Sasquatch

User's Manual

EXTREME TELEMATICS CORP.

Revision 5 (Firmware 1.2.x)

01-Sept-21

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Revision History

Date	Rev	Name	Details
01-Sept-21	5	Mark Scantlebury	Add in Principle of operations Re-arrange kinetic energy settings Update Measurement Status/Confidence Codes as signed values

Installation Location: Class I, Division 2, Groups A, B, C, D or Non-Hazardous Locations Only

Applicable to all models

WARNING - DO NOT REMOVE, REPLACE OR DISCONNECT WHILE CIRCUIT IS LIVE UNLESS THE AREA IS KNOWN TO BE FREE OF IGNITIBLE CONCENTRATIONS OF FLAMMABLE SUBSTANCES.

WARNING – EQUIPMENT SHALL BE CONNECTED TO AN APPROVED POWER SOURCE OR BARRIER THAT DOES NOT PROVIDE MORE THAN 24VDC AND 8A.

WARNING - EXPLOSION HAZARD – SUBSTITUTION OF COMPONENTS MAY IMPAIR SUITABILITY FOR CLASS I, DIVISION 2.

WARNING - THIS EQUIPMENT IS SUITABLE FOR USE IN CLASS I, DIVISION 2, GROUPS A, B, C, D OR NON-HAZARDOUS LOCATIONS ONLY.

WARNING - NO SERVICEABLE PARTS.

WARNING - IF EQUIPMENT IS USED IN A MANNER NOT SPECIFIED BY THE MANUFACTURER, THE PROTECTION PROVIDED BY THE EQUIPMENT MAY BE IMPAIRED.

AVIS – NE PAS ENLEVER, REMPLACER OU COUPER SI LE CIRCUIT EST SOUS TENSION À MOINS QUE LA RÉGION EST SAUF ET SANS SUBSTANCES INFLAMMABLES.

AVIS – L'ÉQUIPEMENT DOIT ÊTRE BRANCHER À UNE SOURCE D'ALIMENTATION APPROUVÉE OU UNE BARRIÈRE QUI NE FOURNIRA PAS PLUS QUE 24VDC ET 8A.

AVIS – RISQUE D'EXPLOSION – LA SUBSTITUTION DE COMPOSANTS PEUT RENDRE CE MATERIEL INACCEPTABLE POUR LES EMPLACEMENTS DE CLASSE I, DIVISION 2.

AVIS – L'ÉQUIPMENT EST ADAPTÉ POUR UTILISATION DANS CLASS I, DIVISION 2, GROUPS A, B, C, D OU DANS DES RÉGIONS SAUFS.

AVIS – PAS DE COMPOSANTS SERVICEABLES.

AVIS – SI L'ÉQUIPEMENT N'EST PAS UTILISÉ TANT QU'AUX INSTRUCTIONS DU FABRICANT, LA PROTECTION PEUT ÊTRE RÉDUITE.

Installation Location: Class I, Division 1, Groups C, D or Class 1 Zone 0 Locations Only

Applicable to model ET-11000-1031-0000 **ONLY**

WARNING – INTRINSICALLY SAFE WHEN CONNECTED PER DRAWING ET-11000-1031-2001.

WARNING – EQUIPMENT SHALL BE CONNECTED TO AN APPROVED POWER SOURCE OR BARRIER THAT DOES NOT PROVIDE MORE THAN 24VDC AND 8A.

WARNING – SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

WARNING – NO SERVICEABLE PARTS.

WARNING – AVOID STRIKING OR EXCESSIVE FRICTION ON THE EQUIPMENT SURFACE DUE TO IGNITION HAZARD.

WARNING – TO PREVENT IGNITION OF FLAMMABLE OR COMBUSTIBLE ATMOSPHERES, DISCONNECT POWER BEFORE OPENING.

AVIS – L'ÉQUIPEMENT EST EN SÉCURITÉ INTRINSÈQUE QUAND IL EST BRANCHÉ SELON LE DESSIN ET-11000-1031-2001.

AVIS – L'ÉQUIPEMENT DOIT ÊTRE BRANCHER À UNE SOURCE D'ALIMENTATION APPROUVÉE OU UNE BARRIÈRE QUI NE FOURNIRA PAS PLUS QUE 24VDC ET 8A.

AVIS – LA SUBSTITUTION DE COMPOSANTS PEUT COMPROMETTRE LA SECURITE INTRINSEQUE.

AVIS – PAS DE COMPOSANTS SERVICEABLES.

AVIS – ÉVITER DE FRAPPER OU FRICTION EXCESSIVE SUR LA SURFACE DE L'ÉQUIPEMENT EN RAISON DE RISQUES D'INFLAMMATION.

AVIS – POUR ÉVITER L'ALLUMAGE DES ATMOSPHÈRES INFLAMMABLES OU COMBUSTIBLES, COUPER LE COURANT AVANT OUVERTURE.

1 Description

The Sasquatch is a revolutionary new sensor for the plunger lift field. Using magnetic field sensors, it can detect the movement of a ferrous plunger arriving at the lubricator and calculate and store its velocity. Sasquatch replaces traditional plunger arrival sensors by replicating the plunger arrival signal and providing the measured velocity via a 2-Wire RS-485 Modbus slave interface.

By programming Sasquatch with the plunger mass, Sasquatch can be used to monitor the kinetic energy absorbed by the lubricator and spring assembly. Sasquatch can also be set to monitor and provide an alarm when the measured plunger velocity exceeds a set threshold or when the sum of all kinetic energy impacts exceeds a limit.

Dual certified as Non-Incendive for Div2/Zone2, and Intrinsically Safe for Div1/Zone 0, Sasquatch offers flexibility for installing in hazardous locations. Sasquatch is designed to operate in the harsh environment of the oil and gas field, an all-aluminum water tight enclosure and extended temperature rating make it a perfect fit.

1.1 Features

- An upgrade to traditional plunger arrival sensors, providing plunger arrival signaling and velocity measurement
- 2-Wire RS-485 Modbus slave interface
- Microprocessor based design reduces false arrivals by filtering environmental noise
- Using ETC vision, visualization of the magnetic signals can be used for troubleshooting
- Rugged aluminum enclosure with integral support for mounting via two band clamps
- ½” NPT threaded strain relief port for wiring connection
- Captive screws in the lid, will not fall out during servicing
- Adjustable sensitivity dial allows the operator to reduce sensitivity to eliminate false detections in noisy environments
- Firmware is field upgradeable
- Monitors kinetic energy absorbed by the lubricator/spring and reports the summation for preventative maintenance.

2 Specifications

Electrical	
Supply Voltage	5 – 24Vdc
Current Draw	Typ. - 7.5mA, Max. – 8mA @ 5Vdc, T=25 °C
Communications	
Communications Port	2-Wire RS-485 Modbus Slave, internally termination
Baud Rates (bps)	1200, 2400, 4800, 9600*, 19200, 38400, 56000, 115200, 128000, 256000
Data Bits	7, 8*
Parity	None*, Odd, Even
Stop Bits	1*, 2
Modbus Mode	RTU*, ASCII
Address	1* - 247
Measurement Performance	
Range	50 to 1000 m/min (164 to 3281 ft/min)
Accuracy	+/- 8% @ 250 m/min
Environmental	
Operating Temperature	-40 to +70 °C (-40 to +158 °F)
Storage Temperature	-40 to +125 °C (-40 to +257 °F)
Physical	
Dimensions	7.5” x 3.25” x 2.25” (190mm x 83mm x 57mm)
Mass	1.4 Lbs (0.64 Kg)
Certification	
Model: ET-11000-1030-0000	• Class 1, Division 2, Groups A, B, C, D T4 • Class 1, Zone 2, Group IIC T4
Model: ET-11000-1031-0000	• Class 1, Division 2, Groups A, B, C and D T4 • Class 1, Zone 2, Group IIC T4 • Ambient Temperature -40 to +70 °C • Class 1, Division 1, Groups C, D T4 • Class 1, Zone 0, AEx ia [ia] IIB T4 Ga • Ex ia [ia] IIB T4 Ga • Ambient Temperature -40 to +70 °C Must be installed in accordance to Control Drawing “ET-11000-1031-2001” to achieve Intrinsic Safety

* Factory default settings

3 Installation

3.1 Wiring

Sasquatch uses the same wiring scheme as a traditional plunger arrival sensor and adds a 2-Wire RS485 Modbus interface.

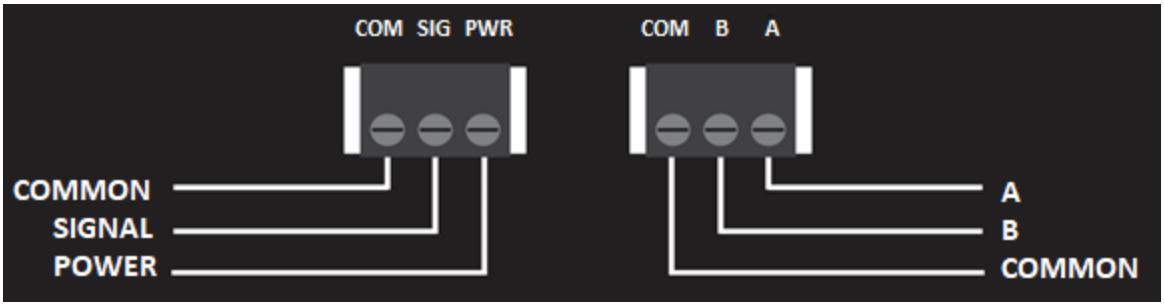

Figure 1 - Sasquatch Physical Connections

Pin Name	Description
COM*	Ground
SIG	Plunger arrival signal, Dry Contact
PWR	Sensor Power
COM*	Ground
B	2-Wire RS485 B
A	2-Wire RS485 A

* COM pins are internally connected together

3.1.1 Plunger Arrival Signal

The Sasquatch SIG pin is an open collector output with an integral 100Ω series resistor. Most controllers that support dry contact DI should work with no external components, wetting current is typically supplied by an internal pull up resistor.

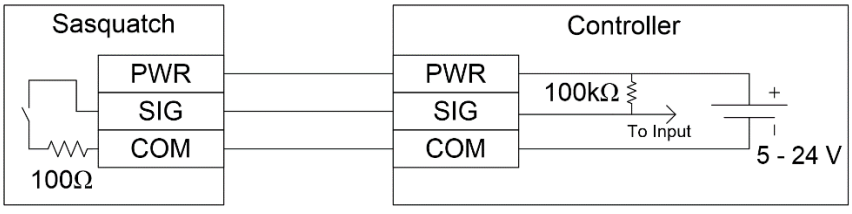

Figure 2 - Typical Plunger Arrival Signal Wiring

Controllers that do not provide wetting current will need an external resistor added between PWR and SIG. Since Sasquatch has a build in series resistor for protection, the external series resistor is

recommended to be **100kΩ**. ETC controllers support dry contact inputs and do not require the external resistor. Refer to your specific controller documentation for information on dry contact input support.

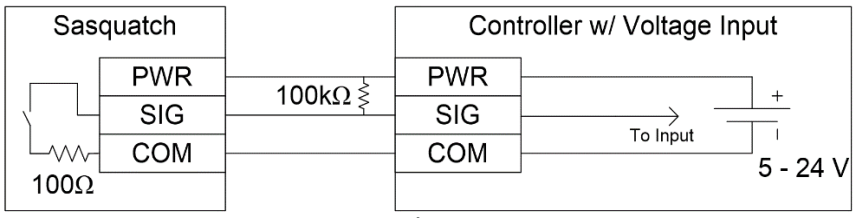

Figure 3 – Plunger Arrival Signal External Resistor Wiring

3.1.2 RS485 Modbus Slave Interface

The COM1 port supports the Modbus protocol (ASCII or RTU) via a 2-Wire RS485 serial bus. Sasquatch can be connected with other standard 2-Wire RS485 slave devices and its station address can be changed via the ETC Vision utility or by writing to the "Modbus Station Address" register. The RS485 lines are internally terminated and therefore no external termination method is required.

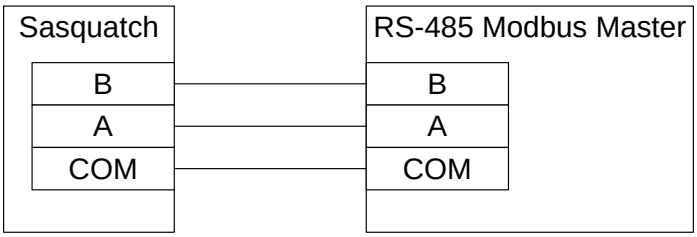

Figure 4 – RS-485 Connection

3.1.3 Hazardous Location Installation and Wiring

If Sasquatch is to be used as part of an intrinsically safe install (Div 1/Zone 0), a barrier device may be required. Installation must be completed according to drawing **ET-11000-1031-2001** and any applicable national and local electrical code by qualified personal.

If Sasquatch is to be installed as part of a Non-Incendive install (Div 2/Zone 2), installation must be completed according to drawing **ET-11000-1019-2006** and any applicable national and local electrical code by qualified personal.

External cabling should be rated for minimum of 77°C.

3.2 Mounting

Sasquatch includes two quick release band clamps for mounting Sasquatch to the lubricator. The band clamps slip though the molded feet on the body of Sasquatch and the quick release mechanisms allow the bands to be tightened around the lubricator.

Figure 5 – Sasquatch Mounted Using Band Clamps

Sasquatch needs to be positioned on the lubricator so that the plunger can pass by the sensor. The sensor should be placed as low on the lubricator as is practical. Since Sasquatch measures the magnetic signature of the plunger, mounting where a balance of metal above and below the sensor will give the best results.

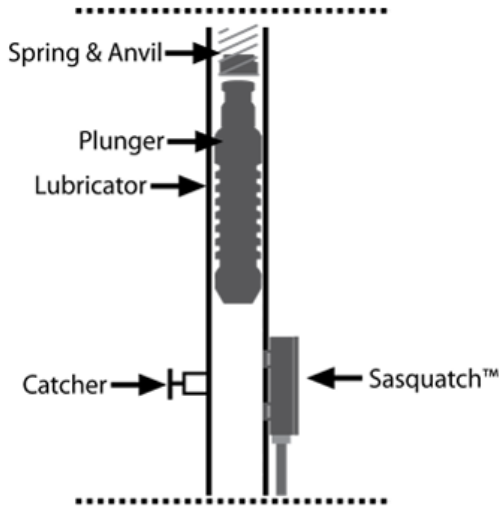

Figure 6 – Sasquatch Mounted Below the Plunger

The recommended location to mount Sasquatch is between upper and lower outlets on the lubricator, as long as there is sufficient room for the plunger to pass by the sensor on arrival. If this is not possible the 2nd choice location is centered on the lower outlet.

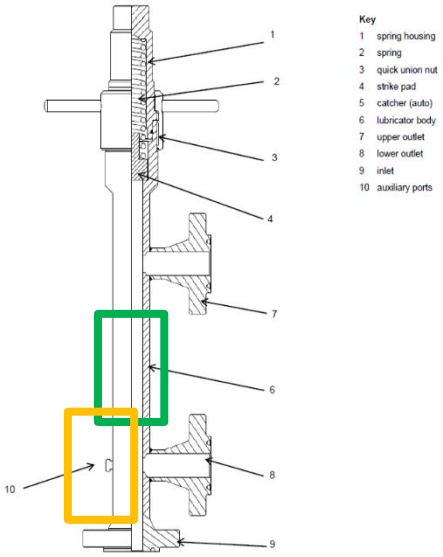

Figure 7 – Recommended Mounting Locations

3.3 Setting Sensitivity

Sasquatch has sensitivity selection dial located above the wire terminals. The sensitivity dial allows the operator to adjust the threshold at which Sasquatch will detect a plunger arrival. By default the switch is set to 4 which is the middle of the range. If false arrivals occur the dial can be set to a less sensitive setting to or conversely if missed arrivals occur, the sensitivity can be increased.

When the sensitivity dial is set to '0', Sasquatch enters 'Program Mode' and using ETC Vision you can program new firmware and change the 'Sensor Modes'.

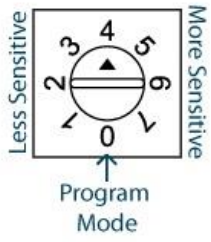

Figure 8 - Sensitivity Dial

4 General Operation

Sasquatch comes with a default configuration that will work for most installations, however any of the settings can be configured via the Modbus interface or ETC Vision. ETC Vision can also update firmware, copy/backup settings, and visualize the magnetic field measured by the sensor.

4.1 Sensor Modes

Sasquatch has several user selectable modes it can operate in. The modes are changed by turning the sensitivity selection dial to 0 (Program Mode) and using ETC Vision to set the desired mode.

While in 'Program Mode' the COM1 interface is configured to interact with ETC Vision and therefore will not respond to Modbus messages, Sasquatch will not detect and signal plunger arrivals, and the velocity will not be calculated and recorded. This mode is strictly for maintenance and the sensitivity dial setting must be restored to the desired setting for normal operation.

4.1.1 Normal Mode

Normal mode is the typical mode Sasquatch will be running in. In this mode Sasquatch will respond to Modbus messages, detect plunger arrivals, and calculate velocity. Except for when debugging, this is the mode of operation Sasquatch must be set to.

4.1.2 Capture –Self Test

In this sensor mode, Sasquatch performs a self-test of the magnetic sensors. The results of this test can be viewed using the 'Capture' tab of ETC Vision. A properly functioning Sasquatch in self-test mode will present a plot with alternating spikes.

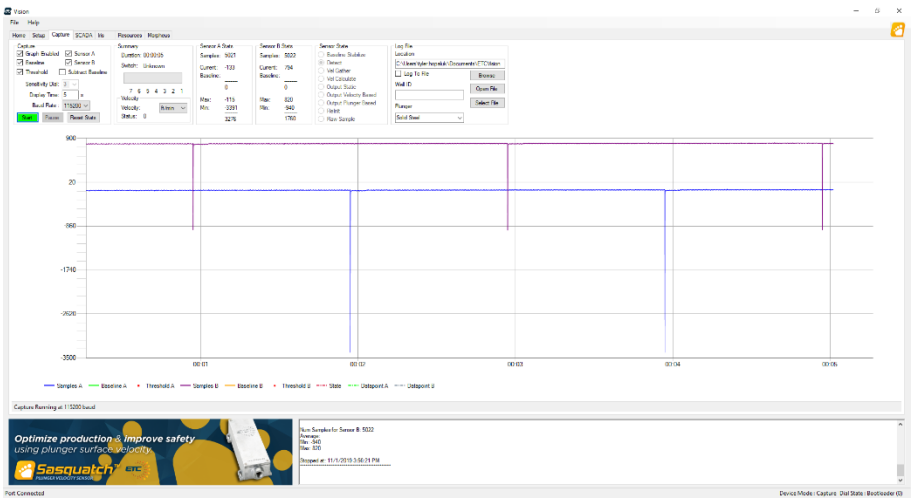

Figure 9 – Sasquatch Self-Test Plot

4.1.3 Capture – Full Debug

In this sensor mode, Sasquatch will send a real time plot of the magnetic field as seen by each of the two sensing elements inside Sasquatch. To view the plot in ETC Vision, select the capture tab and start the

capture. The plot will display the two sensors data along with the currently configured sensitivity thresholds. The data at the top of the capture will report the velocity of last captured arrival along with some statistical information. A capture can be saved to file by selecting a file name/location and enabling ‘Log To File’.

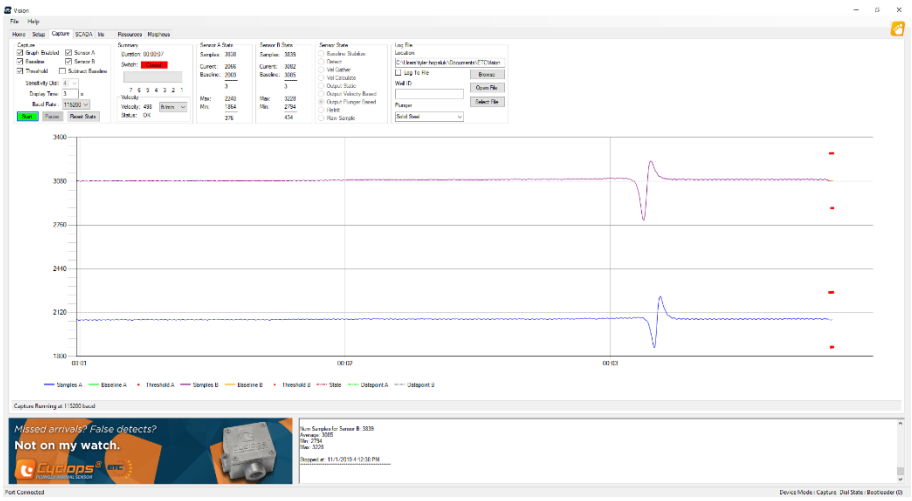

Figure 10 – Sasquatch Full Debug Plot

4.1.4 Capture – Raw Samples

In this sensor mode, Sasquatch will send a real time plot of the magnetic field, however it will not process the data in any manner. This mode may be requested by ETC Support while diagnosing technical issues.

4.2 Plunger Arrival Detection

The Sasquatch by default will take magnetic readings and apply a filter to remove the high frequency noise. These filtered readings are then both incorporated into the long term baseline and used to determine whether the plunger has arrived.

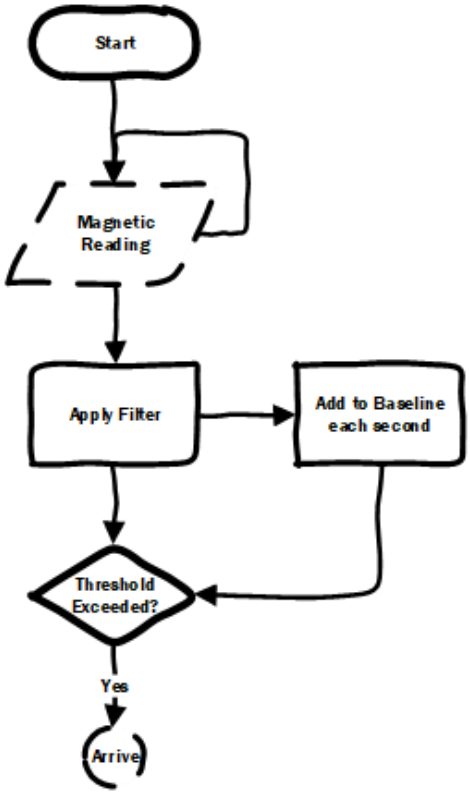

Figure 11 - Arrival Detection Logic

Once the signal has exceeded the baseline by at least the threshold (defined by the sensitivity switch), the plunger is considered arrived. In the case of the Sasquatch, the output is not set until the velocity has been calculated and made available via the Modbus log. This prevents the control system from reading the velocity before it is ready.

The plunger arrival indicator signal output can be configured for three different usage cases.

4.2.1 Plunger Activity Hold

The plunger arrival signal is held low as long as Sasquatch detects movement from the plunger. There is a minimum pulse length that is configurable but after this time elapses the signal will stay held low until Sasquatch no longer detects the plunger moving. The minimum pulse length is programmed with the *Minimum Output Hold Time* setting.

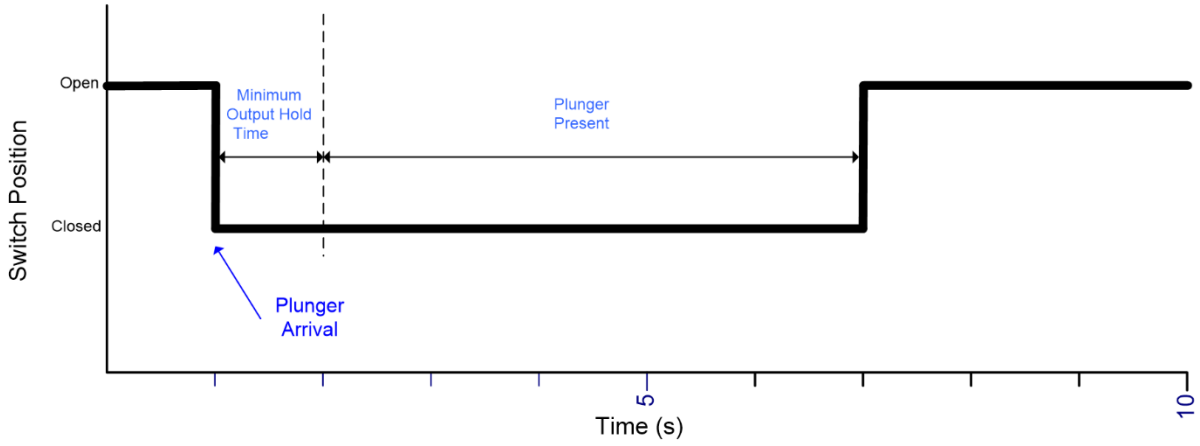

Figure 12 – Plunger Activity Hold Timing

4.2.2 Fixed Pulse Length

This mode ensures that the output signal is held for a specified amount of time each time that the plunger arrives. The length of the pulse is programmed by the *Minimum Output Hold Time* setting. Another arrival pulse will not occur until Sasquatch can no longer detect a moving plunger followed by the plunger arriving again.

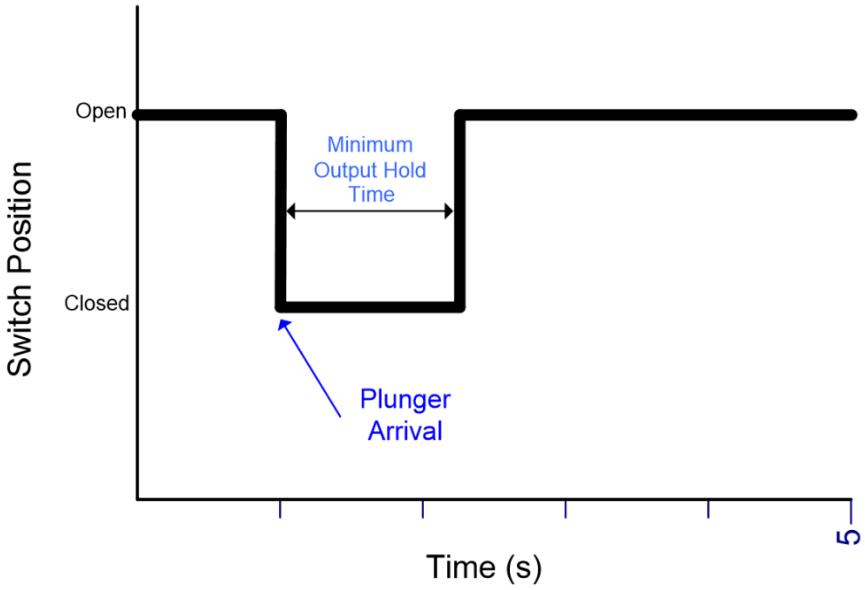

Figure 13 – Fixed Pulse Length Timing

4.2.3 Velocity Scaled Output

The duration of the plunger arrival pulse indicates the plunger arrival velocity. This allows for the velocity information to be transmitted along with the switch closure. The switch will always close for the *Minimum Output Hold Time* as above but will be held closed for an additional time that is calculated based on the *Output Hold Scale* parameter and the measured velocity.

Pulse length is calculated as follows:

*Length = (Minimum Output Hold Time) + (Output Hold Scale * Velocity)*

In the example below, *Minimum Output Hold Time* is set to 1s, and the *Output Hold Scale* is set to 10ms per m/min of velocity, both are the default settings. The plunger arrived at 200 m/min, therefore pulse length is: 1000 + (10 * 200) = 3000ms

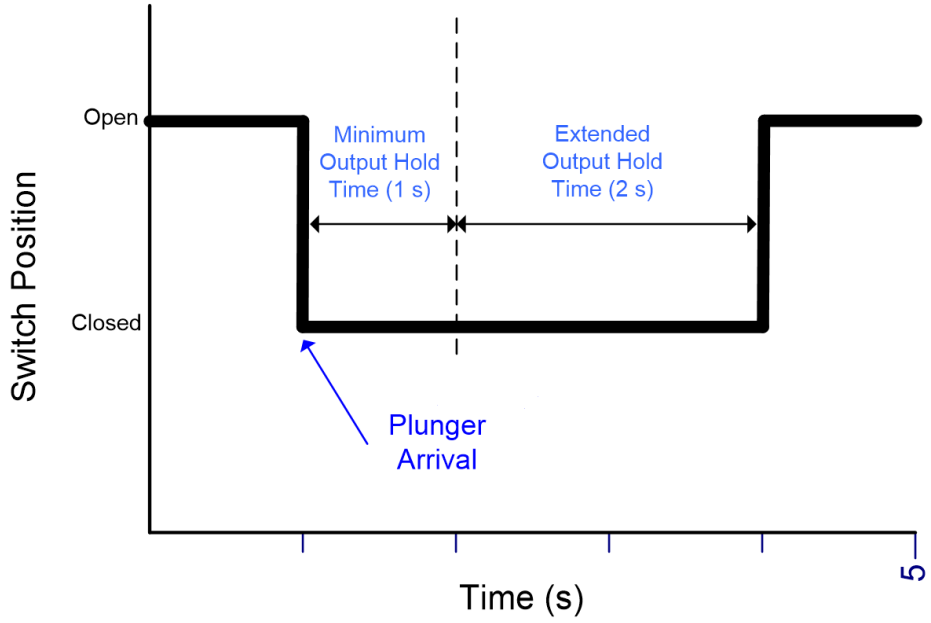

Figure 14 - Velocity Scaled Output Timing

4.3 Post Arrival Operation

Once the Sasquatch has detected the arrival, it calculates the velocity, sets and holds the output switch, and then re-initializes once the plunger has departed to avoid recording numerous arrivals as the plunger bounces around at surface.

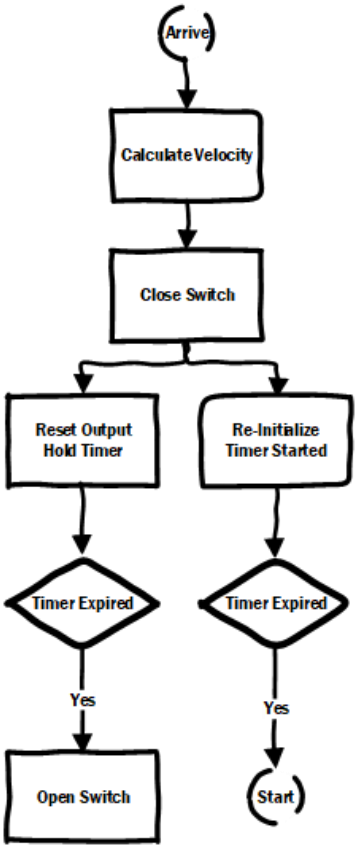

Figure 15 - Post Arrival Operation

4.3.1 Re-Initialize Timer

After an arrival, Sasquatch has a cool-down timer that must elapse before it will detect another arrival. This timer specifies how long to wait after Sasquatch can no longer detect the plunger before re-initializing the sensor, ready to detect the next arrival. In most cases the default value is optimal.

4.4 Velocity Log

The Arrival Log is a historical log that stores the last 120 arrivals in reverse chronological order. This means that the most recent log entry will always appear at the top of the log. Each of the log entries features as Arrival Time, Velocity, and Measurement Status. The Measurement Status relays helps the controller determine whether the value should be relied upon for each arrival. A positive number indicates the number of correlated measurement points while a negative number indicates an error.

5 Monitoring Kinetic Energy at the Lubricator

An important reason for knowing plunger speed at surface is to know if the lubricator is being damaged by hard plunger hits. The Sasquatch can monitor plunger arrivals to determine if the well is operating safely and if the lubricator/plunger/spring may need maintenance or replacement. The ability for a lubricator to absorb a plunger hit is specified in kinetic energy units – inch-pounds (in-lbs) in imperial or

Joules (J) in metric. The Sasquatch can convert plunger speed into kinetic energy and activate an alarm to indicate that the lubricator is under stress.

The API standard for plunger lift well heads specifies that manufactures should stamp a kinetic energy rating on the equipment they produce. The standard lists kinetic energy and plunger mass in these imperial units: in-lbs and lbs, so for convenience, the Sasquatch uses the same units. Likewise, for the metric units of kg and J.

Two key pieces of information are required to configure the Sasquatch for this functionality:

	Where to get it	**Imperial Units**	**Metric Units**
Plunger Mass	Ask vendor to provide it or weigh it	Pounds (lbs)	Kilogram (kg)
Lubricator Kinetic Energy Rating	Stamped on lubricator or ask vendor to provide it	Inch-pounds (in-lbs)	Joules (J)

Table 1 – Lubricator / Spring Wear Settings

The Dangerous Arrival Kinetic Energy Threshold should be set to the lubricator's kinetic energy rating. We recommend that the Hard Arrival Kinetic Energy Setting be set to 85% of the lubricator's kinetic energy rating.

The Sasquatch allows you to specify alarm thresholds in either velocity or kinetic energy units. It is up to the user to decide which to use. Velocity thresholds may be more familiar to some users but requires a manual calculation to check that it is within the lubricator specifications. Kinetic energy lets you use the lubricator rating directly.

Vision provides a settings page (below) to make the settings changes to the Sasquatch for your specific lubricator and plunger. You can also check/reset alarm status and statistics. This settings page is shown below. This tool is useful for initial integration and site auditing. The functionality of this page would typically be integrated into a SCADA system for automated lubricator / spring wear monitoring.

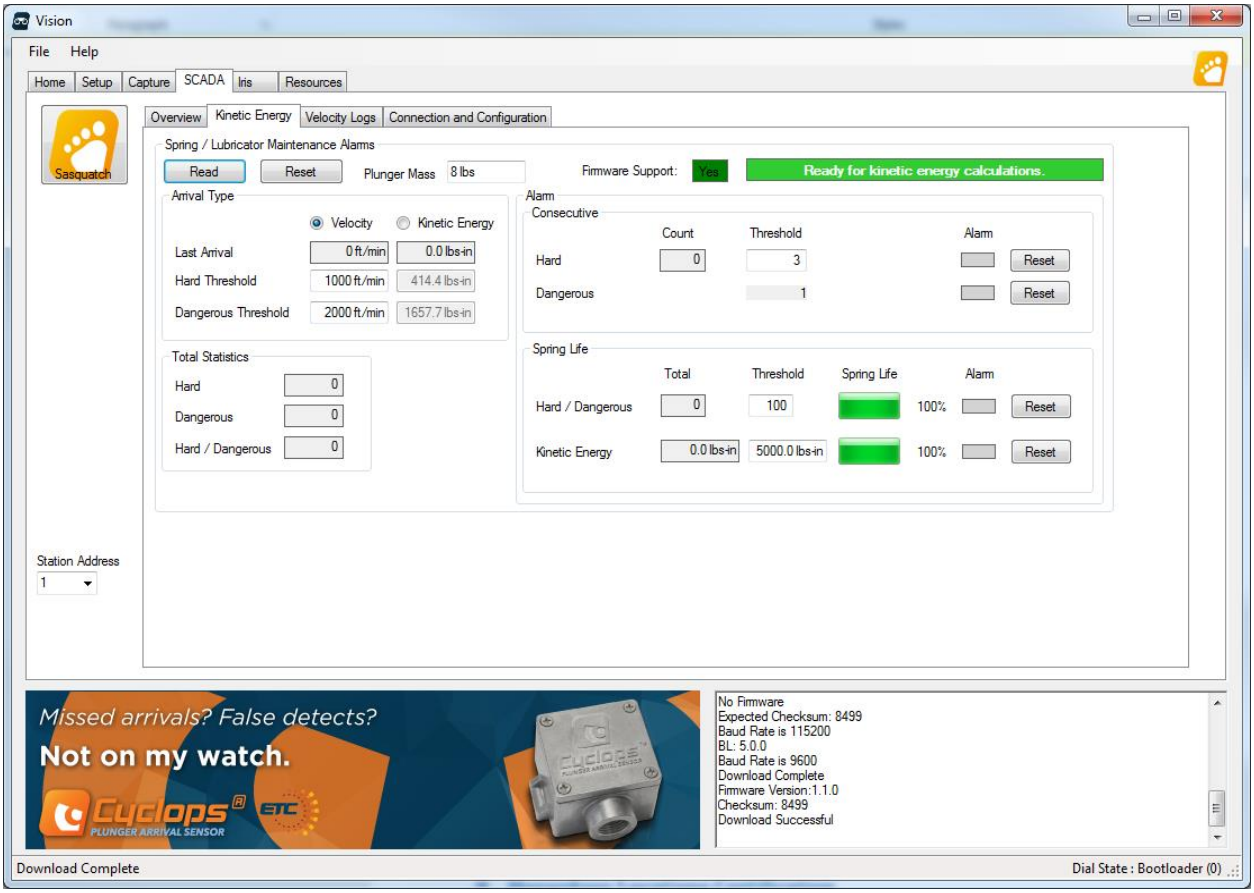

Figure 16 – Vision Sasquatch Kinetic Energy Settings

5.1 Lubricator/Spring Wear Settings

The Sasquatch provides alarms and statistics for monitoring wear and tear due to hard plunger arrivals. This functionality is useful for monitoring well safety and for pre-emptive maintenance scheduling.

5.1.1.1 Plunger Mass

The mass of the plunger in thousandths of a pound (grams).

Ex. 5lbs plunger = 5000

This is required in order for the Sasquatch to calculate accurate kinetic energy of the arriving plunger as it hits the lubricator. If this information is not set, the velocity-based alarms will still operate.

5.1.1.2 Hard Arrival Velocity Threshold

If the velocity of the plunger exceeds this threshold a hard arrival has occurred. If enough consecutive hard arrivals occur an alarm flag will be set. Hard arrivals can also trip the Cumulative Hard Arrival Alarm and the Cumulative Kinetic Energy Alarm

Associated Alarms: Consecutive Hard Arrival Alarm, Cumulative Hard Arrival Alarm, Cumulative Kinetic Energy Alarm

5.1.1.3 Hard Arrival Kinetic Energy Threshold

This is the equivalent kinetic energy of the Hard Arrival Velocity Threshold. This value is linked with the Hard Arrival Velocity Threshold so that if one is changed the other changes as well.

Associated Alarms: Consecutive Hard Arrival Alarm, Cumulative Hard Arrival Alarm, Cumulative Kinetic Energy Alarm

5.1.1.4 Dangerous Arrival Velocity Threshold

If the velocity of the plunger exceeds this threshold a dangerous arrival has occurred. This will trigger a Dangerous Arrival Alarm.

Associated Alarm: Dangerous Arrival Alarm

5.1.1.5 Dangerous Arrival Kinetic Energy Threshold

This is the equivalent kinetic energy of the Dangerous Arrival Velocity Threshold. This value is linked with the Dangerous Arrival Velocity Threshold so that if one is changed the other changes as well.

Associated Alarm: Dangerous Arrival Alarm

5.1.1.6 Consecutive Hard Arrival Alarm Threshold

This setting defines when a consecutive hard arrival alarm will trip. For example, if this setting is 3, then 3 consecutive arrivals with a velocity higher than the Hard Arrival threshold will cause an alarm flag to be set.

Associated Alarm: Consecutive Hard Arrival Alarm

5.1.1.7 Cumulative Hard Arrival Threshold

The Sasquatch counts the number of arrivals above the Hard Arrival threshold. If this count exceeds the Cumulative Hard Arrival Threshold, and alarm flag is set. These do not need to be consecutive hard arrivals to trip the alarm.

Associated Alarm: Cumulative Hard Arrival Alarm

5.1.1.8 Cumulative Kinetic Energy Threshold

The Sasquatch accumulates (adds together) all kinetic energies for arrivals that exceed the Hard Arrival threshold. When that sum exceeds the Cumulative Hard Arrival Threshold, an alarm will occur.

Associated Alarm: Cumulative Kinetic Energy Alarm

6 Cathodic Protection

A common problem with wellhead mounted sensors is that they can become an electrical path between the well and the controller. Often, high voltages associated with cathodic protection can leak back through the sensor to the controller causing erratic behavior or permanent damage.

The Sasquatch has been designed such that its internal circuitry is electrically isolated from the enclosure. This means that even if the enclosure is mounted to a surface that has a stray voltage, it will not be transmitted back through the wiring to the controller.

Please do keep in mind that any shielding on the cable that is connected to the case of the Sasquatch will act as a path for any stray voltage to travel.

Appendix A Connecting ETC Vision to Sasquatch

ETC Vision can use any serial to RS485 adapter to communicate with Sasquatch, however for convenience ETC offers the Link USB to RS485 adapter kits in both a desktop and intrinsically safe version. The desktop kit is to be used for programming/configuring Sasquatch in non-hazardous areas while the IS kit can be used on live installs.

Figure 17 – ETC Link Desktop

Figure 18 – ETC Link IS Kit

To connect Sasquatch to ETC Vision with a generic USB-RS485 adapter, configure the adapter for 2-wire RS485 mode. Wire up the A/B connections to the RS-485 adapter and power/com terminals to an appropriate power source. SIG terminal is not used in this case.

Appendix B Modbus Register Types and Formats

Register Types

There are 4 types of supported Modbus registers

Table 2 – Modbus Register Types

	Description	Modbus Function Code
0XXXX	Coils – 1-bit values with read/write access	01 – Read Coil 05 – Force Single Coil
1XXXX	Discrete Inputs – 1-bit values with read only access	02 – Read Discrete Input
3XXXX	Input Registers – 16-bit values with read only access	04 – Read Input Registers
4XXXX	Holding Registers – 16-bit values with read/write access	03 – Read Holding Registers 06 – Write Single Holding Register 16 – Write Multiple Holding Registers

Data Formats

Input and Holding registers support several different data formats. Those formats and the designators used to refer to them in the Modbus Map are listed below.

Table 3 – Register Data Formats

Designator	Description
U16	16 bit unsigned integer
S16	16 bit signed integer
U32	2 consecutive registers as 32 bit unsinged integer
F	2 consecutive registers as 32 bit IEEE 754 Floating point

Endianness

Data values that span consecutive registers follow Big-Endian format.

Table 4 – Register Endianness Format

Register Number	
N	Most Significant Word
N + 1	Least Significant Word

Date/Time Register

Date and time can be read/written in one of two formats, use the “Time Format” coil to choose the desired format.

- Seconds since Jan 1, 2000 (Seconds Format)
- Individual Year/Month/Day/Hour/Minute/Second registers (H:M:S Format)

To set the date/time writes must occur in sequence from lowest register to highest register and only take effect after the last register is written.

Table 5 - Date/Time Register Format

Number	Description (Seconds Format)	Description(H:M:S Format)
N	Seconds since January 1, 2000 (MSW)	Year
N + 1	Seconds since January 1, 2000 (LSW)	Month
N + 2	Reserved	Day
N + 3	Reserved	Hours
N + 4	Reserved	Minutes
N + 5	Reserved	Seconds

Appendix C Modbus Register Map

Note: Any registers that are not listed have not been implemented. Writes to these registers will be ignored and reads from these registers will return unpredictable results.

Note: Modbus uses a register number that starts at 1 where the address that is passed in the protocol layer starts at 0. This means that depending on the tool you are using, you may need to subtract 1 from the register number to access the appropriate data.

Coils

Table 6 - Available Coils

Register #	Description	Read	Write
Basic Control			
00001	Restart Sensor	N/A	1 - Restart
00002	Reset Velocity Log	N/A	1 - Reset Log
00004	Time Format	Current Value	0 – Seconds* 1 – H:M:S
00005	Units	Current Value	0 – Imperial* 1 – (Metric)
00007	Reset Daily Statistics Log	N/A	1 – Reset Log
00008	Reset Total Statistics Log	N/A	1 – Reset Log
00010	Reset Arrival Log	N/A	1 – Reset Log
00011	Start Plunger Detection	N/A	1 – Start detection
00012	Stop Plunger Detection	N/A	1 – Stop detection
00013	Reset Kinetic Energy Statistics	N/A	1 – Reset statistics
Kinetic Energy Alarm Control			
00014	Reset Consecutive Hard Arrival Alarm	N/A	1 – Reset alarm
00015	Reset Dangerous Arrival Alarm	N/A	1 – Reset alarm
00016	Reset Cumulative Hard Arrival Alarm	N/A	1 – Reset alarm
00017	Reset Cumulative Kinetic Energy Alarm	N/A	1 – Reset alarm

*** = Default Settings**

Discrete Inputs

Table 7 - Available Discrete Inputs

Register	Description	Read
General Information		
10001	Date/Time Set	0 – date/time not set 1 – date/time set
Sensor Status		
10011	Plunger Arrival Status	0 – Absent 1 – Present
10012	New Velocity Indicator	0 – No new velocity measured since last polled 1 – New velocity measured since last polled (value resets to 0 once it has been read)
Kinetic Energy Alarm Status		
10013	Consecutive Hard Arrival Alarm Status	0 – Consecutive Hard Arrival Statistic under threshold 1 – Consecutive Hard Arrival Statistic over threshold
10014	Dangerous Arrival Alarm Status	0 – Dangerous Arrival Alarm Statistic under threshold 1 – Dangerous Arrival Alarm Statistic over threshold
10015	Cumulative Hard Arrival Alarm Status	0 – Cumulative Hard Arrival Alarm Statistic under threshold 1 – Cumulative Hard Arrival Alarm Statistic over threshold
10016	Cumulative Kinetic Energy Alarm Status	0 – Cumulative Kinetic Energy Alarm Statistic under threshold 1 – Cumulative Kinetic Energy Alarm Statistic over threshold

Input Registers

Table 8 - Available Input Registers

Register	Description	Format	Read
General Information			
30001 – 30002	Serial Number	U32	0 – 99999
30003	Firmware Version – Major Version	U16	0 – 99

Register	Description	Format	Read
30004	Firmware Version – Minor Version	U16	0 – 99
30005	Firmware Version – Fix Version	U16	0 – 99
30006	Hardware Version	U16	0 – 99
Sensor Information			
30012	Dial Switch Setting	U16	1 – 7
30013	Sensor Sensitivity Threshold	U16	0 – 65535
Kinetic Energy Statistics			
30031	Consecutive Hard Arrivals	U16	0 – 65535
30032	Cumulative Hard Arrivals	U16	0 – 65535
30033	Cumulative Dangerous Arrivals	U16	0 – 65535
30034	Total Hard/Dangerous Arrivals	U16	0 – 65535
30043 – 30044	Cumulative Kinetic Energy	F	in-lbs (Joules)
Arrival/Velocity Log			
30101	Log Count	U16	0 – 120
30102 + 6(n-1) to 30107 + 6(n-1)	Arrival Time – Entry n n = 1 to 120	U16	Date / Time Register Format
30822 + (n-1)	Velocity – Entry n n = 1 to 120	U16	0 – 3281 ft/min (0 – 1000 m/min)
30942 + (n-1)	Velocity Measurement Status – Entry n where n = 1 to 120	S16	Negative indicates measurement error -32768 = Uninitialized -4 = Velocity Calc Error -3 = Velocity Calc Error -2 = Velocity Over-range -1 = Velocity Under-range 0 = Reserved 1 = Reserved 2 = Valid, 2 Points Used 3 = Valid, 3 Points Used 4 = Valid, 4 Points Used 5 = Valid, 5 Points Used 6 = Valid, 6 Points Used 7 = Valid, 7 Points Used 8 = Valid, 8 Points Used
31062 + (n-1)	Kinetic Energy – Entry n where n = 1 to 120	F	0 – 2788.2 in-lbs (0 – 315.0 J)
Daily Log			
32101	Daily Log Count	U16	0 – 15

Register	Description	Format	Read
32102 + 6(n-1) to 32107 + 6(n-1)	Daily Log Save Time – Entry n n = 1 - 15	U16	Date / Time Register Format
32192 + (n-1)	Daily Log Plunger Arrival Count – Entry n n = 1 – 15	U16	0 – 65534
32207 + (n-1)	Daily Log Maximum recorded Velocity – Entry n n = 1 - 15	U16	0 – 1000 m/min (0 – 3281 ft/min)
32222 + (n-1)	Daily Log Minimum recorded Velocity –Entry n n = 1 – 15	U16	0 – 1000 m/min (0 – 3281 ft/min)
Total Production Log			
32501 – 32506	Total Production Save Time	U16	Date / Time Register Format
32507	Total Production Log Plunger Arrival Count	U16	0 – 65535
32508	Total Production Log Maximum recorded Velocity	U16	0 – 1000 m/min (0 – 3281 ft/min)
32509	Total Production Log Minimum recorded Velocity	U16	0 – 1000 m/min (0 – 3281 ft/min)

Holding Registers

Table 9 - Available Holding Registers

Register	Description	Format	Read/Write
General Settings			
40002 – 40007	Controller Date/Time	U16	Date / Time Register Format
40008	Daylight Savings Time configuration	U16	0 – Disabled***** 1 – Enabled
Output Configuration			
40031	Output Mode	U16	0 – Static Time 1 – Velocity Scaled 2 – Plunger Hold*****
40032	Output Hold Scale	U16	1 – 600ms per m/min (ft/min) default = 10ms
40033	Minimum Output Hold Time	U16	100 – 65535ms default = 1000ms

Register	Description	Format	Read/Write
40047	Re-Initialize Timer	U16	1 – 65535 s default = 1s
Modbus COM Settings			
40051	Baud Rate	U16	0 – 1200 bps 1 – 2400 bps 2 – 4800 bps 3 – 9600 bps***** 4 – 19200 bps 5 – 38400 bps 6 – 56000 bps 7 – 115200 bps 8 – 128000 bps 9 – 256000 bps
40052	Parity	U16	0 – None***** 1 – Even 2 – Odd
40053	Data Bits	U16	0 – 7 Data Bits 1 – 8 Data Bits*****
40054	Stop Bits	U16	0 – 1 Stop Bit***** 1 – 2 Stop Bits
40055	Modbus Slave Station Address	U16	1 – 247 default = 1
40056	Modbus Protocol	U16	0 – RTU***** 1 – ASCII
Kinetic Energy Configuration			
40071	Plunger Mass	U16	0 – 65.535 lbs (kg) Where 65535 = 65.535
40072	Hard Arrival Velocity Threshold	U16	0 – 65535 ft/min (m/min)
40073	Dangerous Arrival Velocity Threshold	U16	0 – 65535 ft/min (m/min)
40074	Consecutive Hard/Dangerous Arrival Threshold	U16	0 – 65535
40075	Cumulative Hard/Dangerous Arrival Threshold	U16	0 – 65535
40081 – 40082	Hard Arrival Kinetic Energy Threshold	F	0 – 3.4028×10^{38} in-lbs (J)
40083 – 40084	Dangerous Arrival Kinetic Energy Threshold	F	0 – 3.4028×10^{38} in-lbs (J)
40085 – 40086	Cumulative Kinetic Energy Threshold	F	0 – 3.4028×10^{38} in-lbs (J)

*** = Default Settings**