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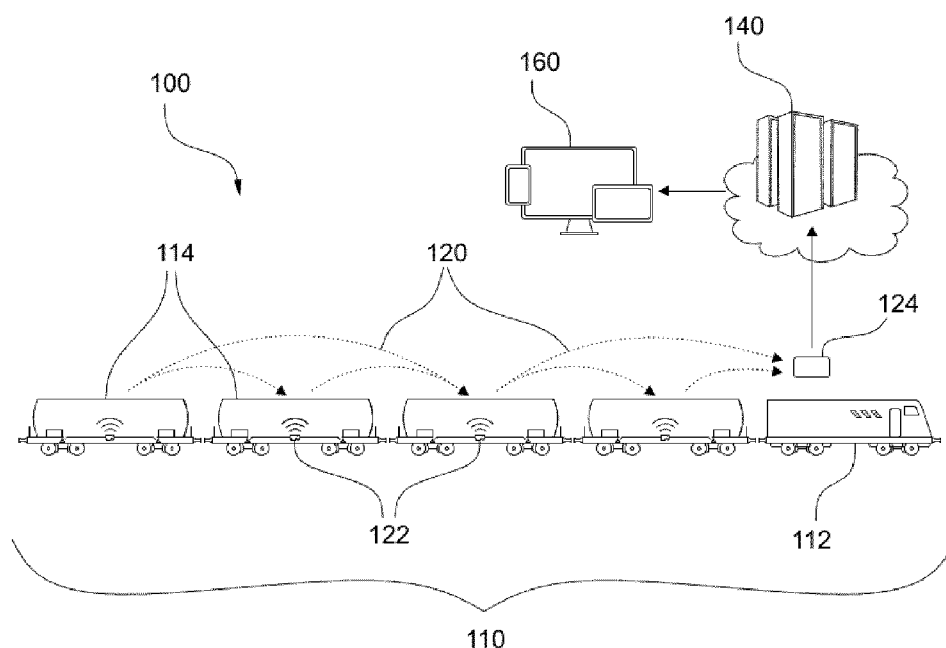


Fig. 1

(57) Abstract: The present invention provides a system and method for automatic generation of a list of units in a train comprising multiple units. Therein, the system comprises a plurality of sensor means, wherein each of the plurality of sensor means is configured to be mounted to a respective unit of the train and each of the plurality of sensor means is configured to detect a parameter of the respective unit of the train to which it is mounted that is suitable to provide an information about the position of the unit with respect to another unit in the train. Further, the system comprises a control device configured to receive the detected parameters from the plurality of sensor means and to process the detected parameters for generation of the list of units.



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DESCRIPTION

Digital Freight Car - Automatic Wagon List**5 1. Technical Field**

The present invention relates to a system and method for automatic generation of a list of units in a train comprising multiple units, or more particularly to a system and method for automatic generation of a wagon list in a freight train comprising multiple wagons.

10 The present invention further relates to a control device for receiving detected parameters from a plurality of sensor means mounted to respective units in the train and for processing the detected parameters for generation of the list of units.

2. The prior art

15 In current practice, the generation of a list of units in a train comprising multiple units, for example a freight train comprising multiple wagons, is carried out manually. In particular, according to current practice train assembly personnel walks alongside the train and identifies the positions of the units in the train, that is the positions of the
20 wagons in the freight train, to generate a list of units or to verify an available list of units. Therein, the units in the train are usually labeled with a wagon number, equipped with a paper-based identification sheet or possess any other kind of identifier that can be checked manually by the train assembly personnel. The identified list of units is then used for further processing, for example for consequent brake testing and brake weight
25 calculation, which is performed on a paper base. However, such manual identifications are time intense since the train assembly personnel needs to walk alongside the train and to identify the units in the train sequentially, one by one. Furthermore, such manual identifications are also error-prone since they rely on the skills of the train assembly personnel, which may also cause an additional delay for correcting errors and rearrange
30 trains. Further, such manual identifications can only be carried out when the train is not in operation, for example, when the train is in an operating site such as a marshalling yard or shunting yard, where the train assembly personnel can walk safely alongside the train.

Furthermore, a train composition may be subject to change. For example, one or more units may be added to the train or removed from the train after an operation phase of the train depending on a freight transported in the respective unit. A following operation phase of the train with changed composition of units may then require a repeated generation of a new list of units in the train, for example for brake testing. However, a repeated manual generation of a new list of units is time intense and causes a significant delay before the new list of units can be used for brake testing and the train with new composition of units can be put into operation.

Current systems detect a sequence of units in a train via GPS for performing brake testing as disclosed in EP3081445B1 or determine a wagon sequence in a train by use of pressure measuring devices in the main air line and time measuring devices synchronized via communication device in the range of a communication device initiating the brake test as disclosed in DE202012012558U1. Furthermore, the continuity of a train for brake testing was detected via pneumatic continuity testers and more specifically via a pneumatic continuity tester on an electrically controlled pneumatic train brake system as disclosed in US2002139181A1.

However, the system of the state of the art have certain shortcomings such as their dependence of the availability of the GPS which can be disturbed if a train is in a tunnel.

It is therefore the technical problem underlying the present invention to provide an improved system and a method for an efficient and fail-safe automatic generation of a list of units in a train that overcomes the shortcomings of the systems of prior art.

3. Summary of the invention

The technical problem is solved by a system and a method for automatic generation of a list of units in a train as defined in the independent claims. Advantageous modifications of embodiments of the invention are defined in the dependent claims.

In general, the present invention provides a system for automatic generation of a list of units in a train comprising multiple units. Therein, the system comprises a plurality of sensor means, wherein each of the plurality of sensor means is configured to be mounted to a respective unit of the train and each of the plurality of sensor means is configured to detect a parameter of the respective unit of the train to which it is mounted that is suitable to provide an information about the position of the unit with respect to another unit in the train. Moreover, each of the plurality of sensor means is configured to communicate with one or more of the plurality of sensor means, and the plurality of sensor means forms a sensor mesh network to transmit the detected parameters for processing. Further, the system comprises a control device configured to receive the detected parameters from sensor mesh network and to process the detected parameters for generation of the list of units.

It is conceivable, that the sensor mesh network is either a cable-based sensor mesh network or a wireless sensor mesh network. A sensor mesh network is a communication network that is made up of sensor means configured to transmit and receive data, and is organized in a mesh topology. A mesh refers to rich interconnection among the sensor means along the train. Each sensor means acts also as a provider forwarding data to a next sensor means. The networking infrastructure is decentralized and simplified because each sensor means need only transmits at least as far as the next connected sensor means. The control device may be configured to access the sensor mesh network at any unit in the train. The position of the control device may be published into and propagated through the sensor mesh network such that the position of the control device along the train is determined.

Consequently, the system can automatically generate a list of units in the train in a matter of seconds irrespective of the location, length and composition of the train and irrespective of the position of the control device along the train by the use of the plurality of sensor means mounted to respective units in the train for detecting a parameter of the respective unit of the train and establishing a unit-to-unit communication and forming a sensor mesh network, and by use of a control device for receiving the collected parameters from the sensor mesh network and for processing the detected

parameters for automatic generation of the list of units. In this way the list of units can be generated without the need for manual inspection of the units in the train. More particularly, there is no need for the train assembly personnel to walk alongside the train to manually identify the positions of the units in the train for generation of the list of units. Thus, the generation of the list of units can be performed efficiently and in a matter of seconds. The generated list of units can then, for example, be used for a brake weight calculation and the control device can be used as a brake test controller without significant delay after assembly of the train and prior to operation of the train. In addition, the generation of the list of units in the train is more reliable and less error-prone since the list of units is generated automatically based on detected parameters from a plurality of sensor means and is thus, not dependent on the skills of the train assembly personnel. Furthermore, this is particularly advantageous when a train composition changes after an operation phase of the train and a new list of units has to be generated for the new train composition prior to brake testing and a new operation phase of the train. The new list of units can be generated within seconds.

According to an embodiment of the invention, each of the plurality of sensor means is associated with an identifier of the respective unit in the train to which it is mounted and each of the plurality of sensor means is configured to transmit the detected parameter and the associated identifier of the unit in the train to which it is mounted to the control device or a server for processing and generation of the list of units. It is conceivable that such identifiers may be a series of numbers, a series of letters, or a series of numbers and letters, a bar code or an QR-Code that can be transmitted by the plurality of sensor means as a stream of data bits and received and processed by the control device.

In another embodiment, the system further comprises a database or a server configured to receive the detected parameters and identifiers from the sensor mesh network or configured to receive the detected parameters and identifiers or the generated list of units from the control device. It is conceivable that the server is then configured to process the detected parameters and identifiers for generation of the list of units or is configured to keep record of the detected parameters and identifiers or the generated list of units. Furthermore, in case the list of units is generated by the server, the control device may be configured to receive the generated list of units from the server for brake testing.

In a further embodiment, the control device comprises at least one interface for a manual input of data related to one or more items of the list of units and is configured to generate the list of units based at least in part on the manual input of the data related to the one or more items of the list of units via the interface.

Thus, the control device may feature at least one interface for manual input of data related to one or more items of the list of units, for example an item corresponding to a newly added unit in the train. The interface for manual input of data may be an interface for manual text input, such as a touch pad or a key board, for inputting of text, for example a series of numbers or letters, associated with the one or more units in the train and correspondingly, associated with the one or more items of the list of units. Further, the control device may comprise an RFID reader to read out RFID tags associated with the one or more units in the train to provide the data related to the one or more items of the list of units. The control device may also comprise a QR code reader or any other type of 2D code reader, such as a camera, to read out QR code or any other type of 2D code associated with the one or more units in the train to provide the data related to the one or more items of the list of units. The control device may have at least one of the interfaces described above depending on the type of units and depending on the used identification solution, i.e. type of identifier, present in the units in the train.

By providing the possibility for manual input of data related to the one or more items of the list of units via the at least one interface, the system is also compatible for recording the position of units in the train that are not equipped with a sensor means. In addition, the position of units can be recorded in the system, where the mounted sensor means on the respective units are not detecting or transmitting any parameters due to a device failure of the sensor means. In this way, the list of units can be generated based on both the manual input of the data related to the one or more items of the list of units via the interface and the detected parameters from a plurality of functional sensor means. Therefore, the availability of the generation of the list of units in the train is ensured and the fail-safety is increased.

In an embodiment, the system further comprises a user device connected to the server. The user device may then comprise a user interface for manual input of data related to the one or more items of the list of units via the interface. The user device may then be configured to send the data related to the one or more items of the list of units to the server for record keeping or generation of the list of units, or for transmitting the data related to the one or more items of the list of units to the control device for further processing, generation of the list of units, and brake testing.

In an embodiment, the control device may be configured to act as the user device.

According to an embodiment, the multiple units of the train are connected in a brake system and at least one unit in the train, for example a locomotive or traction unit, is configured to control the pressure of a fluid in the brake system. Furthermore, each of the plurality of sensor means comprises a pressure sensor and a timestamp generator to detect a pressure of the fluid in the brake system in the respective unit and to generate a corresponding timestamp of when the pressure of the fluid in the brake system in the respective unit exceeds or falls below a predetermined threshold pressure, respectively, from which an information about the position of the respective unit in the train can be derived.

For example, the locomotive may be configured to set the pressure of the fluid in the brake system to a predetermined value and may be configured to ramp up or ramp down the pressure of the fluid in the brake system in case the pressure of the fluid in the brake system differs from the predetermined pressure value after assembly of the train. This causes a pressure wave or fluid wave to propagate through the fluid in the brake system, i.e. starting from the locomotive along the train. Since each of the plurality of sensor nodes is capable to detect a pressure of the fluid in the brake system in the respective unit to which it is mounted and is capable to produce a corresponding timestamp of when the pressure of the fluid in the brake system in the respective unit exceeds or falls below a predetermined threshold pressure, the propagation of the pressure wave through the fluid in the brake system can be tracked. It is conceivable that corresponding to a first sensing procedure the control device may then be configured to receive the detected pressures, timestamps, and identifiers, to calculate

the delays in time between the collected timestamps and, using the corresponding identifiers, the delays in time between the units with which the detected pressures and timestamps are associated and thus, to infer the information about the position of each unit in the train with respect to the another unit in the train and the locomotive for

5 generation of the list of units. Alternatively, the control device may be configured to calculate the distance of the respective units from the locomotive by using the corresponding timestamp and a propagation velocity of the pressure wave in fluid in the brake system, i.e. the speed of sound in the fluid, to generate the list of units. The list of units is then created, for example, by arranging the timestamps in one column of a table

10 according to their increasing or decreasing values and arranging the respective identifiers of the respective units in the train to which the timestamps are assigned in another column according to the sequence of the timestamps. Thus, the column of identifiers of the respective units in the train represents the list of units of the train. As an alternative, the control device may be configured to receive the detected pressures

15 and timestamps for generation of the one column of timestamps of the table as described above. The list of units is then created by assigning identifiers to the sequence of timestamps in another column, for example, assigning identifiers corresponding to the indices of the entries of timestamps in the table. The list of units is then the column of identifiers in the table.

20 In general, the plurality of sensor means can detect the pressure of fluid in the brake system essentially safe from disturbing influences in the surroundings of the train and thus, a fail-safe generation of the list of units is ensured. More particularly, the plurality of sensor means can detect the pressure of fluid in the brake system for the following generation of the list of units independently on the location of the train, i.e. independent

25 from whether the train is in a tunnel, in an assembly hall or in the outside, and thus, the plurality of sensor means can detect the pressure of fluid in the brake system safely from any non-related interfering signals in the surroundings, for example disturbing non-related wireless transmissions. Moreover, since the pressure wave through the brake system travels at the speed of sound in the fluid, the pressures and corresponding

30 timestamps can be sampled and transmitted by the plurality of sensor means and received and processed by the control device within seconds for a fast and efficient generation of the list of units.

According to another embodiment, the plurality of sensor means and the control device each comprise a wireless communication module to send and receive signals, and each of the plurality of sensor means is configured to detect a signal strength and an identifier of a wireless communication module of at least one neighboring sensor means from
5 which an information about the position of the unit in the train to which the sensor means is mounted can be derived. Moreover, each of the plurality of sensor means is configured to use the wireless communication module to implement a wireless unit-to-unit communication, wherein the plurality of sensor means forms a wireless sensor mesh network to wirelessly transmit the detected parameters, identifiers, pressures,
10 timestamps, and signal strengths.

A wireless sensor mesh network is a communication network made up of radio nodes, in particular sensor means or sensor nodes publishing data, and is organized in a mesh topology, wherein a mesh refers to rich interconnection among the sensor means or
15 sensor nodes. Each sensor node acts also as a provider forwarding data to a next sensor node. The networking infrastructure is decentralized and simplified because each node need only transmits at least as far as the next connected node. Wireless sensor mesh networks often consist of mesh clients, such as sensor nodes comprising sensor nodes and/or sensor hubs, and mesh gateways, such as the control device or
20 gateway or a sensor node acting as gateway. The position of the control device or gateway may be published into and propagated through the wireless sensor mesh network such that the position of the control device along the train is determined.

According to one embodiment corresponding to a second sensing procedure the control
25 device of the system is configured to receive from one or more of the plurality of sensor means one or more detected signal strengths emitted by one or more wireless communication modules of one or more neighboring sensor means and the respective one or more identifiers as well as the corresponding identifiers of the one or more of the plurality of the sensor means by which the one or more signal strengths and the
30 respective one or more identifiers of the neighboring sensor means have been detected and thus, to infer therefrom the position of the units in the train with respect to each other for a generation of a list of units.

The list of units is then created, for example, by arranging the identifier of a first sensor means corresponding to a first unit of the train in a field of a table and arranging the identifier of a first nearest neighboring sensor means according to a first detected signal strength in a neighboring field of the table and arranging the identifier of a second nearest neighboring sensor means according to a second detected signal strength which may be similar to the first detected signal strength, which indicates that the second nearest neighboring sensor means is on the opposite side in the train with respect to the first nearest neighboring sensor means, in a field of the table in the same column or row on the opposite side of the identifier of the first sensor means. Thus the column or row of three identifiers of the respective sensor means mounted on units in the train represents the list of units of the train.

If an identifier of a second sensor means and an identifier of a first nearest neighboring sensor means according to a first detected signal strength and an identifier of a second nearest neighboring sensor means according to a second detected signal strength associated with the second sensor means are received, wherein two of the identifiers correspond to identifiers related to the first sensor means it is clear that the second sensor means is a neighboring sensor means of the first sensor means in the train and the identifier of the identifier of the first or second nearest neighboring sensor means which does not correspond to the identifiers related to the first sensor means can be added in the table to the sequence of the three identifiers related to the first unit of the train.

In another embodiment, each of the plurality of sensor means comprises a global navigation satellite system module to detect a position of the unit to which it is mounted from which information about the position of the unit in the train can be derived.

According to an embodiment corresponding to a third sensing procedure the control device of the system is configured to receive the detected positions of the units, which may be described by geographic coordinates, and identifiers and is configured to infer therefrom the position of the units in the train by comparing their relative positions according to the coordinates. The list of units is then created, for example, by arranging

the coordinates in a sequence with increasing or decreasing values in one column of a table and in another column the respective identifiers of the respective sensor means or units in the train to which the coordinates are assigned. Thus the column of identifiers of the respective units in the train represents the list of units of the train.

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According to one embodiment the control device of the system is configured to receive one or more of detected pressures and timestamps according to the first sensing procedure, to calculate the delays in time between the collected timestamps and the corresponding identifiers of the units with which the detected pressures and timestamps are associated and thus, to infer the information about the position of each unit in the train with respect to the another unit in the train and the locomotive for generation of the list of units, one or more detected signal strengths emitted by one or more wireless communication modules of one or more neighboring sensor means and the respective one or more identifiers as well as the corresponding identifiers of the one or more of the plurality of the sensor means by which the one or more signal strengths and the respective one or more identifiers of the neighboring sensor means have been detected according to the second sensing and thus, to infer therefrom the position of the units in the train with respect to each other for a generation of a list of units, and detected positions of the units which may be described by geographic coordinates according to the third sensing and, to infer therefrom the position of the units in the train by comparing their relative positions according to the coordinates.

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The control device may be configured to start receiving and processing parameters according to one of the first, second, and third sensing procedure described above, and infer a list of units therefrom, and subsequently receive and process parameters according to another one of the first, second, and third sensing procedure described above, and therewith complete the list of units or check its accuracy. If the processing of the parameters according to the two of the first, second, and third sensing procedure result in a complete and unambiguous list, the control device may stop further activity of generating the list of units and output the list.

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If the control unit determines that the created list is incomplete or some items are ambiguous or if one of the procedures of processing of parameter fails, one or both of

the procedures can be repeated or receiving and processing of parameters according to the third of the first, second, and third sensing procedure described above can be started and used for completing or correcting the list.

- 5 According to yet another embodiment, the control device is installed on the locomotive or is a handheld device, i.e. a mobile device.

It is conceivable that the control device may be configured to perform a brake test after generation of the list of units and use the generated list of units for a brake weight calculation, which may be necessary prior to operating the train by use of the

- 10 locomotive or traction unit.

Thus, the control device may be a special device called brake test controller and may be a user device such as a smart phone, tablet, personal digital assistant, or the like.

Further, the user device may be a laptop. Furthermore, the user device may also be a

- 15 computing device with a display.

According to the present invention, a method for automatic generation of a list of units in a train comprising multiple units is provided. Therein, the method comprises associating each of a plurality of sensor means to a plurality of respective units of the train. The

- 20 method further comprises detecting, by each of the plurality of sensor means, a parameter of the respective unit the sensor means is associated with that is suitable to provide an information about the position of the respective unit in the train. Further,

each of the plurality of sensor means is configured to use the wireless communication module for a unit-to-unit communication and the plurality of sensor means forms a

- 25 sensor mesh network. The method furthermore comprises transmitting, by each of the plurality of sensor means, the detected parameters to a control device or a server via the sensor mesh network, and receiving the detected parameters from the sensor mesh network at the control device and processing the detected parameters to generate the list of units.

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Each of the plurality of sensor means or sensor nodes mounted to respective units in the train is configured to detect parameters of the respective units and to implement a unit-to-unit communication. The plurality of sensor means forms a sensor mesh network

to transmit the parameters via the sensor mesh network, and the control device is configured for receiving the collected parameters from the sensor mesh network and for processing the detected parameters for automatic generation of the list of units so that the list of units in the train can be generated automatically in a matter of seconds

5 irrespective of the location of the train, length and composition of the train, and the position of the control device along the train. Furthermore, the list of units can be generated without the need for manual inspection of the units in the train. More particularly, there is no need for the train assembly personnel to walk alongside the train to manually identify the positions of the units in the train. Thus, the generation of the list

10 of units can be performed fast and efficiently. In addition, the method of the present invention for automatic generation of the list of units in the train is more reliable and less error-prone since the list of units is generated automatically based on the detected parameters from a plurality of sensor means and is thus, not dependent on the skills of the train assembly personnel. Moreover, this is particularly advantageous when a train

15 composition changes after an operation phase of the train and a new list of units has to be generated for the new train composition prior to brake testing and a new operation phase of the train. The new list of units can be generated within seconds

In its embodiments, the above-described method may comprise additional features as

20 described with regard to the system.

Accordingly, in another embodiment, the method further comprises associating each of the plurality of sensor means with a respective identifier of the respective unit in the train the sensor means is associated with. Furthermore, the method comprises

25 transmitting, by each of the plurality of sensor means, the identifier of the unit in the train to the control device for processing and generation of the list of units.

In another embodiment, the method further comprises receiving the detected parameters and identifiers in a database or server from the sensor mesh network or

30 receiving the detected parameters and identifiers or the generated list of units from the control device. It is conceivable that the method further comprises processing, by the server, the detected parameters and identifiers for generation of the list of units. Alternatively, the method may comprise record keeping, by the server, of the detected

parameters and identifiers or the generated list of units. Furthermore, in case the list of units is generated by the server, the method may further comprise transmitting the generated list of units from the server to the control device for consequent brake testing.

- 5 In yet another embodiment of the present invention, the method further comprises manually inputting via at least one interface for manual input of the control device one or more items of the list of units, and generating the list of units at least in part based on the one or more items of the list of units.
- 10 In an embodiment, the method further comprises connecting the server to a user device. The method may then comprise manually inputting via at least one interface for manual input of the user device one or more items of the list of units. The method may further comprise sending the one or more items of the list of units to the server for record keeping or generation of the list of units, or for transmitting the one or more items
- 15 of the list of units to the control device for further processing, generation of the list of units, and brake testing.

In an embodiment, the method may comprise using the control device as the user device.

- 20 According to an embodiment, the method comprises connecting the multiple units of the train in a brake system, wherein at least one unit in the train, i.e. a locomotive or traction unit, controls a pressure of a fluid in the brake system, and each of the plurality of sensor means comprises a pressure sensor and a timestamp generator, and detecting
- 25 the pressure of the fluid in the brake system with one or more pressure sensors of the plurality of sensor means and producing a corresponding timestamp of when the pressure of the fluid in the brake system in the respective unit exceeds or falls below a predetermined threshold pressure for the one or more pressure sensors from which an information about the position of the respective unit in the train can be derived.

- 30 It is conceivable that the method may comprise setting, by the locomotive, the pressure of the fluid in the brake system to a predetermined value and thus, ramping up or ramping down the pressure of the fluid in the brake system in case the pressure of the

fluid in the brake system differs from the predetermined pressure value after assembly of the train. In that event, a pressure waver or fluid wave propagates through the fluid in the brake system. Since the method further comprises detecting, by each of the plurality of sensor means mounted to a respective unit in the train, a pressure of the fluid in the brake system and producing a corresponding timestamp of when the pressure of the fluid in the brake system in the respective unit exceeds or falls below a predetermined pressure threshold, the propagation of the pressure wave through the fluid in the brake system can be tracked. The method may then comprise calculating, by the control device, delays in time between the detected timestamps and thus, inferring the information about the position of each of the units in the train with respect to the other units in the train and the locomotive to generate of the list of units. Alternatively, the method may comprise calculating, by the control device, the distance of the respective units from the locomotive by using the corresponding timestamps and a propagation velocity of the pressure wave in fluid in the brake system, i.e. the speed of sound in the fluid, to generate the list of units.

Since the detection of the pressures of the fluid in the brake system by use of the plurality of sensor means is essentially safe from disturbing influences in the surroundings, a fail-safe generation of the list of units is ensured. More particularly, the detection of pressures of the fluid in the brake system for the following generation of the list of units is independent from the location of the train, i.e. independent from whether the train is in a tunnel, in an assembly hall or in the outside, and is essentially safe from any non-related interfering signals in the surroundings, for example disturbing non-related wireless transmissions. Moreover, since the pressure wave through the fluid in the brake system travels at the speed of sound in the fluid, the pressures and corresponding timestamps can be sampled and transmitted by the plurality of sensor means and received and processed by the control device within seconds for a fast and efficient generation of the list of units.

According to an embodiment, the method further comprises detecting with one or more of the plurality of sensor means a signal strength of at least one respective neighboring sensor means to provide an information about the position of the respective unit associated with the neighboring sensor means in the train. Therein, each of the plurality

of sensor means and the control device comprise a wireless communication module to send and receive signals, and transmit the information about the position of the respective unit associated with the neighboring sensor means in the train. Further, each of the plurality of sensor means uses the wireless communication module to implement
5 a wireless unit-to-unit communication, wherein the plurality of sensor means forms a wireless sensor mesh network to wirelessly transmit the detected parameters, identifiers, pressures, timestamps, and signal strengths.

According to yet another embodiment of the present invention, the method further
10 comprises detecting with one or more of the plurality of sensors means a position of the respective unit associated with the sensor means. Therein, each of the plurality of sensor means comprises a global navigation satellite system module to detect a position of the unit and transmits the information about the position of the respective unit associated with the sensor means in the train.

15 According to an embodiment of the present invention, the method comprises generating the list of units and evaluating the accuracy of the list of units based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of one or more items of the list of units.

20 Since the generation of the list of units and evaluation of the accuracy of the list of units is performed based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of data related to one or more items of the list of units, the accuracy, availability, and fail-safety of the generation of the list of units
25 in the train is increased.

For example, in each of the units in the train a “filled” state of the brake system may be recognized by the respective sensor nodes if the pressure in the fluid in the brake system reaches a predetermined pressure value, and the method may further comprise
30 waking the system from a sleep mode if any of the units were in sleep mode.

Subsequently, the method may comprise detecting the positions of the units in the train via the global navigation satellite system modules in the sensor nodes for cross-checking. Further, the method may result in determining that the list of units is

sufficiently accurate by using only one or two of the automatic detection means of parameters, pressures, timestamps, signal strengths, or positions. In that case, the method may comprise stopping to use the other detection means for energy saving. Further, if the evaluated accuracy is below a predetermined threshold, for example the
5 presence of two contradicting detected parameters or lack of a parameter is recognized by the control device, the detection of signal strengths and positions may automatically be repeated for the generation of a new list of units. Moreover, if the train is in a tunnel and a detection of the positions of the units in the train via the global navigation satellite system modules in the sensor nodes is not available, the method may comprise
10 reverting to any of the remaining means to detect parameters, pressures, signal strengths, identifiers, or manual input of data related to one or more items of the list of units, for providing the information of the units in the train for generation of the list of units. Thus, by generating the list of units based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of
15 data related to one or more items of the list of units, a reliable and fail-safe generation of the list of units can be ensured.

According to another embodiment, the method further comprises using the control device as a brake test controller for brake testing after generation of the list of units and
20 using the generated list of units for a brake weight calculation.

4. Short description of the drawings

In the following detailed description, presently preferred embodiments of the invention
25 are further described with reference to the following figures in which

Fig. 1 shows a system overview of a system for automatic generation of a list of units in a train comprising multiple units according to an embodiment of the invention;

30 Fig. 2 shows a system overview of a system for automatic generation of a list of units in a train in an individual unit of the train according to an embodiment of the invention.

6. Detailed description of preferred embodiments

In the following, preferred embodiments of the invention are described with respect to a system for automatic generation of a list of units in a train comprising multiple units. The approaches disclosed herein generally serve for providing an efficient and fail-safe automatic generation of a list of units in a train.

Fig. 1 - 2 shows a system overview of a system 100 for automatic generation of a list of units in a train 110 comprising multiple units 114 according to an embodiment of the invention. Therein, the system 100 comprises a plurality of sensor means 222, wherein each of the plurality of sensor means 222 is mounted to a respective unit 114 of the train 110 and is configured to detect one or more parameters of the respective unit 114 of the train 110 to which it is mounted that is suitable to provide an information about the position of the unit 114 with respect to another unit 114 in the train 110. Moreover, the system 100 comprises a control device 124 configured to receive the detected parameters from the plurality of sensor means 222 and to process the detected parameters for generation of the list of units.

As partly shown in Fig.1 and 2, each of the plurality of sensor means or sensor nodes 222 may comprise several components including a microcontroller, timestamp generator, transceiver, wireless communication module 122, memory, power source, one or more pressure sensors 226, and global navigation satellite system module 226. The microcontroller performs tasks, processes data and controls the functionality of other components in the sensor node 222. A power source in each of the plurality of sensor nodes usually comprises a battery, such as a NiCd (nickel-cadmium), NiZn (nickel-zinc), NiMH (nickel-metal hydride), or lithium-ion battery. Alternatively, the plurality of sensor nodes may make use of an electric powerline in the train if present. The memory in each of the plurality of sensor nodes may be one of on-chip or off-chip memory for storing data including the detected parameters and an identifier, such as a digitized series of numbers or letters or a combination of numbers and letters, which is associated with the respective unit 114 of the train 110 to which the sensor node is mounted. The transceiver makes use of the wireless communication module 122 to

transmit and receive data in the form of signals, i.e. data related to the detected parameter and the identifier retrieved from its own memory or other detected parameters and identifiers received from neighboring sensor nodes. Alternatively, the transceiver may make use of cable-based connections between the units 114 in the train 110 if present to transmit and receive signals. The timestamp generator in each of the plurality of sensor nodes is capable of generating timestamps with time intervals between individual timestamps as appropriate. Taking into account the speed of propagation of pressure typical time intervals are in a range equal to or less than 100ms, 10 ms or 1 ms, with no limitation on these numbers. The one or more pressure sensors as described with reference to Fig. 2 may be affixed to a distributor valve of the brake system 210 in the respective unit 114. Preferably, the distributor valve of the unit 114 is the distributor valve of a compressed air circuit. A pressure sensor 226 has specific characteristics such as accuracy, sensitivity etc. appropriate for detecting pressure changes in the brake system of the train.

As presented in Fig. 1 and 2, the multiple units 114 of the train 110 are connected in a brake system 210 and at least one unit 114 in the train 110, for example a locomotive 112, is configured to control the pressure of a fluid in the brake system 210. Further, each of the plurality of sensor nodes 222 are configured to detect a pressure of the fluid in the brake system 210 in the respective unit 114 to which it is mounted and to generate a corresponding timestamp of when the pressure of the fluid in the brake system 210 in the respective unit 114 exceeds or falls below a predetermined threshold pressure, respectively, from which an information about the position of the respective unit 114 in the train 110 can be derived. In particular, the locomotive 112 may be configured to set the pressure of the fluid in the brake system 210 to a predetermined value and for example, may ramp up the pressure in the brake system 210 in case the pressure in the brake system 210 is lower than the predetermined pressure value after assembly of the train 110. In that event, a pressure wave or fluid wave propagates through the fluid in the brake system 210. Since each of the plurality of sensor nodes 222 detect a pressure of the fluid in the brake system 210 in the respective unit 114 to which it is mounted via the one or more pressure sensors 226 and produces a corresponding timestamp of when the pressure of the fluid in the brake system 210 in the respective unit 114 exceeds a predetermined threshold pressure via the timestamp

- generator, the propagation of the pressure wave through the fluid in the brake system 210 can be tracked. An analog signal produced by the one or more pressure sensors 226 in a sensor node 222 may preferably be digitized by an analog-to-digital converter and sent to the microcontroller in the sensor node 222 for further processing or storage in the memory. The control device 124 may then be configured to receive the detected pressures and timestamps from the sensor nodes 222 and to calculate the delays in time between the collected timestamps and thus, is able to infer the information about the position of each of the units 114 in the train 110 with respect to the other units 114 in the train 110 and the locomotive 112 for generation of the list of units. Alternatively, the control device 124 may be configured to calculate the distance of the respective units 114 from the locomotive 112 by using the corresponding timestamps and a propagation velocity of the pressure wave in fluid in the brake system 210, i.e. the speed of sound in the fluid, to generate the list of units.
- 15 The wireless communication module 122 in each of the plurality of sensor nodes 222 may comprise an antenna to send and receive signals, which includes but is not limited to antennas for Wireless Local Area Network (WLAN), Bluetooth or other radio frequency (RF) signals. Each of the plurality of sensor nodes 222 can thus communicate with at least one neighboring sensor node 222 within a range of their antenna, for example within the range of tens or hundreds of meters. Consequently, each of the plurality of sensor nodes 222 is capable of determining a signal strength of at least one neighboring sensor node 222 to provide an information about the position of the respective unit 144 with regard to the neighboring unit 144 in the train 110 for generation of the list of units. Furthermore, each of the plurality of sensor nodes 222 comprises a global navigation satellite system module 226 as described above and detects a position of the unit 114 to which it is mounted from which information about the position of the unit 114 in the train 110 can be derived for generation of the list of units.
- 30 Accordingly, the plurality of sensor nodes 222 are configured to implement a wireless unit-to-unit communication via the wireless communication modules 122, to determine a mesh topology by detecting, with each of the plurality of sensor nodes the one or more sensor nodes 222 in other units 114 they are connected with, via the wireless unit-to-

unit communication, and to form a wireless sensor network 120 as presented in Fig. 1. The wireless sensor network 120 may then be configured to propagate the detected parameters, pressures, timestamps, signal strengths, positions, and identifiers through the wireless sensor network 120 to the control device 124, i.e. sequentially receive and
5 transmit the detected parameters, pressures, timestamps, signal strengths, positions, and identifiers from one sensor node 222 to a neighboring sensor node 222 to the control device 124 as presented in Fig. 1.

As described above, the system 100 comprises a control device 124 or a gateway
10 configured to receive and process the detected parameters, pressures, timestamps, signal strengths, positions, and identifiers from the sensor network 120 for generation of the list of units. The control device 124 may be installed on the locomotive 112 or may be a handheld device, i.e. a mobile device, comprising a wireless communication module 122 as described above. Accordingly, the control device 124 may be a user
15 device such as a smart phone, tablet, personal digital assistant, or the like. Further, the user device may be a laptop or a desktop computer. Furthermore, the user device may also be a computing device with a display.

Moreover, the control device 124 comprises at least one interface for manual input of
20 data related to one or more items of the list of units, for example an item corresponding to a newly added unit 114 in the train 110. The interface for manual input of data may be an interface for manual text input, such as a touch pad or a key board, for inputting of text or an identifier, for example a series of numbers or letters, associated with the one or more units in the train and correspondingly, associated with the one or more
25 items of the list of units. Further, the control device 124 may comprise an RFID reader to read out RFID tags associated with the one or more units 114 in the train 110 to provide the data related to the one or more items of the list of units. The control device 124 may also comprise a QR code reader or any other type of 2D code reader, such as a camera, to read out QR code or any other type of 2D code associated with the one or
30 more units in the train to provide the data related to the one or more items of the list of units.

In case the control device 124 is a handheld device, i.e. a mobile device, as described above, it may further comprise a camera and a processing module embodied by an integrated hardware and software solution for recognition of 2D code or text to recognize identifiers painted on the side of respective units 114 in the train 110, for example a series of numbers or letters, QR code or any other type of visual 2D code identifying the respective units 114 in the train 110 on which they are painted. Further, the control device 124 may comprise an RFID reader to read out RFID tags mounted to the respective units 114 in the train 110, to provide data related to the one or more items of the list of units. In this way, manual input of data related to one or more items on the list of units can be provided as described above.

The generation of the list of units and the evaluation of the accuracy of the list of units based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of data related to one or more items of the list of units, may be embodied by a specific application running on the control device 124 performed by an integrated software and hardware solution.

The system 100 may further comprise a database or server 140 that is configured to receive the detected parameters or the generated list of units from the control device 124 for processing or record keeping. Therein, the control device 124 and server 140 may use any transfer protocol to transfer data related to the generated list of units, such as the Hypertext Transfer Protocol. On the other hand, the control device 124 may receive data related to one or more items on the list of units from the server 140 for generation of the list of units.

The server 140 may be communicatively coupled to a user device 160 or alternatively may be communicatively coupled to the control device 124 acting as user device 160. The user device 160 may be a user device as described above, that is a mobile device, such as a smart phone, tablet, personal digital assistant, or the like. Furthermore, the user device 160 may also be a computer, such as a laptop or a desktop computer. Furthermore, the user device 160 may be a computing device with a display device which is removably affixed to the computing device.

Furthermore, the user device 160 may be configured to perform a component test, and in particular a brake test and brake weight calculation by use of the generated list of units. The brake test and brake weight calculation may be embodied by a specific application running on the user device 160 or control device 124 acting as user device.

5 Thus, the user device 160 or control device 124 acting as user device may be a special device called brake test controller. Such brake test controller may be an integrated hardware and software solution which together perform the application embodying the brake test and the brake weight calculation based on the generated list of units.

10 As described above, the sensor nodes 222 can forward the detected parameters pressures, timestamps, signal strengths, positions, and identifiers through the wireless sensor network 120 to the control device 124 for processing and generation of the list of units. On the other hand, the position of the control device 124 may also be propagated through the wireless sensor network 120 along the train 110, for example for
15 automatically determining the position of the locomotive 112 in the train 110 in case the control device 124 is located on the locomotive 112 and the locomotive 112 does not comprise a dedicated sensor node 222. Thus, the information about the position of the locomotive 112 in the train 110 can be provided to the control device 124 or the server 140 for example, for consequent brake testing.

20 Moreover, if the control device 124 is a portable device, i.e. handheld device, with a wireless communication module 122, the control device 124 can be used as a signal strength detector. Thus, while walking with the control device 124 from one end of the train 110 to the other end of the train 110, for example while walking from the
25 locomotive 112 as one end of the train 110 to the other end of the train 110 or vice versa or both, the control device 124 can generate the list of units in the train by detecting the signal strengths and corresponding identifiers of the units 144 in the train 110. The control device 124 can then generate the list of units based on the detected signals strengths and identifiers. It is conceivable that the control device 124 can then
30 generate a first list of units in the train, for example, by walking from the locomotive 112 as one end of the train 110 to the other end of the train 110, and a second list of units in the train by walking back. Both lists of units can then be used for cross-checking and evaluating the accuracy of the list of units.

Consequently, the system 100 is capable of generating the list of units and evaluating the accuracy of the list of units based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of data related to one or more items of the list of units.

It is conceivable that in each unit 114 in the train 110 a “filled” state of the brake system 210 may be recognized by the respective sensor nodes 222 if the pressure in the fluid in the brake system 210 reaches a predetermined pressure value, and the system 100 is to wake itself from a sleep mode if any of the units 114 were in sleep mode. Subsequently, the positions of the units 114 in the train 110 may be acquired via the global navigation satellite system modules 226 in the sensor nodes 222.

Further, the system 110 may determine that the list of units is sufficiently accurate by using only one or two of the automatic detection of pressures, timestamps, signal strengths, or positions. In that case, the system 100 may be configured to stop using the other detection means for saving energy. Further, if the evaluated accuracy is below a certain threshold, for example the presence of two contradicting detected parameters or the lack of a parameter is recognized by the control device, the detection of signal strengths and positions may automatically be repeated for the generation of a new list of units. Additionally, if the train 110 is in a tunnel and a detection of the positions of the units 114 in the train 110 via the global navigation satellite system modules 226 in the sensor nodes 222 is not available, the system 100 is capable of reverting to any of the remaining means to detect parameters, pressures, signal strengths, identifiers, or manual input of data related to one or more items of the list of units, for providing the information of the units 114 in the train 110 to generate the list of units. Thus, by generating the list of units based on one or more of the detected parameters, identifiers, timestamps, signal strengths, positions, and manual input of data related to one or more items of the list of units, a fail-safe and reliable generation of the list of units is ensured.

Furthermore, once the list of units is generated, it may be checked again for accuracy or if the train 110 was assembled correctly by the assembly personnel. The generated list of units may then be signed and sent to the server 140 for record keeping or further

processing, but mainly is further used for a brake weight calculation and brake testing on the brake test controller 124 or user device 160.

- Various modifications can be done to the embodiments without leaving the scope of the claims. For example, each of the plurality of sensor means 222 may comprise a voltage sensor 226 to measure a voltage drop in an electrical power line along the train 110, in case the units 1114 in the train 110 are connected in a power line, to provide an information about the position of the respective unit 114 in the train 110.
- Moreover, it is noted that the train 110 may comprise more than five or less than five units 114, as well as more than one locomotive in contrast to as it is shown in Fig.1.

LIST OF REFERENCE SIGNS

	100 system
	110 train comprising multiple units
5	120 wireless sensor network
	114 unit in the train
	112 locomotive
	122 wireless communication module
	124 control device, brake test controller
10	140 server
	160 user device
	210 brake system
	222 sensor means, sensor node
	226 pressure sensor, global navigation satellite system module
15	

CLAIMS

1. A system (100) for automatic generation of a list of units in a train (110) comprising multiple units (114), the system comprising:

5 a plurality of sensor means (222), wherein each of the plurality of sensor means (222) is configured to be mounted to a respective unit (114) of the train (110) and each of the plurality of sensor means (222) is configured to detect a parameter of the respective unit (114) of the train (110) to which it is mounted that is suitable to provide an information
10 about the position of the unit (114) with respect to another unit (114) in the train (110), and wherein each of the plurality of sensor means (222) is configured to communicate with one or more of the plurality of sensor means (222), and the plurality of sensor means (222) forms a sensor mesh network (120) to transmit the detected parameters for processing;

15 a control device (124) configured to receive the detected parameters from the sensor mesh network (120) and to process the detected parameters for generation of the list of units.

20 2. The system (100) according to claim 1, wherein each of the plurality of sensor means (222) is associated with an identifier of the respective unit (114) in the train (110) to which it is mounted and each of the plurality of sensor means (222) is configured to transmit the detected parameter and the associated identifier of the unit (114) in the train to which it is mounted to the control device (124) or a server (140) for processing
25 and generation of the list of units.

3. The system (100) according to claim 1 or 2, wherein the control device (124) comprises at least one interface for a manual input of data related to one or more items of the list of units and is configured to generate the list of units based at least in part on
30 the manual input of the data related to the one or more items of the list of units via the interface.

4. The system (100) according to any one of claims 1 to 3, wherein the multiple units (114) of the train (110) are connected in a brake system (210), at least one unit (112) in the train (110) is configured to control the pressure of a fluid in the brake system (210), and each of the plurality of sensor means (222) comprises a pressure sensor (226) and
5 a timestamp generator to detect a pressure of the fluid in the brake system (210) in the respective unit (114) and to generate a corresponding timestamp of when the pressure of the fluid in the brake system (210) in the respective unit (114) exceeds or falls below a predetermined threshold pressure, respectively, from which an information about the position of the respective unit (114) in the train (110) can be derived.

10

5. The system (100) according to any one of claims 1 to 5, wherein each of the plurality of sensor means (222) and the control device (124) comprises a wireless communication module (122) to send and receive signals, and each of the plurality of sensor means (222) is configured to detect a signal strength and an identifier of a
15 wireless communication module of at least one neighboring sensor means (222) from which an information about the position of the unit (114) in the train to which the sensor means is mounted can be derived, and wherein each of the plurality of sensor means (222) is configured to use the wireless communication module (122) for a wireless unit-to-unit communication, and wherein the wireless communication modules (122) of the
20 plurality of sensor means (222) form a wireless sensor mesh network (120) to wirelessly transmit the detected parameters, identifiers, pressures, timestamps, and signal strengths.

6. The system (100) according to any one of claims 1 to 5, wherein each of the
25 plurality of sensor means (120; 222) comprises a global navigation satellite system module (226) to detect a position of the unit (114) to which it is mounted from which information about the position of the unit (114) in the train (110) can be derived.

7. The system (100) according to any one of claims 1 to 6, wherein the control device
30 (124) is a fixed or a handheld device.

8. A method for automatic generation of a list of units in a train (110) comprising multiple units (114), the method comprising:

associating each of a plurality of sensor means (222) to a plurality of respective units (114) of the train (110);

each of the plurality of sensor means (222) being configured to communicate with one or more of the plurality of sensor means (222), and the plurality of sensor means (222) forming a sensor mesh network (120);

each of the plurality of sensor means (222) detecting a parameter of the respective unit (114) the sensor means (222) is associated with that is suitable to provide an information about the position of the respective unit (114) in the train (110);

each of the plurality of sensor means (120) transmitting the detected parameters via the sensor mesh network (120) to a control device (124) or a server (140); and

receiving the detected parameters from the sensor mesh network (120) at the control device (124) and processing the detected parameters to generate the list of units.

9. The method according to claim 8, further comprising associating each of the plurality of sensor means (222) with a respective identifier of the respective unit (114) in the train (110) the sensor means (222) is associated with and each of the plurality of sensor means (222) transmitting the identifier of the unit (114) in the train (110) to the control device (124) for processing and generation of the list of units.

10. The method according to claim 8 or 9, further comprising manually inputting via at least one interface for manual input of the control device (124) one or more items of the list of units, and generating the list of units at least in part based on the one or more items of the list of units.

11. The method according to any one of claims 8 – 10, further comprising connecting the multiple units (114) of the train (110) in a brake system (210), wherein at least one

unit (112) in the train (110) controls a pressure of a fluid in the brake system (210), and each of the plurality of sensor means (222) comprises a pressure sensor (226) and a timestamp generator, and detecting the pressure of the fluid in the brake system (210) with one or more pressure sensors (226) of the plurality of sensor means (222) and
5 producing a corresponding timestamp of when the pressure of the fluid in the brake system (210) in the respective unit (114) exceeds or falls below a predetermined threshold pressure for the one or more pressure sensors (226) from which an information about the position of the respective unit (114) in the train (110) can be derived.

10
12. The method according to one of claims 8 – 11, further comprising detecting with one or more of the plurality of sensors means (222) a signal strength of at least one respective neighboring sensor means (222) to provide an information about the position of the respective unit (114) associated with the neighboring sensor means (222) in the
15 train (110), wherein each of the plurality of sensor means (222) and the control device (124) comprise a wireless communication module (122) to send and receive signals, and transmit the information about the position of the respective unit (114) associated with the neighboring sensor means (222) in the train (110), and wherein each of the plurality of sensor means (222) uses the wireless communication module (122) for a
20 wireless unit-to-unit communication, and wherein the plurality of sensor means (222) forms a wireless sensor mesh network (120) to wirelessly transmit the detected parameters, identifiers, pressures, timestamps, and signal strengths.

25
13. The method according to one of claims 8 – 12, further comprising detecting with one or more of the plurality of sensors means (222) a position of the respective unit (114) associated with the sensor means (222), wherein each of the plurality of sensor means (222) comprises a global navigation satellite system module (226) to detect a position of the unit (114) and transmits the information about the position of the respective unit (114) associated with the sensor means (222) in the train (110).

30
14. The method according to any one of claims 8 – 13, wherein the method comprises generating the list of units and evaluating the accuracy of the list of units based on one

or more of the detected parameters, identifiers, pressures, timestamps, signal strengths, positions, and manual input of data related to one or more items of the list of units.

15. The method according to any one of claims 8 – 14, wherein the method further
5 comprises using the control device (124) as a brake test controller for brake testing after generation of the list of units and using the generated list of units for a brake weight calculation.

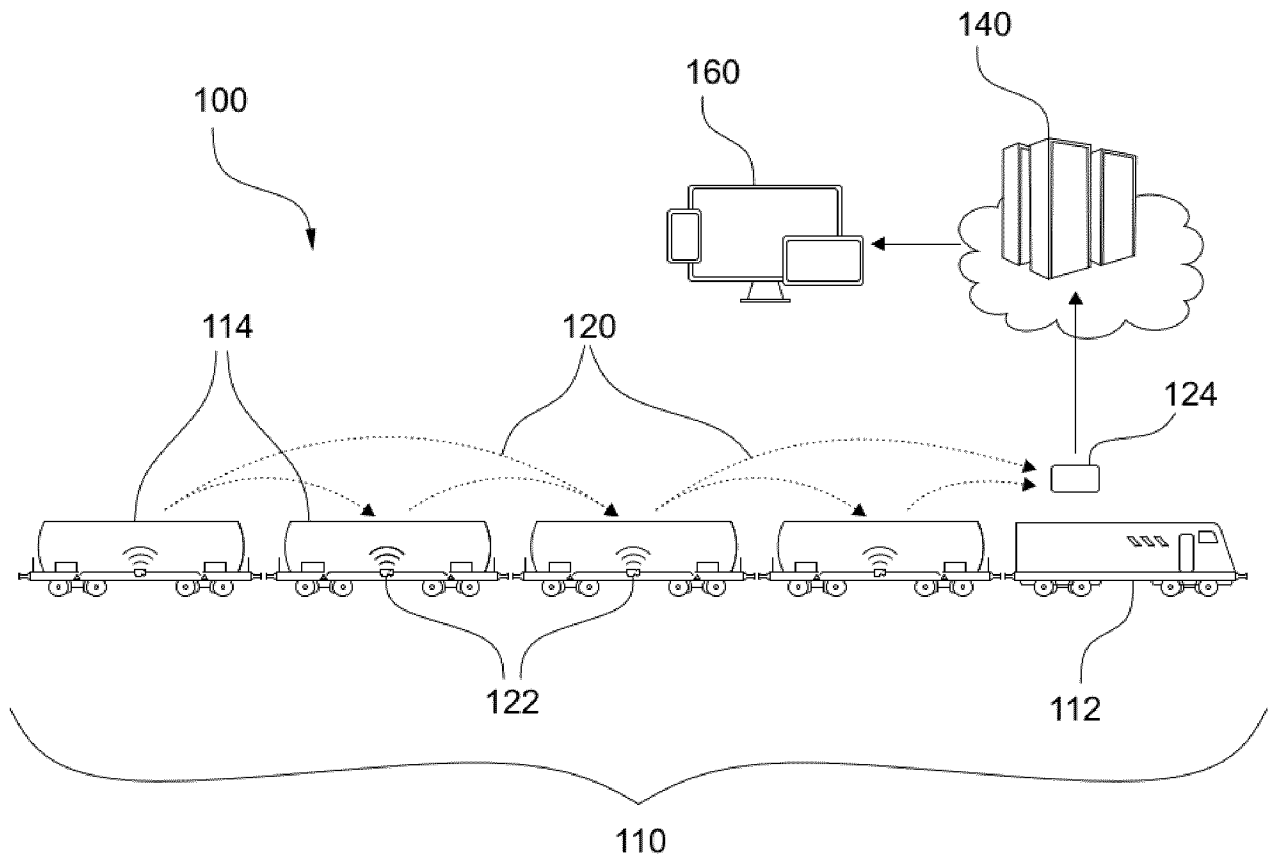


Fig. 1

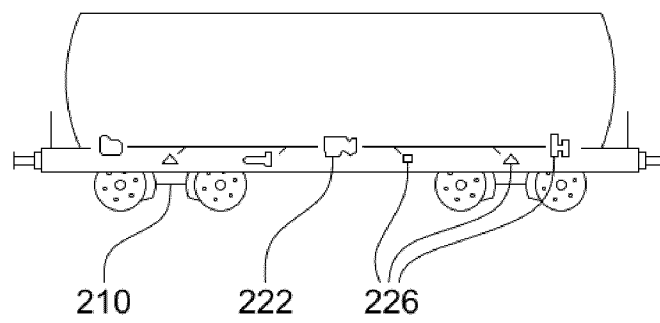


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/065505

A. CLASSIFICATION OF SUBJECT MATTER INV. B61L15/00 B61L25/02 B61L27/00 ADD. 		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B61L		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016/191711 A1 (AMSTED RAIL CO INC [US]) 1 December 2016 (2016-12-01) paragraph [0002] - paragraph [0144]; figures 1-13 -----	1-15
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 29 August 2022		Date of mailing of the international search report 06/09/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Kassner, Holger

INTERNATIONAL SEARCH REPORT

International application No

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