing board, such as the organizing board **702** mounted on stand **704** provided between the wire tree **110** and the direction change apparatus **112**, at the front of the creel row. In the course of operation of the creel system **700**, all the wires in each row and side will flow through a similar path. Here, the LWD system utilizes a plurality of loose wire sensor rods, such as the detector rods **132**, which are placed near the organizing board **702**, a few inches below the flow path of the wire W for a particular row of tension controllers **202** on a side of the frame **102**. The detector rods **132** may be insulated from the wire tree **110** and/or the frame **102**, and be arranged such that (at least) detector rod **132** is positioned to correspond with each row of tension controllers **202** on each side of the frame **102**. The detector rods **132** are mountable at various locations about the creel system where they are sufficiently proximate to a flow path of the wire W for a particular row of tension controllers **202** for a particular wire W in that particular row of tension controllers **202**. For example, the detector rods **132** may be provided on or about the FOS **104** (see, e.g., FIG. **1**C and FIG. **7**) and/or on or about the frame **102**. The loose wire detection rods **132** may detect when an individual one of the individual wires W has broken and fallen into contact with the detection rods **132**. In some examples, the loose wire detection rods **132** may detect loose/broken wires by closing a circuit to ground through the steel wire; however, in some embodiments, detection rods **132** may be differently configured such that they detect when a predetermined number of wires has broken or fallen into contact therewith. Also in the illustrated example, the LWD system includes an electrical enclosure/cabinet **706** that is connected to each of the detector rods **132**, and the electrical enclosure/cabinet **706** includes an indicator panel **708** that alerts the operator when one of the wires W has become loose enough such that it contacts one of the loose wire sensor rods **132**.

In the course of creel operation, not uncommonly a wire W breaks by an upstream snag or a defect in the wire W and, in this instance, the tension control apparatus **202** no longer maintains tension on the end of that wire W, allowing the wire W to sag and contact the detector rod **132**. This contact closes a circuit from the detector rod **132** to the electrical enclosure/cabinet **706**, thereby providing indication on the indicator panel **708**, for example, by activating a light and/or sounding a horn, etc. Based on which light is illuminated on the indicator panel **708**, the creel room operator can determine which row and side of the frame **102** the broken wire W is located. With that information, the operator can locate the broken wire W and manually determine which spool has the broken wire W and take appropriate action.

Embodiments of the control system **116** described herein may be integrated into various creel systems, including but not limited to the creel system **700** of FIG. **7**. The control system **116** may be utilized in combination with the electrical enclosure/cabinet **706** or the control system **116** may replace the electrical enclosure/cabinet **706**. FIG. **7** also illustrates an exemplary enclosure **710** that, for example, may house aspects of the APC **118**, the SPC drive system **122**, or other control features or safety features associated with creel systems. System air pressure is manually controllable via a pneumatic manifold system located in the APC enclosure panel, and an air pressure set point is also received from the calender room controlling the servo-operated pressure valve. Three pressures are monitored: Calender room set point, APC valve feedback and Frame pressure.

Thus, the LWD system may be in communication with the central control system **116**. For example, the LWD may include one or more slave PLCs, with each creel frame **102** being associated with an individual slave PLC (i.e., a slave PLC provided for each creel frame **102**). Here, each slave PLC may send to the central control system **116** signal data for each detector rod **132** associated with the particular frame **102** with which the slave PLC is associated. Thus, when a loose or broken wire W is detected (i.e., via contact with the detector rod **132**), the LWD system sends a signal to the central control system **116** which in turn triggers an alarm/indication. That is, the user interface **117**, or a display associated with the user interface display **117**, may show a graphic representation of the stacked detector rods **132**, highlighting the particular sensor rod **132** that detected the broken wire W. This information may also be recorded to the storage device **119** in the form of an event log. In addition, the central control system **116** may send a signal to the calender, where such signal is indicative of the status of each of the detector rods **132**. In this way, the calender operator has the option to act in response to a broken wire. Accordingly, the control system **116** may provide signal feedback to the calender.

FIGS. **8**A-**8**D illustrate exemplary aspects of the tension monitoring system (TMS) **126**, according to one or more embodiments of the present disclosure. In the illustrated embodiment, the TMS **126** includes a tension monitoring stand **800**. The tension monitoring stand **800** may be positioned at various locations, for example, it may be located in the creel room at a location proximate to where the wires W are exiting the creel room and traveling into the calender (i.e., the calender window). Thus, the tension monitoring stand **800** may be located after the MOS **106** (i.e., downstream from the MOS **106**) such that at least one wire W from the MOS **106** is guided or travels through the tension monitoring stand **800**. In some embodiments, the wires W are fed through a top portion of the stand **800**. The TMS includes one or more individual tension measuring sensors **802** that each measure tension of a wire W by routing the wire W through a plurality of grooved rollers **804**. The tension monitoring stand **800** is positionable over the wire ply, which wire ply may comprise a plurality of individual wires W, e.g. 600-1200 individual wires W. In some embodiments, three tension measuring sensors **802** are positioned along a width of the TMS stand **800** (as shown in FIG. **8**B) such that at least one wire W each from the left **810**, center **811**, and right side **812** of the wire ply can be measured (as shown in FIG. **8**C).

While FIGS. **8**A-**8**D illustrate an exemplary design of the tension monitoring stand **800** measuring tension on 3 discrete wires, the tension monitoring stand **800** may be differently configured to measure tension on a different number of discrete wires (i.e., more or less than 3 wires). For example, the tension monitoring stand **800** may be configured to measure total tension across all wires, for example, as an average of all wire tensions, and such tension monitoring stand may be integrated with a MOS or provided as a stand-alone device.

The TMS is in electronic communication with the central control system **116**. For example, one or more of the tension measuring sensors **802** may include a cable connector **820**, or output leads, such that it may be hardwired to the central control system **116**. In some examples, at least one of the tension measuring sensors **802** is in direct or indirect wireless communication with the central control system **116**. The tension measuring sensors **802** generate a tension output signal that is sent to the central control system **116**, for example, a 4-20 mA tension output signal that is indicative of wire tension. The control system **116** makes available the tension values measured by the tension measuring sensors **802** with a data address for the calender to be readable at any time. Calender equipment logic is able to measure the actual tension output for a specified air pressure input signal. This feedback loop allows the calender to make small adjustments to the air pressure input signal based on the measured tension output providing the calender a more precise method of tension control. The central control system **116** may output the tension measurements, for example, on the IPC touchscreen display, and such IPC touch screen may be made available for the creel room operator to monitor the tension in the wires W.

The user-interface **117** may have various configurations. In some embodiments, for example, as illustrated in FIG. **7**, the user-interface **117** includes a relay logic circuit with each output thereof being controlled by a combination of input or output conditions, such as input switches and/or control relays. In other embodiments such as those described with reference to FIG. **9**, the user-interface **117** includes a controller **116**, which receives signals from the various sensors and/or detection systems (i.e., that monitor the wires W and the environmental conditions present in the creel room during operation) to provide control signals to, for example, the LWD system, and/or the environmental monitoring system. The controller and these various sensors and/or detection systems may communicate by any suitable wired or wireless means. Thus, the user-interface **117** may be configured to provide the operator ability control operation of the creel system **100** during operation. For example, the central control system **116** may be configured to provide the operator of the creel system **100** visual and/or audible performance information in real-time and then receive commands from the operator such that the operator may make corrective inputs and/or optimize performance.

The central control system **116** may be provided in a control console **900**. FIGS. **9**A and **9**B illustrate exemplary control consoles **900**, according to various embodiments of the present disclosure. In various embodiments, the control console **900** houses the central control system **116** and includes a user-interface **917**, for example, in the form of an IPC touchscreen display. The control console **900** includes a controller as detailed above and is configured to provide the operator detailed system information and further configured to receive operator input in response thereto, as hereinafter described. As illustrated, the controllable user-interface **917** includes a touch screen display through which an operator may input commands to control the creel system **100** and watch (monitor) system performance as the creel system **100** may display any number of status alerts or notifications on the touch screen display. Here, the user interface **917** includes a touch screen display that includes a plurality of inputs **904** that an operator may manipulate, for example, to change the information displayed on the touch screen display. In some embodiments, the console **900** may further include a plurality of LED indicators **906** that, for example, may correspond to the inputs **904** and provide indication as to which input **904** is selected. An emergency stop **908** may also be provided.

Thus, the creel system **100** is controllable via the central control system **116** integrated into the control console **900**. The control console **900** may transmit information to and receive information from the the various creel sub-systems and/or devices described herein. With information received from these monitoring systems (or any of them), text or graphics depicting the wire condition (i.e., whether broken), wire tension, and/or environmental conditions in the creel room may be provided to the operator in real-time on the display **917**. The control console **900** may also include (or be connected to) other displays or inputs (not illustrated). For example, where a creel system **100** is installed in a creel room of a facility, one or more other computers may be connected to the user-interface via a LAN network or other means to provide additional users the ability to monitor and/or control the creel system **100**.

FIG. **9**B illustrates an alternate version of the control console **900**, according to one or more alternate embodiments. Here, the control console **900** is divided into separate sides **920**, **922**. The left side **920** includes an IPC **924**, a remote access control key **926**, a foldable shelf **928**, a keyboard and/or mouse access point (connector) **930**, and an emergency stop **932**. Here, the left side **920** includes a left door **934** that may be opened via door access latch **936**. The IPC **924** is programmable to include software for implementing one or more aspects of the central control system **116** described herein.

FIG. **9**C illustrates a close up of the right side **922** of the control console **900** of FIG. **9**B. As shown the right side **922** may include a right door **938** that may be opened via latch **936**. In addition, a power disconnect **940** and a sensor **942** for measuring temperature and/or humidity may be provided on the right side **922** of the control console **900**. Also, a plurality of buttons, indicators, and/or switches may be provided to control or operate the system or sensor systems in the event that the HMI display should fail. It should be appreciated that this would allow the user to continue to operate the system in the event of a screen failure.

The control system **116** may include a software platform that displays live measurements of the creel system **100** on the touch screen display **917** or IPC **924** and permits the operator to control operation thereof in real-time. FIGS. **10**A-**10**I are screenshots of the touch screen display **917** or IPC **924** and illustrate various aspects of the platform, according to one or more embodiments of the present disclosure. However, it should be appreciated that the software platform is fully customizable and modified for an end user's particular application, and that the following screen shots are just one exemplary embodiment of the software platform. Thus, the software platform may comprise any number of other screen shots and/or functions without departing from the present disclosure.

FIG. **10**A illustrates an introduction screen **1002** of the platform, according to one or more embodiments of the present disclosure. Here, the platform includes language translation capabilities so that the user may select which language is displayed on the touch screen display **917**, and FIG. **10**B illustrates a translation selection screen **1004** of the platform, according to one or more embodiments of the present disclosure. In some embodiments, selection of the language will also change the units in which the measurements are displayed. For example, if an operator selects German translation, the units may be displayed in SI units, whereas if an operator selects English translation, the units may be displayed in either US customary units (e.g., for US users) or SI units (e.g., for British users).

FIG. **10**C illustrates a system function selection screen **1006** of the platform, according to one or more embodiments of the present disclosure. Here, the logo of the operator's company may be displayed on the screen, and the operator may select the particular functionality that he/she would like to access. For example, the function selection screen **1006** may include various function selections for the operator, such as an operation screen selection button **1008***a*, an alarm screen selection button **1008***b*, a system information screen selection button **1008***c*, and/or a maintenance screen selection button **1008***d*. This screen **1006** may also include a selection to take the operator back to the home screen **1002**.

FIG. **10**D illustrates an operation screen **1010** according to one or more embodiments of the present disclosure. The operation screen **1010** may be accessible by pressing the operation screen selection button **1008***a*. The operation screen **1010** may be the main production screen, and include various indicators and/or selections, such as Mode of Operation indicator **1011**, temperature and/or humidity indicators **1013**, selected creels indicators (i.e., on or off) and which may be displayed to mirror creel light stacks, position status (i.e., whether the creel position is valid or invalid), selection status (i.e., whether the creel row selection is valid or invalid), machine status (i.e., whether the machine is ready or not ready), etc. This configuration may allow selection of a single creel run position, may allow for starting of automatic shift cycle, and may also include a "ready for production" push button to signal to the calender that the creel is ready for production. Also, a home button **1015***a* may be located on the operation screen **1010** to allow the operator to return to the home screen. Also, operation screen **1010** may include selections to allow migration and navigation between screens on the system, for example, an APC Screen button **1015***b*, an LWD Screen button **1015***c*, and an Alarm Screen button **1015***d*.

FIGS. **10**E-**10**F illustrate a single creel operation or production screen **1014** and a dual creel operation or production screen **1016**, respectively, according to one or more embodiments of the present disclosure. These screens display temperature and humidity data. With regard to the single creel operation or production screen **1014**, APC activity is displayed, for example, calender set-point pressure in psi, APC solenoid valve pressure set-point feedback on selected creel in psi, selected creel frame actual pressure in psi. With regard to the dual creel operation or production screen **1016**, calender pressure set point in psi may be received from calender via a network connection, and information displayed on the screen **1016**. Also, APC solenoid valve pressure set feedback pressure for selected creel(s) is received from the APC (and generated by the pressure transducer located on the APC), and pressure feedback to the servo air valves can be compared against the value sent from the calender. In addition, actual pressure of the selected creel frame(s) may be monitored, as such data is transmitted back to the PLC to show any differences from setpoint, feedback, and the actual frame. Both the single and dual creel operation or production screens **1014**, **1016** may also provide for monitoring of the tension monitoring stand **800**, for example, display of the tension readings from sensors **802**, and the screen **1014** may display an average tension of the wires selected at a tension monitoring stand **800**, and may provide navigational buttons for migrating between screens, such as function screens and the home screen.

FIGS. **10**G-**10**J illustrate various LWD associated screens **1018**, **1020**, according to one or more embodiments of the present disclosure. In particular, FIGS. **10**G and **10**H illustrate representation of the LWD system during a single creel operation, whereas FIGS. **10**I and **10**J illustrate representation of the LWD system during a dual creel operation. These screens depict a wire tree with conductive sensors, and may indicate present of a loose or broken wire by highlighting the particular conductive rod that was tripped or that sensed a loose or broken wire. For example, FIGS. **10**G and **10**I include a graphical representation of a wire tree with conductive rods when unactivated (i.e., not an alarm state), whereas FIGS. **10**H and **10**J include a graphical representation of the wire tree with a conductive rod when activated (i.e., in an alarm state). In FIG. **10**H, the screen displays that conductive rod R**2** has been activated/tripped, where conductive rod R**2** corresponds with the actual conductive rod located on the right side and second row from the top of the wire tree; however, nomenclature may be differently provided, for example, such that R**1** corresponds to the bottom most right-hand side, and R**5** corresponding to the upper most right-hand side. This way, the operator may readily determine that a broken or loose wire is present in the operating creel at wire row right **2**. In FIG. **10**J, the screen displays that conductive rod L**2** has been activated/tripped in the left creel, where conductive rod L**2** corresponds with the actual conductive rod located on the left side and second row from the top of the wire tree of the left creel. This way, the operator may readily determine that a broken or loose wire has been detected in the left creel at left wire row **2**.

FIG. **10**K illustrates an alarm and history log screen **1022**, according to one or more embodiments of the present disclosure. The alarm and history log screen **1022** is accessible via the alarm screen button **1015***d* on any of the preceding screens. The alarm and history log screen **1022** includes a log of active alarms and a log of alarm history, and either or both log may track various statistics associated with each event, including but not limited to date, time, description, associated system, status, and action taken, etc. The screens may be customizable and may log additional data. For example, the operator may customize the either/both logs to list all or only list certain events that require immediate corrective action, and/or to allow for color coding of different events based on their status (e.g., events that have not yet been fixed may be highlighted in red, whereas events that are fixed are green and events that have been checked and/or under examination are yellow). Also, the operator may assign an event to one of his or her colleagues such that said colleague receives notification of the alert (e.g., on his or her mobile device with mobile application as hereinafter described) and may then take corrective action while the operator monitors the status of the event while his or her colleague addresses the same. The logged data and information may be exported to various different devices, including via USB download or other wireless transmission. The alarm and history log screen **1022** exemplified in FIG. **10**K doesn't include any logged events. FIG. **10**L is a listing of example alarm messages that may be populated within the logs on the screen **1022**. Also, the alarm and history log screen **1022** may provide navigational buttons for migrating between screens, such as function screens and the home screen.

FIG. **10**M illustrates a maintenance screen **1024** according to one or more embodiments of the present disclosure. The maintenance screen **1024** may be accessible by pressing the maintenance screen selection button **1008***d*. The maintenance screen **1024** may provide temperature and humidity readings (or other environmental info) in real time, and also provide access to information that may be helpful to maintain and/or operate the system. For example, the operator may access electrical schematics of the various equipment, which he/or she may export to another device or printer for later use. Also, the operator may access the handbook, FAQ and/or other warranty info. In some embodiments, the operator can communicate with maintenance personnel via the software, for example, the operator could schedule a maintenance appointment via functionality accessible on the maintenance screen **1024**. Also, the maintenance screen

1024 may provide navigational buttons for migrating between screens, such as function screens and the home screen.

FIG. **10**N illustrates a System Info screen **1026** according to one or more embodiments of the present disclosure. The System Info screen **1026** may be accessible by pressing the system info selection button **1008***c*. Also, System Info screen **1026** may provide information and details about the particular creel system and equipment utilized therewith, and may include navigational buttons for migrating between screens, such as function screens and the home screen.

Control of the creel system **100**, however, may also be implemented using remote devices, including through use of creel system control and/or visualization applications installed on computers, laptops, or mobile devices, etc. For example, a mobile device or smart phone "app" may be installed to communicate with the control system **116**. In this example, such mobile device could communicate with the central control system **116** to provide remote monitoring of various creel systems, functions, devices, in a similar manner as described with the control console **900**, such that the operator may remotely monitor operation parameters and/or environmental parameters of the creel operation. Such communication between the remote device and the control system **116** (or control console **900**) may occur via various wireless or wired communication means, for example, wirelessly through BlueTooth™ or WiFi™, wirelessly through the Internet where the controller of the control system **116** (or control console **900**) is internet-enabled, via a hard hardwire (e.g., USB cable, Ethernet cable (e.g., CAT6 cable), etc.), or combinations thereof. The app may transmit information to and receive information from control system **116**, or may directly transmit information to and receive information from one or more systems, sensors, or devices of creel system, such as the LWD system and/or the environmental monitoring system.

In alternative or complementary embodiments, the app may include the same operator input options as provided on control system **116** to provide control commands to the controller (of the controllable user-interface **917**) to manually or automatically effect tensioning of the wire W and/or monitor (and/or adjust) environmental conditions of the creel room. In further alternative or complementary embodiments, security features may be provided through or built into the app. For example, the phone can implement a security control (e.g., password, PIN, code, pattern, biometric scan, and others) that may prevent total access to the platform, allow monitoring but prevent remote control, transmitting or receiving data to or from the app, or other activity related to creel system (e.g., changing environmental conditions in the creel room) based upon permission granted through successful passing of the security control.

FIG. **11** illustrates aspects of the shifting platform control (SPC) **122** when implemented on a multi-row creel system **1100**, according to one or more embodiments of the present disclosure. While the multi-row creel system **1100** may be similar in some aspects to the creel system **100**, **700** discussed above, the creel system **1100** is provided on shifting platforms **1110***a*, **1110***b* and includes SPC **122**. In this type of creel system **1100**, individual creel rows **1111***a*, **1111***b* (generally, **1111**), each having its own creel frame **102** (and each comprising one or more frame segments F), a front organizing stand (FOS) **104**, and a main organizing stand (MOS) **106** are mounted to steel platforms **1110***a*, **1110***b* with each such platform P carrying an individual creel row **1111**. The platforms **1110***a*, **1110***b* may include a motor **1108** configured to drive wheels (not illustrated) which ride along rails **1106** embedded on the creel room floor. The motors **1108** may be controlled at a main enclosure of the system which may include, for example, an emergency stop button and push buttons for each row to control right and left shift. The main enclosure may be located in the creel room along with other system controls. In other embodiments, each row may have its own control panel mounted directly to the shifting row. With multiple creel rows **1111***a*, **1111***b* in one system **1100**, one row **1111***a* can be positioned on the calender centerline **1104** while running (in a "run position"), and the other row **1111***b* can be positioned off to the side (in a "loading position"). In other embodiments, 2 rows may be positioned symmetrically about the calender centerline such that both may run together. In this way, the second row **1111***b* is out of the way of the calender centerline **1104** and can be loaded with spools. When the first row **1111***a* completes its run, it may then be moved to the side, for example, on the embedded rails **1106** wherein the second row **1111***b* takes its place along the calender centerline **1104**. This minimizes calender downtime between runs. The rows **1111***a*, **1111***b* can be switched again when the second row **1111***b* is finished.

The central control system **116** and the motors **1108** may communicate with each other. This allows an operator manipulating the user interface **117**, **917**, to move each creel row **1111***a*, **1111***b* to a desired position on the creel room floor. In some embodiments, the creel rows **1111***a*, **1111***b* are configured to move in series to its new target position. While two creel rows **1111***a*, **1111***b* are illustrated, it is to be appreciated that the number of creel rows **1111** is non-limiting. The central control system **116** provides the ability to automatically move all the rows to a desired position based on a single specified operator input, as compared to controlling the platforms using press-buttons in a main enclosure. As a further example, FIG. **12** illustrates a creel room with eleven creel row positions **1111**.

In some embodiments, each platform **1110***a*, **1110***b*, includes at least one proximity sensor **1105** which is configured to detect features **1109** on the creel room floor G. The features **1109** may be in the form of a pad in the floor. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor, for example, as illustrated in FIGS. **15**A-**15**C. In even other embodiments, mechanical limit switches may be used to determine position. This allows each platform **1110***a*, **1110***b* to shift until it reaches the detectable feature **1109**. For example, the detectable features **1109** may be pads that are detectable by the proximity sensor(s) **1105** and located at the loading and running positions for that creel row. In some examples, limit switches may be utilized to prevent overtravel of the platforms **1110**, for example, the outer platforms.

In some embodiments and with reference to FIG. **12**, creel row **1111** position is assisted by placement of encoded proximity plates **1209** at predetermined locations in the creel room. That is, the feature **1109** on the creel room floor is embodied as a proximity plate **1209**. In some embodiments, the plates **1209** are constructed of 0.5 inch nylon with a plurality of machined pockets each configured to received a pad (e.g., a steel or nylon pad) secured to the pocket with fasteners, adhesive, or the like. The plates **1209** are affixed to the creel room floor G, for examples, with screws after the plate position is verified. As compared to designs implementing embedded plates, this design allows for later adjustment of creel row positions. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor. In even other embodiments, mechanical limit switches may be used to determine position.

FIG. **12** illustrates the general layout of proximately plates **1209** in a creel room. Each plate **1209** is encoded by placing either a nylon or metal pad in each of the pockets, described in greater detail below. When the plates **1209** are positioned correctly beneath proximity sensors **1105**, the proximity sensors **1105** are able to read the encoding of the of the plate **1209**. As illustrated in FIG. **12**, multiple plates **1209** having a unique encoding (i.e., position of metal and nylon pads on the plate **1209**) are secured to the floor near the FOS **104**. Each creel row **1111** rides on rails **1106** to a desired position in relation to the plates **1209**. The plates **1209** may be positioned such that multiple zones are defined in the creel room. That is, plates **1209** may be positioned in front of the FOS **104** defining a run zone **1220**. Plates may also be positioned away from the FOS **104**, for example, on opposing sides thereof, defining an exclusion/loading zone **1222**. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor. In even other embodiments, mechanical limit switches may be used to determine position.

The central control system **116** may utilize the plates **1209** to determine where each creel row **1111** is located before automatic functions will execute. The creel rows **1111** not in the run zone **1220**, i.e., the creel row(s) **1111** located in the excluded/loading zone **1222**, may be ignored by the central control system **116** for alarm purposes. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor. In even other embodiments, mechanical limit switches may be used to determine position.

FIG. **13**A illustrates and exemplary plate **1209** for secured attachment to the floor, according to one or more embodiments of the present disclosure. The plates **1209** are configured to be detected by proximity plate detectors to thereby provide location of creel rows **1111** which may be utilizable for automatic functions. The plate **1209** includes a substantially planar body **1302** having a thickness that allows for a plurality of pockets **1304** serially aligned along the planar body. Each pocket **1304** is configured to receive either a metal or non-metal complementary shaped pad (**1305**, **1306**, respectively). The order and number of metal pads **1305** and non-metal pads **1306** in the pockets **1304** provides a binary coding that is able to be read by proximity sensors **1105** located on the platform **1110**. In the illustrated embodiment of FIG. **13**A, the body **1302** includes a total of six pockets **1304** configured to receive a metal pad **1305** or non-metal pad **1306**. In some embodiments, the metal pad **1305** is a steel pad. In some embodiments, the non-metal pad **1306** is a nylon pad. While 6 pockets are illustrated it is to be appreciated that the number of pockets is not limiting and that a body may include more or less than 6 pockets. Furthermore, while the pockets **1304** and inserted pads **1305**, **1306** are illustrated in a spaced apart serial alignment, the serial position is not limiting. That is, any arrangement of pads, e.g., in a circle pattern, block pattern, etc. that can be read by a corresponding proximity sensor **1105** may be used without departing from the scope of the present disclosure. In some embodiments, the plates **1209** may be installed or positioned inside the first or front rail **1106**. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor. In even other embodiments, mechanical limit switches may be used to determine position.

FIG. **13**B illustrates a proximity pad detector unit **1320**, according to one or more embodiments of the present disclosure. The proximity pad detector unit **1320** includes a frame **1322** and at least one sensor or detector **1324** supported by the frame **1322**. The frame **1322** may be connected to the creel row **1111** such that it moves with the creel row **1111** and provides indication when moved over the detection plates **1209** and thereby provides indication as to the location of the creel row **1111** based on which detection plate(s) **1209** is read. In some embodiments, the detector **1324** includes a plurality of individual detector indicators **1326** (e.g., LEDs) that, when energized will provide indication (e.g., be energized or glow). In some examples, the detector indicators **1326** corresponding with the steel inserts **1305** in the plate **1209** would be activated/energized, whereas the detector indicators **1326** associated with the non-metal inserts **1306** would not be energized. In the illustrated example of FIGS. **13**A and **13**B, the plate **1209** includes six pockets **1304** for six inserts, with the first pocket and fifth pocket each being provided with a metal insert **1306*a***, **1306*e***, respectively, and the detector **1324** includes six individual detector indicators **1326** that each correspond with one of the pockets **1304** on the plate **1209**, with the first detector indicator **1326*a*** being activated/energized when oriented over the first metal insert **1306*a*** and the fifth detector indicator **1326*e*** being activated/energized when oriented over the fifth metal insert **1306*a***. In some examples, one or more of the plates **1209** may be provided to include metal inserts **1305** in all of its pockets **1304** to confirm functionality of the detectors **1326**, for example, when the creel rows **1111** are moved individually into a center row location. The proximity pad detector units **1320** may be in communication with the central control system **116**, such that the central control system **116** may access data from the detectors **1324** to thereby determine positions of the creel rows **1111**. In other embodiments, the proximity sensor is replaced with an RFID reader which senses RFID tags mounted to the floor. In even other embodiments, mechanical limit switches may be used to determine position.

FIGS. **15**A-**15**C illustrate an alternate system **1500** for sensing position of the shifting creel rows, according to one or more alternate embodiments. The sensing system **1500** may include one or more RFID tag readers **1502** configured to identify/sense RFID tags **1504** mounted to the floor. Each creel row may include at least one of the readers **1502**. The RFID tags **1504** may be retained on the floor via a plate **1506**. While the sensing system **1500** may be utilized in lieu of the system of FIGS. **13**A-**13**B, in some examples, the sensing system **1500** may be utilized in combination with the system of FIGS. **13**A-**13**B. For example, some creel rows may include the system of FIGS. **13**A-**13**B, whereas other creel rows may include the the sensing system **1500** of FIGS. **15**A-**15**C; and/or at least some creel rows may include both the system of FIGS. **13**A-**13**B and the sensing system **1500**.

Creel systems described herein may also include one or more safety features or devices. Such safety features and/or devices may be controlled by the control system **116**. That is, several devices within the creel system **100**, **1100** generate information to enhance the safety of system operation. Safety features and devices may include, for example, safety rope pull switches, collision detection and avoidance systems, and platform drive photo eyes for variable frequency drive movement interrupt.

Regarding the safety rope emergency switches (SRES) and with reference back to FIG. **11**, pull switches **1140** may be provided to stop operation of the creel system **1100** and/or to send a signal to shut down production. The pull switches **1140** may be mounted along the sides of the creel rows **1111**. The switches **1140** may be mounted or fixed to the frame **102** (or a frame segment F thereof), for example, at a front end **1142** of each creel row **1111**. In other embodiments, the switches **1140** may be mounted to the frame of the FOS. A rope (not illustrated) may be connected to each pull switch **1140** for activating or engaging the pull switch **1140**. The ropes may be routed from their associated pull switch **1140** along the creel row **1111**, for example, along a long side **1144** of the creel row **1111***b* towards a rear end **146** of the creel row **1111***b*. The rope may be positioned at various locations about the frame **102**, for example, where it is user accessible and, in one example, the rope is positioned at the level of the third row of tension controllers **202**. However, the position and length of the rope is adjustable, and may be routed into various positions as may be desirable in a particular end use application. The switch **1140** is designed to send a SRES signal when the rope is pulled, which signal may be used by the calender operator to shut down production in case of emergency. The pull switches **1140** may be in electronic communication with the central control system **116** and, in some embodiments, the safety SRES signals from the pull switches **1140** are routed to the central control system **116** and thereby made available at a data address for the calender to read at any time. For example, the pull switches **1140** may be connected to the central control system **116** such that, when the rope is pulled, a warning light on the user interface **117**, **917** may become illuminated and/or some other indication may be generated thereon, with the SRES signal being appropriately addressed for the calender to read or retrieve at any time. Thus, the generated SRES signals may be addressed for the calender to read at any time, and this information may be consolidated with other data desired by the calender without need for additional wiring. In some embodiments, some of the pull switches **1140** are activate and some are inactive. For example, during a production run, the creel system **1100** may scan only the operating creel row **1111***a* in the calender centerline **1104** for the rope switch **1140** activation, while the safety ropes and pull switches **1140** in inactive creel rows (e.g., creel row **1111***b*) are not monitored, thereby allowing the loading/unloading/maintenance of such inactive creel rows without interrupting the production run in the event that the switch **1140** be tripped.

In some embodiments, the creel system **1100** includes a collision-avoidance system (CAS) for detecting neighboring creel rows **1111** and preventing collisions during movement operations involving any of the creel rows **1111**. The CAS comprises collision-avoidance photo eyes **1150** for detecting neighboring creel rows **1111**. The eyes **1150** may be positioned on the frame **102**, for example, at lower outwardly extending portions of the frame **102**, with two photo eyes for each creel row **1111***a*, **1111***b*, each creel row **1111** having a first eye **1150** for monitoring the left directional movement of the associated creel row **1111** and a second eye **1150** for monitoring the right directional movement of the associated creel row **1111**. The eyes **1150** may be in communication with the central control system **116**. Communication between the photo eyes **1150** and the central control system **116** may be achieved wirelessly and/or via wired connection. The collision-avoidance photo eyes **1150** prevent creel rows **1111***a*, **1111***b* from colliding into each other during any motor driven event.

The CAS system is usable to detect the creel row **1111***b* next to the moving creel row **1111***a* and, upon detection of the neighboring creel row **1111***b*, affect driving of the moving row **1111***a*. For example, the CAS may be configured to transmit a stop signal that disables the drive command in that direction but does not affect drive function in the opposite direction, and in such examples, any disabled drive command or drive functionality may be reset or restored when the moving creel row **1111***a* has moved to a position where the neighboring creel row **1111***b* is no longer within the detection range or zone of the collision-avoidance photo eyes **1150**. In some examples, the CAS may be configured to transmit a stop signal that disables the drive command in that direction and then transmit a go command to automatically enable drive function in the opposite direction. The CAS system may be activated by movement (manual, automatic or IPC mode) of a creel row **1111***a*, **1111***b*, such that the CAS is in an inactive or sleep mode until it is activated or awakened by movement.

In some embodiments, the photo eyes **1150** may comprise beam type devices mounted about the moving creel row **1111**. In some embodiments, the photo eyes **1150** each project a signal or beam (e.g., infrared) to a receiver **1152** at the other end **1146** of the creel row **1111**, thereby creating a beam extending along a perimeter of the creel row **1111**, for example, along the sides of the creel row **1111**. One side will have its transmitter pointed to the rear, while the other side will have its receiver **1152** facing to the rear, whereby mounting them in opposite directions may help avoid any bleed of signal causing a false trip signal. When the beam on either side is interrupted, a corresponding creel frame safety relay is tripped signaling the central system **116** of a fault and shutting down the drive system and thereby stopping movement. Operational information about the eyes **1150** and any faults may be visually presented on the user interface **117**, **917** (e.g., indicators lights, screen alerts or messages, and/or graphics) and/or audibly presented at and/or near the console **900**, for example, speakers, sirens, etc. This operational information may be presented to the operator at the control console **900** in a manner indicative of the location at which interruption of the beam was detected to be (e.g., indicator lights associated at a particular row or column of the creel). The system may help prevent personnel from being hit by a moving frame and creel row and to avoid any obstructions on the floor that would impede the movement of the creel row. Also, the system may be activated by movement (manual, automatic or IPC mode) of a creel row **1111***a*, **1111***b*, such that the system is in an inactive or sleep mode until it is activated or awakened by movement. In some examples, when the system has been tripped and the issue causing the trip has been addressed, the drive system may be brought back online by pressing a reset in of the control system **116**, for example, in the console **900**.

In some embodiments, the central control system **116** is configured to prevent over-travel of the creel rows **1111**. For example, the outer side of the first and last platform **1110***a*, **1110***b*, may be equipped with a mechanical travel limit switch configured to prevent over-travel of the platform **1110***a*, **1110***b*, beyond the extent of the rails **1106**. For example, when a moving platform actuates a limit switch, the limit switch generates a limit switch signal readable by the central control system for controlling the motion of a moving creel row. These switches may directly disengage the drives of the end of creel rows **1111***a*, **1111***b*, for motion in the outward direction. In some examples, such mechanical limit switch may be reset by manually reversing movement of creel row **1111** at the console **900**. In some embodiments, reaching the over-travel limit position may restrict motion to only allow the creel row to travel back away from the end of travel.

In some embodiments, the creel system **100**, **1100** includes environmental sensors, including but not limited to temperature and humidity sensors. That is, if present, at least one of an environmental sensor is in electronic communication with the central control system **116**. The central control system **116** receives environmental data (temperature data, humidity data, etc.), if the values of the environmental data are beyond a predetermined threshold, the central control system **116** issues an alarm notifying an operator at the user interface **117** of the environmental status. In some embodiments, the environmental data is recorded to the data storage **119**. In yet still other embodiments, the environmental data generated by the environmental sensors is made available with a data address for the calender to read at any time.

In some embodiments, the control system **116** is configured to access a cloud network to thereby enable a third party to remotely access the control system **116**. In yet other embodiments, the control system **116** is configured to allow point-to-point direct communication with the system manufacturer via internet protocol. For example, manufacturer technicians may utilize this feature to provide support and troubleshoot any issues with the system **100**, **1100**, remotely. In some examples, this feature allows the manufacturer to connect through a customer network to access the software loaded to the central computer system **116**. Access to the system **100**, **1100** is controlled by the customer by a key on the physical console **900**, so that the manufacturer is only able to access the system **100**, **1100** when the customer explicitly turns on access maintaining security on their network. Using the remote access feature, the manufacturer will be able to provide software updates and enhancements as they are developed without requiring physically accessing the machine.

In accordance with another aspect of the present disclosure and with reference to FIG. **14**, a digital creel system **1400** for automatic and efficient creel functions is provided. It will be appreciated that the various components depicted in FIG. **14** are for purposes of illustrating aspects of the exemplary embodiment, and that other similar components, implemented via hardware, software, or a combination thereof, are capable of being substituted therein. The system **1400** is configured to control the power or operation of a creel system, e.g., creel system **100**, **1100** or similar material handling equipment, based on data received from various sensors and subsystems.

As shown in FIG. **14**, the system **1400** includes a central control system represented generally as the central computer system **1416**, which is capable of implementing the exemplary method described herein and below. The central computer system **1416** may be variously embodied without delineating from the scope of the present disclosure as an industrial computer, programmable logic controller (PLC), personal computer, tablet, smartphone or other known device that hosts a software platform and/or application. The exemplary computer system **1416** includes a processor **1424**, which performs the exemplary method by execution of processing instructions **1426** that are stored in memory **1428** connected to the processor **1424**, as well as controlling the overall operation of the computer system **1416**.

The control system **1416** may also include a user interface similar to the user interface **117**, **917** of central computer system **116** for the monitoring and controlling the various components of the creel system. The control system **1416** is in electronic communication with the sensors and subsystems described in greater detail herein and is configured to receive data (via wired and/or wireless connection) related to or indicative of operation of a creel device **100**, **1100** as collected by such sensors and subsystems.

The instructions **1426** include an air pressure control (APC) module **1430** configured to control air pressure via the APC system **118** to tension control apparatuses **202** as each are described above in relation to system **100**. In this way, the APC module **1430** can increase or decrease friction applied to the spools **108** by increasing/decreasing air pressure, by controlling various servo valves based on a detected tension of the wires W, and/or signals originating from the calender **1410** in communication with the central control system **1416**. In other words, the central control system **1416** receives signals from the calender **1410** to set the target air pressure for at least one tension controller apparatus **202** (or at least one row of tension controllers **202**). In some embodiments, the central control system **1416** is also configured to send a signal back to the calender **1410** including the set pressure point received and/or the actual pressure reading from a servo valve of the APC system **118**.

The instructions **1426** also include an LWD module **1432** that, when implemented by the processor **1424**, controls the power and operation of the LWD system as well as receives data signals therefrom as described above. That is, the LWD module **1432** is configured to determine when the wire W contacts a sensor rod **704**, which may be indicative of a wire W being either loose or broken. Upon a determination of a broken or loose wire W, the central control system **1416** may issue an alarm. In some embodiments, this includes graphically displaying a location on a digital representation of the wire tree **110**, the area a wire W has contacted, for example, in the IPC user interface **917**. The broken/sagging wire indication and location on the wire tree may be recorded to a storage device **119** connected to the system **1416**. In some embodiments, the central control system **1416** is configured to send data to the calender **1410** including an indication of a broken or loose wire W along with a relative location of the broken or loose wire W, determined by which sensor rod **704** was actuated by the loose/broken wire W.

The instructions **1426** also include an environment module **1434** that controls the power and operation of the creel system **100**, **1100** in response to signals received from environmental sensors **1460**, relating to the operating environment of the creel room. In some embodiments, the environmental sensors **1460** include temperature and humidity sensors. When the central control system **1416** receives environmental data beyond a predetermined threshold, e.g., a temperature higher than a threshold temperature, the central control system **1416** issues an alarm. In some embodiments, the environmental alarm includes turning off power to the creel system **100**, **1100**. In other embodiments, the environmental data and alarm signal is provided to the calender **1410**.

The instructions **1426** also include a tension monitoring system (TMS) module **1436** that is configured to receive tension measurements from a tension monitoring system **1480** that may include, for example, the tension monitoring stand **800**, described in greater detail above with respect to FIG. **8**. That is, the tension measuring sensors **802** of the stand **800** generate a tension output signal that is sent to the central control system **1416**. The tension values measured by the tension measuring sensors **802** are made available by the control system **1416** with a data address for the calender to read at any time. The calender logic is able to measure the actual tension output for a specified air pressure input signal. This feedback loop allows either the central control system **1416** or calender to make small adjustments to the air pressure input signal and or the APC **118** based on the measured tension output providing the calender a more precise method of tension control.

In some embodiments, the tension values measured by the tension measuring sensors **802** are displayed on the user interface **117**, **917** for monitoring. This screen is available for the creel room operator monitor the tension in the wires W.

The instructions **1426** also include a position module **1438** that is configured to determine the location of creel rows **1111** as well as control the movement of each row. As described above, each row **1111** may be placed on a movable platform **1110**. The platform **1110** includes a motor **1108** connected to platform wheels that enable the movement of the creel row **1111** that is secured to the wheeled platform **1110**. The movement of the platform **1110** is guided by rails **1106**. The creel room floor may also include at least one feature/marker that is read by a proximity sensor **1105** on the platform, allowing the position module **1438** to determine the location of a particular creel row **1111**. The central control system **1416** is in electronic communication with the motor **1108** such that upon a movement command from a user, the position module activates the motor **1108** and causes movement of the platform **1110** along the rails **1106** is a desired direction.

In some embodiments, the position module **1438** is configured to process signals obtained from the proximity sensors **1105** mounted to a platform **1110** reading features **1109** or plates **1209** and determine a creel row position for each creel row **1111** within the creel room. The position module is also configured to control the motor **1108** of each platform **1110** and initiate movement of the associated creel row **1111** to a target position. For example, in a 4-row creel system, the current state may be that the first creel row is currently in a middle running position, with the second, third, and fourth creel row positioned in loading positions off to one side (e.g., the left side). Here, if the operator commands the third creel row to move to the run position, the position module **1438** will determine the position of each creel row and instruct the first creel row to move right to a loading position, e.g., the first creel row home position, while leaving room for the second creel row to also move to its loading position secondly; and finally, the third creel row will be instructed to move to its designated run position. In such examples, each movement coordinated by the position module **1438** may occur automatically after the operator specifies the command. Thus, the system **1416** may provide the ability to automatically move all the creel rows to a desired position based on a single specified operator input. In other embodiments, the proximity sensor and plates are replaced by an RFID tag reader and RFID tags mounted to the floor. In still other embodiments, mechanical limit switches may be used instead. In yet still further embodiments, other sensor technology may be used. Various types of sensing technologies may be utilized to determine the position of the creel row without departing from the present disclosure.

The instructions **1426** also include a collision avoidance system (CAS) module **1440** that is configured to prevent creel rows **1111** from colliding into each other during any movement. That is, the CAS module **1440** may be configured to receive collision data from collision-avoidance photo eyes **1150** mounted to a creel row **1111** or platform **1110**, described above. The CAS module **1440** may work in concert with the position module **1438** or components thereof, to disable the drive command of the position module **1438** by generating a stop signal based on collision data from the collision-avoidance photo eyes **1150**. In other words, the CAS module **1440** may receive collision data from at least one eye sensor **1150** associated with each creel row **1111** and determine a distance between a creel row **1111** in motion and adjacent creel row. When the moving creel row **1111** travels to a certain threshold distance toward an adjacent creel row **1111**, the CAS module **1440** sends a stop signal to the motor **1108** driving the motion of the creel row **1111**, avoiding a collision between the moving creel row and adjacent creel row.

The various components of the computer system **1416** may all be connected by a data/control bus **1425**. The processor **1424** of the computer system **1416** is in communication with an associated data storage **119** via a link **1442** and is in communication with the various subsystems, e.g., APC system **118**, LWD system, and environmental sensors **1460** and sensors via link **1443**. A suitable communications link **1442**, **1443** may include, for example, the public switched telephone network, a proprietary communications network, infrared, optical, or other suitable wired or wireless data communications.

Therefore, the disclosed systems and methods are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the teachings of the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is, therefore, evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope of the present disclosure. The systems and methods illustratively disclosed herein may suitably be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the elements that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

Directional terms such as above, below, upper, lower, upward, downward, left, right, and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward or upper direction being toward the top of the corresponding figure and the downward or lower direction being toward the bottom of the corresponding figure.

As used herein, the phrase "at least one of" preceding a series of items, with the terms "and" or "or" to separate any of the items, modifies the list as a whole, rather than each member of the list (i.e., each item). The phrase "at least one of" allows a meaning that includes at least one of any one of the items, and/or at least one of any combination of the items, and/or at least one of each of the items. By way of example, the phrases "at least one of A, B, and C" or "at least one of A, B, or C" each refer to only A, only B, or only C; any combination of A, B, and C; and/or at least one of each of A, B, and C.

To aid the Patent Office and any readers of this application and any resulting patent in interpreting the claims appended hereto, applicants do not intend any of the appended claims or claim elements to invoke 35 U.S.C. 112(f) unless the words "means for" or "step for" are explicitly used in the particular claim.

What is claimed is:

1. A creel system, comprising:

a frame having a plurality of tension controller apparatuses for paying out a wire under tension, each of the tension controller apparatuses having a brake shoe that is engageable with a spindle and a control arm that that is rotatable towards the spindle to move the brake shoe away from the spindle and rotatable away from the spindle to move the brake shoe towards the spindle;

an air pressure control system operatively connected to each of the tension controller apparatuses and actuatable to move the brake shoe towards the spindle, the tension control apparatus in communication with at least one apparatus sensor disposed on at least one of the control arms;

a central control system in communication with the air pressure control system, wherein the central control system ascertains a wire tension based on data from the apparatus sensor and the air pressure control system, and wherein the central control system is configured to actuate the air pressure control system in response to the wire tension; and

a platform on which the frame is mounted, wherein the platform includes a set of wheels that are driven by a motor, and wherein the motor is in communication with the central control system which directs the motor to drive the platform to a target position.

2. The creel system according to claim **1**, further comprising a loose wire detection system in communication with the central control system, the loose wire detection system comprising a wire tree positioned downstream from the frame and including a plurality of vertically spaced sensor bars configured to generate a loose wire detection signal upon contact between a wire and at least one sensor bar.

3. The creel system according to claim **1**, further comprising a tension monitoring system in communication with the central control system, the tension monitoring system comprising a tension monitoring stand positioned downstream from the frame, the tension monitoring stand including at least one tension sensor that receives a wire from the frame,

wherein the at least one tension sensor measures the tension of the received wire and generates a tension output signal that is sent to the central control system, wherein the central control system changes the air pressure of the air pressure control system based on the tension output signal.

4. The creel system according to claim **3**, the tension monitoring stand comprising a left tension sensor, a center tension sensor, and a right tension sensor, each configured to receive a wire from a left portion of a plane of wires, a wire from a central portion of the plane of wires, and a wire from a right portion of the plane of wires.

5. The creel system according to claim **1**, wherein the platform includes a proximity sensor configured to generate a position signal in response to reading at least one feature plate located at a predetermined position on a creel room floor.

6. The creel system according to claim **5**, wherein the feature plate comprises a plate body having a plurality of pockets, each pocket is configured to receive one of a steel and nylon pad, an order of steel and nylon pads creating a unique code read by the proximity sensor relating to the position of the platform within a creel room.

7. The creel system according to claim **1**, wherein the platform includes at least one photo eye sensor configured to measure a distance between adjacent platforms, wherein the central control system generates a stop motion signal based on a predetermined threshold distance measured by the at least one photo eye sensor.

8. The creel system according to claim **1**, further comprising at least one mechanical travel limit switch in communication with the central control system configured to prevent over-travel of the platform beyond a predetermined location.

9. The creel system according to claim **1**, further comprising at least one pull switch comprising a rope mounted at a front end of a creel row, the pull switch generates a stop signal when the rope is pulled, the stop signal readable by the central control system to cease operation of the creel system.

10. The creel system according to claim **9**, wherein the central control system is configured to shut down the creel system based on the stop signal generated from the creel row based on a determined position of the creel row in a creel room.

11. The creel system according to claim **1**, further comprising a data storage in communication with the central control system, the data storage configured to storage a log file.

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