3rd Party Submission pursuant to 37 CFR §1.290

This submission is in regard to application US 17/549,519 titled "Devices, systems, and methods for detecting the rotation of one or more components for use with a wellbore", dated December 13th, 2021.

REMARKS

A description of the cited documents and their relevance is provided.
A claim chart is also provided to illustrate the prior art regarding the specific claims.

Brief description of cited documents:

The claimed priority date of US 17/549,519 is December 13, 2021. The following documents should be considered as prior art.

- US 9,140,113 Hurst et al. – "Instrumented rod rotator"
  - This is the primary disclosure of the need to monitor rods for rotation in a rod lift system. It utilizes a discrete switch to count revolutions.
  - In addition to monitoring the rod-string, this also discloses the monitoring of a tubing string.
- US 16/228,233 Phillips – "Apparatus and Method for Detecting the Rotation of a Rod-String in a Wellbore"
  - Discloses a rotation sensor for monitoring rotation including a linear component and a rotational component.
  - This further discloses utilizing a magnetometer and/or a gyro for the purpose of collectively monitoring both linear motion and rotational motion.
  - See Figure 6-9, claims 1, 8-10, 12, and discussion below.
- US 11,319,794 Fyfe et al. – "Oil-Well Pump Instrumentation Device and Method"
  - Discloses rotation sensing; "*rate-gyro sensors to sense rotational accelerations of the polished rod 224 resulting from each yank of the handle*" col 13, lines 40-42.
  - And determining the ends of the stroke with a magnetic sensor "*identifying a reference tick in each stroke uses readings of a magnetic sensor of the polished - rod dynamometer*" col 30, lines 28-30. This discloses the axial motion subsystem, as described by US 17/549,519.
  - And discloses the use of a gyro in conjunction with a magnetometer "*further includes sensing rotation of the polished rod with an accelerometer and a gyroscopic sensor in addition to sensing a magnetic field with a magnetometer*" col 32, lines 61-63
  - Further discloses monitoring a tubing rotator. See the sections "*Rod Rotator Monitor*" and "*Tubing Rotation Monitoring*" (columns 12-14).
- US 9,903,193 Harding et al. – "Systems and Methods for Sucker Rod Pump Jack Visualizations and Analytics"
  - Discloses using a gyro on the polished rod; col 5, line 60-62 "*At least one 6-Axis IMU (accelerometer plus gyroscope) may be attached to the polished rod and is referred to as the bridle sensor.*"
- US 11,339,643 Robison et al. – "Pumping unit inspection sensor assembly, system and method"
  - This relates to the vibration monitoring aspects presented in US 17/549,519.

  - Discloses a gyroscope; col 4, line 19-20 "*The gyroscope 68 in this example is a sensor configured to measure a rate of rotation about at least one gyroscope axis 88*" in reference to the pumping unit crank. It further discloses a means for detecting points within the stroke of the pumping unit; figure 7 shows a 360-degree plot of crankarm vs. acceleration. This application discusses rotation, but specifically rotation of the crank arm of the pumping unit, not of the rod-string. While these are different types of rotation, this disclosure demonstrates that a gyro can be used for the purpose of monitoring at least one type of rotation.
- US 3,343,409 Gibbs – "Method of determining sucker rod pump performance".
  - Discloses monitoring the rod lift system. Of particular relevance is the linear displacement (or "axial motion"). Further it discloses the process of summing sensor data.
- US 11,542,938 Zhao – "Polished Rod Rotation Sensor"
  - This discloses a sensor similar to that of the Hurst disclosure in that it utilizes a discrete switch to determine rotation.
  - Further discloses a means to determine position using an accelerometer.
- US 17/586,292 Navar et al. – "Rotation monitoring assembly for an artificial lift system"
  - This discloses a sensor similar to that of the Hurst disclosure in that it utilizes a discrete switch to determine rotation.
- US 10,167,707 Trapan et al. – "Rod string rotation during well pumping operations"
  - Discusses magnetic sensing of stroke position using a discrete magnet. It is noted that the use of a magnet to determine stroke position dates back to US 3,343,409 Gibbs and is a well-known method of determining position. The use of a continuous magnetometer for this purpose was introduced in US 16/228,233.
- US 11,572,770 Sengul et al. – "System and method for determining load and displacement of a polished rod"
  - Discloses a gyroscope coupled to the polished rod. Col 4, lines 50-53 "*the integrated sensor 200 includes a strain gauge 202, gyroscope 204, and accelerometer 206 which may be positioned on the polished rod 124*".
  - See claim 1 "*a gyroscope configured to measure an orientation, an angular velocity, or both of the beam pump unit as the beam pump unit operates*".

Concise description of relevancy:

Claims from US 17/549,519	Discussion and relative citations
1. *A sensor system for a downhole pumping system, comprising: a sensor subsystem for detecting movement of at least one component of the downhole pumping system, the sensor subsystem comprising:*	See US 16/228,233 claim 1: "*the sensor is configured to generate a signal indicative of instantaneous radial orientation of a rod-string extending down into the well from a polished rod*".
an axial motion sensor subsystem comprising a magnetometer, the magnetometer to be coupled to the at least one component of the downhole pumping system and to detect axial movement of the at least one component of the downhole pumping system based on variations in a magnet field detected by the magnetometer generated by movement of the at least one component of the downhole pumping system; and	See US 16/228,233 Claim 1 "*generate an alarm if the rod lift system is operational but invalid rotation of the rod-string is detected*". The term "*operational*" is indicative of linear, or "*axial*" motion of the rod-string. See claim 8 "*the sensor comprises a magnetometer*". See US 16/228,233 paragraph [00126]; "*As the pumping unit strokes, the sensor sees increasing field distortions as it nears these components.*" And "*observing historical readings and detecting changes in the variation of the historical magnetometer samples*".
a rotation sensor subsystem comprising a gyroscope, the gyroscope to be coupled to the at least one component of the downhole pumping system and to detect rotational movement of the at least one component of the downhole pumping system by detecting rotational velocity values with the gyroscope generated by rotation of the at least one	See US 16/228,233 claim 1 "*the sensor is configured to generate a signal indicative of instantaneous radial orientation of a rod-string extending down into the well from a polished rod*". See claim 12 "*the sensor further comprises an accelerometer, a barometer, a gyroscope, or combinations thereof*". See US 16/228,233 paragraph [00110] "*The magnitude of the rotational acceleration, velocity, and finally displacement can be measured through the use of an accelerometer and a gyroscope over a single stroke.*"

component of the downhole pumping system; and *a processor subsystem to receive data from the axial motion sensor subsystem and the rotation sensor subsystem, the processor subsystem to:* *determine axial movement of the at least one component of the downhole pumping system with the axial motion sensor subsystem; and* *determine rotational velocity of the at least one component of the downhole pumping system with the rotation sensor subsystem by sampling rotational velocity values generated by the rotation of the at least one component of the downhole pumping system with the gyroscope.*	See US 16/228,233 claim 1 "*a processor configured to: receive electrical signals from the sensor*". US 16/228,233 discloses both "*determine axial movement*" and "*determine rotational velocity*". See paragraph [0021] "*The processor is configured to receive signals from the sensing components that are indicative of at least partial radial position of the rod-string, or changing vertical position that is indicative of stroking action.*" US 16/228,233 paragraph [0026]: "*Rotation during idle periods is not expected and therefore does not need to be considered. Indicating non-rotation during idle periods would be considered a false alarm as the functionality of the rotation system is indeterminate during that period.*" US 16/228,233 paragraph [0029] "*The sensing components may comprise a magnetometer, accelerometer and/or a gyroscope. In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the course of a single stroke by way of an inertial reference.*" US 11,319,794 (Fyfe) also discloses this claim; "*In an alternative embodiment, a stand-alone wireless polished-rod rotation monitor has at least one polished-rod rotation sensor including a magnetometer, an accelerometer, or a gyroscopic sensor; a processor; a real-time clock; a wireless communicator; and a memory*" US 11,572,770 (Sengul) Claim 1: "*a gyroscope configured to measure an orientation, an angular velocity, or both of the beam pump unit as the beam pump unit operates*"

Figure 6 from US 16/228,233 discloses the contents of Claim 1 and is replicated below for convenience:

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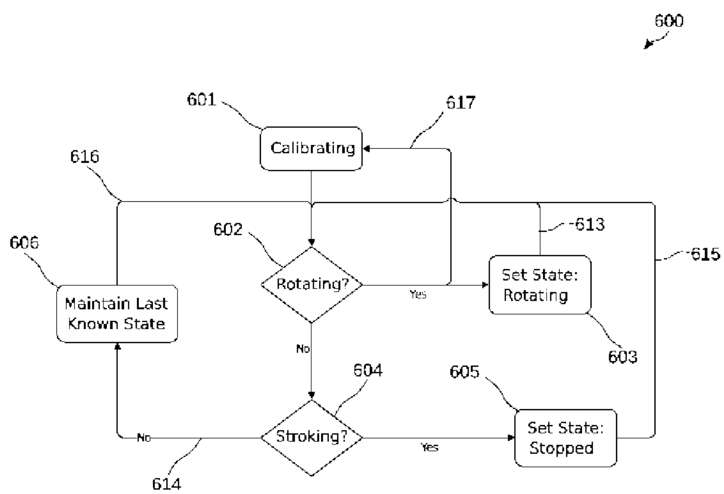

FIG. 6

This figure shows there is a "rotating" determination (or "rotation sensor subsystem") and a "stroking" determination (or "axial motion sensor subsystem"). The order of operations is clarified in US 16/228,233 paragraph [00134] "*The order of detecting rotating and stroking in Query* ***602*** *is not critical, but for power consumption purposes it is preferable to sense rotation first as that is a discrete and low frequency operation*". 605 is a fault condition in the rotation status (see paragraph [00138]).

US 11,319,794 (Fyfe) also provides relevant disclosures regarding claim 1. See the section titled "*Rod Rotator Monitor*" beginning at the bottom of column 12.

Both Fyfe and Phillips provide extensive details regarding how one would process the sensor data, and the challenges in determining both rotation and axial position using inertial sensors (magnetometer, accelerometer, gyro).

2. *The sensor system of claim 1, wherein the sensor subsystem is configured to detect movement of the at least one component of the downhole pumping system comprising at least one rod of the downhole pumping system extending from a surface location into a wellbore.*	See US 16/228,233 claim 1 "*rod-string extending down into the well from a polished rod*". See US 16/228,233 claim 13: "*the processor is further configured to receive signals advising as to whether the rod lift system is stroking*".

3. *The sensor system of claim 2, wherein the processor subsystem is configured to verify the axial movement of the at least one rod before determining the rotation.*	See US 16/228,233 (Phillips) paragraph [0027] "*Stroking action can be indicated by the barometer, accelerometer, or magnetometer individually*". The terms "*operational*", "*stroking*" and "*axial movement*" refer to the same concept. Phillips claim 11: "*generate the alarm if a revolution of the polished rod is not achieved in a given period of time, where the time period is active only while the rod lift system is stroking*". Phillips discloses "*before determining the rotation*": see paragraph [00134] "*The order of detecting rotating and stroking in Query **602** is not critical, but for power consumption purposes it is preferable to sense rotation first as that is a discrete and low frequency operation*". Further, the flow chart depicted in Figure 6 (Phillips) shows a cyclic dependence on the determination of rotation and stroking. In otherwards, the two determinations alternate, each naturally occurring "*before*" the other in a steady state.

4. *The sensor system of claim 2, wherein the processor subsystem is configured to determine a change in direction the at least one rod.*	See US 16/228,233 paragraph [0020]; "*In one aspect, the sensor is also configured to determine vertical motion. This indicates whether the rod lift system is stroking or whether it has stopped.*" See US 16/228,233 [00133] "*Furthermore, the sensing device may incorporate a number of*

	other sensors that can help identify whether the unit is stroking". Fyfe discloses using a magnetic sensor to determine a change in direction. See col 30, lines 26-30: "*wherein the firmware for identifying a reference tick in each stroke uses a magnetic sensor of the polished-rod dynamometer*." And Fyfe claim 1: "*identify, for each polished-rod stroke of a plurality of polished-rod strokes, a reference tick of said each polished-rod stroke to determine a duration of said each polished-rod stroke; and estimate polished-rod position throughout each polished-rod stroke*". Further examples of detecting a change in the linear direction for the purpose of determining the ends of a discrete stroke can also be found in Gibbs, Harding, Zhao, Trapan, and Sengul.

5. *The sensor system of claim 4, wherein the processor subsystem is configured to begin sampling the rotational velocity after determining the change in direction the at least one rod.*	US 11,319,794 (Fyfe) col 7, lines 1-3; "*We use this tick knowing the polished-rod velocity should be the same at the beginning and end of each identified stroke*". Velocity at the beginning and end of the stroke is known to be zero, indicating a change in direction. See US 16/228,233 paragraph [0133] (in regards to calibrating the sensors); "*This could only be done if one knew the exact position in the stroke, and could ensure the sensor is always read in the same position, which is possible but not practical*". This paragraph identifies the determination of the exact position is possible. The term "not practical" in reference to the preferred embodiment and the desire to minimize power consumption. See US 16/228,233 paragraph [0029] "*In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the course of a single stroke by way of an inertial*

	reference." Paragraph [0029] describes this as a single stroke which is well understood in the field of the invention to begin at a change of direction of the polished rod.

6. *The sensor system of claim 5, wherein the processor subsystem is configured to <u>continue sampling the rotational velocity until another change in direction</u> the at least one rod is detected.*	See US 16/228,233 paragraph [00158]; "*Also, the sensor requires no knowledge of the <u>rotation angle per stroke</u>, or likewise strokes per rotation. <u>In fact, the sensor can provide these measured values</u>.*" In other words, US 16/228,233 discloses measuring a rotational change during a stroke. Fyfe identifies in col 7 lines 43-47: "*In an alternative embodiment, both minima and maxima are identified within each stroke so that <u>the stroke is separated into two pieces</u>, such as time from minima to maxima and from maxima to minima. Scaling is then applied to <u>each half of the stroke independently</u>*"

7. *The sensor system of claim 5, wherein the processor subsystem is configured to <u>continue sampling the rotational velocity along substantially an entire stroke</u> of the at least one rod, the sampling beginning at a <u>first</u> change of direction of the at least one rod, continuing through a <u>second</u> change of direction of the at least one rod, and ceasing at a <u>third change of direction</u> of the at least one rod.*	See US 16/228,233 [0029]; "*In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the <u>course of a single stroke</u> by way of an inertial reference.*" Fyfe col 7 lines 43-47 (discussed above) describe splitting the stroke. It is well understood in the field of the invention that a "*stroke*" is defined by a "*<u>first</u>*" (bottom of stroke), "*<u>second</u>*" (top of stroke), and "*<u>third</u>*" (return to bottom of stroke) "*<u>change of direction</u>*". The stroke could alternatively start at the top of stroke and continue to the next top of stroke. Further, the sampling of sensor data "*<u>along substantially an entire stroke</u>*" is commonly done with load and position for the purpose of drawing

	a dynamometer card. Sampling accelerometer data, for example, is commonly performed in this manner. Fyfe, Harding, Zhao, and Sengul disclose this process.

8. *The sensor system of claim 1, wherein the sensor subsystem is configured to detect movement of the at least one component of the downhole pumping system comprising a <u>tubing rotator</u> of the downhole pumping system.*	US 9,140,113 (Hurst) discloses a tubing rotator and sensing rotation of the tubing string. See Hurst claim 2: "*The method of claim 1, wherein the monitoring is performed by a mechanism incorporated in at least one of a load cell, a rod rotator, or a <u>tubing rotator</u>.*" US 11,319,794 (Fyfe) discloses a tubing rotator sensor in addition to sensing using inertial sensors. See the section titled "*Tubing Rotation Monitoring*", column 14.

9. *The sensor system of claim 8, wherein the sensor subsystem is configured to detect rotation of the <u>tubing rotator while detecting axial movement</u> of a polished of the downhole pumping system.*	US 16/228,233 (Phillips) discloses the correlation between stroking motion and rotational motion. See Figure 6 and claim 1 "*generate an <u>alarm if the rod lift system is operational but invalid rotation</u>*". Rod rotators and tubing rotators may be used on the same well. The rotational drive mechanism is mechanically similar (actuated by the stroking action of the pumping unit via a cable and ratchet arm mechanism). US 11,319,794 (Fyfe) discloses a sensor capable of detecting both tubing rotation as well as axial motion of the polished rod. Col 5, line 46-47; "*Sensor 291 may be configured to <u>monitor displacement of the polished rod</u>*" and the section titled "*Tubing Rotation Monitoring*", column 14.

10. *The sensor system of claim 1, wherein the processor subsystem is configured to determine the rotational velocity of the at least one component of the downhole pumping system by summing both positive and negative samples of the rotational velocity values sensed by the rotation sensor subsystem.*	US 16/228,233 paragraph [0029] discloses "*In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the course of a single stroke by way of an inertial reference.*" Velocity and position (or deflection) are related in that velocity is a change in position over time. US 3,343,409 (Gibbs), discloses (col 12, line 40-42) "*The signal generator contains the necessary operational amplifiers to both shape the signals and sum the signals.*" The mathematical process of converting accelerometer measurements from acceleration to velocity to position is common in the field, and involves "*summing both positive and negative samples of the rotational velocity values*." See US 11,319,794 (Fyfe) col 6, lines 61-63 "*To improve position determined by double integration from accelerometer readings taken within the polished-rod dynamometer*". Fyfe col 6, lines 1-2; "*gyroscope to measure angular velocity and angular acceleration with differentiation*". The mathematical terms "*integration*" and "*differentiation*" are inverse operations, both of which involve summation. Gyros inherently measure a rotational velocity, typically in terms of degrees per second. See US 9,903,193 (Harding) col 4, lines 41-46: "*Time series data on the crank angle (theta in radians, θ in rad), the crank angular velocity (in rad/sec), and the crank angular acceleration (in rad/sec^2) may be generated, with a corresponding timestamp, as the crank's phase "cycle" may be estimated using a 6-axis IMU sensor*." The IMU contains a gyroscope sensor.

11. *The sensor system of claim 10, wherein the processor subsystem is configured to compare the determined rotational velocity of the at least one component of the downhole pumping system with an expected amount of rotational velocity to determine a failure in the rotation of the at least one component of the downhole pumping system.*	See US 16/228,233 claim 1: "*generate an alarm if the rod lift system is operational but invalid rotation of the rod-string is detected*" and claim 10: "*The apparatus of claim 9, wherein the expected value is based on a historic rotation rate during periods of active rotation.*" Rate and velocity are interchangeable terms in this context as velocity is fundamentally a rate of change in position over time. See US 16/228,233 paragraph [0138] (in regard to Figure 6); "*This is considered to be a fault condition*". US 11,319,794 (Fyfe) also discloses "*determine a failure in the rotation*" using a rotational velocity. See col 2 line 52-54; "*This may include setting an alarm when data differs from previously recorded data from the same pumpjack by more than a configurable threshold.*" and col 6, line 1; "*gyroscope to measure angular velocity*"

12. *The sensor system of claim 1, further comprising a vibration sensor subsystem for monitoring vibration of the at least one component of the downhole pumping system over a vibrational baseline.*	US 11,339,643 (Robison) discloses a vibration. Robison col 3 line 41-42 "*The principles described below can be used to monitor vibration produced during operation of the pumping unit*". US 11,319,794 (Fyfe) discloses a vibration sensor placed on the polished rod; col 2 line 14-18 "*In an embodiment, a polished-rod dynamometer has at least one accelerometer adapted to measure acceleration and vibration of the polished rod*". And further defines vibration relative to a baseline; Fyfe col 12, line 65-67: "*A change in vibration levels or other sensor inputs such as flows and pressures may indicate a change of state or deterioration in performance*"

13. *A sensor system for a downhole pumping system, comprising:*	See remarks regarding claim 1 above.
a sensor subsystem for detecting movement of at least one component of the downhole pumping system, the sensor subsystem comprising: *an axial motion sensor subsystem comprising an axial motion sensor, the axial motion sensor to be coupled to the at least one component of the downhole pumping system and to detect axial movement of the at least one component of the downhole pumping system based on variations detected by the axial motion sensor generated by movement of the at least one component of the downhole pumping system; and*	US 3,343,409 Gibbs discloses an axial motion sensor to detect axial movement. See Claim 1: *"(c) measuring and recording the load and displacement of the polished rod as functions of time*". The term "*displacement*" here refers to the linear position within the stroke, or "*axial motion*". US 16/228,233 paragraph [0077] "*Short term variation in the magnetometer readings can therefore also be indicative of stroking action.*". More generally, "variations" in position may be used to determine axial motion by other methods: Gibbs US 3,343,409: col 2, line 53: "*a displacement transducer 37*". Fyfe US 11,319,794 col 2, lines 17-19: "*firmware to double-integrate polished-rod acceleration to determine polished-rod position in a pumpjack cycle*". Zhao US 11,542,938 Col 4, lines 58-59: "*In an example, the position sensor may be circuitry including an accelerometer*".
a rotation sensor subsystem comprising a rotational sensor, the rotational sensor to be coupled to the at least one component of the downhole pumping system and to detect rotational movement of the at least one component of the downhole pumping system by sampling rotational velocity values with the rotational sensor generated by rotation of the at least one component of the downhole pumping system; and	Hurst, Phillips, Fyfe, as well as Zhao and Navar disclose a rotational sensor. See claim 1 discussion above. US 16/228,233 claim 1 "*the sensor is configured to generate a signal indicative of instantaneous radial orientation of a rod-string extending down into the well from a polished rod*". Navar [0023]: "*to identify whether the polish rods are not rotating or are not rotating at a target rate*". See Fyfe "*Rod Rotator Monitor*" section, columns 12-13.

a processor subsystem to receive data from the axial motion sensor subsystem and the rotation sensor subsystem, the processor subsystem to: *verify the axial movement of the at least one component of the downhole pumping system with the axial motion sensor subsystem; and* *when the axial movement has been verified, determine rotational velocity of the at least one component of the downhole pumping system with the rotational velocity values detected by the rotation sensor subsystem.*	US 16/228,233 discloses both the axial motion and rotational sensor subsystems. As does Fyfe. See "*Rod Rotator Monitor*" section (col 12-13) and Fyfe claim 1: "*estimate polished-rod position throughout each polished-rod stroke from readings from the accelerometer*". See US 16/228,233 [0021] "*The processor is configured to receive signals from the sensing components that are indicative of at least partial radial position of the rod-string, or changing vertical position that is indicative of stroking action.*" US 16/228,233 figure 6 illustrates combining "*verify the axial movement*" and "*when the axial movement has been verified, determine rotational velocity*". Further, claim 1 from US 16/228,233: "*generate an alarm if the rod lift system is operational but invalid rotation of the rod-string is detected*".

14. *The sensor system of claim 13, wherein the axial motion sensor subsystem comprises a magnetometer and the rotation sensor subsystem comprises a gyroscope.*	US 16/228,233 discloses both a magnetometer; see claim 8 "*the sensor comprises a magnetometer*" and a gyroscope; see claim 12 "*The apparatus of claim 8, wherein the sensor further comprises an accelerometer, a barometer, a gyroscope, or combinations thereof.*" Fyfe discloses a magnetometer for "*axial motion*", see col 6 lines 61-68: "*To improve position determined by double integration from accelerometer ... with an external magnet and magnetometer*". And further discloses a gyroscope, see col 13 lines 38-42 "*In an alternative embodiment, the polished-rod dynamometer 261 includes calibrated rotational accelerometers and rate-gyro sensors to sense rotational accelerations of the polished rod 224 resulting from each yank of the handle 219 of the rod rotator during each stroke of the polished rod*".

15. *The sensor system of claim 14, wherein the sensor subsystem is configured to detect movement of the at least one component of the downhole pumping system comprising at least one rod of the downhole pumping system extending from a surface location into a wellbore, and wherein the processor subsystem is configured to continue sampling the rotational velocity values of the at least one rod over a stroke of the at least one rod.*	See US 16/228,233 paragraph [0029]; "*In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the course of a single stroke by way of an inertial reference*." Phillips paragraph [0042] "*The accelerometer and gyroscope determine rotational deflection of the bridle assembly during the course of a single stroke*". Phillips paragraph [00103]: "*The anti-rotation device 208 makes the entire bridle assembly 240 act as a single mass for the course of a given stroke. The bridle cables 102 are somewhat flexible and resist the rotation, but allow for some limited rotational deflection during the stroke*." Phillips paragraph [00110] "*The magnitude of the rotational acceleration, velocity, and finally displacement can be measured through the use of an accelerometer and a gyroscope over a single stroke*."

16. *A sensor system for a downhole pumping system, comprising:* *a sensor subsystem for detecting movement of a tubing rotator of the downhole pumping system, the sensor subsystem comprising a rotation sensor subsystem comprising a rotational sensor, the rotational sensor to be coupled to the tubing rotator of the downhole pumping system and to detect rotational movement of the tubing rotator of the downhole pumping system by sampling rotational velocity values with the rotational sensor generated by*	US 9,140,113 (Hurst) discloses a tubing rotator in claim 2: "*The method of claim 1, wherein the monitoring is performed by a mechanism incorporated in at least one of a load cell, a rod rotator, or a tubing rotator*." Fyfe further discloses monitoring a tubing rotator. See Fyfe section titled "*Tubing Rotation Monitoring*" on column 14. Fyfe also discloses the means to monitor rotation using inertial sensors. Phillips discloses a processor for the purpose of determining rotational velocity. See paragraph [0030]; "*The processor is configured to receive signals from the sensing components indicative of instantaneous torque induced rotational*

rotation of the tubing rotator of the downhole pumping system; and *a processor subsystem to receive data from the rotation sensor subsystem, the processor subsystem to determine rotational velocity of the tubing rotator of the downhole pumping system with the rotational velocity values detected by the rotation sensor subsystem.*	*deflection of the bridle assembly during stroking, and process those signals to detect intra-stroke torsional deflection over time, indicating a buildup of torque in the rod-string.*" Fyfe col 27 lines 15-18; "*The same polished-rod dynamometer can optionally receive polished rod or tubing rotation information from angular accelerometers and/or gyroscopes or magnetic sensors within the dynamometer*"

17. *The sensor system of claim 16, wherein the rotation sensor subsystem comprises at least one of a gyroscope or an accelerometer.*	Fyfe (which discloses monitoring both a rod rotator and a tubing rotator sensor) col 13, lines 51-53: "*rotation monitor has at least one polished-rod rotation sensor including a magnetometer, an accelerometer, or a gyroscopic sensor; a processor*". See US 16/228,233 (Phillips) claim 12 "*The apparatus of claim 8, wherein the sensor further comprises an accelerometer, a barometer, a gyroscope, or combinations thereof.*" Phillips paragraph [0043] clarifies the selection of sensors is independent. "*The processor periodically receives signals from a magnetometer, accelerometer and/or gyroscope, and processes those signals to detect intra-stroke torsional deflection*".

18. *The sensor system of claim 16, wherein the rotation sensor subsystem is configured to monitor the rotation of the tubing rotator along a path that extends in a direction substantially perpendicular to a surface upon which the downhole pumping system is positioned.*	See US 11,319,794 (Fyfe) col 7 line 66 to col 8 line 2: "*The sensor pod is coupled to monitor rotation of the crank of the pumpjack or monitor rotation of an output shaft of the gearbox of the pumpjack*". While the rotation of the gearbox and crank of the pumping unit is a different mechanism from a tubing rotator, both drive shafts are horizontal. Placing a sensor on the crank arm of the pumping unit, to monitor rotation in a vertical plane (about a horizontal axis), is demonstrated by Fyfe using an accelerometer or gyro.

19. *A method of detecting motion of at least one component of a downhole pumping system, the method comprising:*	For "*variations*" in the magnetic field, see US 16/228,233 paragraph [0077] "*Short term variation in the magnetometer readings can therefore also be indicative of stroking action.*".
detecting axial movement *of at least one component of the downhole pumping system based on variations detected by an axial motion sensor coupled to the at least one component of the downhole pumping system generated by translation of the at least one component of the downhole pumping system;*	For "*variations*" in linear motion, see Gibbs, Zhao, Harding, Sengul. "*Stroking*", "*linear movement*", "*displacement*" in the cited documents are equivalent terms of "*translation*".
detecting rotational movement of the at least one component of the downhole pumping system with a rotational sensor generated by rotation of the at least one component of the downhole pumping system; and	Hurst, Phillips, Fyfe, Navar, and Zhao disclose a rotational sensor.
verifying axial movement of the at least one component of the downhole pumping system with the axial motion sensor before the detecting of the rotational movement of the	Phillips and Fyfe disclose the combination of both the axial motion and rotational sensor subsystems. Figure 6 (Phillips) illustrates the combination of both, for the purpose of combining "*verifying axial movement*" and "*before the detecting of the rotational*

at least one component of the downhole pumping system with the rotational sensor.	*movement*". See further, US 16/228,233 claim 1: "*generate an alarm if the rod lift system is operational but invalid rotation of the rod-string is detected*".

20. *The method of claim 19, further comprising comparing a rotational velocity detected with the rotational sensor with a threshold value to determine a performance characteristic of the at least one component of the downhole pumping system.*	See US 16/228,233 claim 9: "*generate the alarm if rotational travel of the polished rod over a given period of time is different than an expected value*." The term "*rotational travel*" from US 16/228,233 is "*a performance characteristic*". Further performance characteristics are provided in, paragraph [00158] "*the sensor requires no knowledge of the rotation angle per stroke, or likewise strokes per rotation. In fact, the sensor can provide these measured values*". Paragraph [0026] "*the processor is able to determine a rate of rotation at any given point. If this rate effectively falls to zero, the processor can determine this lack of rotation without knowledge of the associated angle per stroke*". The threshold value in this case would be any value greater than zero. It should be understood that other values may be used for this purpose. Fyfe col 2 lines 51-54: "*This may include setting an alarm when data differs from previously recorded data from the same pumpjack by more than a configurable threshold*"

Further discussion:

Axial Motion Subsystem:

Figure 8 (US 16/228,233) is replicated below for convenience. Field variations are illustrated along the vertical traveling path. 802 moves up and down. This is "*linear motion*", "*stroking action*", or "*axial motion*" is relevant to the magnetic field variations discussed in US 17/549,519

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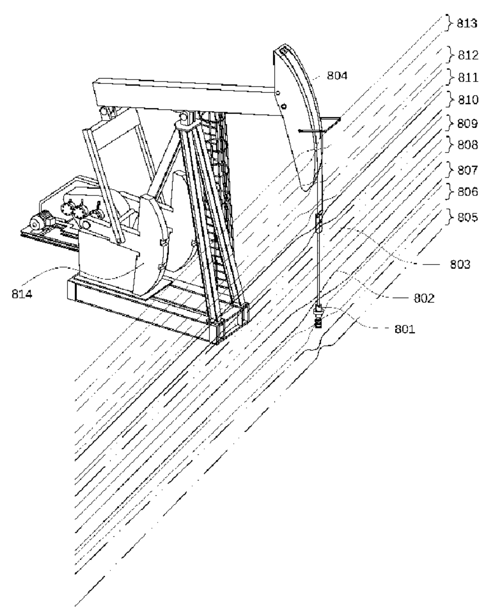

FIG. 8

Paragraph [00127] (US 16/228,233) identifies and attributes the magnetic field variations to specific components of the pumping system and their location along the stroking path: "*The magnitude of the distortions can dominate the reading depending on the proximity of the sensor to the ferrous material present in the pumping system. The wellhead 801, horsehead 804, counterweights 814, etc. all create distortions and act at different longitudinal positions during the motion of the sensor. Magnetic field lines are shown at various elevations (805-813) along the vertical path of the sensor 803*".

US 16/228,233, paragraph [00126] discloses how a magnetic field would be interpreted in a complex and dynamic environment, for the purpose of determining a location within the stroke:

> *In some pumping unit configurations such as a Mark-II unit (not shown), the counterweights 814 come very close to the polished rod and can accordingly*

> *create a very dynamic field distortion which affects the sensor reading. As the pumping unit strokes, the sensor sees increasing field distortions as it nears these components.*

Rotation sensor subsystem:

Claim 1 from US 16/228,233 recites "*indicative of an instantaneous status of rotation*". A gyroscope is a sensor for measuring angular velocity. Velocity is an instantaneous measure of a change in position over time, or a rate of change in position. Claim 12 from US 16/228,233 discloses the use of a gyroscope.

US 16/228,233 discloses the use of an accelerometer or a gyro in paragraph [0029] "*The sensing components may comprise a magnetometer, accelerometer and/or a gyroscope. In this instance, the accelerometer and gyroscope are configured to determine immediate rotational deflection of the bridle assembly during the course of a single stroke by way of an inertial reference.*"

US 9,903,193 B2, titled "Systems and Methods for Sucker Rod Pump Jack Visualizations and Analytics" issued Feb. 27th, 2018, discloses the use of a gyro, primarily on the crank arm to determine rotation in terms of an angle and velocity. This disclosure also provides a very specific description of a gyroscope placed directly on the polished rod. Relevant lines from US 9,903,193 B2 are replicated below for convenience.

Column 5, lines 60-62:

> *At least one 6-Axis IMU (accelerometer plus gyroscope) may be attached to the polished rod and is referred to as the bridle sensor.*

Column 9, lines 62-64:

> *The final result provides accurate crank angle and crank angle velocity time series data, which may be used in further pumping unit analytics.*

Additional observations from the specification:
US 17/549,519, paragraphs [0027], [0037-38] and [0044] discuss wireless communication and a battery powered device. This is disclosed in US 16/228,233:

> [0089] *The preferred embodiment of the sensing device 201 is a self-contained, battery-powered device which is installed on the polished rod. This necessarily requires any external signal to be transmitted wirelessly, and*

then converted to a useable output or to a visual indicator. Thus, in one aspect the wireless I/O module 250 provides the output signals in a convenient location, preferably with access to external power. This allows the sensing device 201 to operate in an extremely low power mode, thus conserving battery life.

US 16/228,233 paragraph [00152] "*It is preferred to keep the sensor asleep as much as possible to conserve battery life*." And:

]00159] *Power consumption of the sensing device is reduced because it does not need to be on all the time. Sensing the orientation within a gravity or magnetic field can be done independently from any previous state. This means the device can be powered down between readings. The readings can be scheduled at regular intervals irrespective of any external positioning. This can be optimized to historical rotational rates, deducting idle periods to help conserve battery life.*

US 17/549,519, paragraph [0038] discusses a self-calibrating sensor. This is disclosed in US 16/228,233 paragraph [00131] "*The inherent rotation of the system also presents an opportunity to automatically calibrate the sensor*."

CONCLUSION

A small entity filing fee of $72 is set forth in accordance with 37 CFR §1.17(o). Should the examiner have any questions regarding this submission, please feel free to contact me at wp@wansco.com.

/Walter Phillips/
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10/29/2023