Title: MEASUREMENT METHODS AND DEVICES FOR VEHICLE TIRES

Abstract: A method of measuring a tread depth of a vehicle tire involves: measuring, at a hand-held device, a measurement of reflected energy reflected from a location between treads of the vehicle tire; and producing an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy. Computer-readable media and apparatuses are also disclosed.
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MEASUREMENT METHODS AND DEVICES FOR VEHICLE TIRES

FIELD

This disclosure relates generally to measurement methods and devices for vehicle tires.

RELATED ART

Vehicle tires, such as tires of off-the-road ("OTR") haul trucks for example, may be inspected from time-to-time. However, some methods of inspecting vehicle tires can be time-consuming or cumbersome. Some tire technicians may inspect many thousands of tires or more per year, so time-consuming or cumbersome methods of inspecting vehicle tires can cause unnecessary delays and expenses.

SUMMARY

According to one embodiment, there is disclosed a method of measuring a tread depth of a vehicle tire, the method comprising: measuring, at a hand-held device, a measurement of reflected energy reflected from a location between treads of the vehicle tire; and producing an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy.

According to another embodiment, there is disclosed at least one non-transitory computer-readable medium encoded with codes that, when executed by at least one processor circuit, cause the at least one processor circuit to implement the method.

According to another embodiment, there is disclosed an apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising a hand-holdable device comprising: the at least one non-transitory computer-readable medium; and the at least one processor circuit in communication with the at least one non-transitory computer-readable medium.

According to another embodiment, there is disclosed an apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising: a hand-holdable device comprising a means for measuring a measurement of reflected energy reflected from a location between treads of the vehicle tire; and a means for producing an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy.
According to another embodiment, there is disclosed an apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising a hand-holdable device comprising: a reflected-energy detector for measuring a measurement of reflected energy reflected from a location between treads of the vehicle tire; and at least one processor circuit configured to produce an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy.

Other aspects and features will become apparent to those ordinarily skilled in the art upon review of the following description of illustrative embodiments in conjunction with the accompanying figures.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a front perspective view of a measurement device according to one embodiment.

FIG. 2 schematically illustrates a processor circuit of the measurement device of FIG. 1.

FIG. 3 illustrates the measurement device of FIG. 1 in use according to one embodiment.

FIG. 4 is a cross-sectional view of the measurement device of FIG. 1 in use as illustrated in FIG. 3 and taken along the line 4-4 in FIG. 3.

FIG. 5 schematically illustrates measurement program instructions stored in a program memory in the processor circuit of FIG. 2.

FIG. 6 schematically illustrates a measurement information store in a storage memory in the processor circuit of FIG. 2.

FIG. 7 schematically illustrates optical-image program instructions stored in the program memory in the processor circuit of FIG. 2.

FIG. 8 schematically illustrates an optical images store in the storage memory in the processor circuit of FIG. 2.

FIG. 9 schematically illustrates work order program instructions stored in the program memory in the processor circuit of FIG. 2.
FIG. 10 schematically illustrates a work order store in the storage memory in the processor circuit of FIG. 2.

FIG. 11 schematically illustrates in-range program instructions stored in the program memory in the processor circuit of FIG. 2.

5 DETAILED DESCRIPTION

Referring to FIG. 1, a measurement device according to one embodiment is shown generally at 100. On a front side shown generally at 102, the measurement device 100 includes a visual display 104 and data-input keys 106. The visual display 104 may display information as described below, and a user of the measurement device 100 may input data using the data-input keys 106 as described below. In alternative embodiments, the visual display 104 and the data-input keys 106 may be combined into a single touch-sensitive screen or into more than one touch-sensitive screen. In other alternative embodiments, the data-input keys 106 may be covered with a flexible and impermeable barrier to protect the data-input keys 106 from water, dirt, or other possible causes of damage.

On an end shown generally at 108, the measurement device 100 has an end surface 110. Extending through the end surface 110, the measurement device 100 includes a light source 112 and a light collector 114. In the embodiment shown, the light source 112 and the light collector 114 may function as part of a triangulation distance sensor as described below and as further described in United States patent no. 6,624,899, although alternative embodiments may include different distance sensors such as, for example, a time-of-flight sensor as described in United States patent no. 5,309,212 or an ultrasonic range finder. Distance sensors such as those described herein may be configured or calibrated to measure distances in a range between, for example, 0 centimeters and 10 centimeters, or any other range that may be desirable for measuring tread depths of vehicle tires.

On the end 108, the measurement device 100 also includes a temperature sensor 116 and an optical camera 118. The temperature sensor 116 may detect temperature by detecting infrared energy, for example.
On a side shown generally at 120, the measurement device 100 has an audio speaker 122, a sensor 123, a measurement-initiation actuator 124, an optical-image-acquisition actuator 126, a power switch 128, a radio transmitter and receiver 130, and a microphone 131.

The sensor 123 is configured to be attached externally to an air valve of a tire to receive a sample of air from inside the tire and detect at least one property of the air from inside the tire. In the embodiment shown, the sensor 123 includes a pressure detector for measuring the air pressure in the vehicle tire, an air temperature detector for measuring the air temperature of air in the vehicle tire, and a nitrogen detector for measuring the concentration of nitrogen gas in the vehicle tire. Also, in the embodiment shown, the sensor 123 is configured to produce an air pressure signal representing a measurement of air pressure in the vehicle tire, an air temperature signal representing a measurement of the air temperature of air in the vehicle tire, and a nitrogen concentration signal representing a measurement of the concentration of nitrogen gas in the vehicle tire.

However, in alternative embodiments, the sensor 123 may be omitted, or may measure more, fewer, or different properties of air from inside a tire. Alternative embodiments may also include more than one sensor instead of the sensor 123. Also, in the embodiment shown, the sensor 123 may be coupled to the measurement device 100 through a flexible hose, but in alternative embodiments the sensor 123 may be built into the measurement device 100.

The power switch 128 may control whether the measurement device 100 is in an inactive or an active state. The radio transmitter and receiver 130 may include one or more antennae and is configured to transmit and receive radio signals according to various standards and protocols such as radio-frequency identification ("RFID"), BLUETOOTH™, WI-FI, or other wireless standards or protocols. Alternative embodiments may communicate using physical connections such as a Universal Serial Bus ("USB") or other physical connection, and still other alternative embodiments may communicate with a combination of one or more wireless standards or protocols and one or more physical connections. The measurement device 100 is sized to be a hand-held device, and is thus a hand-holdable device.

Referring to FIG. 2, the measurement device 100 includes a processor circuit shown generally at 132 and including a microprocessor 134 in communication with the visual display 104, the data-input keys 106, the light source 112, the light collector 114, the temperature
sensor 116, the optical camera 118, the audio speaker 122, the sensor 123, the measurement-
initiation actuator 124, the optical-image-acquisition actuator 126, the power switch 128, the
radio transmitter and receiver 130, and the microphone 131. Further, the microprocessor 134 is
in communication with a clock 136 that produces current date and time values for use by the
microprocessor 134, a program memory 138 that stores blocks of program instructions
executable by the microprocessor 134, and a storage memory 140 that stores data that may be
stored by, and that may be accessible to, the microprocessor 134. The program memory 138
and the storage memory 140 may be implemented on one or more of the same or different
computer-readable storage media, which in various embodiments may include one or more of
a read-only memory ("ROM"), random access memory ("RAM"), a hard disc drive ("FIDD"),
and other computer-readable and/or -writable storage media. Further, in alternative
embodiments, the processor circuit 132 may be partly or fully implemented using different
hardware logic, which may include discrete logic circuits and/or an application specific
integrated circuit ("ASIC") for example.

Referring to FIGS. 3 and 4, a vehicle according to one embodiment is an off-the-road
("OTR") haul truck shown generally at 142, which includes front tires 144 and 146 and rear
tires 148, 150, 152, and 154. Vehicles in other embodiments may be other OTR vehicles or
still other vehicles such as road vehicles, for example. The front tire 146 has a tread surface
156 having tire treads including tire treads 158 and 160. The front tire 146 also has an air
valve 162 that may be used to convey pressurize air into the front tire 146. Further, a sensor
164 is inside the front tire 146 and may be coupled to the air valve 162. The sensor 164 is
configured to measure air pressure, temperature, and concentration of nitrogen gas (N₂) inside
the front tire 146, and to communicate with the radio transmitter and receiver 130 as described
below. The sensor 164 may, for example, be a TTT SENSOR available from Kal Tire of 1540
Kalamalka Lake Road, Vernon, British Columbia, Canada, or a MEMS (Michelin Earthmover
Management System) Evolution3 sensor available from Michelin. However, alternative
embodiments may include different sensors. For example, alternative embodiments may
include a sensor of air pressure and temperature separate from a sensor of concentration of
nitrogen gas. In such embodiments, the sensor of concentration of nitrogen gas may be, for
example, a model #24860 available from AME International of 2347 Circuit Way,
Brooksville, Florida, United States of America. Also, in some embodiments, the sensor 164 may be omitted because, for example, the sensor 123 may measure some or all of the same properties of the air in the front tire 146.

Further, a tire identifier 166 is also positioned inside the front tire 146. The tire identifier 166 in the embodiment shown is an RFID identifier configured to receive an identification-initiation signal from the radio transmitter and receiver 130 and to respond to such an identification-initiation signal with an identification response signal encoded with identification information that identifies the front tire 146 according to identification information stored in the tire identifier 166. However, tire identifiers in other embodiments may differ. For example, a tire identifier in another embodiment may be a bar code or other optical pattern that may be visible on an exterior surface of the front tire 146 and that may be detected by the optical camera 118 and decoded by the microprocessor 134. As another example, a tire identifier in another embodiment may be alphanumeric text or any other code that may be visible on an exterior surface of the front tire 146 or otherwise readable such that a user of the measurement device 100 may enter, for example manually using the data-input keys 106 or using speech recognition of speech received at the microphone 131. Further, although the embodiment shown includes the sensor 164 and the tire identifier 166, alternative embodiments may include variations in which, for example, a sensor that measures air pressure, a sensor that measures temperature, a sensor that measures concentration of nitrogen gas (N₂), and a tire identifier may be combined into one device or separated into two or more various different devices.

As shown in FIGS. 3 and 4, a user of the measurement device 100 may position the end surface 110 against the tread surface 156 of the front tire 146 with the light source 112, the light collector 114, and the temperature sensor 116 positioned in a space 168 between the tire treads 158 and 160. Referring back to FIG. 2, the user may then actuate the measurement-initiation actuator 124, which transmits a measurement-initiation signal to the microprocessor 134. In response to receiving the measurement-initiation signal from the measurement-initiation actuator 124, the microprocessor 134 executes measurement program instructions 170 in the program memory 138.
Referring to FIGS. 2 and 5, the measurement program instructions 170 are illustrated schematically in FIG. 5 and include blocks of instructions for directing the microprocessor 134 to obtain vehicle tire information and to produce output signals representing the vehicle tire information. The measurement program instructions 170 begin at block 172 after receiving the measurement-initiation signal from the measurement-initiation actuator 124, and the instructions at block 172 direct the microprocessor 134 to obtain tire identification information identifying a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100. In the embodiment shown, the instructions at block 172 cause the microprocessor 134 to cause the radio transmitter and receiver 130 to transmit the identification-initiation signal (as described above) to the tire identifier 166, which causes the tire identifier 166 to respond by transmitting the identification response signal (as described above) to the radio transmitter and receiver 130. As described above, the identification response signal is encoded with identification information that identifies the front tire 146 according to identification information stored in the tire identifier 166. However, as indicated above, tire identifiers in other embodiments may include a bar code, another other optical pattern, alphanumeric text, or any other code that may be visible on an exterior surface of a vehicle tire or otherwise readable by the measurement device 100 or by a user of the measurement device 100, and in such embodiments the instructions at block 172 may obtain tire identification information in other ways, for example from input at the data-input keys 106, at the optical camera 118, or at the microphone 131. Therefore, more generally, the instructions at block 172 cause the microprocessor 134 to receive, from the tire identifier 166 or from an alternative tire identifier, a vehicle tire identification input signal representing an identifier of a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100.

The measurement program instructions 170 continue at block 174, which includes instructions for directing the microprocessor 134 to obtain a measurement of tread depth of a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100 at a location within a measurement range of the light source 112 and the light collector 114. As described in United States patent no. 6,624,899, the light source 112 may include a laser that generates a source light beam 176 that reflects off of a surface (in the space
168 at a location 178 in the embodiment shown) as a reflected light beam 180 measured by the light collector 114. The light source 112 thus functions as an energy source to produce reflected energy (the reflected light beam 180 in the embodiment shown), and the light collector 114 is thus a reflected-light detector (or more generally a reflected-energy detector).

Also as described in United States patent no. 6,624,899, the light collector 114 may measure an angle such as an angle 182 between a reference line (namely a line defined by the end surface 110) and the reflected light beam 180, and the angle 182 is related to an angle 184 between another reference line (namely a line defined by the source light beam 176) and the reflected light beam 180 by a configuration or calibration parameter of the measurement device 100 such as an angle between the end surface 110 and the source light beam 176. The angle 182 or the angle 184 may be associated with a distance 186 between the end surface 110 and the location 178, and the distance 186 may be calculated according to configuration or calibration parameters of the measurement device 100 such as a distance between the light source 112 and the light collector 114. Therefore, the angle 182 or the angle 184 indicates the distance 186, and the instructions at block 174 direct the microprocessor 134 to identify the distance 186 according to the angle 182 and configuration or calibration parameters of the measurement device 100. When the measurement device 100 is positioned as shown in FIG. 4, the distance 186 is a measurement of tread depth of the front tire 146 at the location 178 between the tire treads 158 and 160.

Therefore, more generally, the instructions at block 174 cause the microprocessor 134 to measure a measurement (the angle 182 in the embodiment shown) of reflected energy (the reflected light beam 180 in the embodiment shown) reflected from a location (the location 178 in the embodiment shown) between treads (tire treads 158 and 160 in the embodiment shown) of a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100 to measure a distance (the distance 186 in the embodiment shown) from a reference surface (the end surface 110 in the embodiment shown) to the location between the treads of the vehicle tire. However, as indicated above, alternative embodiments may involve different measurements of reflected energy such as, for example, time-of-flight measurements as described in United States patent no. 5,309,212 or measurements of reflected sound.
The measurement program instructions 170 continue at block 188, which includes instructions for directing the microprocessor 134 to obtain a measurement of air pressure in a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100. As indicated above, the sensor 164 (shown in FIG. 3) is inside the front tire 146 and configured to measure air pressure inside the front tire 146, and the instructions at block 188 direct the microprocessor 134 to cause the radio transmitter and receiver 130 to transmit an air-pressure-request signal to the sensor 164, which causes the sensor 164 to transmit to the radio transmitter and receiver 130 an air-pressure-response signal indicating a measurement of air pressure in the front tire 146 by the sensor 164. In alternative embodiments, the sensor 123 may be positioned externally on the air valve 162 of the front tire 146, and the sensor 123 may measure air pressure inside the front tire 146 by measuring a sample of air received through the air valve 162. In such embodiments, the instructions at block 188 may direct the microprocessor 134 to receive, from the sensor 123, an air pressure signal representing a measurement by the sensor 123 of air pressure in the front tire 146. Therefore, more generally, the instructions at block 188 cause the microprocessor 134 to receive, from the sensor 164 or from the sensor 123, an air pressure input signal representing a measurement of air pressure in a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100.

The measurement program instructions 170 continue at block 190, which includes instructions for directing the microprocessor 134 to obtain a measurement of air temperature inside a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100. As indicated above, the sensor 164 (shown in FIG. 3) is inside the front tire 146 and configured to measure temperature inside the front tire 146, and the instructions at block 190 direct the microprocessor 134 to cause the radio transmitter and receiver 130 to transmit a temperature-request signal to the sensor 164, which causes the sensor 164 to transmit to the radio transmitter and receiver 130 a temperature-response signal indicating a measurement of temperature in the front tire 146 by the sensor 164. In alternative embodiments, the sensor 123 may be positioned externally on the air valve 162 of the front tire 146, and the sensor 123 may measure temperature inside the front tire 146 by measuring a sample of air received through the air valve 162. In such embodiments, the instructions at
block 190 may direct the microprocessor 134 to receive, from the sensor 123, an air
temperature signal representing a measurement by the sensor 123 of temperature in the front
tire 146. Therefore, more generally, the instructions at block 190 cause the microprocessor 134
to receive, from the sensor 164 or from the sensor 123, an air temperature input signal
representing a measurement of temperature in a vehicle tire (the front tire 146 in the
embodiment shown) that is adjacent the measurement device 100.

The measurement program instructions 170 continue at block 192, which includes
instructions for directing the microprocessor 134 to obtain a measurement of a temperature
exterior to a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the
measurement device 100. As indicated above, the temperature sensor 116 may be positioned
adjacent the space 168 as shown in FIG. 4, and the instructions at block 192 direct the
microprocessor 134 to obtain a temperature measurement from the temperature sensor 116.
Therefore, more generally, the instructions at block 192 cause the microprocessor 134 to
measure of an exterior temperature of a vehicle tire (the front tire 146 in the embodiment
shown) that is adjacent the measurement device 100.

The measurement program instructions 170 continue at block 194, which includes
instructions for directing the microprocessor 134 to obtain a measurement of a concentration
of nitrogen gas inside the front tire 146. As indicated above, the sensor 164 (shown in FIG. 3)
is inside the front tire 146 and configured to measure concentration of nitrogen gas inside the
front tire 146, and the instructions at block 190 direct the microprocessor 134 to cause the
radio transmitter and receiver 130 to transmit a nitrogen-gas-concentration-request signal to
the sensor 164, which causes the sensor 164 to transmit to the radio transmitter and receiver
130 a nitrogen-gas-concentration-response signal indicating a measurement of concentration
of nitrogen gas in the front tire 146 by the sensor 164. In alternative embodiments, the sensor
123 may be positioned externally on the air valve 162 of the front tire 146, and the sensor 123
may measure concentration of nitrogen gas in the front tire 146 by measuring a sample of air
received through the air valve 162. In such embodiments, the instructions at block 194 may
direct the microprocessor 134 to receive, from the sensor 123, a nitrogen concentration signal
representing a measurement by the sensor 123 of concentration of nitrogen gas in the front tire
146. Therefore, more generally, the instructions at block 194 cause the microprocessor 134 to
receive, from the sensor 164 or from the sensor 123, a nitrogen concentration input representing a measurement of concentration of nitrogen gas in a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100.

The measurement program instructions 170 continue at block 196, which includes instructions for directing the microprocessor 134 to store vehicle tire information obtained at blocks 172, 174, 188, 190, 192, and 194 in a measurement information store 198 in the storage memory 140. Referring to FIG. 6, the measurement information store 198 is illustrated schematically and includes a plurality of entries including an example entry shown generally at 200, an example entry shown generally at 202, and an example entry shown generally at 204. Each of the entries includes a Boolean updated field shown generally at 206, a tire identifier field shown generally at 208, a measurement time field shown generally at 210, a tread depth field shown generally at 212, an air pressure field shown generally at 214, an air temperature field shown generally at 216, an exterior temperature field shown generally at 218, and a nitrogen concentration field shown generally at 220.

Referring to FIGS. 2, 5, and 6, the instructions at block 196 direct the microprocessor 134 to add a new entry in the measurement information store 198. In the new entry, the Boolean uploaded field 206 initially stores codes representing "false", the tire identifier field 208 stores codes representing the tire identification information obtained at block 172, the measurement time field 210 stores codes representing a current date and time retrieved from the clock 136, the tread depth field 212 stores codes representing (in millimeters or other units) the measurement of tread depth obtained at block 174, the air pressure field 214 stores codes representing (in kilopascals or other units) the measurement of air pressure obtained at block 188, the air temperature field 216 stores codes representing (in degrees Celsius or other units) the measurement of air temperature obtained at block 190, the exterior temperature field 218 stores codes representing (in degrees Celsius or other units) the measurement of exterior temperature obtained at block 192, and the nitrogen concentration field 220 stores codes representing (as a molar percentage or other units) the measurement of nitrogen concentration obtained at block 194. In summary, the instructions at block 196 direct the microprocessor 134 to produce an output signal that causes the storage memory 140 to store codes representing
vehicle tire information as described above, and the vehicle tire information is associated with the tire identification information obtained at block 172.

Referring back to FIGS. 2 and 5, the measurement program instructions 170 continue at block 222, which includes instructions for directing the microprocessor 134 to cause the visual display 104 to display the information. The instructions at block 222 therefore direct the microprocessor 134 to produce an output signal that causes the visual display 104 to display vehicle tire information as described above, and the vehicle tire information is associated with the tire identification information obtained at block 172.

The measurement program instructions 170 continue at block 224, which includes instructions for directing the microprocessor 134 to compare the vehicle tire information stored at block 196 and displayed at block 222 with alarm criteria in an alarm criteria store 225 in the storage memory 140. The alarm criteria in the alarm criteria store 225 may include criteria such as a minimum tread depth, a minimum and/or maximum air pressure, a minimum and/or maximum air temperature, a minimum and/or maximum exterior temperature, and a minimum nitrogen concentration to satisfy certain requirements such as safety requirements, for example. If at block 224 the vehicle tire information satisfies at least one alarm criterion in the alarm criteria store 225, then the measurement program instructions 170 continue at block 226, which includes instructions for directing the microprocessor 134 to generate an alarm. In the embodiment shown, the instructions at block 226 direct the microprocessor 134 to generate alarm sounds at the audio speaker 122 and to display an alarm indicator on the visual display 104. If at block 224 none of the vehicle tire information satisfies any alarm criterion in the alarm criteria store 225, or after block 226, the measurement program instructions 170 end.

Alternative embodiments may obtain, display, and store more or less vehicle tire information. For example, some of the measurements described above may be omitted in some embodiments, and in such embodiments some of the sensors, blocks of instructions, and fields may be omitted. As one example, in some embodiments, exterior temperature may be omitted, and in such embodiments, the temperature sensor 116, the instructions at block 192, and the exterior temperature field 218 may be omitted. Vehicle tire information according to still other embodiments may omit other measurements or include additional measurements.
Referring back to FIG. 3, the other front tire 144 and the rear tires 148, 150, 152, and 154 are similar to the front tire 146. In general, a user of the measurement device 100 may obtain numerous measurements, for example at several locations on each tire of a vehicle. The user of the measurement device 100 may actuate the measurement-initiation actuator 124 for each of any number of locations on one or more tires of a vehicle, and each actuation of the measurement-initiation actuator 124 may cause execution of the measurement program instructions 170 and result in a respective entry in the measurement information store 198.

Referring back to FIGS. 1 and 2, while the user of the measurement device 100 is inspecting vehicle tires, the user may notice visual signs of damage or other visual indicators that may be worth reporting or addressing later. To record such visual information of a vehicle tire, the user may direct the optical camera 118 to one or more areas of the tire and actuate the optical-image-acquisition actuator 126. Actuation of the optical-image-acquisition actuator 126 causes an optical-image-acquisition signal to be transmitted to the microprocessor 134, and in response to receiving the optical-image-acquisition signal from the optical-image-acquisition actuator 126, the microprocessor 134 executes optical-image program instructions 228 in the program memory 138.

Referring to FIGS. 2 and 7, the optical-image program instructions 228 are illustrated schematically in FIG. 7 and include blocks of instructions for directing the microprocessor 134 to obtain an optical image and to produce an output signal representing the optical image. The optical-image program instructions 228 begin at block 230 in response to receiving the optical-image-acquisition signal from the optical-image-acquisition actuator 126. The instructions at block 230 direct the microprocessor 134 to obtain tire identification information identifying a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100, substantially as described above with reference to block 172. The optical-image program instructions 228 continue at block 232, which includes instructions for directing the microprocessor 134 to acquire optical image data from the optical camera 118. The optical-image program instructions 228 continue at block 234, which includes instructions for directing the microprocessor 134 to store the optical image data obtained at block 232 in an optical images store 236 in the storage memory 140, and the optical image data are associated with the tire identification information obtained at block 230. The instructions at block 232
therefore direct the microprocessor 134 to produce an output signal that causes the storage memory 140 to store optical image data as described above.

Referring to FIG. 8, the optical images store 236 is illustrated schematically and includes various entries including an example entry shown generally at 238, an example entry shown generally at 240, and an example entry shown generally at 242. Each entry includes a Boolean uploaded field shown generally at 244, a tire identifier field shown generally at 246, a time field shown generally at 248, and an optical image data field shown generally at 250.

Referring to FIGS. 2, 7, and 8, the instructions at block 234 direct the microprocessor 134 to add a new entry to the optical images store 236. In the new entry, the Boolean uploaded field 244 initially stores codes representing "false", the tire identifier field 246 stores codes representing the tire identification information obtained at block 230, the time field 248 stores codes representing a current date and time retrieved from the clock 136, and the optical image data field 250 stores codes representing the optical image data obtained at block 232. In summary, the instructions at block 234 direct the microprocessor 134 to produce an output signal that causes the storage memory 140 to store codes representing optical image data as described above. The optical-image program instructions 228 end after block 234.

Referring back to FIGS. 1 and 2, while the user of the measurement device 100 is inspecting vehicle tires, the user may notice work that must be done to a tire. For example, the user may notice that a tire requires servicing or replacement. To record such information of a vehicle tire, the user may enter information identifying at least one task for a work order, for example using the data-input keys 106 or using speech recognition of speech received at the microphone 131. Such information may identify, for a task, a type of work required (such as replacement of a tire, a type of servicing that a tire requires, or further inspection for a tire, for example) and a level of urgency of the work (such as work required within a certain time frame or work required immediately, for example). User input of such information causes the microprocessor 134 to receive a work order input signal (for example from the data-input keys 106 or from the microphone 131) representing at least one task for the work order, and in response to receiving the work order input signal, the microprocessor 134 executes work order program instructions 264 in the program memory 138.
Referring to FIGS. 2 and 9, the work order program instructions 264 are illustrated schematically in FIG. 9 and include blocks of instructions for directing the microprocessor 134 to obtain the work order input signal and to produce a work order. The work order program instructions 264 begin at block 266 in response to receiving the work order input signal. The instructions at block 266 direct the microprocessor 134 to obtain tire identification information identifying a vehicle tire (the front tire 146 in the embodiment shown) that is adjacent the measurement device 100, substantially as described above with reference to block 172. The work order program instructions 264 continue at block 268, which includes instructions for directing the microprocessor 134 to generate a work order and store the work order in a work order store 270 in the storage memory 140. The instructions at block 268 therefore direct the microprocessor 134 to produce an output signal that causes the storage memory 140 to store a work order as described above.

Referring to FIG. 10, the work order store 270 is illustrated schematically and includes various entries including an example entry shown generally at 272, an example entry shown generally at 274, and an example entry shown generally at 276. Each entry includes a Boolean uploaded field shown generally at 278, a tire identifier field shown generally at 280, a time field shown generally at 282, a type of work field shown generally at 284, and an urgency field shown generally at 286.

Referring to FIGS. 2, 9, and 10, the instructions at block 268 direct the microprocessor 134 to add a new entry to the work order store 270. In the new entry, the Boolean uploaded field 278 initially stores codes representing "false", the tire identifier field 280 stores codes representing the tire identification information obtained at block 266, the time field 282 stores codes representing a current date and time retrieved from the clock 136, the type of work field 284 stores codes representing a type of work (such as replacement of a tire, a type of servicing that a tire requires, or further inspection for a tire, for example) identified by the work order input signal, and the urgency field 286 stores codes representing the urgency of the work (such as work required within a certain time frame or work required immediately, for example) identified by the work order input signal. In summary, the instructions at block 268 direct the microprocessor 134 to produce an output signal that causes the storage memory 140 to store
codes representing the work order as described above. The work order program instructions 264 end after block 268.

Referring back to FIG. 3, a central computer is shown generally at 252 and includes a radio transmitter and receiver 254 that may communicate with the radio transmitter and receiver 130 of the measurement device 100. When the measurement device 100 is in range of an upload connection with the radio transmitter and receiver 254 of the central computer 252, the microprocessor 134 may execute in-range program instructions 256 illustrated schematically in FIG. 11.

Referring to FIGS. 2 and 11, when the microprocessor 134 detects that the measurement device 100 is in range of an upload connection with the radio transmitter and receiver 254 of the central computer 252, the in-range program instructions 256 begin at block 258, which includes instructions for directing the microprocessor 134 to determine whether any entries in the measurement information store 198 (shown in FIG. 6), in the optical images store 236 (shown in FIG. 8), or in the work order store 270 (shown in FIG. 10) have not been uploaded to the central computer 252. To do so, the microprocessor queries the Boolean uploaded field 206 of the measurement information store 198, the Boolean uploaded field 244 of the optical images store 236, and the Boolean uploaded field 278 of the work order store 270. If all of the Boolean uploaded fields 206, 244, and 278 store codes representing "true", then no entries are not uploaded and the in-range program instructions 256 end. However, if block 258 any of the Boolean uploaded fields 206, 244, or 278 store codes representing "false", then the in-range program instructions 256 continue at block 260, which includes instructions for directing the microprocessor 134 to upload the not-uploaded entries to the central computer 252. In summary, the instructions at block 260 direct the microprocessor 134 to produce a wireless signal representing vehicle tire information (which may include optical image data or one or more work orders, or both, as described above), and the vehicle tire information is associated with the tire identification information obtained at blocks 172, 230, and 266 (as the case may be). The in-range program instructions 256 then continue at block 262, which includes instructions for directing the microprocessor 134 to change the Boolean uploaded field 206, 244, or 278 (as the case may be) to store codes representing "true" once
the entry has been uploaded to the central computer 252. The in-range program instructions 256 then end.

As indicated above, alternative embodiments may communicate using physical connections such as a USB or other physical connection, and in such embodiments, program instructions (in addition to or in the alternative to the in-range program instructions 256) may cause any entries in the measurement information store 198 (shown in FIG. 6), in the optical images store 236 (shown in FIG. 8), or in the work order store 270 (shown in FIG. 10) that have not been uploaded to the central computer 252 to be uploaded to the central computer 252 in substantially the same way as the in-range program instructions 256 when a USB or other physical connection to the central computer 252 is available. In such embodiments, a USB or other physical connection to the central computer 252 may transmit a signal representing vehicle tire information (which may include optical image data or one or more work orders, or both, as described above), and the vehicle tire information is associated with the tire identification information obtained at blocks 172, 230, and 266 (as the case may be).

In general, measurement devices such as the measurement device 100 allow a user to measure some or all of various different types of vehicle tire information. Further, the user may measure some vehicle tire information (such as tread depth or exterior temperature, for example) at any one or more locations on a vehicle tire, and thus measurement devices such as the measurement device 100 are not necessarily limited to measuring such vehicle tire information at fixed locations on the vehicle tire. More generally, measurement devices such as the measurement device 100 may facilitate more-efficient or more-convenient inspection vehicle tires when compared to other methods of inspecting vehicle tires.

Although specific embodiments have been described and illustrated, such embodiments should be considered illustrative only and not as limiting the invention as construed according to the accompanying claims.
CLAIMS

1. A method of measuring a tread depth of a vehicle tire, the method comprising:
   measuring, at a hand-held device, a measurement of reflected energy reflected from a
   location between treads of the vehicle tire; and
   producing an output signal representing vehicle tire information comprising a
   measurement of the tread depth in response to the measurement of the reflected energy.

2. The method of claim 1 wherein measuring the measurement of the reflected energy
   comprises:
   positioning a reference surface of the hand-held device against at least one outer
   surface of at least one of the treads of the vehicle tire; and
   measuring a distance from the reference surface to the location between the treads of
   the vehicle tire.

3. The method of claim 1 or 2 wherein measuring the measurement of the reflected
   energy comprises measuring a measurement of reflected light reflected from the location
   between the treads of the vehicle tire.

4. The method of claim 3 wherein measuring the measurement of the reflected light
   comprises measuring an angle of travel of the reflected light relative to a reference line
   defined by the hand-held device.

5. The method of claim 3 wherein measuring the measurement of the reflected light
   comprises measuring a time of flight of the reflected light.

6. The method of any one of claims 1 to 5 further comprising producing the reflected
   energy.

7. The method of any one of claims 1 to 6 wherein the vehicle tire information further
   comprises a measurement of air pressure in the vehicle tire.
8. The method of claim 7 further comprising receiving an air pressure input signal representing the measurement of air pressure in the vehicle tire.

9. The method of claim 8 wherein receiving the air pressure input signal comprises receiving the air pressure input signal from an air pressure sensor inside the vehicle tire.

10. The method of claim 8 wherein receiving the air pressure input signal comprises receiving the air pressure input signal from an air pressure sensor coupled to the hand-held device.

11. The method of any one of claims 1 to 10 wherein the vehicle tire information further comprises a measurement of an air temperature of air in the vehicle tire.

12. The method of claim 11 further comprising receiving an air temperature input signal representing the measurement of the air temperature of air in the vehicle tire.

13. The method of claim 12 wherein receiving the air temperature input signal comprises receiving the air temperature input signal from an air temperature sensor inside the vehicle tire.

14. The method of claim 12 wherein receiving the air temperature input signal comprises receiving the air temperature input signal from an air temperature sensor coupled to the hand-held device.

15. The method of any one of claims 1 to 14 wherein the vehicle tire information further comprises a measurement of an exterior temperature of the vehicle tire.

16. The method of claim 15 further comprising measuring the exterior temperature of the vehicle tire.

17. The method of any one of claims 1 to 16 wherein the vehicle tire information further comprises a measurement of a concentration of nitrogen gas in the vehicle tire.
18. The method of claim 17 further comprising receiving a nitrogen concentration input signal representing the measurement of the concentration of nitrogen gas in the vehicle tire.

19. The method of claim 18 wherein receiving the nitrogen concentration input signal comprises receiving the nitrogen concentration input signal from a nitrogen concentration sensor inside the vehicle tire.

20. The method of claim 18 wherein receiving the nitrogen concentration input signal comprises receiving the nitrogen concentration input signal from a nitrogen concentration sensor coupled to the hand-held device.

21. The method of any one of claims 1 to 20 wherein the vehicle tire information further comprises an optical image of an exterior of the vehicle tire.

22. The method of claim 21 further comprising capturing the optical image of the exterior of the vehicle tire.

23. The method of any one of claims 1 to 22 wherein the vehicle tire information further comprises a work order for the vehicle tire.

24. The method of claim 23 further comprising receiving a work order input signal representing at least one task for the work order.

25. The method of any one of claims 1 to 24 wherein producing the output signal comprises causing a visual display to display the vehicle tire information.

26. The method of any one of claims 1 to 25 wherein producing the output signal comprises causing a computer-readable storage medium to store codes representing the vehicle tire information.

27. The method of any one of claims 1 to 26 wherein producing the output signal comprises transmitting a wireless signal representing the vehicle tire information.
28. The method of any one of claims 1 to 27 further comprising receiving a vehicle tire identification input signal representing an identifier of the vehicle tire.

29. The method of claim 28 wherein receiving the vehicle tire identification input signal comprises receiving the vehicle tire identification input signal from a vehicle tire identifier inside the vehicle tire.

30. The method of claim 28 or 29, when directly or indirectly dependent from claim 26, wherein causing the computer-readable storage medium to store the codes representing the vehicle tire information comprises causing the computer-readable storage medium to store the codes representing the vehicle tire information in association with the identifier of the vehicle tire.

31. The method of claim 28, 29, or 30, when directly or indirectly dependent from claim 27, wherein transmitting the wireless signal representing the vehicle tire information comprises transmitting the wireless signal representing the vehicle tire information in association with the identifier of the vehicle tire.

32. At least one non-transitory computer-readable medium encoded with codes that, when executed by at least one processor circuit, cause the at least one processor circuit to implement the method of any one of claims 1 to 31.

33. An apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising: a hand-holdable device comprising:

the at least one non-transitory computer-readable medium of claim 32; and

the at least one processor circuit in communication with the at least one non-transitory computer-readable medium.

34. An apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising: a hand-holdable device comprising a means for measuring a measurement of reflected energy reflected from a location between treads of the vehicle tire; and
a means for producing an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy.

35. The apparatus of claim 34 wherein:

   the hand-holdable device further comprises a reference surface positionable against at least one outer surface of at least one of the treads of the vehicle tire; and
   the means for measuring the measurement of the reflected energy is configured to measure a distance from the reference surface to the location between the treads of the vehicle tire.

36. The apparatus of claim 34 or 35 wherein the means for measuring the measurement of the reflected energy comprises a means for measuring a measurement of reflected light reflected from the location between the treads of the vehicle tire.

37. The apparatus of claim 36 wherein the means for measuring the measurement of the reflected light comprises a means for measuring an angle of travel of the reflected light relative to a reference line defined by the hand-holdable device.

38. The apparatus of claim 36 wherein the means for measuring the measurement of the reflected light comprises a means for measuring a time of flight of the reflected light.

39. The apparatus of any one of claims 34 to 38 wherein the hand-holdable device further comprises a means for producing the reflected energy.

40. The apparatus of any one of claims 34 to 39 wherein the vehicle tire information further comprises a measurement of air pressure in the vehicle tire.

41. The apparatus of claim 40 further comprising a means for receiving an air pressure input signal representing the measurement of air pressure in the vehicle tire.

42. The apparatus of claim 41 wherein the hand-holdable device further comprises the means for receiving the air pressure input signal.
43. The apparatus of claim 41 or 42 wherein the hand-holdable device further comprises:
   a means for measuring the air pressure in the vehicle tire; and
   a means for producing the air pressure input signal from a measurement by the means
   for measuring the air pressure in the vehicle tire.

44. The apparatus of any one of claims 34 to 43 wherein the vehicle tire information
   further comprises a measurement of an air temperature of air in the vehicle tire.

45. The apparatus of claim 44 further comprising a means for receiving an air temperature
   input signal representing the measurement of the air temperature of air in the vehicle tire.

46. The apparatus of claim 45 wherein the hand-holdable device further comprises the
   means for receiving the air temperature input signal.

47. The apparatus of claim 45 or 46 wherein the hand-holdable device further comprises:
   a means for measuring the air temperature of air in the vehicle tire; and
   a means for producing the air temperature input signal from a measurement by the
   means for measuring the air temperature of air in the vehicle tire.

48. The apparatus of any one of claims 34 to 47 wherein the vehicle tire information
   further comprises a measurement of an exterior temperature of the vehicle tire.

49. The apparatus of claim 48 further comprising a means for measuring the exterior
   temperature of the vehicle tire.

50. The apparatus of any one of claims 34 to 49 wherein the vehicle tire information
   further comprises a measurement of a concentration of nitrogen gas in the vehicle tire.

51. The apparatus of claim 50 further comprising a means for receiving a nitrogen
   concentration input signal representing the measurement of the concentration of nitrogen gas
   in the vehicle tire.

52. The apparatus of claim 51 wherein the hand-holdable device further comprises the
   means for receiving the nitrogen concentration input signal.
53. The apparatus of claim 51 or 52 wherein the hand-holdable device further comprises:
   a means for measuring the concentration of nitrogen gas in the vehicle tire; and
   a means for producing the nitrogen concentration input signal from a measurement by
the means for measuring the concentration of nitrogen gas in the vehicle tire.

54. The apparatus of any one of claims 34 to 53 wherein the vehicle tire information
   further comprises an optical image of an exterior of the vehicle tire.

55. The apparatus of claim 54 further comprising a means for capturing the optical image
   of the exterior of the vehicle tire.

56. The apparatus of any one of claims 34 to 55 wherein the vehicle tire information
   further comprises a work order for the vehicle tire.

57. The apparatus of claim 56 further comprising a means for receiving a work order input
   signal representing at least one task for the work order.

58. The apparatus of any one of claims 34 to 57 wherein the means for producing the
   output signal comprises a means for causing a visual display to display the vehicle tire
   information.

59. The apparatus of any one of claims 34 to 58 wherein the means for producing the
   output signal comprises a means for causing a computer-readable storage medium to store
   codes representing the vehicle tire information.

60. The apparatus of any one of claims 34 to 59 wherein the means for producing the
   output signal comprises a means for transmitting a wireless signal representing the vehicle tire
   information.

61. The apparatus of any one of claims 34 to 60 further comprising a means for receiving a
   vehicle tire identification input signal representing an identifier of the vehicle tire.

62. The apparatus of claim 61 wherein the hand-holdable device further comprises the
   means for receiving the vehicle tire identification input signal.
63. The apparatus of claim 61 or 62, when directly or indirectly dependent from claim 59, wherein the means for causing the computer-readable storage medium to store the codes representing the vehicle tire information comprises is configured to cause the computer-readable storage medium to store the codes representing the vehicle tire information in association with the identifier of the vehicle tire.

64. The apparatus of claim 61, 62, or 63, when directly or indirectly dependent from claim 60, wherein the means for transmitting the wireless signal representing the vehicle tire information comprises is configured to transmit the wireless signal representing the vehicle tire information in association with the identifier of the vehicle tire.

65. An apparatus for measuring a tread depth of a vehicle tire, the apparatus comprising:
   a hand-holdable device comprising:
       a reflected-energy detector for measuring a measurement of reflected energy reflected from a location between treads of the vehicle tire; and
       at least one processor circuit configured to produce an output signal representing vehicle tire information comprising a measurement of the tread depth in response to the measurement of the reflected energy.

66. The apparatus of claim 65 wherein:
   the hand-holdable device further comprises a reference surface positionable against at least one outer surface of at least one of the treads of the vehicle tire; and
   the reflected-energy detector is configured to measure a distance from the reference surface to the location between the treads of the vehicle tire.

67. The apparatus of claim 65 or 66 wherein the reflected-energy detector comprises a reflected-light detector configured to measure a measurement of reflected light reflected from the location between the treads of the vehicle tire.

68. The apparatus of claim 67 wherein the reflected-light detector is configured to measure an angle of travel of the reflected light relative to a reference line defined by the hand-holdable device.
69. The apparatus of claim 67 wherein the reflected-light detector is configured to measure a time of flight of the reflected light.

70. The apparatus of any one of claims 65 to 69 wherein the hand-holdable device further comprises an energy source for producing the reflected energy.

71. The apparatus of any one of claims 65 to 70 wherein the vehicle tire information further comprises a measurement of air pressure in the vehicle tire.

72. The apparatus of claim 71 wherein the at least one processor circuit is further configured to receive an air pressure input signal representing the measurement of air pressure in the vehicle tire.

73. The apparatus of claim 72 wherein the hand-holdable device further comprises a pressure detector for measuring the air pressure in the vehicle tire and configured to produce the air pressure input signal.

74. The apparatus of any one of claims 65 to 73 wherein the vehicle tire information further comprises a measurement of an air temperature of air in the vehicle tire.

75. The apparatus of claim 74 wherein the at least one processor circuit is further configured to receive an air temperature input signal representing the measurement of the air temperature of air in the vehicle tire.

76. The apparatus of claim 75 wherein the hand-holdable device further comprises an air temperature detector for measuring the air temperature of air in the vehicle tire and configured to produce the air temperature input signal.

77. The apparatus of any one of claims 65 to 76 wherein the vehicle tire information further comprises a measurement of an exterior temperature of the vehicle tire.

78. The apparatus of claim 77 wherein the hand-holdable device further comprises a temperature detector for measuring the exterior temperature of the vehicle tire.
79. The apparatus of any one of claims 65 to 78 wherein the vehicle tire information further comprises a measurement of a concentration of nitrogen gas in the vehicle tire.

80. The apparatus of claim 79 wherein the at least one processor circuit is further configured to receive a nitrogen concentration input signal representing the measurement of the concentration of nitrogen gas in the vehicle tire.

81. The apparatus of claim 80 wherein the hand-holdable device further comprises a nitrogen detector for measuring the concentration of nitrogen gas in the vehicle tire and configured to produce the nitrogen concentration input signal.

82. The apparatus of any one of claims 65 to 81 wherein the vehicle tire information further comprises an optical image of an exterior of the vehicle tire.

83. The apparatus of claim 82 wherein the hand-holdable device further comprises an optical camera for capturing the optical image of the exterior of the vehicle tire.

84. The apparatus of any one of claims 65 to 83 wherein the vehicle tire information further comprises a work order for the vehicle tire.

85. The apparatus of claim 84 wherein the at least one processor circuit is further configured to receive a work order input signal representing at least one task for the work order.

86. The apparatus of any one of claims 65 to 85 wherein the at least one processor circuit is further configured to cause a visual display to display the vehicle tire information.

87. The apparatus of any one of claims 65 to 86 wherein the at least one processor circuit is further configured to cause a computer-readable storage medium to store codes representing the vehicle tire information.

88. The apparatus of any one of claims 65 to 87 wherein the at least one processor circuit is further configured to transmit a wireless signal representing the vehicle tire information.
89. The apparatus of any one of claims 65 to 88 wherein the at least one processor circuit is further configured to cause receive a vehicle tire identification input signal representing an identifier of the vehicle tire.

90. The apparatus of claim 89, when directly or indirectly dependent from claim 87, wherein the at least one processor circuit is further configured to cause the computer-readable storage medium to store the codes representing the vehicle tire information in association with the identifier of the vehicle tire.

91. The apparatus of claim 89 or 90, when directly or indirectly dependent from claim 88, wherein the at least one processor circuit is further configured to transmit the wireless signal representing the vehicle tire information in association with the identifier of the vehicle tire.
Receive Measurement-Initiation Signal

Identify tire

Measure tread depth

Receive air pressure measurement

Receive air temperature measurement

Measure exterior temperature

Receive nitrogen concentration measurement

Store measurement information

Display measurement information

Information satisfies criteria?

Yes

Generate alarm

End

FIG. 5
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<th>Tire Identifier</th>
<th>Measurement Time (YYYY-MM-DD HH:MM:SS)</th>
<th>Tread Depth (mm)</th>
<th>Air Pressure (kPa)</th>
<th>Air Temperature (°C)</th>
<th>Exterior Temperature (°C)</th>
<th>Nitrogen Concentration (%)</th>
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<td>15.2</td>
<td>13.1</td>
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FIG. 6
FIG. 7

Receive Optical Image Initiation Signal

Identify Tire

Capture Optical Image

Store Optical Image

End

FIG. 8

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<th>Uploaded?</th>
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**FIG. 9**

- Receive Work Order Input Signal
- Identify Tire
- Store Work Order
- End

**FIG. 10**

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<td>Inspect Valve</td>
<td>Within 24 Hours</td>
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<td>Repair Tread</td>
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In Range of Upload Connection

256

Entries not uploaded?

258

No

Yes

Upload information

260

Set uploaded entries as uploaded

262

End

FIG. 11
INTERNATIONAL SEARCH REPORT

International application No.  
PCT/CA2017/050206

A.  CLASSIFICATION OF SUBJECT MATTER

IPC:  **G01B 21/18** (2006.01),  **G01B 11/22** (2006.01),  **G01M 17/02** (2006.01)

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)

IPC:  **G01B** (2006.01);  **G01M** (2006.01)

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

C.  DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US3696668 A (Patrick J. L.) 10 October 1972 (10-10-1972) <em>see whole document</em></td>
<td>7, 8, 10</td>
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<td>Y</td>
<td>US8794058 B2 (Bigot F. et al.) 05 August 2014 (05-08-2014) <em>col. 4, lines 9-14; col. 7, lines 36-46</em></td>
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Further documents are listed in the continuation of Box C.  

*  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
"I" 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 underdand 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

**Date of the actual completion of the international search**

**Date of mailing of the international search report**  
03 May 2017 (03-05-2017)

Name and mailing address of the ISA/CA  
Canadian Intellectual Property Office  
Place du Portage 1, CI 14 - 1st Floor, Box PCT  
50 Victoria Street  
Gatineau, Quebec K1A 0C9  
Facsimile No.: 819-953-2476

Authorised officer  
Goran Basic (819) 635-8017

Form PCT/ISA/210 (second sheet) (January 2015)  
Page 2 of 3
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Form PCT/ISA/210 (patent family annex) (January 2015)