Lufkin Well Manager™ 2.0

Variable Speed Drive
Rod Pump Controller

User Manual

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Part # 1000306605
Document # 2000301878, Rev. E

January 2022

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Section 1: General Information

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Manual Overview

This manual provides a complete description of the Lufkin Well Manager 2.0 system and the steps required for installing, wiring, and configuring this system.

Notes, Cautions, and Warnings

Notes, cautions, and warnings are used throughout this manual to provide readers with additional information, and to advise the reader to take specific action to protect personnel from potential injury or lethal conditions. They are also used to inform the reader of actions necessary to prevent equipment damage. Please pay close attention to these messages.

Notes

Notes provide useful information and tips that can make the operator’s job easier.

Cautions

The caution symbol indicates that potential damage to equipment or injury to personnel exists. Extreme care should be taken when performing operations or procedures preceded by this caution symbol.

Warnings

The warning symbol indicates a definite risk of equipment damage or danger to personnel. Failure to observe and follow proper procedures could result in serious or fatal injury to personnel, significant property loss, or significant equipment damage.

Illustrations and Photographs

The illustrations and photographs in this manual provide graphical examples of equipment and software screens. These examples are not intended to represent every possible situation and will vary in appearance to the actual equipment and screens.

Safety Guidelines

WARNING: Only qualified service technicians should install, operate, or repair this system.

Observe the safety precautions listed below and all safety precautions provided throughout this manual. Following these precautions will protect the operator and others from injury or death and prevent equipment damage and environmental impact.

- Follow all customer safety guidelines.
- Park vehicles upwind of the wellhead. Stand upwind when installing or dismantling equipment.

WARNING: Hydrogen sulfide gas (H2S) may be present in high concentrations. Wear proper H2S detection equipment at all times and follow all recommended safety precautions when working around wellheads.

- Live or discharging electrical equipment poses an electrocution hazard. Read the following warnings before attempting any work around the controller enclosure:

WARNING: Turn off power from the main power source to the enclosure and follow proper lockout/tagout procedures before opening the controller enclosure. Failure to heed this warning can result in severe injury or death.

WARNING: Capacitors can retain a lethal voltage up to 20 minutes after power has been shut off. While verifying locked-out equipment, allow sufficient time for complete discharge of capacitors. Always refer to the inverter manufacturer's manual for correct discharge times.

WARNING: All electrical equipment covers MUST be in place before turning on the power to the unit.

WARNING: If it is necessary to work on or around live electrical equipment, wear electrical hot gloves, a blast shield, and fire-retardant clothing in addition to regular PPE. (Refer to NFPA70E Electrical Safety Standard for more details.) Failure to do so could result in severe injury or death.

WARNING: The HOL switch MUST be turned to the **OFF** position during service or configuration to ensure that the pumping system does not start. Failure to do so could result in severe injury or death.

WARNING: This VSD must be properly grounded by a qualified electrical technician. Improper grounding can result in severe injury or death.

- When sensors are installed in a well site's hazardous area, the signal wiring installation must comply with the NEC Standard for Electrical Safety in the Workplace (NFPA-70) and local regulations.

WARNING: Signal wiring installed in a well site's hazardous area must be enclosed in properly-rated Type MC-HL sealed cables or conduits with sealed conduit fittings. This will prevent ignitable process gases or fluids from migrating into the electrical system.

- Before leaving the location, return all wellhead equipment to normal operating positions.

Technical Support

For technical support, call Lufkin Automation Technical Support Services at (281) 495-1100, Monday through Friday, between 8:00 AM and 5:00 PM Central Standard Time.

Please have all information that applies to the problem readily available. Write down or print out any onscreen messages that appear when the problem occurs, and have the manual available when calling.

Section 2: System Description

Section Overview

This section describes the major components making up the Lufkin Well Manager™ 2.0 VSD RPC system. A section on general VSD theory is included to provide the operator basic knowledge in order to better understand the operation of the VSD RPC system.

Lufkin Well Manager 2.0 VSD RPC

The Lufkin Well Manager (LWM) 2.0 Variable Speed Drive (VSD) Rod Pump Controller (RPC) is a preprogrammed device mounted at the wellsite that gathers, processes, stores, and analyzes analog data from a load transducer and digital data obtained from motor and crank arm sensors. The LWM 2.0 VSD RPC uses the data from these input devices to monitor and control the operation of a pumping unit and to display graphic data on an LCD display or portable laptop computer in a format easy to understand.

The LWM 2.0 VSD RPC uses the input data to calculate a dynagraph card and analyzes that card to determine the percent fill of the pump barrel. The speed of the pumping unit is continuously varied in order to maintain optimum pump fillage. Secondary control functions protect the drive system and the pumping unit equipment in the event of abnormal loads due to sticking pump, floating rod string, mechanical equipment failure, etc.

Current information about pumping activity can be obtained on demand from both the local keypad/display and data telemetry link (radio, cell modem, satellite, etc.) at a central computer running compatible SCADA software. The LWM 2.0 VSD RPC can be controlled remotely using the same SCADA software.

Note: To enable remote SCADA control, the HOL switch must be set to the **LWM** (Auto) position. If the HOL switch is in the **OFF** position, the unit cannot be started remotely. See “HOL Switch” on page 7-3 for more information.

The LWM 2.0 VSD RPC integrates an LWM 2.0 RPC and a Danfoss FC 302 frequency converter in a common enclosure. The front section of this enclosure has an IP56 ingress rating and the rear section has an IP46 ingress rating.

Other system components include the following:

- circuit breaker
- control transformer
- DC power supply
- line voltage surge protector
- input/output terminals
- control relays

All components are pre-wired and mounted in the enclosure.

The LWM 2.0 RPC components and the Danfoss FC 302 frequency converter are discussed on the following pages.

Enclosure

Figure 2-1 shows a typical Lufkin Well Manager 2.0 VSD RPC enclosure assembly.

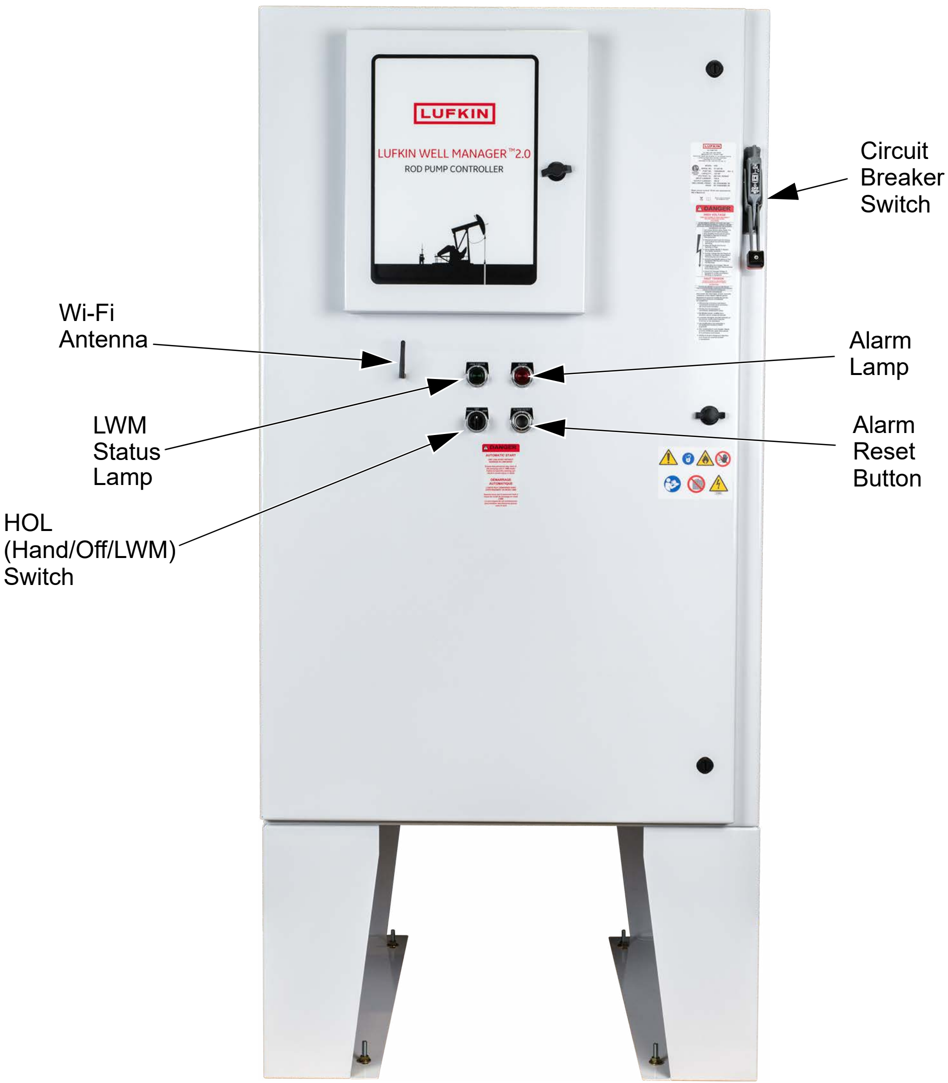


Figure 2-1. Typical Lufkin Well Manager 2.0 VSD RPC Enclosure – Front View

FC 302 Frequency Inverter

The Danfoss FC 302 frequency inverter converts AC line voltage into a variable frequency output voltage to run the pumping unit motor at the speed commanded by the LWM 2.0 VSD RPC control algorithm. The inverter has its own operator interface, but all normal operations can be controlled using the LWM 2.0 VSD RPC keypad/display.

The inverter is mounted on the upper left section of the interior panel (see Figure 2-2), and can only be accessed by opening the main enclosure door. For detailed information, refer to the latest edition of the Danfoss inverter instruction manual.

WARNING: Only authorized service technicians should open this door, which exposes personnel to dangerous high voltage levels that can cause severe injury or death.

WARNING: The VSD DC bus capacitors remain charged for up to 20 minutes after power is turned off. Wait at least 20 minutes before opening the enclosure door.

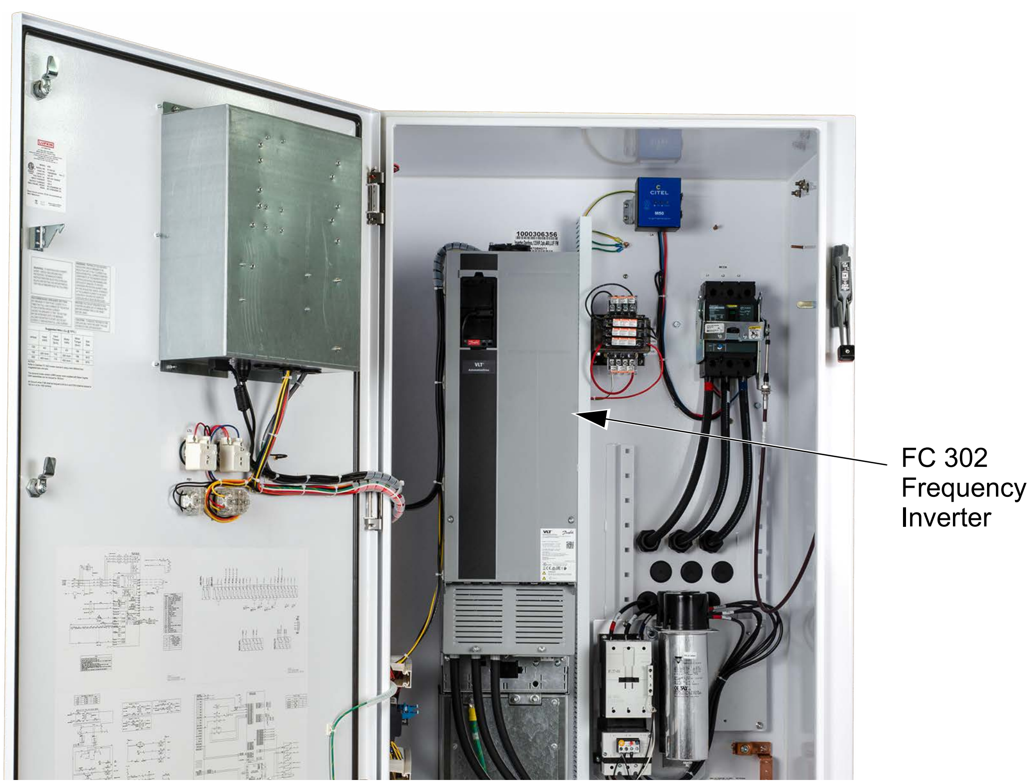


Figure 2-2. FC 302 Frequency Inverter

Communication Gateway

The Communication Gateway Module (GE Part # IS420CCGAH2A-A), mounted on the small door inside the LWM 2.0 controller compartment, is a Remote Terminal Unit (RTU) that provides communication options for the Modbus devices used in this system. This module relays all keypad and SCADA commands to the controller module through a dedicated Ethernet port (ENET0) and displays the controller data on the HMI screen. (See “Controller Module” for details on the controller module.)

Figure 2-3. Communication Gateway Module

The communication gateway module also has the following connectivity options:

- One USB port
- One MicroSD Card slot
- Four Ethernet ports
- One RS232 serial port
- One RS485 serial port
- Built-in Wi-Fi router
- Remote communication device (Not available in this release.)

Refer to the *CCGA Communication Gateway Instructions for GE Lufkin* document (GE Document # GEK-SA-1045) for details on this module.

Controller Module

The controller module is a GE Mark* VIe UCPA controller platform (GE Part # IS420UCPAH2A-A) that runs the control logic functions for the pumping system. This module has both integral I/O capabilities and can communicate with external I/O packs through a simplex I/O network. The UCPA controller is mounted on the back panel inside the LWM 2.0 controller compartment.

Figure 2-4 shows the controller module.

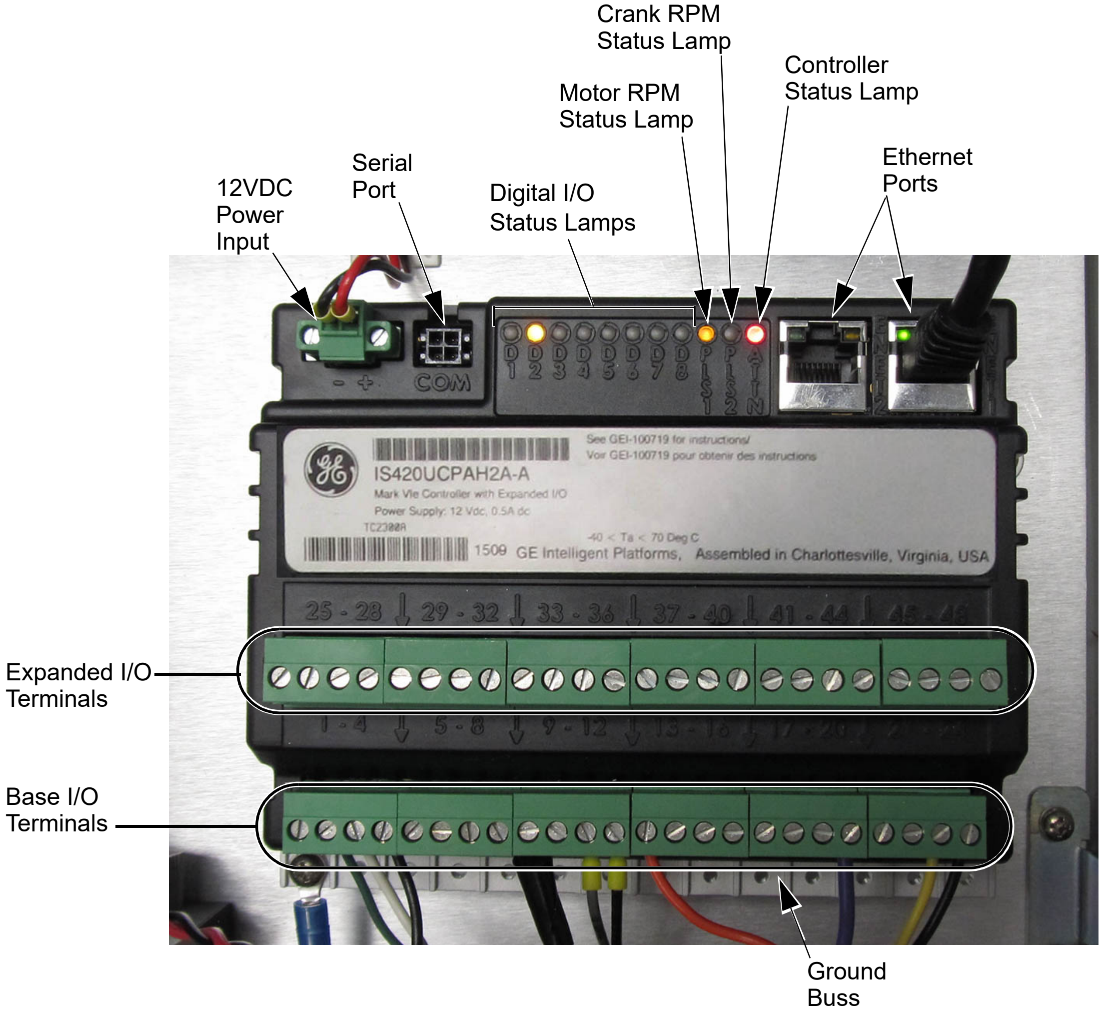


Figure 2-4. Controller Module

The components of this module are described below:

- **12VDC Power Input**: Power is supplied to the controller at this input.
- **Serial Port**: This port is for Engineering use only.
- **Digital I/O Status Lamps**: These lamps indicate the status of each digital input/output channel. The default assignments for each channel are as follows:
  - **D1** – Indicates the MCC (Motor Control Center) is active.
  - **D2** – Indicates the fault relay is energized. If the controller module fails or powers off, the fault relay will de-energize to keep the pumping unit running.

   - **D3** – Indicates a motor start alert.
   - **D4** – Indicates a malfunction error in the pumping system.
   - **D5** – Indicates the HOA switch is in Hand position.
   - **D6** – Indicates the HOA switch is in Auto position.
   - **D7** – Indicates an ESD (Emergency Shutdown) has occurred.
   - **D8** – Not used

   These channel assignments can be disabled and reassigned to other digital input/output devices as needed.

- **PLS1 (Pulse 1)**: This is the Motor RPM status lamp. It blinks rapidly when a signal is being received from the Hall-Effect transducer mounted on the motor shaft.
- **PLS2 (Pulse 2)**: This is the Crank RPM status lamp. It blinks rapidly when a signal is being received from the Hall-Effect transducer mounted on the crank arm speed.
- **ATTN**: This is the controller status lamp. It indicates the status of the controller's processor during operation. When no problems are detected, this lamp flashes green during normal operation. When a problem is detected, the lamp flashes red.
- **Ethernet Ports**: These ports are used to connect the controller module with other system components (such as the communication module).
- **Base I/O Terminals**: These terminals are used for connecting the pumping system's main digital input/output devices.
- **Expanded I/O Terminals**: These terminals provide additional inputs for connecting other system input/output devices.
- **Ground Buss**: Used as a ground point for all input/output devices.

Refer to the *Mark* VIe Controller UCPA Instruction Guide* (GE Document # GEI-100719) for more details on this controller module.

HMI Module

This module connects the LCD display and keypad to the communication gateway module. See "Lufkin Well Manager 2.0 Operator Interface" on page 2-9 for more information on the LCD display and keypad.

Power Supply

All LWM 2.0 controllers use a power supply for converting AC power to 12VDC power. This power supply has an input range of 100 – 240VAC, 50/60 Hz, and 240W.

Terminal Blocks

Terminal blocks are provided for field termination of all transmitter leads, including individual shield termination points. The terminal blocks are front-access compression-clip type, so the field leads do not require crimp lugs.

Lufkin Well Manager 2.0 Operator Interface

The Lufkin Well Manager 2.0 operator interface shown in Figure 2-5 can be used to perform all system operations without opening the large cabinet door and exposing operator personnel to the 3-phase power in the inverter section of the system.

To access this interface, open the small metal door located on the upper left of the front door of the cabinet (see Figure 2-1).

Several parameters need to be defined to program the LWM 2.0. Programming is done through the local operator interface, which consists of a full-function LCD graphics display and 32-key keypad. This operator interface is menu-driven.

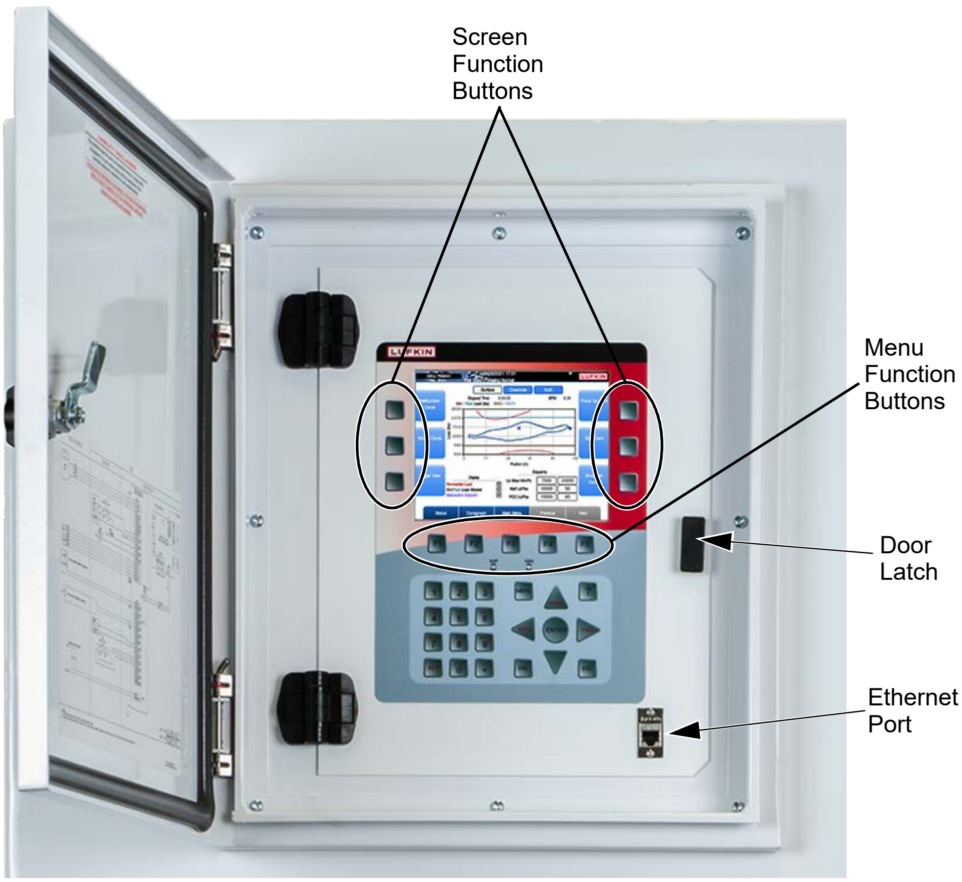


Figure 2-5. Operator Interface

Keypad

The 32-key keypad shown in Figure 2-5 allows the operator to program and calibrate the controller and access a large amount of well data.

The following table shows a description of each key's function on the keypad.

Keypad Functions

Item	Function
Function Buttons	These buttons control the screen functions displayed on the left and right sides of the screens.
F1 – F5	These buttons control the menu functions displayed on the bottom of every screen.
SOP and ERR lamps	These lamps are not used in this system.
0 – 9	The numerical buttons are used to input parameter values on the programming screens.
ALT	Press this button once to enable the alternate (alphabetic) values on the numeric buttons. In this mode, "ALT" is displayed in the status bar at the top of the screen. Press the button again to enable the default numeric values.
MENU	This button is not used.
?	This button displays help messages associated with the active screen. (These will be available in a later release.)
Arrow Keys	Press these buttons to change setpoint position or cursor location in the direction specified by the arrow key. They can also be used to scroll available options in several programming screen fields. The alternate commands (HOME, BACK, AND FWD) are not used in this release.
ENTER	Confirms a correct entry when changing programming data. When this key is pressed, data is updated.
DEL	Voids an incorrect numerical entry if **<ENTER>** is not pressed.
ESC	Displays the previously displayed menu. Cancels any changes made on the current screen if **<ENTER>** is not pressed.

LCD Display

The Lufkin Well Manager 2.0 user interface is menu-driven. All menus and screens are displayed in the LCD display.

The Main Menu screen (Figure 2-6) is the first screen that appears after the controller is turned on and the initialization process is completed. This screen can be accessed from any screen by pressing the **Main Menu** button.

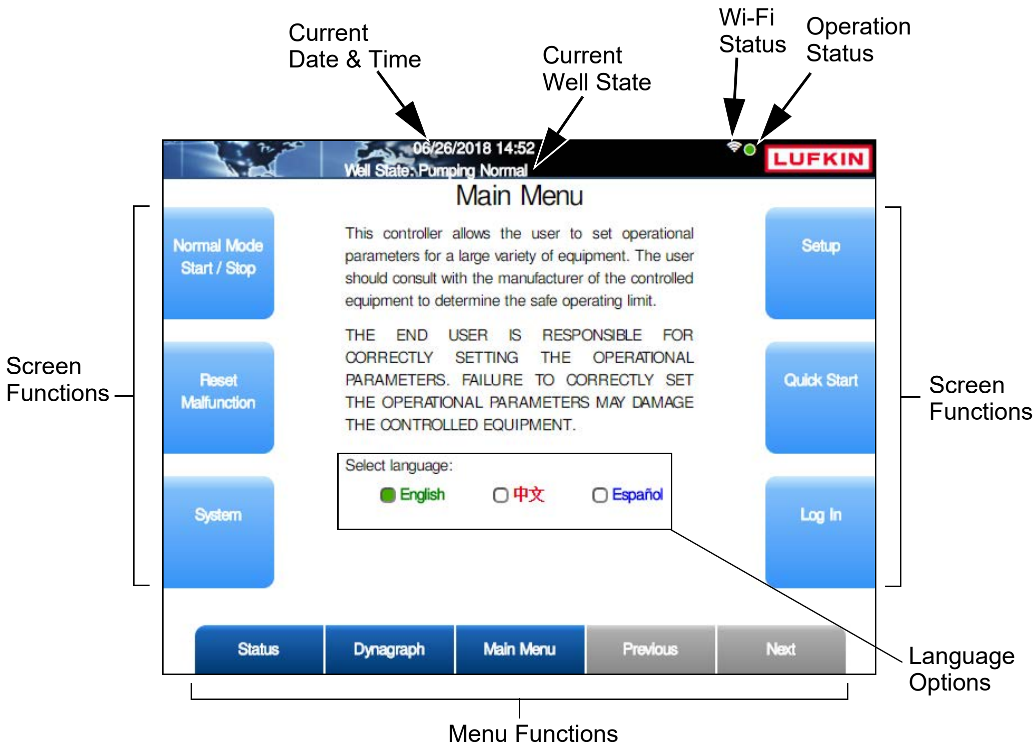


Figure 2-6. Main Menu Screen

Status Information

The following system status information is displayed at the top of every screen:

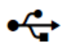
- Current date and time
- Current well state of the controller

Note: Refer to the section titled “Well States” on page 15-1 for more information about each well state.

- USB Status: This icon is visible if a USB drive is being used in the system.
- Wi-Fi Status: This icon indicates that the wi-fi network is active.
- Operation Status: This icon indicates the current operation status of the pumping unit:
    - Green: Indicates normal pumping operation.
    - Amber: Indicates a downtime well state.
    - Red: Indicates a system malfunction.

Additional icons may be visible during certain situations. These are listed in the table below.

Additional Status Icons

Icon	Description
	Indicates an established VSD connection. (Displayed in white.)
	This icon indicates a USB logging session is in progress. (Displayed in white.)
	Indicates an alert condition is present. (Displayed in yellow.)
ALT	Indicates that the alternate keypad characters are enabled.
BYP	Indicates that the VSD inverter has been bypassed.

Buttons

The buttons at the bottom of the screen provide access to the top level menu screens. These buttons are available on every screen.

The buttons on the sides of the screen provide access to specific screen functions and additional screens.

Language Selection

The LWM 2.0 screens can be displayed in three different languages:

- English
- Chinese
- Spanish

To change the screen language, use the left or right arrow keys to select the desired language and then press <**ENTER**>.

Control Parameter Programming

Control parameters are edited (programmed) on a data field basis. To program a parameter, press the arrow keys to highlight the desired parameter field, press <**ENTER**>, and then choose one of the following methods:

- To select an option from a drop-down list, use the arrow keys to highlight the desired option and then press <**ENTER**> again.
- When the parameter is a numerical entry, use the number keys to enter the desired value and then press <**ENTER**> again.

When parameter values are changed, the green **Discard** and **Save** buttons will appear at the bottom of the screen as shown in Figure 2-7.

Figure 2-7. Menu Bar with Discard and Save Buttons

Press the **Save** button to save the programming change or the **Discard** button to discard the change. The **Discard** and **Save** buttons will then be replaced with the **Previous** and **Next** buttons.

After all parameters are correctly programmed on the screen, you can do either of the following to exit from the screen:

- Press the **Main Menu** button to return to the Main Menu screen.
- Press <**Esc**> to move up one level in the menu tree.

LWM 2.0 Mobile Display Options

The LWM 2.0 controller provides options for viewing controller data on other devices such as laptop computers, smartphones, or tablets. Instructions for connecting these devices are discussed below.

Laptop Computers

Laptop computers can connect to the LWM 2.0 controller using an Ethernet cable or Wi-Fi. Once connected, the user can view and make changes to the controller screens with a compatible Internet browser.

Note: The LWM 2.0 controller screens are best viewed using the Google Chrome browser.

Connecting a Single Laptop through Ethernet

To connect a single laptop computer using an Ethernet cable, perform the following steps:

1. Plug the Ethernet cable into the Ethernet port on the front of the controller.
2. Plug the other end of the cable into the Ethernet port on the computer.
3. Open an Internet browser window and type **172.16.0.2/index.php** into the location field. (This is the default Ethernet IP address of the controller.)

   The controller's Main Menu screen should appear as shown in Figure 2-8.

Figure 2-8. Main Menu Screen

Connecting Two Laptops through Ethernet

The LWM 2.0 controller has additional Ethernet ports available on the communication gateway module inside the enclosure. These ports can be used for connecting two laptop computers to the controller.

If more than one laptop computer is connected to the controller, each computer must have a different IP address. Perform the following steps to change one computer's IP address:

1. Click **Start→Control Panel** to display the Control Panel window shown in Figure 2-9.

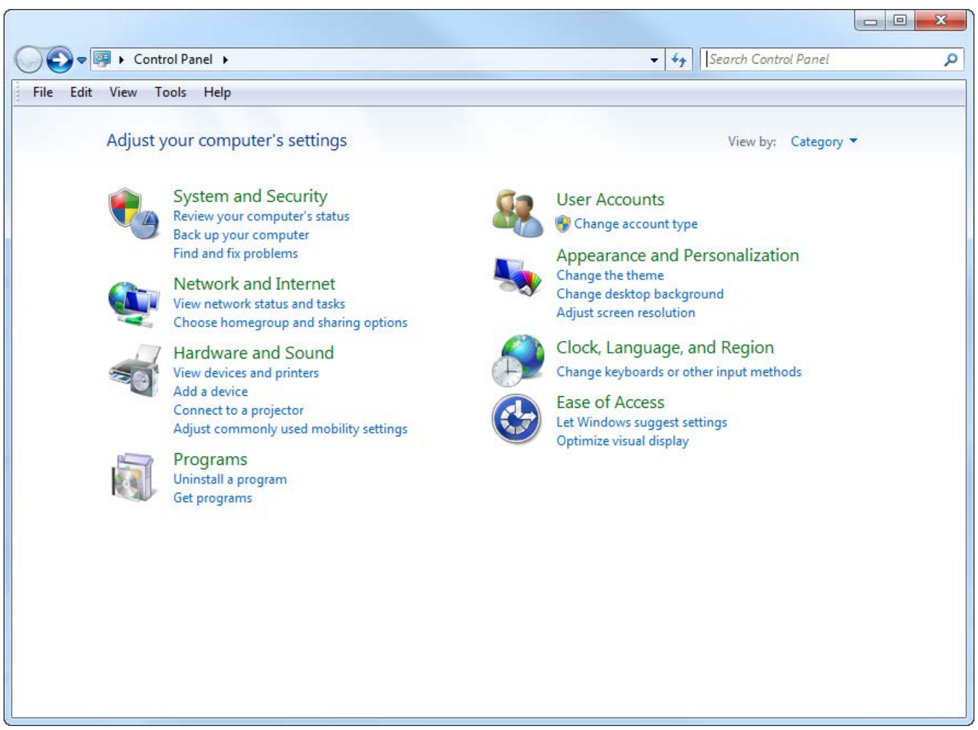


Figure 2-9. Control Panel Window

2. In the Control Panel window, click the **View network status and tasks** link to display the Network and Sharing Center window shown in Figure 2-10.

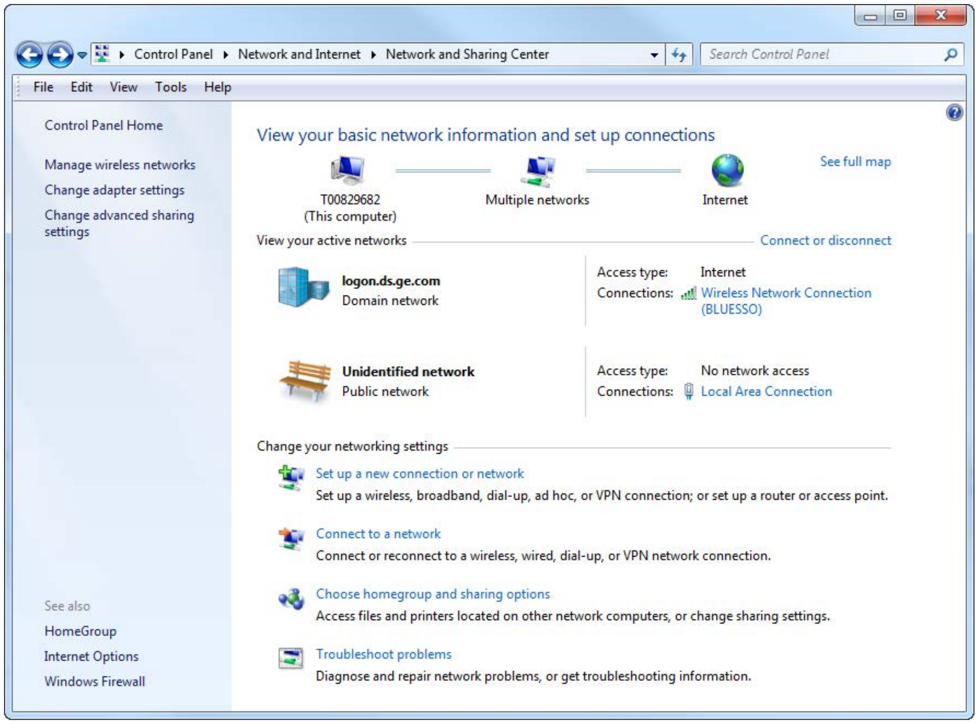


Figure 2-10. Network and Sharing Center Window

3. The Ethernet connection to the controller will be labeled as *Unidentified Network*. Click the **Local Area Connection** link next to this label to display the Local Area Connection Status window shown in Figure 2-11.

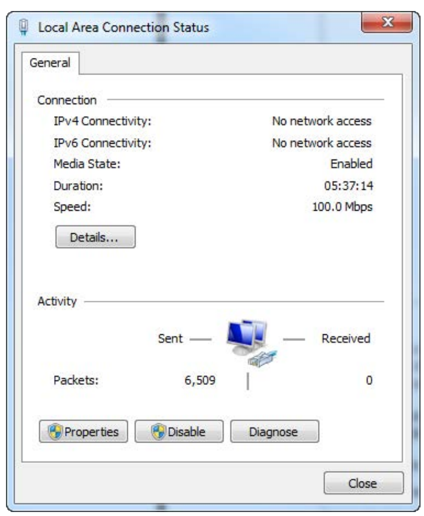


Figure 2-11. Local Area Connection Status Window

4. In the Local Area Connection Status window, click **Properties** to display the Local Area Connection Properties window shown in Figure 2-12.

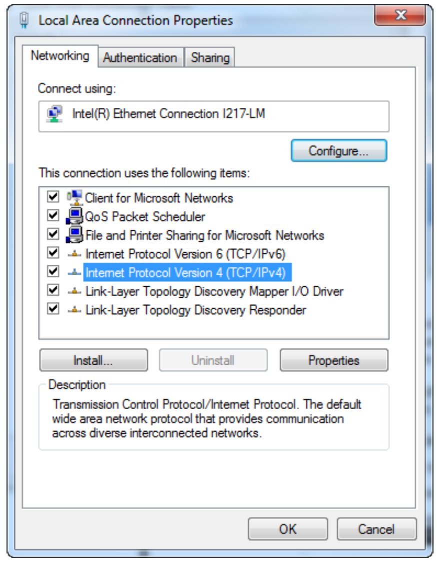


Figure 2-12. Local Area Connection Properties Window

5. In the Local Area Connection Properties window, click **Internet Protocol Version 4 (TCP/IPv4)** and then click **Properties**.

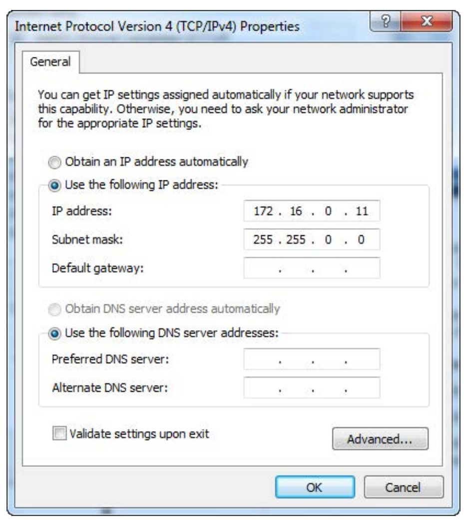


Figure 2-13. Internet Protocol Version 4 (TCP/IPv4) Properties Window

6. In the window that appears, double-click the last two digits in the IP address field. Type a different value in this field and then click **OK**.
7. Click **OK** to close the Local Area Connection Properties window.
8. Click **Close** to close the Local Area Connection Status window.
9. Close the Network and Sharing Center window.

Connecting a Laptop Computer through Wi-Fi

To connect a laptop computer using Wi-Fi, perform the following steps:

Note: These instructions assume that the laptop computer is using a Windows 7 operating system or later.

1. Click the network symbol in the lower right corner of the computer screen as shown below.

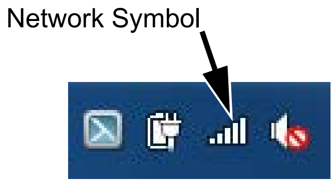


Figure 2-14. Windows Network Symbol

2. In the pop-up window that appears, click the SSID for your controller and then click **Connect**.

Figure 2-15. Available Wi-Fi Network List Window

Note: To automatically connect to the controller whenever it is in range, keep the **Connect automatically** box checked. Otherwise, uncheck this box.

3. In the window that appears next, type the network key and then click **OK**.

Figure 2-16. Network Security Key Pop-Up Window

The network connection is established after a few seconds.

4. Open an Internet browser window and type **192.168.102.15/index.php** into the location field. (This is the default Wi-Fi IP address of the controller.)

   The controller's Main Menu screen should appear as shown in Figure 2-8 on page 2-14.

Smartphones and Tablets

To connect a mobile device such as a smartphone or a tablet, perform the following steps:

Apple Devices

1. Tap the **Settings** icon to open the Settings screen.
2. Tap the **Wi-Fi** icon to open the Wi-Fi screen.
3. Tap the **Wi-Fi** toggle switch to turn on Wi-Fi and then select the SSID for your controller from the **Choose a Network** list.
4. Type the controller's Wi-Fi password and then press **Connect**.
5. After the connection has been established, tap the **Safari** icon and type **192.168.102.15/index.php** into the Location field. The Main Menu screen will be displayed on the screen.

Android Devices

1. Tap the **Wi-Fi** button to open the Wi-Fi screen.
2. From the list of available networks, tap the SSID for your controller.
3. Type the controller's Wi-Fi password and then press **Connect**.
4. After the connection has been established, open a browser window and type **192.168.102.15/index.php** into the Location field. The Main Menu screen will be displayed on the screen.

For more information about the Lufkin Well Manager 2.0 controller and its components, refer to the Lufkin Well Manager 2.0 Rod Pump Controller User's Manual (Lufkin # 099.0081).

System Options

Lufkin offers option packages that may be needed for some applications. These packages include dynamic braking resistor modules, cold weather cabinet heaters, bypass contactor assemblies, and harmonic filter units.

Dynamic Braking Resistor Modules

The optional dynamic braking resistor modules (DBRs) are designed to mount on the top of the system cabinet. They are field-installed only. Installation instructions and a wiring diagram are included in each module. For more information, refer to the *Lufkin Dynamic Braking Resistor User Manual* (Part # 099.5031).

To order one of the DBR modules available, refer to the section titled “Parts Lists” on page 4-1.

Harmonic Filter Units

Optional harmonic filter units are available to supplement the standard harmonic suppression features of the LWM 2.0 VSD RPC if additional harmonic mitigation is desired. This additional filter unit may be required in applications where several drives are installed in close proximity or where the local utility requires it.

Harmonic filter units are mounted inside the VSD enclosure and are wired in series with the leads providing primary three-phase power to the drive system. These units are sized based on voltage, horsepower (or kilowatts), and line frequency (50 Hz or 60 Hz).

Contact the local Lufkin representative for assistance in choosing the correct harmonic filter unit.

VSD Drive Theory

For successful application of a variable speed drive to a beam pumping unit, it is important to have an understanding of the basic principles of how the drive works. Users are strongly encouraged to study this material prior to attempting to start up a Lufkin Well Manager 2.0 VSD RPC system.

AC Induction Motor Basics

The AC induction motor basics covered here include basic operation principles of an AC motor and a high-level overview of AC induction motor speed.

Principals of Operation

An AC motor (Figure 2-17) has two basic components, which are the stator and rotor. The stator is the outer body of the motor which houses the driving (powered) windings on a laminated iron core. The rotor is comprised of a cylinder made of round laminations pressed onto a shaft and a number of short-circuited windings.

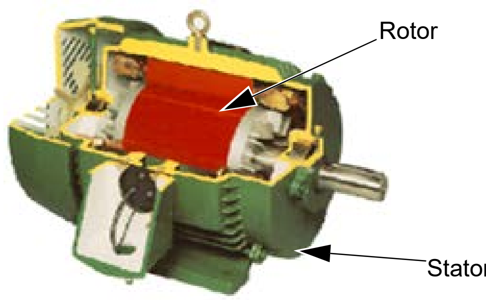


Figure 2-17. Typical AC Motor

As current passes through the stator windings, magnetic fields are established. These fields change polarity at the frequency of the alternating current. With a three-phase motor, the magnetic field rotates inside the stator. See Figure 2-18 below.

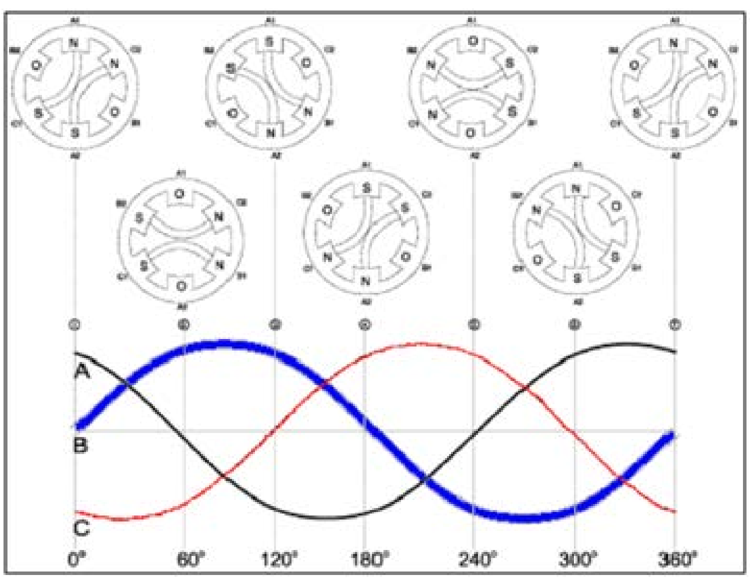


Figure 2-18. Magnetic Fields Created by Three-Phase Motor

The rotating stator magnetic field crosses the air gap between the rotor and stator and extends into the rotor. As the magnetic field of the stator rotates, it passes through the rotor assembly causing:

- Induced voltage
- Rotor magnetic field
- Current in the rotor bars

The magnetic fields induced in the rotor “chase” the stator’s magnetic field.

These combined magnetic fields (stator and rotor) cause the rotor to turn and to produce torque. The speed of the rotor depends on the torque load applied to its shaft. Higher torque causes the rotor speed to lag behind the speed of the rotating stator field. Lower torque causes the rotor speed to increase, thus approaching (but not reaching) the speed of the rotating stator currents. The difference between stator magnetic field rotation speed and rotor speed is referred to as “slip.”

AC Induction Motor Speed

The speed at which the stator field rotates is known as “synchronous speed.” This speed can be calculated with the formula:

$$\textit{Synchronous Speed} = 120 \times \textit{AC Frequency} = \frac{120 \times \textit{AC Frequency}}{\textit{Number of Motor Poles}}$$

Where:

Synchronous Speed = rotating speed of the stator magnetic field [RPM]

AC Frequency = frequency of the alternating current power supply [Hz]

Number of Motor Poles = a function of motor construction. Typically 4 or 6 [dimensionless].

For example, a six-pole motor operating at 60 Hz has a synchronous speed of 1,200 RPM. However, a similar six-pole motor operating at 50 Hz has a different synchronous speed (1,000 Hz).

This equation illustrates how the frequency of the supplied AC current impacts motor speed. With this understanding, it becomes clear that we can alter the speed of and AC induction motor by changing the supplied frequency. In order to maintain proper motor torque, the voltage must also be varied with the frequency. For this reason, VSD control algorithms vary both the voltage and the frequency of the three phases going to the motor.

Typically, the voltage is maintained at a constant V/Hz (Volts per Hertz) ratio. For instance, if a 460-volt, 60-Hz motor is operated by a standard VSD at only 30 Hz (1/2 speed), the RMS voltage at the motor leads would be about 230 volts (1/2 voltage). At very low frequencies, this ratio is modified so that the VFD can overcome motor winding voltage losses and generate reasonable torque.

Inverter Basics for a Six-Pulse PWM VSD

The most common speed adjusting device deployed in industrial applications is the six-pulse PWM VSD. The general architecture of this popular equipment is discussed below.

The purpose of an AC drive is to convert incoming power at a fixed frequency and voltage into output signals of varying frequency and voltage. Common industrial drives do this by converting three-phase AC input voltage to DC voltage. The DC voltage is then “pulsed” out in a manner that resembles AC voltage and current.

A six-pulse PWM VSD has three basic components:

- Passive converter section
- DC bus/filter section (page 23)
- Inverter section (page 24)

Converter Section

The converter section or “front end” of a standard six-pulse drive sometimes includes a three-phase full wave diode bridge rectifier to convert the three-phase AC incoming power to a single DC voltage. Note that in Figure 2-19 six diodes are used (one for each polarity on each of the three phases). This design gives rise to the name “six-pulse drive.”

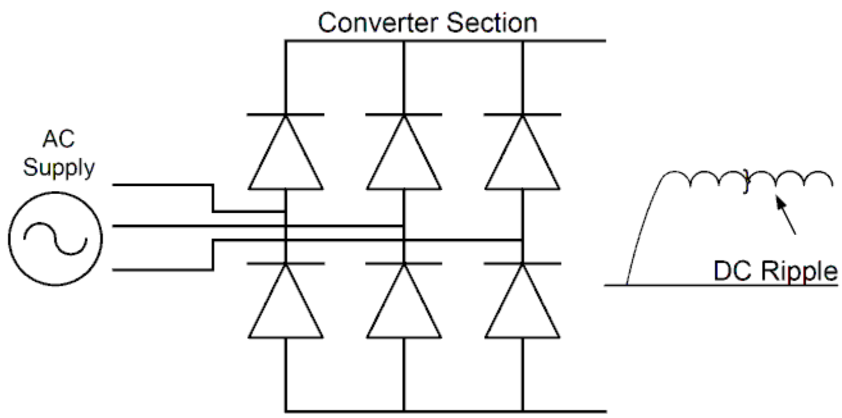


Figure 2-19. Standard Six-Pulse Drive with a Full Wave Diode Bridge Rectifier

Other bridge configurations are available (12-pulse and 18-pulse). These designs provide significant benefits, but also add significant cost, since a custom transformer with multiple secondaries is needed. Therefore, the six-pulse design is used in most applications below 150 hp (110 kW).

In many cases, a hybrid bridge rectifier is used where three diodes and three silicon-controlled rectifiers (SCRs) are used. This configuration (still referred to as “six-pulse”) is shown in Figure 2-20. The overall function of the circuit is to convert AC to a near-DC level.

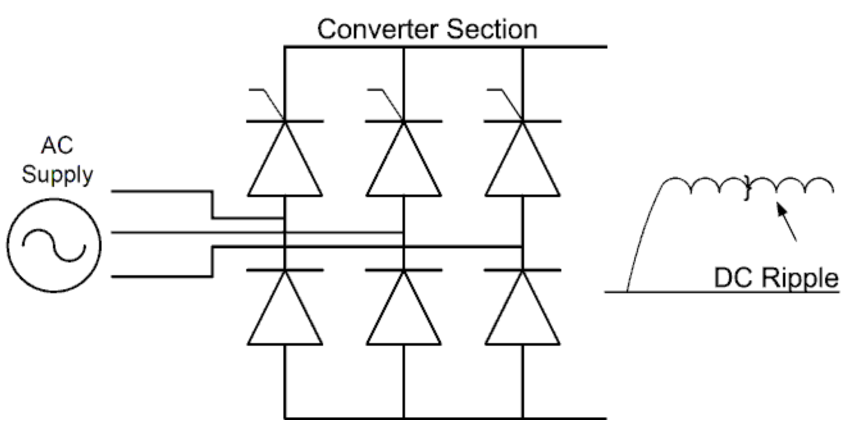


Figure 2-20. Six-Pulse Drive with a Hybrid Bridge Rectifier

Figure 2-20 shows that the output of the converter is a high (and slightly fluctuating) single voltage. The "ripple" in the voltage level is a result of the six-pulse rectifier's conversion of the three-phase AC source. The level of ripple is magnified in the following (abnormal) cases:

- An input phase is lost
- The phase voltages have significant imbalance
- The phase rotation is off (not exactly 120 degrees between phase peaks)

DC Bus/Filter Section

The DC bus or filter section of a VSD consists of a number of large capacitors and (often) an inductor. This filter serves to reduce the bus ripple to a relatively low level. The capacitors in the DC section are quite large and can retain voltage and power for a significant period of time (minutes) after power is removed from the drive input side.

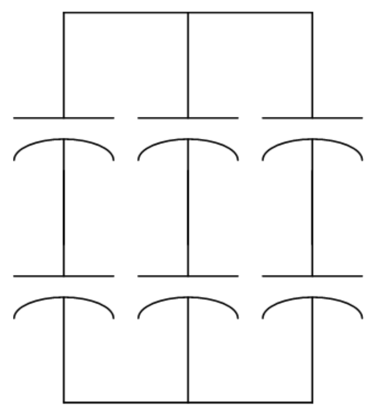


Figure 2-21. DC Bus Capacitors

Under motoring conditions, the voltage level on the DC bus is related to the AC input voltage, as described in the formula below.

DC Bus Voltage = Input AC Voltage x 1.414

Where:

DC Bus Voltage = voltage measured on the DC bus (VDC)

Input AC Voltage = RMS voltage of AC supply [VAC (RMS)]

The VSD does not measure incoming AC voltage levels. Instead, it monitors the DC level on the bus and relies on the relationship described above to infer input voltage. In most cases, a check with a multi-meter will confirm that AC RMS input voltage and DC bus voltage are in compliance with the above relationship. However, poor power quality issues can cause DC bus levels to rise far above levels predicted by the standard equation. These cases require special troubleshooting tools and techniques.

The VSD presents DC bus levels measured in percent (%) rather than actual voltage levels. For the 400-volt class VSDs, this percentage is based on a 400-volt standard. For example, when a 400-volt class VSD is used on a 460-volt input source, the input AC voltage represents:

$$\textit{Input Voltage Percentage} = \frac{460VAC}{400VAC} = 115\%$$

Under these conditions, the DC bus voltage of this system would be presented by the VSD keypad as a level of 115%.

The actual level of the DC bus voltage provides insight into the status of the drive. Poor input power quality can impact the DC bus voltage (high or low). As will be discussed later, DC bus voltage can be driven to very high levels when the motor is being driven by its load. Also, the amount of ripple on the bus provides information about input power quality and integrity of the DC bus filter. High levels of bus ripple always indicate an unfavorable condition.

Inverter Section

The inverter section of a VSD uses the single DC bus voltage to produce an output signal that simulates a sine wave of the desired amplitude and frequency. This signal is then applied to the motor.

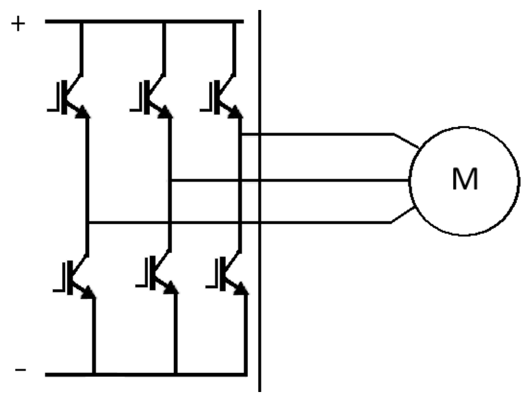


Figure 2-22. Representation of an IGBT Converter

Because the inverter section can access only a single input voltage, it cannot produce a true sine wave signal. The method used to simulate a sine wave is called Pulse Width Modulation (PWM). When PWM is used, the controller switches transistors (IGBTs) for varying periods of time. The length of time (width) of the pulses determines the average output voltage that is produced on the motor lead. For higher voltages, the transistor is left in the ON state for longer time periods. The frequency also must be changed, which is accomplished by adjusting the amount of time positive pulses and negative pulses are on in a given time period. For example, a 60-Hz sine wave occurs in 1/60 sec or 16.7 msec. By adjusting the overall simulated sine wave to the desired time frame, the frequency is changed as well. For example, a simulated 30-Hz sine wave would have a 33.3-msec period.

Figure 2-23 represents a rough depiction of the PWM process. The voltage signal being sent to the motor appears as a series of pulses. The current, however, approximates a sine wave due to the inductance characteristics of the motor.

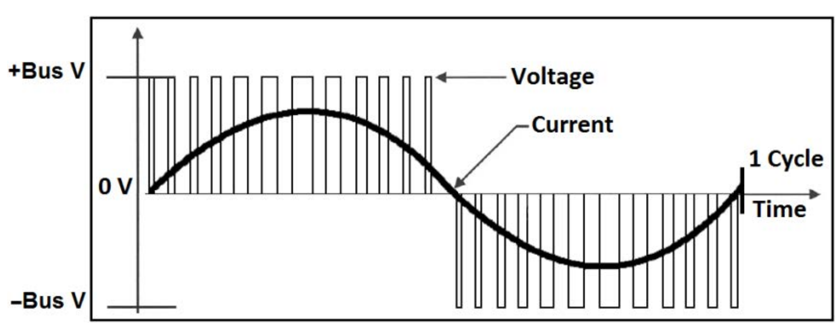


Figure 2-23. Illustration of the PWM Process

Figure 2-24 is an actual power meter capture of voltage and current output from a single-phase of a PWM inverter. Note that the voltage is a series of “pulses” while the current approximates a sine wave.

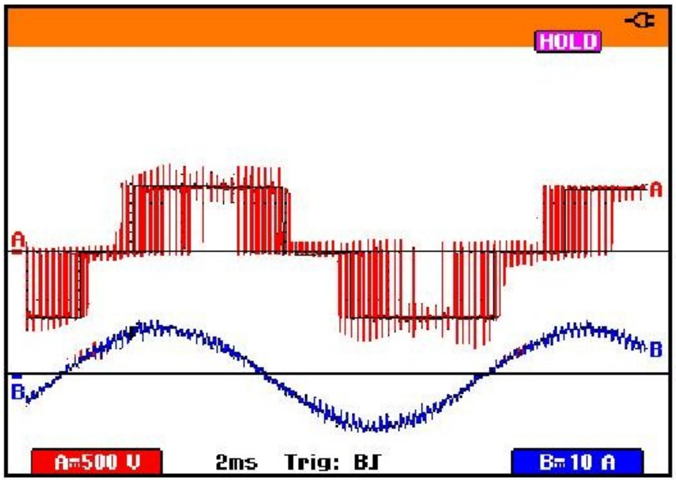


Figure 2-24. Voltage and Current as Seen at the Motor Terminals Using a VSD

Inverter Motor Control Methods

As mentioned on page 2-24, the basic function of the inverter section is to produce a waveform of the proper voltage and frequency. Using this simple objective, an inverter controller can vary the speed of a motor with a reasonable amount of success. This control method is often referred to as volts per Hz, V/f or constant torque.

When an inverter is controlled with a V/f algorithm, the output of the inverter is primarily controlled to manipulate voltage and frequency. In these applications, the motor is allowed to slip as torque increases. Another phenomenon associated with V/f control is that motor torque will “overshoot” load torque as load torque fluctuates. This type of control is quite adequate for many applications.

Another method, known as Sensorless Flux Vector or Open Loop Flux Vector, uses a more sophisticated algorithm to control motor current as well as voltage and frequency. The current is allowed to flow through the motor in a way that provides combined motor magnetizing current and torque current. This method is intended to control torque and speed more precisely. Figure 2-25 provides some insight into the flux vector method.

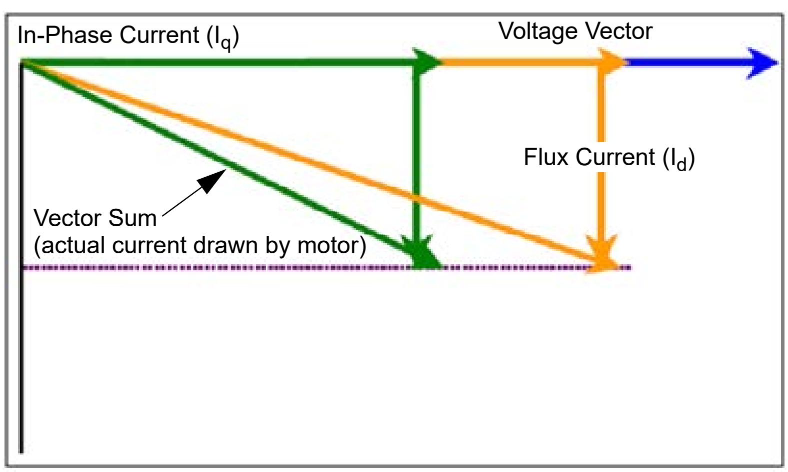


Figure 2-25. Plot Demonstrating Flux Vector Method

In-phase current is the torque producing current. Flux current is used to generate the rotating magnetic field and does not produce torque. When flux current to a motor is constant, torque is proportional to slip, in-phase current is proportional to torque, and slip is directly proportional to in-phase current.

When a VSD operates in vector control, slip can be calculated and controlled by adjusting frequency and torque current. As a result, torque can be controlled by adjusting flux or slip, and flux is controlled by adjusting voltage.

In addition, the flux vector algorithm senses motor speed and motor torque so that the drive understands actual motor speed and actual shaft torque to a reasonable level of accuracy.

The primary difference between flux vector and V/f control is that (under varying or non-constant load) the flux vector mode can sustain a constant motor speed (within one or two RPM under heavy load fluctuation) regardless of the torque demand. This algorithm provides very accurate speed control (with torque override) throughout the cycle of mechanical systems like reciprocating pumping units. In addition to providing very high torque at very low speeds (something that V/f mode has difficulty doing), flux vector can control the upper limit of torque to acceptable accuracy, thereby providing protection for gearboxes (reciprocating pumping units) and torsionally loaded rod strings (top-drive progressing cavity pump applications).

The flux vector algorithm requires the inverter controller to maintain a mathematical model of the specific motor being driven. The model parameters are set to nominal values when the user enters specific information about the motor (power, current, rated RPM). The model is further “tuned” at startup when the drive injects specific signals into the motor and measures the motor’s response. An “auto tune” process is typically performed as one step in commissioning a flux vector drive.

Note that the “low/no” slip nature of flux vector control extends to all types of motors. Even high-slip (NEMA D) motors operated by a flux vector inverter algorithm will not slip.

Benefits of VSDs in Reciprocating Rod Pump Applications

VSDs can provide significant benefits in reciprocating rod pumping applications. Some of the benefits are provided below.

Soft Start

VSDs provide soft start capability that dramatically reduces inrush current demand on the utility grid. When the motor is started at a low speed, much less current is required to initiate rotation of the motor shaft. In cases where a soft start unit is required by the utility, a VSD can be purchased for only a small incremental capital outlay.

Easy Adjustment of Pumping Rate

Obviously, the variable speed feature of a VSD allows the pumping rate to be adjusted by simply changing the speed of the motor. VSDs provide significant dynamic range in their output, typically 0 to 100 Hz or higher. However, the practical speed range that can be used is reduced due to limitations from pumping unit gearboxes, electric motors, and the sucker rod string.

Reduced System Wear

A VSD can automatically change speed in response to downhole pump conditions when used with a proper rod pump controller (RPC). In this way, the wear caused by pump-off can be dramatically reduced. In order to gain this benefit from a VSD, a sophisticated RPC (such as the Lufkin Well Manager 2.0 VSD RPC) is required.

Quick Recovery from Downtime

After downtime is incurred due to power failure, well workover, or flow line shut-in, a VSD can be used to temporarily increase production and to pump down the well. Again, a sophisticated RPC is required to terminate this temporary speed increase when the well reaches pumpoff. Otherwise, a severe fluid pound condition might be incurred for an extended period.

Torque Control

Motors running across the line can produce excessive torque in gearboxes when the pumping unit “loads up.” The torque-limiting features of a flux vector VSD allow almost instantaneous (sub-millisecond) response to increased load. A VSD that is properly configured can limit gearbox torque to a level consistent with gearbox rating. In PCP (progressing cavity pump) applications, the torque limiting features can dramatically control situations that would normally result in rod string damage (rod parts and over-torque of rod boxes).

Improved Power Factor

Electric motors are notorious for their poor power factor, specifically when operated at less than full load. A VSD, however, presents a nearly ideal power factor to the utility grid. The improved power factor frees up capacity in the distribution grid and reduces power factor penalty charges levied by the utility company.

Fluid Pound Avoidance

Fluid pound occurs in a pumping oil well when the pump is not completely filling with fluid on the upstroke. As the downstroke begins, the entire fluid and rod string load moves down through a void until the plunger hits the fluid level in the pump barrel. The traveling valve opens, suddenly transferring the load to the tubing, causing a sharp decrease in load, which transmits a shock wave through the pumping system. It is this shock wave that damages the parts of the pumping system. Figure 2-26 on page 2-28 illustrates a fluid pound scenario and the effect it has on the pumping system.

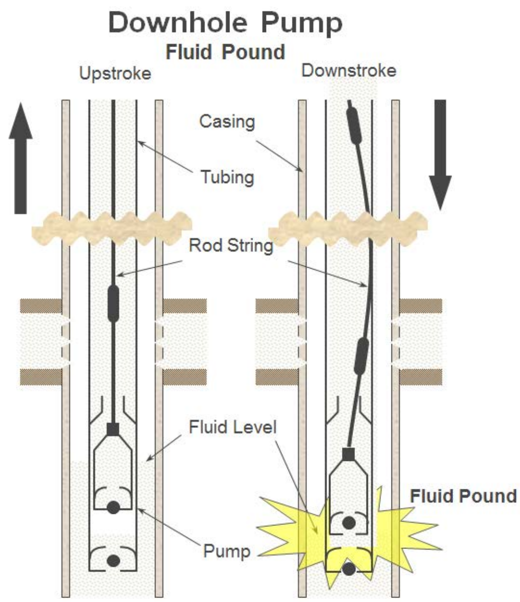


Figure 2-26. Fluid Pound Scenario

The fluid pound avoidance (FPA) control algorithm feature uses the ability of a Variable Speed Drive (VSD) to modulate the speed of the prime mover within one stroke to reduce the effects that fluid pound conditions have on the pumping system.

The FPA velocity profile slowly reduces the plunger velocity just as the plunger encounters the fluid in the barrel of the pump to reduce the relative velocity between the plunger and the fluid. This results in a mitigation/reduction of the shock loading that the system experiences. Figure 2-27 depicts the FPA intra-stroke velocity command profile.

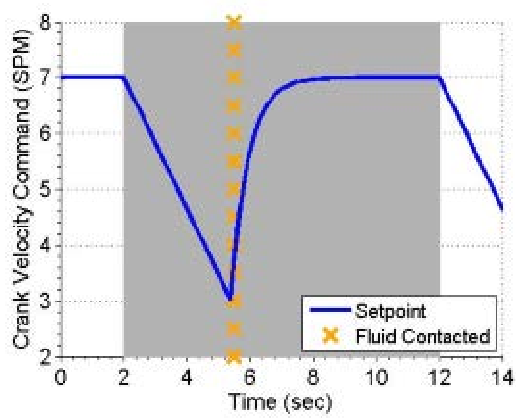


Figure 2-27. FPA Intra-Stroke Velocity Command Profile

To avoid loss in production due to the reduction of speed to mitigate fluid pound, the controller with its adaptive control process will compensate by increasing the speed to make up the loss of SPM. This action allows the overall SPM to be as close as possible to the target/planned SPM of the cycle.

Figure 2-28 on page 2-29 depicts the LWM 2.0 advance analysis and adaptive control process involved in addressing the well fluid pound condition.

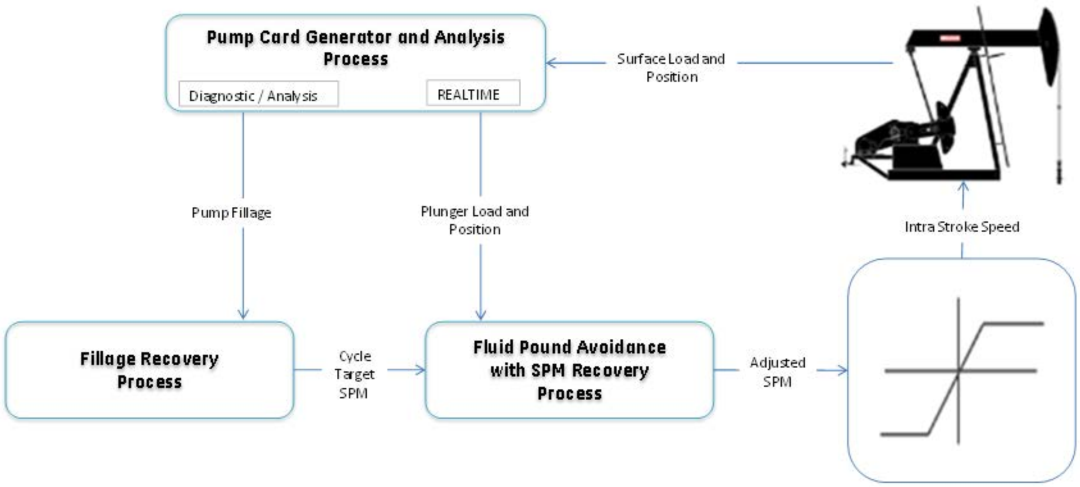


Figure 2-28. LWM 2.0 Fluid Pound Avoidance Process

VSD Output Voltage

As mentioned earlier, a VSD attempts to maintain a constant ratio of frequency to voltage, which is necessary for proper motor performance. However, at very low frequencies and very high frequencies, the constant V/f relationship cannot be maintained. Figure 2-29 depicts the actual V/f relationship for a VSD operating a 460-volt, 60-Hz motor from 460-volt input voltage.

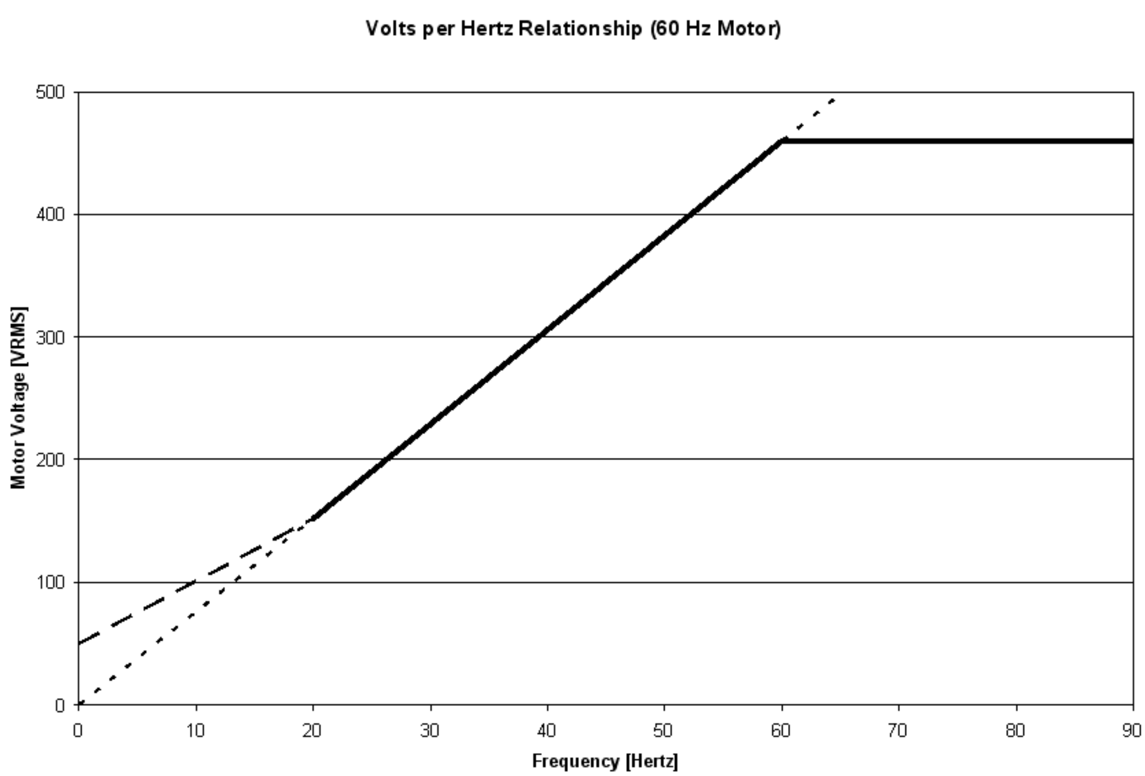


Figure 2-29. Actual V/f relationship for a VSD operating a 460-volt/60-Hz Motor

NEMA Motor Torque with VSD

This section contains information about typical performance of NEMA B and NEMA D motors and their performance with Flux Vector mode. Information is also included about torque and power across the frequency spectrum when a flux vector VSD is used.

NEMA Motors Across the Line

Figure 2-30 shows the typical torque-speed curves for NEMA B and NEMA D motors running across the line.

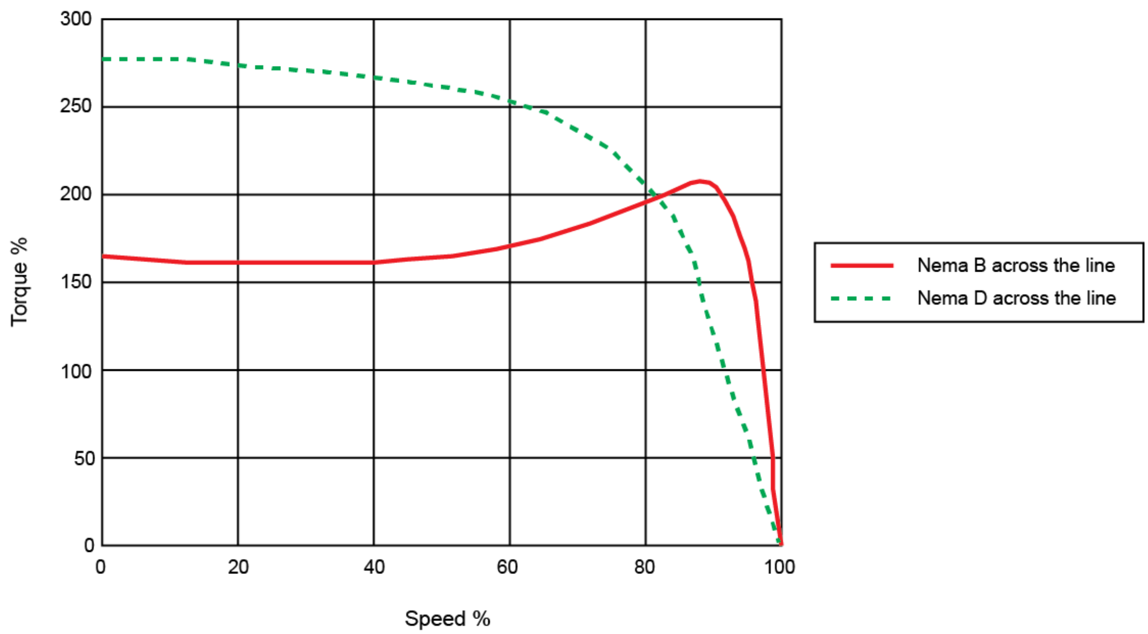


Figure 2-30. Typical NEMA B and NEMA D Motor Performance

From the perspective of this plot, 100% speed is “synchronous” speed. The motor-rated speed at full load written on the nameplate is always less that 100%.

This plot shows that the 100% (motor rated) torque value is achieved by a NEMA D motor at higher slip (lower percent speed) than the NEMA B motor. Both motors are capable of generating far more torque than rated at low speed. However, the NEMA D motor clearly provides greater torque at zero speed. This feature makes the NEMA D motor (running “across the line”) attractive for starting a pumping unit.

NEMA Motors with Flux Vector Mode VSD

Figure 2-31 is equivalent to Figure 2-30, but the frequency range is extended. Curves are also added to depict the torque-speed relationship of both motors (NEMA B or NEMA D) if they were operated using a modern PWM inverter with flux vector control. The dashed curve indicates the maximum torque that the inverter and motor can continuously supply. The dotted curve depicts the maximum torque that the motor and inverter can deliver temporarily.

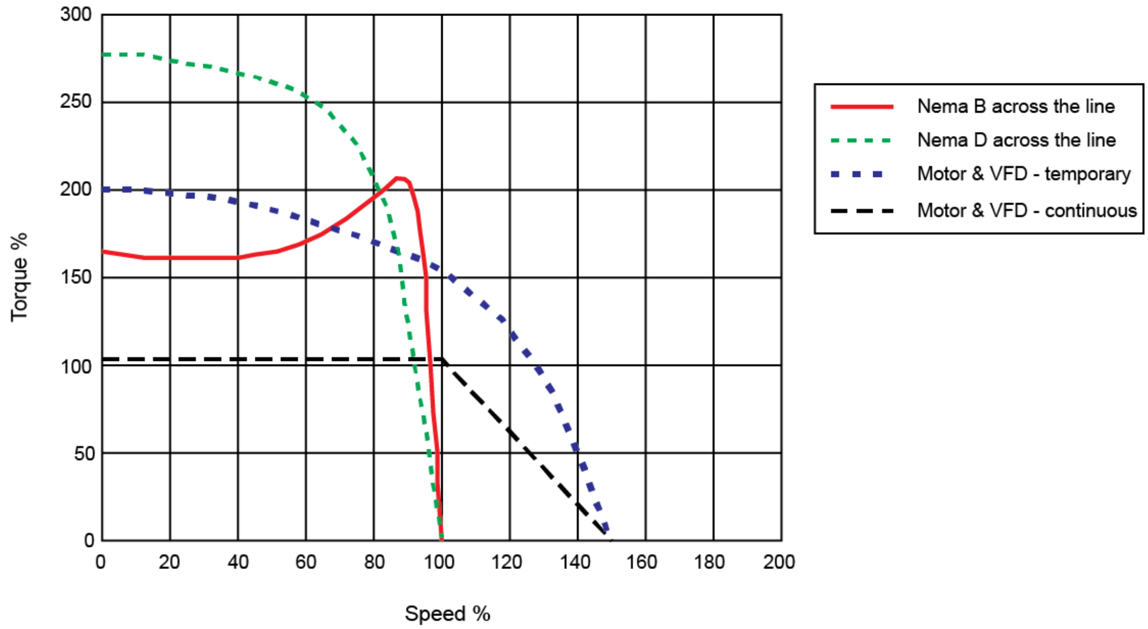


Figure 2-31. Typical NEMA B and NEMA D Motor Performance with Extended Frequency Range

The duration of these temporary torque boosts depends on the amount of boost (typically measured in amps). For instance, below rated motor speed, the system can operate the motor at 150% of full load current for up to 60 seconds and at 165% of full load current for 2 seconds. The drive uses separate mathematical models to approximate motor heating and inverter heating during overcurrent transients. If either mathematic model indicates that an overheat condition is imminent, the inverter will take itself offline and declare either a motor overload condition or an inverter overload condition.

Note: The available VSD torque curves (on the diagram) are independent of motor slip and/or type. The inverter will produce virtually identical torque curves for either motor. The inverter's internal motor model compensates for motor slip. This is possible because the inverter is "tuned" to the motor.

Figure 2-31 shows that either motor running with a modern PWM inverter can provide almost the same starting torque as a NEMA D motor across the line. However, the "soft start" features inherent to an inverter result in dramatically reduced torque demand versus an "across the line" start. When the inverter receives a "run" command, it slowly ramps the motor and load from zero rpm to the desired rpm. This ramping takes place over a configurable length of time (typically from

5 seconds to 60 or more seconds). The combination of “torque boost” and “ramping” action permit the VSD to easily start the pumping unit.

Figure 2-31 also highlights an important feature of VSD applications. When a VSD is used to drive a motor above the rated frequency, the motor is being operated outside of its designed parameters. If the inverter power rating is closely matched to the motor rating, the inverter will also begin to “power limit” above rated motor frequency. The inverter can drive the motor at the higher speed, but only if the load requires decreasing (average) torque at higher speed. If the application requires increased or constant torque at increased speed, the inverter will eventually fail to accelerate the load. This phenomenon presents a practical limit to the “top end” speed to a VSD-driven reciprocating rod pumping system. For some applications, the limit may be only a couple of hertz above the rated motor frequency. In other situations, the VSD might drive the motor to 140% of rated motor frequency or higher.

Challenges with VSDs in Reciprocating Rod Pump Applications

Although VSDs offer tremendous benefits in rod pumping applications, they also present some unique challenges that need to be managed. These challenges are discussed on the following pages.

Harmonics

Earlier in this document, the “converter” or “front end” section of the VSD was discussed. It was noted then that a six-pulse bridge is used to convert three-phase AC input power to a pseudo-DC voltage. The design of the input bridge causes the VSD to only draw current from the power utility at the very peaks of each phase’s voltage cycle. This non-linear loading on the supply induces alternating voltage and current waveforms on the power supply lines. These waveforms possess different frequencies from the fundamental (50 Hz/60 Hz) frequency of the power system. Because these induced frequencies are always at multiples of the fundamental frequency, they are referred to as harmonics. Figure 2-32 shows a severe case of current distortion due to harmonics.

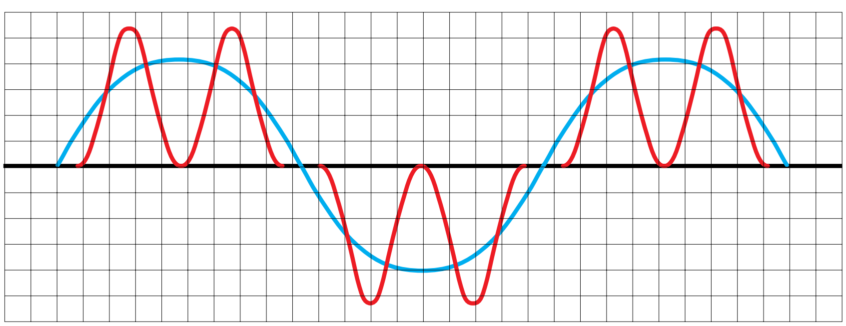


Figure 2-32. Plot Showing Severe Distortion Due to Harmonics

Harmonics distort the AC waveform on the power circuit and can stress transformers and other distribution equipment. In many cases, VSD operators can simply ignore the induced harmonics for the following reasons:

- The distribution system is typically already oversized to account for poor power factors and high inrush currents associated with motors running across the line.
- Harmonics are dampened by the transmission network.

- Harmonics from a number of VSDs can have a canceling effect.

However, if the harmonics are transferred to the power utility network with sufficient amplitude, the utility company can enforce clauses in the service agreement that obligate customers to limit harmonic levels. For more information about harmonics with six-pulse VSDs, see “Harmonics Produced by Six-Pulse Inverters” on page 2-35.

Regeneration

The mechanical loading of a typical reciprocating pumping unit is highly cyclical. Torque loads measured at the gearbox fluctuate from positive to negative within a pumping cycle. For part(s) of every stroke, the pumping unit actually drives the motor, causing the motor to briefly act as a generator.

When a pumping unit is connected to an across-the-line motor, the energy generated is driven back onto the distribution network. However, when the motor is connected to a VSD, this energy passes through the inverter section and into the DC bus section of the VSD. Because the drive’s front end (converter) is coupled to the line via a rectifier bridge, power cannot pass from the DC bus back onto the utility grid.

When a motor attached to a VSD begins to act as a generator, this excess energy must be dissipated by the VSD to protect its internal components. If the energy is not dissipated properly, the drive will eventually take itself offline and signal a bus overvoltage fault.

The customary means of dissipating regenerative energy in a commercial VSD is to attach a large power resistor circuit to the DC bus and route current to these power resistors during times when bus voltage is elevated. The power resistor unit attached to the VSD is referred to as a dynamic braking resistor (DBR).

Lufkin Automation supplies dynamic braking resistor packages (strongly recommended) as optional equipment for reciprocating rod pump VSD applications. These DBR packages include cooling fans and a thermal protection circuit used to stop the drive if the DBR overheats. The DBR packages are field-installed on top of the VSD cabinet.

The Lufkin Automation VSD unit also includes a feature called Regenerative Torque Control (RTC) that can be enabled to address regeneration. When the RTC feature is enabled, the unit is allowed to increase rpm when the pumping unit is attempting to drive the motor. By allowing the VSD to increase motor speed, regeneration can be either fully or partially avoided. When the RTC is used, a conventional pumping unit can be operated without using a DBR package. Depending on the unit size and the degree of imbalance in the unit; however, this feature sometimes causes an undesirable level of speed change within the stroke.

PWM Waveform

Previous topics in this section discussed how a PWM VSD pulses voltage to generate the pseudo-sine wave to the motor. Because the voltage is pulsed into the motor with a VSD, the potential exists for the voltage in the motor windings to overshoot rated motor voltage. Voltage overshoot and its impact on motor insulation is made worse by long motor lead lengths. The carrier frequency setting in the inverter also impacts this phenomenon. Figure 2-33 illustrates these effects.

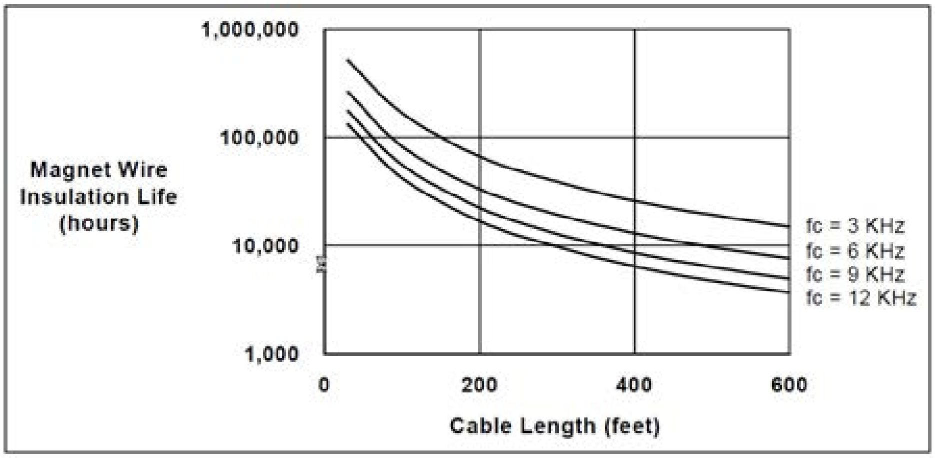


Figure 2-33. Voltage Overshoot Effects

This plot shows that operating a VSD/motor with long motor leads or high carrier frequency can reduce motor lifetime by factors of from 10 to 100.

Lufkin Automation VSD installations use a 4-KHz carrier frequency to minimize carrier frequency effects on motor windings. Lufkin Automation also recommends that the VSD be installed so that motor leads do not exceed 30 feet (9 meters) in length.

In addition, PWM inverters excite capacitive coupling between the motor stator and rotor. This common-mode current travels to ground through the motor bearings, inducing electric discharge machining (EDM) in the bearings. EDM results in bearing fluting that eventually causes the motor bearings to fail.

Special NEMA inverter duty class motors are available to address the issues described above. These motors have enhanced motor winding insulation and large bearing surfaces to allow long motor operating life in a VSD application.

In cases where long motor leads are necessary, a special output filter can be installed between the VSD and motor to reduce voltage overshoot issues. Lufkin Automation can supply these optional filters.

EMI/RFI Noise

The high power switching characteristics of a PWM inverter produce a great deal of high frequency noise. This noise can impact nearby electronic equipment (through radiation) or equipment that is electrically connected to the drive cabinet.

A VSD can generate radio frequency interference (RFI) in the 0.5 MHz to 1.7 MHz range. Electromagnetic interference (EMI) is also generated in the range of about 1.7 MHz to 30 MHz. This high-frequency noise is produced on the output side of the drive (between the motor and the inverter).

The noise produced by the VSD is transferred to the electrical panel, the utility supply through the main power conductors, and the grounding grid. These signals are also radiated to nearby conductors.

The VSD in the Lufkin Automation panel is equipped with a factory-installed EMI/RFI filter. This filter can be used on grounded electrical systems. However, the filter must be disabled on ungrounded electrical systems to avoid damage to the drive.

EMI/RFI noise produced by Lufkin Automation VSD systems is a serious concern for Lufkin Automation in its design of the complete system. This interference can influence all equipment that is connected to the drive cabinet, including end devices like load cells, pressure transmitters, and Hall-Effect position sensors. Therefore, great care should be taken to strictly comply with recommended installation and grounding procedures as provided by Lufkin Automation. Failure to comply with installation instructions can result in unpredictable behavior of the pump control system.

When motor leads and pumping unit instrumentation cables (load cell, Hall-Effect) are installed in a trench, Lufkin Automation highly recommends that using shielded cable and/or rigid conduit. These materials will help minimize radiated transmission of high frequency signals.

Harmonics Produced by Six-Pulse Inverters

It is well known that six-pulse drives (operating on a three-phase supply) produce fairly high amplitude 5th and 7th harmonics, along with much lower amplitude 11th, 13th, and some higher harmonics. This phenomenon is a function of the converter section design that is common to all commercial products in this class.

The actual amplitude of the harmonic distortion is dependent on the load applied to the drive. In stable-load applications (PCP, ESP), the harmonics are also stable. In applications such as reciprocating beam pumping, the cyclical nature of the equipment loading results in drastically time-dependent harmonic distortion.

For a given load, virtually all standard six-pulse drives (regardless of manufacturer) will produce the same level of harmonic distortion.

Reasons for Concerns about Harmonics

The basic problem/concern about harmonic currents is that they can move through the electrical distribution system generating heat and straining transformers. The net result is a stress on the power distribution grid that is similar to that of inductive loads, such as motors running across the line. Electrical distribution systems must be designed with excess capacity beyond the expected load so that they can effectively operate under these conditions (poor power factor and harmonics).

Harmonic distortion can also adversely impact sensitive solid-state electronics (computers, televisions, radios) which are connected to the same power grid and located within a reasonable distance of the source. Another emerging concern is that harmonic distortion can disrupt signals used to communicate with electrical utility grid automated metering and monitoring equipment.

It is important to note that the power factor of the front end of a six-pulse drive is very close to unity (typically about .95) as opposed to a power factor of 0.7 or 0.8 for a loaded motor running across the line. Therefore, switching a motor from running across the line to running off of a VSD produces both benefits and drawbacks for the electrical distribution system. Although the drive introduces harmonics, it brings power factor closer to unity. It has been argued that, in general, these factors offset one another in their impact on the distribution system. However, the actual net difference would depend on the application.

One practical note about (voltage) harmonic distortion is that drives located in close proximity to each other can interact and create some operational difficulties for each other. If one of the drives is unloaded (not driving a motor) the loaded drives can produce voltage distortion that causes an over voltage condition in the unloaded drive, and the drive may refuse to start.

Harmonic distortion will also cause heating and efficiency degradation in adjacent across-the-line motors.

IEEE 519-1992

An international standard was developed to define permissible limits of harmonic distortion from non-linear loads. This standard is not universally enforced, but when limits on harmonics levels are contractually mandated, this standard is typically used.

One important aspect if IEEE 519-1992 is that it defines harmonic levels at the point of common coupling. In this respect, it allows the utility customer to define or ignore harmonic levels within customer-owned equipment.

The impact of IEEE 519-1992 on oil operators is certainly not universal. Within its own electrical distribution equipment, this standard only applies if mandated by company policy. Depending on the relationship between the oil operator and the utility company, IEEE 519-1992 standards may not influence operational decisions.

Mitigation of Harmonics

There are five methods to reduce harmonics. These are discussed below.

Reactors

The most common first level of harmonic mitigation is achieved by including an inductor in either the DC filter circuit of the drive (DC link reactor) or in line with the three-phase input (AC line reactor).

Industry literature differs on the relative benefits of these two approaches, but it seems that the DC reactor has some advantages.

Lufkin Well Manager 2.0 AF650 VSD RPC units are equipped with a DC reactor installed within the drive for power ranges up to 100 hp (74 kW). Units in excess of 100 hp (74 kW) are equipped with an external line reactor.

Although these reactors reduce harmonic distortion significantly, they usually do not bring the system into compliance with IEEE-519.

Passive Filters

Passive filters can be installed upstream of each drive to bring the equipment into compliance with IEEE-519. Passive filters are large and heavy (roughly 3 pounds per horsepower/1.36 kg per kW) arrangements of inductors and capacitors that serve as filters (from the supply perspective). These devices are carefully sized to match the fundamental frequency of the supply system (50 Hz/60 Hz) and the drive current rating.

Lufkin Automation can supply passive filters (normally referred to as harmonic filters) as optional equipment to the installation. These filters are enclosed in a NEMA 3R cabinet that is separate from the drive, but is typically installed adjacent to the drive enclosure and connected immediately upstream of the drive in the power circuit. These filters should be ordered based on the Amp rating of the control and the line frequency being supplied to the VSD (50/60 Hz).

12-Pulse and 18-Pulse drives

By increasing the number of diodes in the input section of the drive, the harmonic distortion can be dramatically reduced. Alternative designs use phase shifting transformers and additional diodes in the input section of the drive to reduce harmonic distortion. This approach adds considerable cost to the drive and is, therefore, not widely used in low-power (less that 150 hp/110 kW) drives. The general industry thought is that below 150 hp (110 kW), a six-pulse drive with harmonic filter is generally most cost effective. Above 150 hp, the 12-pulse products start to exhibit some cost advantages.

Lufkin does not supply a 12-pulse or 18-pulse drive because our applications typically remain well below the point where these products are cost effective.

Active Filters

Active filters monitor the line power in real time and actively correct for harmonic distortion and/or power factor lead/lag. These filters should be ordered based on the Amp rating of the control and the line frequency being supplied to the VSD (50/60 Hz).

An example would be to include active power filters on individual legs of its own electrical distribution system when the drive load on that leg reaches a certain level. This approach would allow the user to leverage capital (installing a single filter to address the harmonics of multiple drives) rather than installing individual passive filters.

Lufkin does not supply active filter equipment as this equipment is more in the domain of “electrical distribution” products. However, these filters are offered by several suppliers.

Active Front End Drives

A few manufacturers produce specialty active front end (AFE) drives. These products are also known as “back-to-back” drives because their architecture resembles two separate drives that share a common DC bus.

AFE drives have been in production for many years and their use in the oilfield is growing rapidly. Lufkin offers an AFE drive, known as the LWM REGEN controller. It meets IEEE 519-1992 for ultra-low harmonic content and does not require any braking resistors. Contact your Lufkin Automation representative for more information.

Digital Transducers

The LWM 2.0 controller is designed to work with input signals for polished rod load and surface stroke position. The polished rod load cell and Hall-Effect transducer combination is commonly used for downhole percent fillage control and in-depth analysis of the pump cards when accurate surface dynagraph data needs to be obtained.

These transducers are discussed in the following paragraphs.

Polished Rod Load Cell

The polished rod load cell (PRLC) is a load input transducer that is used to measure the polished rod load. A low-level load signal is generated by the PRLC and transmitted through a cable to the controller. In the LWM 2.0 controller, the load signal is amplified and conditioned for use.

The PRLC provides a quantitative measurement of the load on the rod string. It is mounted on top of the carrier bar under the rod clamp. The PRLC directly measures the weight of the rod string and fluid column on the pump plunger. A spherical washer set between the PRLC and the carrier bar ensures concentric loading even if the carrier bar is tilted. It is available in full load ratings of 30K or 50K pounds. It is the most accurate of the two load options and requires no field calibration during installation. Disadvantages are that a long working loop is required for the signal cable, damage to the device by service crews is possible, and loss of accuracy due to fluid pound or floating rods is possible.

Hall-Effect Transducers

Hall-Effect transducers are magnetic sensors that sense the passage of magnets mounted on the motor shaft and the pumping unit crank arm. The LWM 2.0 controller uses these two digital inputs and pumping unit dimension data to calculate polished rod position.

Two Hall-Effect transducers are used in this system. One transducer measures precise motor speed and the second transducer marks the crank arm passage at the bottom of each stroke. These two digital signals, coupled with user-entered precise pumping unit dimensional data, allow the controller to accurately calculate surface stroke position. As additional advantages, they can monitor for belt slippage, and instantaneously shut down the pumping unit when a “locked rotor” equipment failure occurs. Their disadvantages are that proper alignment must be maintained between the sensor and magnets, and pumping unit dimensional data must be entered during installation and commissioning.

Lufkin Wireless Load Cell

Introduced in 2021, the Lufkin wireless load cell system uses a wireless load input transducer that measures the polished rod load and transmits this data to a controller-mounted base station. The wireless load cell mounts on top of the carrier bar under the rod clamp just like the wired load cell, and it directly measures the weight of the rod string and fluid column on the pump plunger. The wireless load cell has a transmission range (unobstructed) of 100 feet (30 meters), which allows greater flexibility in placement and eliminates the risk of signal cable damage.

The Lufkin wireless load cell also has an integrated accelerometer that provides rod speed and position data. It sends an analog position signal with 1.5 volts indicating bottom of stroke and 3.5

volts indicating top of stroke. This system is designed to be used with pump strokes ranging from 48 inches to 366 inches, and pump speeds of one stroke per minute to 17 strokes per minute.

For more information on the Lufkin wireless load cell system, refer to the *Lufkin Wireless Load Cell User Manual* (Lufkin Document # 2000302685) or contact your local Lufkin Automation representative.

Section 3: Technical Specifications

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Section Overview

The Lufkin Well Manager™ 2.0 VSD RPC is an integrated system that consists of a Lufkin Well Manager (LWM) 2.0 RPC packaged pre-wired to a Danfoss FC 302 variable speed drive (VSD). This section lists only the pertinent specifications for the LWM 2.0 VSD RPC enclosure and the Danfoss VSD. The specifications for the Lufkin Well Manager 2.0 RPC and the end devices used with it are provided in the Lufkin Well Manager™ 2.0 Rod Pump Control User Manual (Part No. 099.0081). Contact your Lufkin representative for a copy of this user manual.

Lufkin Well Manager 2.0 VSD RPC

Enclosure

Enclosure Type	Convection-cooled cabinet with forced air-cooled frequency converter
Ingress Rating	Front compartment: IP56 Rear compartment: IP46

Dimensions

Size	HP (kW) Range	Leg Height	Enclosure Height	Overall Height	Width	Depth
2	10 – 100 hp (7.5 – 75 kW)	18 inches (449 mm)	53” 1348 mm	71” 1804 mm	34” 864 mm	23” 584 mm
3	125 – 200 hp (90 – 150kW)	18” (449 mm)	55” 1397 mm	73” 1854 mm	34” 864 mm	35” 889 mm

General Technical Data

The following basic technical data applies to the 380-500V rated Danfoss FC 302 inverter. Refer to the *Danfoss Operating Guide* in the documentation package for the latest detailed specifications.

Main Supply

Supply voltage	380 – 500V ±10%

Mains voltage low/mains drop-out:
During low mains voltage or a mains drop-out, the drive continues until the intermediate circuit voltage drops below the minimum stop level, which corresponds typically to 15% below the frequency converter's lowest rated supply voltage. Power-up and full torque cannot be expected at mains voltage lower than 10% below the frequency converter's lowest rated supply voltage.

Supply frequency	50/60 Hz ±5%
Max. imbalance temporary between mains phases	3.0% of rated supply voltage
Environment according to EN60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical Amperes, 500V maximum.

Motor Output (U, V, W)

Output voltage	0 – 100% of supply voltage
Output frequency	0 – 590 Hz (voltage and power dependent)
Output frequency in Flux Mode	0 – 300 Hz
Switching on output	Unlimited
Ramp times	0.01 – 3600 s

Torque Characteristics

Starting torque (constant torque)	Maximum 160% for 60 s[1)] once in 10 min.
Starting/overload torque (variable torque)	Maximum 110% for 60 s[1)] once in 10 min.
Torque rise time in flux vector control (for 5 kHz fsw)	1 ms
Torque rise time in advanced vector control (independent of fsw)	10 ms

1) *Percentage relates to the nominal torque.*
2) *The torque response time depends on application and load but as a general rule, the torque step from 0 to reference is 4-5 x torque rise time.*

Ambient Conditions (Environment)

Enclosure	IP21/Type 1, IP55/ Type 12
Vibration test	1.0 g
Max. THVD	10%
Max. relative humidity	5% – 93% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43)	H2S test class Kd
Ambient temperature	Max. 122° F (50°C) (24-hour average maximum 113° F [45° C])
Minimum ambient temperature during full-scale operation	32° F (0° C)
Minimum ambient temperature at reduced performance	14° F (-10° C)
Temperature during storage and transport	-13 to +149/158°F (-25 to +65/70 °C)
Maximum altitude above sea level without derating	3,300 ft (1,000 m)
EMC standards, Emission	EN 61800-3, EN 550111)
EMC standards, Immunity	EN61800-3, EN 61000-6-1/2

Cable Specifications

Max. motor cable length, shielded	500 ft (150 m)
Max. motor cable length, non-shielded	1,000 ft (300 m)
Max. cross-section to control terminals, flexible/rigid wire w/o cable end sleeves	1.5 mm2/16 AWG
Max. cross-section to control terminals, flexible wire with cable end sleeves	1 mm2/18 AWG
Max. cross-section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm2/20 AWG
Minimum cross-section to control terminals	0.25 mm2/24 AWG

1) *IEC 60947 part 4 and 5*
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).
2) *Overvoltage Category II*
3) *UL applications 300 V AC2A*

Section 4: Parts Lists

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Section Overview

This section lists the parts and accessories available for the Lufkin Well Manager 2.0 VSD RPC.

LWM 2.0 VSD RPC Packages

Part Description	Part No.
LWM 2.0 VSD RPC 25 HP/18.5 kW	1000301780
LWM 2.0 VSD RPC 30 HP/22 kW	1000301781
LWM 2.0 VSD RPC 40 HP/30 kW	1000301782
LWM 2.0 VSD RPC 50 HP/37 kW	1000301783
LWM 2.0 VSD RPC 60 HP/45 kW	1000301784
LWM 2.0 VSD RPC 75 HP/55 kW	1000301785
LWM 2.0 VSD RPC 100 HP/75 kW	1000301786

DBR Units for 400-Volt Class Drives

<table>
<tr><th colspan="2">VSD Rating</th><th colspan="3">Recommended DBR Model</th></tr>
<tr><th>HP (kW)</th><th>R_{MIN} (Ohm)</th><th>Model</th><th>Ohms</th><th>kW</th></tr>
<tr><td>25 (18.5)</td><td>20.3</td><td rowspan="2">Model A (P/N 060.0590)</td><td rowspan="2">21.9</td><td rowspan="2">3.5</td></tr>
<tr><td>30 (22)</td><td>18</td></tr>
<tr><td>40 (30)</td><td>13.4</td><td rowspan="3">Model B (P/N 060.0591)</td><td rowspan="3">14.7</td><td rowspan="3">3.4</td></tr>
<tr><td>50 (37)</td><td>10.8</td></tr>
<tr><td>60 (45)</td><td>8.8</td></tr>
<tr><td rowspan="2">75 (55)</td><td rowspan="2">6.5</td><td>Model E (P/N 060.0594)</td><td>7.5</td><td>4.5</td></tr>
<tr><td>Model J (P/N 1000301145)*</td><td>7.8</td><td>7.3</td></tr>
<tr><td rowspan="2">100 (75)</td><td rowspan="2">4.2</td><td>Model C (P/N 060.0592)</td><td>5.9</td><td>3.6</td></tr>
<tr><td>Model F (P/N 060.0700)*</td><td>5.5</td><td>8</td></tr>
</table>

** Heavy duty ratings. These models are recommended for highly regenerative applications.*

DBR Connection Kits

DBR Model/Part Number	Connection Kit Part Number
Model A (P/N 060.0590) Model B (P/N 060.0591)	530.0263
Model C (P/N 060.0592) Model E (P/N 060.0594)	530.0262
Model F (P/N 060.0700) Model J (P/N 1000301145)	530.0261

Documentation

Description	Document No.
Lufkin Well Manager™ 2.0 Rod Pump Control User Manual	099.0081
Lufkin Well Manager™ 2.0 Variable Speed Drive Rod Pump Controller User Manual	2000301878
Dynamic Braking Resistor Installation Guide	099.5031

How to Order Parts and Accessories

Call the local Lufkin representative or contact the factory directly at 281.495.1100.

Section 5: Installation

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Section Overview

This section covers the installation of an integrated Lufkin Well Manager (LWM) 2.0 VSD RPC and all related system components.

Typical Installation

A typical LWM 2.0 VSD RPC installation includes the following system components:

- LWM 2.0 VSD RPC
- Load cell
- Hall-Effect sensors for motor shaft and crank arm
- Dynamic braking resistor unit (optional)

Figure 5-1 shows an example of a typical LWM 2.0 VSD RPC installation.

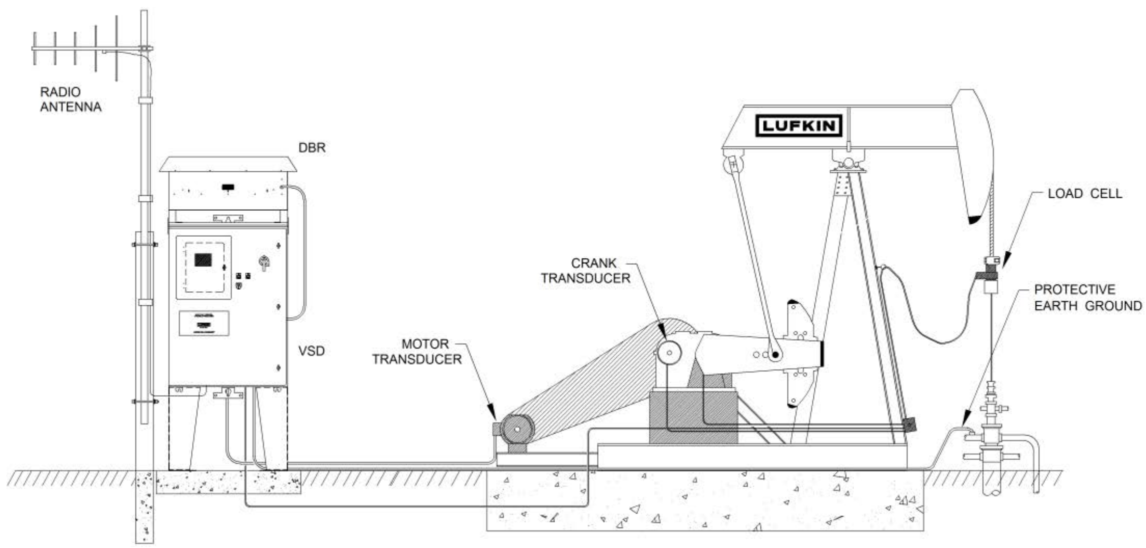


Figure 5-1. Typical LWM 2.0 VSD RPC Installation

Site Selection

When selecting a site for installing the LWM 2.0 VSD RPC, keep in mind the following conditions:

- Mount the LWM 2.0 VSD RPC in a location near the pumping unit so that it is easily accessible to the operator.

Note: A minimum of four feet of clearance is required at the front and rear of the VSD enclosure. This clearance will ensure adequate space to open the front and rear enclosure doors.

WARNING: The LWM 2.0 VSD RPC must be mounted in the Safe Area (Unclassified Area) of the wellsite.

- Keep the motor power leads as short as possible. AC power and motor leads must be run in separate conduit from any other control/signal wiring.

Note: If local practice or specific circumstances require longer power cable lengths, please consult Lufkin Automation for assistance.

- If the system includes optional radio data telemetry equipment, keep in mind the radio signal path from the well to the base radio location. The Yagi antenna for the local wellsite radio should not point directly at the pumping unit structure when properly aligned with the base radio location.

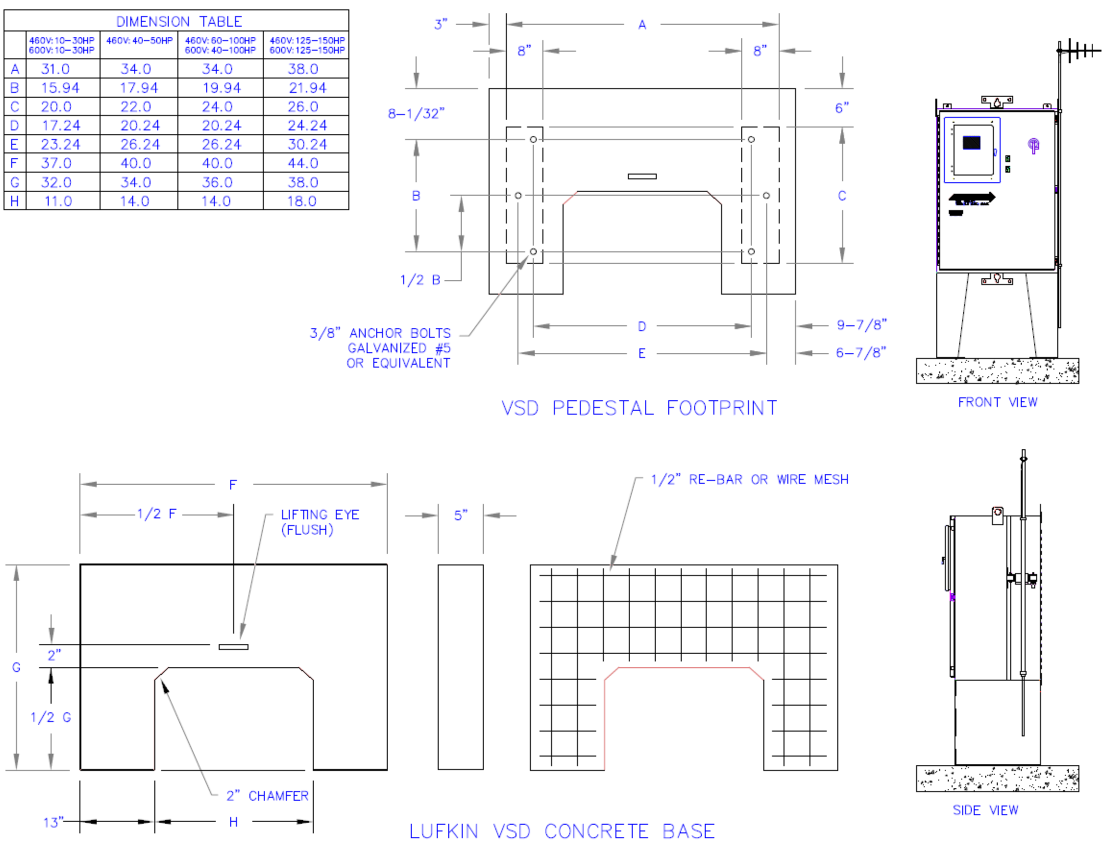
Installing the Integrated LWM 2.0 VSD RPC

The integrated LWM 2.0 VSD RPC unit can be very heavy, particularly for larger horsepower sizes. Lifting equipment will be required.

A solid concrete base is needed to support the unit. Approximate unit shipping weights are listed in the table below.

Description	Weight		Lufkin Part No.
	lb	kg	
25 hp/18.5 kW VSD RPC	325	147.4	1000301780
30 hp/22 kW VSD RPC	340	154.2	1000301781
40 hp/30 kW VSD RPC	420	190.5	1000301782
50 hp/37 kW VSD RPC	420	190.5	1000301783
60 hp/45 kW VSD RPC	450	204.1	1000301784
75 hp/55 kW VSD RPC	480	217.7	1000301785
100 hp/75 kW VSD RPC	500	226.8	1000301786

Figure 5-2 shows an example of a typical recommended concrete base design.



DIMENSION TABLE	460V: 10–30HP 600V: 10–30HP	460V: 40–50HP	460V: 60–100HP 600V: 40–100HP	460V: 125–150HP 600V: 125–150HP
A	31.0	34.0	34.0	38.0
B	15.94	17.94	19.94	21.94
C	20.0	22.0	24.0	26.0
D	17.24	20.24	20.24	24.24
E	23.24	26.24	26.24	30.24
F	37.0	40.0	40.0	44.0
G	32.0	34.0	36.0	38.0
H	11.0	14.0	14.0	18.0

Figure 5-2. Typical Recommended Concrete Base Design

Follow the steps below to properly mount the integrated LWM 2.0 VSD RPC:

1. Excavate a trench to lay conduit from the site for the VSD RPC to both the back of the pumping unit and to the primary power service disconnect.
2. Lay conduit and stub it up so that the ends will come up in the “notch” of the concrete base.
3. After all electrical conduit is in place, level the site for the concrete base using gravel or other suitable fill material, if necessary.
4. Set the concrete base in place, keeping in mind the required alignment for the stubbed-up conduit.
5. Use appropriate lifting equipment to set the LWM 2.0 VSD RPC in place. Carefully align the mounting stand holes with the mounting bolts fixed in the concrete base.
6. Securely bolt the VSD RPC cabinet in place.
7. When the VSD RPC cabinet is set in place and bolted down, complete the conduit installation to the bottom of the VSD RPC enclosure.

Note: Local codes may also require that a buried conduit for the load and position (Hall-Effect transducers) be installed from the VSD RPC unit to the Sampson post of the pumping unit.

The LWM 2.0 VSD RPC is now installed. The following sections discuss installation of the load cell, Hall-Effect transducers for the motor shaft (RPM) and the unit crank shaft (CSW), and an optional dynamic braking resistor,

See Section 7: “Wiring the VSD System” for information about wiring the system.

Installing the Polished Rod Load Cell

The polished rod load cell (PRLC) is installed between the polished rod clamp and the carrier bar as shown in Figure 5-3. When the load cell is properly installed, the load cell supports the full load of the rod string. The PRLC provides a quantitative signal that is directly proportional to the load changes occurring at the polished rod.

Note: For all load cell installations, a spherical washer set must be placed between the top of the carrier bar and the bottom flange of the load cell to ensure an accurate load signal.

Tools Required

The following tools are required for this procedure:

- Polished rod clamp of correct size
- Wrenches for polished rod clamp
- Voltmeter
- Stuffing box protector
- Standoff spacer

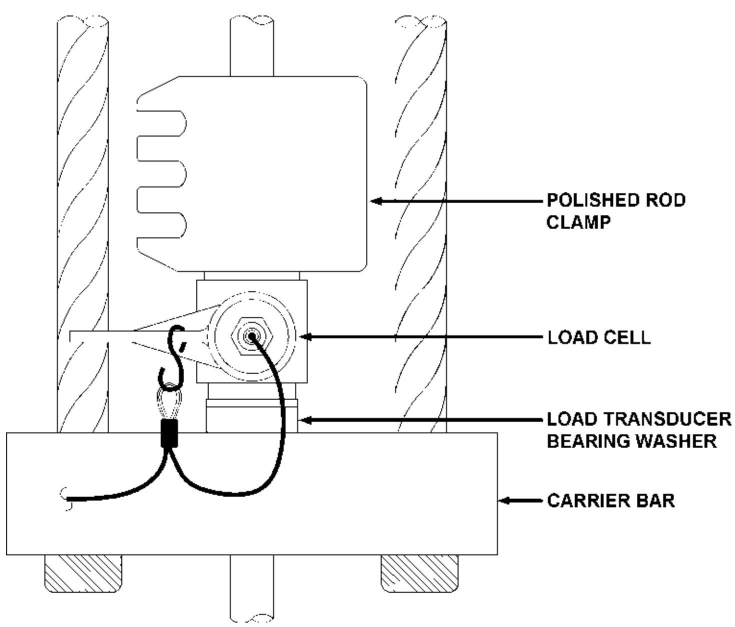


Figure 5-3. Polished Rod Load Cell Installed with a Spherical Leveling Washer Set

Installation Procedure

Warning: Follow the manufacturer's proper lockout/tagout procedures for securing the pumping unit before performing this installation. Failure to heed this warning can result in severe injury or death.

Follow the steps below to properly install the PRLC.

1. Stop the pumping unit on the downstroke.
2. Create a space between the carrier bar and the polished rod clamp for placing the load cell by stacking out the rod string on the wellhead (i.e., temporarily set the rod string on the wellhead). This can be done using a winch truck or by using the pumping unit prime mover. The following steps are suggested:
   a. Make sure the unit brake is holding securely.
   b. Install a temporary polished rod clamp on the polished rod below the carrier bar and above the polished rod liner using the following precautions:
      - Use the correct clamp size.
      - Tighten the clamp securely and use a handle extension as necessary. Use double-bolt clamps in deep wells with heavy rod strings.
      - On hard-faced polished rods, attempt to install the clamp on a portion of the polished rod that is not hard-faced.
   c. Protect the stuffing box using the following precautions:
      - Do not set down the weight of the rod string on the stuffing box packing. Use the proper stuffing box protectors.
      - Select the proper standoff length to avoid throwing too much slack in the bridle.
      - Throw slack at the carrier bar as gently as possible. Avoid "running" into the standoff.

Caution: Installing the PRLC often requires climbing on the wellhead or using a ladder. Use extreme caution when climbing using a ladder and always set it on level ground. Some companies prohibit climbing on the wellhead.

WARNING: Keep fingers and hands out of harm's way in case the polished rod clamp or unit brake slips.

3. After the rod string is independently supported, mark the position of the original rod clamp on the polished rod with a grease pencil or soapstone.
4. Turn off all power at the main supply.
5. Turn off the LWM 2.0 VSD RPC. If it has an optional battery, it may have the unit powered up even though the AC is no longer on.
6. Remove the original polished rod clamp from above the carrier bar.
7. Remove the pony rod or collar from the top of the polished rod.
8. Slide the spherical washer set down over the polished rod and position it on top of the carrier bar.
9. Place the load cell around the polished rod on top of the spherical washer set. Observe the Up arrow on the side of the PRLC, and be sure that it points up.
10. Check that the load-bearing surface of the PRLC rests on the surface of the spherical washer set.
11. Position the PRLC so that the signal wire socket faces the pumping unit.

Note: The PRLC must be installed below the rod rotator if one is present or severe damage can occur to the load cell and/or cable.

12. Replace the pony rod or collar on the polished rod.
13. Replace the original rod clamp above the PRLC. Remember to move the clamp up from the original marked position by the height of the load cell and spherical washer set so that the same downhole pump spacing is maintained.
14. Secure the PRLC to the bridle with wire rope.
15. GENTLY release the unit brake to transfer the weight of the rod string back to the carrier bar and bridle. DO NOT drop the rod string abruptly onto the load cell. A shock loading can introduce a zero offset in the transducer, making the load cell calibration ineffective. Reset the brake after obtaining a small amount of standoff clearance. Remove the standoff and the temporary polished rod clamp installed below the carrier bar.
16. Operate the unit slowly during the first pump cycle to check for possible problems. Examples include:
    - Bridle slipping off the horsehead due to poor horsehead alignment
    - Polished rod liner (if installed) being pulled out of the stuffing box packing, which will create a hazardous leak
    - Inadequate clearance between the horsehead and polished rod clamp when the unit is at the top of stroke

The PRLC is now installed.

Installing the Motor RPM Hall-Effect Transducer

The magnet assembly must be mounted on the motor shaft and the Hall-Effect transducer probe must be mounted so that the magnet passes within about 1/8 inch of the probe tip when it passes the probe. The installation procedure provided below assumes that the belt sheave is far enough out on the motor shaft to mount the magnet between the motor and the sheave. This will work for the majority of installations.

The installation technician may need to be innovative on some locations. Contact a Lufkin representative if problems occur. Extra T-brackets are available if needed.

Tools Required

- Socket set or wrench set
- Screwdriver

Parts Required

- Transducer assembly with motor bracket and T-bracket
- Magnet assembly
- Hose clamp

Installation Procedure

Warning: Follow the manufacturer's proper lockout/tagout procedures for securing the motor and the pumping unit when performing this installation. Failure to heed this warning can result in severe injury or death.

Follow the steps below to properly install the motor RPM Hall-Effect transducer.

1. Turn off the main power switch to the motor.
2. Set the brake on the pumping unit and chain off the unit sheave.
3. Attach the magnet (mounted in holder) to the motor shaft with a stainless steel hose clamp. Cut off excess hose clamp after it is tightened. See Figure 5-4.

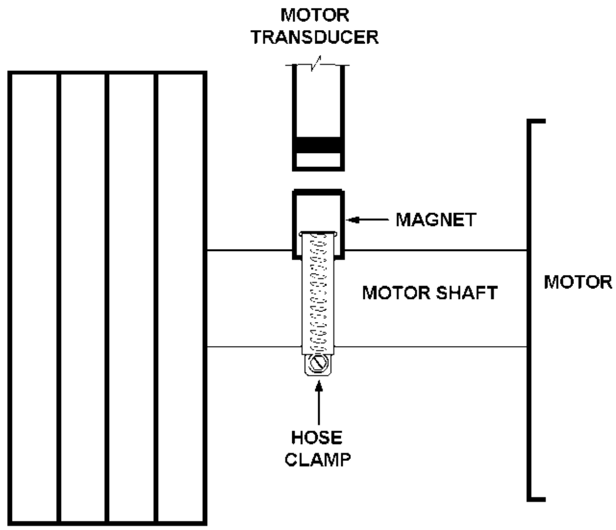


Figure 5-4. Motor Transducer Assembly Diagram Showing T-Bracket Linkage

4. Install the motor transducer bracket on a motor housing bolt. Select a housing bolt that will easily allow the transducer to align with the magnet.
5. Assemble and adjust the T-bracket linkage so that the magnet passes approximately 1/8 inch from the transducer. See Figure 5-5.

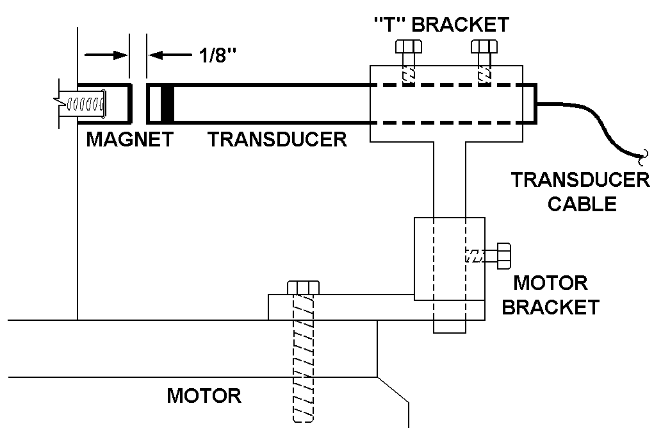


Figure 5-5. Motor Transducer Assembly

6. Tighten all bracket connections.

The RPM Hall-Effect transducer is now installed.

Installing the Crank Arm Hall-Effect Transducer

The crank transducer must be precisely installed to sense the leading edge of the magnet at bottom dead-center of the stroke. An error in this measurement will result in a shift in polished rod positions, which will cause distortions in the surface and downhole pump cards and errors in the diagnostic calculations.

Note: If local safety regulations prevent mounting the sensor for bottom of stroke (with counterweights up), the sensor can be mounted to sense the crank arm at or near the top of the stroke (with counterweights down) and the LWM 2.0 can be configured to make a phase angle adjustment.

Tools Required

- Socket set or wrench set
- Screwdriver
- Silicon sealant/adhesive

Parts Required

- Transducer assembly and brackets
- Magnet

Installation Procedure

Warning: Follow the manufacturer's proper lockout/tagout procedures for securing the motor and the pumping unit when performing this installation. Failure to heed this warning can result in severe injury or death.

Follow the steps below to properly install the crank arm transducer.

1. Position the unit cranks with the polished rod at the bottom center position.
   a. Align the crank and pitman. The centerlines of the pitman and the crank should be in perfect alignment. See Figure 5-6.
   b. Stop the unit near the bottom center position.
   c. With the motor turned off, release the brake slowly and observe the direction that the cranks rotate.

d. Select a low gearbox speed.

2. With the direction of the crank rotation in mind, start the unit and then stop the unit with the polished rod near bottom. When the brake is released gently, the cranks will rotate slowly in the direction that will align the centerlines of the crank and pitman.

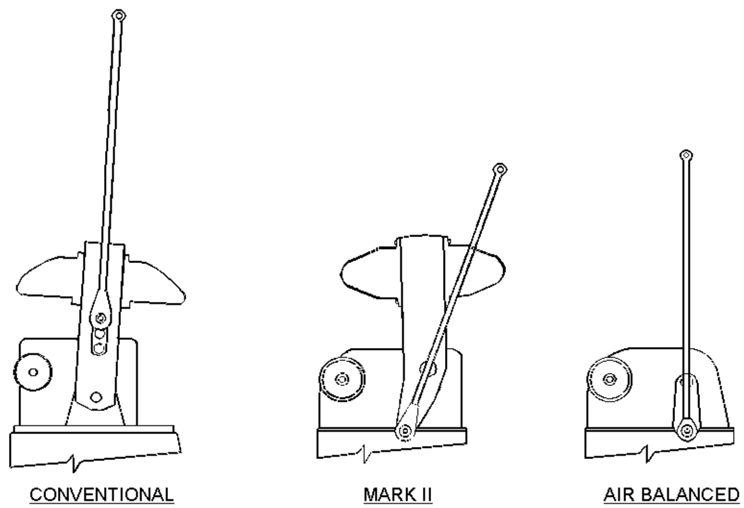


Figure 5-6. Crank/Pitman Alignment at Bottom Dead-Center

If one person is involved in the installation, this procedure can be done in steps by allowing the cranks to rotate a small amount, then set the brake and observe the alignment. Continue this method until the centerlines are in perfect alignment. If this method is not successful (unit behavior differs from well to well), consider stopping the unit slightly before bottom-dead-center, then partially set the brake and “bump” the unit by quickly turning the motor on and off. After each “bump,” observe the crank and pitman position until perfect alignment is obtained.

3. Turn off the main power switch to the motor.

4. Set the brake on the pumping unit and chain off the unit sheave.

5. Select a bolt on the gearbox slow speed shaft bearing cap that will allow the easiest and best alignment of the transducer and the magnet. Remove the bolt and mount the bracket of the Hall-Effect transducer. Reinstall and tighten the bolt to secure the bracket. See Figure 5-7 and Figure 5-8 on page 5-15.

6. Use either method described below to mount a magnet:

   - Bar magnet (see Figure 5-7) – Mount a bar magnet on the crank, and carefully inspect the backside of the crank arm to ensure that the transducer will not be hit by a portion of the crank that extends out further than the surface of the magnet. After making sure that the magnet facing the transducer has the correct polarity, glue the magnet to the crank with silicone.

Note: Incorrect polarity will result in no crank signal. Correct polarity can be determined by holding the bar magnet near a round magnet mounted in a holder used for measuring motor revolutions and speed. The side of the bar magnet attracted to the round magnet is the side glued to the crank.

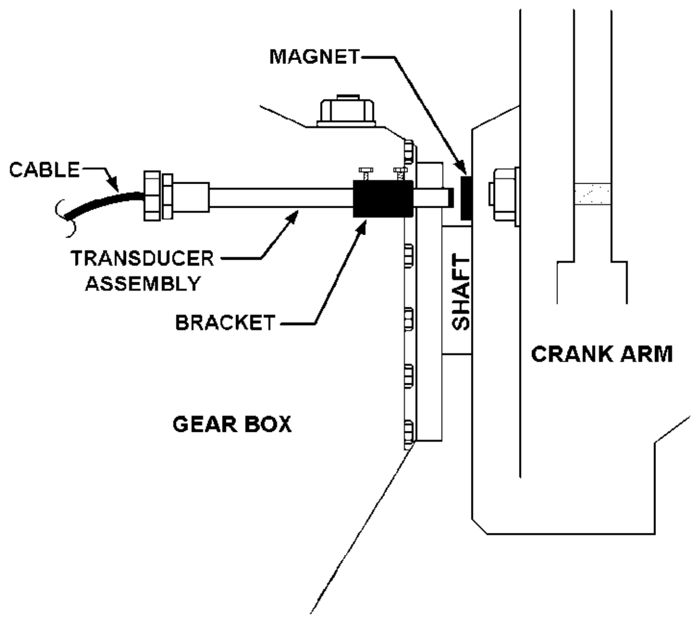


Figure 5-7. Bar Magnet Mounted on Back of Crank Arm

- Round magnet (see Figure 5-8) – Attach a round magnet (mounted in holder) to the slow speed shaft of the gearbox with a stainless steel hose clamp, similar to the motor transducer assembly. If insufficient space is available to mount the magnet between the crank and the gearbox bearing cap, mount a bar magnet on the crank as described above.

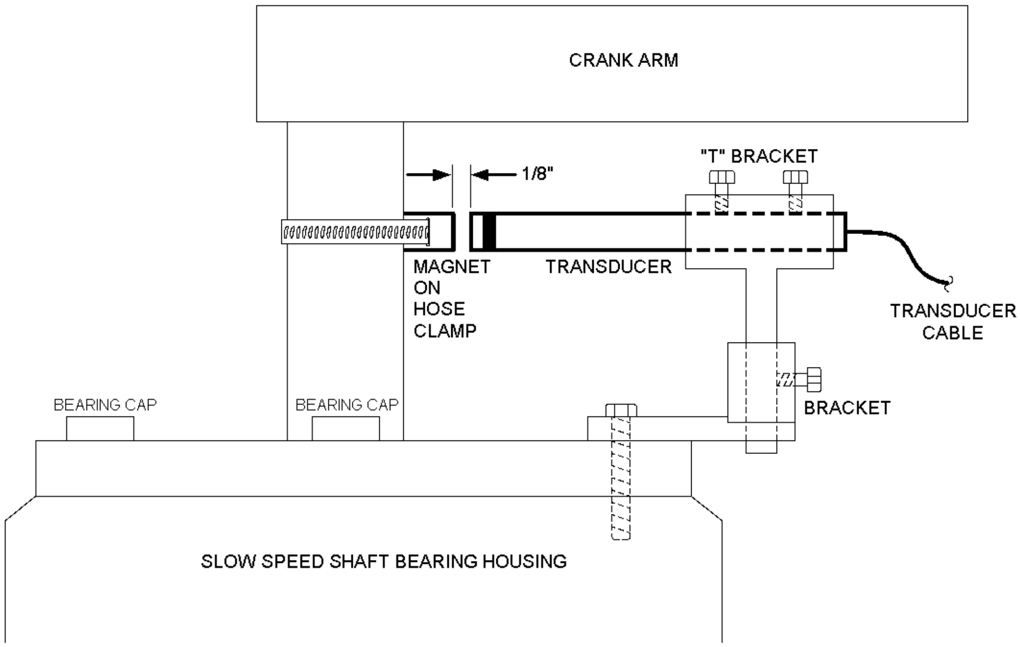


Figure 5-8. Round Magnet Mounted on Low Speed Shaft of Gearbox

7. The Hall-Effect transducer senses the magnet when the leading edge of the magnet is approximately at the center of the transducer probe. With this in mind and with the unit at bottom dead-center, position the transducer or the magnet so that the center of the transducer is at the leading edge of the magnet and approximately 1/8-inch from the magnet. (See Figure 5-9 for proper magnet alignment.) Tighten all connections securely.

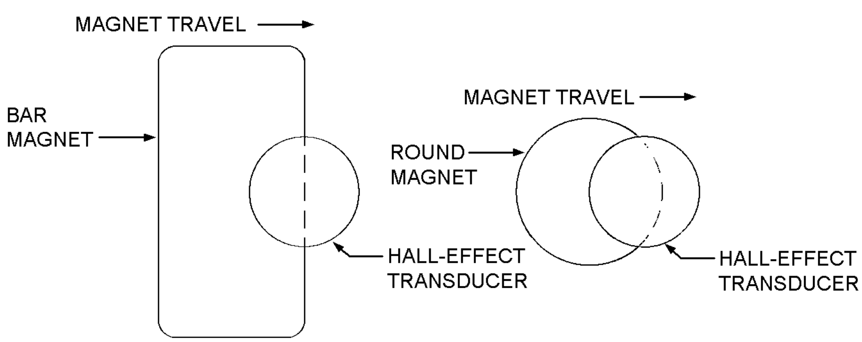


Figure 5-9. Proper Magnet Alignment

The crank arm Hall-Effect transducer is now installed.

Installing a Dynamic Braking Resistor (Optional)

If a dynamic braking resistor (DBR) unit is included, refer to the *Lufkin Dynamic Braking Resistor User Manual* (Part No. 099.5031) for installation instructions.

Section 6: Wiring the VSD System

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Section Overview

This section describes how to wire the various components making up the Lufkin Well Manager 2.0 VSD RPC system. The following recommended wiring guidelines are crucial for successful performance.

WARNING: This VSD must be properly grounded by a qualified electrical technician. Improper grounding can result in severe injury or death.

Warning: Turn off power from the main power source to the enclosure and follow proper lockout/tagout procedures before opening the controller enclosure. Failure to heed this warning can result in severe injury or death.

WARNING: Capacitors can retain a lethal voltage up to 20 minutes after power has been shut off. While verifying locked-out equipment, allow sufficient time for complete discharge of capacitors. Always refer to the inverter manufacturer’s manual for correct discharge times.

Overview of VSD Components Wiring

This manual covers the following wiring procedures for the Lufkin Well Manager 2.0 VSD RPC system.

- Power wiring
- Signal wiring
- Dynamic Braking Resistor (DBR) wiring
- External safety relay wiring
- Wiring torque requirements

Refer to the wiring diagram on the inside of the VSD enclosure door when performing the procedures in this section.

Power Wiring

The topics below provide useful information for wiring:

- Primary input power (page 6-5)
- Power between the motor and Lufkin Well Manager 2.0 VSD RPC (page 6-6)
- System grounding (page 6-7)

The table below shows the recommended wire sizes for a maximum run length of 100 feet (30 meters).

Recommended Wire Sizes for Power and Ground Leads (Copper @ 75° C)

HP (Kw)	Power Lead Size AWG (mm^2)		Ground Lead Size AWG (mm^2)
	Input	Motor	
10 HP (7.5 kW)	12 (3.5)	12 (3.5)	2 (34)
15 HP/11 kW	10 (5.5)	10 (5.5)	2 (34)
20 hp/15 kW	8 (8.5)	8 (8.5)	2 (34)
25 hp18 kW	8 (8.5)	8 (8.5)	2 (34)
30 hp/22 kW	8 (8.5)	6 (13.5)	2 (34)
40 hp/29 kW	4 (22)	4 (22)	2 (34)
50 hp/37 kW	4 (22)	3 (27)	2 (34)
60 hp/45 kW	2 (34)	2 (34)	2 (34)
75 hp/55 kW	1 (43)	1/0 (54)	2 (34)
100 hp/75 kW	2/0 (68)	3/0 (85)	1/0 (54)

Note: For wire lengths longer than 100 feet (30 meters), increase wire sizes by one gauge size.

Note: Wire sizes are based on individual conductors (single core wires). If multi-conductor cable is used, the wire size will need to be increased.

Primary Input Power

Warning: Turn off power at the main power source and follow proper lockout/tagout procedures before opening the VSD enclosure. Failure to heed this warning can result in severe injury or death.

Three-phase voltage in the range of 380 to 480VAC, 50/60 Hz must be provided to the line side of the circuit breaker in the Lufkin Well Manager 2.0 VSD RPC. The line side contains the top three connectors that are labeled L1, L2, and L3 as shown in Figure 6-1.

Wires from the power company interface (meter or service disconnect) should be run in rigid metal conduit buried at suitable depth according to local codes. The conduit should be run up into the bottom of the Lufkin Well Manager 2.0 VSD RPC cabinet.

Pull a ground wire along with the three power wires. Dress the three power wires up the side of the cabinet away from the inverter and connect at the top of the circuit breaker.

The plastic safety shields covering the terminals can be removed by firmly pulling straight up. Safety shields should be snapped back in place after leads are terminated.

Dress the ground lead to the ground bus in the lower right corner of the cabinet and terminate it in one of the ground lugs provided. Avoid making sharp bends in the ground lead.

Figure 6-1. Line Side of Circuit Breaker in VSD RPC

Motor Power and Ground Leads

Lufkin recommends using the wire sizes for motor leads listed in the table on page 6-4.

Power Leads from Inverter to Motor

The power leads from the converter to the motor should be no longer than 30 feet (9 meters), and they must be run in separate conduit from primary power source leads and any signal cable leads. Long motor leads can amplify VSD voltage fluctuations and cause premature motor failure.

Running Power Leads from LWM VSD RPC to Motor Junction Box

Three motor power leads must be run from the converter output to the junction box on the motor. These leads should be run in a combination of rigid and flexible conduit, or an armored flexible cable can be used. Pull a ground lead to ground the motor chassis in the conduit with the power leads. For details about ground wire size, refer to the table on page 6-4. Follow the guidelines in the section titled “System Grounding” on page 6-7.

Terminating Power Leads from Motor Junction Box to LWM VSD RPC

Power leads are terminated in the Lufkin Well Manager 2.0 VSD RPC cabinet on terminals at the bottom of the converter module labeled 96/U, 97/V, and 98/W. See Figure 6-2.

To access the power output terminals:

1. Remove the front cover from the inverter.
2. Insert the power leads through the opening in the bottom of the cover plate and into the terminals. Use an Allen hex wrench to tighten the terminals.
3. Tighten all wire connections to the torque specified in the table on the inside of the enclosure door.
4. Replace the front cover on the inverter.

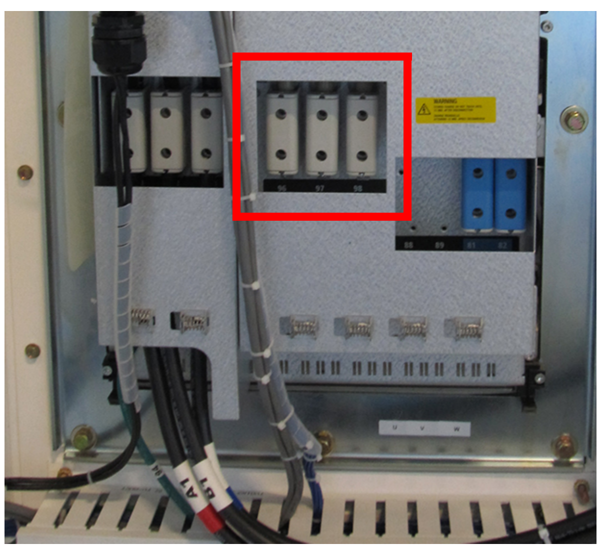


Figure 6-2. VSD RPC Power Leads from Inverter

System Grounding

WARNING: The VSD grounding procedure must be performed by a qualified electrical technician. Improper grounding can result in severe injury or death.

Warning: Turn off power at the main power source and follow proper lockout/tagout procedures before opening the VSD enclosure. Failure to heed this warning can result in severe injury or death.

WARNING: Capacitors can retain a lethal voltage up to 20 minutes after power has been shut off. While verifying locked-out equipment, allow sufficient time for complete discharge of capacitors. Always refer to the inverter manufacturer's manual for correct discharge times.

Note: Refer to the table on page 6-4 for recommended ground wire sizes.

Proper earth grounding of the Lufkin Well Manager 2.0 VSD RPC is critical to minimize transient voltages that can damage the control system electronics and to prevent high frequency noise from interfering with the signal inputs. Use the following guidelines for system grounding:

- As a general rule, the larger and shorter the ground lead used, the better the ground. It is best practice to avoid any sharp bends in a ground lead.
- For the VSD RPC application, Lufkin recommends using the wellhead as the system ground electrode. The ground bus bar in the Lufkin Well Manager 2.0 VSD RPC should be connected to the wellhead, and all other parts of the system should in turn be connected to the VSD ground bus.
- For drives of size 75 HP and smaller, the Lufkin Well Manager 2.0 VSD RPC ground bus bar should be connected to the wellhead with an uninterrupted length of stranded green ground wire.

- Terminate the ground wire at the VSD ground bus bar with one of the lugs provided and to the wellhead with an approved pipe ground clamp rated for the wire size used.
- The connection spot at the wellhead must be cleaned down to bare metal before installing the clamp, and it must be sufficiently coated afterward to prevent corrosion.
- The ground bus bar in the VSD should be connected to the motor chassis with an uninterrupted length of stranded green ground. Use the wire size listed in the table on page 6-4.
- The primary power source service ground should be terminated on the VSD ground bus bar using one of the ground lugs provided.
- All signal cable shields should be terminated at the ground bus on the controller module. See Figure 6-7 on page 6-13.
- Make sure all installed ground connections meet the requirements according to the local standards and/or practices. (The typical practice is to confirm low resistance between the VSD ground bus bar, the local ground point (e.g. well head), and the motor).

The system is now grounded.

Signal Wiring

Warning: Turn off power at the main power source and follow proper lockout/tagout procedures before opening the VSD enclosure. Failure to heed this warning can result in severe injury or death.

WARNING: Make sure this VSD has been properly grounded by a qualified electrical technician. Improper grounding can result in severe injury or death.

WARNING: Capacitors can retain a lethal voltage up to 20 minutes after power has been shut off. While verifying locked-out equipment, allow sufficient time for complete discharge of capacitors. Always refer to the inverter manufacturer's manual for correct discharge times.

Typical system signal wiring includes running and terminating the cables for the load cell and for the two Hall-Effect transducers. Optional transmitters to monitor other wellhead process variables, such as tubing pressure and/or casing pressure can also be included.

WARNING: Signal wiring installed in a well site's hazardous area must be enclosed in properly-rated Type MC-HL sealed cables or conduits with sealed conduit fittings. This will prevent ignitable process gases or fluids from migrating into the electrical system.

Signal wiring for analog inputs should be kept as short as possible. These wires must be installed independent of any AC power wiring; otherwise noise may be induced into the controller causing erroneous signals. The cabling should be a twisted pair shielded type.

Note: Analog signal common connections should be kept separate from earth ground connections.

The terminal blocks for connecting the load cell and Hall-Effect transducer cable leads are located on the bottom of the LWM 2.0 controller module. To access this module, do the following:

1. Open the small metal door located on the upper left of the front door of the cabinet. The keypad is exposed as shown in Figure 6-3.

Figure 6-3. Front Panel and Latch

2. Lift up on the latch located to the right of the keypad, and then pull the panel outwards.

   The controller module is shown in Figure 6-4.

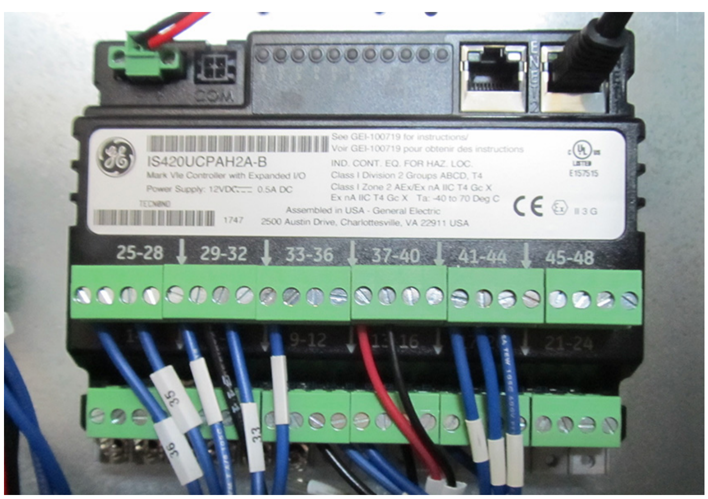
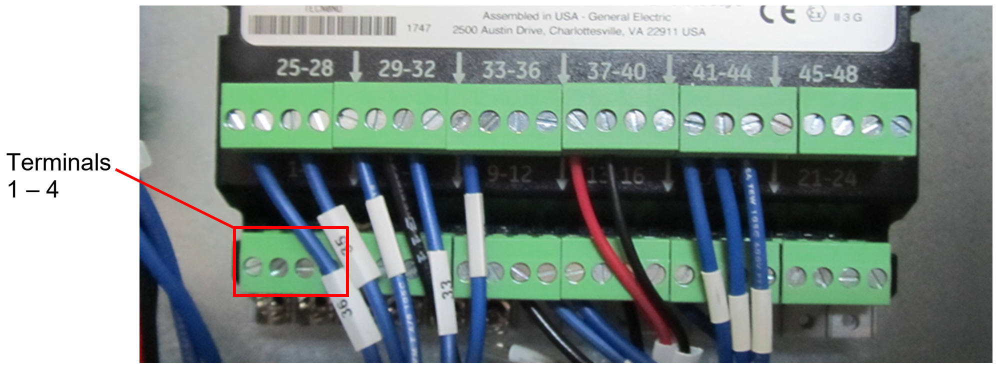


Figure 6-4. LWM 2.0 Controller Module

A field wiring diagram is attached to the inside of the LWM 2.0 VSD RPC enclosure door. Refer to this diagram when performing the following procedures.

Load Cell Cable

The load cell cable leads must be terminated at terminals 1 – 4 on the controller module. See Figure 6-5.



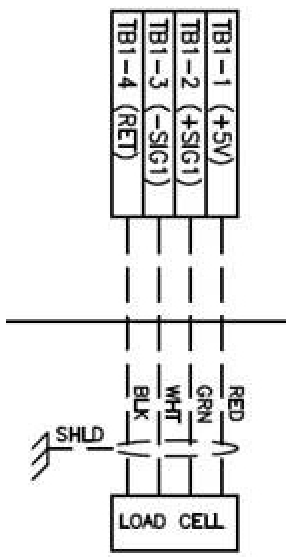


Figure 6-5. Terminals for Load Cell Cable Connection

Hall-Effect Transducer Cables

Terminals work better with leads that are not “tinned” with solder. Clip off the “tinned” ends of the two Hall Effect cables and strip the insulation to expose the stranded wire.

The two Hall-Effect transducer cables must be terminated at the following terminals on the controller module:

- RPM transducer: Terminals 19 – 21
- Crank transducer: Terminals 22 – 24

See Figure 6-6 below.

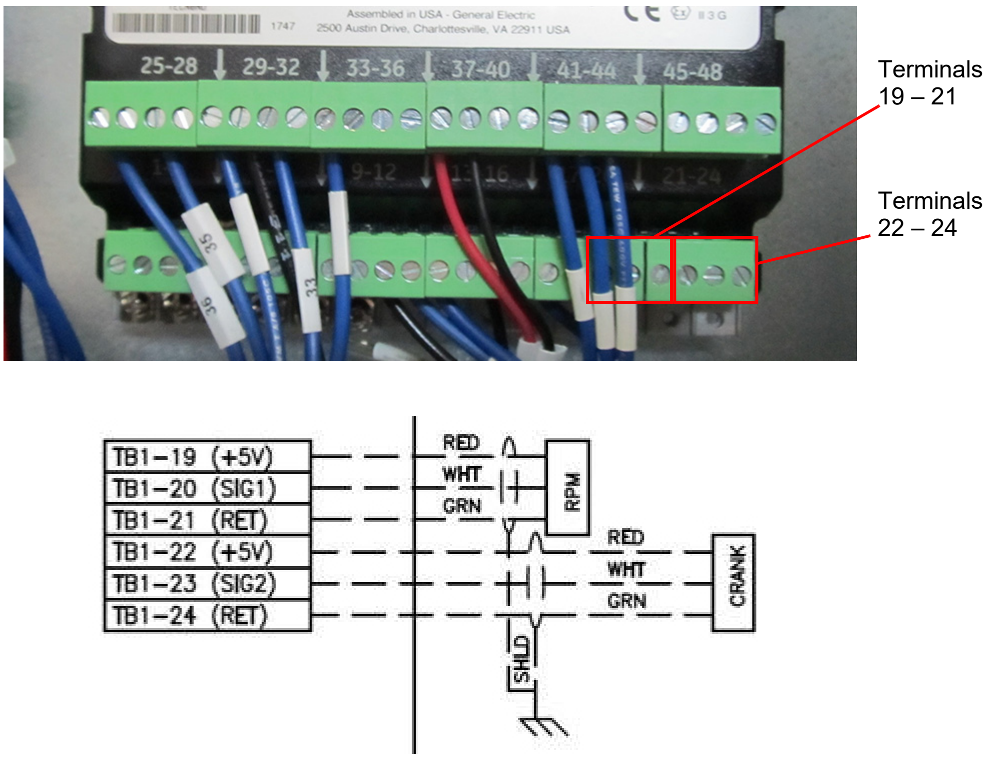


Figure 6-6. Terminals for Hall-Effect Transducer Cable Connections

Shielded Cables

Shielded cables must be used for the signal leads from the load cell and the Hall-Effect transducers. Shields should be terminated inside the enclosure at the ground bus bar on the bottom of the controller module.

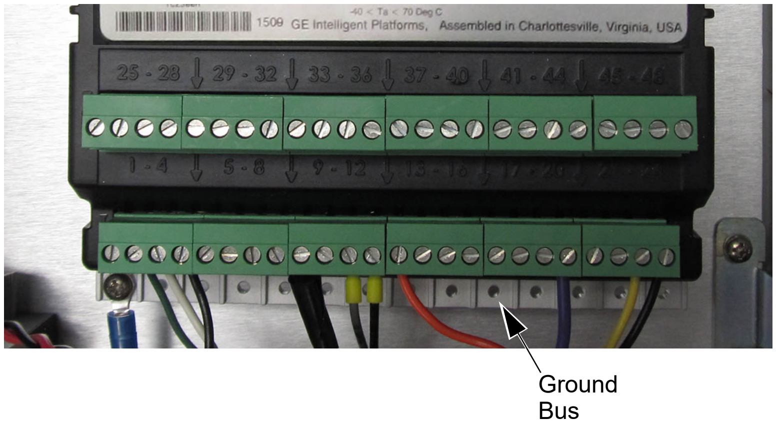


Figure 6-7. Controller Module Ground Bus

The shield of each cable must be connected only at the controller end. The transducer end of the shield should be left unconnected; otherwise a ground loop could form causing erroneous signals.

Dynamic Braking Resistor Wiring

Warning: Turn off power at the main power source and follow proper lockout/tagout procedures before opening the VSD enclosure. Failure to heed this warning can result in severe injury or death.

WARNING: Make sure this VSD has been properly grounded by a qualified electrical technician. Improper grounding can result in severe injury or death.

WARNING: Capacitors can retain a lethal voltage up to 20 minutes after power has been shut off. While verifying locked-out equipment, allow sufficient time for complete discharge of capacitors. Always refer to the inverter manufacturer's manual for correct discharge times.

This section provides an overview on the wiring of the DBR. For detailed instructions, refer to the *Lufkin Dynamic Braking Resistor User Manual* (Part No. 099.5031).

When an optional dynamic braking resistor (DBR) unit is added to a VSD RPC drive, it must be wired to the drive and the DBR thermostat shutdown control relay.

The wiring chamber on the DBR unit has a conduit knockout. Conduit must be run from that wiring chamber to the lower part of the Lufkin Well Manager 2.0 VSD RPC cabinet, either through the side of the cabinet or up through the bottom of the cabinet. Pull two power wires, four control wires, and a ground wire through the conduit. Use 16 AWG (2 mm^2) for control wiring. Power and ground conductor sizes should meet or exceed the values provided in the table on the next page.

DBR Power and Ground Conductor Sizes

DBR Model	Conductor Size [AWG]	Conductor Size [mm^2]
Model A Model B	8	9
Model C Model E	6	14
Model F Model J	3	27

Note: For convenience, DBR connection kits are available. See “DBR Connection Kits” in Section 4: “Parts and Accessories.”

All wiring should be 1000VAC class at 105° C.

To access the DBR wiring chamber, remove the endplate where the black model number tag is mounted. Refer to the wiring diagram on the back of the cover plate for wire termination details. The ground wire should be terminated at the ground stud on the upper right wall of the DBR wiring chamber, and at the ground bus in the Lufkin Well Manager 2.0 VSD RPC cabinet.

The DBR power wires are terminated at Terminals 81 and 82, which are located along the bottom edge of the inverter module in the Lufkin Well Manager 2.0 VSD RPC cabinet. Remove the front cover from the inverter to access these terminals. See Figure 6-8 below.

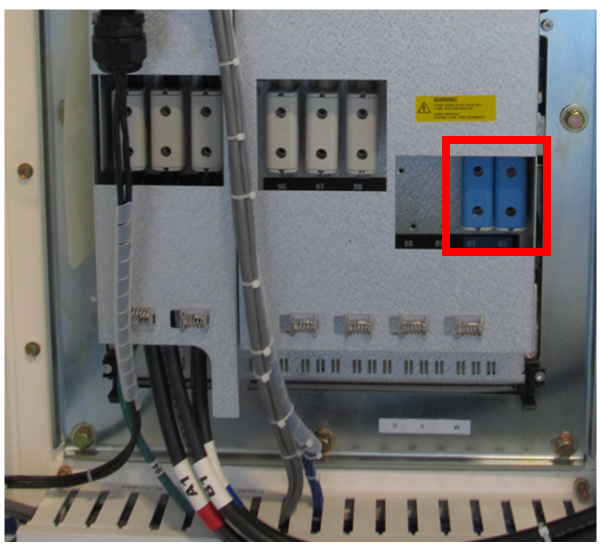


Figure 6-8. DBR Power Wire Termination Points

The DBR thermostat control wires are connected to relay LS3, which is wired to Pseudo Digital Input 5 (PDI 5). This pseudo digital input must be assigned to the **DBR** Device Name with the **Motor Stop (downtime)** alarm option selected. See “Pseudo Digital Input Configuration” on page 10-69 for details.

WARNING: The DBR’s thermostat must be wired to the drive’s fault trip circuit to prevent overheating of the DBR. Failure to do so may result in damage to the VSD and/or the DBR.

External Safety Relay Connections

Five external safeties (shown in Figure 6-9) can be connected to the terminal block to provide shutdowns. These safeties can be used for inputs such as vibration, temperature, pressure, and DBR overheat. The unit is wired to accept a normally open (N.O.) contact input on the Safety #1 terminals and four normally closed (N.C.) input contacts on Safety #2 – 5. See Figure 6-9 below.

These contact states are duplicated onto the LWM 2.0 controller at terminals TB2-25 through TB2-33. Only safeties with dry contacts rated at a minimum of 12VDC and 100 mA should be used. No externally powered inputs are allowed.

Note: Remove the factory jumpers before installing these contacts.

Additional N.C. safety contacts can be wired in series to replace the jumper across terminal block TD1 & TD2. These safeties will cause VSD shutdown but will not be monitored by the LWM 2.0 controller.

An LWM 2.0 digital output and a VSD digital output are also available on the same terminal strip.

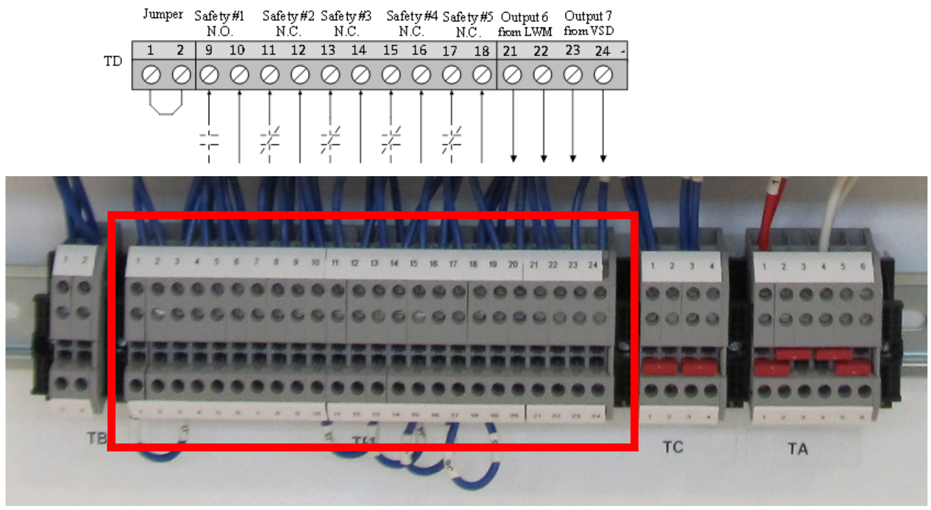


Figure 6-9. External Safety Relay Connections

Note: External Safety #3 is typically designated for the DBR.

Wiring Torque Requirements

WARNING: All wiring connections must be torqued according to their relevant torque specifications. A loose connection can create an electrocution hazard and result in serious injury or death.

These specifications are described below.

Power Wiring Specifications

- Power input wiring and motor output wiring torque specifications are listed on a label inside the front enclosure door.
- Grounding lug torque specifications are defined on labels placed near the ground bus bar inside the VSD enclosure.

LWM 2.0 Controller Wiring Specifications

- The LWM 2.0 controller module's TB1 & TB2 connections are to be torqued at 5 lb-in.
- The controller module's power connector and both terminal blocks on the communication gateway module are to be torqued to 2 lb-in.

Torque specifications for other components can be obtained from the component manufacturer data sheets.

Initial Power-Up

WARNING: Voltage checks should only be performed by a qualified electrical technician who has experience working with motor control boxes and their high-voltage circuits. Technicians **MUST** use proper arc flash PPE and measuring equipment rated for the energy present in the system when performing this procedure. Failure to heed this warning can result in severe injury or death.

1. Shut off power to the VSD at the local power source.
2. Turn the VSD's internal breaker switch and HOL switch to their OFF positions.

WARNING: The VSD has DC bus capacitors that remain charged after power is turned off. Wait at least 20 minutes after turning off power before opening the VSD enclosure door.

3. Tighten all electrical connections (both field and internal wiring) to the proper torque.
4. Make sure the local power to be applied is within the range of the voltage listed on the ID/Ratings label of the unit door.
5. Close all unit doors and panels.

WARNING: All electrical equipment covers MUST be in place before turning on the power to the unit.

WARNING: Make sure all unnecessary personnel are clear of the VSD cabinet and the pumping unit before turning on the power.

6. Turn the local power on.
7. Turn the unit circuit breaker on. Make sure the unit powers up without signs of power issues such as sparks or smoke.

The LWM 2.0 VSD RPC unit is now ready for programming. See Section 8: “Quick-Start Programming” for step-by-step programming instructions.

Section 7: Operation

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Section Overview

This section discusses basic operation of the LWM 2.0 VSD RPC. Functions of the HOL switch and the operation functions located on the Main Menu screen are described in the following pages.

HOL Switch

The HOL switch (also known as the HOA switch) is located on the front of the VSD enclosure. This switch controls the basic operation modes of the VSD controller.

Figure 7-1. HOL Switch

The three positions of the HOL switch are described below:

- **HAND**: The HAND position serves to bypass the LWM 2.0 controller by applying a run command directly to the VSD. The VSD then runs the unit at a fixed speed regardless of any existing violation conditions. In this mode, the LWM 2.0 controller can monitor pumping operation, but it cannot stop the unit even if a violation condition is present. The user must manually turn the HOL switch to the OFF position to stop the unit.
- **OFF**: The OFF position shuts off the unit. Run and start signals are not applied to the VSD nor LWM 2.0 controller.

Note: When the HOL switch is in the OFF or HAND positions, remote users using SCADA or similar interfaces cannot start, stop, or change the speed of the unit. They can only monitor parameter values and send new configurations.

- **LWM (Auto)**: The LWM (Auto) position enables the LWM 2.0 controller to control the speed, start and stop the unit, and react to violation conditions. Remote users can monitor and control the system via SCADA or similar remote control systems.

WARNING: When the HOL switch is in the **LWM** (Auto) position, the unit can start and stop at any time. If the Start Alert feature is not enabled or an audible start alert device is not connected, there will be no warning when the unit starts or stops.

Operation Functions

This section discusses the operation functions shown on the Main Menu screen shown in Figure 7-2 below.

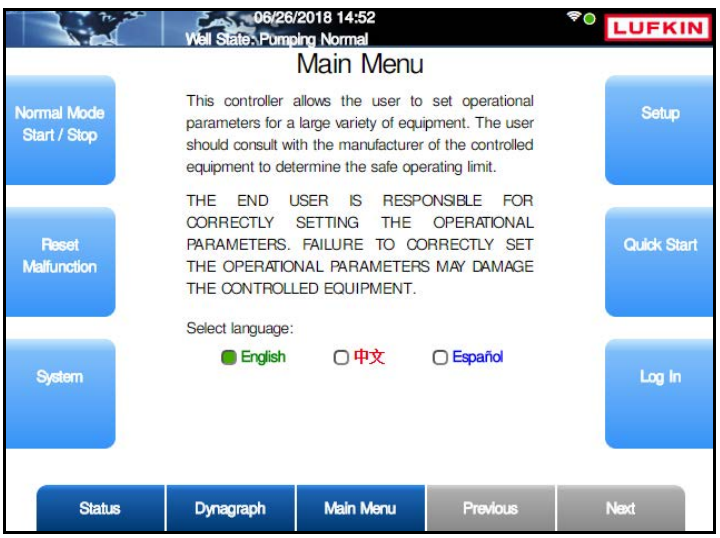

Figure 7-2. Main Menu Screen

System Starting and Stopping

The pumping system can be started or stopped at the controller using the **Normal Mode Start/ Stop** button on the Main Menu screen.

Note: This function requires the HOL switch to be in the **LWM** (Auto) position.

The action this command executes is based on the current state of the well. For example, if the well is pumping, this is a stop command; if the well is stopped, this is a start command.

After pressing the **Normal Mode Start/Stop** button from the Main Menu screen, one of the following messages displays for five seconds:

- When the system is operating, the **Motor Stop** message appears at the top of the screen, notifying you that the system is shutting down.
- When the system is shut down, the **Motor Start** message appears at the top of the screen, notifying you that the system is starting.
- When the system is stopped, the Well State field at the top of the screen reads **DT – Operator Stop**.

WARNING: The **DT-Operator Stop** well state is a temporary well state. The pumping unit will automatically restart after the programmed downtime elapses. Keep all personnel clear of the pumping unit when the controller is in this well state. Failure to heed this warning can result in severe injury or death.

When the controller starts the pumping system, the system goes through the following sequence of well states:

1. **Starting Alert**: The system sounds an audible alert (if an audible alert device is installed) and waits a programmed number of seconds before sending the command to start the pump motor.
2. **Starting Unit**: The controller sends a signal to the VSD to start the pump motor and waits for position input and load input signals to verify that the motor is running.
3. **Minimum Pump Strokes**: The controller waits for the pumping unit to pump for a programmed number of strokes before it starts analyzing the dynagraph data.
4. **Pumping-Normal Mode**: The system begins pumping with all enabled functions active. The controller remains in this well state until a setpoint violation or malfunction occurs.

Reset Malfunction

When the controller is in a malfunction state, the malfunction must be cleared. To reset malfunctions and restart the pumping system, press the **Reset Malfunction** button on the Main Menu screen. (See Figure 7-2 on page 7-4.)

Note: The Reset Malfunction button requires the HOL switch to be in the **LWM** (Auto) position. This button will not work when the HOL switch is in the **OFF** or **HAND** position.

WARNING: The pumping unit will immediately restart when the **Reset Malfunction** button is pressed. Keep all personnel clear of the pumping unit when the controller is in this well state. Failure to heed this warning can result in severe injury or death.

Log In/Log Out

The LWM 2.0 controller provides the option of restricting access to system configuration and well control functions. This feature is disabled by default. Refer to the section titled “Manage Users” on page 9-11 for information on setting up user access.

From the Main Menu screen, press the **Log In/Log Out** button to log in or log out of the system.

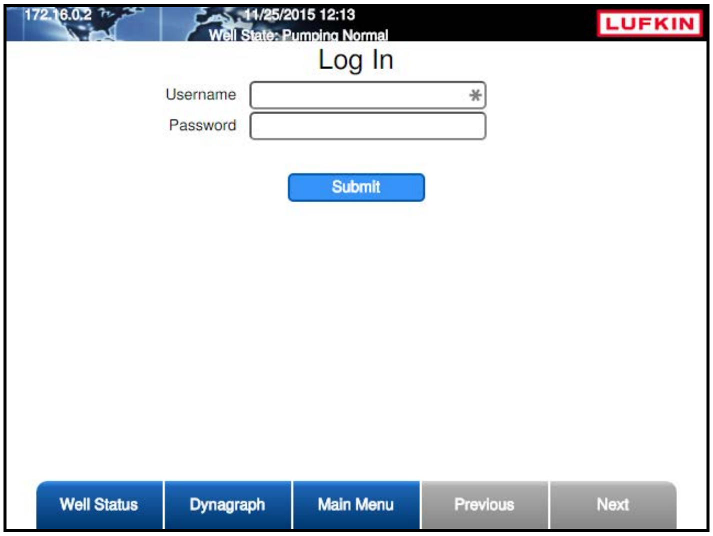

Figure 7-3. Log In Screen

If password protection is enabled, log into the system using the following steps:

1. With the **Username** field highlighted, press <**ENTER**>. Use the keypad to type the username and then press <**ENTER**> again. If logging in as an administrator, type **ADMINISTRATOR** as the username.

Note: Press the <**ALT**> key to switch the keypad input method from numbers to letters.

2. Press the down arrow to highlight the **Password** field and then press <**ENTER**>. Use the keypad to type the password and then press <**ENTER**> again.

Section 8: Quick Start Feature

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Section Overview

The Quick-Start configuration feature is designed to help you quickly enter the basic programming parameters necessary to configure the Lufkin Well Manager 2.0 controller and get it into operation. This feature sets certain default parameters for the controller to operate in normal pumping conditions. These parameters use values that are designed to work for most pumping unit systems. For a list of these default parameter values and instructions on changing these values, refer to the *Lufkin Well Manager 2.0 Rod Pump Controller User Manual* (Lufkin Document # 099.0081).

This section covers the use of the Quick-Start feature to program the VSD functionality of the Lufkin Well Manager 2.0 VSD RPC. For information about programming other features of the LWM RPC that are not specifically related to the VSD application, refer to the *Lufkin Well Manager™ 2.0 Rod Pump Control User Manual* (Part No. 099.0081).

The LWM 2.0 Quick Start configuration procedure is discussed on the following pages.

Note: This manual describes the functions included in Version 1.36.00 of the LWM 2.0 firmware.

Parameter Programming

Control parameters are edited (programmed) on a data field basis. To program a parameter, press the arrow keys to highlight the desired parameter field, press <**ENTER**>, and then choose one of the following methods:

- To select an option from a drop-down list, use the arrow keys to highlight the desired option and then press <**ENTER**> again.
- When the parameter is a numerical entry, use the number keys to enter the desired value and then press <**ENTER**> again.

When parameter values are changed, the green **Discard** and **Save** buttons will appear at the bottom of the screen as shown in Figure 8-1.

Figure 8-1. Menu Bar with Discard and Save Buttons

Press the **Save** button to save the programming change or the **Discard** button to discard the change. The **Discard** and **Save** buttons will then be replaced with the **Previous** and **Next** buttons.

Starting the Quick Start Procedure

Note: Make sure the pumping unit is operational and the HOL switch is set to the **OFF** position before starting the Quick Start procedure.

From the Main Menu screen, press the **Quick Start** button to start the Quick Setup procedure.

The Quick Start Welcome screen appears as shown in Figure 8-2.

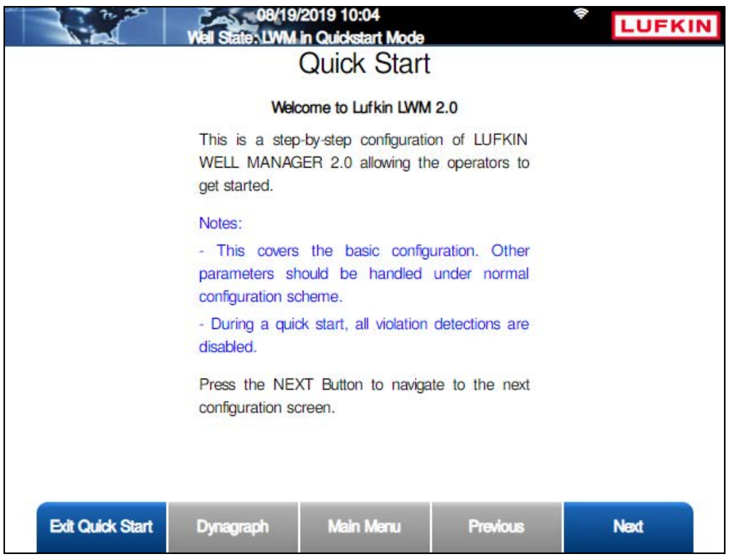


Figure 8-2. Quick Start Welcome Screen

To exit the Quick Start screen and return to the Main Menu screen, press the **Exit Quick Start** button.

Press the **Next** button to begin the Quick Start configuration procedure. This procedure is discussed on the following pages.

Operational Limits 1

The Operational Limits 1 screen is the first screen displayed. The contents of this screen are discussed below.

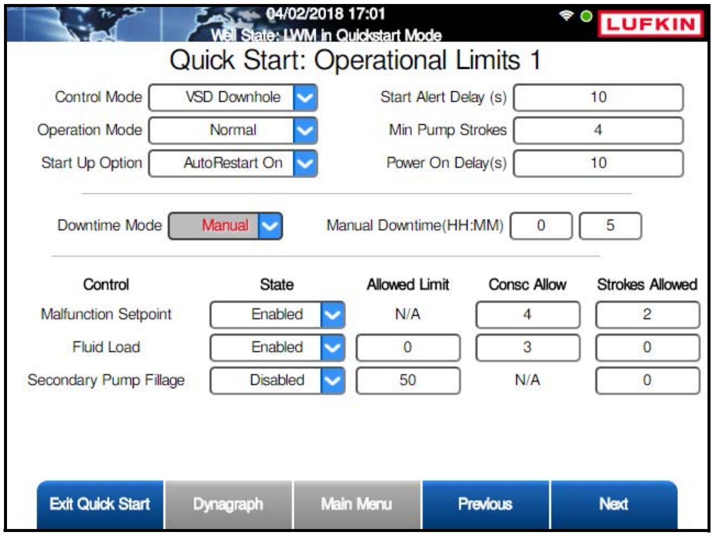


Figure 8-3. Quick Start: Operational Limits 1 Screen

The following parameters are configured on this screen:

- **Control Mode**: Select the desired control mode from the drop-down list. The available VSD options are:
  - **VSD Surface** – For systems containing variable speed drives, the controller adjusts the speed of the drive based on the surface dynagraph shape using the Pump Off setpoint.
  - **VSD Downhole** – For systems containing variable speed drives, the controller adjusts the speed of the drive to maintain a desired downhole pump fillage.
  - **VSD DH Pressure** – In this control mode, the controller uses the downhole intake pressure measurement and adjusts the speed of the pump to achieve a predetermined pressure (fluid level) at the pump intake. This method allows the controller to maintain the fluid level in the well at a desired setpoint when pump-off control is not required.

  To change the control mode, use the arrow keys on the keypad to highlight that field and then press <**ENTER**>. Use the up or down arrow keys to change the type and then press <**ENTER**> again.
- **Start Alert Delay (s)**: This parameter provides control of an optional audible or visible start alarm device. The Start Alert output is held ON (low) for the number of seconds programmed in this field. The controller delays starting the pumping unit until the Start Alert Delay time has elapsed. The default value is 10 minutes.

- **Operation Mode**: Select the desired mode of operation from the drop-down list. The available options are:
  - **Normal** – The controller performs all of the enabled safety and control functions. This mode takes full advantage of the LWM 2.0 controller's capabilities.
  - **Host** – The controller ignores load and position input and makes no control decisions. The pump or downtime decision is made by the operator and requires operator intervention to change. Typical use would be when several wells need to be shut down due to a power company request. A global data message can be sent to all LWM 2.0 RPC units on the radio network to place them in the Downtime-Host Mode well state. The LWM 2.0 RPC controls would stop the wells and keep them down until receiving a command to restart.
  - **Timed** – The LWM 2.0 RPC can be programmed to cycle on/off for user set times. Limited control functions by the LWM 2.0 RPC include peak and minimum load checking. Typical use might be to temporarily operate a well while waiting for one of the signal input end devices to be repaired.
- **Minimum Pump Strokes**: When a pumping cycle starts, the controller will not perform any dynagraph analysis for this number of initial strokes. Peak and minimum load protection is provided during Minimum Pump Strokes mode.

  Many pumping systems may need a few strokes to clear gas or trash from the pump at the start of a pump cycle. As a result, this number should be programmed at a fairly low value because the controller has very limited capabilities during Minimum Pump Strokes mode.

  The allowed range is 0 to 999, and the default is 3. Use the keypad to define this value.
- **Start Up Option**: This option allows the controller to automatically restart the pumping unit after the user-defined time delay has passed.

  To enable this option, select **AutoRestart On** from the drop-down list. To disable this option, select **AutoRestart Off**.
- **Power On Delay (s)**: (This parameter is only visible when the **AutoRestart On** option is selected.) When power is applied to the controller, the initial control state is Downtime Power On Delay. The controller delays starting the pumping unit for this number of seconds specified. This feature allows the operator to stagger the startup of pumping units on a transformer bank or distribution line after a power outage.

  The default value is 1 second. If a different value is desired, use the keypad to define the number of seconds for this value.
- **Downtime Mode**: (This release only features **Manual** downtime mode.) Manual downtime mode uses a user-programmed idle time after a stop for pump off (surface setpoint or downhole pump fillage) or pumping equipment malfunction can be specified. The controller automatically restarts the pumping unit when the specified downtime elapses.

Note: If the motor is a gas engine, the engine has to be manually restarted by an operator.

- **Manual Downtime (HH:MM)**: This value defines the initial downtime period used when the controller is in Manual Downtime mode. (See "Downtime Mode" above for description.)

  Program this value short enough to prevent the fluid level in the well bore from reaching the static fluid level, but long enough to allow good pump fillage for more than the minimum pump strokes. (The default value is 5 minutes.)

- **2ry Downtime Mode**: (This parameter is only visible when the **Secondary Pump Fillage** setpoint is enabled at the bottom of the screen.) Select one of the following downtime modes from the drop-down list:
  - **Manual**: In this mode, the controller stays in a Downtime/Pump-Off state until the Manual Downtime period expires.
  - **Pressure**: In this mode, the controller stays in a Downtime/Pump-Off state until the Downhole Pressure Recovery Target pressure is reached.
- **DH Pressure Recovery Target (psi)**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.

The bottom half of the screen contains controls for configuring parameter setpoints for malfunctions, pump off, fluid load, and pump fillage. Use the arrow keys to select **Enable** or **Disable** from the drop-down list to enable or disable these setpoints and then press <**ENTER**>. Use the keypad to define the Allowed Limit, Consecutive Allowed, and Strokes Allowed values (where applicable) for these setpoints and then press <**ENTER**> to save these values.

- **Malfunction Setpoint**: This parameter sets the number of malfunctions allowed before the controller shuts down the pumping unit. Select **Enabled** or **Disabled** from the drop-down list. The values that apply to this setpoint are described below:
  - **Malfunction Setpoint Consec Allowed**: The controller allows for re-tries for all of the malfunction types of control actions. For example, if the maximum allowed peak load is violated, the controller counts that as a peak load violation and initially shuts down the pumping unit in a downtime state. After the programmed downtime elapses, the controller tries to restart the pumping unit. If the peak load violation is repeated before a normal pump off cycle occurs, the controller counts that as the second consecutive peak load violation and again shuts down the pumping unit in a downtime state. Subsequent violations of the peak load limit increment the consecutive violation counter until the allowed consecutive for peak load is exceeded. The controller at that point shuts down the pumping unit in a malfunction state and operator intervention is required to clear alarms and re-start the unit. This column allows an operator to program the consecutive allowed for malfunction control action.

    Use the keypad to define this value.
  - **Malfunction Setpoint Strokes Allowed**: The number of consecutive strokes that the surface malfunction setpoint must be violated before the controller shuts down the pumping unit for one of the consecutive malfunctions allowed.

    The default value is 2 strokes. Use the keypad to define this value.
- **Pump Off Setpoint**: (This parameter is only used in **Surface** and **VSD Surface** control modes.) Select **Enabled** or **Disabled** from the drop-down list.

  The **Pump Off Strokes Allowed** value sets the number of consecutive strokes that the **Pump Off** control parameter must be violated before the controller shuts down the pumping unit. Use larger numbers for gassy wells or wells with trash interference with pumping action.

  The default value is 2 strokes. Use the keypad to define this value.
- **Fluid Load**: (This parameter is only used in **VSD Downhole** and **VSD DH Pressure** control modes.) The controller analyzes the realtime downhole dynagraph and uses this data to

calculate fluid load for each pump stroke. If the fluid load drops below this limit, the pumping unit is stopped for a downtime cycle early in the next upstroke.

The values that apply to this parameter are as follows:

- The **Allowed Limit** value defines the allowed fluid load limit described above. Use the keypad to define this value.
- The **Consecutive Allowed** value defines the number of times the fluid load can drop below the limit before the controller shuts down the pumping unit.
- The **Strokes Allowed** value defines the number of pump strokes allowed in a low fluid load situation before the controller shuts down the pumping unit.

- **Secondary Pump Fillage**: (This parameter is only used in **VSD Downhole** and **VSD DH Pressure** control modes.) When the current pump fillage drops below this limit, the controller will accumulate the number of times this drop occurs. When the number of occurrences exceeds the defined limit, the controller will stop the pump and then switch to a Downtime/ Pump-Off state. It will stay in this state until the Manual Downtime period expires.

Note: This feature is supported in the Normal operation mode only.

Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.

The values that apply to this parameter are as follows:

- The **Allowed Limit** value defines the allowed fillage limit described above. Use the keypad to define this value.

Note: The **Allowed Limit** value for the Secondary Pump Fillage parameter must be set below the deadband range in order to function properly.

- The **Strokes Allowed** value defines the number of pump strokes allowed in a limit violation situation before the controller shuts down the pumping unit.

Press the **Next** button to continue.

Operational Limits 2

The Operational Limits 2 screen is the next screen displayed. This screen is used to enable or disable violation setpoints for use during pumping operation. It also displays the current operation mode, control mode, load transducer type, and position transducer type.

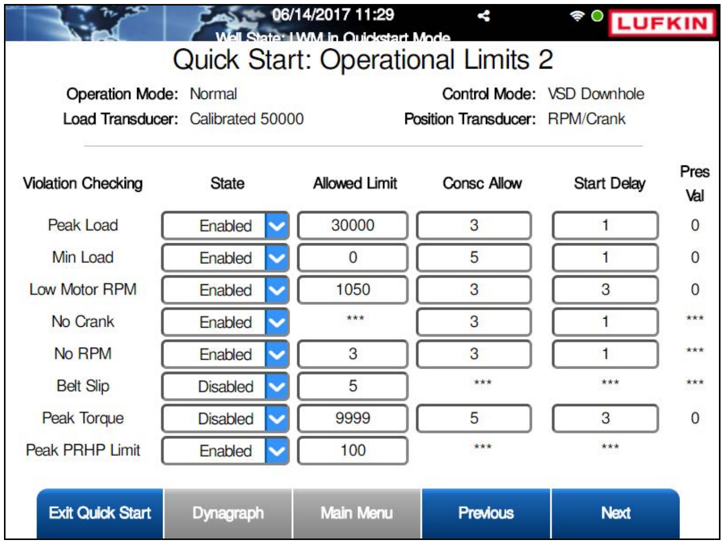


Figure 8-4. Quick Start: Operational Limits 2 Screen

Select **Enable** or **Disable** from the drop-down list to enable violation limit parameters. Using the keypad, define the desired values for **Allowed Limit**, **Consecutive Allowed**, and **Start Delay** parameters where applicable.

The available violation limits are:

- **Peak Load**: The maximum allowed value for load input. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay. Units are in pounds. The default value will be the full scale of the programmed load end device.
- **Min Load**: The lowest allowed value for load input. If the load falls below this value, the controller instantly shuts down the pumping unit with no consecutive stroke delay. The default value is zero.
- **Low Motor RPM**: The lowest motor RPM at which the controller will continue to run the pumping unit. This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for Low Motor RPM violations.
- **No Crank**: Triggers an alarm when a crank switch input is not detected.
- **No RPM**: Triggers an alarm when there is no RPM signal from the pumping unit. This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for No RPM violations.
- **Belt Slip**: The maximum allowed value for belt slippage. When in the Pumping Normal mode well state, the controller counts the Motor Rev/Stroke for each stroke. At the end of each stroke, the count is compared to the Reference Rev number programmed above. If the current Motor Rev/Stroke count is greater than the Reference Rev by greater than this Belt Slippage

percentage, the controller sets an alarm flag to indicate possible belt slippage. No other control action is taken. The default value is 5%.

- **Peak PRHP Limit (lbs)**: Specify a value at which the controller will set an alert flag to advise the operator that a paraffin treatment may be required. This value is a high limit.

Press the **Next** button to continue.

Operational Limits 3

The Operational Limits 3 screen is the next screen to be displayed.

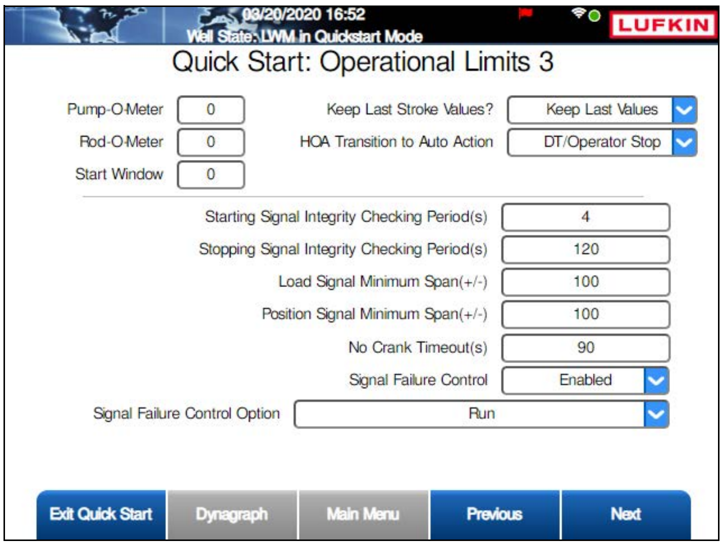


Figure 8-5. Quick Start: Operational Limits 3 Screen

Using the keypad, define the desired values for the following parameters:

- **Pump-O-Meter**: Use this field to clear the counter for rod pump activity. The controller counts and accumulates the number of strokes since the last time pump work was performed. These counts give operators a tool to measure pump life.
- **Rod-O-Meter**: Use this field to clear the counter for rod stroke activity. The controller counts and accumulates the number of strokes since the last time rod string work was performed. These counts give operators a tool to measure rod life.
- **Start Window**: Specify an additional delay time, in seconds, after the well start output is energized before the controller begins checking load and position inputs. This time may be necessary to allow a gas engine prime mover to start and run up to speed or for a clutch to engage. Typically, installations with electric motors do not need an additional delay.
- **Keep Last Stroke Values?**: Use the arrow keys to select one of the following options:
  - Keep Last Values
  - Clear Last Values
- **HOA Transition to Auto Action**: This parameter determines the action the controller takes when the HOA switch is turned to the Auto position. Available options are **DT/Operator Stop** and **Restart**.

  Use the arrow keys to select the desired option and then press <**ENTER**>.

- **Starting Signal Integrity Checking Period(s)**: This field displays the system-defined value for this parameter and cannot be changed by the operator.
- **Stopping Signal Integrity Checking Period(s)**: Use the keypad to define this value.
- **Load Signal Minimum Span (+/–)**: Use the keypad to define this value.
- **Position Signal Minimum Span (+/–)**: Use the keypad to define this value.
- **No Crank Timeout(s)**: Use the keypad to define this value.
- **Signal Failure Control**: (Not available in **VSD DH Pressure** control mode.) This parameter provides control options for handling signal failure situations. To enable or disable this parameter, select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.
- **Signal Failure Control Option**: (This field is only visible when the **Signal Failure Control** parameter is set to **Enable**.) When a signal failure is detected in the system, the controller has several control options for handling this situation. These options are described below:
  - **Malfunction** – With this option, the controller treats the signal failure as a malfunction and shuts down the pumping unit. This malfunction state must be cleared by the user before the controller will restart the unit.
  - **Downtime** – With this option, the controller shuts down the pumping unit for a designated period of time when a signal failure is detected.

    Use the arrow keys to highlight the hours and minutes fields and then press <**ENTER**>. Use the keypad to define the desired downtime period and then press <**ENTER**> again.
  - **Run** – With this option, the controller continues to run normally when a signal failure is detected.

  The next two options allow the pumping unit to run for a user-defined time period when a signal failure is detected.

  - **Timer 1 - User Define** – This option uses user-defined time limits to control the length of time the pumping unit should run in a signal failure situation.

    Use the arrow keys to highlight the hours and minutes fields and then press <**ENTER**>. Use the keypad to define the desired on and off periods and then press <**ENTER**> again.
  - **Timer 2 - % Run Time – since GOT**: This option sets a minimum and maximum time period the pumping unit can run since the last gauge-off time event.

    Use the arrow keys to highlight the hours and minutes fields for the **Off**, **Minimum On Period**, and **Maximum On Period** parameters and then press <**ENTER**>. Use the keypad to define the desired time period for each parameter and then press <**ENTER**> again.

Press the **Save** button to save changes made on this screen. Press the **Next** button to continue.

Operational Limits 4

The Operational Limits 4 screen is displayed next. Use this screen to configure a downhole gauge.

Figure 8-6. Quick Start: Operational Limits 4 Screen

Configure the downhole gauge using the following parameters:

- **DH Gauge Source**: Use the arrow keys to select the downhole gauge source from the drop-down list:
  - **Unavailable**: Select this option if a downhole gauge is not present in the system.
  - **Zenith DH Gauge**: Select this option for Zenith downhole gauges.
  - **AI 8**: Select this option for downhole gauges from other manufacturers.
- **Zenith DH Gauge Model**: (This parameter applies to the **Zenith DH Gauge** Source option only.) Select the desired downhole gauge model from the drop-down list:
  - Model C2
  - Model C5
  - Model C6
- **Intake Pressure Type**: (This parameter applies to the Zenith **Model C5** gauge option only.) Select the desired intake pressure type from the drop-down list. Available options are **Tubing** and **Annulus**.

For Zenith downhole gauge configuration, press or click the **COMM** button to display the Zenith DH Gauge configuration screen shown in Figure 8-7.

For configuration of other downhole gauges by other manufacturers, press the **Analog Input** button to display the Analog Input Configuration screen.

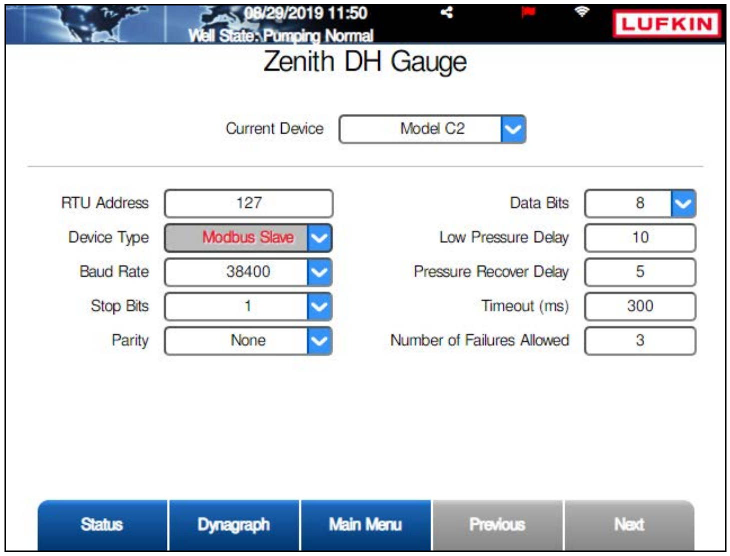


Figure 8-7. Zenith DH Gauge Configuration Screen

The following parameters are configured on this screen:

- **RTU Address**: Each downhole gauge must have a different address number. Address numbers of less than 247 are indicated by the standard Modbus guidelines. The address must match the downhole gauge setting.
- **Device Type**: As of this release, Modbus Slave is the only available option for device type.
- **Baud Rate**: Select from a range of options from 300 to 115,200 baud. The value must match the slave device setting.
- **Stop Bits**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Parity**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Data Bits:** This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Low Pressure Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Pressure Recover Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Timeout**: Specify the time, in milliseconds, that the controller waits after sending a poll message to check the reply message buffer.
- **Number of Failures Allowed**: Specify the number of times that the controller will continue to try to poll a downhole gauge once that gauge is enabled. If the controller does not receive a valid response after this number of consecutive polling attempts, a communication failure alarm is flagged for the downhole gauge to alert the operator that data from the gauge is not current. Communication failure flags are displayed in red at the top of the screen.

Press the **Save** button to save changes made on this screen, and then press the <**ESC**> button to return to the Operational Limits 4 screen.

Press the **Next** button to continue to the next screen.

Load and Position Configuration

The Load/Position configuration screen is the next screen to be displayed. This screen is used to configure the transducer types and indicate the location of the crank sensor.

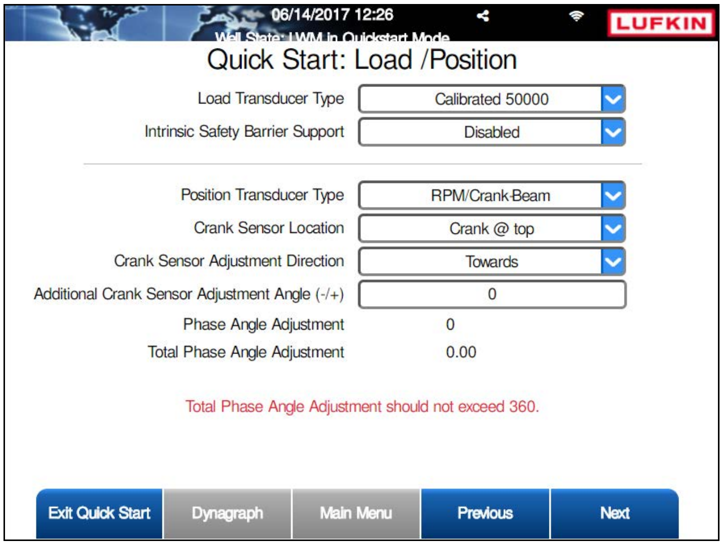


Figure 8-8. Quick Start: Load/Position Setup Screen

The following parameters are configured on this screen:

- **Load Transducer Type**: Select the load transducer type from the drop-down list.
- **Intrinsic Safety Barrier Support**: When an I.S. barrier is used in the pumping system, a voltage drop can occur in the excitation wiring to the load cell. This feature allows the user to define the compensation method for this voltage drop. Select one of the following options from the drop-down list:
  - **Disabled**: Select this option if compensation is not required (e.g. if a barrier is not installed or the barrier type does not introduce a voltage drop).
  - **Analog**: Select this option if the voltage drop will be compensated automatically (e.g. by measuring the drop at Analog Input #2).
  - **Manual**: Select this option if the voltage drop will be compensated with a fixed value.

    With this option selected, the **Load Cell Excitation Volts** field is displayed. Use the keypad to define the expected or measured voltage value at the load cell and then press <**Enter**>.
- **Position Transducer Type**: Select the position transducer type from the drop-down list.
- **Crank Sensor Location**: Select the crank sensor location from the drop-down list.
- **Crank Sensor Adjustment Direction**: Select the crank sensor adjustment direction from the drop-down list.
- **Additional Crank Sensor Adjustment Angle**: Using the keypad, define this value.
- **Phase Angle Adjustment:** This field displays the current phase angle adjustment value.
- **Total Phase Angle Adjustment**: This field displays the total phase angle adjustment value.

Press the **Save** button to save the new values and then press the **Next** button to continue.

Pumping Unit Configuration

The Pumping Unit Configuration screen is displayed next.

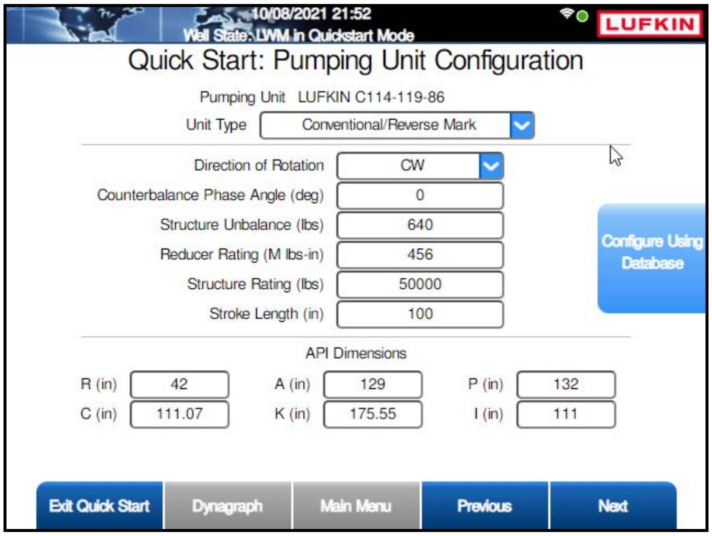


Figure 8-9. Quick Start: Pumping Unit Configuration Screen

The following pumping unit parameters are configured on this screen:

- **Unit Type**: Select the pumping unit type from the drop-down list.
- **Direction of Rotation**: Select the pumping unit's direction of rotation from the drop-down list. **CW** (clockwise) or **CCW** (counterclockwise) are the available options.
- **Counterbalance Phase Angle (deg)**: Use the keypad to define this value and then press <**ENTER**>.
- **Structure Unbalance (lbs)**: Use the keypad to define this value and then press <**ENTER**>.
- **Reducer Rating (lbs)**: Use the keypad to define this value and then press <**ENTER**>.
- **Structure Rating (lbs)**: Use the keypad to define this value and then press <**ENTER**>.

  When the structure rating of the selected pumping unit is lower than the configured **Peak Load Allowed Limit** violation setpoint, the pop-up warning message shown in Figure 8-10 appears:

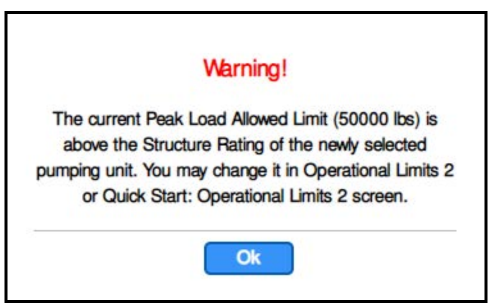


Figure 8-10. Pumping Unit Structure Rating Warning

  See "Operational Limits 2 Screen" on page 8-29 and "Surface Card Setpoints" on page 10-7 for details on configuring the Peak Load Allowed Limit violation setpoint.

- **Stroke Length (in)**: Use the keypad to define this value and then press <**ENTER**>.

- **API Dimensions**: Use the keypad to define these values and then press <**ENTER**>.

The **Configure Using Database** button allows a user to select a pumping unit from that database and automatically fill the required dimensional data fields. The database presently contains dimensional data for 1,570 pumping units.

To use this feature, perform the following steps:

1. Press the **Configure Using Database** button to display the Pumping Unit Database screen shown in Figure 8-11 on page 8-16.
2. Select the pumping unit type using one of the following methods:
    - With the **Search** field highlighted, press <**ENTER**>. Use the keypad to input the unit type into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
    - Use the down arrow key to highlight the box next to the desired unit type and then press <**ENTER**>.

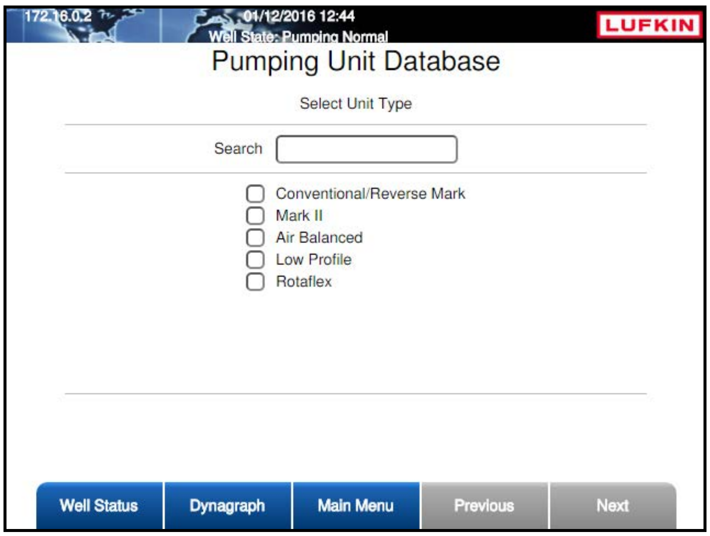


Figure 8-11. Pumping Unit Database – Select Unit Type

Press **Next** to continue.

3. The next screen enables you to select the direction of rotation for the pumping unit.

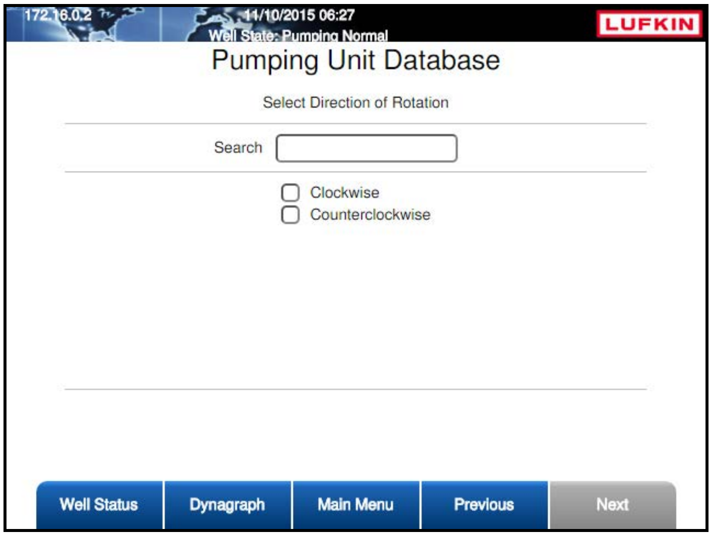


Figure 8-12. Pumping Unit Database – Select Direction of Rotation

Select the direction of rotation using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the direction into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the down arrow key to highlight the box next to **Clockwise** or **Counterclockwise** and then press <**ENTER**>.

Press **Next** to continue.

4. The next screen is used to select the pumping unit's manufacturer code.

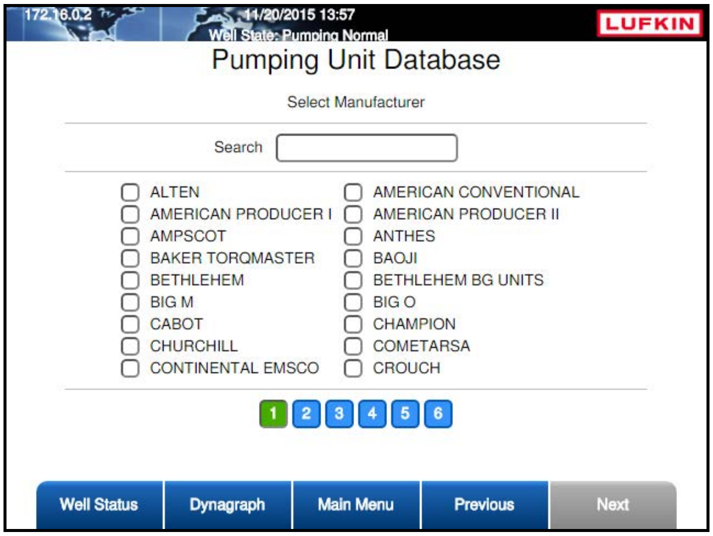


Figure 8-13. Pumping Unit Database – Select Manufacturer Code

Select the manufacturer code using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the manufacturer's name into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.

- Use the arrow keys to highlight the box next to the manufacturer's name in the list and then press <**ENTER**>. To select a different page of names, use the arrow keys to highlight the page number and then press <**ENTER**>.

Press the **Next** button to continue.

5. The next screen is used to select the pumping unit's ID number.

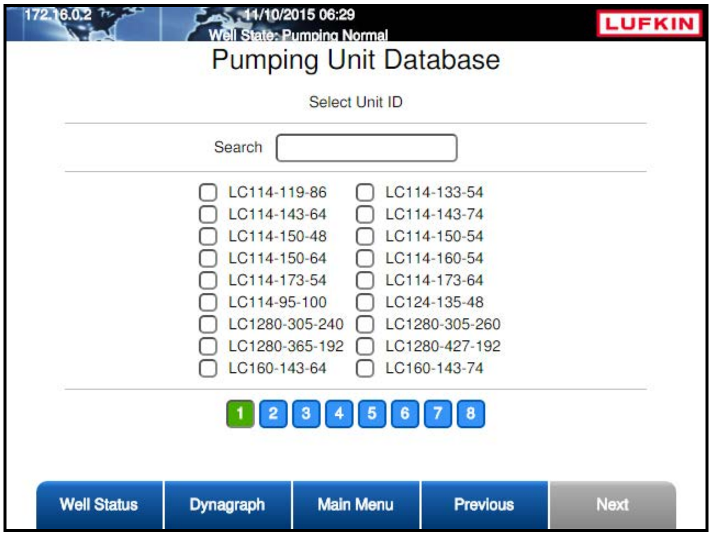


Figure 8-14. Pumping Unit Database – Select Unit ID

Select the unit ID using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the unit ID number into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the arrow keys to highlight the box next to the manufacturer's name in the list and then press <**ENTER**>.

Press the **Next** button to continue.

6. The next screen is used to select the number of crank holes on the pumping unit.

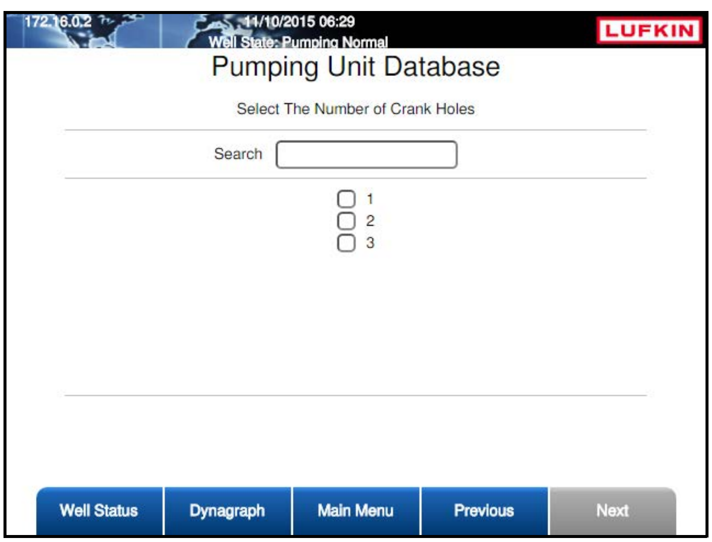


Figure 8-15. Pumping Unit Database – Select Number of Crank Holes

Select the number of crank holes using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the number into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the arrow keys to highlight the box next to the correct number in the list and then press <**ENTER**>.

Press the **Next** button to continue.

7. The next screen displays the results of the database search. Figure 8-16 on page 8-19 shows an example.

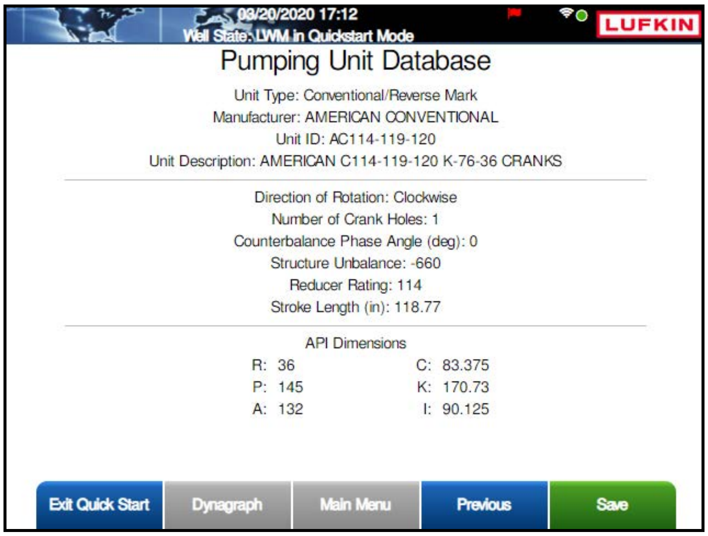


Figure 8-16. Pumping Unit Database – Search Results

Press the **Save** button to save the pumping unit parameters and return to the Pumping Unit Configuration screen.

Press the **Next** button to continue.

Rod Taper Configuration

The Rod Taper Configuration screen is the next screen displayed. The controller must have rod string and pump diameter data to calculate the downhole pump card for each stroke. This screen includes default rod data that applies to most pumping configurations.

Figure 8-17. Quick Start: Rod Taper Configuration Screen

To make changes to this list, press the **Rod Design** button to display the Rod Design screen shown in Figure 8-18.

Figure 8-18. Quick Start: Rod Design Screen

This screen allows the operator to change existing rod data, add new rod data, and delete rod data in the rod string list. These procedures are discussed on the following pages.

Change Existing Rod Data

To change existing rod data, perform the following steps:

1. Use the arrow keys to highlight the rod to be changed and then press <**ENTER**>. The rod field will turn green.
2. Use the **Search Rods** field to search the database for rods by manufacturer. Type the desired name in the field and press <**ENTER**>. The **Rod Name** field automatically shows all the available rod options listed for that manufacturer.
3. Select the desired rod name from the **Rod Name** drop-down list and then press <**ENTER**>. The database automatically fills the remaining fields with the default values for that rod name.

Note: If the desired rod name is not listed, select the **CUSTOM** option and manually input the rod data in each field.

4. Select the desired rod diameter (measured in inches) from the **Diameter** drop-down list and then press <**ENTER**>.
5. Type the desired rod length (measured in feet) in the **Length** field and then press <**ENTER**>.
6. **(CUSTOM rods only)** With the **Rod Type** field highlighted, press <**ENTER**>. Use the up or down arrow keys to select **Steel** or **Fiberglass** from the drop-down list and then press <**ENTER**> again.
7. **(CUSTOM rods only)** Type the rod weight (measured in pounds per foot) in the **Weight** field and then press <**ENTER**>.
8. **(CUSTOM rods only)** Type the rod modulus in the **Modulus** field and then press <**ENTER**>.
9. Press the **Save** button to save the changed values.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Add New Rod Data

The Rod Design screen allows the operator to insert new rod data anywhere in the rod string list.

Note: A maximum of 12 rods can be used in this system.

To add new rod data, perform the following steps:

1. Select one of the following options:
    - To insert a new rod at the top of the rod string list, use the arrow keys to highlight the **Rod 1** field and then press the **Insert Before** button.
    - To insert a new rod in the middle of the rod string list, use the arrow keys to select the **Rod 1** or the **Rod 2** field and then press the **Insert After** button.

- To insert a new rod at the end of the rod string list, use the arrow keys to highlight the **Rod 3** field and then press the **Insert After** button.

The new rod field appears with the Rod Type field highlighted.

2. Use the **Search Rods** field to search the database for rods by manufacturer. Type the desired name in the field and press <**ENTER**>. The **Rod Name** field automatically shows all the available rod options listed for that manufacturer.
3. Select the desired rod name from the **Rod Name** drop-down list and then press <**ENTER**>. The database automatically fills the remaining fields with the default values for that rod name.

Note: If the desired rod name is not listed, select the **CUSTOM** option and manually input the rod data in each field.

4. Select the desired rod diameter (measured in inches) from the **Diameter** drop-down list and then press <**ENTER**>.
5. Type the desired rod length (measured in feet) in the **Length** field and then press <**ENTER**>.
6. **(CUSTOM rods only)** With the **Rod Type** field highlighted, press <**ENTER**>. Use the up or down arrow keys to select **Steel** or **Fiberglass** from the drop-down list and then press <**ENTER**> again.
7. **(CUSTOM rods only)** Type the rod weight (measured in pounds per foot) in the **Weight** field and then press <**ENTER**>.
8. **(CUSTOM rods only)** Type the rod modulus in the **Modulus** field and then press <**ENTER**>.
9. Press the **Save** button to save the changed values.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Delete Rod Data

To delete rod data, perform the following steps:

1. Use the arrow keys to highlight the rod field to be deleted and then press <**ENTER**>. The rod field will turn green.
2. Press the **Delete Rod** button to delete the rod data.
3. Press the **Save** button to save the change.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Press the **Next** button to continue.

LWT/PIP Parameters

The next three screens allow the operator to use Lufkin's patented algorithms that can calculate pump intake pressure (PIP) and make automated fluid volume adjustments for pump slippage, fluid shrinkage, and tubing movement to determine the pump fluid load (LWT). These screens are described in the following paragraphs.

LWT/PIP Parameters 1/3 Screen

The first of three LWT/PIP Parameters screens is displayed next.

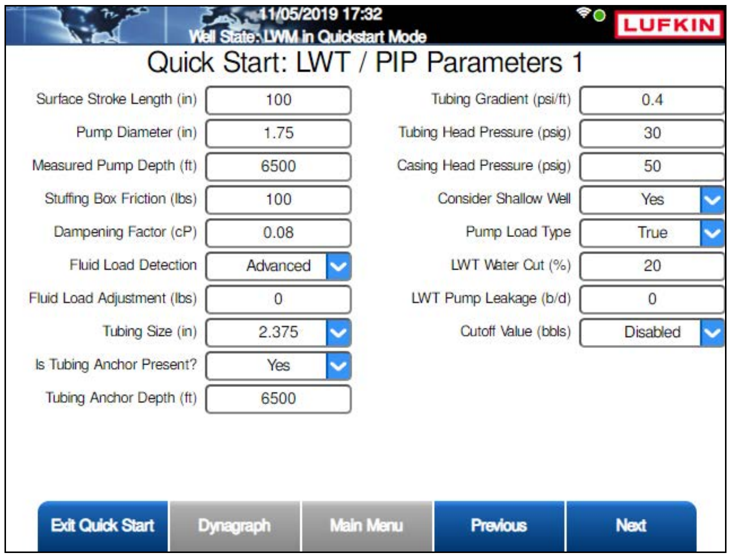


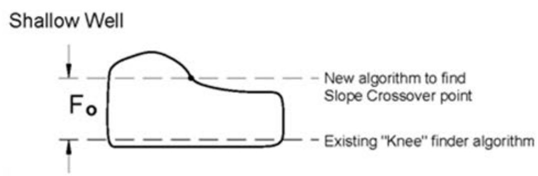
Figure 8-19. Quick Start: LWT/PIP Parameters Screen

The following values are configured on this screen:

- **Surface Stroke Length (in)**: Specify the correct surface stroke length in inches. The length needs to be precise to get accurate results, so use a tape measure when in doubt.
- **Pump Diameter (in)**: Specify the diameter of the pump plunger in inches.
- **Measured Pump Depth (ft)**: Specify the true vertical depth from the surface to the pump intake, in feet.
- **Stuffing Box Friction**: This factor is used to compensate for surface friction due to tight stuffing box seals. Enter in pounds.
- **Dampening Factor**: If the tubing string is not anchored at all, or if the tubing anchor is more than a few hundred feet above the pump intake, specify **Yes**.
- **Fluid Load Detection**: Select **Basic** or **Advanced** from drop-down list.
  - If **Basic** is selected, the controller calculates fluid load by subtracting the average downstroke load from the average upstroke load without making any attempt to analyze the pump card shape for friction loads.
  - If **Advanced** is selected, the controller uses more advanced techniques of PIP calculation theory for calculating fluid load.
- **Fluid Load Adjustment (lbs)**: The fluid load that the controller calculates by either the Basic or Advanced fluid load detection method can be adjusted by using this field.

- **Tubing Size (in)**: Specify the API tubing size in inches.
- **Is Tubing Anchor Present?**: Select **Yes** or **No** from the drop-down list. If the tubing string is not anchored at all, or if the tubing anchor is more than a few hundred feet above the pump intake, select **Yes**.
- **Tubing Anchor Depth (ft)**: (This field is only visible when the **Is Tubing Anchor Present?** parameter is set to **Yes**.) The tubing should be secured or "anchored" at the surface as a minimum. Therefore, if no tubing anchor is present, specify a value of 0 for the anchor depth. If an anchor is present up hole from the pump intake, specify the depth of the anchor in feet along the tubing (as opposed to true vertical depth).
- **Tubing Gradient (psi/ft)**: Specify the gradient for the fluid in the tubing in psi/feet.
- **Tubing Head Pressure (psig)**: Specify the gauge pressure at the well head tubing in PSI.
- **Casing Head Pressure (psig)**: Specify the pressure in PSI gauge of the casing at the surface.
- **Consider Shallow Well**: Select **Yes** or **No** from the drop-down list. No generally accepted exact definition of a "shallow well" exists. As a general rule, a shallow well is a well with a pump depth of less than 3,000 feet or a deeper well with a large diameter pump. The primary indicator is the shape of the downhole pump card.

  If the pump card has the general shape as illustrated in the example below, select **Yes**.



- **Pump Load Type**: Select **True** or **Effective** from the drop-down list.
- **LWT Water Cut (%)**: Specify the percentage of the produced fluid that is water.
- **LWT Pump Leakage (b/d)**: Specify the amount of leakage around the pump plunger in barrels per day.
- **LWT Cutoff Control**: Select **Enabled** or **Disabled** from the drop-down list.
- **Cutoff Value (bbls)**: (This parameter is only visible when the **LWT Cutoff Control** parameter is set to **Enabled**.) Use the keypad to specify a daily production cutoff value in barrels.

Press the **Save** button to save new or changed values, and then press the **Next** button to display the next screen.

LWT/PIP Parameters 2/3 Screen

This is the second of three LWT/PIP Parameters screens.

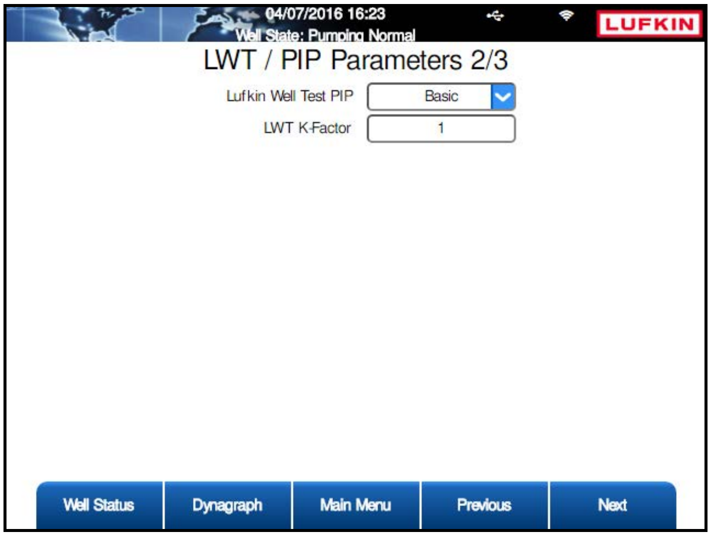


Figure 8-20. Quick Start: LWT/PIP Parameters Screen (2 of 3)

Details of this screen are discussed below.

Lufkin Well Test PIP Configuration

Select the desired Lufkin Well Test PIP configuration. The two drop-down list options are **Basic** or **Advanced**. These options are discussed below:

- When the **Basic** option is selected, the basic calculation for PIP uses only the pump depth and diameter, tubing fluid gradient, and tubing head pressure. No adjustments are made for effects of gas in solution.

  The Basic option uses the LWT K-Factor parameter as a calibration factor to correct for slippage and shrinkage. Use the keypad to define this value.

- When the **Advanced** option is selected, the following parameters are displayed:
  - **Oil Density Degree API**: This is the oil density expressed in degrees API. Use the keypad to define this value.
  - **Water Specific Gravity**: This is the specific gravity of the produced water. Use the keypad to define this value.
  - **Gas Specific Gravity**: This is the specific gravity of the produced gas. Use the keypad to define this value.
  - **Pump Temperature (°F)**: This is the fluid temperature at the pump intake. Use the keypad to define this value.
  - **Bubble Point Pressure (psia)**: This is the pressure at which gas that has been forced into solution by reservoir pressure will start to break out of solution and form gas bubbles. Use the keypad to define this value.
  - **Formation Volume Factor (rb/stb)**: This is the volume of produced fluid will shrink as the ambient pressure decreases and solution gas breaks out of solution. The volume of fluid that passes through the pump barrel reservoir barrel (or rb) may therefore be greater than the volume of fluid production measured at a surface storage unit (stock tank barrel or stb). The shrinkage factor is pump volume divided by surface volume. The formation

volume factor is a theoretical shrinkage factor when the fluid is at bubble point pressure rather than actual surface pressure. Use the keypad to define this value.

- **Solution GOR (scf/stb)**: This is a measure of how much gas is evolved from oil (at or above bubble point) as the oil goes from the reservoir pressure and temperature to separator conditions. The units are volume of gas divided by volume of oil at separator conditions. Use the keypad to define this value.

Figure 8-21 shows the Advanced option enabled. Use the keypad to define these values.

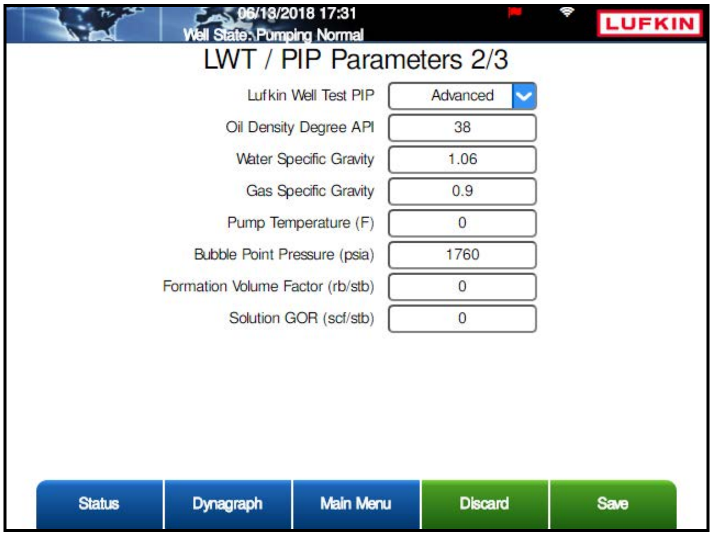


Figure 8-21. Quick Start: LWT/PIP Parameters Screen (2 of 3) – Advanced Option

Press the **Save** button to save the new values.

Press the **Next** button to display the next screen.

LWT/PIP Parameters 3/3 Screen

This is the third LWT/PIP Parameters screen.

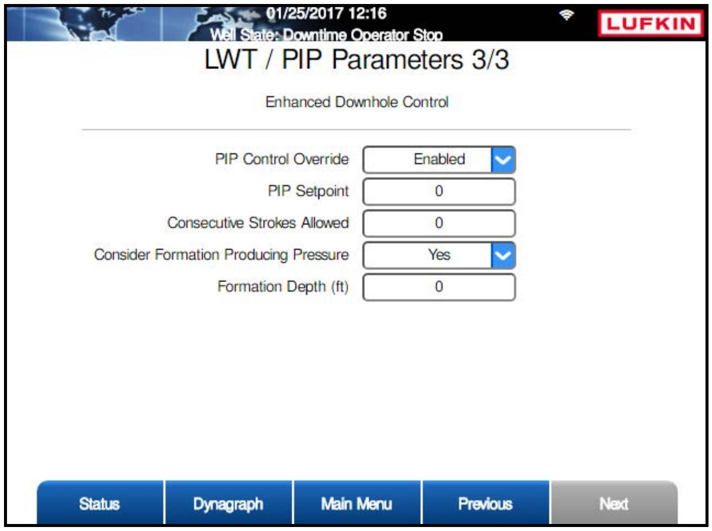


Figure 8-22. Quick Start: LWT/PIP Parameters Screen (3 of 3)

The LWM 2.0 VSD RPC is capable of cycling the well based on the calculated PIP. If the calculated PIP falls below the PIP setpoint (described below), the pumping unit will be shut down for a downtime cycle even though the calculated pump fillage is greater than the fillage setpoint.

Select **Enabled** to enable the PIP Control Override feature. The following fields appear when this feature is enabled:

- **PIP Setpoint**: Specify the low limit for calculated PIP. If the calculated PIP falls below the specified number of strokes in the Consecutive Strokes Allowed field (see below), the pumping unit will be stopped for a downtime cycle.

  Use the keypad to define the pump intake pressure setpoint.
- **Consecutive Strokes Allowed**: Specify the number of consecutive pump strokes that the calculated PIP must be below the PIP setpoint before the pumping unit is stopped. Use the keypad to define the number of consecutive strokes allowed before the override is activated.
- **Consider Formation Producing Pressure**: Specify whether you want to use the Consider Formation Pressure query feature. Select **Yes** if the pump is set above “mid-perfs.”

Note: When **Yes** is selected, the Formation Depth field appears below it.

- **Formation Depth**: (This field is only visible when the **Consider Formation Producing Pressure** parameter is enabled.) Use the keypad to specify the depth of the topmost perforations in feet.

Press the **Save** button to save the parameter changes.

Drive Selection/Motor Data

The Drive Selection/Motor Data screen is displayed next as shown in Figure 8-23 below.

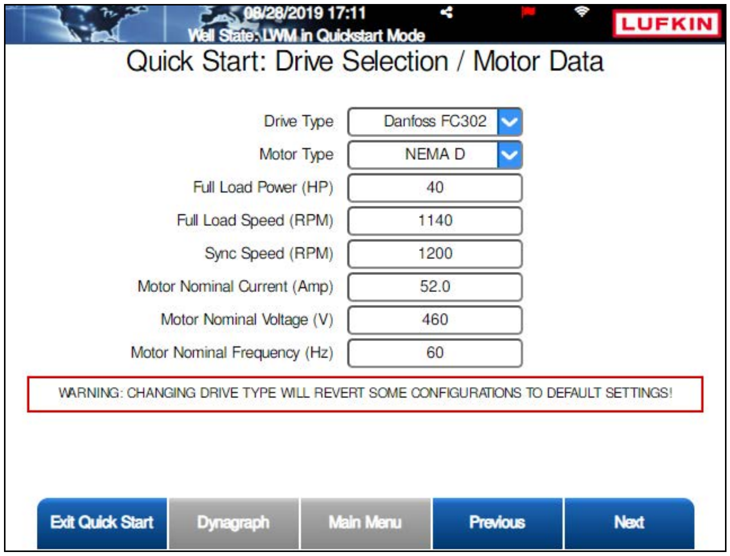


Figure 8-23. Quick Start: Drive Selection/Motor Data Screen

Using the keypad, select the drive type and define the motor data as described below:

- **Drive Type**: Select **Danfoss FC302** from the drop-down list.
- **Motor Type**: Select the appropriate motor type from the drop-down menu and then press <**ENTER**>. The available options are **NEMA D** and **Ultra High Slip**.
- **Full Load Power (HP)**: This value is the nameplate horsepower rating of the motor.

Note: The power rating of the motor must be entered in horsepower. If the motor is rated in kilowatts (kW), convert kW to HP by multiplying the kW value by 1.33.

- **Full Load Speed (RPM)**: This parameter is the full load speed of the motor.
- **Sync Speed (RPM)**: This parameter specifies the no-load speed of the motor. This information should be available on the motor's nameplate.
- **Motor Nominal Current (Amp)**: This parameter configures the full rated load motor current. This information is typically written on the motor's nameplate.
- **Motor Nominal Voltage (V)**: This parameter configures the design operating voltage for the motor. This information is typically written on the motor's nameplate.
- **Motor Nominal Frequency (Hz)**: This parameter configures the nominal motor frequency. This value should be written on the nameplate. The frequency is typically 60 Hz in the US or 50 Hz in many international locations.

Press the **Next** button to display the next screen.

VSD Parameter Settings

The first of two Parameter Settings screens is displayed next.

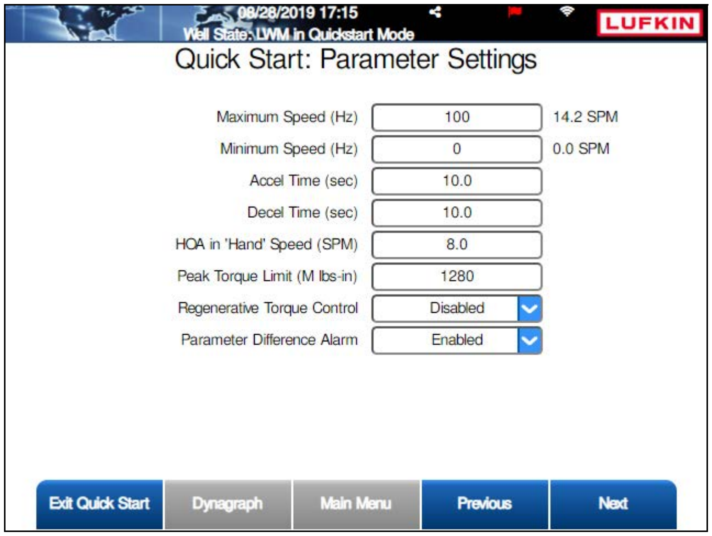


Figure 8-24. Quick Start: Parameter Settings Screen

The following parameters are configured on this screen:

- **Maximum Speed**: This parameter sets the maximum speed (measured in Hz) of the inverter drive. The current pumping speed is displayed to the right of the text field.

  Using the keypad, define the value for this parameter.

- **Minimum Speed**: This parameter sets the minimum speed (measured in Hz) of the inverter drive. The current pumping speed is displayed to the right of the text field.

  Using the keypad, define the value for this parameter.

- **Accel Time (sec)**: This parameter sets the length of time for acceleration from 0 to 120 Hz. This ramp rate will apply to all speed increase operations, regardless of the speed increase amount.
- **Decel Time (sec)**: This parameter sets the length of time for deceleration from maximum speed to minimum speed. For more details, see “Accel Time” above.
- **HOA in ‘Hand’ Speed (SPM)**: (This parameter applies to HOA or HOL switch-equipped controllers only.) When the controller’s HOA or HOL switch is set to Hand mode, the pumping speed is controlled by this parameter. Using the keypad, define the value for this parameter. See “HOL Switch” on page 7-3 for details on this switch.
- **Peak Torque Limit (M-in-lbs)**: The maximum allowed torque value in thousands of inch-pounds. If the controller calculates a torque value greater than this limit at the completion of a stroke, the pumping unit shuts down early in the next upstroke.
- **Regenerative Torque Control**: A beam pumping unit has a tendency to overdrive the prime mover at certain points in the pumping cycle due to counterbalance conditions and unit inertia. This overdrive condition causes the motor to change from a motoring state to a generating state and begin to return power to the drive inverter section. The returned power causes the DC bus of the variable speed drive to rise, possibly reaching a high enough level for the drive to trip out on a high bus voltage. The **Regenerative Torque Control** feature (when enabled) automatically switches the VSD from Speed Control mode to Torque Control mode when

rising DC bus voltage is detected. In Torque Control mode, the drive will increase the speed signal to the inverter in order to stay in a positive torque, or motoring, mode of operation. This speed will increase up to the programmed maximum speed.

If well conditions are favorable, the Regenerative Torque Control feature can eliminate the need for dynamic braking resistors (DBR).

With certain types of pumping units and in situations where the unit is not well balanced, RTC can cause undesirable behavior of the pumping unit. In these cases, RTC should be disabled and a DBR package will be required.

When a DBR is used, the RTC feature may still be enabled and the working peak speed can be adjusted so that the torque control operation can handle some of the regenerated energy, thereby decreasing the energy that needs to be dissipated by the DBR. For more suggestions about the best way to handle regenerative energy in your particular application, consult your Lufkin representative.

Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.

- **Parameter Difference Alarm**: The LWM 2.0 verifies its defined parameters with the parameters used by the VSD. A difference in these parameters will trigger an alarm when the Parameter Difference Alarm is enabled.

  Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.

Press the **Next** button to display the second VSD Parameters screen shown in Figure 8-25.

Figure 8-25. Quick Start: VSD Parameter Settings Screen (2 of 2)

This screen allows the operator to assign an action for connected status output relays. Available options are

- Disabled
- Run
- Fault

Use the arrow keys to select the desired option from the drop-down list and then press <**ENTER**>.

Press the **Save** button to save changes made on this screen and then press the **Next** button.

VSD Application Miscellaneous Control Settings

The VSD Application Misc. Control Settings screen is the next screen displayed. See Figure 8-26.

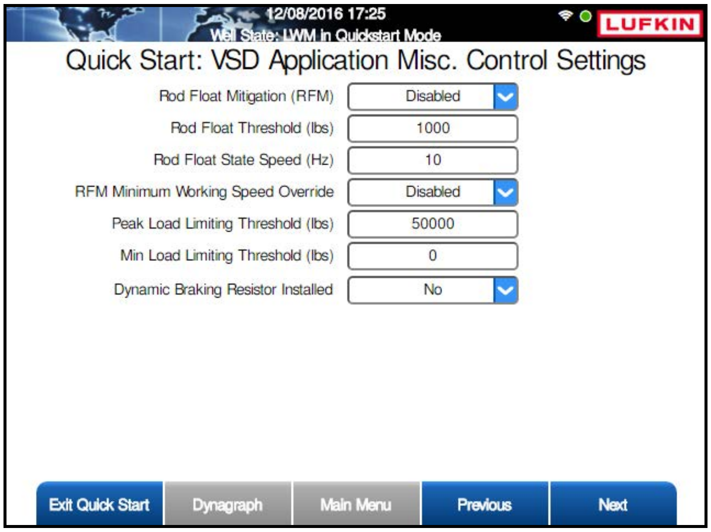


Figure 8-26. Quick Start: VSD Application Miscellaneous Control Settings Screen

Use the keypad to configure the following parameters on this screen:

- **Rod Float Mitigation (RFM)**: This is a powerful feature for dynamically operating a pumping unit to minimize or eliminate rod float. If rod float or rod hangup is not a problem for this well, leave this parameter disabled.

  To enable or disable this feature, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to highlight the desired option and then press <**ENTER**> again.

Note: The RFM feature is only available with wired position transducers.

- **Rod Float Threshold (lbs)**: When the rod load drops below this threshold, the controller determines that it is likely that rod float is occurring, and it activates the Rod Float Mitigation feature. This feature stays active until the load again rises above the threshold. Lufkin Automation recommends a value of 200 – 300 lbs (91 – 135 kg).

  Use the keypad to define this value.

- **Rod Float State Speed (SPM)**: This value is the speed the pumping unit uses when the Rod Float Mitigation feature is activated by the current polished rod load falling below the programmed Rod Float Load Threshold value. The response time to this slower speed command is dependent on the deceleration time programmed in the VSD and the response time of the VSD analog output function.

  Use the keypad to define this value.

- **RFM Minimum Working Speed Override**: This parameter allows the pumping unit to temporarily run below its defined minimum working speed until the rod float condition is no longer present.

  Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.

- **Peak Load Limiting Threshold (lbs)**: Setting this parameter to a value below the Peak Load Allowed limit activates this safety feature. The units for this parameter are in pounds, with a default value of 50,000 lbs.

  If the peak load observed during a pumping unit cycle exceeds the Working Peak Load Limiting value, the controller makes a decision to slow the pumping unit by one step, reducing the current Speed Output by the Speed Decrease Size. If the Working Peak Load Limiting value is again exceeded on the following stroke, the unit will be slowed again. In this fashion, the speed will be adjusted slower until the Working Peak Load Limit is no longer violated. Working Peak Load violations override the pump fillage control decision. When this limit is not violated, the algorithm returns to the normal speed change decision process based on fillage.

- **Min Load Limiting Threshold (lbs)**: Setting this parameter to a value above the Minimum Load Allowed activates this safety feature. The units for this parameter are in pounds, and the default is 0 lbs.

  If the minimum load observed during a pumping unit cycle falls below the Minimum Load Limiting value, the controller makes a decision to slow the pumping unit by one step. If the Working Minimum Load Limiting value is again exceeded on the following stroke, the unit will be slowed again. In this fashion the speed will be adjusted slower until the Working Minimum Load Limiting value is no longer violated. When this limit is not violated, the algorithm returns to the normal speed change decision process based on pump fill percent.

- **Dynamic Braking Resistor Installed**: If a dynamic braking resistor (DBR) unit is installed, select **Yes** from the drop-down list. Two additional fields will appear:

  - **Dynamic Braking Resistance (Ohm)** – Use the keypad to define the resistance of the installed DBR.
  - **Allowable Continuous Braking Power (kw)** – Use the keypad to define the power rating of the installed DBR.

Note: This information is listed on the DBR nameplate.

  If there is no DBR installed, select **No** from the drop-down list.

Press the **Next** button to display the next screen.

VSD Control Settings

The VSD Control Settings screen is the next screen displayed.

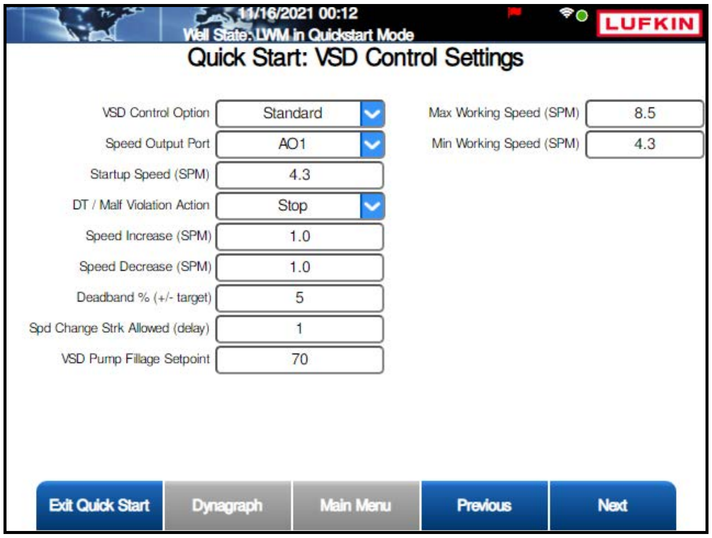


Figure 8-27. VSD Control Settings Screen

Use the keypad to define the values for the following parameters:

- **VSD Control Option:** Select **Standard**, **Fixed Speed**, or **Advanced** from the drop-down list.
- **Speed Output Port**: Select **AO1** or **AO2** from the drop-down list.
- **Startup Speed (SPM)**: Using the keypad, define the value for this parameter.
- **DT/Malf Violation Action**: Select the method the controller will use when a fault occurs. **Stop** and **Run Low Speed** are the options available in the drop-down list.
- **Speed Increase (SPM)**: When the controller decides that it should increase pumping unit speed, it will add the **Speed Increase** value to the current speed output, and change the speed output accordingly thereby speeding up the pumping unit.

  Using the keypad, define the value for this parameter.
- **Speed Decrease (SPM)**: When the controller decides that it should decrease pumping unit speed, it will subtract the **Speed Decrease** value from the current **Speed Output** value and change the analog output accordingly thereby slowing the pumping unit.

  Using the keypad, define the value for this parameter.
- **Deadband % (+/– target)**: This parameter is used in the decision making process to determine whether the controller should speed up or slow down the pumping unit.

  Using the keypad, define the value for this parameter.
- **Speed Change Stroke Allowed (delay)**: This parameter controls how many strokes are allowed before the controller speeds up or slows down the pumping unit.

  Using the keypad, define the value for this parameter.
- **VSD Pump Fillage Setpoint**: (This parameter is only used in **VSD Downhole** control mode.) The VSD Pump Fillage Setpoint sets the target fillage level in the pump barrel. When the fillage level exceeds this value, the controller speeds up the pumping unit. When the fillage level drops below this value, the controller slows down the pumping unit.

- **VSD DH Pressure Setpoint**: (This parameter is only used in **VSD DH Pressure** control mode.) The VSD DH Pressure setpoint sets the target downhole pressure level in the well. When the downhole pressure drops below
- **Max Working Speed (SPM)**: Using the keypad, define the maximum working speed for the drive to run.
- **Min Working Speed (SPM)**: Using the keypad, define the minimum working speed for the drive to run.

Press the **Next** button to display the next screen.

Variable Speed Drive Initialization

The Variable Speed Drive Initialization screen shown in Figure 8-28 is displayed next.

Figure 8-28. Quick Start: Variable Speed Drive Initialization Screen

Press <**ENTER**> to start the initialization process. When initialization is complete, press the **Next** button to display the next screen.

Start Motor

The Start Motor screen is displayed next. This screen enables the operator to start or stop the pumping unit during the configuration process.

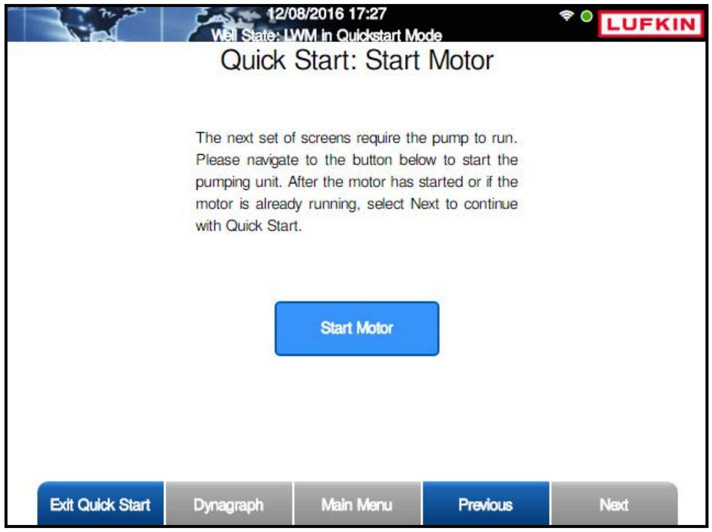


Figure 8-29. Quick Start: Start Motor Screen

WARNING: Make sure all personnel are clear of the pumping unit before starting the motor.

Note: Turn the HOL switch to the **LWM** (Auto) position before starting the motor.

Press <**ENTER**> to start or stop the motor. Once the system detects the motor is running, the **Next** button will turn blue. Press the **Next** button to display the next screen.

Reference NREV Calibration

The Reference NREV screen is the next screen displayed as shown in Figure 8-30.

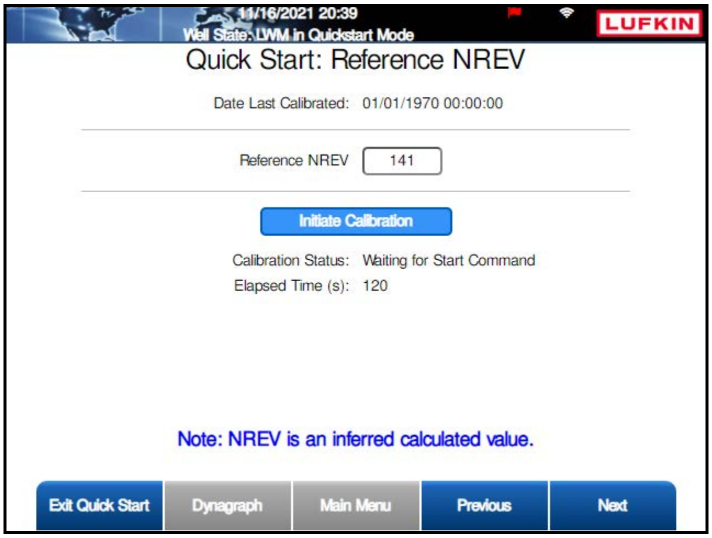


Figure 8-30. Reference Revolution Calibration Screen

In order for some control features to work properly, the LWM 2.0 RPC needs to know the number of motor revolutions required per pump cycle under normal pumping. If the diameter of either drive belt sheave is changed, the pumping speed will change, requiring recalibration of this reference revolution (Ref NREV) parameter.

The following status information is shown on this screen:

- Current Reference Revolution Reading
- Date of Last Calibration
- Reference NREV
- Reference Revolution Calibration Status
- Calibration Elapsed Time

If reference revolution calibration is needed, use the arrow keys to highlight the **Initiate Calibration** button. Press <**ENTER**> to start the calibration procedure. Watch the **Ref Rev Calibration Status** field to check progress of the automatic calibration operation. When the operation is completed, the status field reads SUCCESSFUL.

To stop the calibration operation, use the arrow keys to highlight the **Abort** button and then press <**ENTER**> on the keypad.

Press the **Next** button to display the next screen.

Dynagraph Configuration

The Dynagraph configuration screen is the next screen displayed.

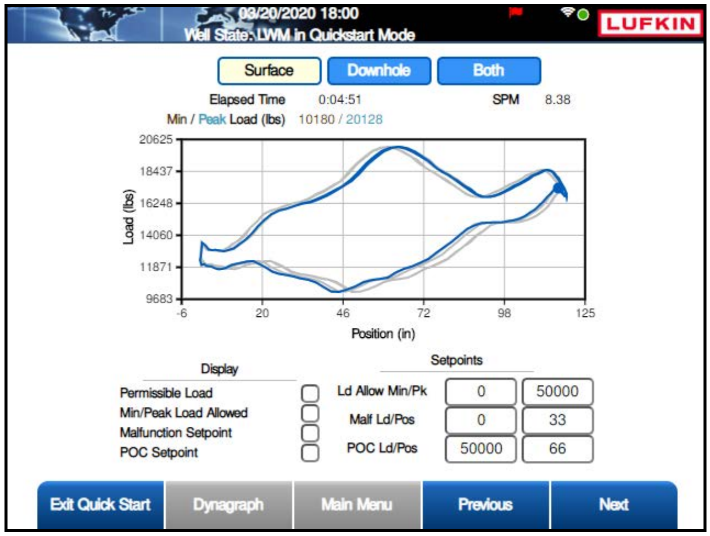


Figure 8-31. Quick Start – Dynagraph Card Configuration Screen

This screen shows a real-time dynagraph of the load and position data recorded during pumping operation. Three dynagraph display options are provided:

- **Surface**: This button displays the Surface card. This card and its functions are described below.
- **Downhole**: This button displays the Downhole card. See “Downhole Card” on page 8-40 for details on this card and its functions.
- **Both**: This button displays a combined view of the surface and downhole cards. See “Both Cards” on page 8-41 for more details.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

Surface Card

The Surface Card shown in Figure 8-31 is displayed by default. This card shows a real-time dynagraph of the surface load and position data recorded during pumping operation. Relevant status information is also displayed.

Display Options

The Surface Card has several options for displaying load and setpoint data. These are described on the following pages.

- **Permissible Load**: This check box provides the option of displaying the defined permissible load values. See “Surface Card Setpoints” on page 8-39 for details on configuring these parameters.

  Press the down arrow to highlight the **Permissible Load** check box and then press <**ENTER**> to select this option. The Permissible Load data is displayed in red on the card.

  To hide these values, clear the **Permissible Load** check box using the same method described above.

- **Min/Peak Load Allowed**: This check box provides the option of displaying the minimum and the maximum allowed values for load input. See “Surface Card Setpoints” on page 8-39 for details on configuring these parameters.

  Press the down arrow to highlight the **Min/Peak Load Allowed** check box and then press <**ENTER**> to select this option. The Min/Peak Load Allowed values are displayed as horizontal lines on the card.

  To hide these values, clear the **Min/Peak Load Allowed** check box using the same method described above.

- **Malfunction Setpoint**: This check box provides the option of displaying the Malfunction Setpoint value on the dynagraph. See “Surface Card Setpoints” on page 8-39 for details on configuring the parameters for this setpoint.

  Press the down arrow to highlight the **Malfunction Setpoint** check box and then press <**ENTER**> to select this option. The Malfunction Setpoint value is displayed as a purple square on the card.

  To hide this setpoint, clear the **Malfunction Setpoint** check box using the same method described above.

- **POC Setpoint**: This check box provides the option of displaying the POC Setpoint value on the dynagraph. See “Surface Card Setpoints” for details on configuring the parameters for this setpoint.

  Press the down arrow to highlight the **POC Setpoint** check box and then press <**ENTER**> to select this option. The POC Setpoint value is displayed as a green diamond on the card.

  To hide this setpoint, clear the **POC Setpoint** check box using the same method described above.

- **Sectional Speed**: (This check box is only visible when the Sectional Speed feature is enabled. See “Sectional Speed Control” on page 10-39 for more information.) Select this check box to display the sectional speed data as shown in Figure 8-32.

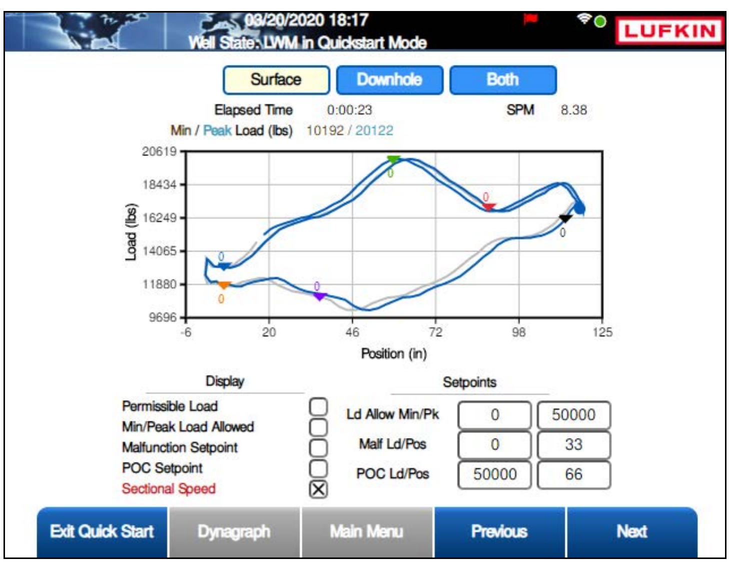


Figure 8-32. Surface Card with Sectional Speed Data

Surface Card Setpoints

The configurable surface card setpoints are as follows:

- **Ld Allow Min/Pk**: These setpoints set the minimum and peak load allowed during operation. If the load exceeds the peak load setpoint or drops below the minimum load setpoint, the controller instantly shuts down the pumping unit with no consecutive stroke delay.

  The setpoint parameters are as follows:

  - **Allowed Minimum Load**: The left parameter field sets the minimum load allowed during operation. If the load drops below this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay.
  - **Allowed Peak Load**: The right parameter field sets the maximum load allowed during operation. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay.

  To change these parameters, do the following:

  a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

  b. Use the keypad to define the parameter value and then press <**ENTER**> again.

  Note: The controller automatically scales the dynagraph screen to show both Allowed Peak and Allowed Min Load. If the programmed values are far above or below the actual working peak and minimum loads, the dynagraph trace on the screen will be fairly small. To obtain a larger dynagraph trace, configure the Allowed Peak and Allowed Min Load values to within 15 percent or 25 percent above/below the working loads.

- **Malf Ld/Pos**: These setpoints are used to check for rod parts or other pump malfunctions that cause no fluid load to be picked up by the pump. If the load falls below the Malfunction load setpoint in the upstroke, the controller counts that as a violation of the setpoint. The number of consecutive Malfunction Strokes Allowed can be configured on the Operational Limits 1 screen. (See "Operational Limits 1 Screen" on page 10-26 for details on this screen.)

  The configurable parameters are:

  - **Load** – The left parameter field sets the minimum load weight allowed during operation.
  - **Position (inches)** – The right parameter field sets the minimum distance the rod must move during operation.

  To change these parameters, do the following:

  a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

  b. Use the keypad to define the parameter value and then press <**ENTER**> again.

  The malfunction setpoint is displayed as a black square on the dynagraph.

- **POC Ld/Pos Setpoint**: This setpoint is the pump off control **"**limit**"** for the Surface control mode. When the load goes above the POC setpoint in the downstroke, the controller counts that as a pump off stroke. The consecutive number of pump off strokes allowed is specified with the RPC Control Parameter programming screen.

The parameters for this setpoint are:

- **Load (lbs)** – the maximum load weight allowed during operation
- **Position (inches)** – the maximum distance the rod can move during operation

To change these parameters, do the following:

a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

b. Use the keypad to define the parameter value and then press <**ENTER**> again.

The POC setpoint is displayed as a round black dot on the dynagraph.

Downhole Card

The Downhole card displays a realtime live trace of the well's downhole activity. Relevant status data is also displayed at the top and lower left sides of the screen. Figure 8-33 shows an example of this card.

Figure 8-33. Quick Start – Dynagraph Configuration Screen (Downhole Card)

The configurable downhole card parameters are as follows:

- **Pump Fillage**: This value is the pump off shutdown level when Downhole control mode is selected.
- **DH Press Low Limit (psi)**: This value is the low pressure limit when VSD DH Pressure control mode is selected.
- **2ry Pump Fillage (%)**: This value is the secondary pump off shutdown level for the Downhole control mode.
- **Fluid Load (lbs)**: This value is the Low limit for the fluid load control function. See "Current Fluid Load" on the previous page.
- **Fill Base**: This value is the full range load percentage of the downhole card at which the controller, in the downstroke, starts to look for the slope change indicating plunger contact with fluid in the pump barrel. The adjustable fill base allows the controller to find accurate net stroke

with a variety of unusual pump conditions. If net stroke calculation results do not appear to be reasonable, adjust the fill base up or down for more logical results. Zero percentage is the minimum load value for the downhole card. The default value of 45 will work for most wells.

To change these parameters, do the following:

1. Use the arrow keys to highlight the desired parameter and then press <**ENTER**>.
2. Use the keypad to define the parameter value and then press <**ENTER**> again.

Both Cards

The Both display option shows a split-screen realtime live trace of both surface and downhole activity.

Figure 8-34. Both Cards Displayed

This screen displays status information only and is not configurable.

Press the **Next** button to display the next screen.

Completing the Quick Start Procedure

The next screen indicates successful completion of the Quick Start configuration process. Press the **Exit Quick Start** button to exit Quick Start and return to the Main Menu screen.

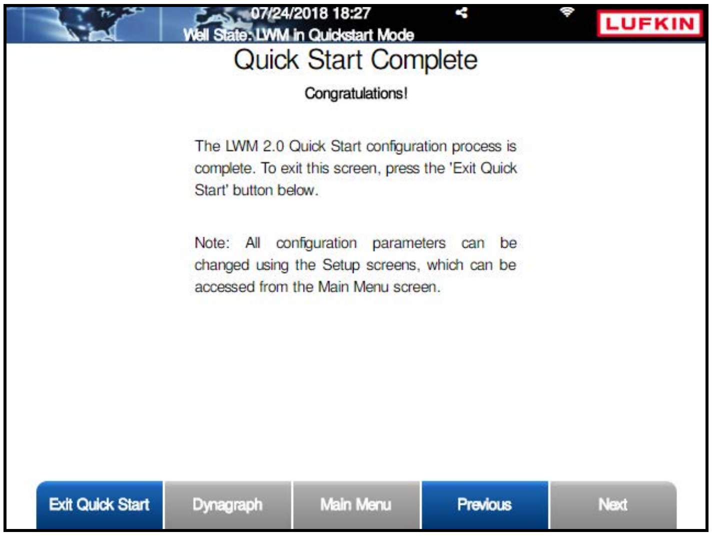


Figure 8-35. Quick Start Complete Screen

Note: The pumping unit will continue running after exiting the Quick Start process. Turn the HOL switch to the **OFF** position if the pumping unit is required to be off.

Section 9: System Configuration

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Section Overview

This section discusses the system configuration of the LWM 2.0 controller. Basic functions like setting current date and time, units of measurement, password setup, and sleep configuration are all needed to ensure accurate data analysis by the controller.

Note: This manual describes the functions included in Version 1.36.00 of the LWM 2.0 firmware.

System Menu Screens

From the Main Menu screen, press the **System** button to display the first of two system configuration screens shown in Figure 9-1.

Figure 9-1. System 1 Menu Screen

From the first System menu screen, press the **Next** button to display the second System menu screen shown in Figure 9-2.

Figure 9-2. System 2 Menu Screen

The options available on these screens are discussed on the following pages.

Date and Time

From the System 1 screen, press the **Date/Time** button to display the Date/Time Configuration screen.

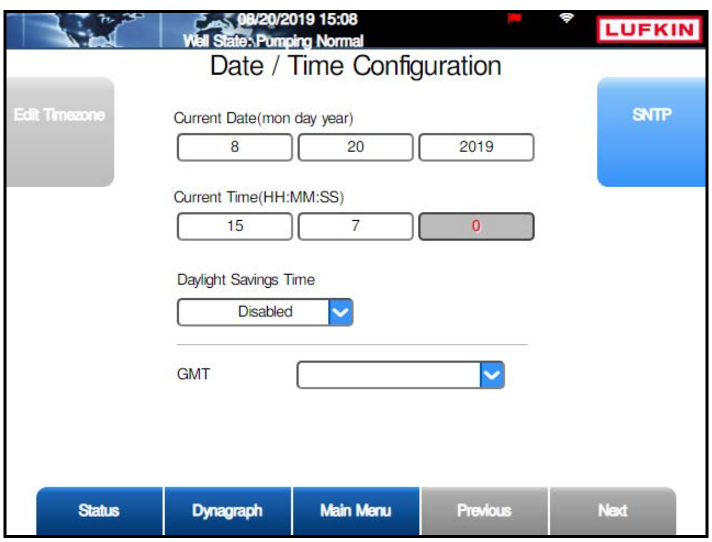

Figure 9-3. Date/Time Configuration Screen

Use the arrow keys to navigate to the desired field. Use the number keys to define the correct date and time and then press <**ENTER**>.

This screen provides options for selecting time zones. These are discussed in the following sections.

Daylight Savings Time

To enable the Daylight Savings Time feature, use the arrow keys to highlight the **Daylight Savings Time** field and then press <**ENTER**>. Press the down arrow to select the **Enabled** option and then press <**ENTER**> again.

The **Edit Timezone** button will then become active. Perform the following steps to configure the time zone:

1. Press the **Edit Timezone** button to display the Time Zone Configuration screen shown in Figure 9-4.

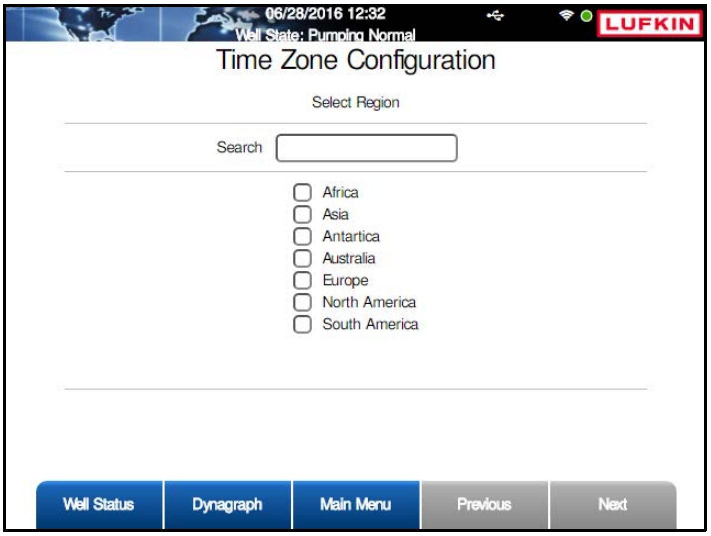

Figure 9-4. Time Zone Configuration Screen – Select Region

2. Select the appropriate region and then press the **Next** button.
3. In the screen shown in Figure 9-5, select the desired location and then press the **Next** button.

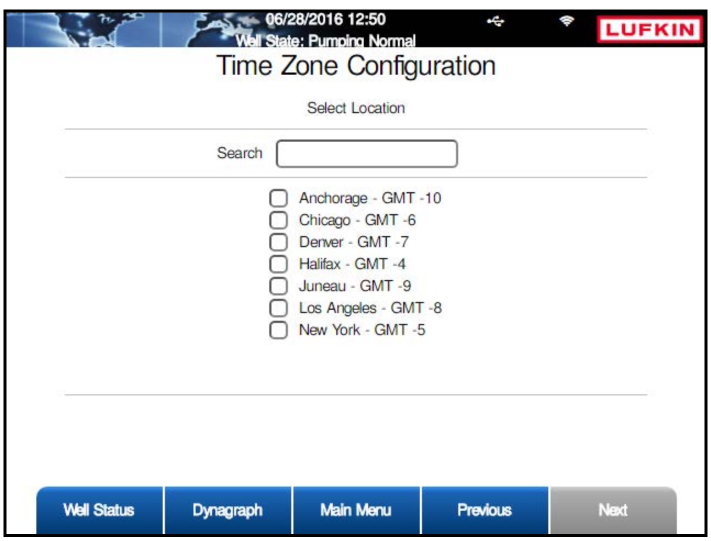

Figure 9-5. Time Zone Configuration Screen – Select Location

4. Press the **Save** button to save the selected time zone configuration.

Greenwich Mean Time (GMT)

Use the arrow keys to highlight the GMT drop-down list and then press <**ENTER**>. Use the down arrow to highlight the desired time zone and then press <**ENTER**> again.

Press the **Save** button to save the selected time zone configuration.

Simple Network Time Protocol (SNTP)

The Simple Network Time Protocol is used to synchronize the LWM 2.0 controller's clock when it is connected to a network.

From the Date/Time Configuration screen, press the **SNTP** button to display the SNTP Configuration screen shown in Figure 9-6.

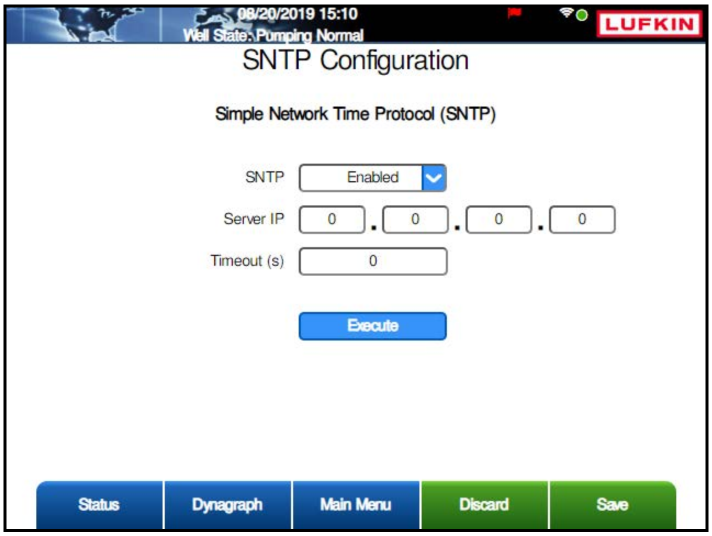

Figure 9-6. SNTP Configuration Screen

To enable the SNTP feature, use the arrow keys to highlight the **SNTP** field and then press <**ENTER**>. Press the down arrow to select the **Enabled** option and then press <**ENTER**> again.

The following parameters will appear:

- **Server IP**: Use the keypad to type the IP address of the SNTP server.
- **Timeout(s)**: Use the keypad to set the time, in milliseconds, that the controller waits after sending a poll message to the SNTP server.

Press the **Execute** button to send an initial poll message to the SNTP server.

Press the **Save** button to save the new values and then press <**ESC**> to return to the Date/Time Configuration screen.

Press <**ESC**> again to return to the System 1 menu screen.

Version and Serial Number

From the System 1 menu screen, press the **Version and Serial Number** button to display the Version and Unit Serial Number screen shown in Figure 9-7.

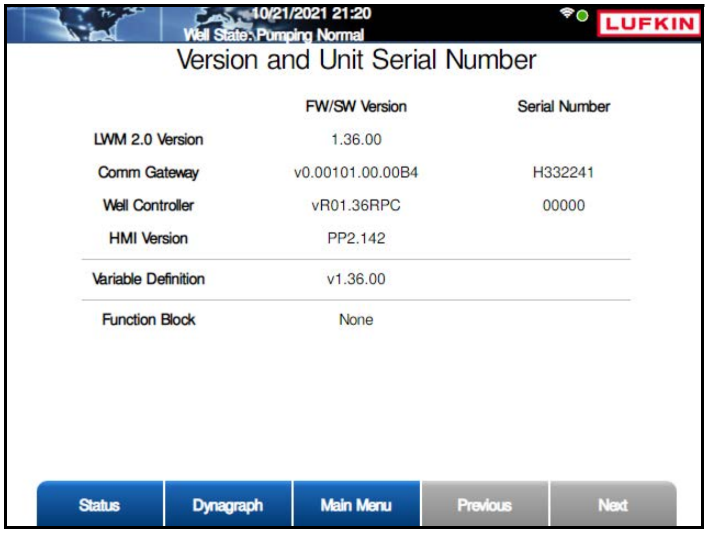

Figure 9-7. Version and Unit Serial Number Screen

This screen displays the firmware and software versions and serial numbers for the main components of the controller. The software variable definition version number and available function blocks are also displayed.

Press <**ESC**> to return to the System 1 menu screen.

Reset Settings

This screen provides options for resetting the controller’s parameters and alarms to a factory-default value. Normally, parameters and alarms do not need to be reset, but this feature is useful in some cases.

Note: This function erases all user-defined parameters. Once the controller is reset, each parameter must be reprogrammed one field at a time.

From the first System menu screen, press the **Reset Settings** button to display the Reset Settings screen shown in Figure 9-8 on page 9-8.

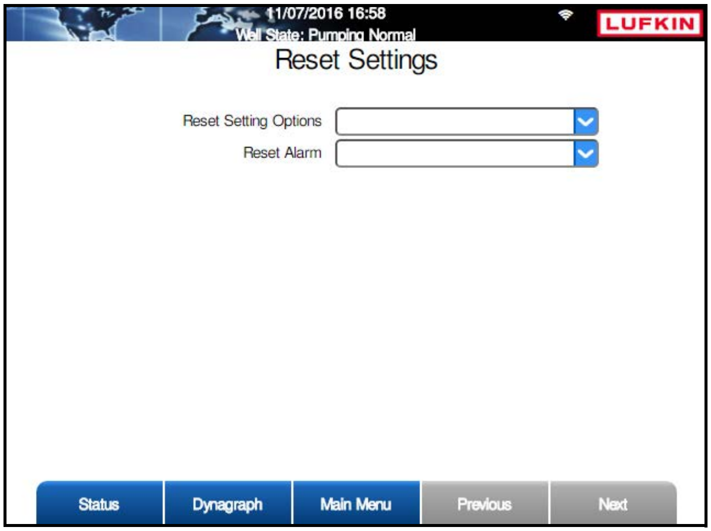

Figure 9-8. Reset Configurations Screen

Resetting Controller Parameters

WARNING: Turn the HOL switch to the **OFF** position before resetting controller parameters. This will prevent the unit from starting unexpectedly.

With the **Reset Setting Options** field highlighted, press the <**ENTER**> key to display the drop-down list. There are two options:

- Reset to Manufacturer Settings
- Reset to Default Settings
- Reset to AGA Config Default Settings

Use the arrow keys to select the desired option and then press <**ENTER**>. In the pop-up window that appears, use the arrow keys to highlight **OK** and then press <**ENTER**> again. See Figure 9-9 for an example.

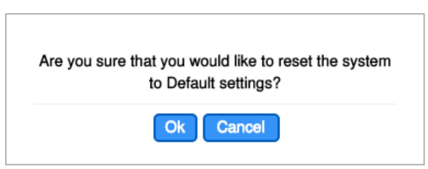

Figure 9-9. Reset Confirmation Pop-Up Window

Resetting Alarms

Use the down arrow to highlight the **Reset Alarm** field and then press <**ENTER**> to display the drop-down list. There are four options available:

- Clear App/Function Block
- Clear AI Alarms
- Clear DI Alarms
- Clear All Alarms

Use the arrow keys to select the desired option and then press <**ENTER**>. In the pop-up window that appears, use the arrow keys to highlight **OK** and then press <**ENTER**> again. See Figure 9-9 for an example.

Figure 9-10. Reset Alarm Pop-Up Window

Reset Event Log

Use the down arrow to highlight the **Reset Event Log** field and then press <**ENTER**> to display the drop-down list. There are five options available:

- Clear RPC Event Log
- Clear Alarm Event Log
- Clear RPC Timestamped Events
- Clear Shutdown Event Log
- Clear All Event Logs

Use the arrow keys to select the desired option and then press <**ENTER**>. In the pop-up window that appears, use the arrow keys to highlight **OK** and then press <**ENTER**> again. See Figure 9-11 for an example.

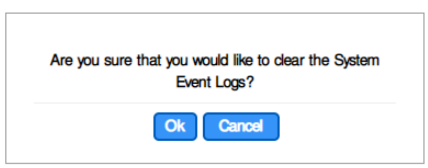

Figure 9-11. Reset Event Pop-Up Window

Unit Preferences

From the first System menu screen, press the **Unit Preferences** button to display the first of two Unit Preferences screens. These screens enable the operator to set how measured values are displayed.

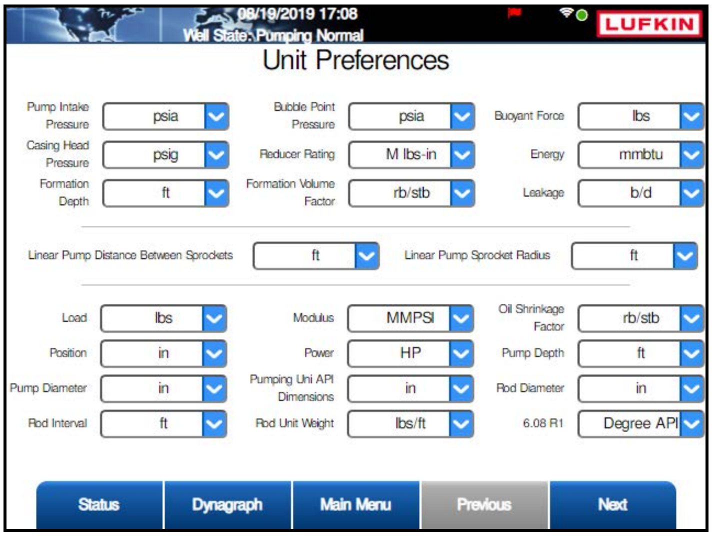

Figure 9-12. Unit Preferences Screen 1 of 2

When the controller is first commissioned, all operational parameters in the status screens display their values in engineering units specified at the factory. These engineering units can be changed for many operational parameters using this screen. For example, length can be displayed in meters instead of feet and volume in cubic meters instead of barrels.

Figure 9-13. Unit Preferences Screen 2 of 2

To change engineering units, do the following:

1. Use the arrow keys to highlight the desired parameter and then press <**ENTER**>.

2. Use the up or down arrow keys to select the desired engineering unit and then press <**ENTER**> again.

Press the **Save** button to save the new values and then press <**ESC**> to return to the System 1 menu screen.

Manage Users

From the first System screen, press the **Manage Users** button to access the user management functions. When this button is first pressed, the screen shown in Figure 9-14 is displayed.

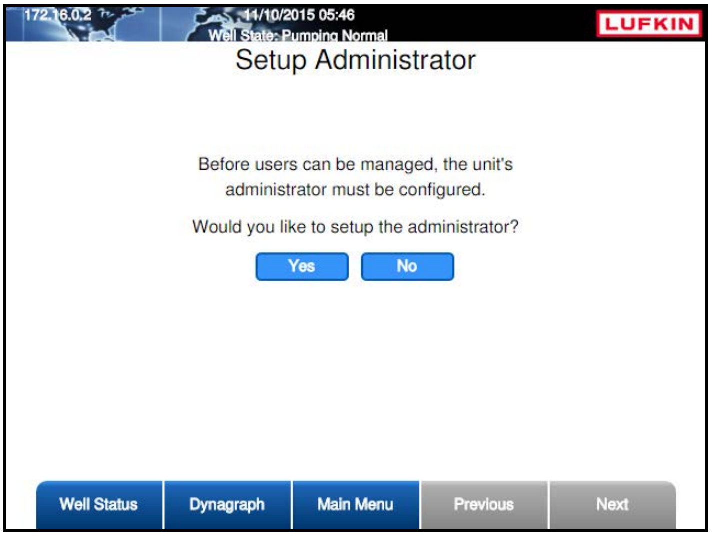

Figure 9-14. Set Up Administrator Screen

Administrator access must be configured before the user management functions can be accessed. With the **Yes** button highlighted on the screen, press <**ENTER**> to display the Setup Administrator screen shown in Figure 9-15.

Figure 9-15. Setup Administrator Screen

By default, the controller does not require a password. This screen allows the operator to set up administrator access privileges in order to prevent unauthorized changes being made to the system.

To create a new administrator password, perform the following steps:

1. With the **Default Password** field highlighted, press <**ENTER**> to edit the field. Use the keypad to type the default password (**PASS123**) and then press <**ENTER**> again.

Note: Press the <**ALT**> key to switch the keypad input method from numbers to letters.

2. Use the down arrow key to highlight the **New Password** field and then press <**ENTER**>. Use the keypad to type the desired password and then press <**ENTER**> again.

Note: There is no limit to the number of characters required for a password. Any combination of letters (A–Z) and numbers (0–9) can be used.

3. Use the down arrow key to highlight the **Confirm Password** field and then press <**ENTER**>. Using the keypad, retype the password that was used in the previous step and then press <**ENTER**> again.
4. Use the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

This password will be used to log in on the main screen. See “Log In/Log Out” on page 7-7 for more information on this function.

Note: After the first password setup procedure has been performed, this password will be required to access or change the functions displayed on the System menu screen.

The user management functions are now available. These functions are discussed on the following pages.

Add User

Note: This function requires the administrator to be logged into the system. See "Log In/Log Out" on page 7-7 for details.

From the Manage Users menu screen, press the **Add User** button to display the Add User screen shown in Figure 9-16.

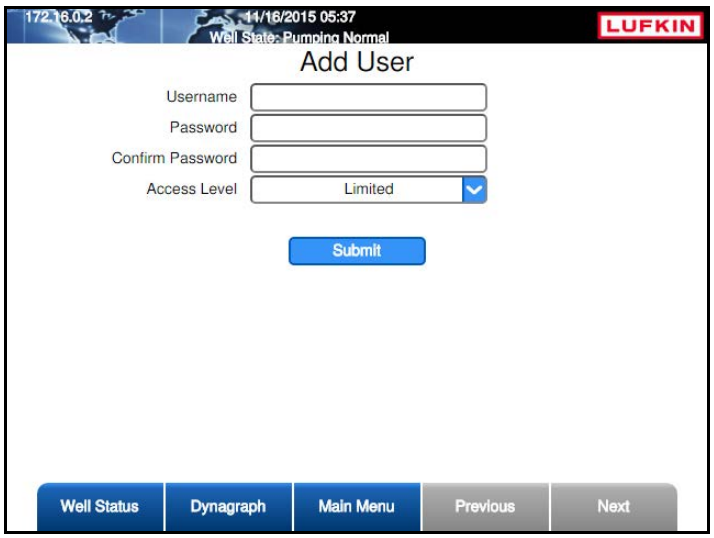

Figure 9-16. Add User Screen

This screen allows the administrator to set up controller access for individual users. Each user is assigned a username and password with limited or full access to system functions.

Perform the following procedure to add a new user profile:

1. With the **Username** field highlighted, press <**ENTER**> to edit the field. Use the keypad to type the username and then press <**ENTER**>.

Note: Press the <**ALT**> key to switch the keypad input method from numbers to letters.

2. Use the down arrow key to highlight the **Password** field and then press <**ENTER**>. Use the keypad to type the desired password and then press <**ENTER**> again.
3. Use the down arrow key to highlight the **Confirm Password** field and then press <**ENTER**>. Using the keypad, retype the password that was used in the previous step and then press <**ENTER**> again.
4. Use the down arrow key to highlight the **Access Level** field and then press <**ENTER**> to display the drop-down list. Two access levels are available:
   - **Limited** – Provides access to basic system functions and RPC parameters.
   - **Full** – Provides full access to all system functions and RPC parameters.

   Use the down arrow key to highlight the desired option and then press <**ENTER**> again.
5. Use the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

Remove User

Note: This function requires the administrator to be logged into the system. See “Log In/Log Out” on page 7-7 for details.

From the Manage Users menu screen, press the **Remove User** button to display the Remove User screen shown in Figure 9-17.

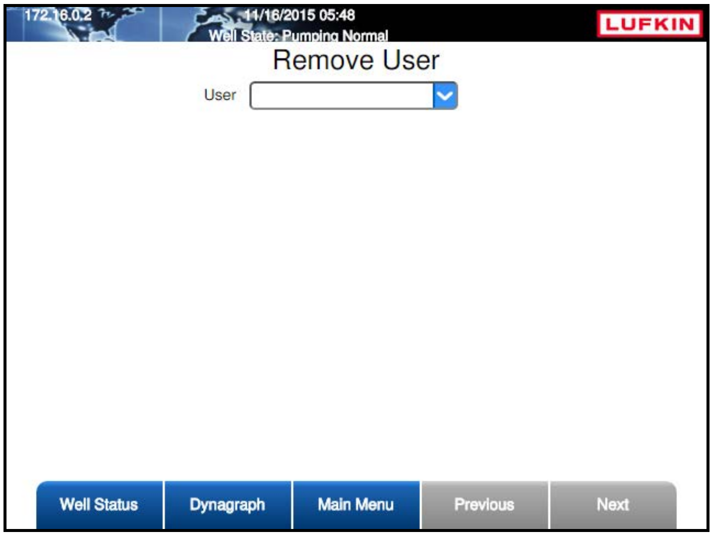

Figure 9-17. Remove User Screen

With the **User** field highlighted, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to select the user profile you wish to delete and then press <**ENTER**> again.

Use the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

Edit User

From the Manage Users menu screen, press the **Edit User** button to display the Edit User screen shown in Figure 9-18.

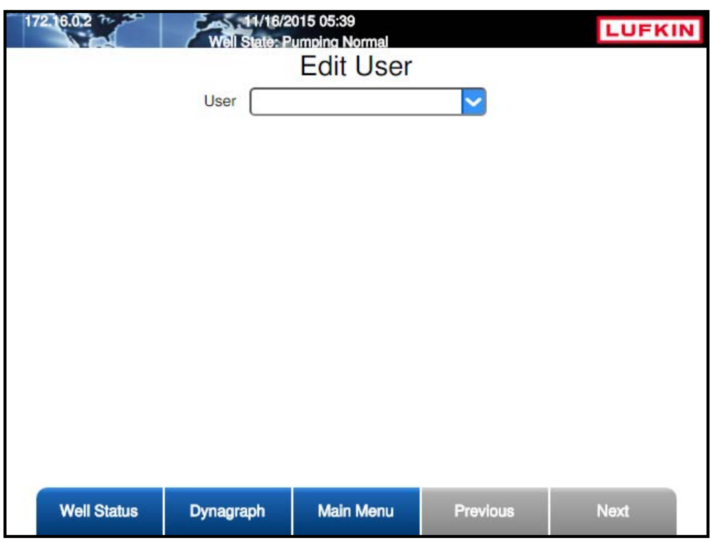

Figure 9-18. Edit User Screen

With the **User** field highlighted, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to select the user profile you wish to edit and then press <**ENTER**> again.

To change the user password, do the following:

1. Highlight the **Change Administrator Password** field and then press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to select **Yes** then press <**ENTER**> again.

   The **New Password** and **Confirm Password** fields appear when the **Yes** option is selected.

2. Use the keypad to type the new password in the **New Password** field and then press <**ENTER**>.

3. Using the keypad, type the new password again in the **Confirm Password** field and then press <**ENTER**>.

4. Press the down arrow key to highlight the **Access Level** field and then press <**ENTER**> to display the drop-down list. Two access levels are available:

   - **Limited** – Provides access to basic system functions and RPC parameters.
   - **Full** – Provides full access to all system functions and RPC parameters.

   Use the down arrow key to highlight the desired option and then press <**ENTER**> again.

5. Press the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

Edit Administrator Functions

Press the **Edit Admin** button to display the Edit Admin screen shown in Figure 9-19.

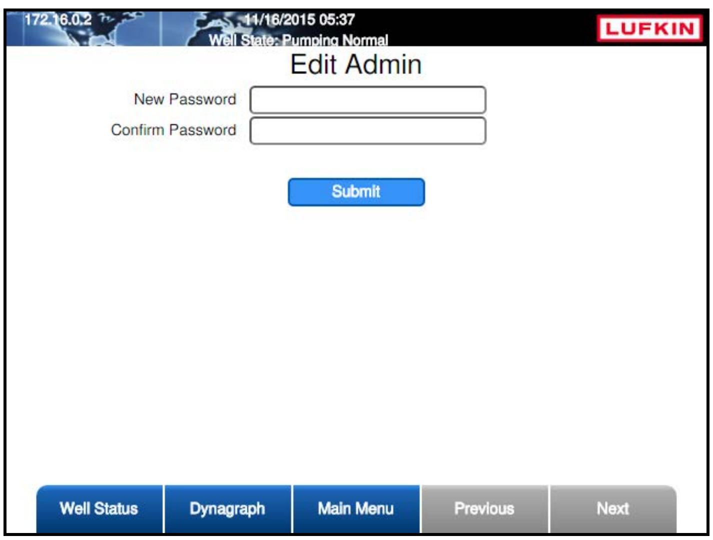

Figure 9-19. Edit Administrator Screen

This screen enables the operator to change the administrator password. The procedure is as follows:

1. Highlight the **New Password** field and then press <**ENTER**>. Use the keypad to type the new password in the **New Password** field and then press <**ENTER**>.

2. Use the down arrow key to highlight the **Confirm Password** field and then press <**ENTER**>. Using the keypad, type the new password again in the **Confirm Password** field and then press <**ENTER**>.

3. Use the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

Enable/Disable Users

Press the **Enable/Disable Users** button to display the Enable/Disable Users screen shown in Figure 9-20 below.

Figure 9-20. Enable/Disable Users Screen

This screen allows the administrator to enable or disable user access to the controller. With this feature enabled, user profiles can be created with limited or full access to change system settings.

Perform the following steps to enable or disable user access:

1. With the **User Login** field highlighted, press <**ENTER**> to display the drop-down list. Use the arrow keys to select **Enabled** or **Disabled** and then press <**ENTER**> again.
2. Press the down arrow key to highlight the **Submit** button and then press <**ENTER**>.

Diagnostics

The LWM 2.0 RPC has diagnostic tools available for troubleshooting issues in the controller. From the first System menu screen, press or click the **Diagnostics** button to display the Diagnostics menu screen shown in Figure 9-21.

Figure 9-21. Diagnostics Menu Screen

The diagnostic functions are described on the following pages.

Communication Diagnostics

From the Diagnostics menu screen, press or click the **Comm Diagnostics** to display the Comm Diagnostics screen shown in Figure 9-22.

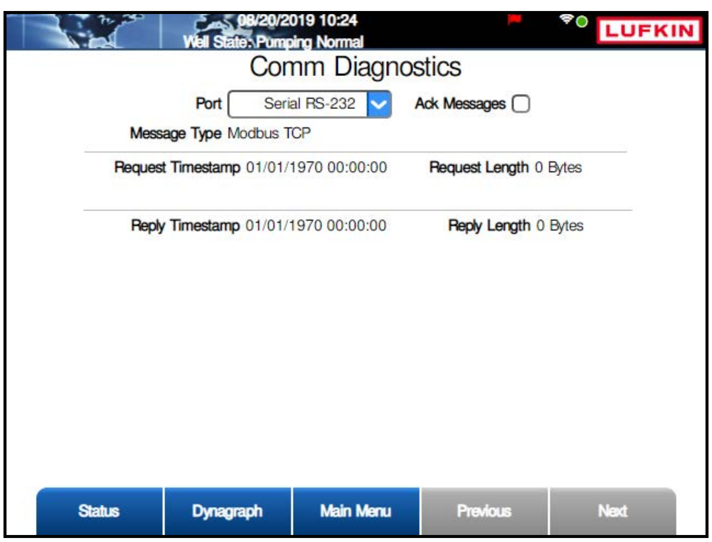

Figure 9-22. Comm Diagnostics Screen

The information displayed on this screen can be used to troubleshoot communication issues in the system.

To view data for each connected port, select **Serial RS-232** or **Ethernet** from the **Port** drop-down list. When finished viewing the data, select the **Ack Messages** checkbox to acknowledge the messages.

Keypad Diagnostic

From the Diagnostic menu screen, press the **Keypad Diagnostic** button to display the Keypad Diagnostic screen shown in Figure 9-23.

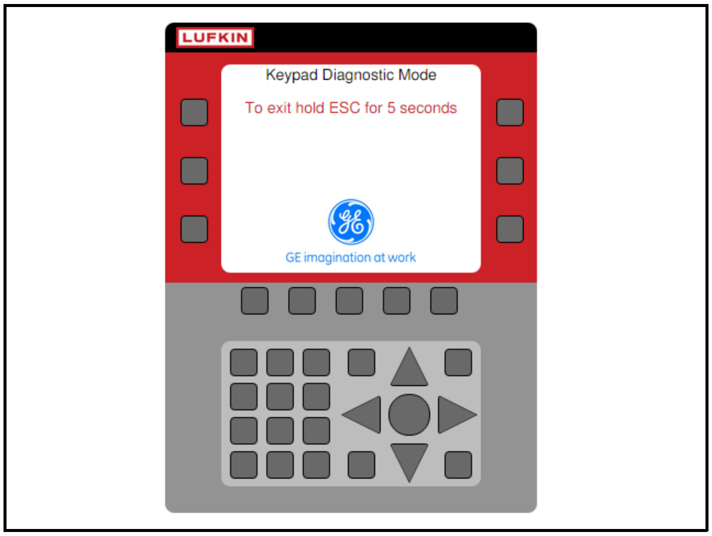

Figure 9-23. Keypad Diagnostic Screen

These screen helps you determine if all keys on the controller keypad are operating properly. As you press each key on the membrane keypad, the corresponding square on the Keypad Diagnostic screen lights up. When you press a key and the square representing it does not light up, you need to return the controller to Lufkin Automation for service.

To exit this screen, press and hold the <**ESC**> button for five seconds.

Sleep Configuration

From the second System menu screen, press the **Sleep Config** button to display the Sleep Configuration screen shown in Figure 9-24.

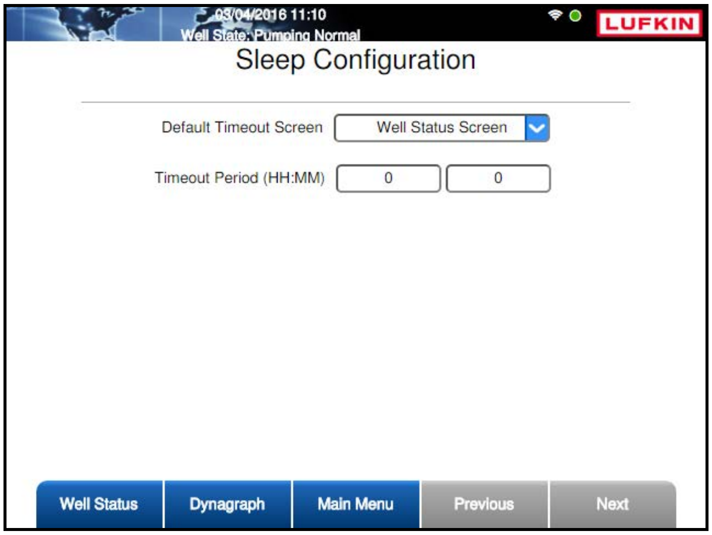

Figure 9-24. Sleep Configuration Screen

This screen sets the time period the controller will display a screen before it reverts back to a user-defined default screen. The default options are:

- Well Status Screen
- Dynagraph Screen
- Main Menu Screen

To select a default timeout screen, press the <**ENTER**> button to display the drop-down list. Use the arrow keys to highlight the desired screen and then press <**ENTER**> again.

The timeout period can be configured in hours or minutes or a combination of both. To configure the timeout period, perform the following steps:

1. Press the down arrow to highlight the hours field and press <**ENTER**>. Use the number keys to define this value and then press <**ENTER**> again. (Skip this step if the desired timeout period is less than one hour.)
2. Press the right arrow to highlight the minutes field and press <**ENTER**>. Use the number keys to define this value and then press <**ENTER**> again.

Press the **Save** button to save the changes.

Advanced Features

From the second System menu screen, press the **Advanced Features** button to display the Advanced Features screen shown in Figure 9-25.

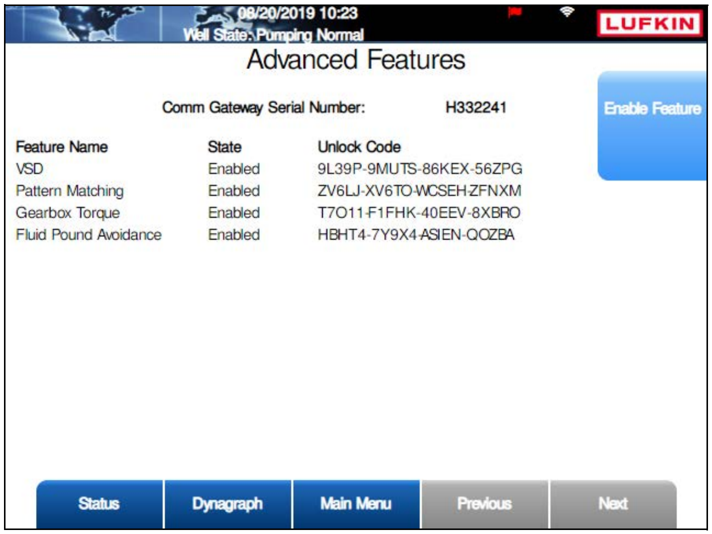

Figure 9-25. Advanced Features Screen

This screen provides access to the controller's advanced features. These features require an unlock code in order to be enabled.

To enable a feature, do the following:

1. Press the **Enable Feature** button to display the Enable Advanced Feature screen shown in Figure 9-26.

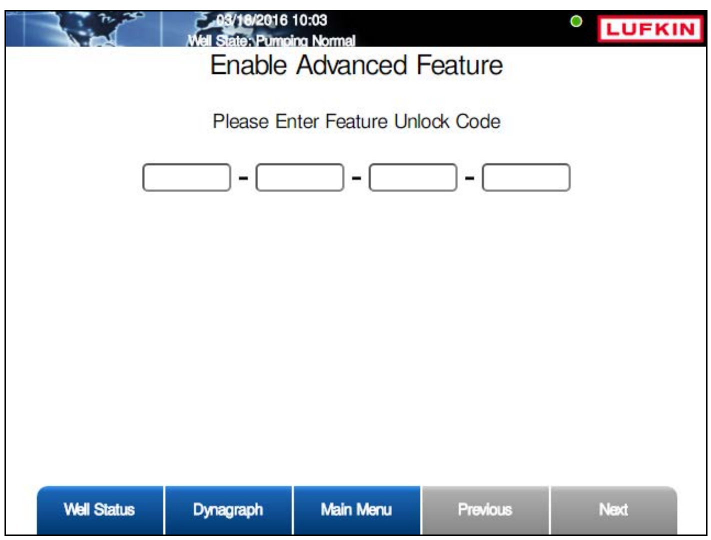

Figure 9-26. Enable Advanced Feature Screen

2. Use the keypad to input the necessary unlock code for the desired feature and then press the **Save** button.

   The feature is now enabled.

USB Card/Register Log

From the second System menu screen, press the **USB Card/Register Log** button to display the USB Card / Register Log screen shown in Figure 9-27.

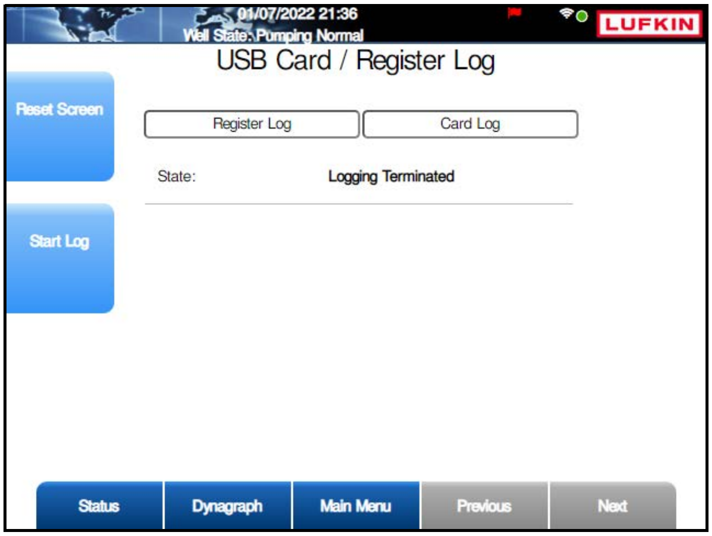

Figure 9-27. USB Card / Register Log Screen

This screen enables the user to create and store dynagraph cards and register logs onto a removable USB card. These options are discussed below.

To create a register log, perform the following steps:

1. Use the arrow keys to highlight the **Register Log** button and then press <**ENTER**>. The following screen appears:

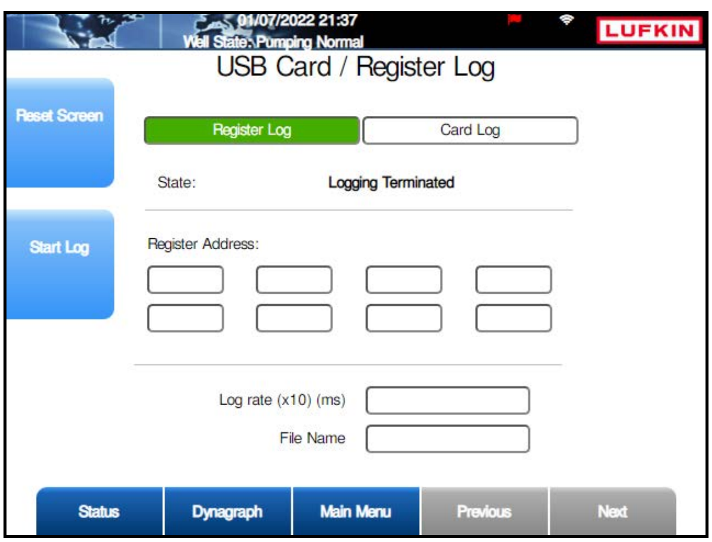

Figure 9-28. Register Log Screen

2. Use the keypad to define the register addresses to be logged and then press <**ENTER**>.
3. Use the keypad to define the log rate in milliseconds and then press <**ENTER**>.
4. Use the keypad to name the log file and then press <**ENTER**>.

5. Press the **Start Log** button to start recording register data.

To create a card log, perform the following steps:

1. Use the arrow keys to highlight the **Card Log** button and then press <**ENTER**>. The following screen appears:

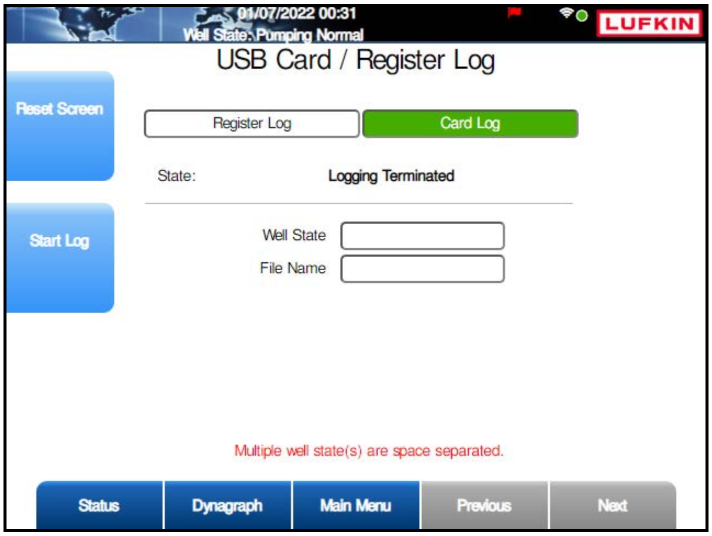

Figure 9-29. Card Log Screen

2. Use the keypad to define the well state to be recorded and then press <**ENTER**>.

Note: To record all well state occurrences, enter a well state value of 0.

3. Use the keypad to name the log file and then press <**ENTER**>.
4. Press the **Start Log** button to start recording card data.

Press the **Stop Log** button to stop recording data.

Press the **Reset Screen** button to clear the text fields after the logging process is complete.

Section 10: Controller Programming

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Section Overview

Several parameters need to be defined in the LWM 2.0 controller in order to obtain well control, end device calibration, and downhole calculations. This section describes the VSD programming screens for these parameters and how to access them. For information about the other programming screens and their functions, refer to the *Lufkin Well Manager 2.0 Rod Pump Controller User Manual* (Lufkin Document # 099.0081).

Note: This manual describes the functions included in Version 1.36.00 of the LWM 2.0 firmware.

Overview of Parameter Programming

Note: Make sure the HOL switch is set to **OFF** before changing controller parameters.

Several configuration screens are used to program general parameters that control operations at the well site. Some of the key parameters include:

- End device parameter configuration
- Pumping unit dimensions
- Rod string data
- Control mode (VSD Surface, VSD Downhole, or VSD DH Pressure)
- Operation mode (normal, host, or timed)

General parameter programming must be completed regardless of the type of end devices used in the system or else effective well control, well monitoring, and well data accumulation is not possible.

Note: Lufkin Automation recommends that the initial programming be done using the Quick Start feature. These control parameters can be revised later by accessing the specific programming screens described in this section. For information about Quick Start, see “Quick Start Feature” on page 5-1.

Control parameters are edited (programmed) on a data field basis. To program a parameter, press the arrow keys to highlight the desired parameter field, press <**ENTER**>, and then choose one of the following methods:

- To select an option from a drop-down list, use the arrow keys to highlight the desired option and then press <**ENTER**> again.
- When the parameter is a numerical entry, use the number keys to enter the desired value and then press <**ENTER**> again.

When parameter values are changed, the green **Discard** and **Save** buttons will appear at the bottom of the screen as shown in Figure 10-1.

Figure 10-1. Menu Bar with Discard and Save Buttons

Press the **Save** button to save the programming change or the **Discard** button to discard the change. The **Discard** and **Save** buttons will then be replaced with the **Previous** and **Next** buttons.

All the functions described in this section are accessed from the Setup menu screens shown below. To display these screens, press the **Setup** button on the Main Menu screen.

Figure 10-2. RPC Setup Menu Screen 1 of 2

Press the **Next** button to display the second Setup menu screen shown in Figure 10-3 below.

Figure 10-3. RPC Setup Menu Screen 2 of 2

The functions listed on these screens are discussed on the following pages.

RPC Programming

From the first Setup screen, press the **RPC** button to display the RPC menu screen shown in Figure 10-4.

Figure 10-4. RPC Menu Screen

The RPC configuration options are discussed in the following paragraphs.

Site Information

From the RPC menu screen, press or click the **Site Information** button to display the Site Information screen shown in Figure 10-5.

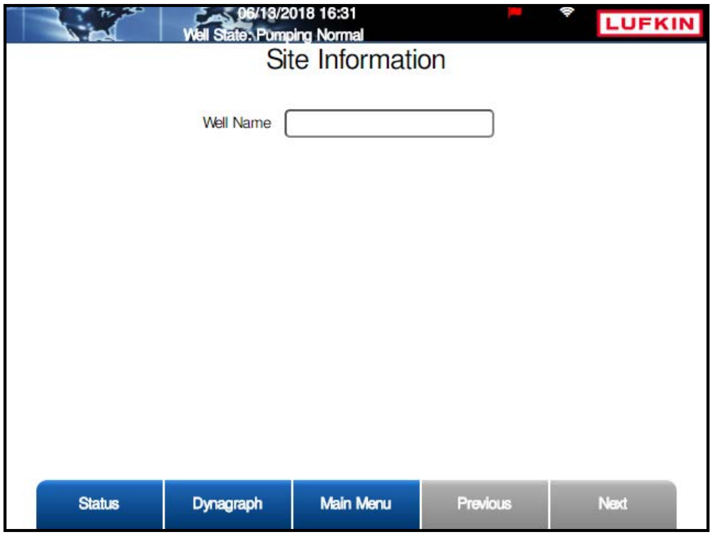


Figure 10-5. Site Information Screen

Type the desired well name in the field and then press or click the **Save** button.

Pumping System Configuration

Press the **Pumping System** button to display the Pumping System Configuration screens. These are discussed in the following paragraphs.

Prime Mover Configuration

The Prime Mover configuration screen is the first screen displayed.

Figure 10-6. Prime Mover Configuration Screen

The prime mover parameters are described below:

- **Motor Type**: Select the motor type from the drop-down list. The available options are **NEMA D** and **Ultra High Slip**.
- **Full Load Speed (RPM)**: Specify the full load RPM rating of the prime mover.
- **Full Load Power (HP)**: Specify the horsepower of the prime mover.
- **Synch Speed (RPM)**: Specify the no-load speed of the motor.

Note: These values are usually listed on the side of the motor.

Press the **Save** button to save the new values, and then press the **Next** button to continue.

Pumping Unit Configuration Screen

This is the second configuration screen.

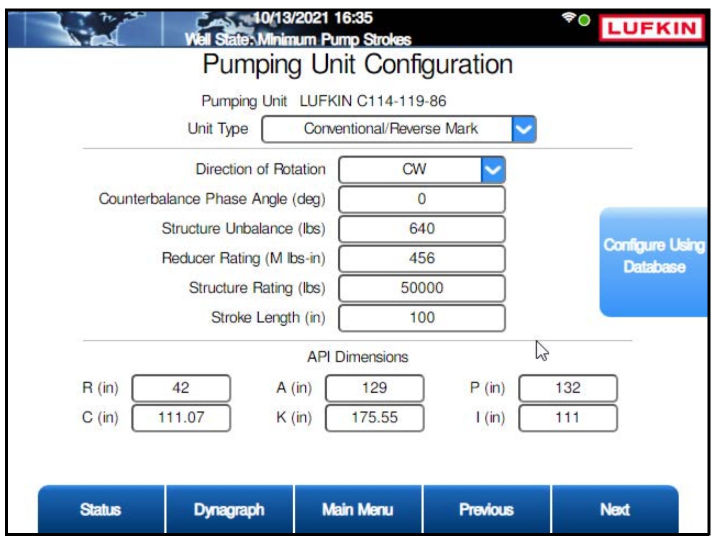


Figure 10-7. Pumping Unit Configuration Screen

The following pumping unit parameters are configured on this screen:

- **Unit Type**: Select the pumping unit type from the drop-down list.
- **Direction of Rotation**: Select the pumping unit's direction of rotation from the drop-down list. **CW** (clockwise) or **CCW** (counterclockwise) are the available options.
- **Counterbalance Phase Angle (deg)**: Use the keypad to define this value and then press <**ENTER**>.
- **Structure Unbalance (lbs)**: Use the keypad to define this value and then press <**ENTER**>.
- **Reducer Rating (lbs)**: Use the keypad to define this value and then press <**ENTER**>.
- **Structure Rating (lbs)**: Use the keypad to define this value and then press <**ENTER**>.

  When the structure rating of the selected pumping unit is lower than the configured **Peak Load Allowed Limit** violation setpoint, the pop-up warning message shown in Figure 10-8 appears:

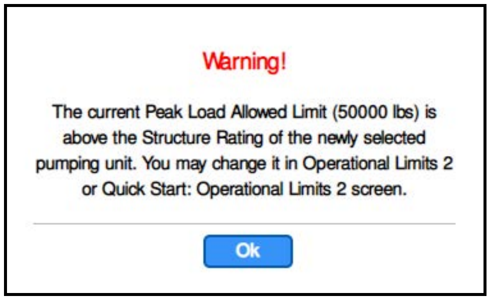


Figure 10-8. Pumping Unit Structure Rating Warning

See “Operational Limits 2 Screen” on page 8-29 and “Surface Card Setpoints” on page 10-7 for details on configuring the Peak Load Allowed Limit violation setpoint.

- **Stroke Length (in)**: Use the keypad to define this value and then press <**ENTER**>.
- **API Dimensions**: Use the keypad to define these values and then press <**ENTER**>.

The **Configure Using Database** button allows a user to select a pumping unit from that database and automatically fill the required dimensional data fields. The database presently contains dimensional data for 1,570 pumping units.

To use this feature, perform the following steps:

1. Press the **Configure Using Database** button to display the Pumping Unit Database screen shown in Figure 10-9 on page 10-8.
2. Select the pumping unit type using one of the following methods:
   - With the **Search** field highlighted, press <**ENTER**>. Use the keypad to input the unit type into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
   - Use the down arrow key to highlight the box next to the desired unit type and then press <**ENTER**>.

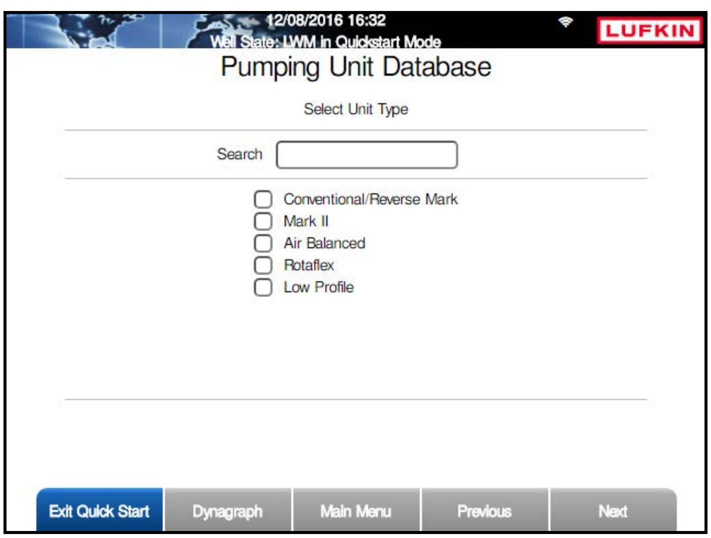


Figure 10-9. Pumping Unit Database – Select Unit Type

Press **Next** to continue.

3. The next screen enables you to select the direction of rotation for the pumping unit.

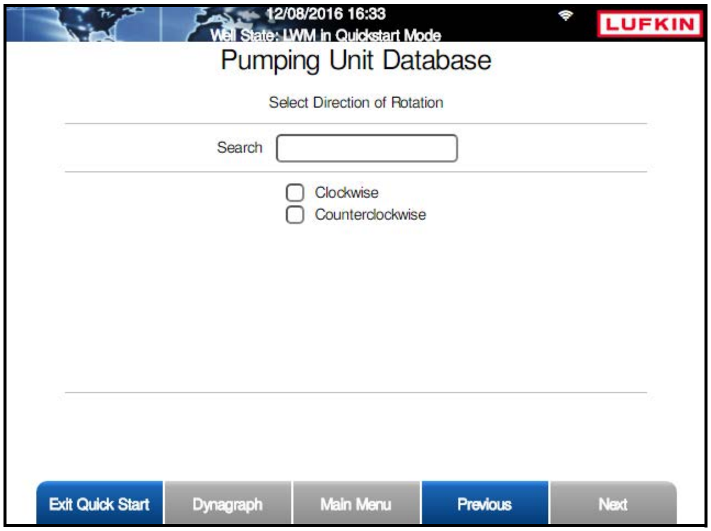


Figure 10-10. Pumping Unit Database – Select Direction of Rotation

Select the direction of rotation using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the direction into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the down arrow key to highlight the box next to **Clockwise** or **Counterclockwise** and then press <**ENTER**>.

Press **Next** to continue.

4. The next screen is used to select the pumping unit's manufacturer code.

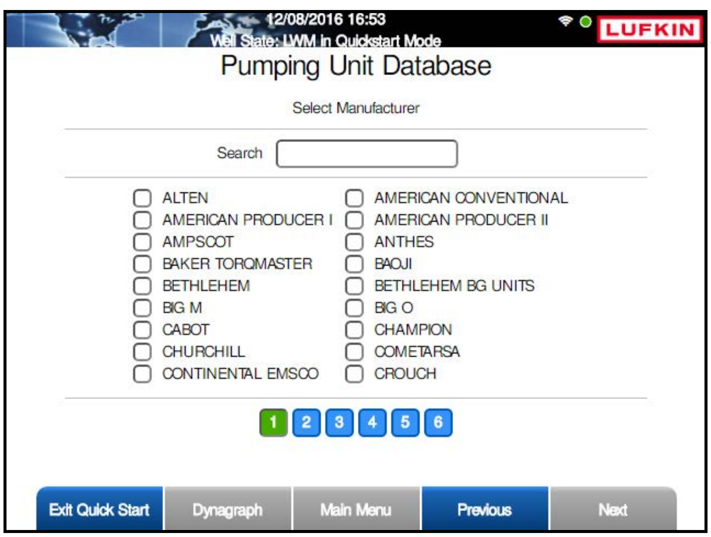


Figure 10-11. Pumping Unit Database – Select Manufacturer Code

Select the manufacturer code using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the manufacturer's name into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the arrow keys to highlight the box next to the manufacturer's name in the list and then press <**ENTER**>. To select a different page of names, use the arrow keys to highlight the page number and then press <**ENTER**>.

Press the **Next** button to continue.

5. The next screen is used to select the pumping unit's ID number.

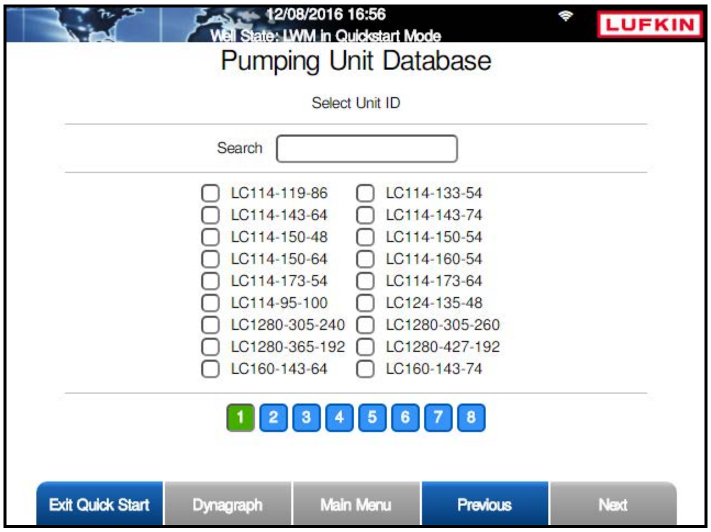


Figure 10-12. Pumping Unit Database – Select Unit ID

Select the unit ID using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the unit ID number into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the arrow keys to highlight the box next to the manufacturer's name in the list and then press <**ENTER**>.

Press the **Next** button to continue.

6. The next screen shown in Figure 10-13 is used to select the number of crank holes on the pumping unit.

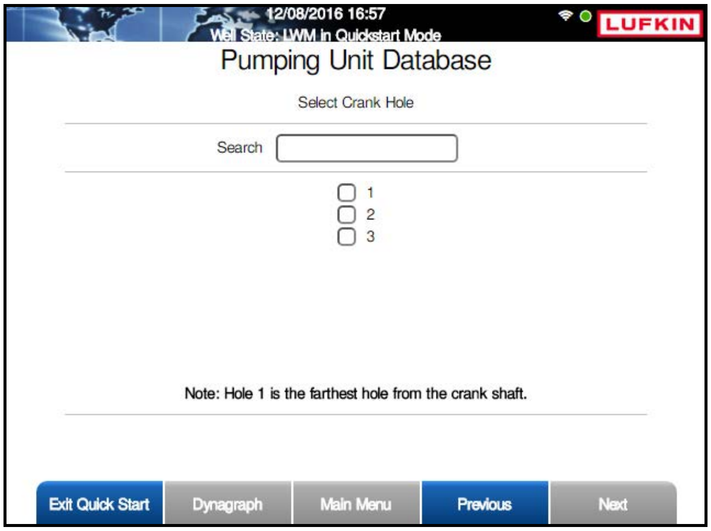


Figure 10-13. Pumping Unit Database – Select Number of Crank Holes

Select the number of crank holes using one of the following methods:

- With the **Search** field highlighted, press <**ENTER**>. Use the keypad to type the number into the **Search** text box. Press the down arrow key to select the search result and then press <**ENTER**>.
- Use the arrow keys to highlight the box next to the correct number in the list and then press <**ENTER**>.

Press the **Next** button to continue.

7. The next screen displays the results of the database search. Figure 10-14 shows an example.

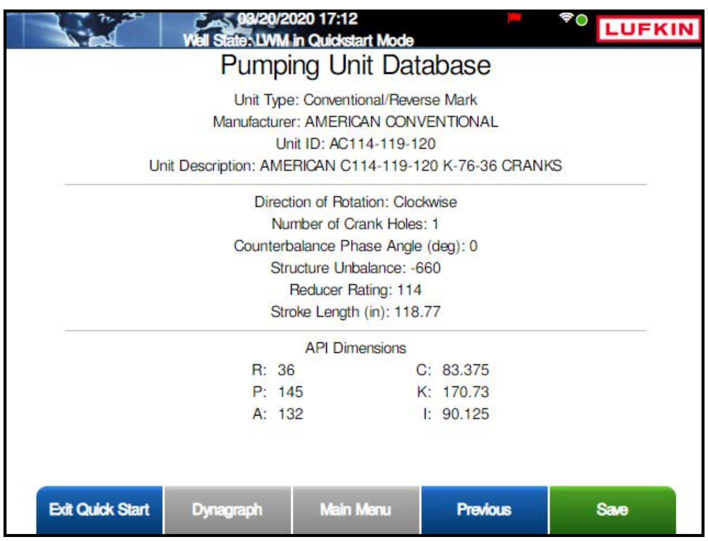


Figure 10-14. Pumping Unit Database – Search Results

Press the **Save** button to save the pumping unit parameters and return to the Pumping Unit Configuration screen.

Press the **Next** button to continue.

Rod Taper Configuration Screen

The Rod Taper Configuration screen is the next screen displayed.

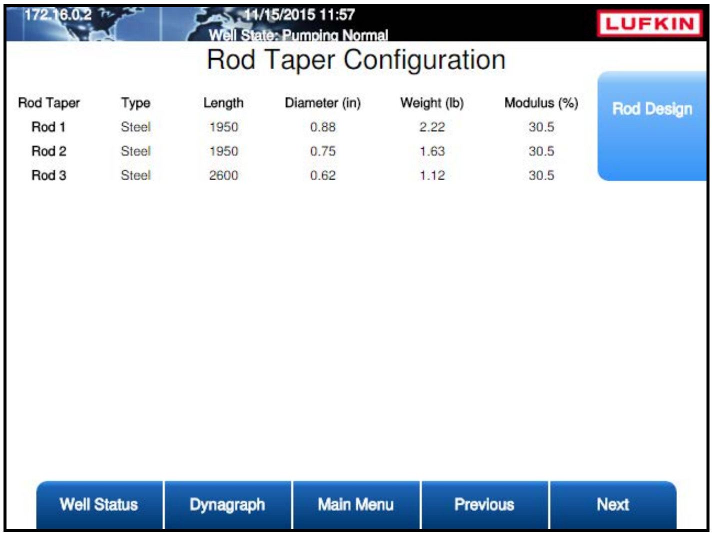


Figure 10-15. Rod Taper Configuration Screen

The controller must have rod string and pump diameter data to calculate the downhole pump card for each stroke. This screen includes default rod data that applies to most pumping configurations.

To make changes to this list, press the **Rod Design** button to display the Rod Design screen shown in Figure 10-16 on page 10-12.

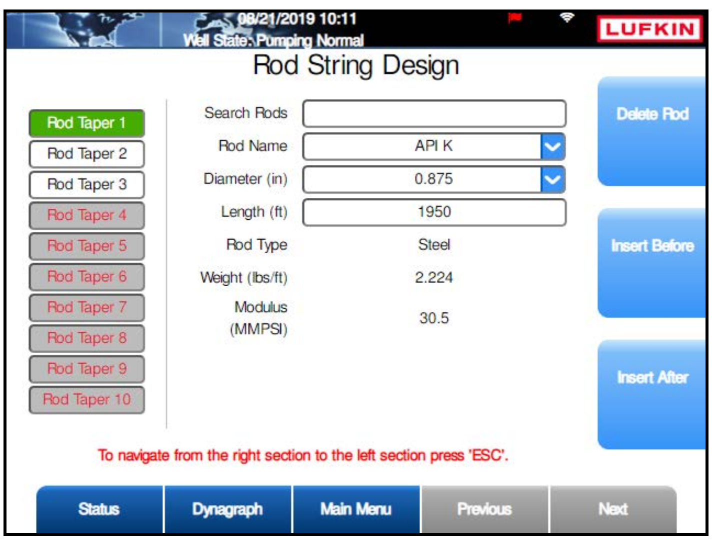


Figure 10-16. Rod Design Screen

This screen allows the operator to change existing rod data, add new rod data, and delete rod data in the rod string list. These procedures are discussed on the following pages.

Change Existing Rod Data

To change existing rod data, perform the following steps:

1. Use the arrow keys to highlight the rod to be changed and then press <**ENTER**>. The rod field will turn green.
2. Use the **Search Rods** field to search the database for rods by manufacturer. Type the desired name in the field and press <**ENTER**>. The **Rod Name** field automatically shows all the available rod options listed for that manufacturer.
3. Select the desired rod name from the **Rod Name** drop-down list and then press <**ENTER**>. The database automatically fills the remaining fields with the default values for that rod name.

Note: If the desired rod name is not listed, select the **CUSTOM** option and manually input the rod data in each field.

4. Select the desired rod diameter (measured in inches) from the **Diameter** drop-down list and then press <**ENTER**>.
5. Type the desired rod length (measured in feet) in the **Length** field and then press <**ENTER**>.
6. **(CUSTOM rods only)** With the **Rod Type** field highlighted, press <**ENTER**>. Use the up or down arrow keys to select **Steel** or **Fiberglass** from the drop-down list and then press <**ENTER**> again.
7. **(CUSTOM rods only)** Type the rod weight (measured in pounds per foot) in the **Weight** field and then press <**ENTER**>.
8. **(CUSTOM rods only)** Type the rod modulus in the **Modulus** field and then press <**ENTER**>.
9. Press the **Save** button to save the changed values.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Add New Rod Data

The Rod Design screen allows the operator to insert new rod data anywhere in the rod string list.

Note: A maximum of 12 rods can be used in this system.

To add new rod data, perform the following steps:

1. Select one of the following options:
   - To insert a new rod at the top of the rod string list, use the arrow keys to highlight the **Rod 1** field and then press the **Insert Before** button.
   - To insert a new rod in the middle of the rod string list, use the arrow keys to select the **Rod 1** or the **Rod 2** field and then press the **Insert After** button.

- To insert a new rod at the end of the rod string list, use the arrow keys to highlight the **Rod 3** field and then press the **Insert After** button.

The new rod field appears with the Rod Type field highlighted.

2. Use the **Search Rods** field to search the database for rods by manufacturer. Type the desired name in the field and press <**ENTER**>. The **Rod Name** field automatically shows all the available rod options listed for that manufacturer.
3. Select the desired rod name from the **Rod Name** drop-down list and then press <**ENTER**>. The database automatically fills the remaining fields with the default values for that rod name.

Note: If the desired rod name is not listed, select the **CUSTOM** option and manually input the rod data in each field.

4. Select the desired rod diameter (measured in inches) from the **Diameter** drop-down list and then press <**ENTER**>.
5. Type the desired rod length (measured in feet) in the **Length** field and then press <**ENTER**>.
6. **(CUSTOM rods only)** With the **Rod Type** field highlighted, press <**ENTER**>. Use the up or down arrow keys to select **Steel** or **Fiberglass** from the drop-down list and then press <**ENTER**> again.
7. **(CUSTOM rods only)** Type the rod weight (measured in pounds per foot) in the **Weight** field and then press <**ENTER**>.
8. **(CUSTOM rods only)** Type the rod modulus in the **Modulus** field and then press <**ENTER**>.
9. Press the **Save** button to save the changed values.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Delete Rod Data

To delete rod data, perform the following steps:

1. Use the arrow keys to highlight the rod field to be deleted and then press <**ENTER**>. The rod field will turn green.
2. Press the **Delete Rod** button to delete the rod data.
3. Press the **Save** button to save the change.

Press the **ESC** button to return to the Rod Taper Configuration screen.

Press the **Next** button to continue.

LWT/PIP Parameters 1/3 Screen

The first of three LWT/PIP Parameters screens is displayed next. These screens allow the operator to use Lufkin's patented algorithms that can calculate pump intake pressure (PIP) and make automated fluid volume adjustments for pump slippage, fluid shrinkage, and tubing movement to determine the pump fluid load (LWT).

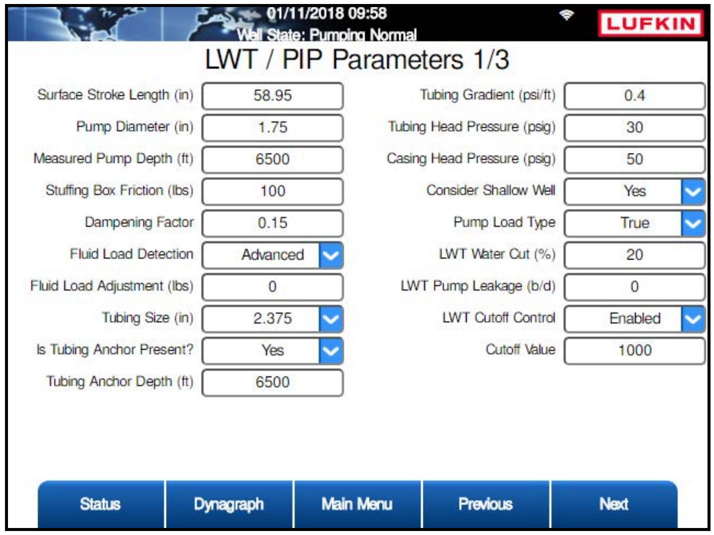


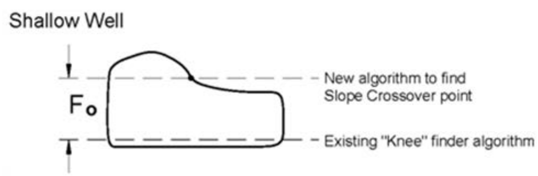
Figure 10-17. LWT/PIP Parameters Screen (1 of 3)

The following values are configured on this screen:

- **Surface Stroke Length (inches)**: Use the keypad to specify the correct surface stroke length in inches. The length needs to be precise to get accurate results, so use a tape measure when in doubt.
- **Pump Diameter (inches)**: Use the keypad to specify the diameter of the pump plunger in inches.
- **Measured Pump Depth (feet)**: Use the keypad to specify the measured pump depth from the surface to the pump intake, in feet.
- **Stuffing Box Friction**: This factor is used to compensate for surface friction due to tight stuffing box seals. Enter in pounds.
- **Dampening Factor**: If the tubing string is not anchored at all, or if the tubing anchor is more than a few hundred feet above the pump intake, select **Yes**.
- **Fluid Load Detection**: Select **Basic** or **Advanced** from the drop-down list.
  - If **Basic** is selected, the controller calculates fluid load by subtracting the average downstroke load from the average upstroke load without making any attempt to analyze the pump card shape for friction loads.
  - If **Advanced** is selected, the controller uses more advanced techniques of PIP calculation theory for calculating fluid load.
- **Fluid Load Adjustment (lbs)**: The fluid load that the controller calculates by either the Basic or Advanced fluid load detection method can be adjusted by using this field. Use the keypad to define this value.
- **Tubing Size (inches)**: Select the API tubing size (in inches) from the drop-down list.

- **Is Tubing Anchor Present?**: Select **Yes** or **No** from the drop-down list. If the tubing string is not anchored at all, or if the tubing anchor is more than a few hundred feet above the pump intake, select **Yes**.
- **Tubing Anchor Depth (feet)**: (This field is only visible when the **Consider Unanchored Tubing** parameter is set to **Yes**.) The tubing should be secured or "anchored" at the surface as a minimum. Therefore, if no tubing anchor is present, specify a value of 0 for the anchor depth. If an anchor is present up hole from the pump intake, specify the depth of the anchor in feet along the tubing (as opposed to true vertical depth).
- **Tubing Gradient (psi/feet)**: Specify the gradient for the fluid in the tubing in psi/feet.
- **Tubing Head Pressure (psig)**: Specify the gauge pressure at the well head tubing in PSI.
- **Casing Head Pressure (psig)**: Specify the pressure in PSI gauge of the casing at the surface.
- **Consider Shallow Well**: Select **Yes** or **No** from the drop-down list. No generally accepted exact definition of a "shallow well" exists. As a general rule, a shallow well is a well with a pump depth of less than 3,000 feet or a deeper well with a large diameter pump. The primary indicator is the shape of the downhole pump card.

  If the pump card has the general shape as illustrated in the example below, select **Yes**.



- **Pump Load Type**: Select **True** or **Effective** from the drop-down list.
- **LWT Water Cut (%)**: Use the keypad to specify the percentage of the produced fluid that is water.
- **LWT Pump Leakage (b/d)**: Use the keypad to specify the amount of leakage around the pump plunger in barrels per day.
- **LWT Cutoff Control**: Select **Enable** or **Disable** from the drop-down list.
- **Cutoff Value (bbls)**: (This parameter is only visible when the **LWT Cutoff Control** parameter is set to **Enable**.) Use the keypad to specify a daily production cutoff value in barrels.

Press the **Save** button to save the new values and then press the **Next** button to display the next screen.

LWT/PIP Parameters 2/3 Screen

This is the second of three LWT/PIP Parameters screens.

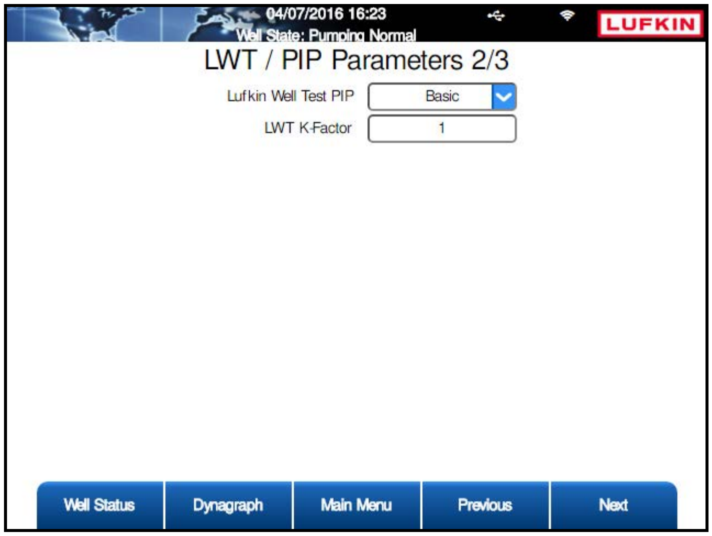


Figure 10-18. LWT/PIP Parameters Screen (2 of 3)

Details of this screen are discussed below.

Lufkin Well Test PIP Configuration

Select the desired Lufkin Well Test PIP configuration. The two drop-down list options are **Basic** or **Advanced**. These options are discussed below:

- When the **Basic** option is selected, the basic calculation for PIP uses only the pump depth and diameter, tubing fluid gradient, and tubing head pressure. No adjustments are made for effects of gas in solution.

  The Basic option uses the LWT K-Factor parameter as a calibration factor to correct for slippage and shrinkage. Use the keypad to define this value.

- When the **Advanced** option is selected, the following parameters are displayed:
  - **Oil Density Degree API**: This is the oil density expressed in degrees API. Use the keypad to define this value.
  - **Water Specific Gravity**: This is the specific gravity of the produced water. Use the keypad to define this value.
  - **Gas Specific Gravity**: This is the specific gravity of the produced gas. Use the keypad to define this value.
  - **Pump Temperature (°F)**: This is the fluid temperature at the pump intake. Use the keypad to define this value.
  - **Bubble Point Pressure (psia)**: This is the pressure at which gas that has been forced into solution by reservoir pressure will start to break out of solution and form gas bubbles. Use the keypad to define this value.
  - **Formation Volume Factor (rb/stb)**: This is the volume of produced fluid will shrink as the ambient pressure decreases and solution gas breaks out of solution. The volume of fluid that passes through the pump barrel reservoir barrel (or rb) may therefore be greater than the volume of fluid production measured at a surface storage unit (stock tank barrel or stb). The shrinkage factor is pump volume divided by surface volume. The formation

volume factor is a theoretical shrinkage factor when the fluid is at bubble point pressure rather than actual surface pressure. Use the keypad to define this value.

- **Solution GOR (scf/stb)**: This is a measure of how much gas is evolved from oil (at or above bubble point) as the oil goes from the reservoir pressure and temperature to separator conditions. The units are volume of gas divided by volume of oil at separator conditions. Use the keypad to define this value.

Figure 10-19 shows the **Advanced** option enabled. Use the keypad to define these values.

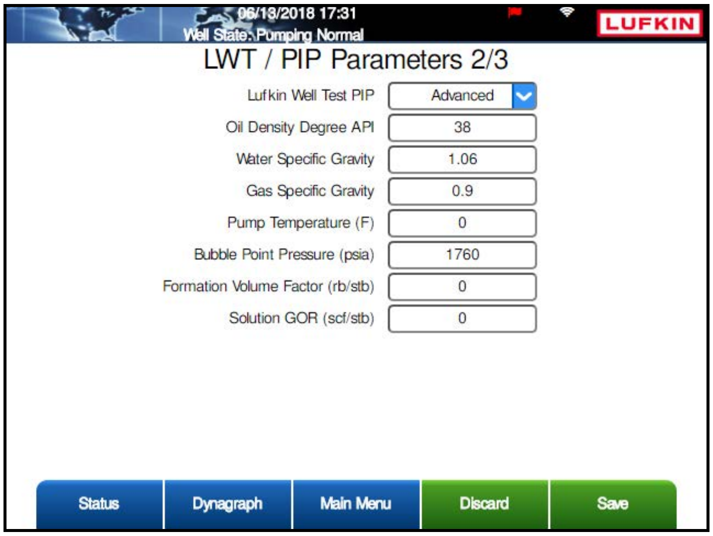


Figure 10-19. LWT/PIP Parameters Screen (2 of 3) – Advanced Option

Press the **Save** button to save the new values.

Press the **Next** button to display the next screen.

LWT/PIP Parameters 3/3 Screen

This is the third LWT/PIP Parameters screen.

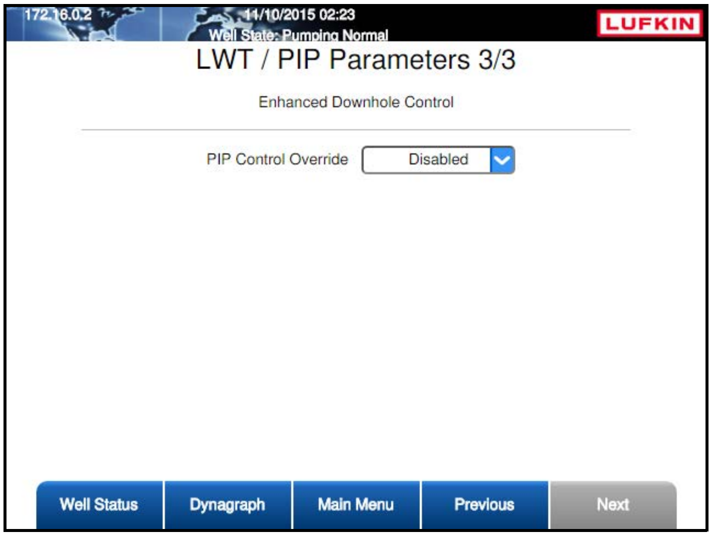


Figure 10-20. LWT/PIP Parameters Screen (3 of 3)

The LWM 2.0 VSD RPC is capable of cycling the well based on the calculated PIP. If the calculated PIP falls below the PIP setpoint (described below), the pumping unit will be shut down for a downtime cycle even though the calculated pump fillage is greater than the fillage setpoint.

Select **Enabled** to enable the PIP Control Override feature. The following fields appear when this feature is enabled:

- **PIP Setpoint**: Specify the low limit for calculated PIP. If the calculated PIP falls below the specified number of strokes in the Consecutive Strokes Allowed field (see below), the pumping unit will be stopped for a downtime cycle.

  Use the keypad to define the pump intake pressure setpoint.
- **Consecutive Strokes Allowed**: Specify the number of consecutive pump strokes that the calculated PIP must be below the PIP setpoint before the pumping unit is stopped. Use the keypad to define the number of consecutive strokes allowed before the override is activated.
- **Consider Formation Producing Pressure**: Specify whether you want to use the Consider Formation Pressure query feature. Select **Yes** if the pump is set above "mid-perfs."

Note: When **Yes** is selected, the Formation Depth field appears below it.

- **Formation Depth**: (This field is only visible when the **Consider Formation Producing Pressure** parameter is enabled.) Use the keypad to specify the depth of the topmost perforations in feet.

Figure 10-21 on page 10-20 shows the PIP Control Override feature enabled.

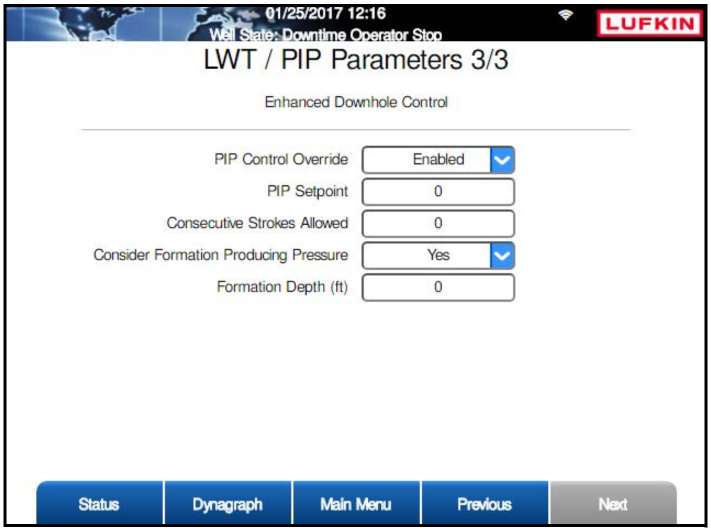


Figure 10-21. LWT/PIP Parameters Screen (3 of 3) – PIP Control Override Enabled

Press the **Save** button to save the parameter changes.

Load/Position Configuration

From the RPC screen, press the **Load/Position** button to display the Load/Position menu screen.

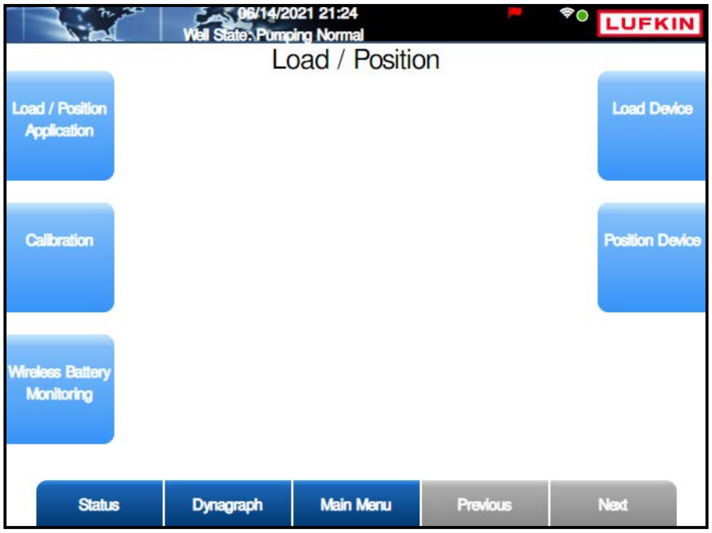


Figure 10-22. Load/Position Menu Screen

The load and position configuration options are discussed on the following pages.

Load/Position Application

Press the **Load/Position Application** button to display the Load/Position Setup screen.

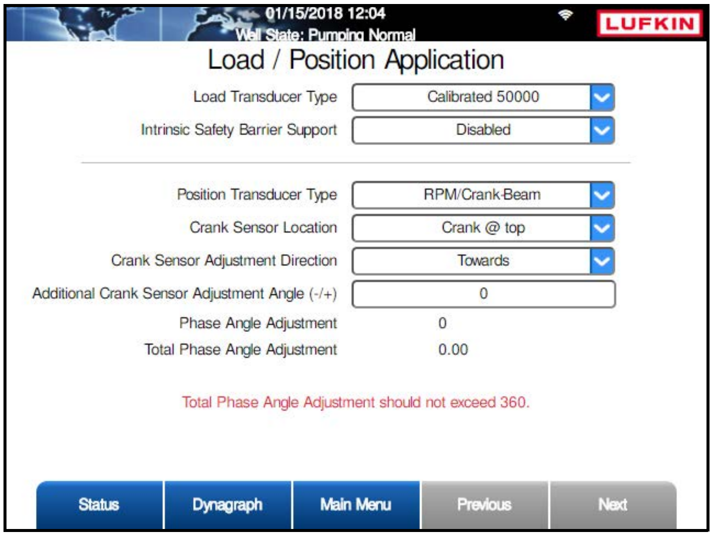


Figure 10-23. Load/Position Setup Screen

The user must specify the types of end devices used for load and position inputs. The parameters on this screen are discussed below.

- **Load Transducer Type**: Select the load transducer type from the drop-down list. Available options are:
  - Calibrated 50,000 (Polished Rod Load Cell)
  - Calibrated 30,000 (Polished Rod Load Cell)
- **Intrinsic Safety Barrier Support**: When an I.S. barrier is used in the pumping system, a voltage drop can occur in the excitation wiring to the load cell. This feature allows the user to define the compensation method for this voltage drop. Select one of the following options from the drop-down list:
  - **Disabled**: Select this option if compensation is not required (e.g. if a barrier is not installed or the barrier type does not introduce a voltage drop).
  - **Analog**: Select this option if the voltage drop will be compensated automatically (e.g. by measuring the drop at Analog Input #2).
  - **Manual**: Select this option if the voltage drop will be compensated with a fixed value.

    With this option selected, the **Load Cell Excitation Volts** field is displayed. Use the keypad to define the expected or measured voltage value at the load cell and then press <**Enter**>.
- **Position Transducer Type**: Select the position transducer type from the drop-down list. Available options are:
  - Analog
  - RPM/Crank-Beam
  - RPM/Crank-Linear
  - Interface Wireless Position

- **Crank Sensor Location**: Select the crank sensor location from the drop-down list. Available options are:
    - Crank at top
    - Crank at bottom
- **Crank Sensor Adjustment Direction**: Select the crank sensor adjustment direction from the drop-down list. Available options are:
    - Towards
    - Against
- **Additional Crank Sensor Adjustment Angle (–/+)**: Using the keypad, define this value.
- **Phase Angle Adjustment:** This field displays status information only.
- **Total Phase Angle Adjustment**: This field displays status information only

Note: The total phase angle adjustment value should not exceed 360.

Press the **Save** button to save the new values.

Press **<ESC>** to return to the Load/Position menu screen.

Calibration

From the Load/Position menu screen, press the **Calibration** button to display the Calibration Menu screen.

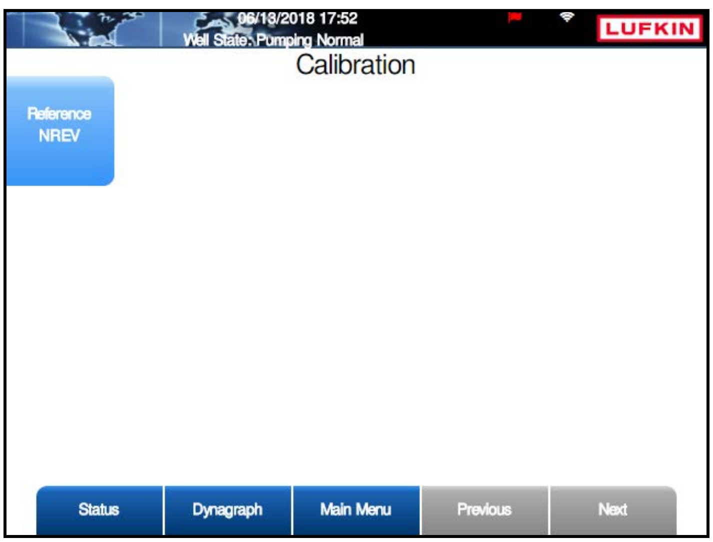


Figure 10-24. Calibration Menu Screen

From the Calibration Menu screen, press the **Reference NREV** button to display the Reference NREV Calibration screen.

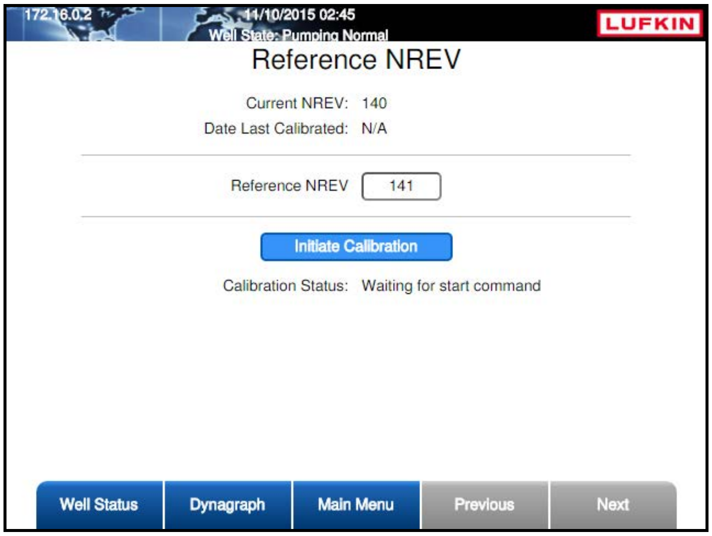


Figure 10-25. Reference Revolution Calibration Screen

In order for some control features to work properly, the controller needs to know the number of motor revolutions required per pump cycle under normal pumping. If the diameter of either drive belt sheave is changed, the pumping speed will change, requiring recalibration of this reference revolution parameter.

The following status information is shown on this screen:

- Current NREV
- Date Last Calibrated
- Reference NREV
- Calibration Status
- Elapsed Time: (This value is displayed during and after the calibration process.)

If reference revolution calibration is needed, use the arrow keys to highlight the **Initiate Calibration** button and then press <**ENTER**> to start the calibration procedure.

WARNING: This command will start the pumping system. All electrical equipment covers MUST be back in place before starting the calibration procedure.

Watch the **Calibration Status** field to check progress of the automatic calibration operation. When the operation is completed, the status field reads **Complete**.

To stop the calibration operation, use the arrow keys to highlight the **Abort** button and then press <**ENTER**> on the keypad.

Press <**ESC**> to return to the Calibration menu screen.

Press <**ESC**> again to return to the Load/Position menu screen.

Load Device Configuration

From the Load/Position menu screen, press the **Load Device** button to display the Load Device screen.

Figure 10-26. Load Device Screen

The load device's analog input designation and current load are displayed at the top of the screen.

The following parameters are configured on this screen:

- **Load Transducer Type**: Select the load transducer type from the drop-down list. The available options are:
  - Calibrated 50,000 (Polished Rod Load Cell)
  - Calibrated 30,000 (Polished Rod Load Cell)
- **Input Swing @ 5V Excitation (mV x 100)**: Using the keypad, define the input swing value.
- **Max Weight (lbs)**: Using the keypad, define the maximum allowed weight for the load device.
- **Bipolar/Unipolar**: Select **Bipolar** or **Unipolar** from the drop-down list.
- **Gain Setting**: Select the desired gain setting from the drop-down list.
- **Zero Load Offset (lbs)**: Using the keypad, define the current zero load offset value.
- **Intrinsic Safety Barrier Support**: When an I.S. barrier is used in the pumping system, a voltage drop can occur in the excitation wiring to the load cell. This feature allows the user to define the compensation method for this voltage drop. Select one of the following options from the drop-down list:
  - **Disabled**: Select this option if compensation is not required (e.g. if a barrier is not installed or the barrier type does not introduce a voltage drop).
  - **Analog**: Select this option if the voltage drop will be compensated automatically (e.g. by measuring the drop at Analog Input #2).
  - **Manual**: Select this option if the voltage drop will be compensated with a fixed value.

    With this option selected, the **Load Cell Excitation Volts** field is displayed. Use the keypad to define the expected or measured voltage value at the load cell and then press <**Enter**>.

Press the **Save** button to save the new values and then press **<ESC>** to return to the Load/ Position Setup menu screen.

Position Device Configuration

From the Load/Position menu screen, press the **Position Device** button to display the Position Device screen shown in Figure 10-27.

Figure 10-27. Position Device Screen

This screen is used to specify the position device being used in the system. The position device's analog input designation and current position reading are displayed at the top of the screen.

Select the position transducer type from the drop-down list. The available options are:

- Analog
- RPM/Crank-Beam
- RPM/Crank-Linear
- Interface Wireless Position

When the **RPM/Crank-Beam** or **RPM/Crank-Linear** options are selected, the following status information is displayed:

- RPM
- Crank Counter
- Crank Period(s)
- NREV

When the Interface Wireless Position option is selected, the **Setting Strokes Allowed** parameter is displayed. Available options are:

- Minimum (2)
- Minimum + 1
- Minimum + 2

Press the **Save** button to save the new values and then press **<ESC>** to return to the Load/ Position Setup menu screen.

Operational Limits Configuration

From the RPC menu screen, press the **Operational Limits** button to display the Operational Limits screens. These screens and their functions are discussed in the following paragraphs.

Operational Limits 1 Screen

This is the first of three Operational Limits screens. The contents of this screen are discussed on the following pages.

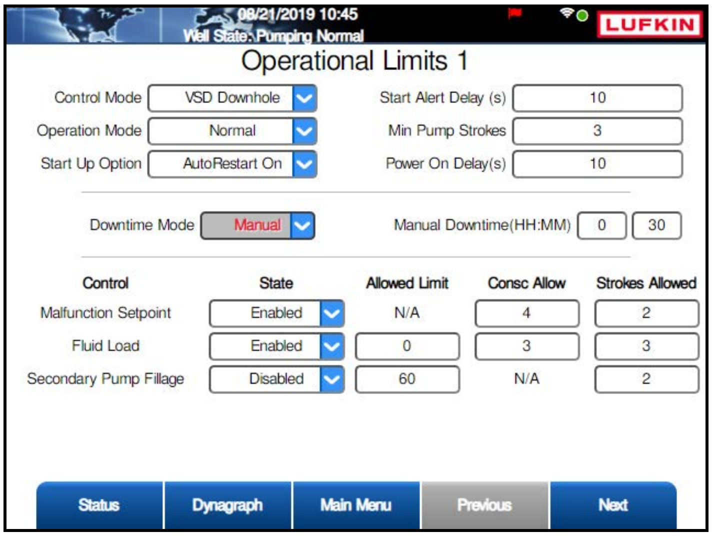


Figure 10-28. Operational Limits 1 Screen

The following VSD parameters are configured on this screen:

- **Control Mode**: Select the desired control mode from the drop-down list. The available VSD options are:
  - **VSD Surface** – For systems containing variable speed drives, the controller adjusts the speed of the drive based on the surface dynagraph shape using the Pump Off setpoint.
  - **VSD Downhole** – For systems containing variable speed drives, the controller adjusts the speed of the drive to maintain a desired downhole pump fillage.
  - **VSD DH Pressure** – In this control mode, the controller uses the downhole intake pressure measurement and adjusts the speed of the pump to achieve a predetermined pressure (fluid level) at the pump intake. This method allows the controller to maintain the fluid level in the well at a desired setpoint when pump-off control is not required.

  To change the control mode, use the arrow keys on the keypad to highlight that field and then press <**ENTER**>. Use the up or down arrow keys to change the type and then press <**ENTER**> again.
- **Start Alert Delay (s)**: This parameter provides control of an optional audible or visible start alarm device. The Start Alert output is held ON (low) for the number of seconds programmed in this field. The controller delays starting the pumping unit until the Start Alert Delay time has elapsed. The default value is 10 minutes.

- **Operation Mode**: Select the desired mode of operation from the drop-down list. The available options are:
  - **Normal** – The controller performs all of the enabled safety and control functions. This mode takes full advantage of the LWM 2.0 controller’s capabilities.
  - **Host** – The controller ignores load and position input and makes no control decisions. The pump or downtime decision is made by the operator and requires operator intervention to change. Typical use would be when several wells need to be shut down due to a power company request. A global data message can be sent to all LWM 2.0 RPC units on the radio network to place them in the Downtime-Host Mode well state. The LWM 2.0 RPC controls would stop the wells and keep them down until receiving a command to restart.
  - **Timed** – The LWM 2.0 RPC can be programmed to cycle on/off for user set times. Limited control functions by the LWM 2.0 RPC include peak and minimum load checking. Typical use might be to temporarily operate a well while waiting for one of the signal input end devices to be repaired.
- **Minimum Pump Strokes**: When a pumping cycle starts, the controller will not perform any dynagraph analysis for this number of initial strokes. Peak and minimum load protection is provided during Minimum Pump Strokes mode.

  Many pumping systems may need a few strokes to clear gas or trash from the pump at the start of a pump cycle. As a result, this number should be programmed at a fairly low value because the controller has very limited capabilities during Minimum Pump Strokes mode.

  The allowed range is 0 to 999, and the default is 3. Use the keypad to define this value.
- **Start Up Option**: This option allows the controller to automatically restart the pumping unit after the user-defined time delay has passed. See “Power On Delay” below for details.

  To enable this option, select **AutoRestart On** from the drop-down list. To disable this option, select **AutoRestart Off**.
- **Power On Delay(s)**: (This parameter is only visible when the **AutoRestart On** option is selected.) When power is applied to the controller, the initial control state is Downtime Power On Delay. The controller delays starting the pumping unit for the specified number of seconds. This feature allows the operator to stagger the startup of pumping units on a transformer bank or distribution line after a power outage.

  The default value is 10 seconds. If a different value is desired, use the keypad to define the number of seconds for this value.
- **Downtime Mode**: (VSD units use **Manual** downtime mode only.) Manual downtime mode uses a user-programmed idle time after a stop for pump off (surface setpoint or downhole pump fillage) or pumping equipment malfunction can be specified. The controller automatically restarts the pumping unit when the specified downtime elapses.

Note: If the motor is a gas engine, the engine has to be manually restarted by an operator.

- **Manual Downtime (HH:MM)**: This value defines the initial downtime period used when the controller is in **Manual** downtime mode. (See “Downtime Mode” above for description.)

  Program this value short enough to prevent the fluid level in the well bore from reaching the static fluid level, but long enough to allow good pump fillage for more than the minimum pump strokes. (The default value is 30 seconds.)

- **DH Pressure Recovery Target (psi)**: This value defines the downtime period for the **Pressure** option of 2ry Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.

The bottom half of the screen contains controls for configuring setpoints for malfunctions, pump fillage, and fluid load. Use the arrow keys to select **Enable** or **Disable** from the drop-down list to enable or disable these setpoints and then press <**ENTER**>. Use the keypad to define the Allowed Limit, Consecutive Allowed, and Strokes Allowed values (where applicable) for these setpoints and then press <**ENTER**> to save these values.

- **Malfunction Setpoint**: This parameter sets the number of malfunctions allowed before the controller shuts down the pumping unit. Select **Enabled** or **Disabled** from the drop-down list. The values that apply to this setpoint are described below:
  - **Malfunction Setpoint Consec Allowed**: The controller allows for re-tries for all of the malfunction types of control actions. For example, if the maximum allowed peak load is violated, the controller counts that as a peak load violation and initially shuts down the pumping unit in a downtime state. After the programmed downtime elapses, the controller tries to restart the pumping unit. If the peak load violation is repeated before a normal pump off cycle occurs, the controller counts that as the second consecutive peak load violation and again shuts down the pumping unit in a downtime state. Subsequent violations of the peak load limit increment the consecutive violation counter until the allowed consecutive for peak load is exceeded. The controller at that point shuts down the pumping unit in a malfunction state and operator intervention is required to clear alarms and re-start the unit. This column allows an operator to program the consecutive allowed for malfunction control action.

    Use the keypad to define this value.
  - **Malfunction Setpoint Strokes Allowed**: The number of consecutive strokes that the surface malfunction setpoint must be violated before the controller shuts down the pumping unit for one of the consecutive malfunctions allowed.

    The default value is 2 strokes. Use the keypad to define this value.
- **Fluid Load**: (This parameter is only used in the **VSD Downhole** control mode.) The controller analyzes the realtime downhole dynagraph and uses this data to calculate fluid load for each pump stroke. If the fluid load drops below this limit, the pumping unit is stopped for a downtime cycle early in the next upstroke.

  The values that apply to this parameter are as follows:
  - The **Allowed Limit** value defines the allowed fluid load limit described above. Use the keypad to define this value.
  - The **Consecutive Allowed** value defines the number of times the fluid load can drop below the limit before the controller shuts down the pumping unit.
  - The **Strokes Allowed** value defines the number of pump strokes allowed in a low fluid load situation before the controller shuts down the pumping unit.
- **Secondary Pump Fillage**: (This parameter is only used in **VSD Downhole** and **VSD DH Pressure** control modes.) When the current pump fillage drops below this limit, the controller will accumulate the number of times this drop occurs. When the number of occurrences exceeds the defined limit, the controller will stop the pump and then switch to a Downtime/ Pump-Off state.

The time period in which the controller will stay in this state is controlled by the **2ry Downtime Mode** described on the previous page.

Note: This feature is supported in the Normal operation mode only.

Use the down arrow key to highlight this field and then press <**ENTER**>. In the drop-down list that appears, use the up or down arrow key to select **Enabled** or **Disabled** and then press <**ENTER**> again.

The values that apply to this parameter are as follows:

- The **Allowed Limit** value defines the allowed fillage limit described above. Use the keypad to define this value.

Note: The **Allowed Limit** value must be set below the deadband range in order to function properly.

- The **Strokes Allowed** value defines the number of pump strokes allowed in a limit violation situation before the controller shuts down the pumping unit.

Press the **Save** button to save the new values and then press the **Next** button to continue.

Operational Limits 2 Screen

The second Operational Limits screen is used to enable or disable violation setpoints for use during pumping operation. It also displays the current operation mode, control mode, load transducer type, position transducer type, and present system values.

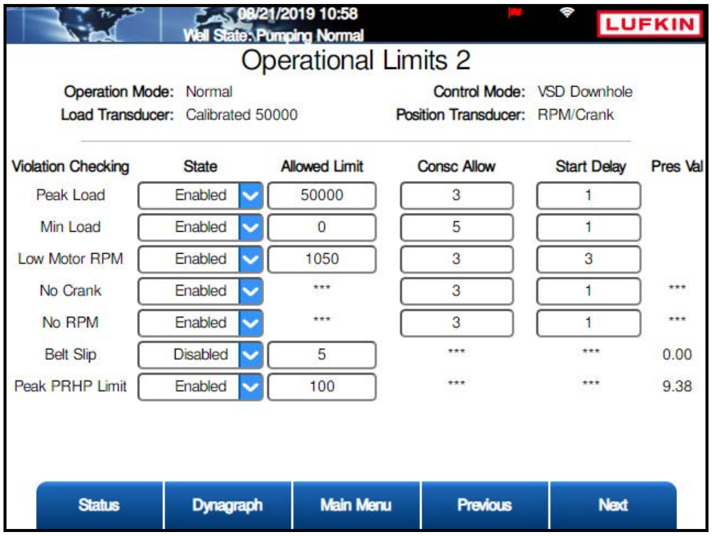


Figure 10-29. Operational Limits 2 Screen

Select **Enabled** or **Disabled** from the drop-down list to enable violation limit parameters. Using the keypad, define the desired values for Allowed Limit, Consecutive Allowed, and Start Delay parameters where applicable.

The available violation limits are:

- **Peak Load**: The maximum allowed value for load input. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay. Units are in pounds. The default value will be the full scale of the programmed load end device.
- **Min Load**: The lowest allowed value for load input. If the load falls below this value, the controller instantly shuts down the pumping unit with no consecutive stroke delay. The default value is zero.
- **Low Motor RPM**: The lowest motor RPM at which the controller will continue to run the pumping unit. This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for Low Motor RPM violations.
- **No Crank**: Triggers an alarm when a crank switch input is not detected. This setpoint specifies the number of motor revolutions that the controller should wait before it detects the first crank switch input. If a crank switch input is not detected within this number of motor revolutions, the controller declares a No Crank alarm and stops the pumping unit. If the unit is pumping extremely slow and it causes this reference revolution value to be near 300, you may need to program a higher value than the default of 300 revolutions.
- **No RPM**: Triggers an alarm when there is no RPM signal from the pumping unit. This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for No RPM violations.
- **Belt Slip**: The maximum allowed value for belt slippage. When in the Pumping Normal mode well state, the controller counts the Motor Rev/Stroke for each stroke. At the end of each

stroke, the count is compared to the Reference Rev number programmed above. If the current Motor Rev/Stroke count is greater than the Reference Rev by greater than this Belt Slippage percentage, the controller sets an alarm flag to indicate possible belt slippage. No other control action is taken. The default value is 5%.

- **Peak PRHP Limit**: Specify a value at which the controller will set an alert flag to advise the operator that a paraffin treatment may be required. This value is a high limit.

Press the **Next** button to continue.

Operational Limits 3 Screen

The third Operation Limits screen is displayed next.

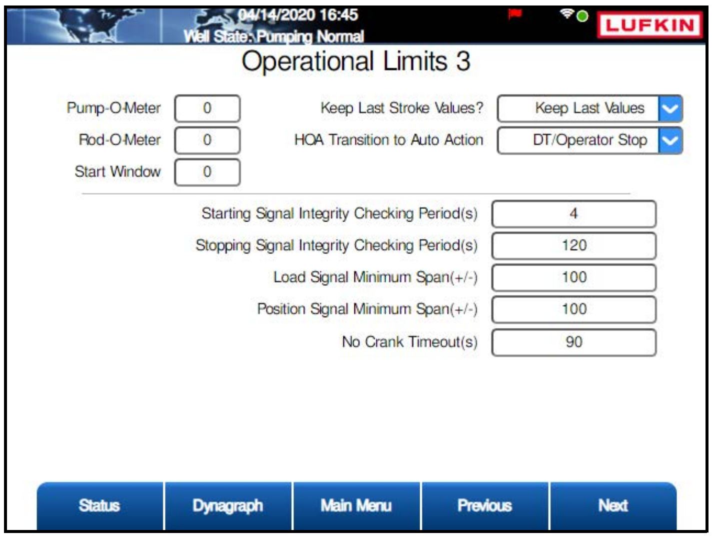


Figure 10-30. Operational Limits 3 Screen

Using the keypad, define the desired values for the following parameters:

- **Pump-O-Meter**: Use this field to clear the counter for rod pump activity. The controller counts and accumulates the number of strokes since the last time pump work was performed. These counts give operators a tool to measure pump life.
- **Rod-O-Meter**: Use this field to clear the counter for rod stroke activity. The controller counts and accumulates the number of strokes since the last time rod string work was performed. These counts give operators a tool to measure rod life.
- **Start Window**: Specify an additional delay time, in seconds, after the well start output is energized before the controller begins checking load and position inputs. This time may be necessary to allow a gas engine prime mover to start and run up to speed or for a clutch to engage. Typically, installations with electric motors do not need an additional delay.
- **Keep Last Stroke Values?**: Use the arrow keys to select one of the following options:
  - Keep Last Values
  - Clear Last Values
- **HOA Transition to Auto Action**: This parameter determines the action the controller takes when the HOA switch is turned to the Auto position. Available options are **DT/Operator Stop** and **Restart**.

  Use the arrow keys to select the desired option and then press <**ENTER**>.

- **Starting Signal Integrity Checking Period(s)**: Use the keypad to define this value.
- **Stopping Signal Integrity Checking Period(s)**: Use the keypad to define this value.
- **Load Signal Minimum Span (+/–)**: Use the keypad to define this value.
- **Signal Failure Control**: Select **Enable** or **Disable** from the drop-down list and then press <**ENTER**>.
- **Signal Failure Control Option**: (This field is only visible when the **Signal Failure Control** parameter is set to **Enable**.) When a signal failure is detected in the system, the controller has several control options for handling this situation. These options are described below:
    - **Malfunction** – With this option, the controller treats the signal failure as a malfunction and shuts down the pumping unit. This malfunction state must be cleared by the user before the controller will restart the unit.
    - **Downtime** – With this option, the controller shuts down the pumping unit for a designated period of time when a signal failure is detected.

      Use the arrow keys to highlight the hours and minutes fields and then press <**ENTER**>. Use the keypad to define the desired downtime period and then press <**ENTER**> again.
    - **Run** – With this option, the controller continues to run normally when a signal failure is detected.
    - **Timer 1 - User Define** – This option uses user-defined time limits to control the length of time the pumping unit should run in a signal failure situation.

      Use the arrow keys to highlight the hours and minutes fields and then press <**ENTER**>. Use the keypad to define the desired on and off periods and then press <**ENTER**> again.

  The next two options allow the pumping unit to run for a user-defined percentage of the normal run time period when a signal failure is detected.
    - **Timer 1 - User Define** – This option uses user-defined time limits to control the length of time the pumping unit should run in a signal failure situation.

      Use the arrow keys to highlight the hours and minutes fields and then press <**ENTER**>. Use the keypad to define the desired on and off periods and then press <**ENTER**> again.
    - **Timer 2 - % Run Time – since GOT**: This option sets a minimum and maximum time period the pumping unit can run since the last gauge-off time event.

      Use the arrow keys to highlight the hours and minutes fields for the **Off**, **Minimum Run Period**, and **Maximum Run Period** parameters and then press <**ENTER**>. Use the keypad to define the desired time period for each parameter and then press <**ENTER**> again.

Operational Limits 4 Screen

The Operational Limits 4 screen is displayed next. Use this screen to configure a downhole gauge.

Figure 10-31. Operational Limits 4 Screen

Configure the downhole gauge using the following parameters:

- **DH Gauge Source**: Use the arrow keys to select the downhole gauge source from the drop-down list:
    - **Unavailable**: Select this option if a downhole gauge is not present in the system.
    - **Zenith DH Gauge**: Select this option for Zenith downhole gauges.
    - **AI 8**: Select this option for downhole gauges from other manufacturers.
- **Zenith DH Gauge Model**: (This parameter applies to the **Zenith DH Gauge Source** option only.) Select the desired downhole gauge model from the drop-down list:
    - Model C2
    - Model C5
    - Model C6
- **Intake Pressure Type**: (This parameter applies to the Zenith **Model C5** gauge option only.) Select the desired intake pressure type from the drop-down list. Available options are **Tubing** and **Annulus**.

For Zenith downhole gauge configuration, press or click the **COMM** button to display the Zenith DH Gauge configuration screen shown in Figure 10-32.

For configuration of other downhole gauges by other manufacturers, press the **Analog Input** button to display the Analog Input Configuration screen.

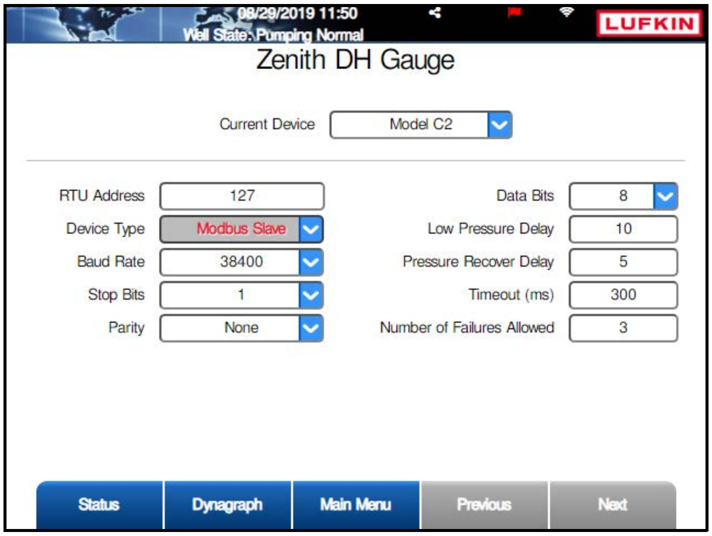


Figure 10-32. Zenith DH Gauge Configuration Screen

The following parameters are configured on this screen:

- **RTU Address**: Each downhole gauge must have a different address number. Address numbers of less than 247 are indicated by the standard Modbus guidelines. The address must match the downhole gauge setting.
- **Device Type**: As of this release, Modbus Slave is the only available option for device type.
- **Baud Rate**: Select from a range of options from 300 to 115,200 baud. The value must match the slave device setting.
- **Stop Bits**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Parity**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Data Bits:** This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Low Pressure Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Pressure Recover Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Timeout**: Specify the time, in milliseconds, that the controller waits after sending a poll message to check the reply message buffer.
- **Number of Failures Allowed**: Specify the number of times that the controller will continue to try to poll a downhole gauge once that gauge is enabled. If the controller does not receive a valid response after this number of consecutive polling attempts, a communication failure alarm is flagged for the downhole gauge to alert the operator that data from the gauge is not current. Communication failure flags are displayed in red at the top of the screen.

Press the **Save** button to save changes made on this screen.

VSD Configuration

From the RPC menu screen, press the **VSD** side button to display the VSD Configuration menu screen shown in Figure 10-33.

Figure 10-33. VSD Configuration Menu Screen

Select **Danfoss FC302** from the **Drive Type** drop-down list and then press or click the **Save** button.

The VSD Configuration menu options are discussed on the following pages.

VSD Application Control

Press the **Control** button to display the VSD Application Control Setting screen shown in Figure 10-34.

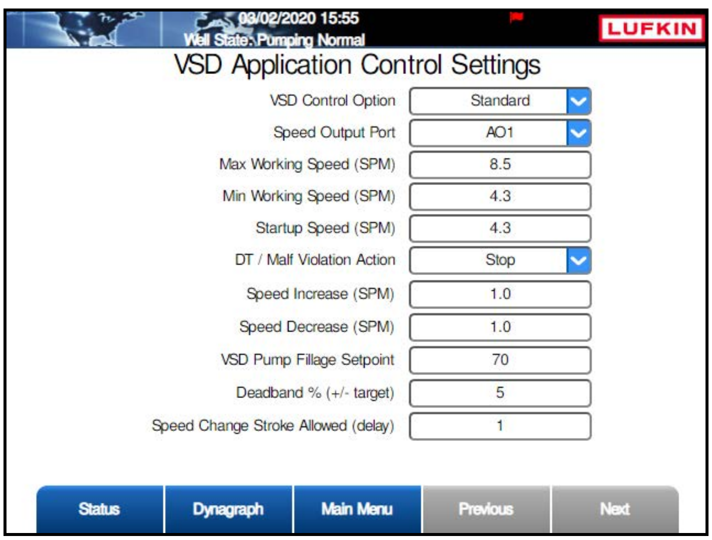


Figure 10-34. VSD Application Control Settings Screen

Using the keypad, define the values for the following parameters:

- **VSD Control Option**: Select **Standard**, **Fixed Speed**, or **Advanced** from the drop-down list.
- **Speed Output Port:** This parameter defines the output port for the VSD speed command. Available options are **AO1** and **AO2**. Use the arrow keys to select the desired port from the drop-down list and then press <**ENTER**>.
- **Max Working Speed (SPM)**: Using the keypad, define the maximum working speed for the drive to run. The current working speed is displayed to the right of the text field.
- **Min Working Speed (SPM)**: Using the keypad, define the minimum working speed for the drive to run. The current working speed is displayed to the right of the text field.
- **Startup Speed (SPM)**: Using the keypad, define the value for this parameter.
- **DT/Malf Violation Action**: Select the method the controller will use when a fault occurs. **Stop** and **Run Low Speed** are the options available in the drop-down list.
- **Speed Increase (SPM)**: When the controller decides that it should increase pumping unit speed, it will add the **Speed Increase** value to the current speed output, and change the speed output accordingly thereby speeding up the pumping unit.

  Using the keypad, define the value for this parameter.
- **Speed Decrease (SPM)**: When the controller decides that it should decrease pumping unit speed, it will subtract the **Speed Decrease** value from the current **Speed Output** value and change the analog output accordingly thereby slowing the pumping unit.

  Using the keypad, define the value for this parameter.
- **VSD Pump Fillage Setpoint**: (This parameter is only used in VSD Downhole control mode.) The VSD Pump Fillage Setpoint sets the target fillage level in the pump barrel. When the fillage level exceeds this value, the controller speeds up the pumping unit. When the fillage level drops below this value, the controller slows down the pumping unit.
- **VSD DH Pressure Setpoint**: (This parameter is only used in VSD DH Pressure control mode.) The VSD DH Pressure Setpoint sets the target downhole pressure recorded by the installed downhole pressure gauge. When the downhole pressure exceeds this value, the controller speeds up the pumping unit. When the downhole pressure drops below this value, the controller slows down the pumping unit.
- **Deadband (+/– target)**: This parameter is used in the decision making process to determine whether the controller should speed up or slow down the pumping unit.

  Using the keypad, define the value for this parameter.
- **Speed Change Stroke Allowed (delay)**: This parameter controls how many strokes are allowed before the controller speeds up or slows down the pumping unit.

  Using the keypad, define the value for this parameter.

Press <**ESC**> to return to the VSD Configuration menu screen.

VSD Application Miscellaneous Control

From the VSD Configuration menu screen, press the **Misc. Control** button to display the VSD Application Misc. Control Settings screen shown in Figure 10-35.

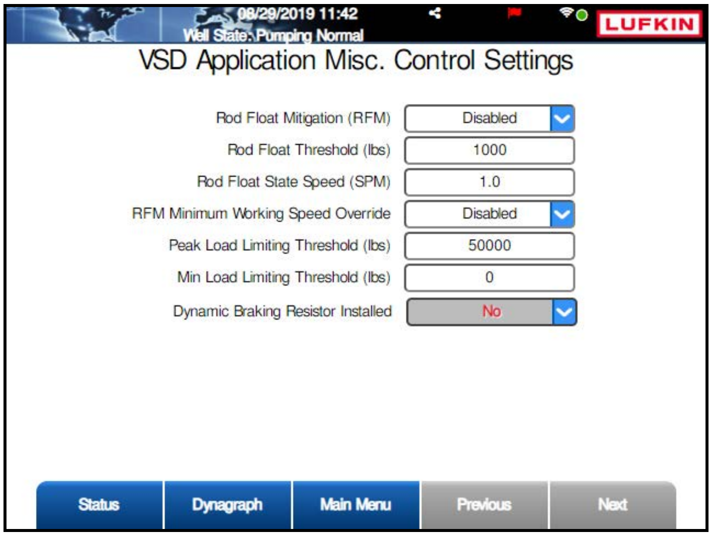


Figure 10-35. VSD Application Miscellaneous Control Settings Screen

Use the keypad to configure the following parameters on this screen:

- **Rod Float Mitigation (RFM)**: This is a powerful feature for dynamically operating a pumping unit to minimize or eliminate rod float. If rod float or rod hangup is not a problem for this well, leave this parameter disabled.

  To enable or disable this feature, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to highlight the desired option and then press <**ENTER**> again.

- **Rod Float Threshold (lbs)**: When the rod load drops below this threshold, the controller determines that it is likely that rod float is occurring, and it activates the Rod Float Mitigation feature. This feature stays active until the load again rises above the threshold. Lufkin Automation recommends a value of 200 – 300 lbs (91 – 135 kg).

  Use the keypad to define this value.

- **Rod Float State Speed (SPM)**: This value is the speed the pumping unit uses when the Rod Float Mitigation feature is activated by the current polished rod load falling below the programmed Rod Float Load Threshold value. The response time to this slower speed command is dependent on the deceleration time programmed in the VSD and the response time of the VSD analog output function.

  Use the keypad to define this value.

- **RFM Minimum Working Speed Override**: When enabled, this feature allows the pumping unit to temporarily operate below the minimum working speed.

Caution: This feature should only be enabled when the Rod Float Mitigation feature is enabled. Operating the pumping unit below its minimum working speed for extended periods can damage the unit.

To enable or disable this feature, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to highlight the desired option and then press <**ENTER**> again.

- **Peak Load Limiting Threshold (lbs)**: Setting this parameter to a value below the Peak Load Allowed limit activates this safety feature. The units for this parameter are in pounds, with a default value of 50,000 lbs.

  If the peak load observed during a pumping unit cycle exceeds the Working Peak Load Limiting value, the controller makes a decision to slow the pumping unit by one step, reducing the current Speed Output by the Speed Decrease Size. If the Working Peak Load Limiting value is again exceeded on the following stroke, the unit will be slowed again. In this fashion, the speed will be adjusted slower until the Working Peak Load Limit is no longer violated. Working Peak Load violations override the pump fillage control decision. When this limit is not violated, the algorithm returns to the normal speed change decision process based on fillage.

- **Min Load Limiting Threshold (lbs)**: Setting this parameter to a value above the Minimum Load Allowed activates this safety feature. The units for this parameter are in pounds, and the default is 0 lbs.

  If the minimum load observed during a pumping unit cycle falls below the Minimum Load Limiting value, the controller makes a decision to slow the pumping unit by one step. If the Working Minimum Load Limiting value is again exceeded on the following stroke, the unit will be slowed again. In this fashion the speed will be adjusted slower until the Working Minimum Load Limiting value is no longer violated. When this limit is not violated, the algorithm returns to the normal speed change decision process based on pump fill percent.

- **Dynamic Braking Resistor Installed**: If a DBR (dynamic braking resistor) unit is installed, select **Yes** from the drop-down list. Two additional fields will appear:
  - **Dynamic Braking Resistance (Ohm)** – Use the keypad to define the resistance of the installed DBR.
  - **Allowable Continuous Braking Power (kw)** – Use the keypad to define the power rating of the installed DBR.

Note: This information is listed on the DBR nameplate.

If there is no DBR installed, select **No** from the drop-down list.

Advanced VSD Applications

From the VSD Configuration Menu screen, press the **Advanced VSD Applications** button to display the Advanced VSD Applications screen shown in Figure 10-36.

Figure 10-36. Advanced VSD Applications Menu Screen

These menu options are discussed on the following pages.

Sectional Speed Control

From the VSD Configuration Menu screen, press the **Sectional Speed** button to display the VSD Sectional Speed screen shown in Figure 10-37.

Note: This feature is only available when the Fluid Pound Avoidance feature is disabled. See “Fluid Pound Avoidance” on page 10-42 for more information.

The LWM 2.0 controller uses a sectional speed change algorithm when calculating the appropriate upstroke and downstroke speed. This algorithm enables the controller to change the speed at up to six different positions (or sections) of the upstroke and downstroke cycle.

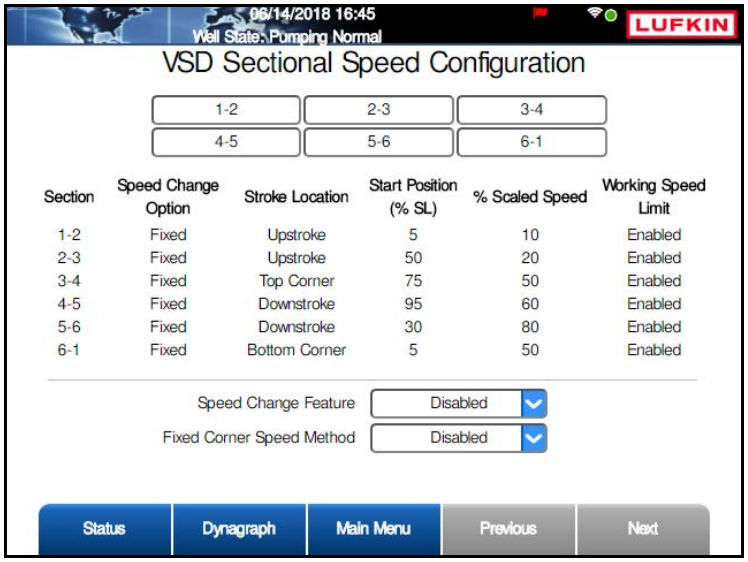


Figure 10-37. VSD Sectional Speed Configuration Screen

This screen allows the operator to adjust the speed of the stroke throughout its entire cycle. The speed control parameters have a non-linear range of 0 – 100% with 100% being the fastest speed. By adjusting the working speed output and starting position of the polished rod, the operator can achieve different pumping speed variations throughout the pumping cycle. This maximizes pumping efficiency and reduces stress on the components.

Note: This feature is only available when the Fluid Pound Avoidance feature is disabled. See “Fluid Pound Avoidance” on page 10-42 for more details.

Each button on this screen provides access to the six sections of the pumping cycle. Use the arrow keys to highlight the desired section and then press <**ENTER**>. The speed control parameters are displayed for that section as shown in Figure 10-38.

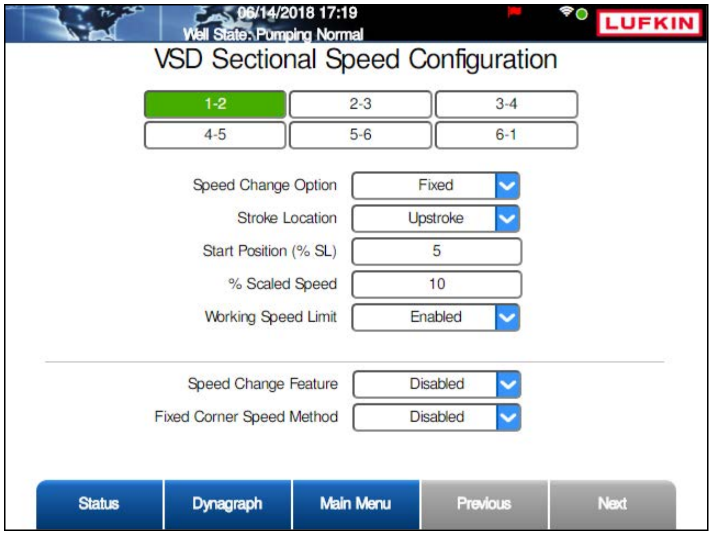


Figure 10-38. VSD Sectional Speed Parameters

The VSD Sectional Speed Configuration parameters are described below.

- **Speed Change Option**: There are four speed change options available for each section:
  - **Not Used**: There is no speed change set for this position.
  - **Fixed**: The pump runs at a fixed speed, regardless of the existing conditions.
  - **Auto**: The Auto setting allows the controller to adjust the speed as needed.
  - **Auto+**: Same as the Auto setting, but allows the speed to be increased by the amount defined in the % Scaled Speed parameter. Refer to the “% Scaled Speed” description below for more information.
  - **Auto-**: Same as the Auto setting, but allows the speed to be decreased by the amount defined in the % Scaled Speed parameter. Refer to the “% Scaled Speed” description below for more information.

  With the **Speed Change Option** field highlighted, press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to highlight the desired option and then press <**ENTER**> again.
- **Stroke Location**: Use the right arrow key to highlight the **Stroke Location** field. Press <**ENTER**> to display the drop-down list. Four options are available:
  - Upstroke
  - Downstroke
  - Top Corner
  - Bottom Corner

  Use the up or down arrow keys to highlight the desired option and then press <**ENTER**> again.
- **Start Position (% SL)**: The **Start Position** parameter determines the stroke position at which the speed control should begin.

  Use the right arrow key to highlight this field and then press <**ENTER**>. Use the keypad to define the start position value and then press <**ENTER**> again.

- **% Scaled Speed**: The **% Scaled Speed** parameter determines what percentage to reduce the speed for the highlighted stroke section.

  Use the right arrow key to highlight this field and then press <**ENTER**>. Use the keypad to define the start position value and then press <**ENTER**> again.
- **Working Speed Limit**: Use the arrow keys to highlight the **Working Speed Limit** field for the desired section. Press <**ENTER**> to display the drop-down list. Use the up or down arrow key to select **Enabled** or **Disabled** and then press <**ENTER**> again.
- **Speed Change Feature**: Use the arrow keys to highlight the **Speed Change Feature** field for the desired section. Press <**ENTER**> to display the drop-down list. Use the up or down arrow key to select **ENABLED** or **DISABLED** and then press <**ENTER**> again.
- **Fixed Corner Speed Method**: Use the arrow keys to highlight the **Fixed Corner Speed Method** field for the desired section. Press <**ENTER**> to display the drop-down list. Use the up or down arrow key to select **ENABLED** or **DISABLED** and then press <**ENTER**> again.

Press the <**ESC**> button to return to the Advanced VSD Applications menu screen.

Fluid Pound Avoidance

From the Advanced VSD Application menu screen, press the **Fluid Pound Avoidance** button to display the Fluid Pound Avoidance screen shown in Figure 10-39.

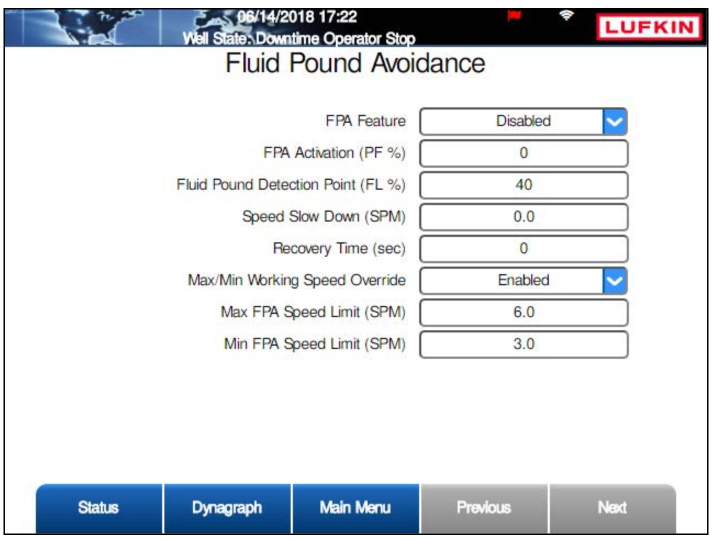


Figure 10-39. Fluid Pound Avoidance Screen

The fluid pound avoidance (FPA) control algorithm feature takes advantage of the ability of a Variable Speed Drive (VSD) to modulate the speed of the prime mover within one stroke to reduce the effects that fluid pound conditions have on the pumping system.

The parameters available on this screen are discussed below.

- **FPA Feature**: Use this parameter to enable or disable the FPA feature. With FPA disabled, the VSD operates with its standard control settings. With FPA enabled, several settings can be programmed to modify the intra-stroke speed to automatically achieve a much-reduced plunger downstroke velocity when it contacts the gas or liquid in the well.
- **FPA Activation (PF %)**: The standard VSD settings trigger a slowdown if Actual Fillage falls below the Reference Fillage setpoint, minus the Deadband % and delayed by the Check Event number of strokes. The FPA Activation parameter initiates a slowdown during the beginning of

the downstroke at a more conservative Actual Fillage value than a typical Reference Fillage value of 75 or 80%.

FPA Activation	Units	Default	Min	Max
	%	92	85	95

Note: The default **FPA Activation (PF %)** value is recommended since the overall SPM and Inferred Liquid will stay the same as FPA automatically "makes up" exactly for the early downstroke slowdown when activated. There is no harm, and much potential benefit to having FPA activated on almost every stroke except near 100% liquid fillage.

- **Fluid Pound Detection Point (FL %)**: This horizontal line functions similarly to Fill Base in the standard control settings, avoiding a false TV opening pick within erratic pump card shapes near the beginning of the downstroke. The Actual Fillage and Fluid Pound Detection Point should be almost identical for most pump cards.
- **Speed Slow Down (SPM)**: The optimum setting is usually the same as the gas fillage percentage in the barrel when the VSD will be instructed to slow down for pumpoff. The default will generally work fine for a Reference Fillage setting of 75 - 80%.

Speed Slow Down	Units	Default	Min	Max
	%	25	10	50

Note: If the pump is greatly over-displaced and liquid fillage rapidly falls to 50% before VSD slowdown occurs, a Speed Slowdown value of as high as 50% may be desirable.

- **Recovery Time (sec)**: If FPA is enabled and active due to the Actual Fillage being below 95%, the value set in the parameter "FPA Activation (PF%)" above, FPA will automatically try to "make up" for the lost SPM during the early downstroke slowdown by increasing the SPM during the other parts of the stroke. It is desirable to "spread out" resumption of normal SPM in region 1 of the plot in Figure 10-40:

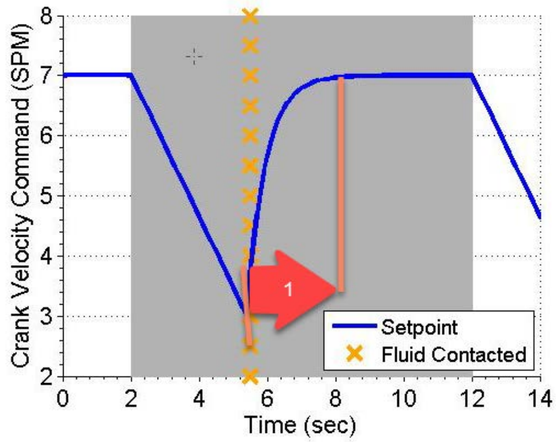


Figure 10-40. Fluid Pound Recovery Time

Recovery Time	Units	Default	Min	Max
	sec	2.5	0.5	5

Note: The default of 2.5 seconds is optimal for a stroke period of 10 seconds (6 SPM), and should be changed proportionally for SPM much different than this. The majority of the speed recovery occurs within the first second under this setting.

- **Max/Min Working Speed Override**: When enabled, this feature allows the pumping unit to temporarily operate above the maximum and/or below the minimum working speed.
- **Max and Min FPA Speed Limit (SPM)**: The normal Max and Min Working Speed VSD settings will prevent FPA from functioning properly if they are set too close together. FPA should be allowed to override these limits by a reasonable amount, in particular on the Minimum side. These parameters control the pumping unit's maximum and minimum speeds while FPA is active.

  For example, if the standard VSD Maximum and Minimum Working Speeds are set at 48Hz and 42Hz on a stable well, the desired Minimum FPA Speed Limit would be 36Hz (48 x 0.75) when FPA is activated at 25%. The standard Minimum Working Speed of 42Hz would prevent this, but the default Minimum FPA Speed parameter allows the pumping unit's speed to dip briefly to 36Hz when necessary.

  Similarly, the Maximum FPA Speed Limit allows the pumping unit to "recover" at a speed slightly above 48Hz to "make up" for the SPM lost during the FPA slowdown period. These values are shown in the table below.

	Units	Default	Min	Max
Min FPA Speed Limit	Hz	30	0	100
Max FPA Speed Limit	Hz	60	0	100

Note: For this example, a good starting point for the Max FPA Speed Limit is

(Max Working Speed) x 1.10 = 48 x 1.1 = 53Hz.

The Min FPA Speed Limit should be

(Min Working Speed) x 0.7 = 42 x 0.7 = 29Hz.

If FPA Speed Slowdown has been set higher or lower than 25%, these speed limits should be adjusted accordingly.

Drive Parameters

From the VSD Configuration menu screen, press the **Drive Parameter** button to display the first VSD Drive Parameter Setting screen shown in Figure 10-41.

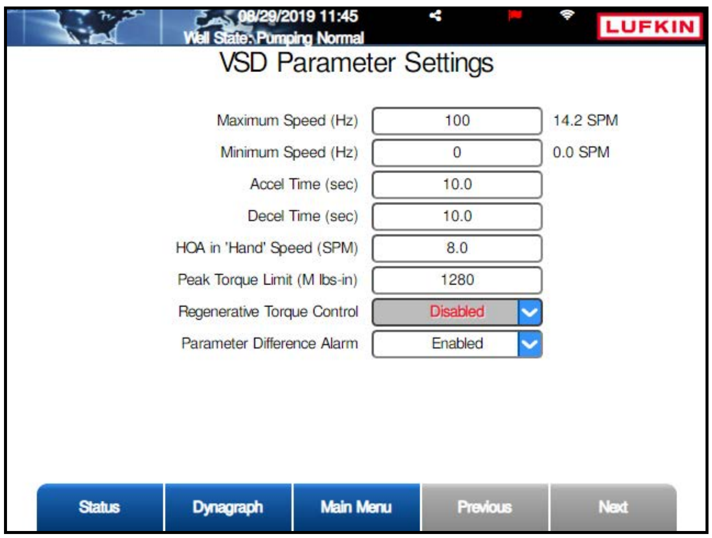


Figure 10-41. VSD Load/Position Setup Screen

Note: Drive parameters can only be changed while the drive is not running. These values are grayed out when the drive is in operation.

The parameters displayed are as follows:

- **Maximum Speed**: This parameter sets the maximum speed (measured in Hz) of the inverter drive. The current pumping speed is displayed to the right of the text field.

  Using the keypad, define the value for this parameter.

- **Minimum Speed**: This parameter sets the minimum speed (measured in Hz) of the inverter drive. The current pumping speed is displayed to the right of the text field.

  Using the keypad, define the value for this parameter.

- **Accel Time (sec)**: This parameter sets the length of time for acceleration from 0 to 120 Hz. This ramp rate will apply to all speed increase operations, regardless of the speed increase amount.
- **Decel Time (sec)**: This parameter sets the length of time for deceleration from maximum speed to minimum speed. For more details, see “Accel Time” above.
- **HOA in ‘Hand’ Speed (SPM)**: (This parameter applies to HOA or HOL switch-equipped controllers only.) When the controller’s HOA or HOL switch is set to Hand mode, the pumping speed is controlled by this parameter. Using the keypad, define the value for this parameter. See “HOL Switch” on page 7-3 for details on this switch.
- **Peak Torque Limit (M-in-lbs)**: This parameter sets the maximum allowed torque value for the pumping unit measured in thousands of inch-pounds. If the controller calculates a torque value greater than this limit at the completion of a stroke, the pumping unit shuts down early in the next upstroke. Use the keypad to define the value for this parameter.
- **Regenerative Torque Control**: A beam pumping unit has a tendency to overdrive the prime mover at certain points in the pumping cycle due to counterbalance conditions and unit inertia. This overdrive condition causes the motor to change from a motoring state to a generating state and begin to return power to the drive inverter section. The returned power causes the DC bus of the variable speed drive to rise, possibly reaching a high enough level for the drive to trip out on a high bus voltage. The **Regenerative Torque Control** feature (when enabled) automatically switches the VSD from Speed Control mode to Torque Control mode when rising DC bus voltage is detected. In Torque Control mode, the drive will increase the speed signal to the inverter in order to stay in a positive torque, or motoring, mode of operation. This speed will increase up to the programmed maximum speed.

  If well conditions are favorable, the Regenerative Torque Control feature can eliminate the need for dynamic braking resistors (DBR).

  With certain types of pumping units and in situations where the unit is not well balanced, RTC can cause undesirable behavior of the pumping unit. In these cases, RTC should be disabled and a DBR package will be required.

  When a DBR is used, the RTC feature may still be enabled and the working peak speed can be adjusted so that the torque control operation can handle some of the regenerated energy, thereby decreasing the energy that needs to be dissipated by the DBR. For more suggestions about the best way to handle regenerative energy in your particular application, consult your Lufkin representative.

  Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.
- **Parameter Difference Alarm**: The controller polls the configuration registers in the drive and compares them to the values saved in the controller. If one or more of these registers is different, a general alarm is triggered when the Parameter Difference Alarm feature is enabled.

  Select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.

Press the **Save** button to save changes made on this screen.

Press the **Next** button to display the second VSD Parameters screen shown in Figure 10-42.

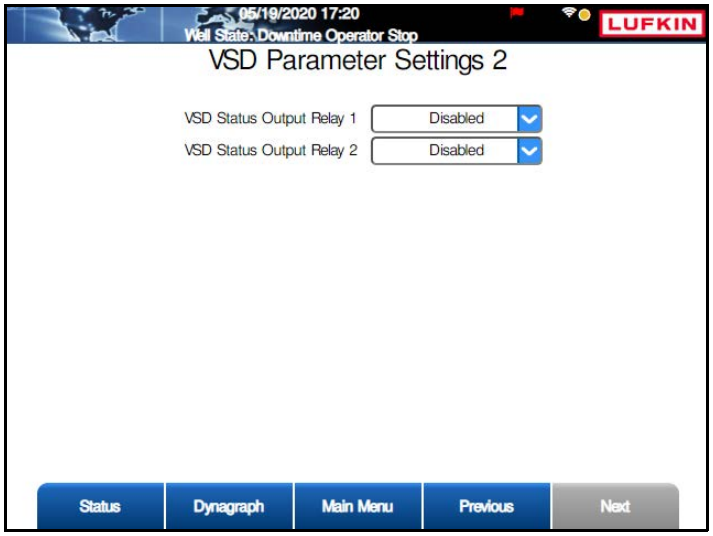


Figure 10-42. VSD Parameters Screen (2 of 2)

This screen allows the operator to assign an action for connected status output relays. Available options are

- Disabled
- Run
- Fault

Use the arrow keys to select the desired option from the drop-down list and then press <**ENTER**>.

Press the **Save** button to save changes made on this screen.

Press <**ESC**> to return to the VSD Configuration menu screen.

VSD Motor Data

From the VSD Configuration menu screen, press the **Motor Data** button to display the VSD Motor Data screen shown in Figure 10-43.

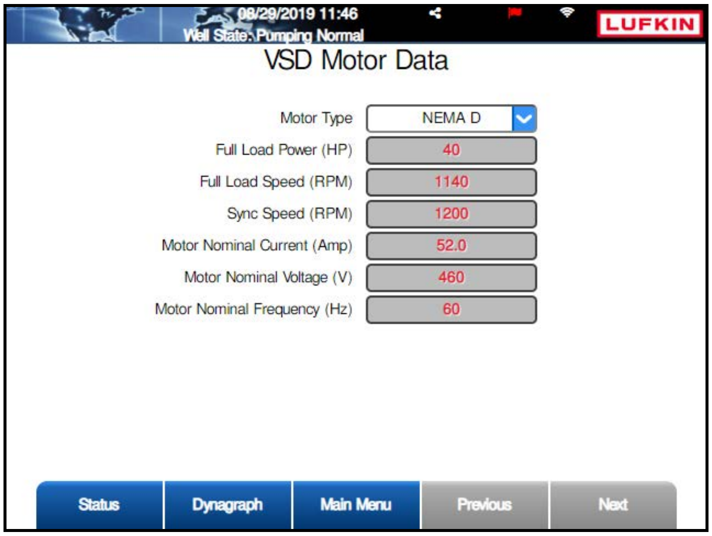


Figure 10-43. VSD Motor Data Screen

The parameters on this screen are discussed in the following paragraphs.

Note: The parameters on this screen can only be changed when the pumping unit is stopped.

Using the keypad, define the value for the following parameters:

- **Motor Type**: Select **NEMA D** or **Ultra High Slip** from the drop-down menu and then press or click the **Save** button.
- **Full Load Power (HP)**: This value is the nameplate horsepower rating of the prime mover.

Note: The power rating of the motor must be entered in horsepower. If the motor is rated in kilowatts (kW), convert kW to HP by multiplying the kW value by 1.33.

- **Full Load Speed (RPM)**: This parameter is the full load speed of the prime mover specified on the Prime Mover screen.
- **Sync Speed (RPM)**: This parameter specifies the no-load speed of the motor. This information should be available on the motor nameplate.
- **Motor Nominal Current (Amp)**: This parameter configures the full rated load motor current. This information is typically written on the motor nameplate.

- **Motor Nominal Voltage (V)**: This parameter configures the design operating voltage for the motor. This information is typically written on the motor nameplate.
- **Motor Nominal Frequency (Hz)**: This parameter configures the nominal motor frequency. This value should be written on the nameplate. The frequency is typically 60 Hz in the US or 50 Hz in many international locations.

Press the <**ESC**> button to return to the VSD Configuration Menu screen.

VSD Fault Configuration

Press the **Drive Fault** button to display the VSD Fault Settings screen shown in Figure 10-44.

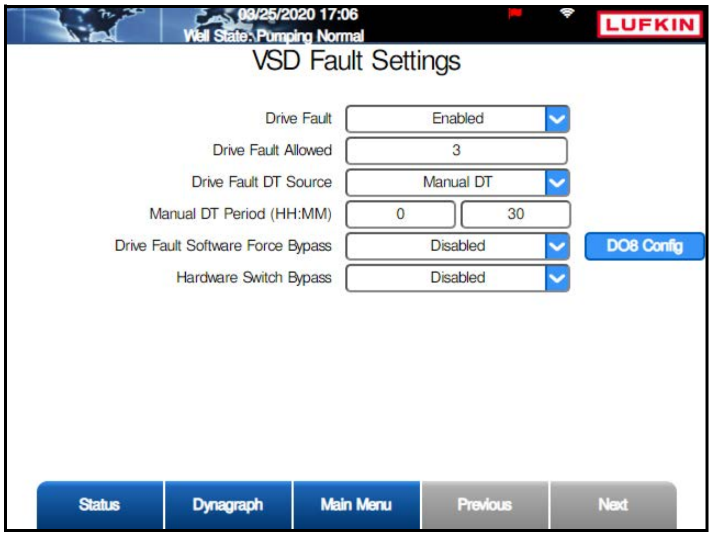


Figure 10-44. VSD Fault Settings Screen

The available parameters on this screen are as follows:

- **Drive Fault**: Select **Enabled** or **Disabled** to enable or disable the drive fault parameter.
- **Drive Fault Allowed**: Using the keypad, define the number of consecutive drive faults allowed. If this parameter is set to 0 (zero) or 1, the controller will immediately declare a Malfunction state after a drive fault is detected. If the consecutive allowed limit is set greater than 1, the controller will go to downtime, after which it will attempt to restart the drive. After the controller detects more than the consecutive allowed drive faults, it declares a Malfunction/ Drive Fault state, which will require user intervention. The one exception to this depends on the setting specified for the **Drive Fault Software Force Bypass** parameter, which is explained below.
- **Drive Fault DT Source**: This parameter gives the option of using the standard system downtime period or the Drive Fault DT Period shown on this screen. (See “Operational Limits Configuration” on page 10-26 for details on the standard system downtime period.)

  Select **Manual DT** or **Drive Fault DT** from the drop-down list and then press or click the **Save** button.
- **Drive Fault/Manual DT Period (HR:MM)**: This is the time in minutes that the system will stay in an Off state when a drive fault signal or a manual downtime signal is received. (See the description about the Drive Fault Allowed field above.)

  Use the keypad to define this value.

- **Drive Fault Software Force Bypass**: If an optional bypass assembly is included in the system installation, use the keypad to define the output of the drive while running in bypass mode. The controller will run the pumping unit in bypass (across the line; for example, 60 Hz) rather than declaring a malfunction state due to a drive fault after the consecutive allowed drive faults have occurred. (See the description about the **Drive Fault Allowed** field above.)

Note: When the **Drive Fault Software Force Bypass** feature is enabled, the controller will run the pumping unit in an on-off cycle control mode until the drive fault is corrected. See “Pump Off Control Actions” on page 2-5 for more information on this control mode.

- **Hardware Switch Bypass**: (This feature is only visible when the **Drive Fault Software Force Bypass** option is enabled.) If a hardware bypass switch is included with the VSD unit, use this parameter to enable that switch. To enable this feature, select **Enabled** from the drop-down list and then press <**ENTER**>.

Press the <**ESC**> button to return to the VSD Configuration Menu screen.

Gauge-Off Time and Peak Energy Management

From the RPC screen, press the **GOT/PEM** button to display the Gauge-Off Time and Peak Energy Management screen shown in Figure 10-45.

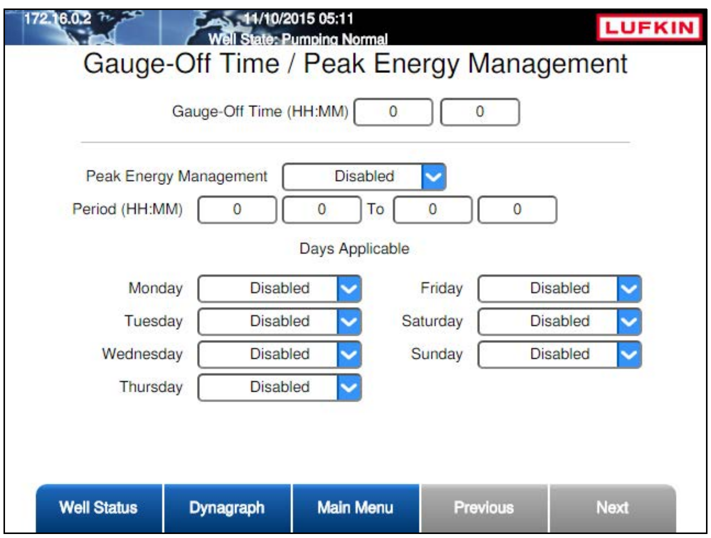


Figure 10-45. Gauge-Off Time and Peak Energy Management Screen

Gauge-Off Time

Gauge-Off Time is the time of day that the controller updates all of the 60-day historical data buffers. This feature enables the operator to specify the time of day that the controller updates all of the 60-day historical data buffers. Time is specified using the 24-hour clock format of HH:MM:SS.

To configure gauge-off time, perform the following steps:

1. With the **HH** (hours) field highlighted, use the number keys to define the hours value.
2. Press the right arrow key to highlight the **MM** (minutes) field. Use the number keys to define the minutes value.
3. Press the **Save** button to save the values in the system.

Peak Energy Management

The Peak Energy Management feature enables the controller to shut down the pump during peak times, go into a Downtime Peak Energy Management state, and suspend all normal operation. The operator can program the period of day and which days this function is to take effect. Normal operation resumes at the end of the programmed period.

To configure peak energy management, perform the following steps:

1. Use the arrow keys to highlight the **Peak Energy Management Enabled/Disabled** field.
2. Press <**ENTER**> to display the drop-down list. Press the down arrow key to select the **Enable** option and then press <**ENTER**> again.
3. Use the down and left arrow keys to highlight the **Period (HH:MM)** fields. Using the number keys, define the hours and minutes values for the start and stop times.
4. Use the left and down arrows to highlight the **Monday** drop-down list. Press <**ENTER**> to display the drop-down list. Press the up or down arrow keys to select the **Enable** or **Disable** option and then press <**ENTER**> again.
5. Repeat step 4 for each day.
6. Press the **Save** button to save the values in the system.

Press the **Main Menu** button to return to the Main Menu screen.

RPC Miscellaneous I/O

From the Setup screen, press the **RPC MISC I/O** button to display the RPC Miscellaneous I/O screen shown in Figure 10-46.

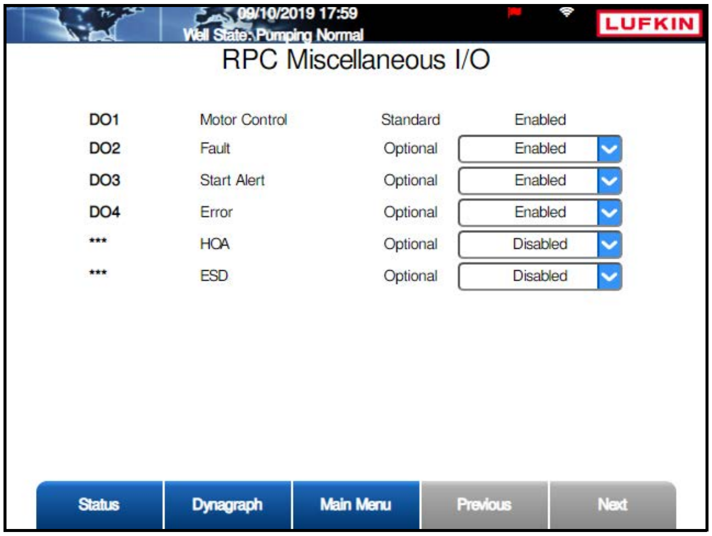


Figure 10-46. RPC Miscellaneous I/O Screen

Use this screen to enable or disable the miscellaneous digital input/output channels for optional features such as an HOA/HOL switch or an ESD switch. These features use a signal relay that is wired to discrete inputs or outputs on the Mark VIe controller terminal strip.

Note: Each input or output must be assigned using the Digital Input/Output Configuration screen. See “Digital Input/Output Configuration” on page 10-67 for details.

These optional features are described below:

- **Motor Control**: This channel is enabled by default and cannot be disabled. Motor control uses **DO1** as the default output point.
- **Fault**: Fault sensing devices use **DO2** as the default output point. Select **Enabled** to enable this channel.
- **Start Alert**: The optional Start Alert relay may be wired to a siren or light beacon to warn personnel that the unit is about to start. If this device is installed, enable this channel. Start alert devices use **DO3** as the default output point.
- **Error**: Enable this feature if an external error lamp is used with the controller. When enabled, this lamp will flash when an error is detected in the controller. This feature uses **DO4** as the default input/output point.
- **HOA**: An extra contact block on the unit Hand-Off-LWM (Auto) switch can be wired to discrete inputs on the LWM 2.0 controller to give an operator at the host computer a definitive indication of the position of that switch. The contacts must be wired so that one discrete input (**DI6**) is connected to the signal common when the switch is in the LWM (Auto) position. A

second discrete input (**DI5**) is connected to the signal common when the switch is in the HAND position. When the switch is in the OFF position, neither of the programmed discrete inputs is connected to the signal common.

When this channel is enabled, the well states “Pumping/HOA in Hand” and “Downtime/HOA Off” are activated.

- **ESD**: For systems equipped with an ESD (Emergency Shutdown) switch, enable this channel. The default digital input/output point for ESD is **DI7**.

Use the up or down arrow keys to highlight the desired field and then press <**ENTER**>. Use the up or down arrow keys to select **Enabled** or **Disabled** and then press <**ENTER**> again.

Advanced RPC Applications

From the Setup screen, press the **Advanced RPC Applications** button to display the Advanced RPC Applications menu screen shown in Figure 10-47.

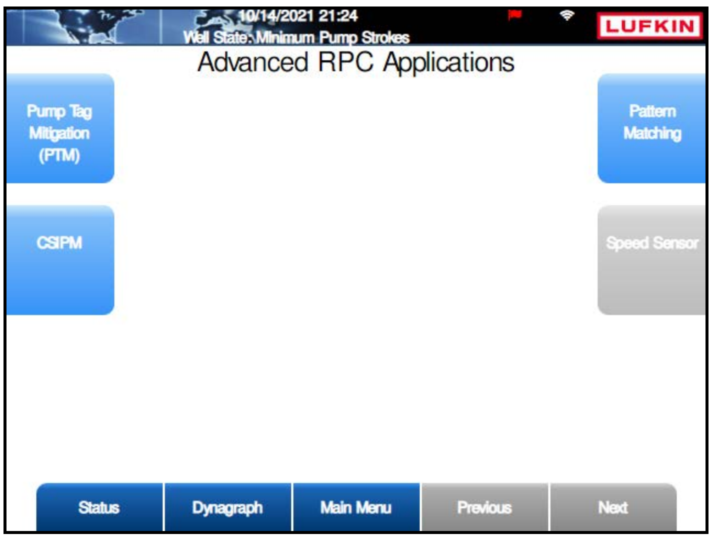


Figure 10-47. Advanced RPC Applications Menu Screen

The functions available on this screen are discussed in the following pages.

Pump Tag Mitigation

From the Advanced RPC Applications menu screen shown in Figure 10-47, press the **Pump Tag Mitigation (PTM)** button to display the Pump Tag Mitigation (PTM) screen shown in Figure 10-48 below.

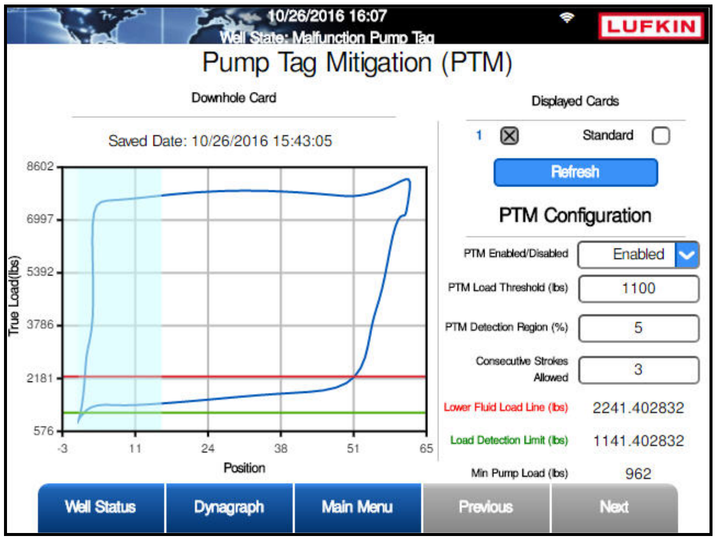


Figure 10-48. Pump Tag Mitigation (PTM) Screen

Pump tagging (also known as pump tapping) is defined as the mechanical contact that can occur between the pump plunger and the lower end of the pump barrel. This is a common condition that is sometimes intentionally set by operators on shallow and mid-depth applications as a way to ensure complete stroke efficiency in downhole conditions.

In deep well pumping, such conditions must be avoided as the total weight of the rod string (several tons) will usually overcome the mechanical integrity limits of the pump and its landing array. This causes catastrophic damage and generates deferred production and well intervention costs.

The Pump Tag Mitigation (PTM) feature allows the LWM 2.0 controller to recognize the pump tag condition by analyzing runtime metrics data contained in the downhole card. Once the condition is detected, the controller will shut down the pumping unit to prevent damage to the pump and the rod string.

Note: This feature is only available in Normal operation mode and the Downhole and VSD Downhole control modes with the controller in a “Pumping Normal” well state. It is not supported in Timed or Host operation modes. Refer to the section titled “Operational Limits 1 Screen” on page 10-26 for details on operation and control modes.

The standard LWM 2.0 RPC generates a downhole card at the end of stroke after a complete pumping cycle. When the PTM feature is enabled, the controller analyzes the downhole card in the specified Pump Tag Mitigation Detection Region. When the pump load in this region drops below the defined Pump Tag Mitigation Detection Load setpoint, the controller initiates one of two actions:

- In Downhole control mode, the controller shuts down the pumping unit after the Consecutive Strokes Allowed setpoint has been violated.
- In VSD Downhole control mode, the controller can run the pumping unit at low speed after the Consecutive Strokes Allowed setpoint has been violated.

Note: The option to run the pumping unit at low speed is configured on the VSD Application Control Settings screen. Refer to “VSD Application Control” on page 10-35 for details.

After the pumping unit has been shut down or slowed to low speed, the controller then goes into a Malfunction Pump Tag well state, requiring the user to restart.

Status Information

This screen displays relevant status information related to the pump tag mitigation feature. This information is discussed below.

- **Displayed Cards**: There are two options available for displayed cards:
  - **Most Recent** – When a pump tag condition is detected, a timestamped copy of the downhole card showing the most recent pump tag occurrence is saved and displayed on this screen.
  - **Standard** – A downhole card can be saved as a reference for troubleshooting purposes. To view this standard card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

  Press the **Refresh** button to clear the saved card and load the most recent saved downhole card.
- **Lower Fluid Load Line**: The controller automatically detects this load value from the downhole card and displays the value in green on the saved dynagraph card.
- **Load Detection Limit**: This value is calculated as follows:

  Lower Fluid Load Line – PTM Load Threshold

  This calculated value is displayed in red on the saved dynagraph card. When the pump load within the PTM Detection Region drops below the PTM Detection Limit value, the controller issues a Shutdown or Run Low Speed command after the Consecutive Strokes Allowed setpoint has been violated.
- **Minimum Pump Load**: This value is determined by the controller as the minimum load in pounds.

PTM Configuration

The following parameters are used in configuring PTM:

- **PTM Enabled/Disabled**: Select **Enabled** or **Disabled** to enable or disable the Pump Tag Mitigation function.

- **PTM Load Threshold (lbs)**: This is a user-defined parameter to calculate the pump tag mitigation detection load.
- **PTM Detection Region (%)**: This is the pump position region from the bottom of stroke expressed as percentage of the total gross stroke length. This is a user-defined variable.
- **Consecutive Strokes Allowed** – This user-defined variable defines the number of consecutive strokes that detected pump tag is allowed before the controller shuts down the pumping unit.

Cyclic Steam Injection Pressure Monitoring (CSIPM)

For pumping systems that use cyclic steam injection in their wells, this feature allows operators to monitor steam injection pressure status with SCADA software.

From the Advanced RPC Applications menu screen, press or click the **CSIPM** button to display the Cyclic Steam Injection Pressure Monitoring Config screen shown in Figure 10-49.

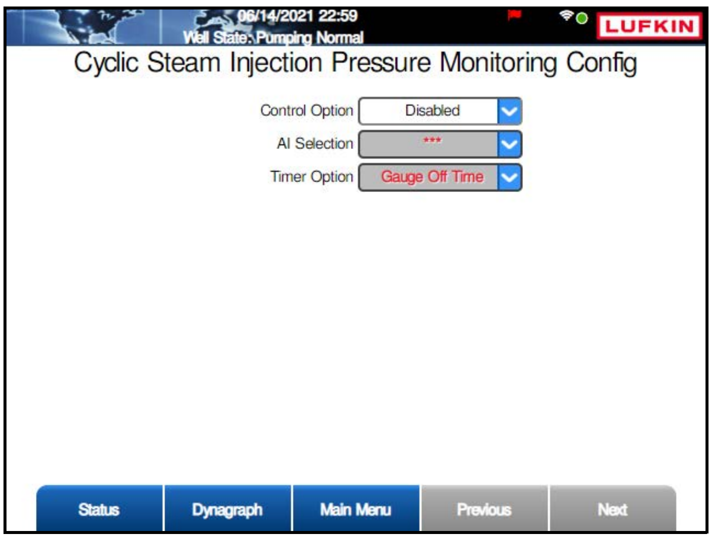


Figure 10-49. Cyclic Steam Injection Pressure Monitoring Configuration Screen

Use this screen to configure the following parameters:

- **Control Option**: Select **Enabled** from the drop-down list to enable this feature.
- **AI Selection**: Select an analog input from the drop-down list. Available options are **AI 3** – **AI 8**.
- **Timer Option**: Select a timer option from the drop-down list. Available options are **Gauge Off Time** and **User Defined**.

  When the **User Defined** option is selected, the **User Defined** timer parameter fields are displayed. Use the keypad to define the desired hours and minutes for the timer and then press <**ENTER**>.

Press the **Save** button to save these changes.

Pattern Matching

From the Advanced RPC Applications menu screen, press or click the **Pattern Matching** button to display the Pattern Matching screen shown in Figure 10-50.

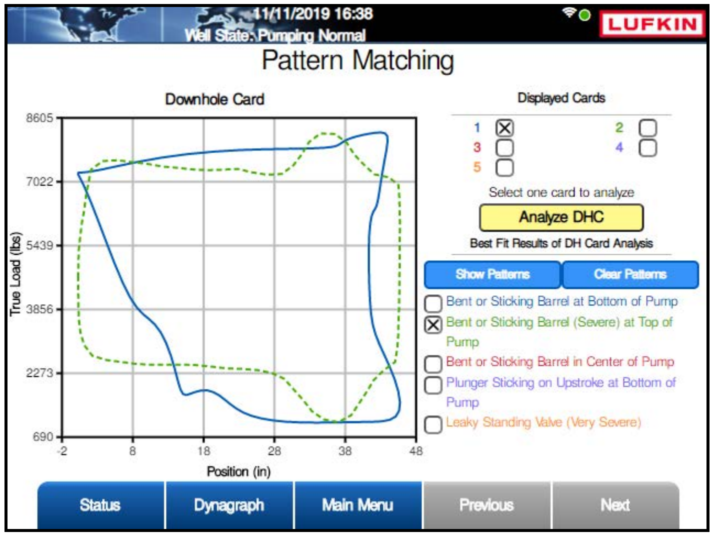


Figure 10-50. Pattern Matching Screen

Pattern matching allows the user to analyze patterns in saved downhole cards for troubleshooting purposes. To start the analysis, perform the following steps:

1. Use the arrow keys to select the check box for the desired card to display and then press <**ENTER**>.
2. Use the arrow keys to highlight the **Analyze DHC** button and then press <**ENTER**>.

   The controller then compares the stored card against a database of stored cards and displays the results on the screen.

There are two methods for viewing the patterns:

- To display all the patterns, use the arrow keys to highlight the **Show Patterns** button and then press <**ENTER**>. All five patterns will be displayed on top of the card being analyzed.
- To display individual patterns, use the arrow keys to highlight the desired pattern and then press <**ENTER**>.

To clear patterns from the screen, use the arrow keys to highlight the **Clear Patterns** button and then press <**ENTER**>.

Speed Sensor

Note: This feature is used for Rotaflex pumping systems only.

From the Advanced RPC Applications menu screen, press or click the **Speed Sensor** button to display the Speed Sensor screen shown in Figure 10-51.

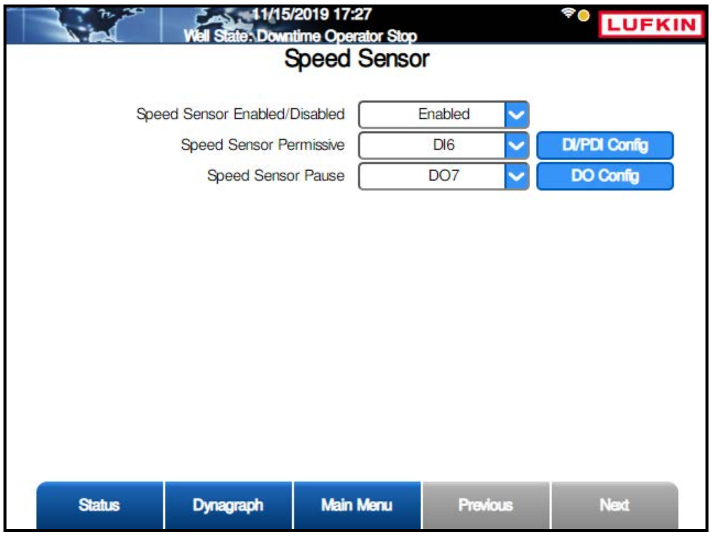


Figure 10-51. Speed Sensor Configuration Screen

Rotaflex linear pumping unit systems use an automatic braking system that engages in the event the pumping unit goes into a free fall. This braking system uses a speed sensor that monitors the pumping unit’s speed and engage the brake when the sensor’s speed setpoint is exceeded.

Configure these speed sensors using the following parameters:

- **Speed Sensor Enabled/Disabled**: To enable the speed sensor, select **Enabled** from the drop-down list.
- **Speed Sensor Permissive**: This parameter directs the speed sensor to send data to the controller. Select the desired digital or pseudo digital input from the drop-down list and then press the **Save** button.

  To configure the selected input, press the **DI/PDI Config** button to display the configuration screen for the selected input.

Note: If a digital input is selected, the Digital Input/Output Configuration screen will be displayed. If a pseudo digital input is selected, the Pseudo Digital Input Configuration screen will be displayed. Refer to “Digital Input/Output Configuration” on page 10-67 and “Pseudo Digital Input Configuration” on page 10-69 for details on configuring these inputs.

After configuring the selected input, press the <**ESC**> button to return to the Speed Sensor configuration screen.

- **Speed Sensor Pause**: This parameter directs the speed sensor to temporarily stop sending speed data to the controller. Select the desired digital output from the drop-down list and then press the **Save** button.

  To configure the selected digital output, press the **DO Config** button to display the Digital Output Configuration screen. Refer to “Digital Input/Output Configuration” on page 10-67 for details on configuring digital outputs.

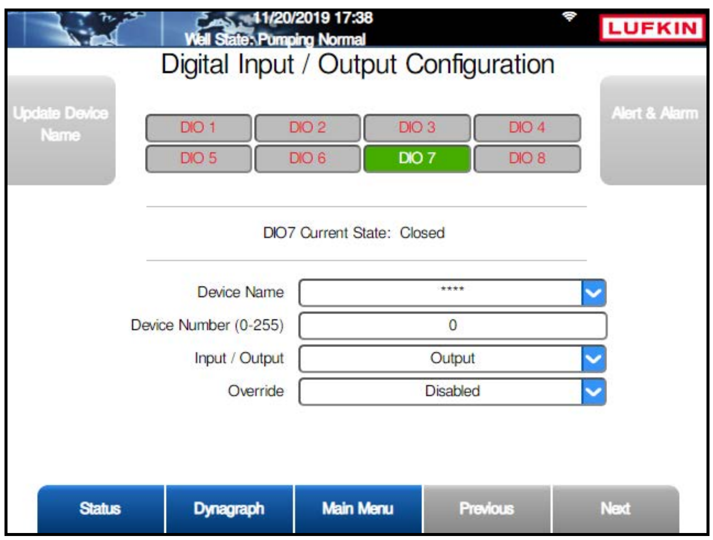


Figure 10-52. Speed Sensor Digital Output Configuration

After configuring the selected output, press the <**ESC**> button to return to the Speed Sensor configuration screen.

General I/O Programming

From the Setup menu screen, press the **General I/O** button to display the General Input/Output Configuration menu screen shown below.

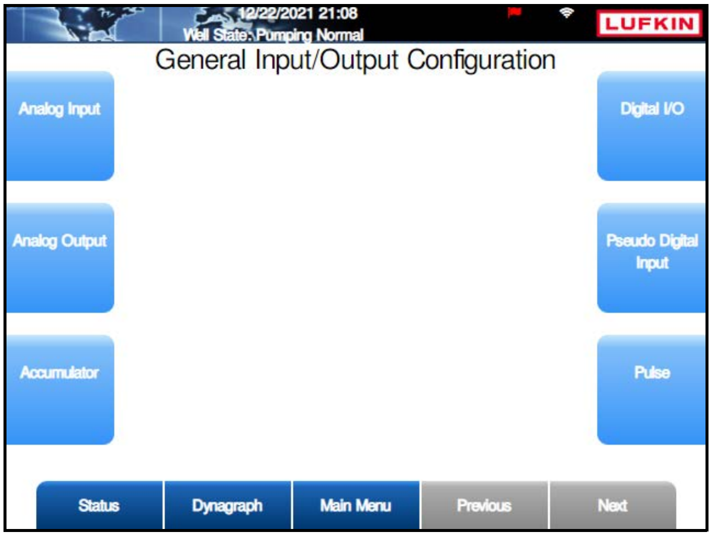


Figure 10-53. General I/O Menu Screen

The input and output options available on this screen are discussed on the following pages.

This screen enables the operator to configure and troubleshoot analog and digital inputs and outputs. Press the appropriate button to access the desired configuration screen.

These screens are discussed on the following pages.

Analog Input Configuration

From the General Input/Output Configuration menu screen, press the **Analog Input** button to display the Analog Input Configuration screen shown in Figure 10-54.

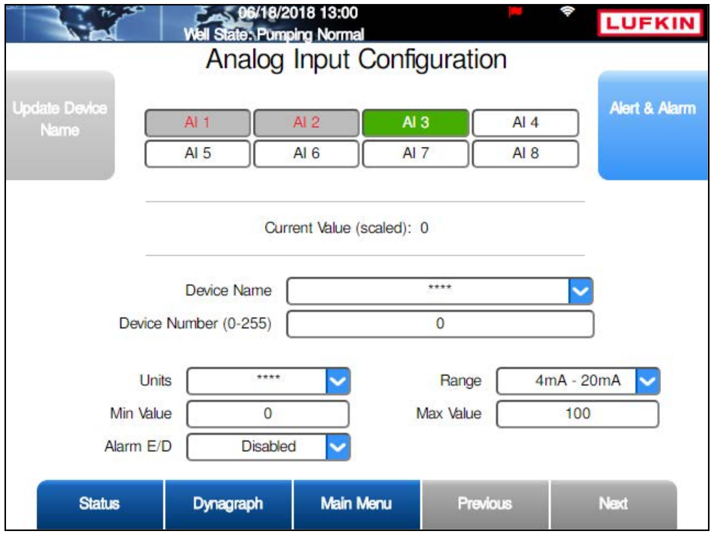


Figure 10-54. Analog Input Configuration Screen

This screen is used to configure all configurable analog inputs in the system. The top of the screen lists all available analog input points. Unavailable analog input points are grayed out.

Use the arrow keys to highlight the analog input point to be configured. The **Current Value** field indicates the present scaled value of the highlighted input.

Each point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

- **Device Name**: Select one of the preprogrammed device names from the drop-down list or create a custom device name. Available options are:
  - Casing Pressure
  - Tubing Pressure
  - Flowline Pressure
  - Upstream Pressure
  - Delta Pressure
  - Tank Level
  - Custom Name (1 – 5)

  Select the **Custom Name** option to create up to five custom device names. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.
- **Device Number (0-255)**: Use the keypad to type a device number in the text field and then press or click the Save button.
- **Units**: Select the desired engineering units of measurement from the drop-down list and then press <**ENTER**>.

- **Range:** Use the up or down arrow keys to select the expected input range of the transducer being used for the highlighted analog input point.
- **Min Value**: This parameter defines the value in engineering units for the minimum output level from the transducer. This value will typically be zero, but if the transducer has a known offset, the controller is able to compensate if the correct value is entered in this field.
- **Max Value**: This parameter defines the value in engineering units for the maximum output from the transducer.
- **Alarm E/D**: Use the up or down arrow keys to select **Enabled** or **Disabled** and then press <**ENTER**>.

Press or click the **Alert & Alarm** button to display the alert and alarm configuration options for the available analog input points. These options are described below:

- **Alarm Option**: Use the keypad to select what action the controller takes when an alarm condition is detected:
    - **Disabled**: No action is taken.
    - **Alarm Only**: An alarm is activated, but the system continues running.
    - **Motor Stop (downtime)**: The motor is stopped and the controller stays in a downtime state until the alarm is cleared.
    - **Malfunction**: A malfunction is logged and the controller responds to this malfunction based on its current malfunction setpoint configuration. See “Operational Limits 1 Screen” on page 10-26 for details on the malfunction setpoint.
    - **DO Ctrl**: With this option, a command is sent to an assigned digital output port. For example, a high pressure alarm could trigger a command to open a valve to relieve the pressure.

Note: When selecting this option for an analog input point, that point must have an assigned name (preprogrammed or custom) selected in the **Device Name** parameter. See “Device Name” on the previous page for details.

- **DO Ctrl Port**: (This parameter is only visible when the **DO Ctrl** alarm option is selected.) This parameter allows the user to configure a digital output port to be triggered when an alarm condition is present.
- **Alert Setpoint**: Use the keypad to specify the high and low alert setpoints in engineering units and then press <**ENTER**>.
- **Alarm Setpoint**: Use the keypad to specify the high and low alarm setpoints in engineering units and then press <**ENTER**>.
- **Alarm Delay(s)**: Use the keypad to specify the high and low setpoints for delay time before the alarm is declared. Press <**ENTER**> to save this value.
- **Alarm Hold(s)**: Use the keypad to specify the high and low values for alarm hold time. Press <**ENTER**> to save this value.

Press or click the **Save** button to save all changes.

Press or click the **General** button to display the device general parameters again.

Press <**ESC**> to return to the General Input/Output Configuration menu screen.

Analog Output Configuration

From the General Input/Output Configuration menu screen, press the **Analog Output** button to display the Analog Output Configuration screen shown in Figure 10-55.

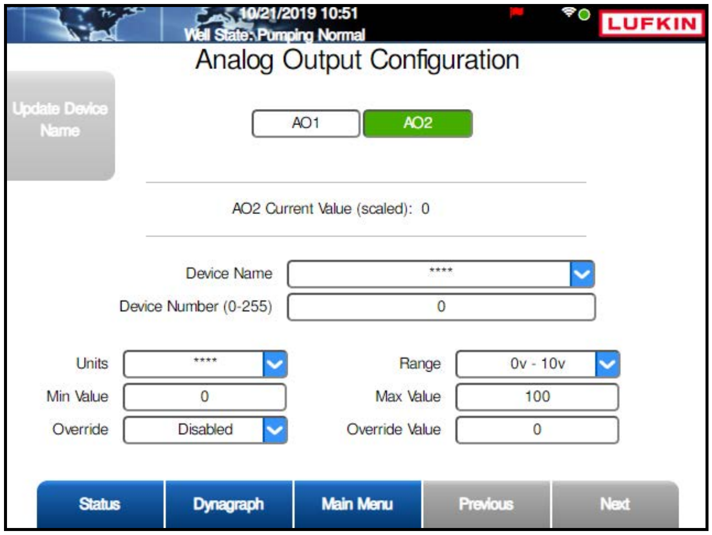


Figure 10-55. Analog Output Configuration Screen

This screen is used to configure the analog outputs in the system. The top of the screen lists the available analog output points.

Use the arrow keys to highlight the analog output point to be configured. The Current Reading field indicates the present raw value of the highlighted output.

Each point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

- **Device Name**: Select one of the preprogrammed device names from the drop-down list or create a custom device name. Available options are:
    - Casing Pressure
    - Tubing Pressure
    - Flowline Pressure
    - Upstream Pressure
    - Delta Pressure
    - Tank Level
    - Custom Name (1 – 5)

  Select the **Custom Name** option to create up to five custom device names. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.

- **Device Number (0-255)**: Use the keypad to type a device number in the text field and then press or click the Save button.
- **Units**: Select the desired engineering units of measurement from the drop-down list.
- **Range**: Specify the expected output range from the process transducer. Use the up or down arrow keys to select the desired range from the drop-down list and then press <**ENTER**>.
- **Min Value**: Enter the engineering units for the minimum output level from the transducer/transmitter. This value will typically be zero, but if the transducer has a known offset, the controller is able to compensate if the correct value is entered in this field.
- **Max Value**: Enter the full scale engineering value for the maximum output from the transducer.
- **Override**: Use the up and down arrow keys to select **Enabled** or **Disabled** from the drop-down list and then press <**ENTER**>.
- **Override Value**: Use the keypad to specify the value to transmit through the analog output if the override feature is enabled. When override is enabled, the application has no control over the analog output.

Press <**ESC**> to return to the General Input/Output Configuration menu screen.

Accumulator Configuration

From the General Input/Output Configuration menu screen, press the **Accumulator** button to display the Accumulator Configuration screen shown in Figure 10-56.

Figure 10-56. Accumulator Configuration Screen

This screen is used to configure all accumulator input points in the system. These input points are displayed at top of the screen.

Use the arrow keys to highlight the accumulator input point to be configured and then press <**ENTER**>. Status information and available parameters are displayed as shown in Figure 10-57 below.

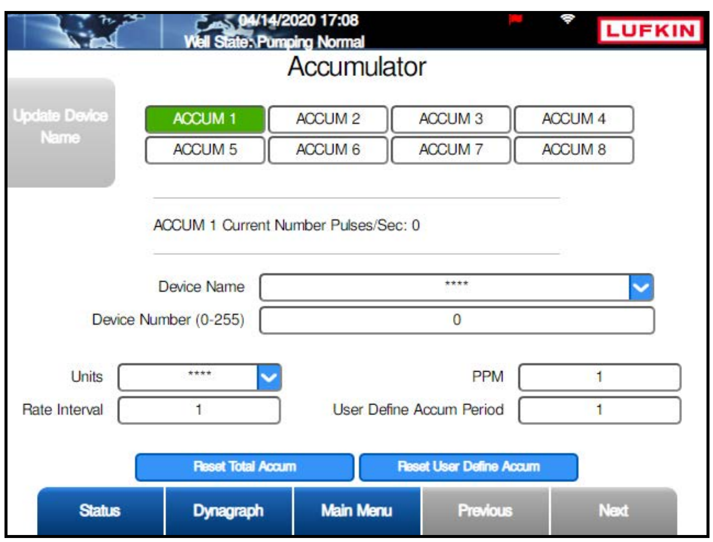


Figure 10-57. Accumulator Configuration Screen with Parameters Displayed

The **Current Number Pulses/Sec** status field indicates the present value of the highlighted input.

Each point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

- **Device Name**: Select one of the preprogrammed device names from the drop-down list or create a custom device name. Available options are:
  - Casing Pressure
  - Tubing Pressure
  - Flowline Pressure
  - Upstream Pressure
  - Delta Pressure
  - Tank Level
  - Custom Name (1 – 5)

  Select the **Custom Name** option to create up to five custom device names. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.
- **Device Number (0-255)**: Use the keypad to type a device number in the text field and then press or click the Save button.
- **Units**: The controller offers approximately 29 options for the unit of measurement to be associated with each auxiliary input. The units selected will be displayed on the Accumulator Status screen. (See “Accumulator Status” on page 9-24.) It is logically related to the PPM field below, but the unit selected does not impact the actual scaling of the accumulator input.
- **PPM**: Pulses per unit of measure (PPM) is an integer that programs the controller to scale this given number of pulses counted at the defined accumulator input point as a single unit. The range is 1 to 999,999.
- **Rate Interval**: This is a user-defined sampling period, measured in minutes. The range is 0 to 1440 minutes. As an example, if a value of 8 is programmed, a 24-hour rate will be calculated based on the number of pulses accumulated during the most recent eight-minute period. The formula for this example of a rate interval of 8 minutes is as follows:

  $$\text{Rate} = \frac{\text{\# of pulses for last 8 minutes}}{\text{PPM}} \times \frac{\text{1440 minutes}}{\text{8 minutes}}$$

  Using the keypad, define this value and then press <**ENTER**>.
- **User Defined Accum Period**: The controller will accumulate a total for this user-defined number of days. The range is 1 to 365 days. At the end of the user-defined period, the accumulated value for that period is saved in a “Previous User-Defined Accumulator” register in the memory map and then the accumulator is cleared to start the accumulation for the next user-defined period. In addition to the User-Defined Period, the controller also maintains a 60-day record of the totals accumulated for the each of the previous sixty 24-hour days specified by Gauge Off Time.

  Use the keypad to define this value.
- **Reset Total Accum**: This button clears the total accumulation value for the highlighted point.
- **Reset Today’s Accum**: This button clears the accumulation value for the last 24 hours.
- **Reset User Define Accum**: This button clears the value for the user-defined accumulation period.

Press <**ESC**> to return to the General I/O menu screen.

Digital Input/Output Configuration

From the General Input/Output Configuration menu screen, press the **Digital I/O** button to display the Digital Configuration screen.

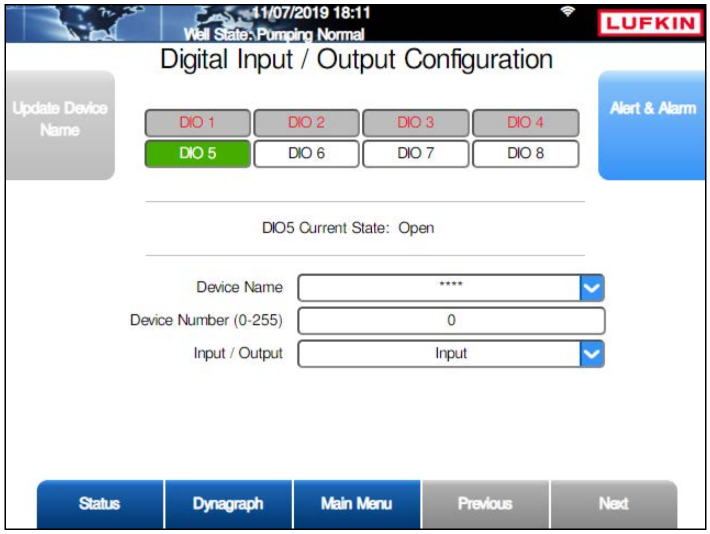


Figure 10-58. Digital Configuration Screen

This screen is used to configure all digital inputs and outputs in the system. The top of the screen lists all available digital input/output points.

Use the arrow keys to highlight the digital input/output point to be configured. The **Current State** field indicates the present raw value of the highlighted point.

Each point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

This screen is used to configure digital inputs and outputs in the system. The top of the screen lists all digital input/output points.

Note: Points that are grayed out are factory-configured and are not configurable.

Use the arrow keys to highlight the digital input/output point to be configured. The **Current State** field indicates the present raw value of the highlighted point.

Each available point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

- **Device Name**: Select one of the preprogrammed device names from the drop-down list or create a custom device name. Available options are:
    - DBR

- Vibration Switch
- Pressure Switch
- Pump Switch
- Environmental Pot
- Facility Shutdown
- PLC
- Run Status
- Output
- Stuffing Box Leak Detector
- Kill Switch
- Flowline Pressure
- Tank Level
- Casing Pressure
- Tubing Pressure
- Custom Name (1 – 5)

Select the **Custom Name** option to create up to five custom device names. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.

Press or click the **Alert & Alarm** button to display the alert and alarm configuration options described below:

- **Alarm Option**: Use the keypad to select what action the controller takes when an alarm condition is detected:
  - **Disabled**: No action is taken.
  - **Alarm Only**: An alarm is activated, but the system continues running.
  - **Motor Stop (downtime)**: The motor is stopped and the controller stays in a downtime state until the alarm is cleared.
  - **Malfunction**: A malfunction is logged and the controller responds to this malfunction based on its current malfunction setpoint configuration. See "Operational Limits 1 Screen" on page 10-26 for details on the malfunction setpoint.
  - **DO Ctrl**: With this option, a command is sent to an assigned digital output port. For example, a high pressure alarm could trigger a command to open a valve to relieve the pressure.

Note: When selecting this option for a digital input point, that point must have an assigned name (preprogrammed or custom) selected in the **Device Name** parameter. See "Device Name" on the previous page for details.

- **DO Ctrl Port**: (This parameter is only visible when the **DO Ctrl** alarm option is selected.) This parameter allows the user to configure a digital output port to be triggered when an alarm condition is present.
- **Alarm Type**: (This parameter is available for input points only.) Use the up or down arrow keys to select the desired alarm type for the highlighted point. The options are **Open** or **Closed**.
- **State Change Delay**: (This parameter is available for input points only.) Use the keypad to specify the number of seconds that a digital state change must be observed before the controller acknowledges the change.

Press or click the **General** button to display the device general parameters again.

Press <**ESC**> to return to the General Input/Output Configuration menu screen.

Pseudo Digital Input Configuration

From the General Input/Output Configuration menu screen, press the **Pseudo Digital Input** button to display the Pseudo Digital Input Configuration screen shown in Figure 10-59.

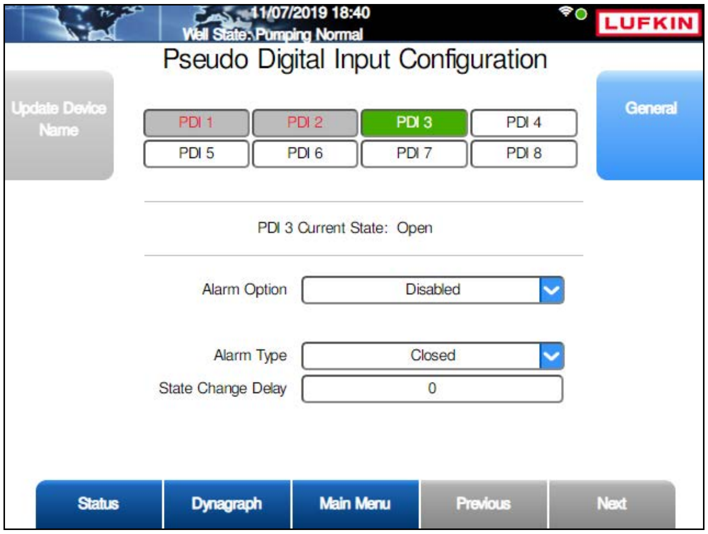


Figure 10-59. Pseudo Digital Input Configuration Screen

Pseudo digital inputs are analog inputs that can be configured to operate like digital inputs. They use the same physical terminal as the analog input channel.

This screen is used to configure pseudo digital inputs in the system. The top of the screen lists all pseudo digital input points.

Note: Points that are grayed out are factory-configured and are not configurable.

Use the arrow keys to highlight the pseudo digital input to be configured and then press <**ENTER**> to make changes. The **Current State** field indicates the present raw value of the highlighted input.

Each available input is configurable using the fields at the bottom of the screen. Available parameters are as follows:

- **Device Name**: Select one of the preprogrammed device names from the drop-down list or create a custom device name. Available options are:
  - DBR
  - Vibration Switch
  - Pressure Switch
  - Pump Switch
  - Environmental Pot
  - Facility Shutdown
  - PLC
  - Run Status
  - Output
  - Stuffing Box Leak Detector
  - Kill Switch
  - Flowline Pressure
  - Tank Level
  - Casing Pressure
  - Tubing Pressure
  - Custom Name (1 – 5)

  Select the **Custom Name** option to create up to five custom device names. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.
- **Device Number (0-255)**: Use the keypad to type a device number in the text field and then press or click the **Save** button.

Press or click the **Alert & Alarm** button to display the alert and alarm configuration options available for the selected pseudo digital input:

- **Alarm Option**: Use the keypad to select what action the controller takes when an alarm condition is detected:
  - **Disabled**: No action is taken.
  - **Alarm Only**: An alarm is activated, but the system continues running.
  - **Motor Stop (downtime)**: The motor is stopped and the controller stays in a downtime state until the alarm is cleared.
  - **Malfunction**: A malfunction is logged and the controller responds to this malfunction based on its current malfunction setpoint configuration. See “Operational Limits 1 Screen” on page 10-26 for details on the malfunction setpoint.

- **DO Ctrl**: With this option, a command is sent to an assigned digital output port. For example, a high pressure alarm could trigger a command to open a valve to relieve the pressure.

Note: The **DO Ctrl** option requires the pseudo digital input to have an assigned name (preprogrammed or custom) selected in the **Device Name** parameter field. See "Device Name" on the previous page for details.

- **DO Ctrl Port**: (This parameter is only visible when the **DO Ctrl** alarm option is selected.) This parameter allows the user to configure a digital output port to be triggered when an alarm condition is present.
- **Alarm Type**: (This parameter is available for input points only.) Use the up or down arrow keys to select the desired alarm type for the highlighted point. The options are **Open** or **Closed**.
- **State Change Delay**: Specify the number of seconds that a digital state change must be observed before the controller acknowledges the change. Use the arrow keys to highlight this field and then press <**ENTER**>. Use the keypad to define this value and then press <**ENTER**> again.

Press <**ESC**> to return to the General Input/Output Configuration menu screen.

Pulse Configuration

From the General Input/Output Configuration menu screen, press the **Pulse** button to display the Accumulator Configuration screen shown in Figure 10-56.

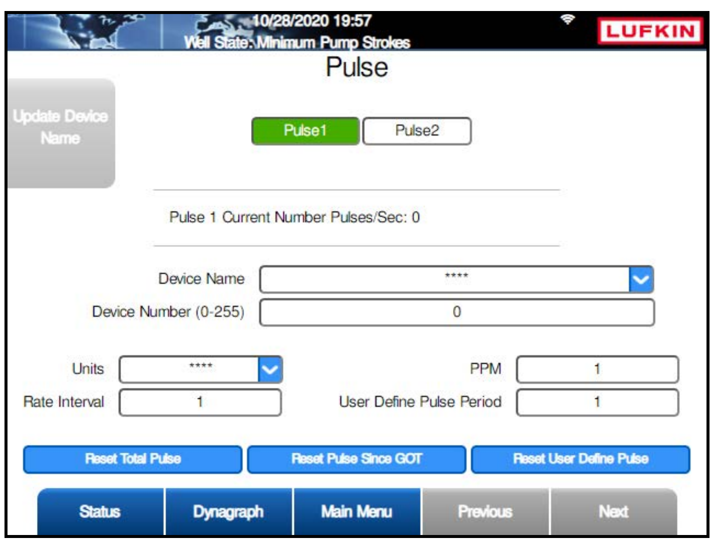


Figure 10-60. Accumulator Configuration Screen

This screen is used to configure all pulse input points in the system. These input points are displayed at top of the screen.

Use the arrow keys to highlight the pulse input point to be configured and then press <**ENTER**>. Status information and available parameters are then displayed as shown above.

The **Current Number Pulses/Sec** status field indicates the present value of the highlighted input.

Each point is configurable using the fields at the bottom of the screen. Use the arrow keys to highlight the desired parameter and then press <**ENTER**> to edit the parameter. Available parameters are as follows:

- **Device Name**: Select one of the five custom name fields from the drop-down list. Press or click the **Update Device Name** button, type the desired name, and then press or click **Update**.
- **Device Number (0-255)**: Use the keypad to type a device number in the text field and then press or click the Save button.
- **Units**: The controller offers approximately 29 options for the unit of measurement to be associated with each auxiliary input. The units selected will be displayed on the Pulse Status screen. (See “Accumulator Status” on page 9-24.) It is logically related to the PPM field below, but the unit selected does not impact the actual scaling of the pulse input.
- **PPM**: Pulses per unit of measure (PPM) is an integer that programs the controller to scale this given number of pulses counted at the defined pulse input point as a single unit. The range is 1 to 999,999.
- **Rate Interval**: This is a user-defined sampling period, measured in minutes. The range is 0 to 1440 minutes. As an example, if a value of 8 is programmed, a 24-hour rate will be calculated based on the number of pulses accumulated during the most recent eight-minute period. The formula for this example of a rate interval of 8 minutes is as follows:

  $$\text{Rate} = \frac{\text{\# of pulses for last 8 minutes}}{\text{PPM}} \times \frac{\text{1440 minutes}}{\text{8 minutes}}$$

  Using the keypad, define this value and then press <**ENTER**>.
- **User Defined Pulse Period**: The controller will accumulate a total for this user-defined number of days. The range is 1 to 365 days. At the end of the user-defined period, the accumulated value for that period is saved in a “Previous User-Defined Pulse” register in the memory map and then the pulse is cleared to start the accumulation for the next user-defined period. In addition to the User-Defined Period, the controller also maintains a 60-day record of the totals accumulated for the each of the previous sixty 24-hour days specified by Gauge Off Time.

  Use the keypad to define this value.
- **Reset Total Pulse**: This button clears the total pulse value for the highlighted point.
- **Reset User Define Pulse**: This button clears the value for the user-defined pulse accumulation period.

Press or click the **Save** button to save all changes.

Press <**ESC**> to return to the General I/O menu screen.

Communication Setup

From the Setup screen, press the **COMM** button to display the COMM menu screen shown in Figure 10-61.

Figure 10-61. COMM Menu Screen

These options are discussed on the following pages.

Radio Port Configuration

Press the **Radio** button to display the Radio Port Configuration menu screen shown in Figure 10-62 on page 10-73.

Figure 10-62. Radio Port Configuration Screen

The options on this screen are described in the following pages.

Serial Port Configuration

From the Radio Port Configuration menu screen, press or click the **Serial** button to display the Serial Port Configuration shown in Figure 10-63.

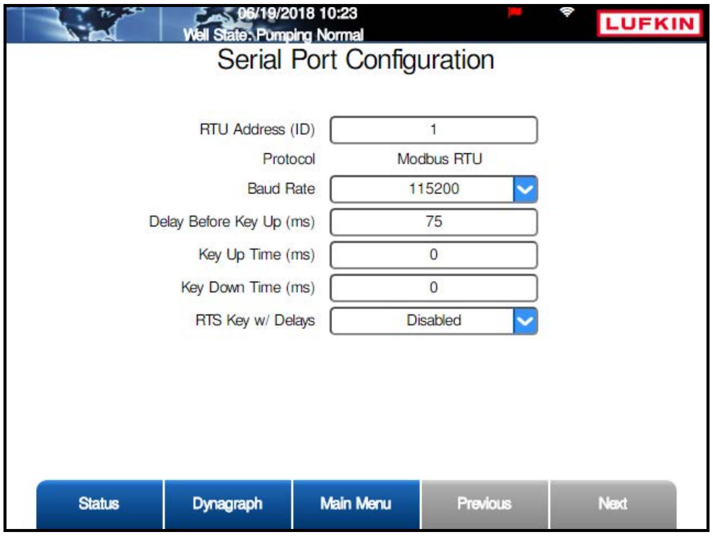


Figure 10-63. Serial Port Configuration Screen

- **RTU Address (ID)**: Specify a unique identifier number for the controller that must be coordinated with the address entry in the host computer SCADA software. The controller uses standard RTU Modbus protocol for address settings of 247 and below. The Extended Lufkin Automation Modbus (ELAM) protocol is used for addresses of 248 through 2295. ELAM protocol allows for much larger blocks of data to be transmitted, and it also allows standard Modbus messages to be combined together.

  Use the keypad to define this value and then press <**ENTER**>.
- **Protocol**: This field displays the communication protocol used by the serial port.
- **Baud Rate**: The controller supports a range of data transmission rates from 300 to 115,200 baud. The baud rate of the front panel DB-9 RS-232 laptop port can be set at a different value from that of the radio port.

  Use the down arrow key to highlight this field and then press <**ENTER**> to display the drop-down list. Use the down arrow key to highlight the desired baud rate and then press <**ENTER**> again.
- **Delay before Key Up**: The time delay, in milliseconds, from the time that the controller recognizes an incoming message addressed to it before the RTS line is raised to key the radio to send a reply.

  Use the keypad to define this value and then press <**ENTER**>.
- **Key Up Time (ms)**: Once the RTS line is raised, the controller will delay this amount of time before actually starting to send data.

  Use the keypad to define this value and then press <**ENTER**>.
- **Key Down Time (ms)**: At the end of the message string, the RTS is held high for this amount of time.

  Use the keypad to define this value and then press <**ENTER**>.

- **RTS Key w/Delays**: Select this option if an RTS key with delays is used for the serial port.

  Use the arrow keys to select **Disabled** or **Enabled** and then press <**ENTER**>.

Press the **Save** button to save the changes.

Press <**ESC**> to return to the COMM menu screen.

Ethernet Port Configuration

From the Radio Port Configuration menu screen, press or click the **Ethernet** button to display the Ethernet Port Configuration screen shown in Figure 10-64.

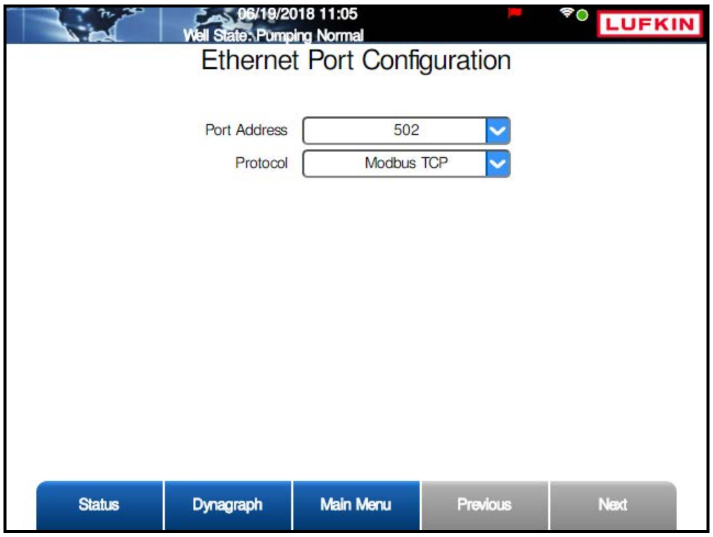


Figure 10-64. Ethernet Port Configuration Screen

Select the desired port address from the **Port Address** drop-down list and then press or click the **Save** button.

Select the desired protocol from the **Protocol** drop-down list and then press or click the **Save** button.

Network Configuration

From the COMM menu screen, press the **Network** button to display the Network Configuration screen shown in Figure 10-65.

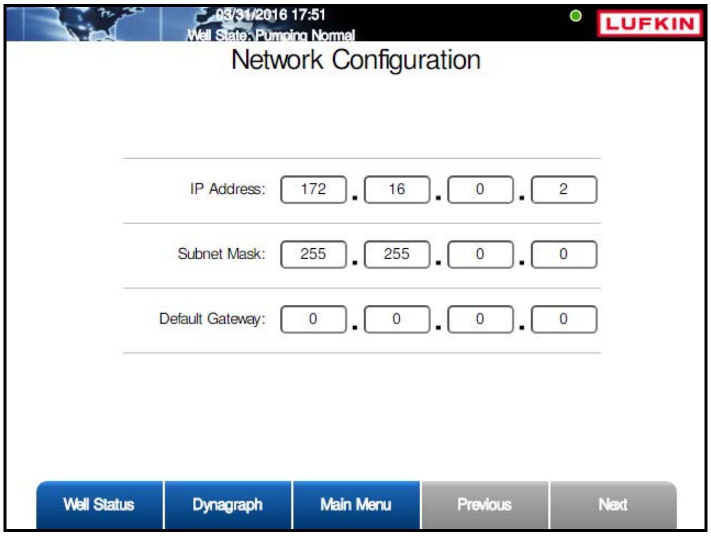


Figure 10-65. Network Configuration Screen

This screen allows the operator to change the network settings for the controller.

Use the arrow keys to highlight the desired field and then press <**ENTER**>. Use the number keys to define the value and then press <**ENTER**> again.

Press the **Save** button to save the new values.

Modbus Master Configuration

Press the **Modbus Master** button to display the Modbus Master menu screen shown in Figure 10-66.

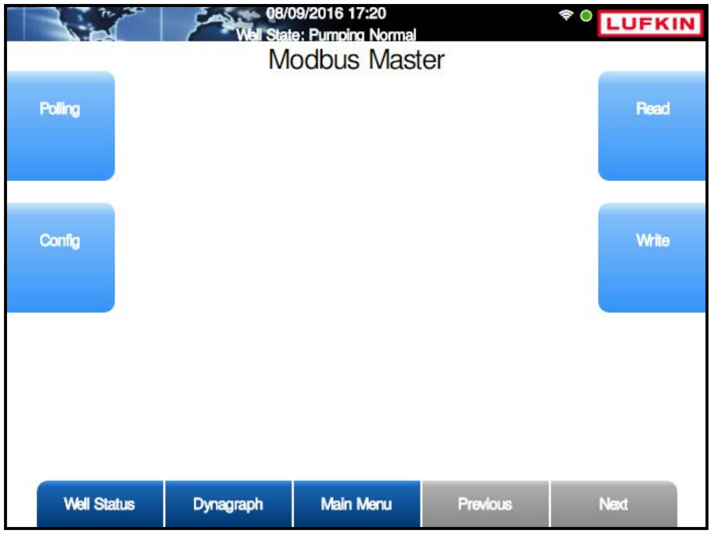


Figure 10-66. Modbus Master Menu Screen

The LWM 2.0 controller can read and store data from other Modbus RTUs on location. This data is stored in the controller's Modbus register map and can be read on the local LCD and/or with host SCADA software. This feature allows a single on-location radio in the controller to read data from and write data to any of up to 10 Modbus-protocol RTUs at the wellsite.

Slave RTUs must be compatible with the Modbus RTU protocol and have an RS-485 communication port available. A two-wire or four-wire RS-485 data cable network must be installed to connect the controller master with each slave device.

The configuration functions are discussed on the following pages.

Polling

From the Modbus Master menu screen, press the **Polling** button to display the Modbus Master Polling screen shown in Figure 10-67.

Figure 10-67. Modbus Master Polling Screen

Type the desired polling rate in the field provided and then press the **Save** button.

Configuration

Press the **Config** button to display the Modbus Master Configure screen. The available slave devices are listed on this screen.

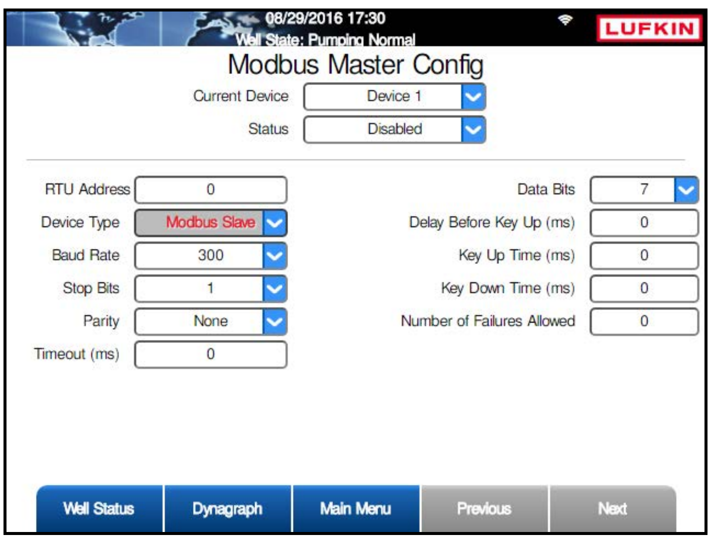


Figure 10-68. Modbus Master Configure Screen

With the **Current Device** field highlighted, press <**ENTER**> to display the drop-down list. Use the arrow keys to select the slave device to be configured and then press <**ENTER**.>.

The **Status** field is used to enable or disable the polling of the slave device. Polling must be enabled to activate the polling function. If a slave device is to be offline for service, disable it to prevent nuisance communication failure alarms.

Use the arrow keys to highlight this field and then press <**ENTER**> to display the drop-down list. Press the down arrow key to highlight **Enable** or **Disable** and then press <**ENTER**> again.

The following parameters are configured on this screen:

- **RTU Address**: Each slave device must have a different address number. Address numbers of less than 247 are indicated by the standard Modbus guidelines. The address must match the slave device setting.
- **Device Type**: As of this release, Modbus Slave is the only available option for device type.
- **Baud Rate**: Select from a range of options from 300 to 115,200 baud. The value must match the slave device setting.
- **Stop Bits**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Parity**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Timeout**: Specify the time, in milliseconds, that the controller waits after sending a poll message to check the reply message buffer.
- **Data Bits:** This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Delay before Key Up**: Specify the time, in milliseconds, that the processor needs to pause before raising the RTS line when the controller is ready to poll a slave device.
- **Key Up Time**: Specify the time, in milliseconds, that are to be added before data is actually transmitted once the RTS line is raised.
- **Key Down Time**: Specify the time, in milliseconds, that the RTS line is held high at the end of the outgoing message string.
- **Number of Failures Allowed**: Specify the number of times that the controller will continue to try to poll a slave device once that device is enabled. If the controller does not receive a valid response after this number of consecutive polling attempts, a communication failure alarm is flagged for the slave device to alert the operator that data from the slave is not current. Communication failure flags can be checked using the local LCD display. For more information, see the description about the Status field.

Read

Press the **Read** button to display the Modbus Master Read screen shown in Figure 10-69 below.

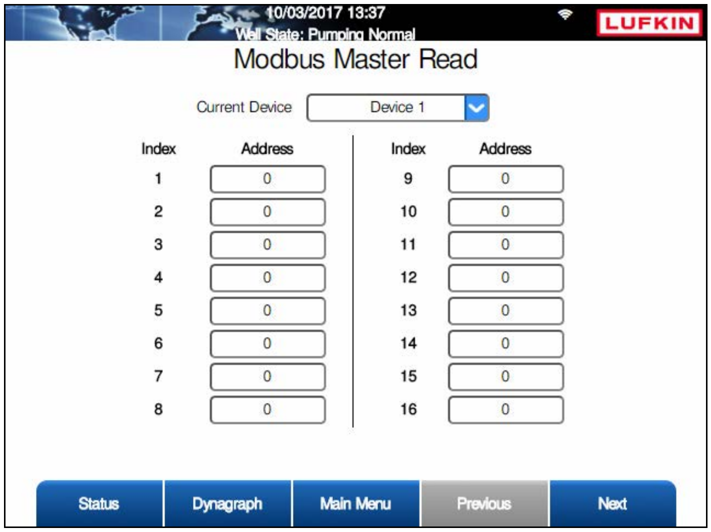


Figure 10-69. Modbus Master Read Screen

After the type of slave device used is specified as an RTU, and the slave device communication parameters to be used for it are specified, the operators need to configure register addresses to register indices. The Modbus Master function is capable of reading data from a maximum 125 register addresses per Modbus slave device. These addresses are associated to register indices in groups of 16 to a screen. This configuration is performed using the Modbus Master Config screen shown in Figure 10-68 on page 10-78.

The numbers in the Index column are the numbers assigned in the LWM's buffer of values. The values in the Address column must be programmed with the register numbers in the slave device that contains the data to be read. Perform this operation separately for each Modbus slave device on the data network.

When assigning register numbers, keep in mind the generic Modbus organization guidelines. This type of organization minimizes the number of data transmissions required to read all of the desired data, and it reduces data access time.

- Group together all registers read with a given function code
- Read contiguous groups of registers where possible
- Arrange the Register Address column with the smaller register numbers at the top of each group

The procedure for assigning register numbers is as follows:

1. On the Modbus Master Read screen, select the desired slave device from the Current Device drop-down list.
2. Use the keypad to type the register address in the Address field next to the desired index number.
3. Press the **Save** button to save the address.

4. Repeat these steps for each register address.

Note: Every slave device that is to be polled by the controller must have an index number assigned to it.

Write

Press the **Write** button to display the Write Utility screen shown in Figure 10-70.

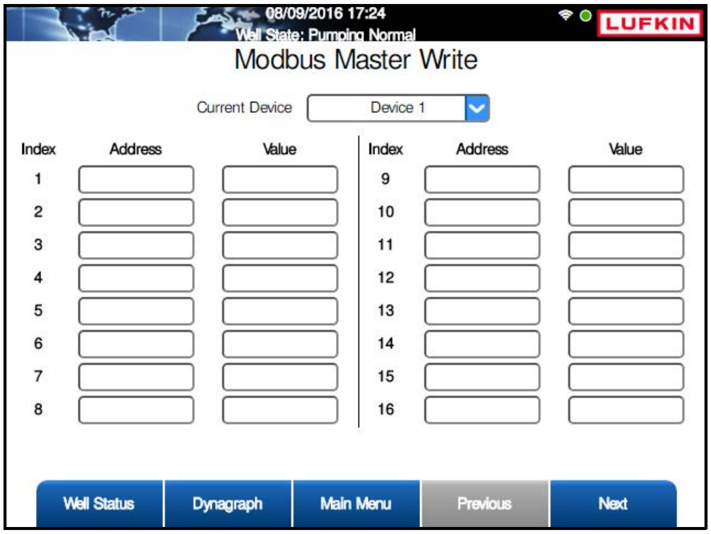


Figure 10-70. Modbus Master Write Screen

The Modbus Master Write function can write register values to one or multiple registers of a Modbus slave device. Register values can be assigned to a maximum of 25 register addresses. After the addresses are configured, specify the Modbus slave device that is to receive these values and then write them to it.

The procedure for assigning register numbers is as follows:

1. On the Modbus Master Read screen, select the desired slave device from the Current Device drop-down list.
2. Use the keypad to type the register address in the Address field next to the desired index number.
3. Press the **Save** button to save the address.
4. Repeat these steps for each register address.

Press the **Next** button to display the next communication setup screen.

VSD Communication

Press the **VSD** button to display the VSD Communication screen shown in Figure 10-71. This screen is used to configure the communication channel between the LWM 2.0 controller and the VSD inverter.

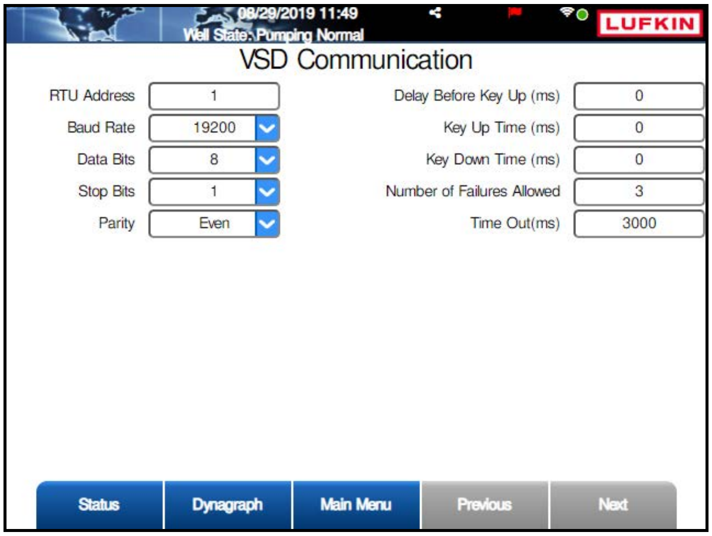


Figure 10-71. VSD Communication Screen

When connected to a VSD inverter, the default communication values are displayed on this screen. These values typically must be used for all parameters with the possible exception of the **Number of Failures Allowed** field.

The **Number of Failures Allowed** parameter defines the number of consecutive communications failures that are allowed between the controller and the VSD before an entry is made into the alarm log indicting VSD communications errors. In some situations where grounding impedance is high, communications errors between both devices can occur frequently. This situation does not materially impact the pump control operation, but it can fill up the alarm log with VSD communications alarms. In such cases, other more important alarms may get “scrolled out” of the alarm log buffer. If you experience frequent VSD communications errors in your alarm log, and you cannot resolve this situation with corrections to grounding, you can increase the parameter value to a higher number in an effort to reduce the number of times this alarm is created.

Zenith Downhole Gauge

From the COMM menu screen, press the **Zenith DH Gauge** button to display the Zenith DH Gauge screen shown in Figure 10-72.

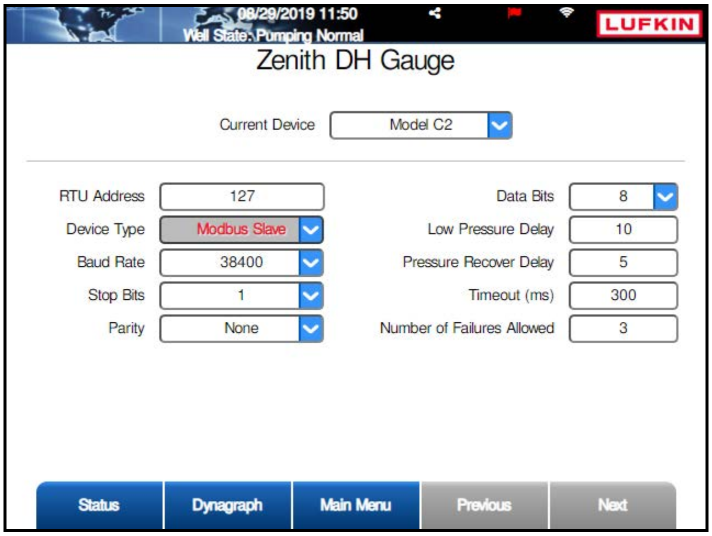


Figure 10-72. Zenith Downhole Gauge Configuration Screen

The following parameters are configured on this screen:

- **RTU Address**: Each downhole gauge must have a different address number. Address numbers of less than 247 are indicated by the standard Modbus guidelines. The address must match the downhole gauge setting.
- **Device Type**: As of this release, Modbus Slave is the only available option for device type.
- **Baud Rate**: Select from a range of options from 300 to 115,200 baud. The value must match the slave device setting.
- **Stop Bits**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Parity**: This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Data Bits:** This is one of three fields (Stop Bits, Parity, and Data Bits) that define the data format to be used by the controller. These settings must be the same as the slave device.
- **Low Pressure Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Pressure Recover Delay**: (Applies to the **Pressure** mode for Secondary Downtime Mode only.) Use the keypad to define this value and then press <**ENTER**>.
- **Timeout**: Specify the time, in milliseconds, that the controller waits after sending a poll message to check the reply message buffer.
- **Number of Failures Allowed**: Specify the number of times that the controller will continue to try to poll a downhole gauge once that gauge is enabled. If the controller does not receive a valid response after this number of consecutive polling attempts, a communication failure alarm is flagged for the downhole gauge to alert the operator that data from the gauge is not current. Communication failure flags are displayed in red at the top of the screen.

Press the **Save** button to save changes made on this screen.

Function Block Variable Configuration

Press the **FB Variable** button to display the FB Variable screen shown in Figure 10-73.

Figure 10-73. Function Block Variable Screen

Use this screen to configure function block programming parameters.

- **Function Block E/D**: Press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to select **Enabled** or **Disabled** and then press <**ENTER**> again.
- **Function Block Downtime**: There are two options available:
  - **Standard DT** – Select this option to use the standard system downtime parameter. (See "Operational Limits Configuration" on page 10-26 for details on the standard system downtime parameter.)
  - **Func Blk DT** – Select this option to use the Function Block Downtime parameter shown on this screen.
- **Manual DT (HH:MM)**: Use the keypad to define the downtime period in hours and minutes and then press <**ENTER**>.

Press the **Save** button to save the changes.

The function block variable buttons are discussed in the following pages.

Function Block Variable Command

From the FB Variable screen, press or click the **FB Variable Command** button to display the FB Variable Command screen shown in Figure 10-74.

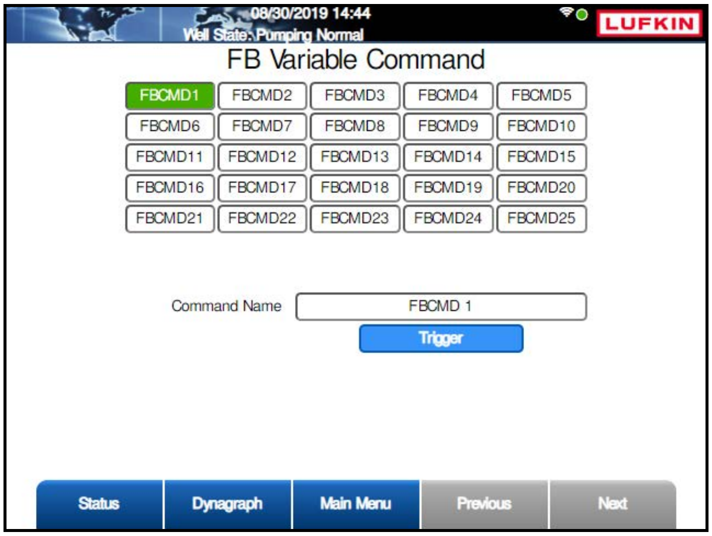


Figure 10-74. Function Block Variable Command Screen

This screen is used to assign names for up to 25 existing function block variable commands. The operator can also trigger these commands from this screen.

To assign a name to a function block variable command, perform the following steps:

1. Select the button for the function block alarm variable to be named.
2. In the **Alarm Name** field, type the desired alarm variable name and then press or click the **Save** button.
3. Repeat these steps as needed.

To trigger a command, use the arrow keys to highlight the **Trigger** button and then press <**ENTER**>. The results from the triggered command can be viewed on the RPC Event Log screen. See “RPC Event Log” on page 11-11 for details on this screen.

Function Block Variable Alarm

From the FB Variable screen, press or click the **FB Variable Alarm** button to display the FB Variable Alarm screen shown in Figure 10-74.

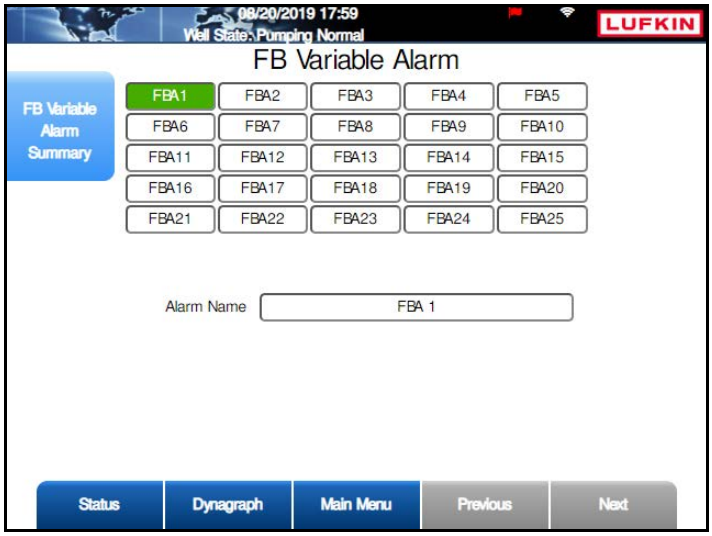


Figure 10-75. Function Block Variable Alarm Screen

This screen is used to assign names to function block variable alarms. Perform the following steps:

1. Select the button for the function block alarm to be named.
2. In the **Alarm Name** field, type the desired alarm variable name and then press or click the **Save** button.
3. Repeat these steps as needed.

Press the **FB Variable Alarm Summary** button to view a summary of function block variable alarm data.

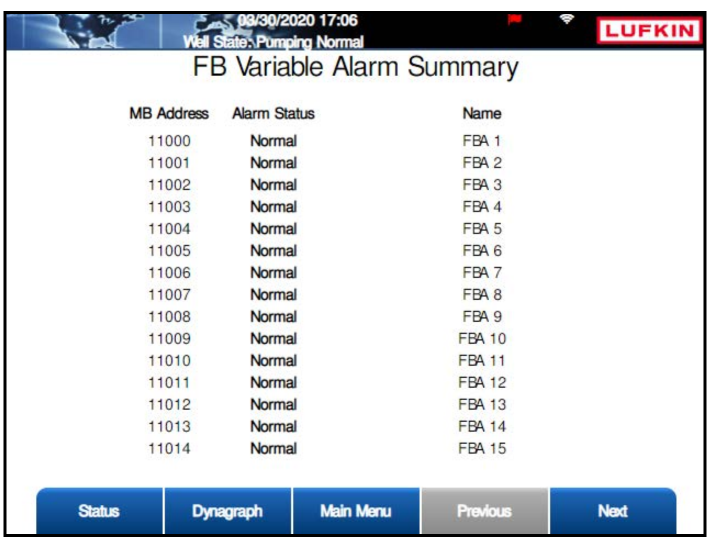


Figure 10-76. Function Block Variable Alarm Summary Screen

Use the **Next** and **Previous** buttons to navigate through the variable list. When finished, press the **FB Variable Alarm** button to return to the FB Variable Alarm screen.

Press the **<ESC>** button to return to the FB Variable screen.

Function Block Variable Status

From the FB Variable screen, press the **FB Variable Status** button to display the FB Variable Status screen shown in Figure 10-77.

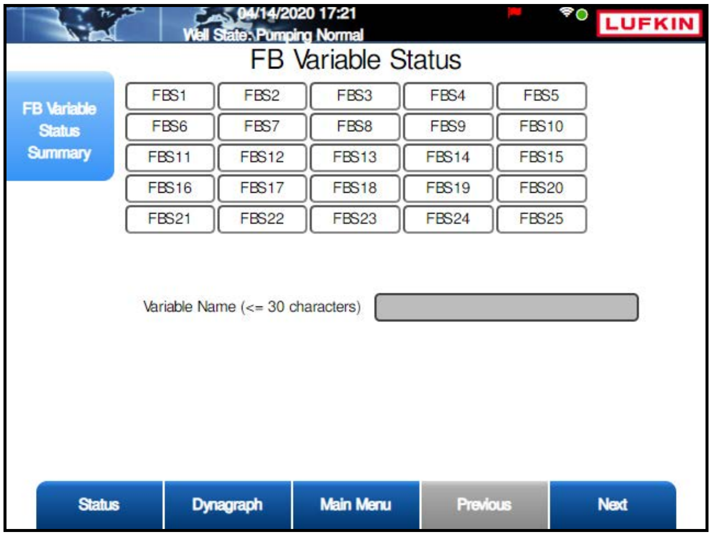


Figure 10-77. Function Block Variable Status Screen

This screen is used for assigning names for up to 75 existing function block status variables. These variables are grouped into three categories:

- **REAL**: The first 25 variables (FBS1-FBS25) use a real number system and allow values with decimal points.
- **SIGNED**: The next 25 variables (FBS26-FBS50) use a signed number system, which allows positive and negative values.
- **UNSIGNED**: The next 25 variables (FBS51-FBS75) use an unsigned number system, which allows positive values only.

Perform the following steps to assign status variable names:

1. Select the button for the function block status variable to be named.
2. In the **Variable Name** field, type the desired alarm variable name and then press or click the **Save** button.
3. Repeat these steps as needed. Use the **Next** and **Previous** buttons to navigate through the variable list.

Press the **FB Variable Status Summary** button to view a summary of function block variable status data.

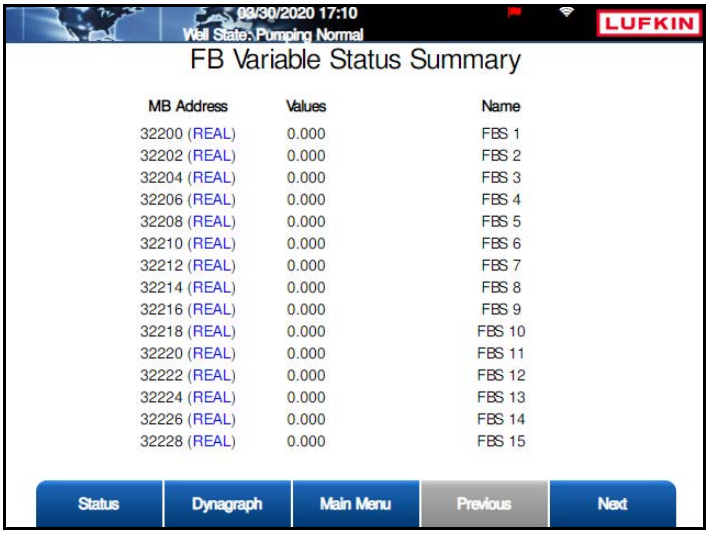


Figure 10-78. Function Block Variable Status Summary Screen

Press the **FB Variable Status** button to return to the FB Variable Status screen.

Press the **<ESC>** button to return to the FB Variable screen.

Function Block Variable Configuration

From the FB Variable screen, press the **FB Variable Config** button to display the FB Variable Config screen shown in Figure 10-79.

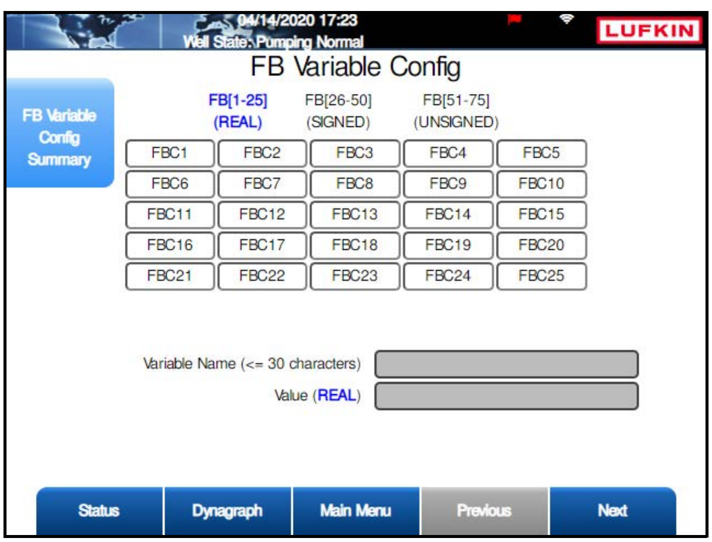


Figure 10-79. Function Block Variable Configuration Screen

This screen is used for assigning names and values to existing function block variables. This screen is used for assigning names and values for up to 75 existing function block variables.These variables are grouped into three categories:

- **REAL**: The first 25 variables (FBS1-FBS25) use a real number system and allow values with decimal points.
- **SIGNED**: The next 25 variables (FBS26-FBS50) use a signed number system, which allows positive and negative values.
- **UNSIGNED**: The next 25 variables (FBS51-FBS75) use an unsigned number system, which allows positive values only.

Perform the following steps:

1. Select the button for the function block variable to be configured.
2. In the **Variable Name** field, type the desired alarm variable name and then press or click the **Save** button.
3. In the **Value (REAL)** field, type the desired value and then press or click the **Save** button.
4. Repeat these steps as needed. Use the **Next** and **Previous** buttons to navigate through the variable list.

Press the **FB Variable Config Summary** button to view a summary of function block variable configuration data.

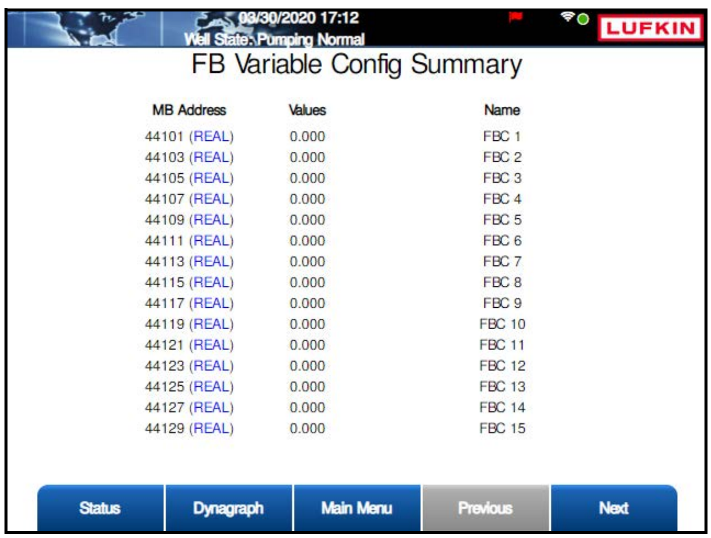


Figure 10-80. Function Block Variable Config Summary Screen

Press the **FB Variable Config** button to return to the FB Variable Config screen.

Press the **<ESC>** button to return to the FB Variable screen.

AGA Configuration

From the second Setup menu screen, press the **AGA Configuration** button to display the AGA Configuration screen shown in Figure 10-81.

Figure 10-81. AGA Configuration Screen

The following parameters are configured on this page:

- **AGA Calculation**: To enable this feature, select **Enabled** from the drop-down list and then press <**ENTER**>.
- **Meter Type**: Select **Orifice Plate** or **Turbine Meter** from the drop-down list and then press <**ENTER**>.
- **Control Override**: To enable this feature, select **Enabled** from the drop-down list and then press <**ENTER**>.
- **Control Threshold (MCFD)**: Use the keypad to define this value and then press <**ENTER**>.
- **Keep Last Results On Error**: Select **Yes** to keep the last results when an error occurs. Select **No** to erase the last results.

Press the **Save** button to save the new values.

AGA Parameter

From the AGA Configuration screen, press the **AGA Parameter** button to display the AGA Design Parameters screen shown in Figure 10-82.

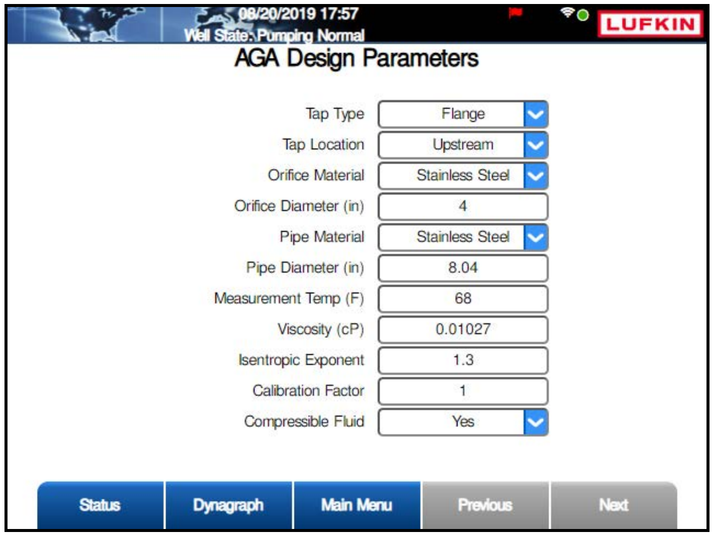


Figure 10-82. AGA Design Parameters Screen

The following parameters are configured on this screen:

- **Tap Type**: Select **Flange** or **PIpe** from the drop-down list and then press <**ENTER**>.
- **Tap Location**: Select **Upstream** or **Downstream** from the drop-down list and then press <**ENTER**>.
- **Orifice Material**: Select the appropriate orifice material from the drop-down list and then press <**ENTER**>. Available options are:
  - Stainless Steel
  - Monel
  - Carbon Steel
- **Orifice Diameter**: Use the keypad to define the orifice diameter and then press <**ENTER**>.
- **Pipe Material**: Select the appropriate orifice material from the drop-down list and then press <**ENTER**>. Available options are:
  - Stainless Steel
  - Monel
  - Carbon Steel
- **Pipe Diameter (in)**: Use the keypad to define the pipe diameter and then press <**ENTER**>.
- **Measurement Temp (F)**: Use the keypad to define the measurement temperature and then press <**ENTER**>.
- **Viscosity (cP)**: Use the keypad to define the viscosity and then press <**ENTER**>.
- **Isentropic Exponent**: Use the keypad to define this value and then press <**ENTER**>.
- **Calibration Factor**: Use the keypad to define this value and then press <**ENTER**>.

- **Compressible Fluid**: Select **Yes** or **No** from the drop-down list and then press <**ENTER**>.

Press the **Save** button to save the new values.

NX-19 Parameter

From the AGA Configuration screen, press the **NX-19 Parameters** button to display the NX-19 Design Parameters screen shown in Figure 10-83.

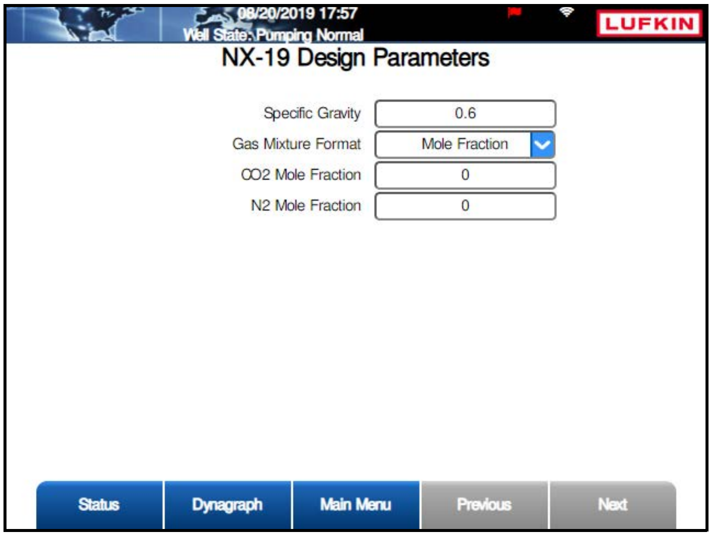


Figure 10-83. NX-19 Design Parameters Screen

The following parameters are configured on this screen:

- **Specific Gravity**: Use the keypad to define this value and then press <**ENTER**>.
- **Gas Mixture Format**: Select **Mole Fraction** or **Mole Percent** from the drop-down list and then press <**ENTER**>.
- **CO2 Mole Fraction**: Use the keypad to define this value and then press <**ENTER**>.
- **N2 Mole Fraction**: Use the keypad to define this value and then press <**ENTER**>.

Press the **Save** button to save the new values.

Temperature/Pressure

From the AGA Configuration screen, press the **Temperature Pressure** button display the Temperature/Pressure Configuration screen shown in Figure 10-84.

Use the keypad to define the following base conditions parameters:

- **Base Pressure**: Use the keypad to define this value and then press <**ENTER**>.
- **Base Temperature**: Use the keypad to define this value and then press <**ENTER**>.
- **Adj Pressure**: Use the keypad to define this value and then press <**ENTER**>.

The flowing conditions parameters are configured as follows:

- **Differential Pressure**: Select an analog input from the drop-down list and then press <**ENTER**>. To configure this input, press the **AI Config** button to display the Analog Input Configuration screen. See "Analog Input Configuration" on page 10-61 for details.
- **Zero Cutoff**: Use the keypad to define this value and then press <**ENTER**>.

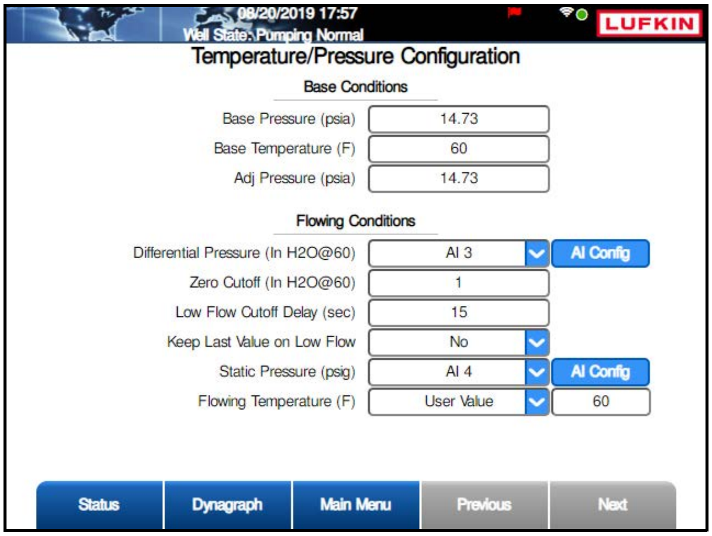


Figure 10-84. Temperature/Pressure Configuration Screen

- **Low Flow Cutoff Delay**: Use the keypad to define this value and then press <**ENTER**>.
- **Keep Last Value on Low Flow**: Select **Yes** to keep the last value in a low flow condition. Select **No** to erase the last value in a low flow condition.
- **Static Pressure**: Select an analog input from the drop-down list and then press <**ENTER**>. To configure this input, press the **AI Config** button to display the Analog Input Configuration screen. See "Analog Input Configuration" on page 10-61 for details.
- **Flowing Temperature**: This parameter is defined using an analog input or a user-defined value:
  - **AI 3-8**: Select an analog input from the drop-down list and then press <**ENTER**>. To configure this input, press the **AI Config** button to display the Analog Input Configuration screen. See "Analog Input Configuration" on page 10-61 for details.
  - **User Value**: This option uses a user-defined value for the flowing temperature. Use the keypad to define this value in the text field.

Press the **Save** button to save the new values.

Default Parameter Values

The following list contains the default parameter values that are assigned during the Quick Start configuration procedure. See “Quick Start Feature” on page 5-1 for more information.

LWM 2.0 Default Parameter Values

Parameter Name	Default Value
Control Mode	Downhole
Operation Mode	Normal Mode
Host Switch	Host Off
Time Mode On Hour	0
Time Mode On Minute	5
Time Mode Off Hour	0
Time Mode Off Minute	5
Power On Delay in Seconds	10
Start Alert in Seconds	10
Minimum Pump Strokes	3
Downtime Mode	Manual Downtime
Downtime Period Hours	0
Downtime Period Minutes	5
Auto Downtime Run To Completion	Auto Downtime Run To Completion
HOA Enable/Disable Option	Disable
Violation Host Mode Enabled	Host Mode
Violation Timed Mode Enabled	Timed Mode
Violation Normal Mode Enabled	Normal Mode
Low RPM Limit	1050
Consecutive Low RPM Allowed	3
Low RPM Start Delay	3
Peak Load Limit	50000
Consecutive Peak Load Allowed	3
Minimum Load Limit	0
Consecutive Min Load Allowed	5
No RPM Limit	3
Consecutive No RPM Allowed	3
No RPM Start Delay	1
Peak Torque Limit	9999
Consecutive Peak Torque Allowed	5
Peak Torque Start Delay	3
Power Cutoff	100
Consecutive Fluid Load Strokes Allowed	2
Reference Fluid Load	0
Consecutive Fluid Load Allowed	3

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
Consecutive No Crank Allowed	3
Load Pumpoff Setpoint (Scaled)	50000
Position Pumpoff Setpoint (Scaled x100)	6600
Consecutive Pumpoff Strokes Allowed	2
Load Malfunction Setpoint (Scaled)	0
Position Malfunction Setpoint (Scaled x100)	3300
Consecutive Malfunction Strokes Allowed	2
Consecutive Malfunction Violations Allowed	4
Peak Load Start Delay	1
Min Load Start Delay	1
No Crank Start Delay	1
High Failure Rate Detection Enable/Disable	Disable
Start Window	0
ESD Enable Disable Option	0
Starting Signal Integrity Checking Period	200
Stopping Signal Integrity Checking Period	1000
True Or Effective Pump Load	True
Belt Slippage Percent Reference	5
Reference Revolutions (NREV)	141
Belt Slippage Control Mode	Alert Only
Fill Base	45
Reference Pump Fillage Control Setpoint	70
Reference Startup Revolutions	50
Power Cut Off Mode Configuration	Auto
Damping Factor	0.08
Stuffing Box Friction	100
Tubing Head Pressure	30
Tubing Gradient	0.4
Pumping Unit Type	Conventional
Crank Rotation	Clockwise
Counter Balance Phase Angle (signed x100)	0
R Dimension	53
K Dimension	197.56
C Dimension	122.62
P Dimension	147
A Dimension	158.37
I Dimension	132
Number of Rod Tapers (Max 6)	3
Rod Types 0	Steel
Rod Types 1	Steel
Rod Types 2	Steel

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
Rod Types 3	Steel
Rod Types 4	Steel
Rod Types 5	Steel
Rod Taper Intervals 1	2220
Rod Taper Intervals 2	2850
Rod Taper Intervals 3	210
Rod Taper Intervals 4	0
Rod Taper Intervals 5	0
Rod Taper Intervals 6	0
Rod Taper Diameters 1	0.875
Rod Taper Diameters 2	0.75
Rod Taper Diameters 3	1.5
Rod Taper Diameters 4	0
Rod Taper Diameters 5	0
Rod Taper Diameters 6	0
Rod Taper Weights 1	2.224
Rod Taper Weights 2	1.634
Rod Taper Weights 3	6
Rod Taper Weights 4	0
Rod Taper Weights 5	0
Rod Taper Weights 6	0
Rod Taper Moduli 1	30.5
Rod Taper Moduli 2	30.5
Rod Taper Moduli 3	30.5
Rod Taper Moduli 4	30.5
Rod Taper Moduli 5	30.5
Rod Taper Moduli 6	30.5
Motor Type	NEMA-D
Full Load Horsepower	40
Full Load RPM	1140
Synch Speed	1200
Max Reduced Torque	3
Q Factor	4.4233
Reference Polished Rod HP Timestamp	0
Reference Polished Rod HP (x10)	0
Peak Allowed Polished Rod HP (x10)	1000
Consecutive Peak PRHP Allowed	3
Linear Pump Distance Between Sprockets	0
Linear Pump Sprocket Radius	0
Linear Pump Malfunction Digital Out Channel	
Output Ratio	1.0

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
Unanchored Tubing Movement Support Enabled	Disabled
Tubing Anchor Depth	0
Tubing Size	2 3/8 inches
Bubble Point Pressure	1760
Formation Volume Factor	0
Solution GOR	0
Oil API	38
SG Water	1.06
Pump Temperature	0
SG Gas	0.9
Casing Head Pressure	147
Fluid Load Detection	Advanced
Fluid Load Adjustment	0
SWT PIP Option	Basic
Shallow Well	No
Tubing Head Pressure Source	Constant
PIP Control Override Enabled	Disable
PIP Setpoint	0 PSI
Num Consecutive Low PIP Strokes Allowed (x10)	3
Consider Formation Producing Pressure	No
Formation Depth	0 feet
DH Gauge Pressure Low Level	
DH Gauge Pressure Recovery Target	
User Defined Tubing Outer Diameter	2.375
User Defined Tubing Inner Diameter	1.995
Rodometer	Rodometer
Pumpometer	Pumpometer
VSD Speed Output (Analog Out Channel For VSD Output)	AO1
VSD Dead Band (+/- dead band of pump off setpoint)	5
VSD Check Event (Speed Change Stroke Delay)	1
VSD Min Scaling (Min Speed Scaled)	0
VSD Speed Unit	Hz
VSD Max Scaling (Max Speed Scaled)	90
VSD Startup Speed (Percent of Full Scale)	20
VSD Speed Increase (Percent of Full Scale)	5
VSD Speed Decrease (Percent of Full Scale)	5
VSD Host Mode High Speed (Percent of Full Scale)	50
VSD Host Mode Low Speed (Percent of Full Scale)	0
VSD Timed Mode High Speed (Percent of Full Scale)	50
VSD Timed Mode Low Speed (Percent of Full Scale)	0

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
VSD Host Timed Mode Low Speed Control	Run To Low Speed
VSD Protection Down Time State Control	Low Speed
VSD Peak Load Limiting (Scaled Value)	50000
VSD Min Load Limiting (Scaled Value)	Minimum Load Limiting
VSD Speed Constant	VSD Speed Override Value
VSD Max Working Speed	60
VSD Min Working Speed	30
VSD Drive Type	AS1
VSD Stroke State Detection Option	Disable
VSD Up Down Speed Enabled	Disabled
VSD Secondary Pump Fillage Enabled	Disabled
VSD Downstroke Speed Change Percent SL (x100)	1000
VSD RFM Flag Enabled	Disabled
Rod Float Load Threshold	1,000
VSD Torque Limit Percent Threshold	50
VSD Max Counter Balance	0
VSD Drive Fault Input Type	Comm
VSD Drive Fault Delay Time	5
VSD Drive Fault Consecutive Allowed	3
VSD Force Drive Bypass Enabled	Disabled
VSD Memory Address	42534 & 42535
VSD Write Value	Write single reg value to VSD
VSD Memory RWCMD	Read VSD single reg value
VSD Motor Nominal Current (x10)	520
VSD Motor Nominal Voltage	460
VSD Motor Nominal Frequency	60
VSD Peak Torque Limit	1280
VSD Downstroke Fixed Torque Limit	300
VSD Acceleration Time (x10)	100
VSD Deceleration Time (x10)	100
VSD Current Limit	125
VSD Reset Drive Parameters	0
VSD Control Word 1	0
VSD Start Current Limit	200
VSD Start Torque Limit	0
VSD Torque Limit Min Speed (x10)	10
VSD RFM Type	0
VSD Rod Float Preset Speed	10
VSD Up Down Speed Percent	100
VSD HOA On Speed	80
VSD Motor Overload Protection Level	100%

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
VSD Inverter Duty Motor Flag	0
VSD Comm Parameters RTU Address	1
VSD Comm Parameters Baud Rate	19200
VSD Comm Parameters Num Data Bits	8
VSD Comm Parameters Num Stop Bits	1
VSD Comm Parameters Parity	Even
VSD Comm Parameters Delay Before Key Up	0
VSD Comm Parameters Key Up Time	0
VSD Comm Parameters Key Down Time	0
VSD Comm Parameters Timeout	45
VSD Comm Parameters Num Consec Comm Fails Allowed	0
VSD Comm Parameters RTS Enabled	0
VSD Comm Parameters Inner Character Timeout	0
VSD Comm Parameters Num Retries	3
VSD Comm Parameters Device Type	0
Enhanced Fixed Torque RFM Enabled	1
Alarm On Parameter Differences Enabled	Disabled
VSD Speed Source	AO1
VSD Drive Fault Bypass Digital	0
VSD Drive Bypass Switch Enabled	0
VSD Drive Bypass Switch Input Digital	0
VSD IGBT Fans Enabled	0
VSD IGBT Fans Output Digital	0
VSD IGBT Fans Temp Threshold	0
VSD IGBT Fans Min Run Time	0
Consecutive Critical Faults Allowed	3
VSD Drive Fault Downtime Period Source	10 minutes minimum (VSD Downtime only)
VSD Drive Fault Downtime Period Hr	0
VSD Drive Fault Downtime Period Min	10
VSD Speed Control Option	Standard Speed Control
Secondary Reference Pump Fillage Setpoint	50
AS1 Dynamic Braking Resistance Installed	No
AS1 Regenerative Torque Control Enabled	Enabled
Sectional Speed Enable/Disable Option	Disabled
Cornering Deceleration Starting Position (% of Stroke Length)	20
Cornering Acceleration Starting Position (% of Stroke Length)	80
Cornering Pumping Speed	Hz
Linear Pump Speed Change Method	Cornering

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
Sectional Override Fixed Option	Enabled
Section Stroke Location 1	0
Section Start Position 1	5
Speed Change Option 1	0
Section Percent Inc Dec Or Fixed Speed 1	10
Section Working Speed Limit Override 1	0
Section Stroke Location 2	0
Section Start Position 2	5
Speed Change Option 2	3
Section Percent Inc Dec Or Fixed Speed 2	20
Section Working Speed Limit Override 2	0
Section Stroke Location 3	2
Section Start Position 3	75
Speed Change Option 3	1
Section Percent Inc Dec Or Fixed Speed 3	50
Section Working Speed Limit Override 3	0
Section Stroke Location 4	1
Section Start Position 4	95
Speed Change Option 4	4
Section Percent Inc Dec Or Fixed Speed 4	60
Section Working Speed Limit Override 4	0
Section Stroke Location 5	1
Section Start Position 5	5
Speed Change Option 5	0
Section Percent Inc Dec Or Fixed Speed 5	80
Section Working Speed Limit Override 5	0
Section Stroke Location 6	3
Section Start Position 6	30
Speed Change Option 6	1
Section Percent Inc Dec Or Fixed Speed 6	50
Section Working Speed Limit Override 6	0
Press Air Ctr Bal	0
Dis Sam Bear	0
Counter Weight	0
Max Air Press	0
Min Air Press	0
Weight Of Pump	150
Structure Unbalance	640
Reducer Rating	320000
Switch Mounting Error Angle	0
Crank Switch Position	0

LWM 2.0 Default Parameter Values (Continued)

Parameter Name	Default Value
Phase Angle	0
Switch Mounting Error Adj Direction	0
DH Gauge Model	
DH Gauge Status	
DH Gauge Annulus Intake Pressure	
DH Gauge Tubing Pressure	
DH Gauge Annulus Intake Temperature	
DH Gauge Tubing Temperature	
DH Gauge Vibration Vz	
DH Gauge Vibration Vx	
DH Gauge Tool Current Ct	
DH Gauge Tool Voltage Vt	

Section 11: Status Screens

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Section Overview

The LWM 2.0 controller has several well status screens that display information about current values for measured process variables, alarms and alerts, and reminders on about how control parameters are configured. This section discusses these screens and the available data.

Note: This manual describes the functions included in Version 1.36.00 of the LWM 2.0 firmware.

Main Status Data Screens

There are five main status data screens available. These are discussed in the following paragraphs.

Well Status

Press the **Status** button to display the Well Status screen shown in Figure 11-1.

Figure 11-1. Well Status Screen

This is the first of five main well status screens available. Current pumping unit, well state, control and operation modes, and runtime status information are displayed on this screen.

Each main well status screen contains menu buttons that provide access to additional data screens. These screens are discussed later in this section.

- **Pumping Unit**: This field displays the pumping unit currently used in the system.
- **Well State Elapsed Time**: States how long (HH:MM:SS format) the LWM 2.0 controller has been in the current well state.

- **Operation Mode**: This field displays the operation mode currently being used by the controller. The LWM 2.0 controller has three available operation modes:

  See “Operational Limits Configuration” on page 10-25 for more information on operation modes.
- **Control Mode**: The control mode field shows which control algorithm is currently being used for well control decisions. In some cases, the controller automatically changes the control method. See “Operational Limits Configuration” on page 10-25 for more information on control modes.
- **Downtime Duration**: This field indicates the amount of time (displayed in HH:SS format) the pumping unit has been in downtime mode.
- **Today’s Runtime**: This field shows the amount of time the pumping unit has been operating on the current date.
- **Yesterday’s Runtime**: This field indicates the amount of time the pumping unit was in operation on the previous date.
- **Motor Revs/Stroke (NREV)**: This field displays the number of motor revolutions required for each pump stroke.
- **Actual Pumping Speed**: States the actual pumping speed in strokes per minute as measured by the controller using the position input data. Slight variations may be shown from one stroke to the next.
- **Pump Fillage**: When operating in Downhole or VSD Downhole control mode, the controller calculates a dynagraph pump card each stroke. This card is analyzed to determine gross pump stroke and net pump stroke.

  Net pump stroke is the part of the downhole pump stroke that is actually lifting fluid for a given stroke. Net stroke as a percentage of gross stroke is referred to as pump fillage. Fillage is the control parameter for pump off detection in the Downhole control mode.

  When the calculated pump fillage falls below the setpoint for fillage, the controller counts that stroke value as a pumped off stroke. When the number of consecutive pumped off strokes equals the programmed number of pump off strokes allowed, the controller stops the pumping unit for the programmed downtime.
- **DH Pressure (psi)**: Displays the current downhole pressure reading from an installed downhole gauge.

Note: This field is only visible in **VSD DH Pressure** control mode.

- **VSD Command Speed**: This field shows the most recent analog voltage output speed command from the controller to the integrated VSD. The value is updated once a second.

Note: This field is only visible in **VSD Surface** or **VSD Downhole** control modes.

- **VSD Output Speed**: The VSD Output Speed field provides information about the actual speed that the VSD is attempting to drive the motor. In most cases, this speed will be very close to the VSD Command Speed (within the tolerance of the analog speed command tuning). However, under certain circumstances (ramping and torque limiting), these two values will be different.

Note: This field is only visible in **VSD Surface** or **VSD Downhole** control modes.

Press the **Alarm Status** button in the menu bar to display the Alarm Status screen shown in Figure 11-2.

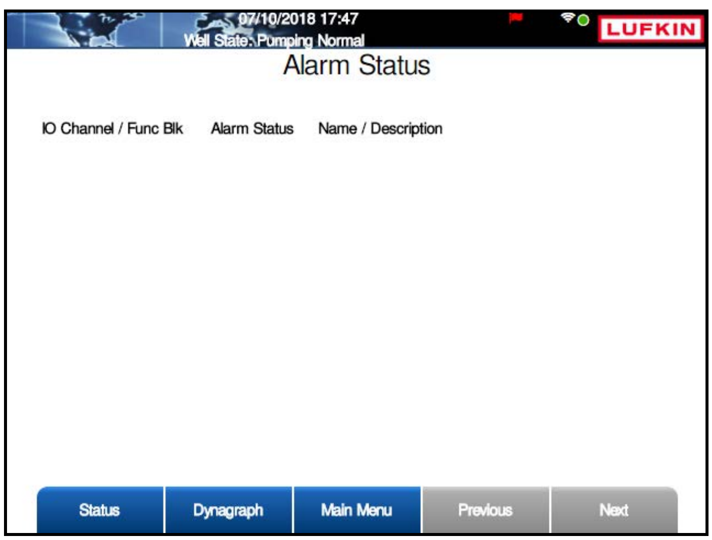

Figure 11-2. Alarm Status Screen

This screen displays a list of active system alarms.

Press the **Status** button to return to the Well Status screen.

Press **Next** to display the next screen.

Violation Status

The Violation Status screen shown in Figure 11-3 is the next status screen displayed. This screen shows all violation occurrences for system setpoints such as weight and fluid loads, motor RPM, and malfunction setpoints. Each setpoint's current state (**E** for Enabled or **D** for Disabled), parameter value, and present value are also displayed.

Figure 11-3. Violation Status Screen

The following violation data is displayed in column format:

- **Violation**: This column shows the name of the violation setpoint.
- **State**: This column shows the current state of the violation setpoint. **E** indicates that the function is enabled, and **D** indicates that the function is disabled.

  Each parameter can be enabled or disabled independently using the Operational Limits screens. For more information about these screens, see "Operational Limits Configuration" on page 10-26.
- **Consc Allow**: This column displays the number of programmed retries (consecutive allowed) for that function. For more information about this parameter, see "Operational Limits Configuration" on page 10-26.
- **Consc/Cum**: This column displays a historical record of consecutive retries and the cumulative number the malfunction has occurred with no consecutive criteria.
- **Pres Val**: This column displays the present value of the variable associated with the malfunction control. Typically, the controller updates present values at the bottom of stroke when in a pumping well state.

The following setpoint violations are shown:

- **Peak Load**: The maximum allowed value for load input. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay. Units are in pounds. The default value will be the full scale of the programmed load end device.
- **Min Load**: The lowest allowed value for load input. If the load falls below this value, the controller instantly shuts down the pumping unit with no consecutive stroke delay. The default value is zero.

- **No RPM**: This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for No RPM violations.
- **No Crank**: This setpoint specifies the number of motor revolutions that the controller should wait before it detects the first crank switch input. If a crank switch input is not detected within this number of motor revolutions, the controller declares a No Crank alarm and stops the pumping unit. If the unit is pumping extremely slow and it causes this reference revolution value to be near 300, you may need to program a higher value than the default of 300 revolutions.
- **Low Motor RPM**: Like the No RPM setpoint, this is also a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for Low Motor RPM violations.
- **Peak Torque**: The maximum allowed torque value in thousands of inch-pounds. If the controller calculates a torque value greater than this limit at the completion of a stroke, the pumping unit shuts down early in the next upstroke.
- **Malf Setpoint**: States the number of consecutive strokes that the surface malfunction setpoint has been violated. This feature shuts down the well if surface load on the upstroke falls below the malfunction setpoint for the programmed number of consecutive strokes.
- **Low Fluid Load**: The controller analyzes the realtime downhole dynagraph and uses this data to calculate fluid load for each pump stroke. If the fluid load drops below this low limit, the pumping unit is stopped for a downtime cycle early in the next upstroke.

Alarm and control setpoints are displayed at the bottom of the screen. The state of each setpoint is displayed as **E** (enabled) or **D** (disabled).

When an alarm setpoint is active, the system will sound an audible alarm when a setpoint violation occurs. The following alarm setpoints are displayed:

- **Belt Slippage**: When in the Pumping Normal mode well state, the controller counts the Motor Rev/Stroke for each stroke. At the end of each stroke, the count is compared to the Reference Rev number programmed above. If the current Motor Rev/Stroke count is greater than the Reference Rev by greater than this Belt Slippage percentage, the controller sets an alarm flag to indicate possible belt slippage. No other control action is taken. The default value is 5%.
- **Peak PRHP**: This is the value at which the controller will set an alert flag to advise the operator that a paraffin treatment may be required. This value is a high limit.

Control setpoints determine pump downtime based on the control mode currently being used. When the controller is in Surface control mode, the Pump Off setpoint is displayed. When the controller is in Downhole control mode, the Pump Fillage setpoint is displayed.

All the setpoints displayed on this screen are configured on the Operational Limits Configuration screen and on the dynagraph screens. See “Operational Limits Configuration” on page 10-26 for details on configuring these setpoints.

Press **Next** to display the next screen.

Downhole Gauge Status

The DH (Downhole) Gauge Status screen is the next status screen displayed. This screen shows realtime and average data for the installed downhole gauge.

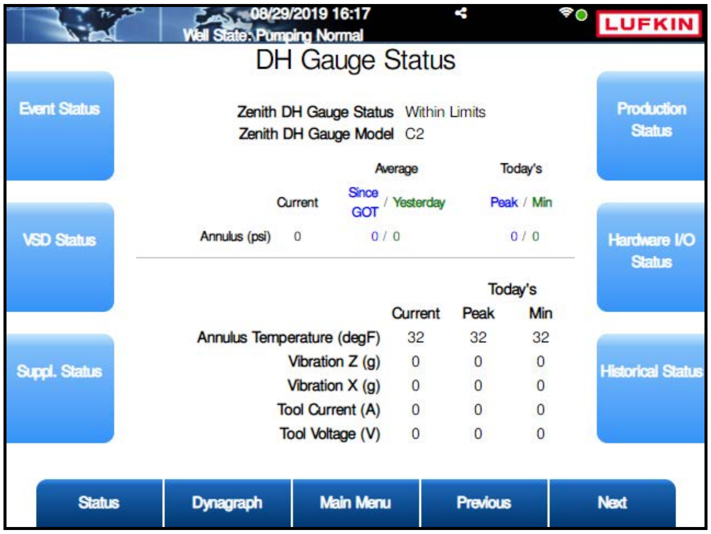

Figure 11-4. Downhole Gauge Status Screen

The available downhole gauge data varies depending on the model installed.

- **Annulus Pressure (psi)**: Available for Models C2 and C6 only
- **Tubing Pressure (psi)**: Available for Model C6 only
- **Annulus Temperature (degF)**: Available for Models C2 and C6 only
- **Tubing Temperature (degF)**: Available for Models C5 and C6 only
- **Vibration Z (g)**: Available for all models
- **Vibration X (g)**: Available for all models
- **Tool Current (A)**: Available for Model C2 only
- **Tool Voltage (V)**: Available for all models

Press **Next** to display the next screen.

Stroke Status

The Stroke Status screen shown in Figure 11-5 is the next status screen displayed. This screen shows pump stroke status data including power values, stroke counters, and average stroke speed.

Figure 11-5. Stroke Status Screen

The data fields are described below.

Power Values

The recorded horsepower of the polished rod and the pumping unit are displayed at the top of the screen. Values displayed are:

- **Current Polished Rod Power**: This value shows the current horsepower of the polished rod during pumping operation.
- **Peak Polished Rod Power**: This value displays the peak horsepower recorded for the polished rod since the pumping system was started.
- **Last Stroke Pump Power**: This value displays the horsepower recorded during the pumping unit's last stroke.
- **Average Downstroke Motor Power**: This value displays an average of the motor power recorded during each downstroke of the pumping unit.

Stroke Counters

The stroke counters display the following data:

- **Today's Total Strokes**: This value indicates the total recorded pump strokes for the current day.
- **Yesterday's Total Strokes**: This value shows the total recorded pump strokes for the previous day.
- **Rod-O-Meter**: This resettable accumulating value displays the current pump cycles of the rod string.
- **Pump-O-Meter**: This resettable accumulating value displays the current pump cycles of the pumping unit.

Stroke Speed Data

The system records the speed of the pump strokes and averages this data for each day of operation. Values displayed on this screen are:

- **Today's Average Stroke Speed**: This is the average speed calculated for the current day's pump strokes.
- **Yesterday's Average Stroke Speed**: This is the average speed calculated for the previous day's pump strokes.

Press **Next** to display the next screen.

Control Override Status

The Control Override Status screen shown in Figure 11-6 is the next status screen displayed. This screen provides status information on all control override functions that are active in the system.

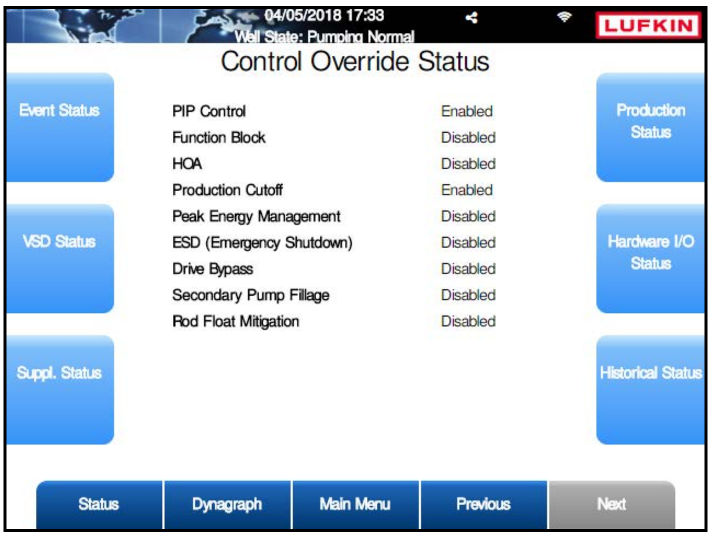

Figure 11-6. Control Override Status Screen

The control settings shown on this screen are:

- **PIP (Pump Intake Pressure) Control**: When the PIP control setting is enabled, the controller shuts down the pumping unit if the calculated PIP value falls below the PIP setpoint. See "LWT/PIP Parameters 3/3 Screen" on page 10-19 for more information on this setpoint.
- **Function Block**: This field indicates whether the Function Block Downtime feature is enabled or disabled. See "Function Block Variable Configuration" on page 10-84 for more information on this feature.
- **HOA**: This field indicates whether the HOA switch override feature is enabled or disabled. See "RPC Miscellaneous I/O" on page 10-52 for details on enabling this feature.
- **Production Cutoff**: This field indicates whether the Production Cutoff feature is enabled or disabled. When this feature is enabled, the pumping unit shuts down for the day when a programmed daily production volume is reached and remains shut down until next GOT, at which time normal operation resumes.

- **Peak Energy Management**: This field indicates whether the Peak Energy Management feature is enabled or disabled. See “Gauge-Off Time and Peak Energy Management” on page 10-50 for details on enabling this feature.
- **ESD (Emergency Shutdown):** This field indicates whether the Emergency Shutdown feature is enabled or disabled. See “RPC Miscellaneous I/O” on page 10-52 for details on enabling this feature.
- **Drive Bypass**: This field indicates whether the drive bypass is enabled or disabled.
- **Secondary Pump Fillage**: This field indicates whether the secondary pump fillage feature is enabled or disabled. See
- **Rod Float Mitigation**: This field indicates whether the rod float mitigation feature is enabled or disabled.

Event Status

Event status data displays the recorded date and time that significant events relating directly to the RPC control processes occurred, including startups/shutdowns and alarms.

From any of the main status menu screens, press the **Event Status** button to display the Event Status menu screen shown in Figure 11-7.

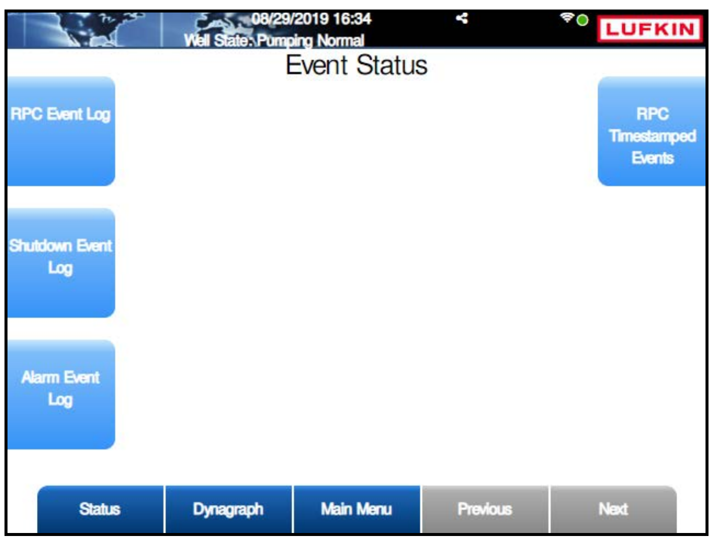

Figure 11-7. Event Status Menu Screen

The event status screens are discussed in the following paragraphs.

RPC Event Log

Press the **RPC Event Log** button to display the RPC Event Log screen shown in Figure 11-8.

This log screen is one of three screens that display a list of 22 significant RPC events and a date/time stamp for the last time each event occurred.

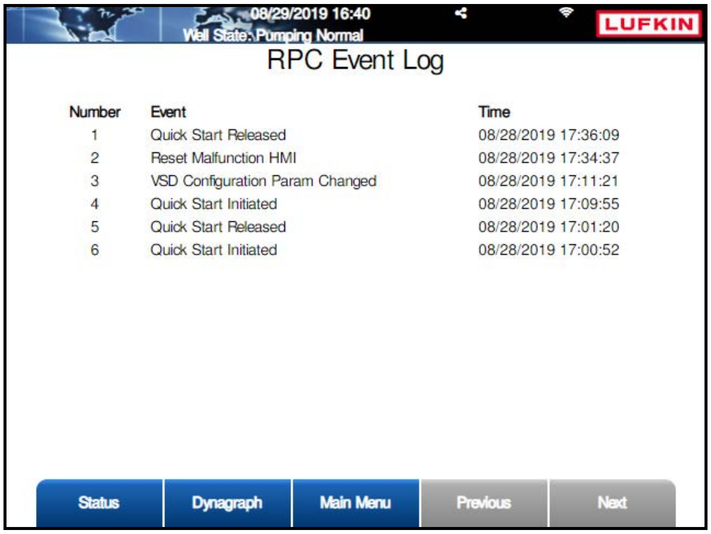

Figure 11-8. RPC Event Log Screen

Press **Next** or **Previous** buttons to navigate between the RPC event pages.

Press <**ESC**> to return to the Event Status menu screen.

Shutdown Event Log

Press the **Shutdown Event Log** button to display the Shutdown Event Log screen shown in Figure 11-9.

Figure 11-9. Shutdown Event Log

This screen displays the last 20 times that the controller stopped and started the pumping unit with a date/time stamp for each. The reason for the stop or shutdown decision is included.

Press the **Next** or **Previous** buttons to navigate between the shutdown event log pages.

Press <**ESC**> to return to the Event Status menu screen.

Alarm Event Log

Press the **Alarm Event Log** button to display the Alarm Log screen shown in Figure 11-10.

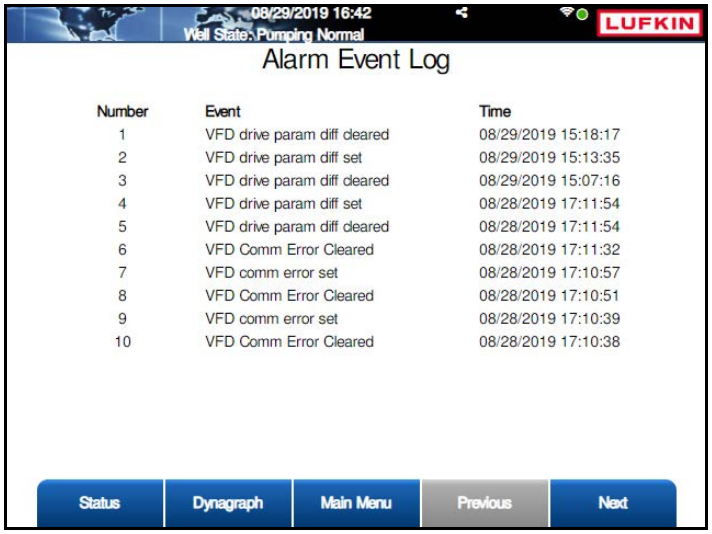

Figure 11-10. Alarm Log Screen

This screen displays data for alarms that have been triggered in the system. This log screen can display a maximum of 100 recorded alarm logs with date and time stamps and descriptions of each alarm.

Press the **Next** or **Previous** buttons to navigate between the alarm log pages.

Press <**ESC**> to return to the Event Status menu screen.

RPC Timestamped Events

Press the **RPC Timestamped Events** button to display the RPC Event Log screen shown in Figure 11-8 on page 11-12.

Figure 11-11. RPC Event Log Screen

This log screen is one of three screens that display a list of significant RPC events and a date/time stamp for the last time each event occurred.

Press **Next** or **Previous** buttons to navigate between the event pages.

Press <**ESC**> to return to the Event Status menu screen.

VSD Status

The VSD Status 1 screen shown in Figure 11-12 is one of two screens that display status data specific to VSD operation. The data shown on this screen is read directly from the variable speed drive.

Figure 11-12. VSD Status 1 Screen

Press or click the **Next** button to display the VSD Status 2 menu screen shown in Figure 11-13.

Note: This second menu screen is only available when the **Sectional Speed** or **Fluid Pound Avoidance** features are enabled. See “Advanced VSD Applications” on page 10-38 for details on these features.

Figure 11-13. VSD Status 2 Screen

The active speed control feature determines which of the two buttons displayed is enabled.

The status screens for each feature are discussed in the following paragraphs.

Drive Status and Trip Code Help

Additional drive status and trip code information can be accessed by pressing the help buttons on the left side of the screen.

Reset Drive Fault

To clear any existing drive faults in the system, press the **Reset Drive Fault** button.

Configuration Mismatch

When the **Parameter Difference** alarm is enabled, this button is enabled. (See “Drive Parameters” on page 10-45 for more information.) When the controller parameters do not match the parameters detected in the drive, an alarm message is displayed at the bottom of the VSD Status 1 screen.

Press or click the **Configuration Mismatch** button to display the Configuration Mismatch screen shown in Figure 11-14.

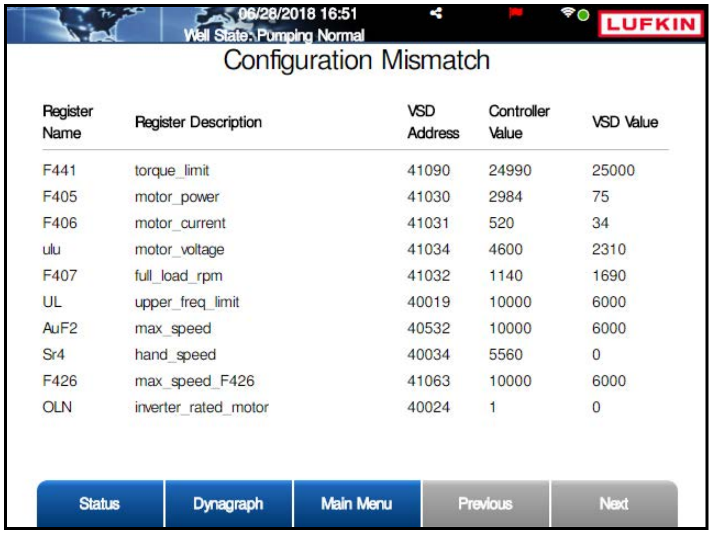

Figure 11-14. Configuration Mismatch Screen

This screen displays a list of all detected parameter differences between the controller and the drive.

Press **<ESC>** to return to the VSD Status 1 screen.

VSD Trip Log

From the Event Status menu screen, press or click the **VSD Trip Log** button to display the VSD Trip Log screen shown in Figure 11-15.

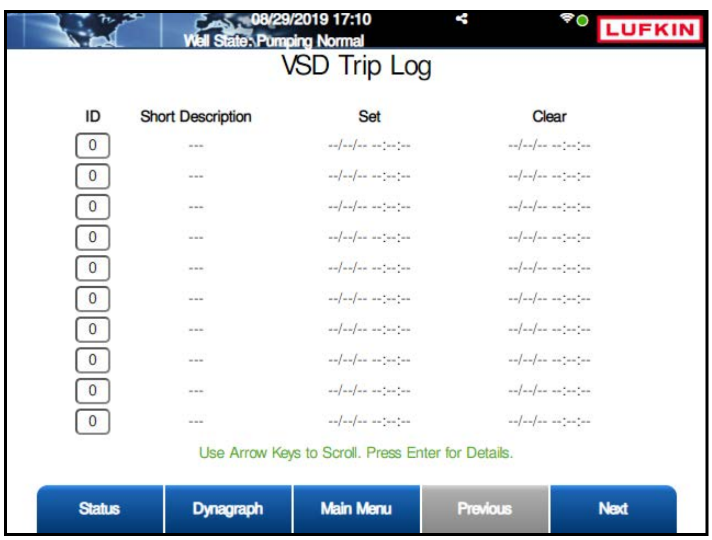

Figure 11-15. VSD Trip Log Screen

The controller can pull the recorded trip data for the last 45 trips stored in the VSD. The VSD has a block of memory registers that record VSD activity at the time of the trip and the controller can read these registers.

The following status information is displayed:

- The **ID** column contains the log numbers for each trip event.
- The **Short Description** column provides a short description of the trip event.
- The **Set** column displays the date and time when the trip occurred.
- The **Clear** column displays the date and time when the trip cleared. This time can be when the controller cleared the trip or when the operator cleared the trip.

Press or click the **Next** button to view the next page of trip log data.

Select a trip ID button to open a pop-up window with trip details.

Note: The trip log details displayed will vary depending on the drive selection.

Press or click **Ok** to close the pop-up window.

Press <**ESC**> to return to the Event Status menu screen.

Sectional Speed

From the VSD Status 2 menu screen, press or click the **Sectional Speed** button to display the Sectional Speed screen shown in Figure 11-16.

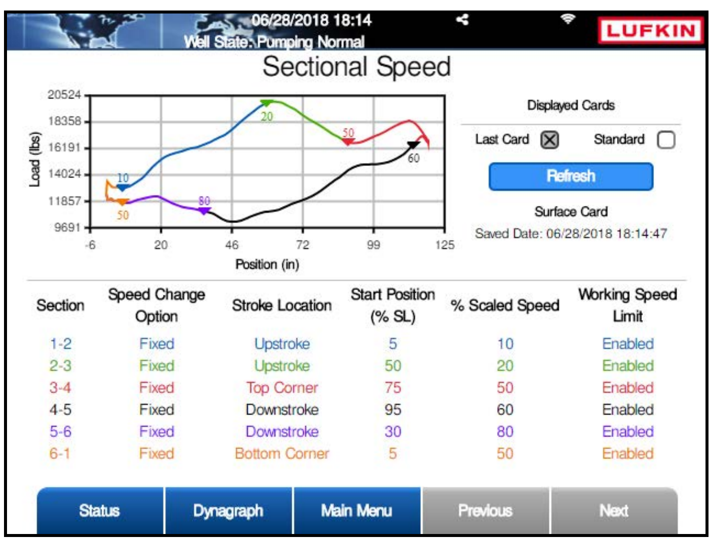

Figure 11-16. Sectional Speed Status Screen

This screen displays status data for the Sectional Speed control feature. Press or click the **Refresh** button to display the most current data.

Press **<ESC>** to return to the VSD Status 1 screen.

Fluid Pound Avoidance

From the VSD Status 2 menu screen, press the **Fluid Pound Avoidance** button to display the first Fluid Pound Avoidance Status screen shown in Figure 11-17.

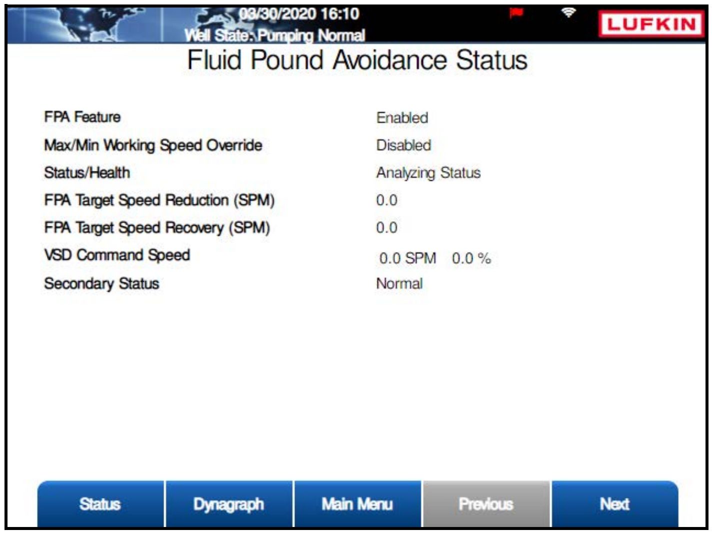

Figure 11-17. Fluid Pound Avoidance Status Screen

This screen displays the following status information:

- **FPA Feature Enabled/Disabled**: Displays the current setting of the FPA feature.
- **Max/Min Working Speed Override**: Displays the current setting of the FPA Max/Min Working Speed Override parameter. When this feature is enabled, FPA can override the standard operation Max and Min Working Speed that is set by the controller.
- **Status/Health**: This field displays the current status and health of the FPA features. The following table lists the possible status/health messages that may be displayed:

State	Remarks
Analyzing Status	FPA Inactive
FPA Activation Key Not Available	FPA Inactive
Disabled	FPA Inactive
Initializing	FPA Active
Re-initializing Due to Calculation Error	FPA Active
Operation Normal - Monitoring (Fillage Above Threshold)	FPA Active
Operation Normal - Engaged (Fillage Below Threshold)	FPA Active
FD Diag Setup Error	FPA Inactive
Unable to Initialize	FPA Inactive
Malfunction	FPA Inactive

- **FPA Target Speed Reduction**: This field displays the speed that the FPA is aiming to mitigate fluid pound.

- **FPA Target Speed Recovery**: This field displays the speed that the FPA is aiming to "make up" for the lost SPM during the early downstroke slowdown to mitigate fluid pound.
- **VSD Command Speed (%)**: Instantaneous values of commanded VSD speeds are shown here.
- **VSD Output Speed (Hz)**: Instantaneous values of actual VSD speeds are shown here.
- **Secondary Status**: This field indicates the secondary pump fillage status.

Press **Next** to display the second Fluid Pound Avoidance status screen shown in Figure 11-18.

Figure 11-18. Fluid Pound Avoidance Status Screen 2

This screen provides a realtime graphical view of the data. There are different display options available. These options are discussed below.

Display Group 1

This group has four display options. When an option is selected, the text color changes to match that option’s line color on the graph. These options are as follows:

- **Normalize**: Select this checkbox to enhance the appearance of the values displayed in the graph. See Figure 11-19 for an example of this option.
- **Command Speed**: Select this checkbox to display the commanded VSD speed on the graph.
- **Pump Load**: Select this checkbox to display the current pump load on the graph.
- **Pump Position**: Select this checkbox to display the current pump position on the graph.

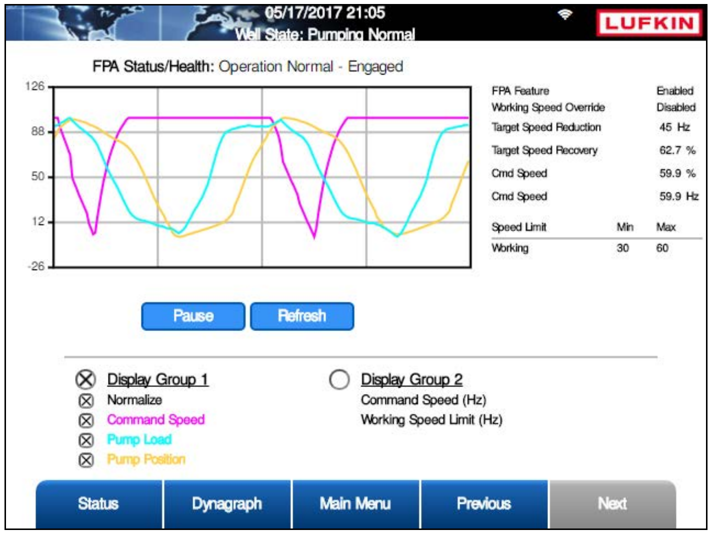

Figure 11-19. FPA Status Screen 2 – Normalized View

Display Group 2

Display Group 2 is used when the Working Speed Override feature is enabled. This group displays the Command Speed and Working Speed Limit values only.

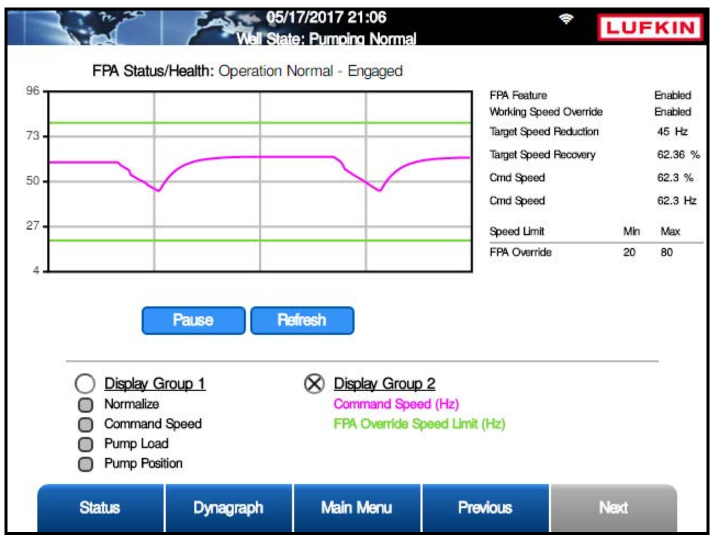

Figure 11-20. FPA Status Screen 2 – Display Group 2

Select the **Display Group 2** option to display those values.

Press <**ESC**> to return to the VSD Status menu screen.

Supplemental Status

The supplemental status screens display status data for gearbox torque, Modbus Master, and coil tracking.

Press the **Supplemental Status** button to display the Supplemental Status Menu screen.

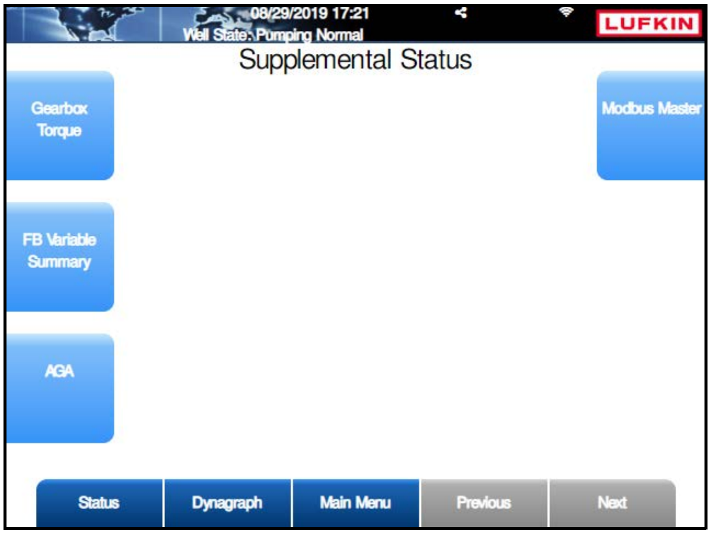

Figure 11-21. Supplemental Status Menu Screen

The supplemental status screens are discussed in the following pages.

Gearbox Torque

From the Supplemental Status menu screen, press the **Gearbox Torque** button to display the Gearbox Net Torque screen shown in Figure 11-22.

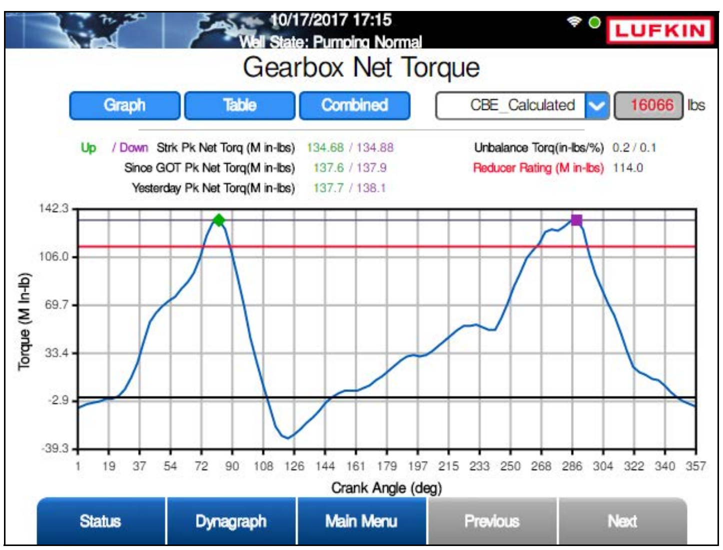

Figure 11-22. Gearbox Net Torque Screen – Graph Format

This screen shows the pumping unit's gearbox net torque values and counterbalance effect (CBE). These values are displayed in real time both numerically and graphically.

There are two options for displaying counterbalance effect:

- **CBE_Calculated**: This option displays the value calculated by the controller.
- **CBE_Entered (lbs)**: This option allows the operator to set a specific counterbalance effect value in the text box.
- **CBM_Entered (M in-lbs)**: This option allows the operator to set a specific counterbalance moment value in the text box.

Select the desired option from the drop-down list and then press the **Save** button.

The following peak net torque data is displayed numerically:

- Upstroke
- Downstroke
- Since GOT (Gauge-Off Time)
- Yesterday

Unbalance torque and reducer rating is also displayed as realtime data.

This data can be displayed in three formats:

- **Graph**: Select this option to display the data graphically as shown in Figure 11-22 above. This is the default display option.
- **Table**: Select this option to display the data in table format.
- **Combined**: Select this option to display the data in a combination of graph and table format.

Press the appropriate button for the desired display option.

Press the **Previous** or **Next** buttons to navigate between pages of data when viewed in Table or Combined format.

Press the <**ESC**> button to return to the Supplemental Status menu screen or press the **Main Menu** button to return to the Main Menu screen.

Function Block Variable Summary

From the Supplemental Status menu screen, press the **FB Variable Summary** button to display the FB Variable Summary menu screen shown in Figure 11-23.

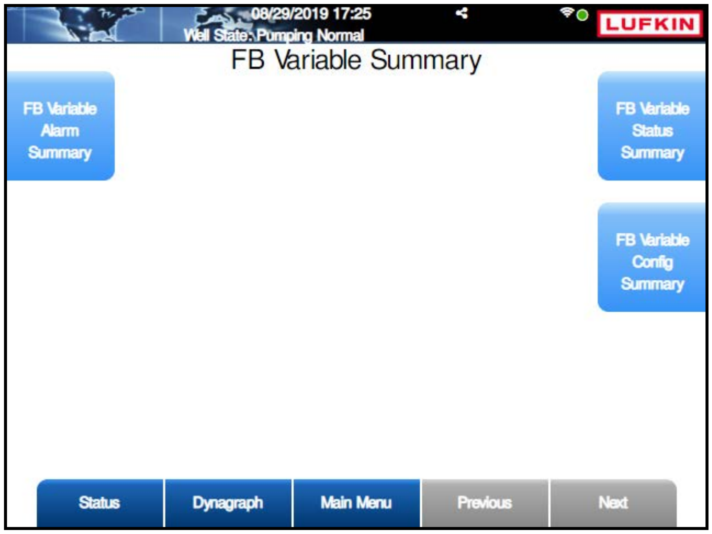

Figure 11-23. Function Block Variable Summary Menu Screen

The function block variable summary screens are discussed in the following pages.

Function Block Variable Alarm Summary

From the FB Variable Summary menu screen, press the **FB Variable Alarm Summary** button to view a summary of function block variable alarm data. See Figure 11-24.

Use the **Next** and **Previous** buttons to navigate through the list.

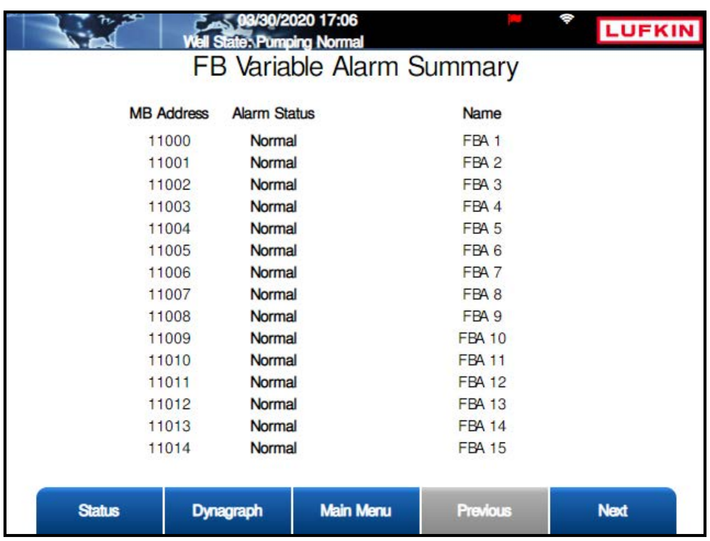

Figure 11-24. Function Block Variable Alarm Summary Screen

Press the **FB Variable Alarm** button to display the FB Variable Alarm screen. This screen is used to assign names to function block variable alarms. See “Function Block Variable Alarm” on page 10-86 for details.

Press the **<ESC>** button to return to the FB Variable Summary menu screen.

Function Block Variable Status Summary

From the FB Variable Summary menu screen, press the **FB Variable Status Summary** button to view a summary of function block variable status data.

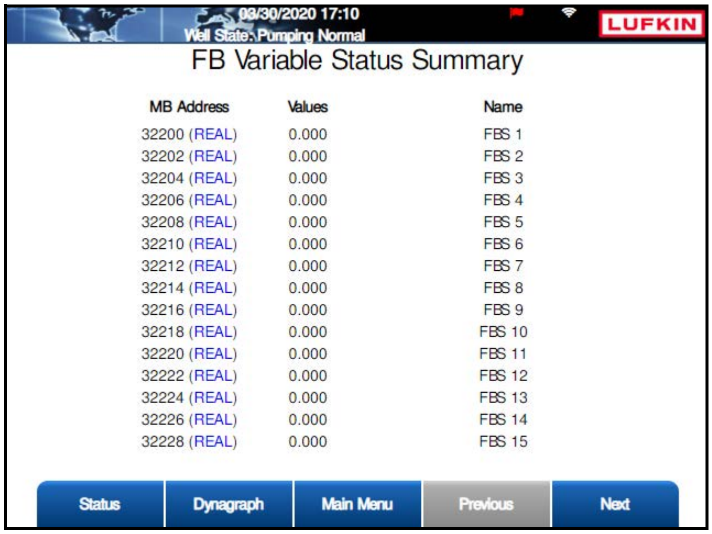

Figure 11-25. Function Block Variable Status Summary Screen

Use the **Next** and **Previous** buttons to navigate through the list.

Press the **<ESC>** button to return to the FB Variable Summary menu screen.

Function Block Variable Configuration Summary

From the FB Variable Summary menu screen, press the **FB Variable Config Summary** button to view a summary of function block variable configuration data.

Figure 11-26. Function Block Variable Config Summary Screen

Use the **Next** and **Previous** buttons to navigate through the list.

AGA Status

From the Supplemental Status menu screen, press the **AGA Status** button to display the AGA Status screen shown in Figure 11-27.

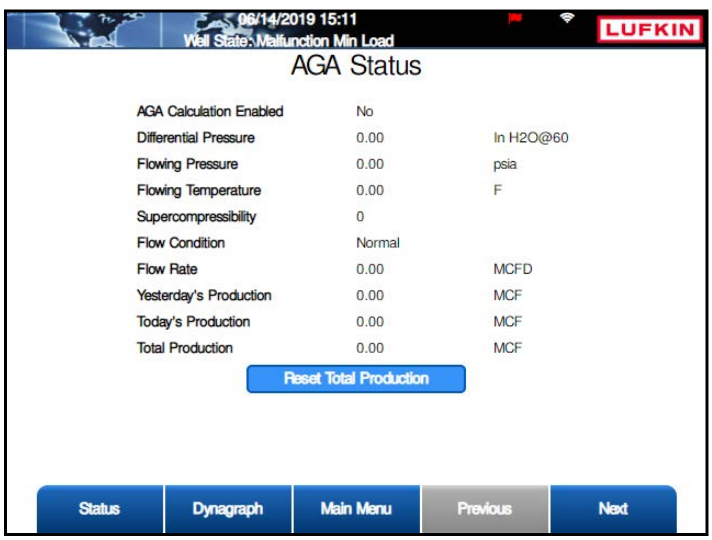

Figure 11-27. AGA Status Screen

This is the first of two screens that display status information related to the AGA Calculation feature. To clear the Total Production counter, press the **Reset Total Production** button.

Press the **Next** button to display the AGA Diagnostic screen shown in Figure 11-28.

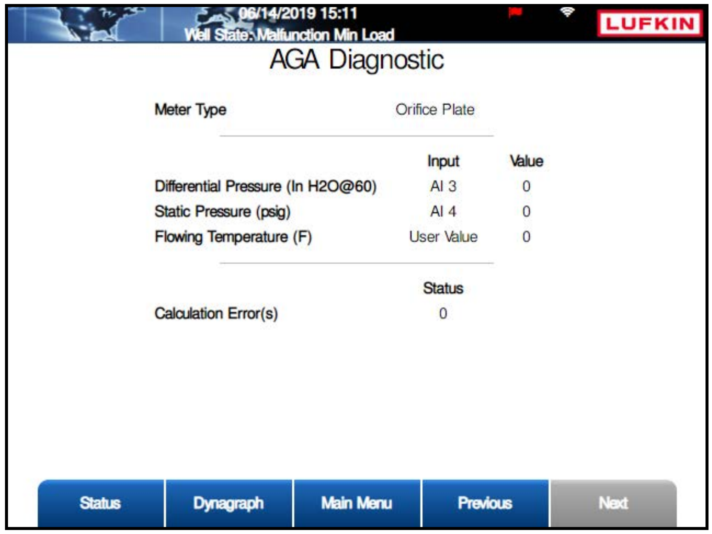

Figure 11-28. AGA Diagnostic Screen

This screen displays AGA diagnostic status data.

Modbus Master

From the Supplemental Status menu screen, press the **Modbus Master** button to display the Modbus Master Status screen shown below.

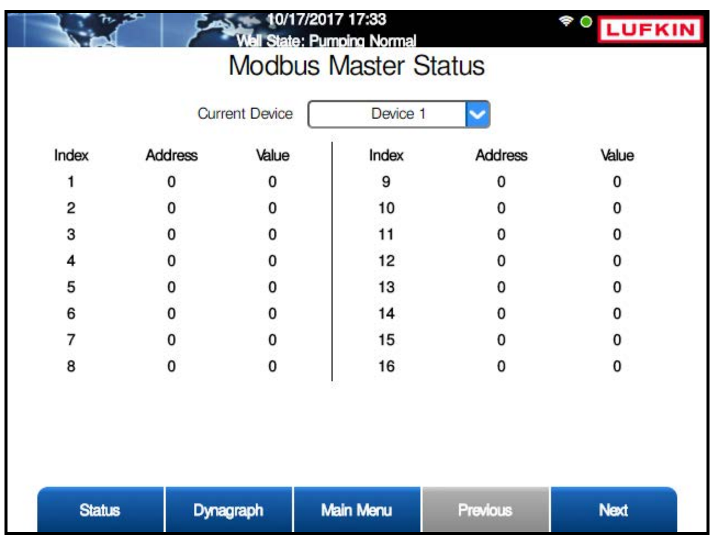

Figure 11-29. Modbus Master Status Screen

Status information for all connected Modbus Master devices are shown on this screen.

Select the desired device from the **Current Device** drop-down menu and then press **<Enter>** to display its status.

Press the **Previous** or **Next** buttons to navigate between pages of data.

Press <**ESC**> to return to the Supplemental Status menu screen.

Production Status

Press the **Production Status** button to display the first of two screens showing production status data. The first screen displays inferred production status data. (See Figure 11-30.) Total fluid, oil, and water amounts are shown along with last stroke data.

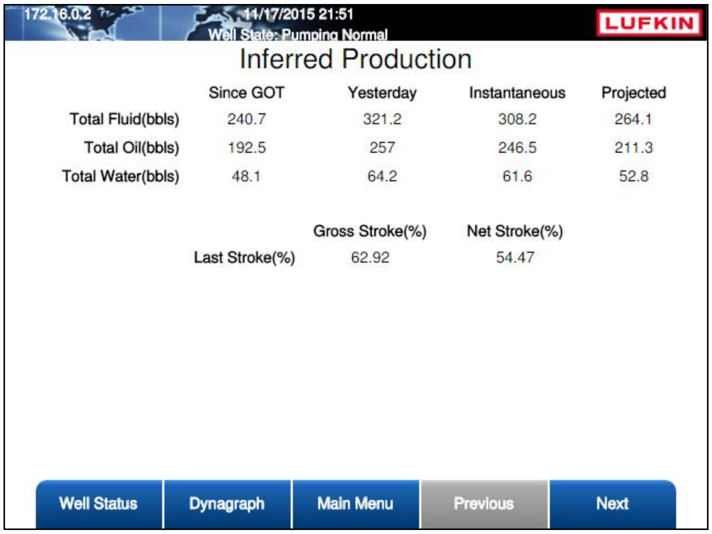

Figure 11-30. Inferred Production Status Screen

Press the **Next** button to display the next screen.

The next screen displays pump intake pressure (PIP) status data. Figure 11-31 shows an example of this screen.

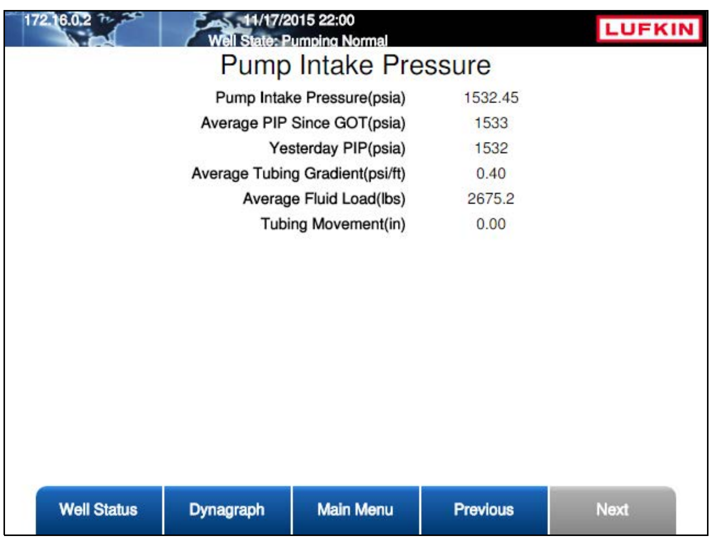

Figure 11-31. Pump Intake Pressure Status Screen

Hardware Input/Output Status

Press the **Hardware I/O Status** button to display the first of two Hardware Input/Output Status menu screens shown in Figure 11-32 and Figure 11-33.

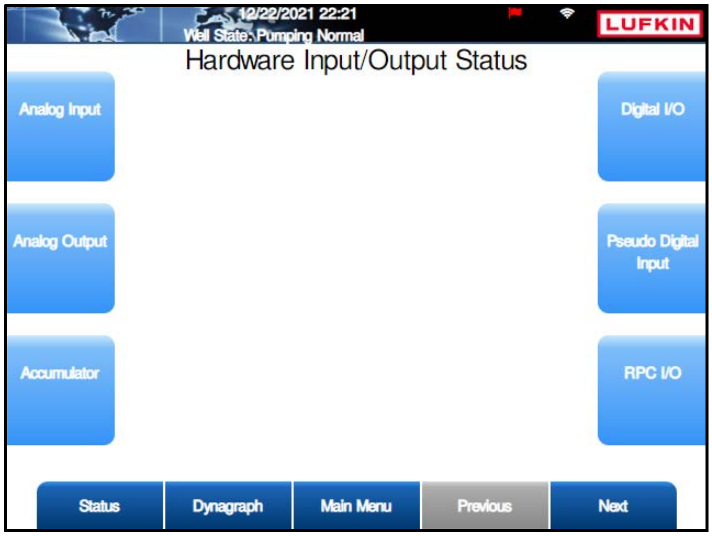

Figure 11-32. Hardware Input/Output Status Menu Screen 1 of 2

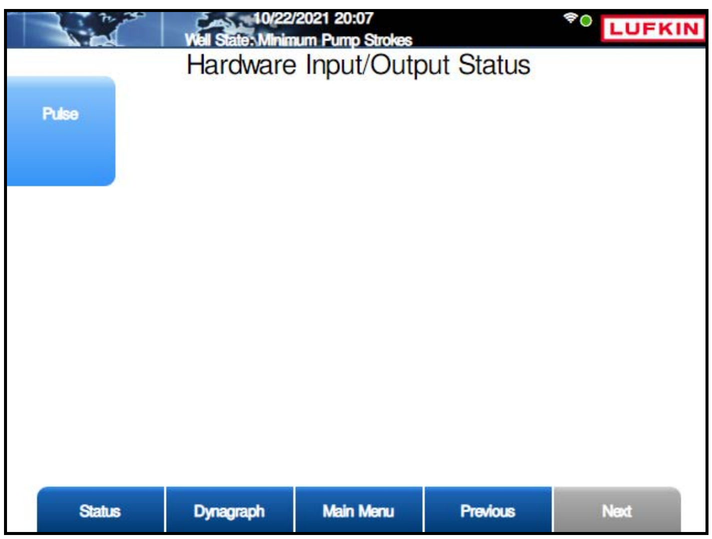

Figure 11-33. Hardware Input/Output Status Menu Screen 2 of 2

The hardware input and output status screens are discussed in the following pages.

Analog Input Status

From the first Hardware Input/Output Status menu screen, press the **Analog Input** button to display the Analog Input Status screen shown in Figure 11-34.

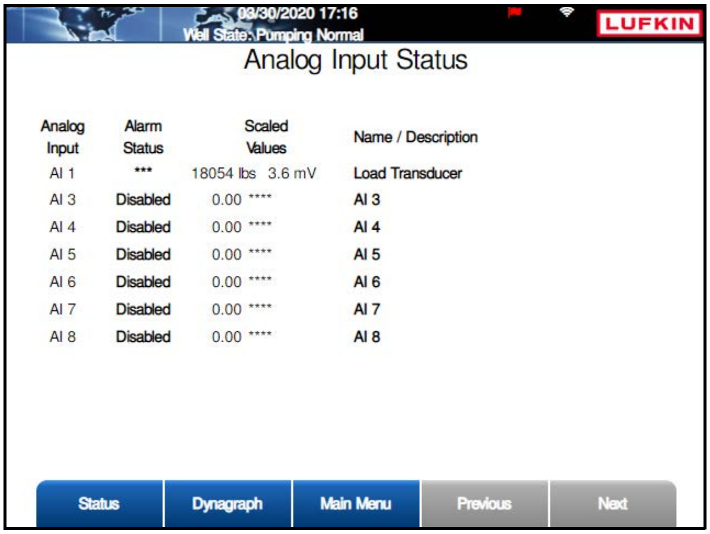

Figure 11-34. Analog Input Status Screen

This screen displays status information for all analog inputs in the system. These inputs are configured using the Analog Input Configuration screen. For information about this screen, see “Analog Input Configuration” on page 10-61.

Information about each data field is provided below:

- **Analog Input**: States the analog input channel number.
- **Alarm Status**: States whether an alarm is enabled or disabled for the channel.
- **Scaled Value**s: States the present value of the analog input in engineering units.
- **Name/Description**: States either the programmed virtual analog input number or the function description.

Press <**ESC**> to return to the first Hardware Input/Output Status menu screen.

Analog Output Status

From the first Hardware Input/Output Status menu screen, press the **Analog Output** button to display the Analog Output Status screen shown in Figure 11-35.

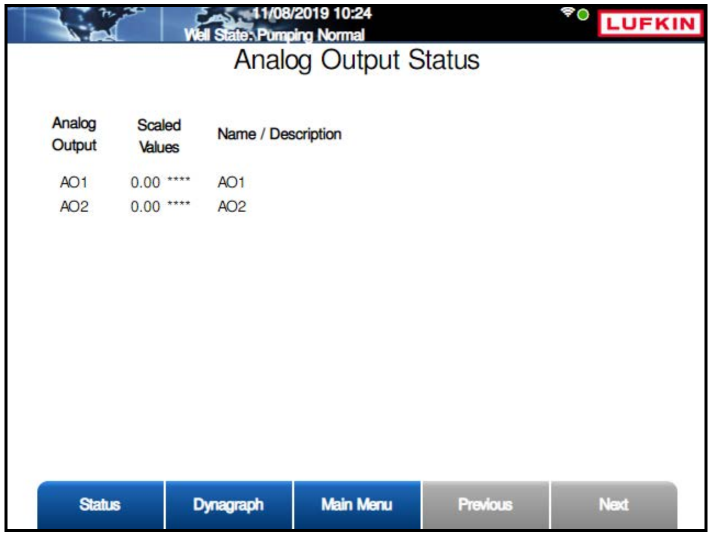

Figure 11-35. Analog Output Status Screen

This screen displays status information for all analog outputs in the system. These outputs are configured using the Analog Output Configuration screen. For information about this screen, see “Analog Input Configuration” on page 10-61.

Information about each data field is provided below:

- **Analog Output**: States the location of the output channel on the controller module. (See “Controller Module” on page 2-19 for more information.)
- **Scaled Values**: States the present value of the analog output in engineering units.
- **Name/Description**: States either the programmed virtual analog output number or the function description.

Press <**ESC**> to return to the first Hardware Input/Output Status menu screen.

Accumulator Status

From the first Hardware Input/Output Status menu screen, press the **Accumulator** button to display the first of two Accumulator Status screens.

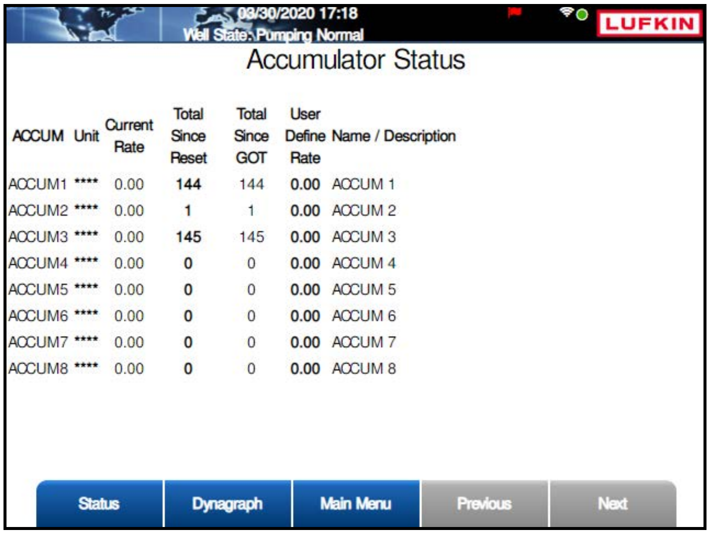

Figure 11-36. Accumulator Status Screen

This screen shows the status of the two accumulator inputs. The data fields are described below:

- **ACCUM:** States the location of the accumulator input channel on the controller module. (See “Controller Module” on page 2-7 for more information.)
- **Unit**: States the unit of measurement to be associated with each accumulator input.
- **Current Rate**: States the current recorded pulse rate for each input.
- **Total Since Reset**: States the total accumulation value since the last reset was performed.
- **Total Since GOT**: States the total accumulation value since the controller last updated the 60-day historical data buffers.
- **User Define Period**: States the user-defined number of days for the total accumulation value.
- **Name/Description**: Displays the programmed accumulator input name.

Press <**ESC**> to return to the first Hardware Input/Output Status menu screen.

Digital Input/Output Status

From the first Hardware Input/Output Status menu screen, press the **Digital I/O** button to display the Digital Input/Output Status screen shown in Figure 11-37.

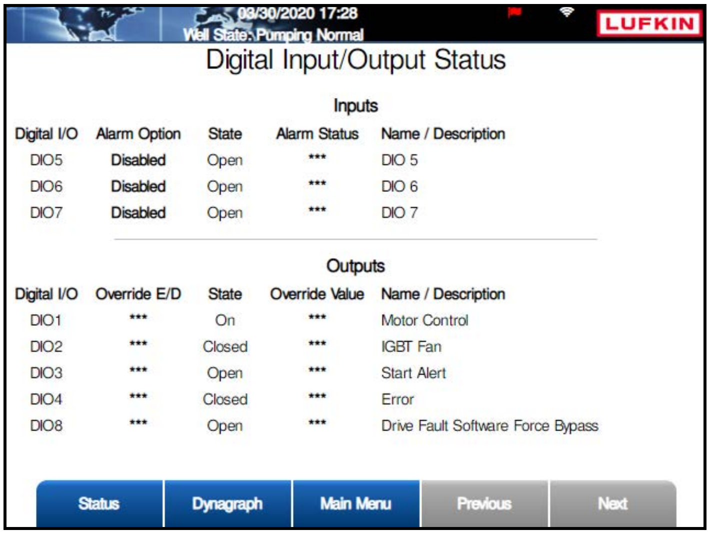

Figure 11-37. Digital Input/Output Status Screen

This screen shows status information for all digital inputs and outputs in the system. This information is grouped into input and output sections.

The input status information lists the following fields:

- **Digital I/O**: States the programmed virtual digital input number.
- **Alarm Option**: Indicates whether the alarm state is enabled or disabled for that channel.
- **State**: Indicates an open or closed state.
- **Alarm Status**: Indicates the current alarm status for that channel.
- **Name/Description**: States the location of the digital input point on the controller module.

The output status information lists the following fields:

- **Digital I/O**: States the programmed virtual digital output number.
- **Override E/D**: Indicates whether the override function is enabled or disabled for that point.
- **State**: Indicates an open or closed state.
- **Override Value**: Indicates the current override status for that point.
- **Name/Description**: States the location of the digital output point on the controller module.

Press <**ESC**> to return to the first Hardware Input/Output Status menu screen.

Pseudo Digital Input Status

From the first Hardware Input/Output Status menu screen, press the **Pseudo Digital Input** button to display the Pseudo Digital Input Status screen shown in Figure 11-38.

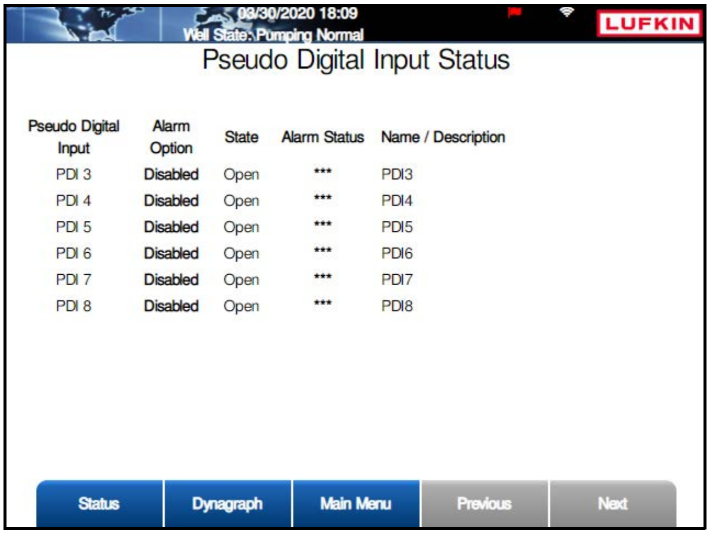

Figure 11-38. Pseudo Digital Input Status Screen

This screen displays status information for the pseudo digital inputs. The following information is provided:

- **Pseudo Digital Input**: States the programmed pseudo digital input number.
- **Name**: States the location of the pseudo digital input channel on the controller module. (See “Controller Module” on page 2-19 for more information.)
- **State**: Indicates an active (1) or inactive (0) state.
- **Alarm E/D**: Indicates whether the alarm is enabled or disabled for that channel.
- **Alarm Status**: Indicates the current alarm status for that channel.

Press <**ESC**> to return to the first Hardware Input/Output Status menu screen.

RPC I/O Status

From the first Hardware Input/Output Status menu screen, press the **RPC I/O** button to display the RPC Input/Output Status screen shown in Figure 11-39 on page 11-35.

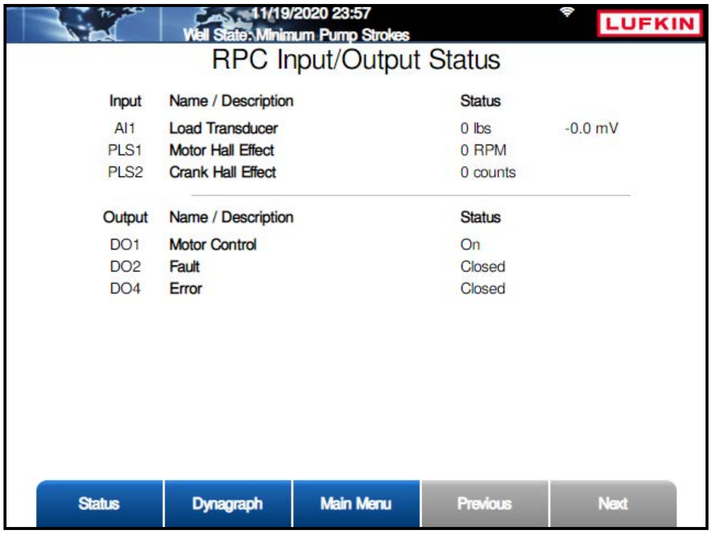

Figure 11-39. RPC Input/Output Status Screen

Realtime status information for all connected RPC inputs and outputs are displayed on this screen.

Pulse Status

From the second Hardware Input/Output Status menu screen, press the **Pulse** button to display the Pulse Status screen shown in Figure 11-40.

Figure 11-40. Pulse Status Screen

This screen displays realtime status information for the configured pulse inputs. See “Pulse Configuration” on page 8-57 for details on configuring pulse input points.

Historical Status

Press the **Historical Status** button to display the Historical Status menu screen. This screen provides access to historical data values for process variables such as RPC production and performance, calculated flow rates and production volumes, and VSD performance.

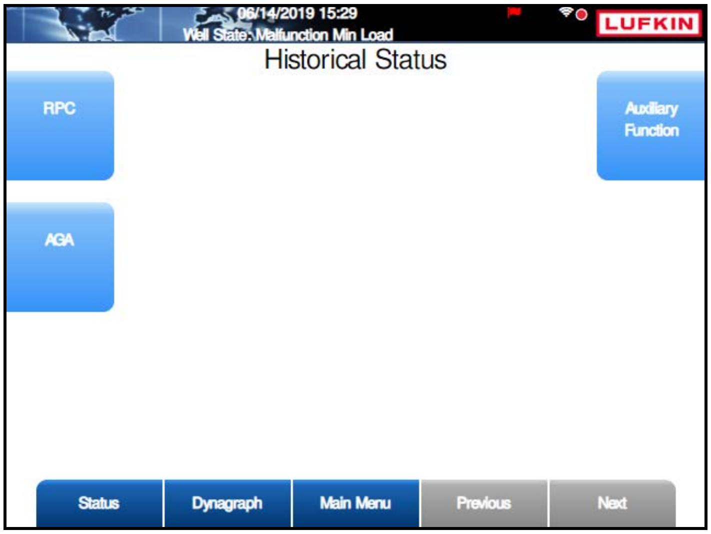

Figure 11-41. Historical Data Menu Screen

Refer to the section titled “Historical Status Data” on page 11-1 for details on these data screens.

Section 12: Historical Status Data

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Section Overview

The LWM 2.0 controller maintains historical status data in various formats to provide useful information about RPC production and performance. This section discusses the different types of available historical data.

Note: This manual describes the functions included in Version 1.36.00 of the LWM 2.0 firmware.

Historical Data Description

The LWM 2.0 controller saves into onboard memory historical data values for process variables, such as RPC production and performance, calculated flow rates and production volumes, VSD performance, and alarm and event logs. Historical data can be retrieved and displayed for activity from the previous 24-hour period in one-minute intervals, or the daily average for the previous 60 days.

To access this historical data, press the **Well Status** button to display the Well Status screen shown in Figure 12-1.

Figure 12-1. Well Status Screen

From this screen, press the **Historical Status** button to display the Historical Status menu screen shown in Figure 12-2 on page 12-4.

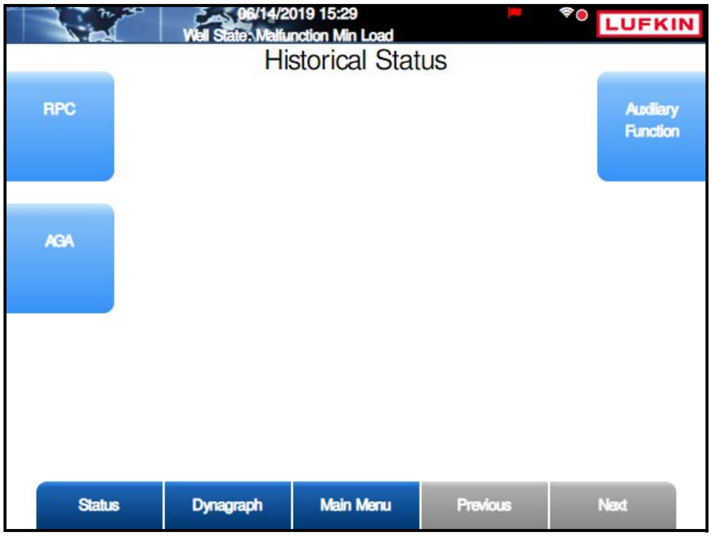

Figure 12-2. Historical Status Menu Screen

This screen displays historical data values for process variables such as RPC production and performance, calculated flow rates and production volumes, and VSD performance.

These options are discussed on the following pages.

RPC Data

Press the **RPC** button to display the Historical RPC Status menu screen shown in Figure 12-3.

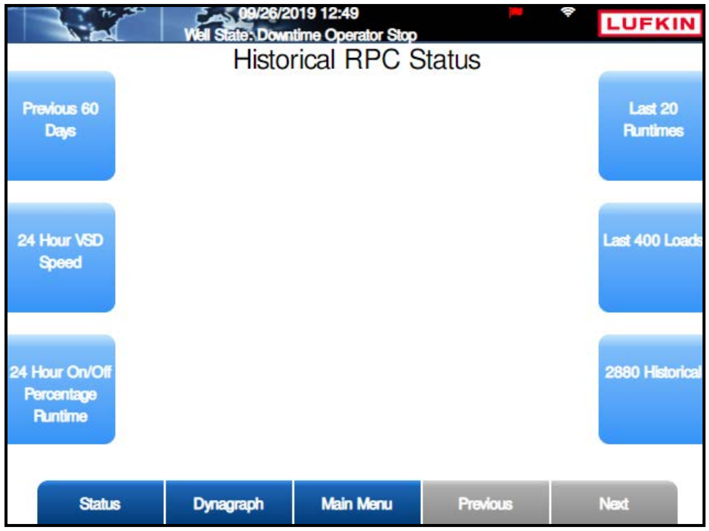

Figure 12-3. Historical RPC Status Menu Screen

The available options are discussed on the following pages.

Previous 60 Days

Press the **Previous 60 Days** button to display the first Previous 60 Days menu screen shown in Figure 12-4.

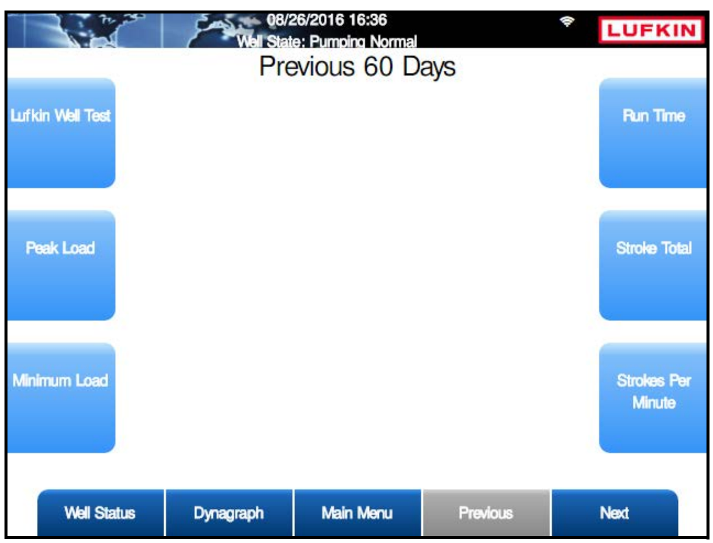

Figure 12-4. Previous 60 Days Menu Screen 1 of 2

Press the **Next** button to display the second menu screen shown in Figure 12-5.

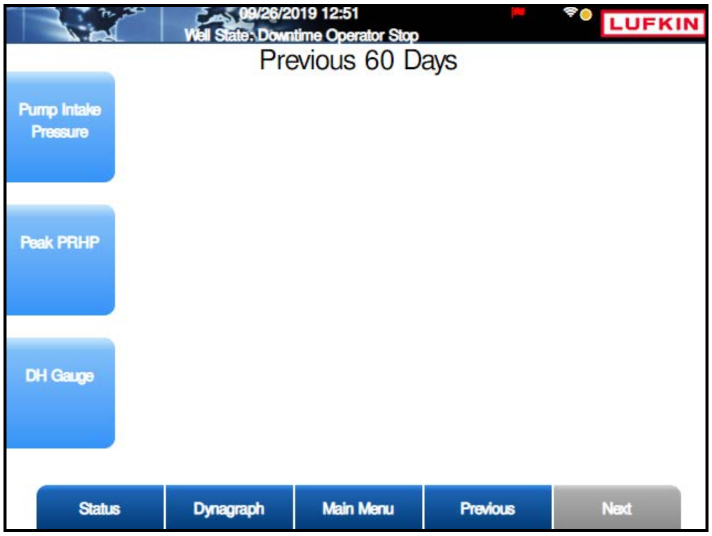

Figure 12-5. Previous 60 Days Menu Screen 2 of 2

These screens provide several options for displaying historical data from the previous 60 days. These options are discussed on the following pages.

Lufkin Well Test

From the first Previous 60 Days menu screen, press the **Lufkin Well Test** button to display the LWT 60 Day History screen shown in Figure 12-6 below.

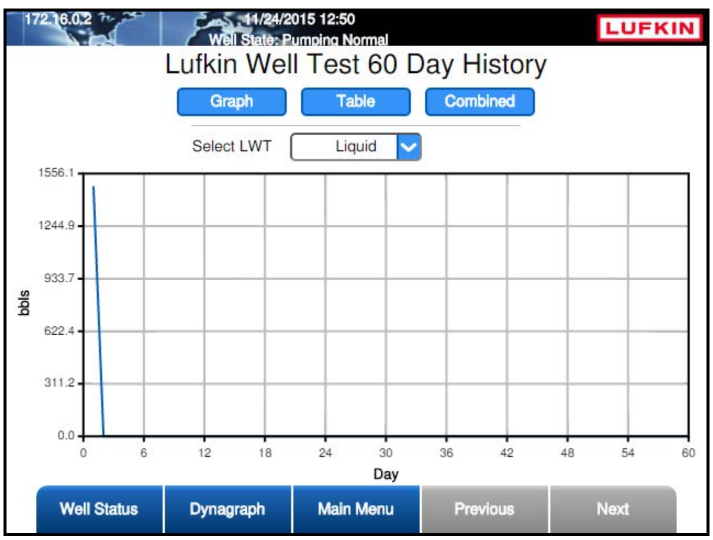

Figure 12-6. Lufkin Well Test 60 Day History Screen

This screen shows the calculated production volume (measured in barrels per day) for the previous 60 days using the Lufkin Well Test (LWT) algorithm. Data is displayed as a graph, a table, or a combined view of both formats for the following:

- Liquid
- Water
- Oil
- Gas

Press <**ENTER**> to display the drop-down list. Use the up or down arrow keys to highlight the desired display option and then press <**ENTER**> again.

Press the **Next** or **Previous** buttons to navigate between the pages.

Press <**ESC**> to return to the Previous 60 Days menu screen.

Peak Load

From the first Previous 60 Days menu screen, press the **Peak Load** button to display the Peak Load 60 Day History screen shown in Figure 12-7.

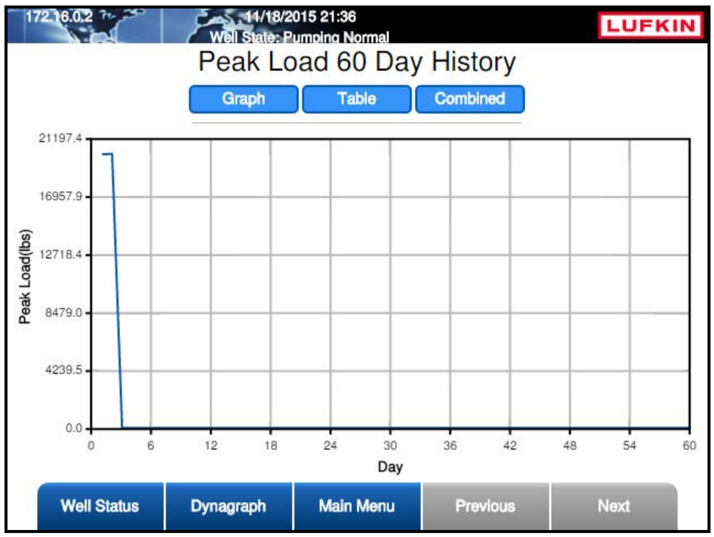

Figure 12-7. Peak Load 60 Day History Screen

This screen shows the highest value for the peak load recorded for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Minimum Load

From the first Previous 60 Days menu screen, press the **Minimum Load** button to display the Minimum Load 60 Day History screen shown in Figure 12-8 below.

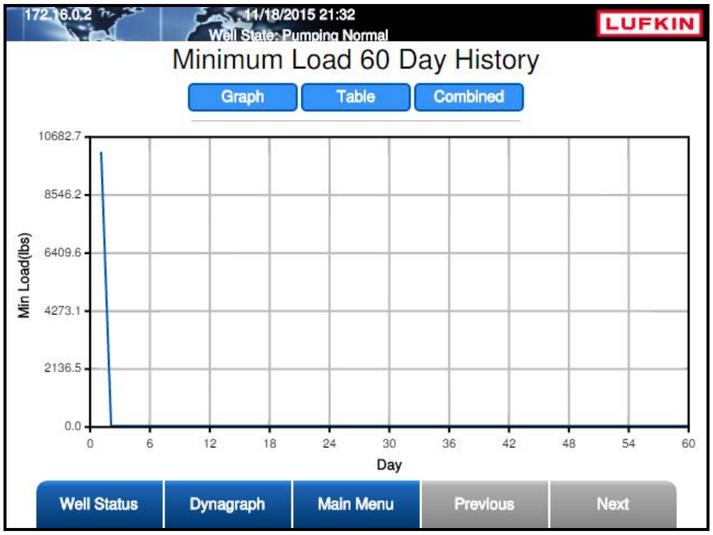

Figure 12-8. Min Load 60 Day History Screen

This screen displays the lowest value for minimum load (measured in pounds) recorded for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Run Time

From the first Previous 60 Days menu screen, press the **Run Time** button to display the Run Time 60 Day History screen shown in Figure 12-9.

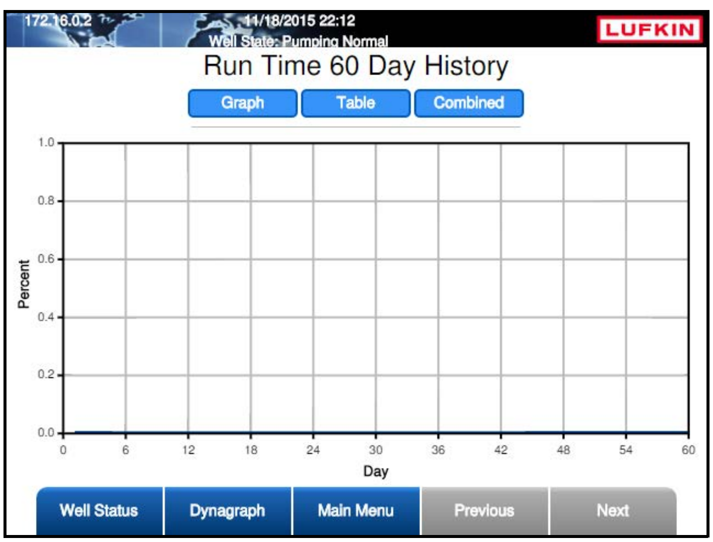

Figure 12-9. Runtime 60 Day History Screen

This screen shows the run time percentage for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Stroke Total

From the first Previous 60 Days menu screen, press the **Stroke Total** button to display the Stroke Total 60 Day History screen shown in Figure 12-10.

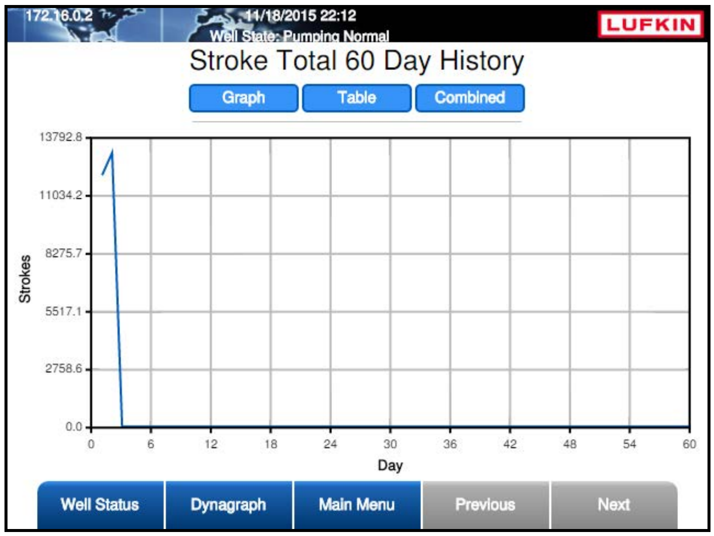

Figure 12-10. Stroke Total 60 Day History Screen

This screen displays the total number of strokes completed by the pumping unit during a set time period. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Press <**ESC**> twice to return to the Historical RPC Status menu screen or press the **Main Menu** button to return to the Main Menu screen.

Strokes Per Minute

From the first Previous 60 Days menu screen, press the **Strokes Per Minute** button to display the Strokes Per Minute 60 Day History screen shown in Figure 12-11.

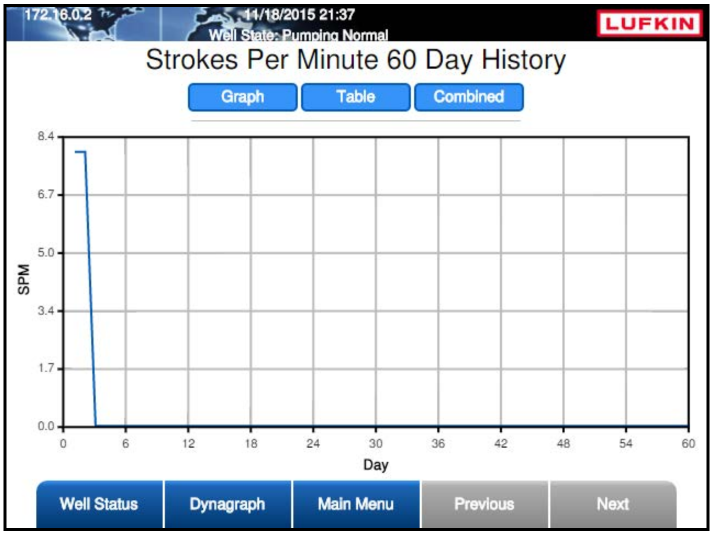

Figure 12-11. Stroke Per Minute 60 Day History Screen

This screen displays the number of strokes per minute completed by the pumping unit during the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Pump Intake Pressure

From the second Previous 60 Days menu screen, press the **Pump Intake Pressure** button to display the Pump Intake Pressure 60 Day History screen shown in Figure 12-12.

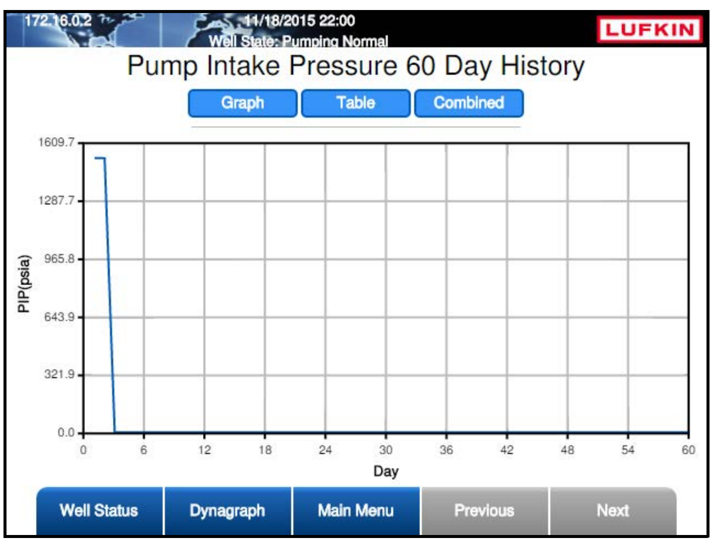

Figure 12-12. Pump Intake Pressure 60 Day History Screen

This screen displays the measured values for pump intake pressure (PIP) for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Peak PRHP (Polished Rod Horsepower)

From the first Previous 60 Days menu screen, press the **Peak PRHP** button to display the Peak Polished Rod Power 60 Day History screen shown in Figure 12-13.

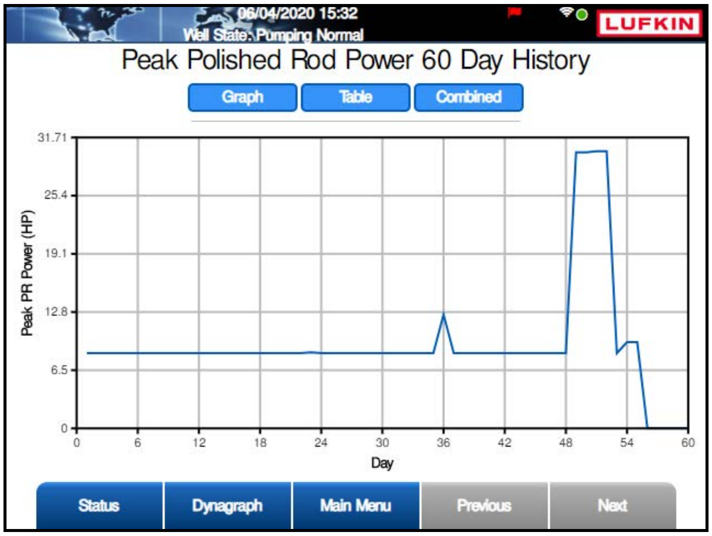

Figure 12-13. Peak Polished Rod Power 60 Day History Screen

This screen displays the highest value for polished rod horsepower recorded for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Downhole Gauge

From the second Previous 60 Days menu screen, press the **DH Gauge** button to display the DH Gauge 60 Day History screen shown in Figure 12-13.

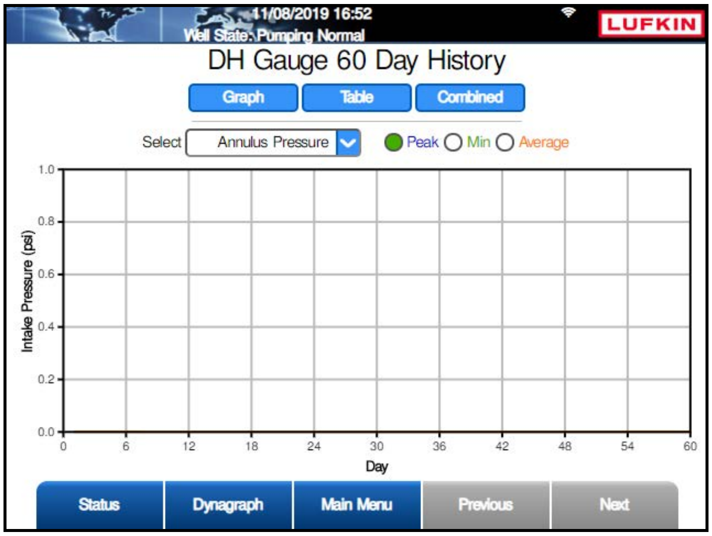

Figure 12-14. Downhole Gauge 60 Day History Screen

This screen displays the peak, minimum, and average values for downhole gauge data recorded for each of the previous 60 days. The following data is available from the drop-down list:

- Annulus Pressure
- Tubing Pressure
- Annulus Temperature
- Tubing Temperature
- Vibration X
- Vibration Z
- Tool Current
- Tool Voltage

Select the desired data option from the drop-down list and then press <**ENTER**>.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

24 Hour VSD Speed

From the Historical RPC Status menu screen, press the **24 Hour VSD Speed** button to display the 24 Hour VSD Speed screen shown in Figure 12-15.

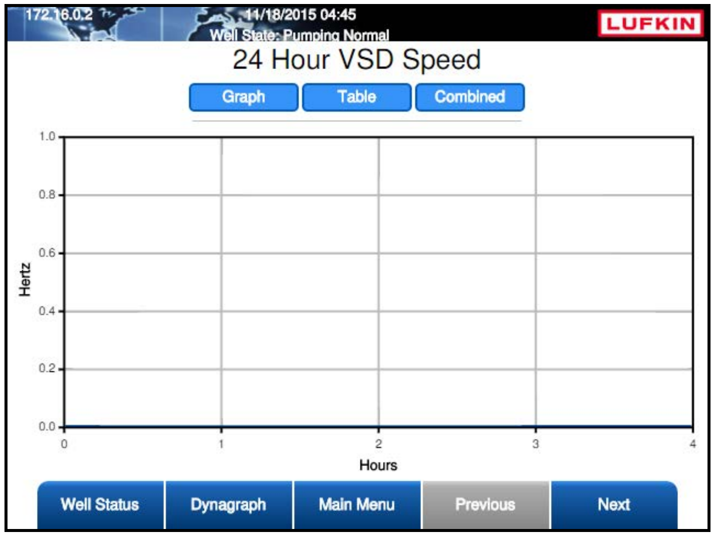

Figure 12-15. 24 VSD Speed Screen

This plot displays the VSD speed for the previous 24 hours. The LWM 2.0 controller takes one sample point each minute (1440) and uses it to represent that minute’s activity.

This data represents activity for the previous 24-hour period, and is not linked to gauge off time (GOT). It is a moving window of data from the time that you start viewing the data and moving back in time for the last 24 hours.

The plots show time as the x-axis. The time 0.0 (shown on the left of the plot) is the present time. Time numbers increase as you read to the right going back in time.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

24 Hour On/Off Percentage Runtime

From the Historical RPC Status menu screen, press the **24 Hour On/Off Percentage Runtime** button to display the 24 Hr On/Off Percentage Runtime screen shown in Figure 12-16.

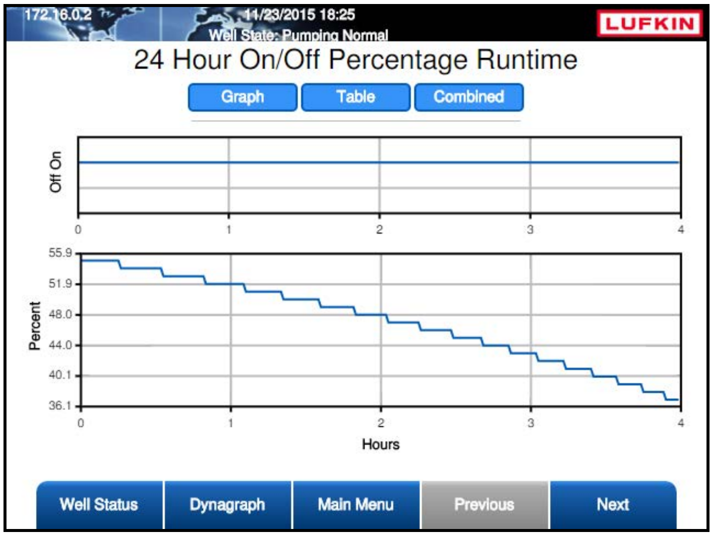

Figure 12-16. 24 Hr On/Off Percentage Runtime Screen

This plot displays a record of the runtime activity for the previous 24 hours. The LWM 2.0 controller takes one sample point each minute (1440 in a 24-hour period) and uses it to represent that minute's activity. This data represents activity for the previous 24-hour period, and is not linked to gauge off time (GOT). It is a moving window of data from the time that you start viewing the data and moving back in time for the last 24 hours.

The plots show time as the x-axis. The time 0.0 (shown on the left of the plot) is the present time. Time numbers increase as you read to the right going back in time. The top of the plot indicates if the pump was on or off and the resulting percent run trend plotted below.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Last 20 Runtimes

From the Historical RPC Status menu screen, press the **Last 20 Runtimes** button to display the Last 20 Runtimes screen shown in Figure 12-17.

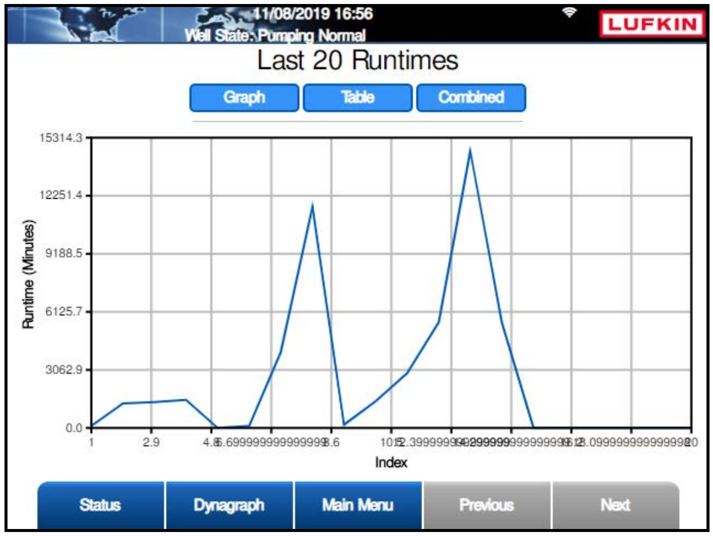

Figure 12-17. Last 20 Runtimes History Screen

This plot displays the previous 20 runtime periods measured in minutes. The plot shows the runtimes on the x-axis and the runtime on the y-axis.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Last 400 Loads

From the Historical RPC Status menu screen, press the **Last 400 Loads** button to display the Last 400 Loads screen shown in Figure 12-18 on page 12-16.

This plot displays the last 400 load values prior to a shutdown decision versus time. This plot is included to ensure that you have a record of a LWM 2.0 controller shutdown decision due to a peak or minimum load violation. The dynagraph card record might not capture events of these types since the card data is only updated at the bottom of a stroke, and a peak or minimum load violation would call for a shutdown before the end of the present stroke.

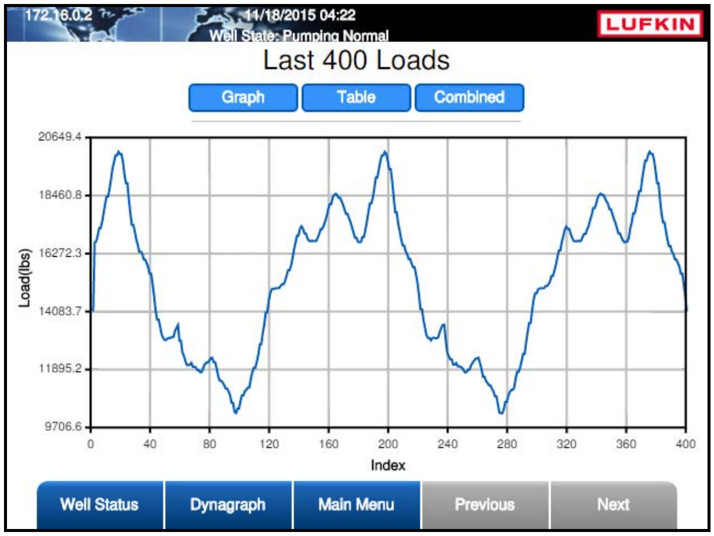

Figure 12-18. Last 400 Loads Screen

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

2880 Historical

From the Historical RPC Status menu screen, press the **2880 Historical** button to display the 2880 Historical menu screen shown in Figure 12-19.

Figure 12-19. 2880 Historical Menu Screen

The 2880 historical screens are discussed in the following pages.

Last 2880 Average PIP

From the RPC Data menu screen, press the **Last 2880 Average PIP** button to display the Last 2880 Avg PIP screen shown in Figure 12-20.

Every tenth stroke the current PIP value is captured and added to this data buffer. The most recent 2880 values are stored and available for display in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

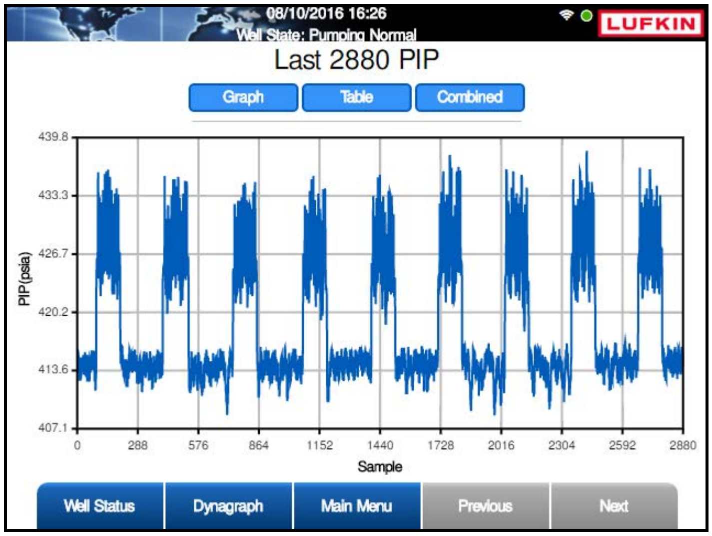

Figure 12-20. Last 2880 Avg PIP Screen

2880 DH Gauge

From the 2880 Historical menu screen, press the **2880 DH Gauge** button to display the 2880 DH Gauge screen shown in Figure 12-21.

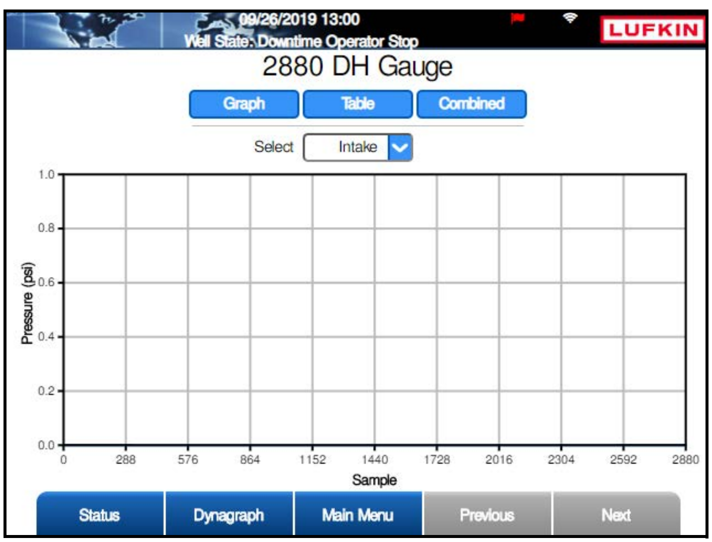

Figure 12-21. 2880 DH Gauge Screen

This screen displays the most recent 2880 values for the downhole gauge. These values can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Historical AGA Data

From the Historical Status menu screen, press the **AGA** button to display the Historical AGA menu screen shown in Figure 12-22.

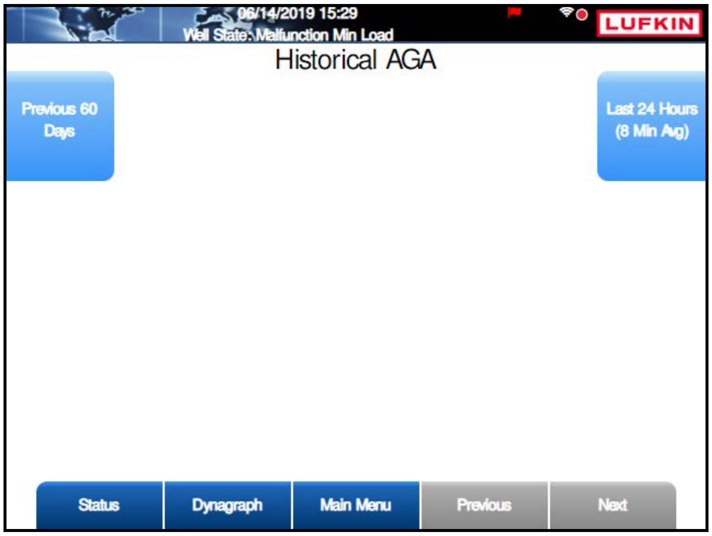

Figure 12-22. Historical AGA Menu Screen

The historical AGA data is discussed in the following pages.

AGA Previous 60 Days

From the Historical AGA menu screen, press the **Previous 60 Days** button to display the Previous 60 Days screen shown in Figure 12-23.

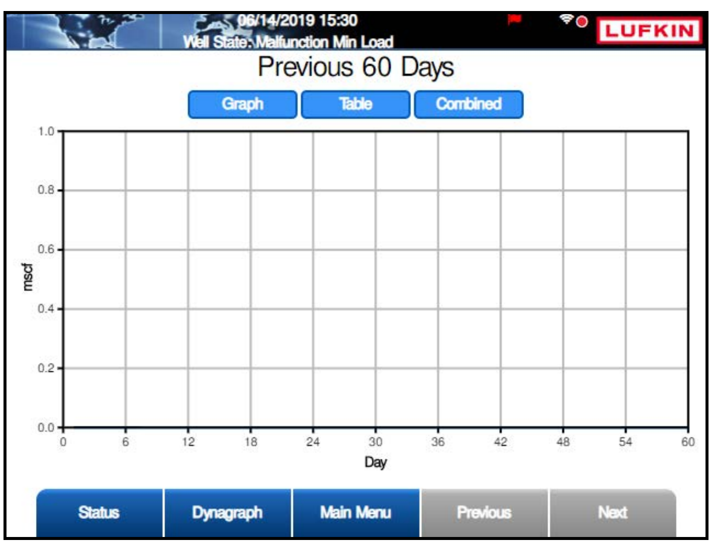

Figure 12-23. AGA Previous 60 Days Screen

This screen shows the AGA calculation results for each of the previous 60 days. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Press <**ESC**> to return to the Historical AGA menu screen.

Last 24 Hours (8 Minute Averages)

From the Historical AGA menu screen, press the Last 24 Hours (8 Min Avg) button to display the Last 24 Hours (8 Minute Averages) screen shown in Figure 12-24.

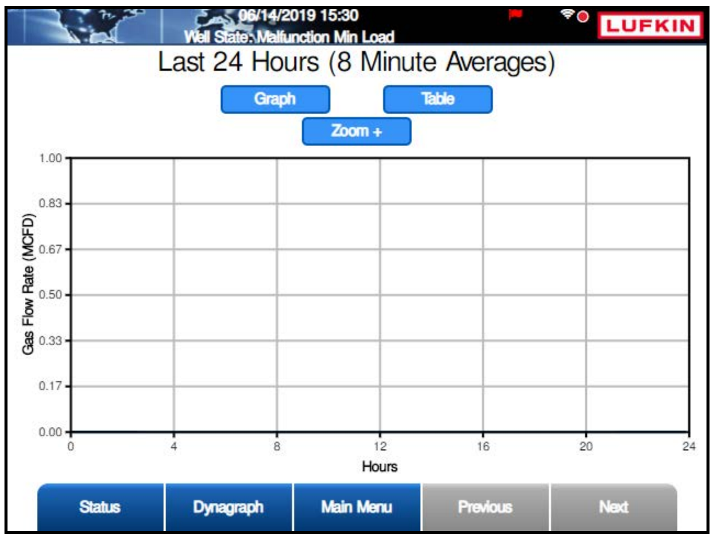

Figure 12-24. AGA Last 24 Hours (8 Minute Averages) Screen

This screen shows 8 minute averages of the AGA calculation results for the last 24 hours. This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press the **Next** or **Previous** buttons to navigate between the pages of data.

Auxiliary Function Data

From the Historical Menu screen, press the **Auxiliary Function** button to display the Auxiliary Function Data menu screen shown in Figure 12-25 below

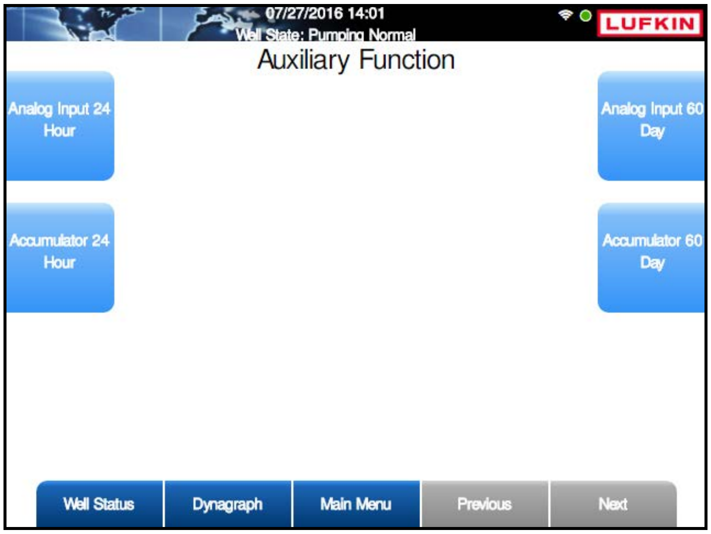

Figure 12-25. Auxiliary Function Screen

The controller maintains records for configured auxiliary inputs and accumulators. Data is available for the current 24-hour period and for the past 60 days.

These data screens are discussed in the following pages.

Analog Input 24 Hour

From the Aux Funct. Data menu screen, press the **Analog Input 24 Hour** button to display the Analog Input 24 Hour screen shown in Figure 12-26 below.

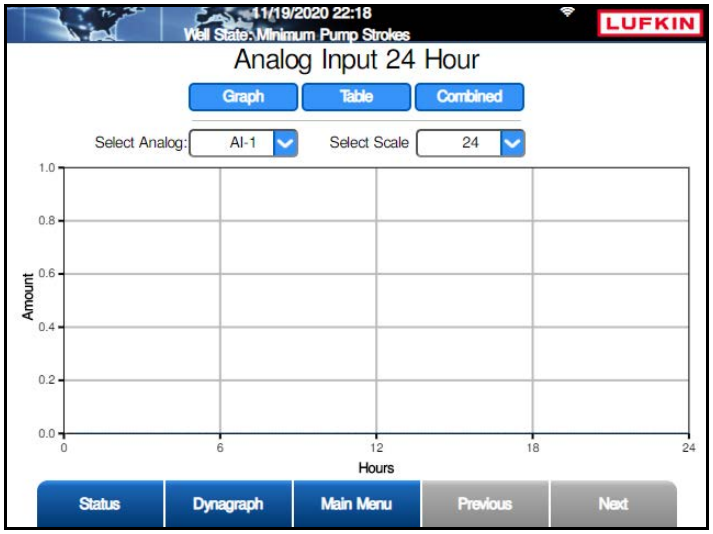

Figure 12-26. Analog Input 24 Hour Screen

The values of a selected configured auxiliary analog input are collected over the previous 24-hour period and can be displayed as either a graphical plot or as a table. This data consists of 180 values that are an average value for an eight-minute interval.

Press <**ENTER**> to display the drop-down list of available analog inputs. Use the up or down arrow keys to select the desired input and then press <**ENTER**> again.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press <**ESC**> to return to the Auxiliary Function Data screen.

Analog Input 60 Day

From the Aux Funct. Data menu screen, press the **Analog Input 60 Day** button to display the Analog Input 60 Day screen shown in Figure 12-29 on page 12-23.

The average value of the selected configured auxiliary analog input for each of the previous 60 days is stored and can be displayed as either a graphical plot or as a table.

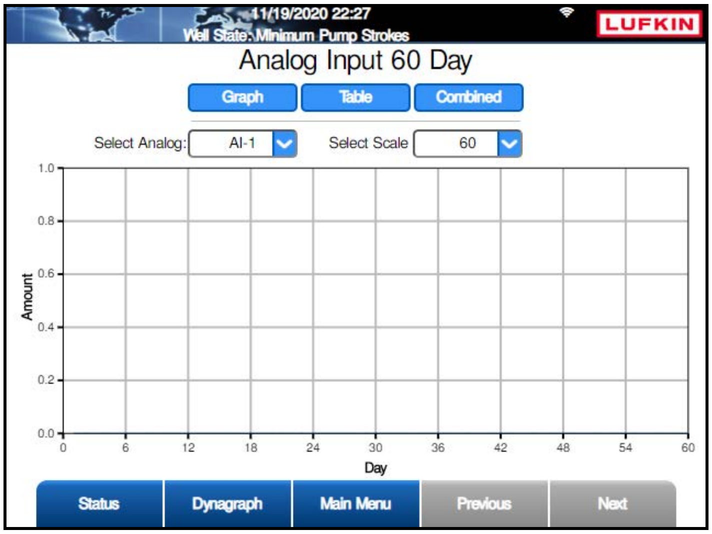

Figure 12-27. Analog Input 60 Day Screen

Press <**ENTER**> to display the drop-down list of available analog inputs. Use the up or down arrow keys to select the desired input and then press <**ENTER**> again.

This data can be displayed in a graph, a table, or a combined view of both formats. Press the appropriate button for the desired display option.

Press <**ESC**> to return to the Auxiliary Function Data screen.

Accumulator 24 Hour

From the Aux Funct. Data menu screen, press the **Accumulator 24 Hour** button to display the Accumulator 24 Hour screen shown in Figure 12-28.

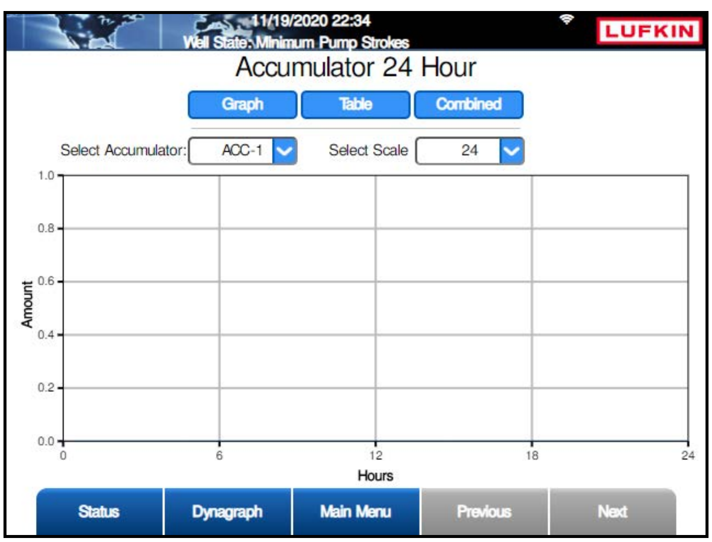

Figure 12-28. Accumulator 24 Hour Screen

For each configured accumulator, a history is maintained of the total scaled value accumulated in each of the previous 180 eight-minute sample periods during the previous 24-hour period. This data can be displayed in a graph, a table, or a combined view of both formats.

Press <**ENTER**> to display the drop-down list of available accumulator inputs. Use the up or down arrow keys to select the desired input and then press <**ENTER**> again.

Press <**ESC**> to return to the Auxiliary Function Data screen.

Accumulator 60 Day

From the Aux Funct. Data menu screen, press the **Accumulator 60 Day** button to display the Accumulator 60 Day screen shown in Figure 12-29.

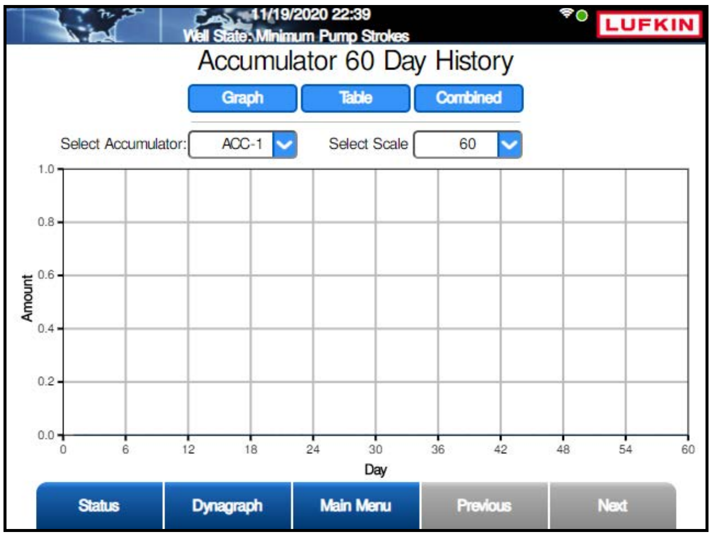

Figure 12-29. Accumulator 60 Day Screen

A history of the total scaled value for each configured accumulator input is maintained for each of the last 60 days. This data can be displayed in a graph, a table, or a combined view of both formats.

Press <**ENTER**> to display the drop-down list of available accumulator inputs. Use the up or down arrow keys to select the desired input and then press <**ENTER**> again.

Press <**ESC**> to return to the Auxiliary Function Data screen.

Section 13: Dynagraph Screens

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Section Overview

The LWM 2.0 controller displays a live real-time dynagraph trace and stores historical dynagraph cards. Control parameters related to the dynagraph shape analysis are programmed on the dynagraph screens. This section discusses the various dynagraph screens that are available.

Note: This manual describes the functions included in Version 1.34 of the LWM 2.0 firmware.

Dynagraph Screen

Press the **Dynagraph** button (**F2**) to display the Dynagraph screen shown in Figure 13-1. This screen shows a real-time dynagraph of the load and position data recorded during pumping operation. Three dynagraph display options are provided:

- **Surface**: This button displays the Surface card. This card and its functions are described below.
- **Downhole**: This button displays the Downhole card. See “Downhole Card” on page 13-9 for details on this card and its functions.
- **Both**: This button displays a combined view of the surface and downhole cards. See “Both Cards” on page 13-11 for more details.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

This screen also provides a full-screen view of the dynagraph. Press the **Toggle View** button to switch between the standard view and the full-screen view.

These dynagraph cards and their features are discussed in the following paragraphs.

Surface Card

The Surface Card shown in Figure 13-1 is displayed by default. This card shows a real-time dynagraph of the surface load and position data recorded during pumping operation.

Figure 13-1. Dynagraph Screen – Surface Card

Current status data, display options, and applicable setpoints are also displayed on this screen.

Status Data

The following status data is displayed on this screen:

- **Elapsed Time**: This field displays the amount of time (measured in hours, minutes, and seconds) the pumping unit has been running.
- **SPM:** This field displays the current strokes per minute at which the pumping unit is operating.
- **Min/Peak Load**: This field displays the current recorded minimum and peak load of the pumping cycle. These values are updated at the end of each stroke and are the minimum and maximum values of the polished rod load in the stroke just completed.
- **PO Setpoint Csc**: This field displays the consecutive number of times the POC setpoint has been violated.

Display Options

The Surface Card has several options for displaying load and setpoint data. These are described on the following pages.

- **Permissible Load**: This check box provides the option of displaying the defined permissible load values as shown in Figure 13-2. See “Surface Card Setpoints” on page 13-7 for details on configuring these parameters.

  Press the down arrow to highlight the **Permissible Load** check box and then press <**ENTER**> to select this option. The Permissible Load title flashes red while the data is calculated and then the surface card is displayed with the defined load values as shown below.

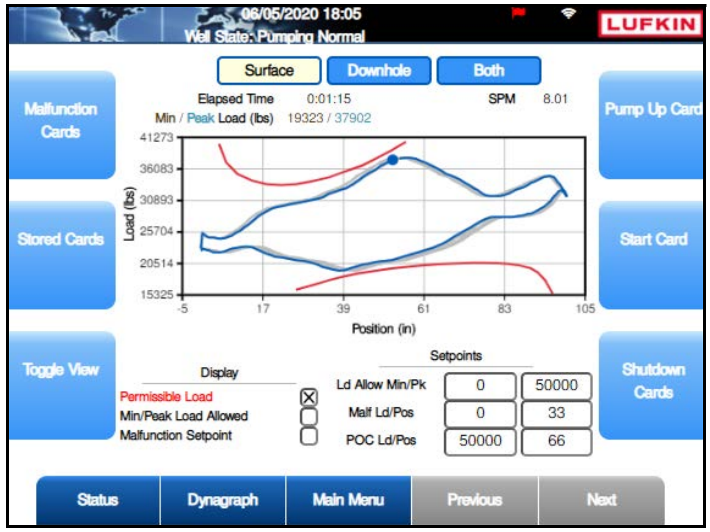

Figure 13-2. Surface Card with Permissible Load Display

To hide these values, clear the **Permissible Load** check box using the same method described above.

- **Min/Peak Load Allowed**: This check box provides the option of displaying the minimum and the maximum allowed values for load input. Figure 13-3 shows an example of the Min/Peak Allowed display option. See “Surface Card Setpoints” on page 13-7 for details on configuring these parameters.

  Press the down arrow to highlight the **Min/Peak Load Allowed** check box and then press <**ENTER**> to select this option. The Minimum and Peak Load Allowed setpoint values are displayed as horizontal colored lines at the top and bottom of the card.

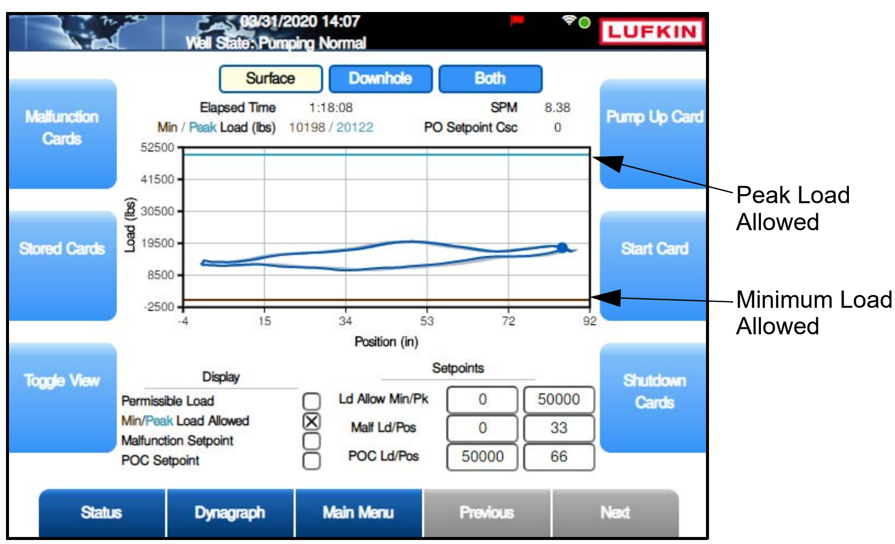

Figure 13-3. Surface Card with Min/Peak Allowed Display

To hide these values, clear the **Min/Peak Load Allowed** check box using the same method described above.

- **Malfunction Setpoint**: This check box provides the option of displaying the Malfunction Setpoint value on the dynagraph as shown in Figure 13-4. See “Surface Card Setpoints” on page 13-7 for details on configuring the parameters for this setpoint.

  Press the down arrow to highlight the **Malfunction Setpoint** check box and then press <**ENTER**> to select this option. The Malfunction Setpoint title turns purple when active and its value is displayed as a purple square on the card.

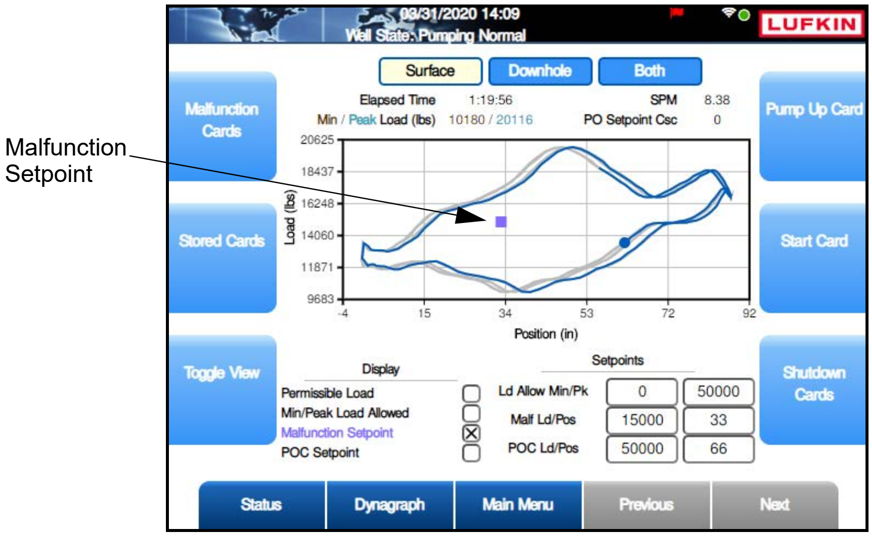

Figure 13-4. Surface Card with Malfunction Setpoint Display

  To hide this setpoint, clear the **Malfunction Setpoint** check box using the same method described above.

- **POC Setpoint**: This check box provides the option of displaying the POC Setpoint value on the dynagraph as shown in Figure 13-5. See “Surface Card Setpoints” on page 13-7 for details on configuring the parameters for this setpoint.

  Press the down arrow to highlight the **POC Setpoint** check box and then press <**ENTER**> to select this option. The POC Setpoint title turns green while active and its value is displayed as a green diamond on the card.

Figure 13-5. Surface Card with POC Setpoint Display

To hide this setpoint, clear the **POC Setpoint** check box using the same method described above.

- **Sectional Speed**: (This check box is only visible when the Sectional Speed feature is enabled. See "Sectional Speed Control" on page 10-39 for more information.) Select this check box to display the sectional speed data as shown in Figure 13-6.

Figure 13-6. Surface Card with Sectional Speed Data

Surface Card Setpoints

The configurable surface card setpoints are as follows:

- **Permissible Load:** This setpoint represents the minimum and peak load allowed for the pumping unit's gearbox. These values are graphically displayed in red on the card.
- **Ld Allow Min/Pk**: These setpoints set the minimum and peak load allowed for the polished rod during operation. If the rod load exceeds the peak load setpoint or drops below the minimum load setpoint, the controller instantly shuts down the pumping unit with no consecutive stroke delay.

  The setpoint parameters are as follows:

  - **Allowed Minimum Load**: The left parameter field sets the minimum load allowed during operation. If the load drops below this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay.
  - **Allowed Peak Load**: The right parameter field sets the maximum load allowed during operation. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay.

  To change these parameters, do the following:

  a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

  b. Use the keypad to define the parameter value and then press <**ENTER**> again.

These values are displayed as colored horizontal lines at the top and bottom of the card.

Note: The controller automatically scales the dynagraph screen to show both Allowed Peak and Allowed Min Load. If the programmed values are far above or below the actual working peak and minimum loads, the dynagraph trace on the screen will be fairly small. To obtain a larger dynagraph trace, configure the Allowed Peak and Allowed Min Load values to within 15 percent or 25 percent above/below the working loads.

- **Malf Ld/Pos**: These setpoints are used to check for rod parts or other pump malfunctions that cause no fluid load to be picked up by the pump. If the load falls below the Malfunction load setpoint in the upstroke, the controller counts that as a violation of the setpoint. The number of consecutive Malfunction Strokes Allowed can be configured on the Operational Limits 1 screen. (See “Operational Limits 1 Screen” on page 10-26 for details on this screen.)

  The configurable parameters are:

  - **Load** – The left parameter field sets the minimum load weight allowed during operation.
  - **Position (inches)** – The right parameter field sets the minimum distance the rod must move during operation.

  To change these parameters, do the following:

  a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

  b. Use the keypad to define the parameter value and then press <**ENTER**> again.

  The malfunction setpoint is displayed as a purple square on the dynagraph. (See Figure 13-4 on page 13-6.)

- **POC (Pump Off Control) Setpoint**: This setpoint is the pump off **“**limit**”** for the Surface control mode. When the load goes above the POC setpoint in the downstroke, the controller counts that as a pump off stroke. The consecutive number of pump off strokes allowed is specified with the RPC Control Parameter programming screen.

  The parameters for this setpoint are:

  - **Load (lbs)** – the maximum load weight allowed during operation
  - **Position (inches)** – the maximum distance the rod can move during operation

  To change these parameters, do the following:

  a. Use the arrow keys to highlight the desired parameter field and then press <**ENTER**>.

  b. Use the keypad to define the parameter value and then press <**ENTER**> again.

  The POC setpoint is displayed as a green diamond on the dynagraph. (See Figure 13-5 on page 13-6.)

Downhole Card

The Downhole card displays a realtime live trace of the well's downhole activity. Figure 13-7 shows an example of this card.

Figure 13-7. Downhole Card

Status Data

The following status data is displayed on this screen:

- **Elapsed Time**: This field displays the amount of time (measured in hours, minutes, and seconds) the pumping unit has been running.
- **SPM:** This field displays the current strokes per minute at which the pumping unit is operating.
- **Pump Fillage:** The Pump Fillage value is updated at the end of each stroke after the Minimum Pump Strokes. It is the calculated percent pump fillage represented by the downhole pump card. When this value falls below the Pump Fillage-Set % value, that stroke is counted as a pump off stroke. You can specify the consecutive number of pump off strokes allowed using the RPC Control Parameter programming screen.
- **Fluid Load:** This value is the difference between the average upstroke load and the average downstroke load of the downhole pump card as calculated by the LWM 2.0 controller. This value is the input for the Fluid Load control function. If this calculated fluid load falls below the set low fluid load limit, the LWM 2.0 controller stops the pumping unit.
- **Buoyant Force:** This value is the upward force on the rod string caused by the displaced fluid in the tubing. It is calculated by multiplying the cross sectional area of the bottom rod taper times the pressure at the bottom of the rods.
- **Net Stroke:** The LWM 2.0 controller uses an algorithm to find the point that the pump plunger in the downstroke contacts fluid in the pump. Net stroke length is used to calculate the percent pump fillage for pump off control in the Downhole control mode. This value is also used in the inferred production calculations.
- **Gross Stroke:** This value is the maximum possible pump plunger stroke length calculated by the LWM 2.0 controller.
- **Min Pump Load:** This value is the lowest value for load in the displayed downhole card.
- **Peak Pump Load:** This value is the highest value for load in the displayed downhole card.

- **DH Pressure (psi)**: (Displayed in **VSD DH Pressure** control mode only.) This value is the current recorded downhole pressure.

Downhole Card Setpoints

The configurable downhole card parameters are as follows:

- **Pump Fillage**: This value is the pump off shutdown level when Downhole Control mode is selected.
- **2ry Pump Fillage**: This value is the secondary pump off shutdown level for the Downhole Control mode.
- **Fluid Load**: This value is the Low limit for the fluid load control function. See “Current Fluid Load” on the previous page.
- **Fill Base**: This value is the full range load percentage of the downhole card at which the controller, in the downstroke, starts to look for the slope change indicating plunger contact with fluid in the pump barrel. The adjustable fill base allows the controller to find accurate net stroke with a variety of unusual pump conditions. If net stroke calculation results do not appear to be reasonable, adjust the fill base up or down for more logical results. Zero percentage is the minimum load value for the downhole card. The default value of 45 will work for most wells.
- **PTM Region & Ld Detection Lmt**: Select this parameter when the Pump Tag Mitigation feature is active. Refer to “Pump Tag Mitigation” on page 8-39 for more information.

To change these parameters, do the following:

1. Use the arrow keys to highlight the desired parameter and then press <**ENTER**>.
2. Use the keypad to define the parameter value and then press <**ENTER**> again.

The **Pump Fillage** and **Fill Base** setpoints can be displayed graphically on the downhole card. To display these setpoints, use the arrow keys to highlight the check box next to the desired setpoint and then press <**ENTER**>. The Pump Fillage setpoint is represented by a vertical red line and the Fill Base setpoint is represented by a horizontal blue line.

Both Cards

The Both display option shows a split-screen realtime live trace of both surface and downhole activity.

Figure 13-8. Both Cards Displayed

This screen displays status information only and is not configurable.

Historical Dynagraph Cards

The Lufkin Well Manager 2.0 also stores historical dynagraph cards. These cards can be accessed by pressing the menu buttons displayed on the main dynagraph screen.

Each option provides saved dynagraph screens for surface, downhole, and a split-screen view of both surface and downhole cards. The time and date of the saved card and relevant status information are displayed on each saved screen.

These screens are discussed in the following paragraphs.

Malfunction Cards

From any of the dynagraph screens, press the **Malfunction** button to access the Malfunction Card screen shown in Figure 13-9.

This screen shows a copy of both the surface and downhole dynagraph cards as they appeared at the time of the malfunction. Figure 13-9 shows an example of this screen.

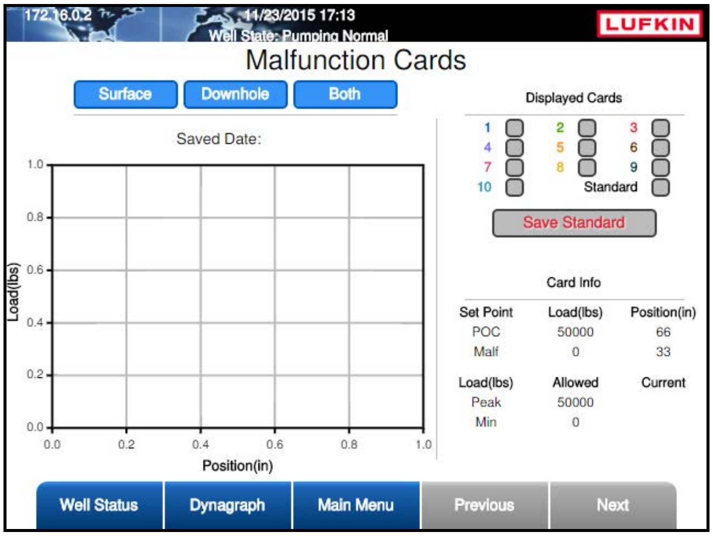

Figure 13-9. Malfunction Card Screen

When a malfunction occurs, the controller takes the data obtained during the malfunction and stores it in the malfunction card buffer. A timestamped copy of the dynagraph card is displayed along with the cause of the malfunction and relevant status data. The last ten malfunctions are stored.

No card is stored after a NO RPM or a NO Crank malfunction occurred because, due to the nature of these malfunctions, any card data that is available cannot be guaranteed to be accurate. These malfunctions are stored in the buffer with a malfunction time and cause.

There are three options for viewing the stored malfunction cards:

- **Surface**: This button displays the stored surface cards.
- **Downhole**: This button displays the stored downhole cards.
- **Both**: This button displays a combined view of the stored surface and downhole cards.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

The stored malfunction cards can be displayed one at a time or overlaid on top of one another. Use the arrow keys to highlight the check box for the desired stored card or cards to display and then press <**ENTER**>.

Press the **Save Standard** button to save the card displayed as the standard card.

Note: Only one card can be saved as a standard card.

To view the standard card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

Press <**ESC**> to return to the main Dynagraph screen.

Stored Cards

From any of the dynagraph screens, press the **Stored Cards** button to access the Stored Cards screen. Figure 13-10 shows an example of a stored surface card.

Figure 13-10. Stored Cards Screen

This screen displays the most-recent five strokes. If the controller is in a pumping state, the buffer is updated at the bottom of each stroke by replacing the oldest card with the latest completed stroke. If the controller is in a downtime or malfunction condition, the stored cards will be duplicates of the Group 1 shutdown cards.

There are three options for viewing the stored cards:

- **Surface**: This button displays the stored surface cards. The Surface card view is displayed by default as shown in Figure 13-10 above.
- **Downhole**: This button displays the stored downhole cards.
- **Both**: This button displays a combined view of the stored surface and downhole cards.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

The stored cards can be displayed one at a time or overlaid on top of one another. Use the arrow keys to highlight the check box for the desired stored card or cards to display and then press <**ENTER**>.

Press the **Save Standard** button to save the card displayed as the standard card.

Note: Only one card can be saved as a standard card.

To view the standard card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

The stored downhole card screen provides the option of analyzing the stored card for troubleshooting purposes. (See Figure 13-11 below.) To start the analysis, use the arrow keys to highlight the **Analyze DHC** button and then press <**ENTER**>. The controller then compares the stored card against a database of stored cards and displays the results on the screen.

Figure 13-11. Stored Cards Screen – Downhole Card

Press <**ESC**> to return to the Dynagraph menu screen.

Pump Up Cards

From any of the dynagraph screens, press the **Pump Up Card** button to access the Pump Up Card screen. Figure 13-12 shows an example of a stored pump up card.

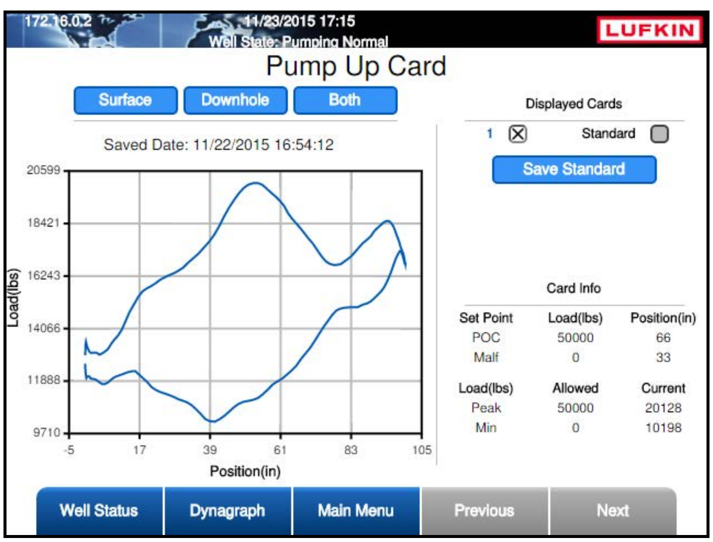

Figure 13-12. Pump Up Card Screen

The Pump Up card is a single card saved at the last transition from Minimum Pump Strokes to Pumping. This card is updated each time the controller goes through a stop/start cycle.

There are three options for viewing the pump up cards:

- **Surface**: This button displays the stored surface card.
- **Downhole**: This button displays the stored downhole card.
- **Both**: This button displays a combined view of the stored surface and downhole cards.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

The saved pump up card can be displayed by itself or overlaid on top of a saved standard pump up card described below. Use the arrow keys to highlight the check box for the pump up card to display and then press <**ENTER**>.

Press the **Save Standard** button to save the card displayed as the standard card.

Note: Only one card can be saved as a standard card.

To view the standard card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

Press <**ESC**> to return to the Dynagraph menu screen.

Start Cards

From any of the dynagraph screens, press the **Start Card** button to access the Start Card screen. Figure 13-13 shows an example of a typical start card.

Figure 13-13. Start Card

This is a single dynagraph card saved by the controller as early in the pumping cycle as possible. This dynagraph represents the start of minimum pump strokes as opposed to the Pump Up card that is saved at the end of Minimum Pump Strokes.

There are three options for viewing the startup cards:

- **Surface**: This button displays the stored surface startup card.
- **Downhole**: This button displays the stored downhole startup card.
- **Both**: This button displays a combined view of the stored surface and downhole startup cards.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

The saved start card can be displayed by itself or overlaid on top of a saved standard start card described below. Use the arrow keys to highlight the check box for the start card to display and then press <**ENTER**>.

Press the **Save Standard** button to save the card displayed as the standard start card.

Note: Only one card can be saved as a standard start card.

To view the standard start card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

Press <**ESC**> to return to the Dynagraph menu screen.

Shutdown Cards

From any of the dynagraph screens, press the **Shut Down Cards** button to access the Shut Down Cards screens. Figure 13-14 shows an example of a typical shutdown card screen.

Figure 13-14. Shut Down Card

This option displays the last five strokes leading up to the last two shutdown events. Shutdown cards are saved when the pump is shut down for any reason, including operator action using the keypad. Shutdown cards may therefore not always indicate a “pumped off” condition.

There are three options for viewing the shutdown cards:

- **Surface**: This button displays the surface shutdown card.
- **Downhole**: This button displays the downhole shutdown card.
- **Both**: This button displays a combined view of the surface and downhole shutdown cards.

Use the arrow keys to highlight the desired display option and then press <**ENTER**>.

Two groups of saved cards are available for viewing:

- Group 1 represents the most recent shutdown.
- Group 2 represents the shutdown prior to the most recent.

Use the arrow keys to highlight the desired group button and then press <**ENTER**>.

The shutdown cards can be displayed one at a time or overlaid on top of one another. Use the arrow keys to highlight the check box for the desired shutdown card or cards to display and then press <**ENTER**>.

Press the **Save Standard** button to save the card displayed as the standard card.

Note: Only one card can be saved as a standard card.

To view the standard card, use the arrow keys to highlight the **Standard** check box and then press <**ENTER**>.

Press <**ESC**> to return to the Dynagraph menu screen.

Section 14: Troubleshooting

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Section Overview

This section provides information to help in troubleshooting malfunctions or downtime states.

WARNING: Technicians **MUST** use proper arc flash PPE and measuring equipment rated for the energy present in the system when working around an energized VSD controller. Failure to heed this warning can result in severe injury or death.

WARNING: The VSD inverter contains DC bus capacitors that retain charge after the unit power has been turned off. If troubleshooting requires the user to access the main compartment, wait at least 20 minutes for the DC bus voltage to discharge to a safe level before opening the enclosure door.

WARNING: All electrical equipment covers MUST be in place before turning on the power to the unit.

HOL Switch

The HOL switch (also known as the HOA switch) on the front of the VSD enclosure controls the basic operation modes of the VSD controller. It is important to check the position of the HOL switch when troubleshooting problems.

Figure 14-1. HOL Switch

The three positions of the HOL switch are described below:

- **HAND**: The HAND position serves to bypass the LWM 2.0 controller by applying a run command directly to the VSD. The VSD then runs the unit at a fixed speed regardless of any existing violation conditions. In this mode, the LWM 2.0 controller can monitor pumping operation, but it cannot stop the unit even if a violation condition is present. The user must manually turn the HOL switch to the OFF position to stop the unit.
- **OFF**: The OFF position shuts off the unit. Run and start signals are not applied to the VSD nor LWM 2.0 controller.

Note: When the HOL switch is in the **OFF** or **HAND** positions, remote users using SCADA or similar interfaces cannot start, stop, or change the speed of the unit. They can only monitor parameter values and send new configurations.

- **LWM (Auto)**: The LWM (Auto) position enables the LWM 2.0 controller to control the speed, start and stop the unit, and react to violation conditions. Remote users can monitor and control the system via SCADA or similar remote control systems.

WARNING: When the HOL switch is in the **LWM (Auto)** position, the unit can start and stop at any time. If the Start Alert feature is not enabled or an audible start alert device is not connected, there will be no warning when the unit starts or stops.

WARNING: All electrical equipment covers MUST be back in place before starting the pumping system.

Well States

The present well state in many cases will be the first indicator that a problem exists with the LWM 2.0 system. The well state can point you to the part of the system that should be checked.

The following table lists the problem well states and the possible sources for problems.

Problem Well States and Possible Solutions

Well State	Possible Solution
Unable to Run Unable to Stop	Check for problem with the LWM 2.0 controller output, the motor starter panel, or the HOL switch position.
Downtime Bad Load or Pumping Bad Load Downtime Minimum Load or Malfunction Minimum Load Downtime Peak Load or Malfunction Peak Load	Check load cell and load cable.
Downtime Bad Position or Pumping Bad Position Downtime No RPM or Malfunction No RPM Downtime No Crank or Malfunction No Crank	Check for problem with position input.
Loss of Configuration Load Not Calibrated	Need to complete or restore parameter programming.

Refer to the section titled “Well States” on page 15-1 for more information on well states and the situations in which they occur.

Load/Position Data and Dynagraphs

The Last 400 Loads historical screen or the Shutdown Event Log screen may give insight into a Bad Load well state. If the 400 Load plot is flat line at either full scale or zero, a loose connection in the load cell cable could be the problem. If the Last 400 Load Plot or the shutdown cards record an isolated load “spike,” an intermittent conductor in the load cell cable is probably the cause.

Setpoint Violations and Malfunctions

The LWM 2.0 controller is programmed with a series of setpoints that determine how the controller reacts to situations that occur during pumping operation.

The following is a list of setpoint violations that can occur:

- **Pumpoff Setpoint**: Used for surface card application.
- **Pump Fillage Setpoint**: Used for downhole card application. If the calculated downhole pump card fillage is equal to or less than this value for the number of allowed strokes, the pumping unit is stopped for a downtime cycle.
- **Peak Load**: The maximum allowed value for load input. If the load exceeds this limit, the controller instantly shuts down the pumping unit with no consecutive stroke delay. Units are in pounds. The default value will be the full scale of the programmed load end device.
- **Minimum Load**: The lowest allowed value for load input. If the load falls below this value, the controller instantly shuts down the pumping unit with no consecutive stroke delay. The default value is zero.
- **No RPM**: This is a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for No RPM violations.
- **No Crank**: This setpoint specifies the number of motor revolutions that the controller should wait before it detects the first crank switch input. If a crank switch input is not detected within this number of motor revolutions, the controller declares a No Crank alarm and stops the pumping unit. If the unit is pumping extremely slow and it causes this reference revolution value to be near 300, you may need to program a higher value than the default of 300 revolutions.
- **Low Motor RPM**: Like the No RPM setpoint, this is also a time delay setpoint, measured in seconds. It is designed to allow the pumping unit time to accelerate up to operating speed. When the unit starts up, the controller waits a predefined number of seconds before checking for Low Motor RPM violations.
- **Peak Torque**: The maximum allowed torque value in thousands of inch-pounds. If the controller calculates a torque value greater than this limit at the completion of a stroke, the pumping unit shuts down early in the next upstroke.
- **Malfunction Setpoint**: States the number of consecutive strokes that the surface malfunction setpoint has been violated. This feature shuts down the well if surface load on the upstroke falls below the malfunction setpoint for the programmed number of consecutive strokes.
- **Low Fluid Load**: The controller analyzes the realtime downhole dynagraph and uses this data to calculate fluid load for each pump stroke. If the fluid load drops below this low limit, the pumping unit is stopped for a downtime cycle early in the next upstroke.

- **Motor Power**: This setpoint defines the minimum amount of motor power needed to keep the pumping system running. When the amount drops below this value, the controller shuts down the pumping unit.
- **Belt Slippage**: When in the Pumping Normal mode well state, the controller counts the Motor Rev/Stroke for each stroke. At the end of each stroke, the count is compared to the Reference Rev number programmed above. If the current Motor Rev/Stroke count is greater than the Reference Rev by greater than this Belt Slippage percentage, the controller sets an alarm flag to indicate possible belt slippage. No other control action is taken. The default value is 5%.
- **Peak PRHP**: This is the value at which the controller will set an alert flag to advise the operator that a paraffin treatment may be required. This value is a high limit.

These can be viewed on the Violation Status Data screen shown in Figure 14-2.

Figure 14-2. Violation Status Screen

To reset these malfunctions and restart the controller, press the **Reset Malfunction** button on the Main Menu screen.

System Grounding

WARNING: Make sure this VSD has been properly grounded by a qualified electrical technician. Improper grounding can result in severe injury or death.

Use the following guidelines when checking system grounding:

- Make sure the resistance of all ground connections to the local point meets the wiring standards observed at the site.
- Make sure all ground connections are torqued to specification.

Inputs to the LWM 2.0 Controller

Information is provided for troubleshooting the following input problems:

- Load signals
- Load cells and cables
- Analog and digital position signals
- Keypad

These are discussed in the following paragraphs.

Load Signal Input

The load input signal should be a smoothly varying voltage signal. Signal magnitude should increase in the early part of the upstroke, and decrease in the early part of the downstroke. An erratic load signal generally indicates a load signal cable problem. The voltage levels you should check are as follows:

- **Excitation Voltage**: The excitation voltage must read +5.0VDC. If the 5.0VDC excitation is not present, either the voltage regulator on the analog input board has failed or an external short is pulling down the voltage level. To check for an external short, disconnect the load cell cable leads and check the excitation voltage again.
- **Signal Voltage**: The differential load signal is connected to terminals 2 and 3 on Terminal Block 1 (TB1). Terminal 2 should be a few MVDC positive with respect to terminal 3. The magnitude of the signal depends on the type of load device used. These types and their outputs are discussed below.
  - **Polished rod load cell output** is 2 mVDC/Volt of excitation at full rated load of either 30,000 pounds or 50,000 pounds. Therefore, the signal voltage will be somewhere between 0 and 10 mVDC.
  - **Beam-mounted load transducer output** should swing through approximately a 4 millivolt range as the pumping unit goes through a pump cycle. The center point of that swing varies from installation to installation, but typically falls between -10 MV and +20 MV. The mid-point of the load signal should never exceed +100 MV. Exact numbers are not important, but a swing of less than 2 MV usually indicates a problem with either the beam transducer or the mounting welds. If the high point of the signal is above 20 MV, it will be necessary to change the gain setting for the load transducer from the default value of 64 to a lower setting according to the table below.

Load Transducer Gain Settings

Highest Signal Level	Gain Setting
<20 MV	64
>19MV but <75 MV	32
>74 MV	1 or 2

Load Cell and Cable

The cable to the load cell can frequently be the cause of load input problems. Some simple checks using an ohmmeter can help isolate a problem.

1. Disconnect the wiring at the LWM 2.0 controller before taking any readings.
2. Leave the connection in place at the load device end.
3. From the LWM 2.0 controller end of the cable, measure the resistance between wire color pairs as shown below.

Ohmmeter readings depend on the load cell type in use. These types are discussed below:

- **Beam mounted transducer**
  - Red to Black: 350 ±5
  - Green to White: 350 ±5
  - Red to Green, Red to White, Black to Green, and Black to White: These should all read 262 ±5.
  - Each wire to earth ground: Ohmmeter on the highest scale; open circuit or infinite resistance
- **Polished Rod Load Cell**
  - Red to Black: 693 to 770
  - Green to White: 693 to 707

For both types of load devices, each wire to earth ground should read greater than 10 M.

Note: It is best to make these measurements with the pumping unit in operation, since cable problems may be intermittent and show up at only a certain point in the stroke as the cable flexes.

If the ohmmeter readings indicate a problem, move to the load device itself and repeat the ohmmeter checks right on the input connector to the device. This second set of checks will help you decide if the problem is in the cable or in the device.

Digital Position Signal Inputs

The digital position input is actually two discrete inputs from the Hall-Effect transducers. The Hall-Effect inputs are connected to terminal strip TB1 on the controller module. The controller module has a voltage regulator that provides excitation voltage for the Hall-Effect transducers. Voltage levels are as follows:

- **Excitation Voltage**: Terminal 19 and 22 of terminal strip TB1 must measure +5.0 VDC. If the excitation voltage is not correct, either the voltage regulator in the controller module has failed, or an external short exists in the Hall-Effect cables. To check for an external short, disconnect the Hall-Effect cable leads and check the excitation voltage again.
- **Signal Voltage**: The RPM signal on terminal 20 and the CSW signal on terminal 23 of TB1 are pulled up to the module +5 VDC reference voltage through a 150-ohm resistor. Therefore, the voltage level on these terminals should be at about +4 VDC when the Hall-Effect is not sensing a magnetic field or the leads are disconnected. When the Hall-Effect transducer does sense the presence of the magnet, the input terminal will be pulled down to about 0.2 VDC and the LED should illuminate. The Hall-Effect transducers are polarity-sensitive. If the wrong side of the crank arm magnet is stuck to the crank arm, the Hall-Effect transducer will not sense the magnet. The side of the flat magnet that is attracted to the motor RPM magnet is the side that should be stuck to the crank arm.

Diagnostics

The LWM 2.0 RPC has diagnostic tools available for troubleshooting issues in the controller. From the first System menu screen, press or click the **Diagnostics** button to display the Diagnostics menu screen shown in Figure 14-3.

Figure 14-3. Diagnostics Menu Screen

Refer to “Diagnostics” on page 9-18 for details on using these diagnostic tools.

Outputs from the LWM 2.0 Controller

The digital outputs of the LWM 2.0 controller are semiconductor switches that can drive 500mA DC resistive loads or 100mADC inductive loads per output. A built-in voltage clamp is included on the outputs for inductive transient protection. The maximum source voltage rating is 16VDC.

An interposing relay is required for any output that is connected to switch a high voltage AC control circuit. These applications include a motor starter circuit, start alarm light or klaxon, etc. Interposing relays can be solid-state or electro-mechanical. Solid-state devices that are compatible with DMOS transistors can be directly connected to the digital outputs. When using electro-mechanical relays, it is recommended that a surge suppression diode be connected across the relay coil to suppress the inductive kick of the relay coil as the relay is de-energized.

Typically, the nominal +12VDC supply (13.8 VDC actual) is used as the source voltage for the interposing relay. The positive terminal of the relay would be wired to one of the +12VDC terminals provided on the upper left corner of the LWM 2.0 controller back panel. The negative terminal of the interposing relay is wired to the appropriate digital output terminal on terminal strip TB1 or TB2.

When the LWM 2.0 controller turns off an output, the voltage level at the associated terminal will be pulled up to about 11VDC. When the controller turns on an output, the voltage level at that terminal will be pulled down to less than 1VDC.

Section 15: Well States

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Section Overview

The LWM 2.0 controller will be in only one of a number of well states at any given time. The current well state is displayed on the top line of every screen.

A well state can indicate a phase of normal operation, or it may alert the user to a problem with the LWM 2.0 controller's input devices or the pumping equipment.

Types of Well States

There are three types of well states. These types are discussed below.

Well States Involved in Downtime

A well state that includes the word Downtime (or the acronym DT) in a well state, with two exceptions, tells the user that the controller will automatically start the pumping unit when the programmed downtime elapses. The two exceptions to this general rule are:

- Downtime Global Off Command well state – When the controller receives a Global Off command from a connected SCADA system, it keeps the pumping unit shut down until told to do otherwise.
- Downtime Peak Energy Management well state – The controller keeps the pumping unit in a downtime state for the entire period programmed for Peak Energy Management.

Well States Involved in Malfunctions

The word Malfunction (Malf) in a well state means that the controller detected a malfunction with equipment and that an operator must take action to return the unit to a pumping condition.

Well States Not Observed

Some well states may not be observed on the local interface because they are transient well states having a very short duration. For example the Stopped well state quickly changes to one of the downtime or malfunction states to give the user more complete information about why the unit stopped. Other well states will typically be observed only through host computer software, since an onsite operator will be using other local interface screens such as Load Calibration.

Well State Descriptions

The well states that can be displayed are described in the following tables.

Normal Well States While Pumping

Well State	Definition
Starting Unit	Controller has pulled digital output low to start the pumping unit and is in the process of checking that the unit actually started. Checks of position input, then load input are performed to make that determination.
Min Pump Strokes	Controller will pump for the programmed number of strokes with no analysis of dynagraph data.
Pumping-Normal Mode	Controller is performing all enabled functions.
Pumping-Host Mode	Controller has been user-programmed to operate in Host Operation mode and is currently programmed to run the pumping unit.
Pumping-Timed Mode	Controller has been user-programmed to operate in the Timed Operation mode.
BS Calibration	The operator is presently performing a bottom of stroke adjustment on the crank arm Hall-Effect transducer.

Normal Well States While Not Pumping

Well State	Definition
Initializing	Well state during boot-up period when power is first turned on or the Reset button has been pushed.
DT/Power-On Delay	Initial well state following Initializing. The controller waits the programmed number of seconds before starting the pumping unit.
Starting Alert	Digital Output 3 is held low for the programmed number of seconds to sound an optional audible start alert device.
Stopping Unit	The controller has made a decision to stop the pumping unit. In this well state, load and position inputs are checked until they become static indicating that the pumping unit has actually stopped.
Stopped	A transient condition that users are not likely to see.
DT/Pump Off	The controller detected a pumped off condition and was successfully able to stop the pumping unit.
DT/Malf Setpt	The Malfunction setpoint in the surface dynagraph has been violated and the controller has successfully stopped the pumping unit. controller will start the pumping unit after the programmed downtime elapses. If the Malf setpoint violation was due to a transient wellbore condition, the consecutive malfunction counter will be cleared, and normal operation will continue. If the Malf setpoint violation occurs repeatedly for the number of consecutive allowed violations, the controller will arrive at the Malf/Setpoint well state.

Normal Well States While Not Pumping (Continued)

Well State	Definition
DT/Peak Load	Peak Load Allowed Limit in the surface dynagraph has been violated and the controller has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the peak load violation was due to a transient wellbore condition, the consecutive malfunction counter will be cleared, and normal operation will continue. If the peak load violation occurs repeatedly for the number of consecutive allowed violations, the controller will arrive at the Malf/Peak Load well state.
DT/Min Load	Min. Load Allowed Limit in the surface dynagraph has been violated and the controller has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the Min. Load violation was due to a transient wellbore condition, the consecutive malfunction counter will be cleared, and normal operation will continue. If the Min. Load violation occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/Minimum Load well state.
DT/HOA in Off	This well state does not indicate any trouble with controller system. The operator may want to check why the H-O-A switch has been placed in the Off position since the well is probably not pumping. Only if digital inputs have been wired to H-O-A switch contacts and programmed for Hand and Auto use.
DT/Host Mode	Indicates that controller has been deliberately programmed to keep the pumping unit shut down until further operator action.
DT/Timed Mode	Indicates that controller has been deliberately programmed to cycle the pumping unit in the Timed Operation mode. The pumping unit will start after the programmed Set Off Time elapses.
DT/Low RPM	Low RPM Allowed Limit has been violated and the controller has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the Low RPM violation was due to a transient well bore condition, the consecutive malfunction counter will be cleared and normal operation will continue. If the Low RPM violation occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/Low RPM well state.
DT/Global Off CMD	An all-call Global Off command has been received from the host software to stop the pumping unit. The controller will remain in the downtime mode until an operator programs otherwise.
DT/Valves Measure	A local user has programmed the controller to record and/or analyze valve and counterbalance effect loads. Typically observed only via host software, since an onsite user is using other screens to complete the valve check routine.
DT/Low Fluid Load	The Fluid Load Allowed Limit has been violated and the controller has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the low fluid load violation was due to a transient well bore condition, the consecutive malfunction counter will be cleared, and normal operation will continue. If the low fluid load violation occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/Low Fluid Load well state.
DT/Peak Torque	Peak Torque Allowed Limit has been violated and the controller has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the Peak Torque violation was due to a transient well bore condition, the consecutive malfunction counter will be cleared, and normal operation will continue. If the Peak Torque violation occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/Peak Torque well state.
DT/Low Power	The controller has stopped the pumping unit because the present average downstroke pseudo motor power dropped below the set reference power. The operator should look for a potential load signal input failure.

Normal Well States While Not Pumping (Continued)

Well State	Definition
DT/No RPM Signal	The controller lost input pulses from the motor RPM Hall-Effect transducer and has successfully stopped the pumping unit. The controller will start the pumping unit after the programmed downtime elapses. If the loss of RPM pulses was due to a transient condition, such as the H-O-A switch being momentarily turned off, the consecutive malfunction counter will be cleared, and normal operation will continue. If the loss of RPM pulses occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/No RPM Signal well state.
DT/No Crank Sig	The controller lost input pulses from the crank arm Hall-Effect transducer and has successfully stopped the pumping unit. The controller will start the pumping unit after programmed downtime elapses. If the loss of crank switch pulses was due to a transient condition, such as the H-O-A switch being momentarily turned off, the consecutive malfunction counter will be cleared, and normal operation will continue. If the loss of crank switch pulses occurs repeatedly for the number of Consecutive Allowed violations, the controller will arrive at Malf/No Crank Signal well state.
DT/Peak Energy	Peak Energy management function has been enabled and the controller has the pumping unit shut down during the programmed Peak Energy Management Period. The controller will return to the programmed operating and control mode after the energy management period.
DT/Operator Stop	The controller has stopped the pumping unit in response to an operator command. Operator command may be via the local keypad or from host software via the data telemetry link. The pumping unit will automatically restart after the programmed downtime elapses.
DT/PIP Override	The Pump Intake Override (PIP) feature has been enabled and the calculated PIP has fallen below the programmed PIP Setpoint for the consecutive number of strokes allowed. The controller has successfully stopped the pumping unit and will restart after the programmed downtime elapses.
DT/Prod Cutoff	The Lufkin Well Test (LWT) Cutoff Control feature has been enable and the calculated fluid production since the last Gauge Off time has reached the programmed allowed daily production. The controller has successfully stopped the pumping unit. The unit will remain down until the next Gauge Off time at which time it will automatically re-start.
Line loading State	The Line Loading feature of the controller has been enabled and the feature is active. Normal pump off control is overridden.

Well States Indicating Equipment Problem or Operator Override

Well State	Definition
Loss of Programming	Controller has lost the programmed parameters and has therefore returned to default conditions.
Pumping/HOA in Hand	Well State only when digital inputs are wired to contacts on the H-O-A switch and programmed for Hand and Auto use. Two digital inputs are required. This state indicates that the H-O-A switch has been set to a position to override well control by controller.
Unable to Run	Controller is trying to start the pumping unit but does not see dynamic load and position signals to confirm that the unit is actually pumping. Conditions such as drive belts thrown off, motor overloads tripped, or operator selection of H-O-A position would lead to this well state.

Well States Indicating Equipment Problem or Operator Override (Continued)

Well State	Definition
Pumping/Bad Load	Controller has detected a problem with the load input signal. In the event of a load signal input problem, the controller reverts to a secondary control method of internal percent timer. The well is cycled off/on using the programmed downtime and the percent run for the previous 24 hours.
Pumping/Bad Position	With analog position input only, the controller has detected a problem with the position input. In the event of an analog position signal input problem, the controller reverts to a secondary control method of internal percent timer. The well is cycled off/on using the programmed downtime and the percent run for the previous 24 hours.
Unable to Stop	The check during the Stopping Unit well state continued to see dynamic load or position after the maximum allowed Stopping Unit time of 3 minutes and 30 seconds. The operator should check the position of the H-O-A switch.
DT/Bad Pos Signal	The controller has detected a problem with the position input and is cycling the pumping unit base on historical run time and programmed downtime; i.e., an internal percent timer type of control.
DT/Bad Load Signal	Only with analog position input, the controller has detected a problem with the load input and is cycling the pumping unit base on historical run time and programmed downtime; i.e., an internal percent timer type of control.
Malf/Peak Load	Refer to DT/Peak Load above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Min Load	Refer to DT/Min Load above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Setpoint	Refer to DT/Malf Setpoint above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Low RPM	Refer to DT/Low RPM above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/No RPM	Refer to DT/No RPM Signal above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/No Crank	Refer to DT/No Crank Sig above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Peak Torque	Refer to DT/Peak Torque above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Low Fluid Load	Refer to DT/Low Fluid Load above. The pumping unit will stay down until a reset malfunctions is done by the operator.
Malf/Lockout	The controller’s lockout feature has been enabled and the primary power has been off for longer than the programmed time limit. Operator intervention is required to return to normal operation.

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Part # 1000306605
Document # 2000301878, Rev. E

January 2022