FLOWCO

APEX Multi-Well Controller

VERSION: 1.18

OPERATORS MANUAL

The APEX Multi-Well Controller was developed to optimize oil and gas production through more than 30 years of experience and customer feedback. Flowco is focused on serving oil & gas operators through plunger lift and gas lift innovative solutions. Apex is built to optimize production.

The Apex makes significant strides above and beyond existing artificial lift controllers by offering combined and optimized control of Plunger Lift, Gas-Assisted Plunger Lift, and Continuous Gas Lift technologies, including the ability to control up to 16 discrete artificial lift wells from a single master controller. The data from these wells can be analyzed on Flowco's LiftSight SCADA platform using a single cellular modem for maximized value and ROI.

Contents

1 Certifications and Protections

1.1 Safety

The Apex system is designed for use in Hazardous Locations, specifically Class I, Division 2 environments. It is designed as Nonincendive Electrical Equipment in compliance with the following standards:

- UL 121201:2017Ed.9
- CSA C22.2#213:2017Ed.3
- UL 61010-1:2012 Ed.3
- CSA C22.2#61010-1-12:2012 Ed.3

The Apex system should not be relied upon for use in any life safety system. The use of external safety monitoring and emergency shutdown systems is strongly encouraged.

1.2 Installation, Operating and Safety Instructions

Instructions for installation and use of this product are provided by the manufacturer. The equipment shall be installed within a permanently mounted tool secured metallic enclosure or non-metallic enclosure with a flame rating of V-1 or better. The enclosure shall have a minimum ingress protection Type 3 or IP54 rating, suitable for indoor/outdoor use. Connectors and insulation materials on enclosure shall have a flammability rating of V-2 or better.

1.3 Patents and Copyright

The Gas-Assisted Plunger Lift Algorithms within the Flowco Apex system are protected by United States Patent 11,448,049 B2.

1.4 Markings

The following safety markings are present on each Apex keypad and have been reproduced here for convenient reference:

Flowco Production Solutions
APEX Multi-Well Controller
AUT-APEX-SW
Serial Number: <SERIAL>
Manufacture Date: <DATE>

CLASS I DIVISION 2
GAS GROUPS C & D
T4

-40 °C ≤ T_a ≤ 85 °C

Solar Input:
PV Panel V_{max}: DC 18 V
PV Panel I_{max}: 2 A
DC Power Input:
V_{max}: DC 30 V
P_{max}: 100 W

Certified to
UL 121201
CSA STD C22.2 # 213

XXXXXXX

WARNING – EXPLOSION HAZARD. DO NOT DISCONNECT WHILE THE CIRCUIT IS LIVE OR UNLESS THE AREA IS FREE OF IGNITIBLE CONCENTRATIONS.

AVERTISSEMENT – RISQUE D'EXPLOSION. NE PAS DÉBRANCHER PENDANT QUE LE CIRCUIT EST SOUS TENSION OU À MOINS QUE L'EMPLACEMENT NE SOIT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

2. Introduction

Disclaimer: Flowco advises that installers, technicians, and maintainers read this manual in its entirety and perform several practice runs prior to attempting a field installation, especially one that involves Multi-Well or integration with complex Modbus RTU systems.

Plunger operation can be set to 3 main modes: Disabled, Timer, and Plunger operation.

2.2 Disabled

In this mode the Controller will not operate the control valves. The user can configure control parameters and then enable the desired control modes. Flowco recommends placing the controller into the Disabled control mode prior to modifying critical parameters.

2.3 Timer

In this mode the controller operates as a simple plunger time only controller, no auto-adjust parameters are enabled in this mode. Most parameters are ignored in timer mode. The operation in timer mode is centered around the well state as follows:

Closed –

"Base Duration" is the amount of time the system will stay in the closed state. In full plunger operation this base time may be auto adjusted, but in timer mode it is only user set.

Open –

"No Arrival" time is the maximum amount of time the system will stay in the open state before moving to either closed or recovery state.

"Fast Arrival" and "Slow Arrival" are the two thresholds for categorizing an arrival as either fast or slow. No auto-adjust is performed on the time of plunger arrival, but the arrival will be logged as fast or slow depending on the time setting in these fields.

Afterflow – "Base Duration" is the amount of time the system will stay in the afterflow state following plunger arrival.

Recovery –

"Enabled" allows the recovery state to be part of the plunger cycle. If disabled, closed state will be entered in place of recovery state.

"Recovery Time" is the amount of time the system will stay in the recovery state.

"No Arrivals Before Recovery" is the number of failed arrivals in a row the system will count before recovery states will be used on subsequent failed arrivals. This count value accumulates only on a failed plunger and is reset to zero on every successful plunger arrival.

2.4 Plunger

In plunger mode, time of the plunger arrival as well as inputs from pressure sensors affect the operation of the Apex. In the configuration menu, the user has several options which allow complete customization of the system.

2.4.1 Pressure Overrides

Pressure Overrides (when enabled) allow the well to change state upon well pressure being too high or low during operation. No pressure overrides will occur in that well state before the **Min Duration** has elapsed. The user should note that the **Base Pressure** setting can be auto adjusted by the system if enabled in controls via **Plunger Arrival Adjustments.** If the user does not want **Base Pressure** to be adjusted, **Plunger Arrival Adjustments** should be disabled.

There are 4 pressure scenarios that may trigger a pressure override.

- Tubing pressure crosses Tubing Base Pressure.
- Casing pressure crosses Casing Base Pressure.
- Tubing-Line differential pressure crosses TL Base Pressure
- Load Factor (Load Ratio) crosses Load Factor Base Pressure

Whether the override triggers on exceeding the Base Pressure, or falling below the Base Pressure, depends on what state the well is in. A value of zero in any Base Pressure means that pressure override is ignored.

- In the Open State, pressures below the user specified Base Pressure will trigger a move to the closed state.
- In the Closed State, pressures above the user specified Base Pressure will trigger a move to the open state.
- In the Afterflow State, pressures below the user specified Base Pressure will trigger a move to the closed state

Users can set pressure overrides for Emergency Shutdown.

- Tubing Pressure falls below Min Tubing Pressure – user selectable Open /Close
- Tubing Pressure exceeds Max Tubing Pressure – user selectable Open /Close
- Casing Pressure exceeds Max Casing Pressure – user selectable Open /Close

2.4.2 B valve enabled

B Valve (when enabled) controls the injection assist or vent valve. This can aid a well in building pressure and has several operational parameters depending on the well state.

- In the Closed State, the **Assist Time** specifies the amount of time that the B valve will be open prior to open state.
- In the Open State, the **Assist Delay** specifies the amount of time the system will delay before opening the valve. **Assist Time** is the amount of time the valve will stay open.
- In the Afterflow State, **Assist Time** is the amount of time the valve will stay open.

2.4.3 Afterflow on Slow Arrival

Allows the user to select whether the afterflow state will be used if a slow plunger arrives, or if the closed state will be used on slow plunger arrival. This option is also seen on the Open Configuration page in the checkbox Slow Arrival Afterflow.

2.4.4 Plunger Arrival Sensor

When enabled, the system will move to the Afterflow state when a plunger arrival is detected while in the Open state. If disabled, the plunger arrival is still logged, but the full Open time is allowed to expire with no system action taken.

2.4.5 Plunger Arrival Adjustments

Adjustments to base times and base pressures can be adjusted automatically using the Plunger Arrival Adjustments. All plunger arrivals are categorized as either good arrival, slow arrival, fast arrival, or no arrival.

- When a slow, fast, or no arrival occurs, base durations (and base pressures) are increased or decreased according to their respective input fields.
- Base durations and pressures will be increased up to the **Max Duration or Max Pressure**
- Base durations and pressures will be decreased up to the **Min Duration or Min Pressure**
- Plungers arriving after the **Fast Arrival** time, but before the **Slow Arrival** time are considered good or normal plungers, and no auto-adjust of base durations or base pressures will occur.

2.5 Analog Valve Control

The Apex has two analog valve control outputs for Gas Injection and Sales Throttle Valve control. Several configuration options are available for both outputs. These outputs can be calibrated by field technicians to maximize output accuracy.

2.5.1 Gas Injection Valve Control

When enabled in the Injection Valve Analog Configuration menu, the AO2 port may be used to control a Gas Injection Valve. The Apex will try to keep the flow rate at the Setpoint (MCF) by adjusting the Gas Injection Valve. Users must input the 4mA and 20mA flow rate, as well as a Gain value. When readings from a flow meter are outside of the Deadband for the Delay time, the error is multiplied by the Gain, and adjustments are made to the Gas Injection Valve. Typical Gain values are between 5% and 15%. Injection Flow Rate Sensor is configured in the Sensor Configuration page from the Hardware Configuration Tab.

2.5.2 Gas Assisted Plunger Lift

When enabled, the plunger arrival time will adjust the Setpoint up or down depending on the speed of the arrival. If the plunger arrives at a fast speed, the setpoint is reduced by the Fast Arrival decrement amount. If the plunger is slow or does not arrive, the set point is increased by the Slow/No Arrival increment time. Both increment and decrement are bounded by the Minimum Setpoint and Maximum Setpoint. Skip cycles allow several plunger runs to accumulate before making adjustments. A Skip Cycles of zero will make adjustments on every plunger arrival if necessary.

2.5.3 Sales Throttle Valve

When enabled in the Sales Throttle Valve Configuration menu, the AO1 port may be used to control the Sales Throttle Valve. The Apex will try to keep the flowrate at the Setpoint (MCF) by adjusting the Sales Throttle Valve. Users must input the 4mA and 20mA flow rate, as well as an Initial Open % and Stepping %.

The Sales Throttle Valve will increase the valve opening by the Stepping % until the Setpoint is achieved, or the Control Time expires. When either event occurs, the flow meter readings are monitored and the error between the actual flow and the Setpoint are multiplied by the Gain, if the error is outside of the Deadband for longer than the Delay time.

When Max Time expires, the valve will move to the Valve End State.

2.6 COM Ports and Modbus

The Apex features 5x fully configurable serial communications ports that can be used for Modbus RTU connectivity to other devices. RS-232 and RS-485 are available with no jumper selection or configuration necessary; simply connect cabling to the correct pins on the COM port connector. Each port is configurable for Modbus RTU master or slave mode, as well as typical serial parameters such as baud rate, parity, etc. When in Modbus slave mode, each COM port has a configurable Modbus slave ID.

The Apex can be accessed by Modbus master devices via read and write holding register function codes (0x03, 0x06, 0x10). 32-bit data points (floating point or large integers) are stored as in the following big-endian format:

- Example: Battery Voltage, registers 8018, 8019
- Value: 10.4813 V
- IEEE-754 32-bit floating-point representation: 0x4127B387
    - Register 8018 = 0x4127
    - Register 8019 = 0xB387

Depending on the system architecture and registry configuration, the master device may have to be configured for word swapping to match the Apex's convention.

When the Apex is configured as a master, it can be configured to request variables from slaves with word swapping, byte swapping, signed/unsigned, etc. on a per-variable basis.

If Multi-Well is employed, the Apex itself can be considered Subwell 1, the first expander is Subwell 2, the next expander is Subwell 3, and so on. Each Subwell has a full Modbus registry and is fully configurable as its own logical well.

The Modbus registry associated with Subwell 1 is accessible at the Modbus Slave ID that each port is configured for. Subwell 2's registry is accessible at the next Slave ID, and so on.

As an example, say that the Apex's COM1 Slave ID is 5 and the system is configured for a 4-well system. The subwells would be accessible at the following addresses:

- Subwell 1: 5
- Subwell 2: 6
- Subwell 3: 7
- Subwell 4: 8

2.7 Downhole gauge communication

The Apex can be configured to communicate with the Flowco Downhole Gauge through the Flowco Surface Transceiver. The surface transceiver connects to the Apex via Modbus over RS-232 or RS-485 and can pull down hole pressure and temperature, as well as vibrational data. Alternatively, if downhole gauge data is available on an onsite SCADA system, this data can be pushed to the Apex. Depending on the configuration of the Apex, the data can be used to optimize gas lift based on down hole pressure or can simply be logged for later analysis.

2.8 Gas Lift Optimization

Beyond traditional fixed-setpoint gas injection, the Apex can perform two types of continuous-flow gas lift optimization based on the availability of ancillary equipment. If real-time bottomhole pressure data is available from a Flowco Down Hole Gauge or similar device, then DHG-based optimization can be used. Otherwise, Flowco critical rate optimization can be performed.

Note that the user must specify an initial injection setpoint for the gas lift algorithms to function.

2.8.1 Down Hole Pressure Optimization

When a Down Hole Gauge is available and the system is configured for Down Hole optimization mode, the system will adjust the gas injection flow rate to achieve the minimum bottomhole pressure and maximize production. Once the minimum has been found, a user-specified over-injection percentage will be applied to ensure long-term well stability. The system will continually monitor for a loss of optimization and again seek minimal bottomhole pressure if this occurs due to changing well conditions or setup.

2.8.2 Critical Rate Optimization

If only wellhead measurements are available, the Apex can calculate the target gas injection flow rate using proprietary Flowco algorithms. Surface variables such as temperature, sales and injection flow rates, specific gravities of the produced gas and water, API gravity of the produced oil, Z-factor, water cut, and tubing and casing dimensions are used to calculate the optimal injection rate.

2.9 Kick-off / Unloading “KUL” Procedure: Gas Lift

The Apex also provides the capability of automating the unloading procedure for gas lift installations. The procedure is accomplished through several stages and consists in gradually opening the injection line valve based on changes in measured injection line flow rate and pressure until a determination has been made that the well has been successfully unloaded.

After unloading, the transition to the chosen gas lift optimization routine (or fixed-setpoint gas injection) is then automatically made. Injection line pressure is monitored throughout the process via the Casing or Tubing Pressure Analog Input Ports or their equivalent modbus registers.

2.10 Multi-well

The Apex can be used to control up to 16 wells, each with unique configurations and settings. In complex instances with on-site SCADA networks or monitoring PLCs, the Apex can control these wells entirely through Modbus interaction with said systems. For smaller or more remote installations, the Apex can be paired with up to 15 Expander devices, where each Expander is placed at a wellhead and connected to the Apex via RS-232, RS-485, or Flowco's transparent RF-485 radios.

Configuration of a multiwell system **requires** the use of the PC application.

2.11 Ethernet Module

The Apex Ethernet module provides Modbus connectivity to the Apex. Both true Modbus TCP and Modbus RTU over TCP are supported. The module translates the TCP messages to RS-485. It can either be wired into one of the 5 COM ports or can be fitted into COM5 and mounted directly to the Apex using the standoffs.

2.12 Apex Expander

The Apex Expander provides additional resources to enable multi well support. The Expander can be used as a local or remote device, and monitors inputs such as pressure sensors and can control valves. The Expander does not provide its own control algorithms and relies on the main Apex to analyze the data and make control decisions.

The Expander can be mounted in local use to the Apex via the expansion connector and the associated standoffs, or can be remotely connected via RS-232, RS-485, or radio module. When used remotely, the Expander can be DIN rail mounted. When mounted directly to the Apex, the Expanders and Apex communicate via Modbus RTU over the SPI protocol, meaning that all Apex COM ports are still available for use with other devices.

The slave ID for the direct expansion port and Expander COM3 is configured using a rotary hex dip switch, supporting Expander addresses of 1-15. The other COM ports are configurable through the Apex via the keypad HMI or PC app.

2.13 Wi-Fi Module

The Wi-Fi module provides wireless connectivity to the Apex for both the PC app and mobile app. The device will broadcast a wireless network SSID of "ApexWIFI". Once the laptop or mobile device is connected to that network, the application can run. The module can directly mount and connect to the Apex using the COM5 port and standoffs, or it can be DIN rail mounted and wired into any COM port on the Apex.

The WiFi module has a hard-coded IP address of 10.0.4.254. It is accessed on TCP port 55555.

2.14 Radio Module RF-485

The radio module is intended to connect the Apex to the Expanders when the Expander is mounted remotely, and a wired connection is not feasible. It can be wired into any of the COM ports on the Expander or Apex via the RS-485 pins. The RF-485 system **requires** a 19200 baud RS-485 connection to the Apex, expanders, and to any other devices that they are connected to.

3. Keypad UI

The Controller KEYPAD is designed for the Operator to move through settings and commands in a MENU format. This is divided into 4 main group menus with the selections as detailed below:

3.2 Status Screen

The status screen will show the most basic and relevant real time information in the system, such as current system mode, pressures, flow rates, system voltage etc. During state changes and other events, informative messages will be displayed on the screen.

Press left or right while on the status screen to change which well is selected in a multiwell system.

3.3 Set Menu

The Set Menu allows the user to change time settings, system overrides, flow rate options and other system features. The Set Menu is entered by hitting the Set key on the keypad. There are 7 sub-menus within the Set Menu. Each sub menu provides settings associated with a specific plunger lift state, as follows:

- Root Set Menu, providing access to:
    - Closed – these settings apply while the sales valve is closed
    - Open – these settings apply while the sales valve is open and awaiting arrival
    - Afterflow – these settings apply following an arrival
    - Recovery – these settings apply in recovery mode if enough no arrivals occur
    - Failsafe – configure absolute maximum pressure limits, fast ESD time limits, etc.
    - Analog Flow Control, including 4-20 mA output calibration
        - AO1 – Configure analog valve 1 control based on sales EFM data or tubing pressure
        - AO2 – Configure analog valve 2 control based on injection EFM data
    - Gas Lift Optimization
        - Critical Rate
        - Downhole

3.4 Data Menu

The Data Menu allows the user to view a variety of information about the well

- Root Data Menu, providing access to:
    - Sensors – view real-time sensor data, including remote modbus sensors
    - Statistics – view system operating statistics, total times, etc.
    - DHG Data – view data from Flowco Down Hole Gauge
    - Arrivals – view counts of total and consecutive classified arrivals
    - Run Times – view the last 15 plunger run times
    - Spring Inspection and Plunger Installation cycle counters

3.5 System Menu

The System menu is used to configure the basic operating characteristics of the Apex

- Root System Menu, providing access to:
    - Control Options
    - Gauge Calibration
        - Configure data acquisition settings for
            - Tubing Pressure
            - Casing Pressure
            - Line Pressure
            - Remote Differential Pressure
            - Sales Flow Rate
            - Injection Flow Rate
            - Down Hole Gauge data
            - Gas Lift data
        - In general, each gauge/sensor can be configured in one of the following modes:
            - Local:
                - acquired from local analog input port (only applicable for Tubing, Casing, and Line pressure transducers)
                    - Configure minimum and maximum points for pressure and voltage
                - OR entered by user (only applicable for some gas lift parameters)
            - Modbus Poll as Master:
                - The Apex or Expander polls a slave device for the data. Configure:
                    - COM port to poll from
                    - Slave ID to poll
                    - Slave register to poll
                    - Slave register type (e.g. float, uint16, etc.)

            - Signed (yes/no)
            - Word swap (yes/no)
            - Byte swap (yes/no)
        - Modbus Receive as Slave:
            - No configuration options on the Apex; all such values can be pushed to the Apex by a master according to the register map.
- Clock
    - View and set the local time and data, including the UTC offset
- Port Configuration
    - Configure COM port settings, including:
        - Modbus Master or Slave
        - Modbus Slave ID
        - Baud Rate
        - Data Bits
        - Stop Bits
        - Parity
    - To change COM port settings, enter the desired configuration, then set the “Commit?” line to “Yes” and press Enter. This will commit the desired settings and activate the COM port in that configuration.
- Diagnostics
    - View firmware and hardware version information
    - Reboot Apex
    - Load default settings for a well
    - Clear log configuration
- Display Sleep
    - To save power, the display can be put into sleep mode. Select “Yes” under “Display Sleep?” to enable sleep mode. Set “Sleep Dly” to the time that the display will remain on after pressing a key.

3.6 Analog Output Calibration

Analog outputs can only be calibrated from the Keypad UI to prevent calibrations from being incorrectly set. Follow these steps to calibrate the analog outputs on the Apex and Expanders:

1. Navigate to Set->Flow Rate Settings->AO1 SALES FLOW or AO2 INJ FLOW/GAPL
2. Enter the “Analog Out 1 Cal” or “Analog Out 2 Cal” menu
3. Ensure that the Analog Output mode jumper is in the 4-20 mA position
4. Connect a multimeter between the AO1 or AO2 output and ground
    a. A precision multimeter such as Fluke 87V, Fluke 787, etc. is required for calibration. Standard multimeters such as the Fluke 115, 117, etc. do not have the precision necessary to calibrate these outputs.
5. Change “Cal Mode” to “Yes”
6. The Apex or Expander will now command a 12 mA (50%) output from the requested port
7. Change the “Measured mA” value to the value displayed on your multimeter and press Enter
8. The multimeter should now display very close to 12.000 mA exactly
9. Change “Cal Mode” to “No” to store the calibration and return to normal operation

4. Licensed Features

Certain features of the Apex require a license key in order to function. License keys may be obtained from Flowco Production Solutions. Licenses can be applied via the HMI or the LiftLink.

The features that are protected by license keys are as follows:

- Multi-well support
    - Without this license, only a single well is supported by the Apex. The Apex will be unable to communicate with subwell expanders.
- Enhanced Gas Lift Optimization
    - Without this license, only basic gas injection is supported. No autonomous optimization of gas lift is supported (including Kickoff / Unloading).

Application of a license key will be covered in the next section.

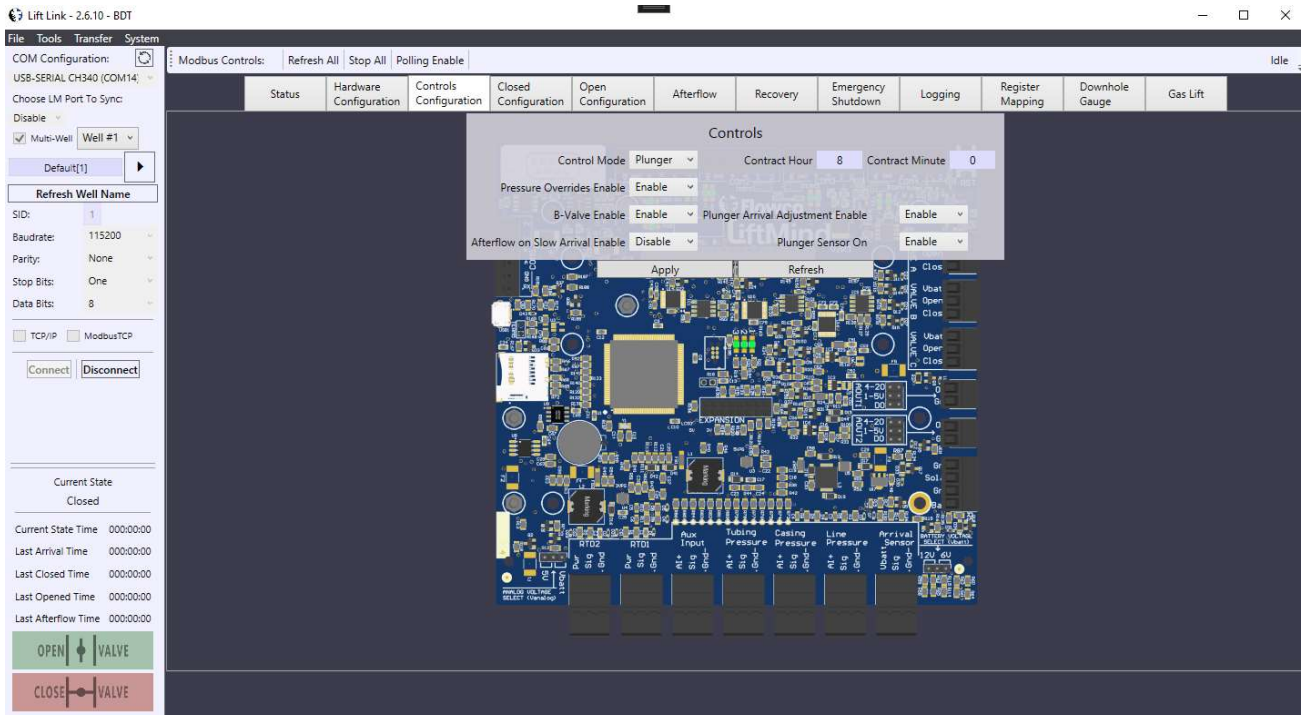
5. PC Application – LiftLink

The LiftLink is an application that runs on Windows PCs enabling rapid configuration, data retrieval, and firmware update capabilities. The Utility is the preferred way to configure an Apex system as it is significantly faster than using the keypad to navigate a 4-line LCD screen. Several features can only be configured using the Utility, such as Multi-Well Configuration, Ethernet, Logging, and Remappable Registers, as these features would be impossible or very tedious to set up directly on the Apex. Once Multiwell has been enabled and configured, subwells can be configured either through the HMI or the Utility.

Throughout this section, the matching names and menus of the Apex Keypad UI settings will be listed in **bold blue text** for easy correlation.

5.2 Overall Layout

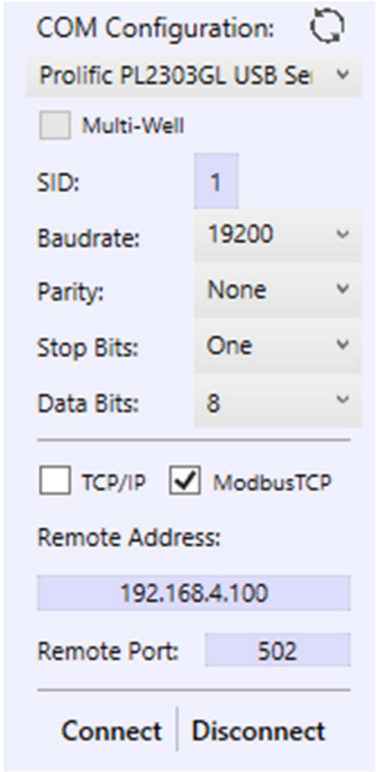
The Utility features a fixed connection and status panel on the left-hand side of the screen that is visible at all times. The main portion of the window contains a number of tabs that offer a variety of configuration options and data displays. Additional options are accessible from the menu bar at the top of the window. The main window can be resized as needed; if the window is reduced below the size required to fit all display elements, scroll bars will appear to allow the user to view the hidden elements.

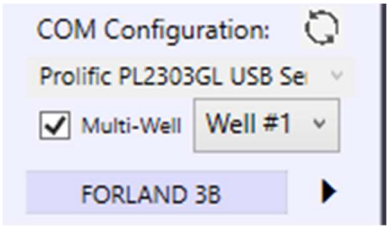


5.3 Connection and Status Panel

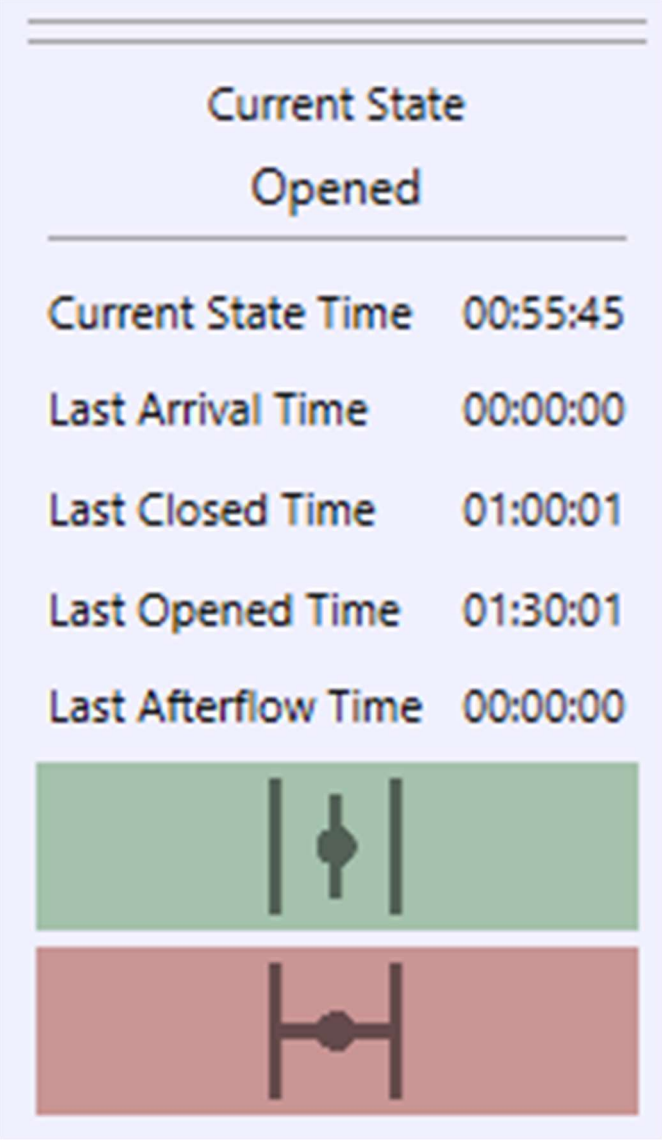
5.2.a COM Configuration

- This panel is used to select the COM port used to communicate to the Apex.
- Click the Refresh button to refresh the list of COM ports available on your PC
- Configure the COM settings to match those on the Apex
    - Default settings are SID 1, 19200 baud, None parity, One stop bit, 8 data bits
- Should you wish to connect to an Apex that is equipped with the optional Ethernet or WiFi module or is connected to another serial to TCP/IP gateway, the Utility supports two methods of remote connection:
    - Modbus RTU over TCP/IP
        - Allows for simple serial tunnelling encapsulating standard Modbus RTU transactions in TCP packets
        - Used with serial to TCP/IP devices; IP address and port will vary
    - Modbus TCP
        - Provides more robust communication conforming to Modbus TCP specification
        - Used with Apex Ethernet or WiFi adapters; IP address may vary
        - The standard port for Modbus TCP is 502
- When connected to a Multi-Well installation, the Multi-Well checkbox will allow you to select which well to configure.
    - The well name is displayed and can be changed by entering a new name and clicking the adjacent arrow.





5.2.b Well State and Open/Close Controls



- The bottom of the Connection and Status panel shows the current well state as well as timers showing the time remaining in the current state as well as the last times spent in each state.
- The Green Open button and Red Close button will open and close the sales valve and start the open or closed periods, respectively.

5.4 Modbus Controls

- The top of the window contains the Modbus Controls panel
  - Refresh All: Reads all values from the Apex
  - Stop All: Stops any current Modbus transaction
  - Polling Enable: When selected, the Utility will continuously poll the Apex for sensor data
- The right-hand side of this panel will display the name of the register that is currently being accessed by the Utility, or “Idle” if no transaction is ongoing

5.5 Utility Tabs

Configuration of setpoints in the Utility is organized much the same as the Keypad UI, with separate sections for settings that apply in Closed, Open, Afterflow, and Recovery. These tabs are shown on the following pages, with descriptions of each configurable option.

The general convention applied throughout these settings is that the **tab** will bring you to settings associated with a particular well state, while the **names of the individual options** describe their functionality. For example, on the Closed tab, the option "Open if TP >= Threshold" indicates that the well will move from the closed to the opened state if that threshold is met; that is, if the tubing pressure rises above that setpoint.

The Utility is arranged into the following tabs, with each configuration tab or window featuring discrete apply and refresh buttons:

a. Status
   - View system parameters such as valve status and pressures

b. Hardware Configuration
   - Configure serial COM ports
   - Configure pressure transducer inputs and remote sensor acquisition settings
   - Configure Sales Throttle and Gas Injection Valve settings

c. Controls Configuration
   - Configure baseline operating parameters for the well

d. Closed Configuration
   - Configure settings that are in effect while the sales valve is closed

e. Open Configuration
   - Configure settings that are in effect while the sales valve is open and the well is awaiting plunger arrival

f. Afterflow Configuration
   - Configure settings that are in effect following plunger arrival

g. Recovery Configuration
   - Configure settings for additional recovery time following successive no arrivals

h. Emergency Shutdown Configuration
   - Configure settings that will cause the well to enter ESD

i. Logging Configuration
   - Configure data logging

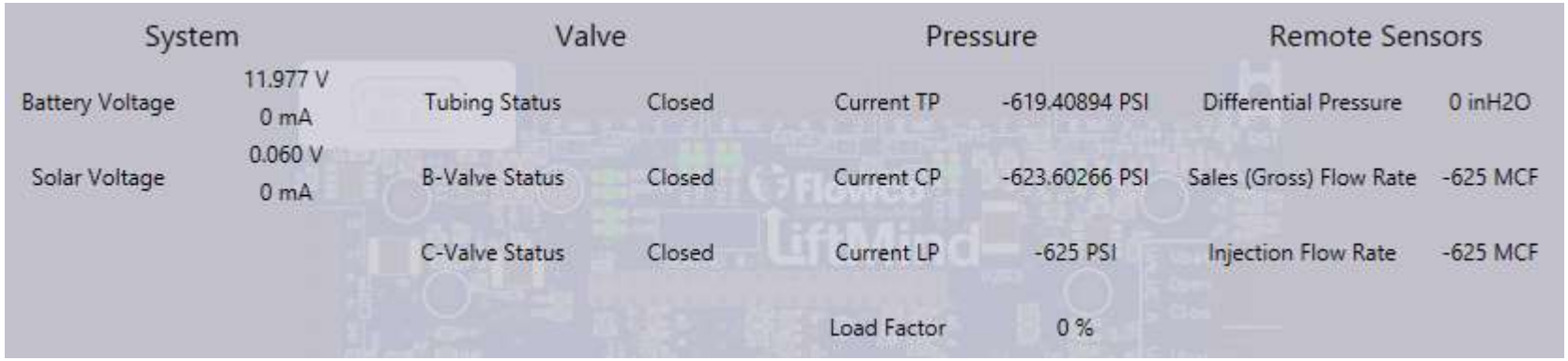
j. Register Mapping Configuration
   - Configure and view generic holding registers

k. Downhole Gauge Data
   - View data retrieved from the Flowco Down Hole gauge

l. Gas Lift Data and Configuration
   - View data relevant to gas lift
   - Configure gas lift optimization

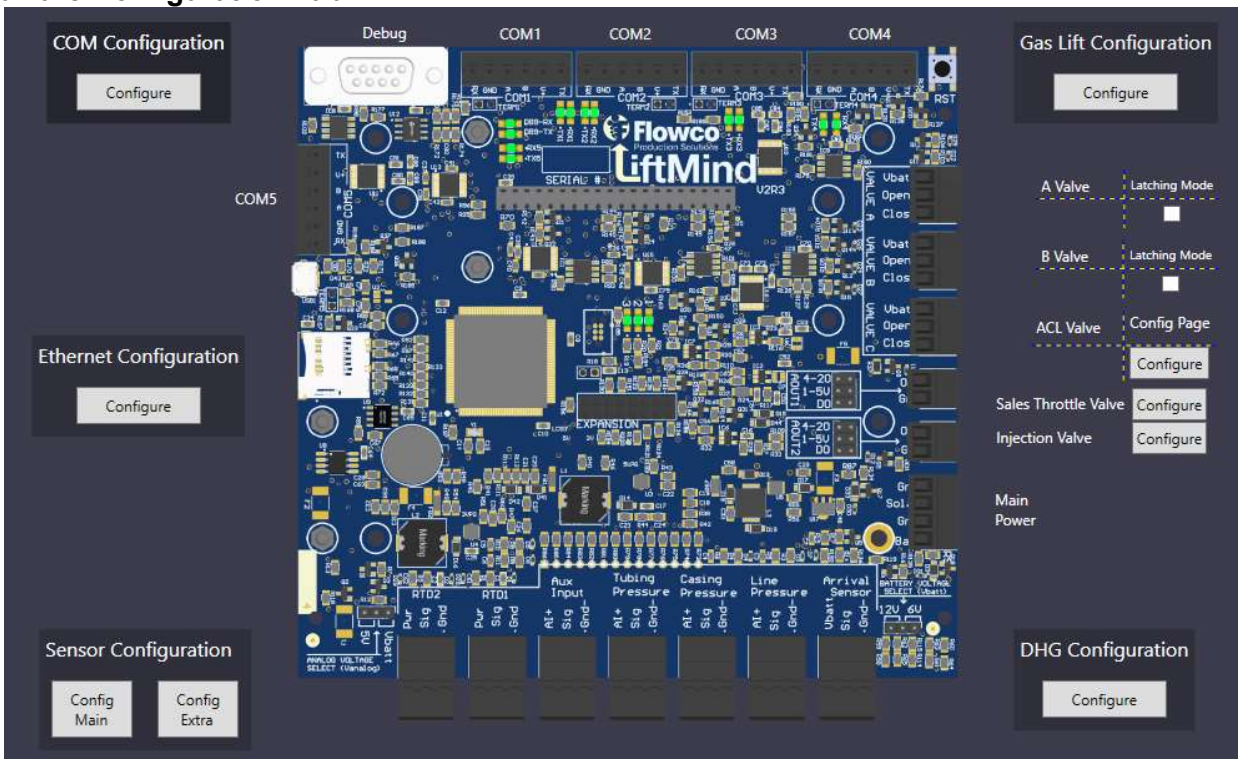
5.4.a Status Tab

Found on Apex Status Screens



- The Status tab displays operating parameters such as system voltages, valve states, and pressures measured by the connected transducers.

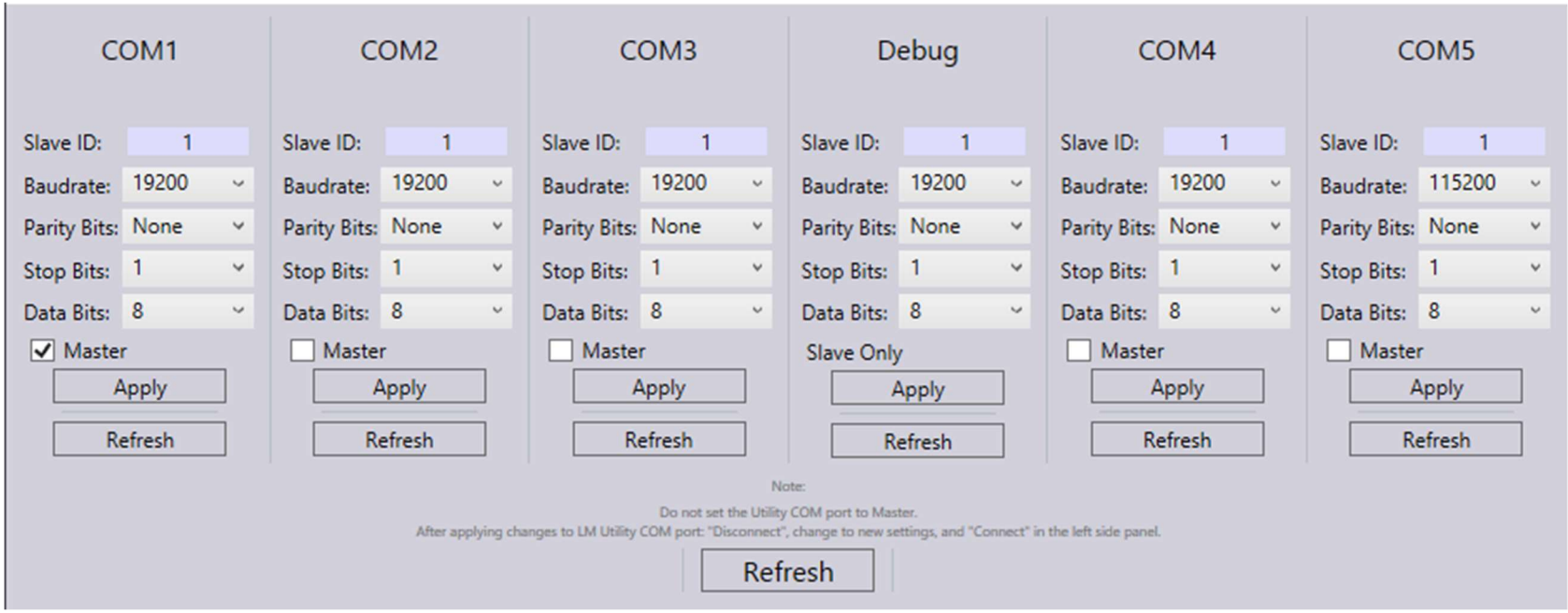
5.4.b Hardware Configuration Tab



- Select “COM Configuration” to set up the Apex’s serial ports
- Select “Ethernet Configuration” to configure up to 2x Ethernet modules for use with the Apex
- Select “Sensor Configuration” to set up pressure transducers and other Modbus sensors
    - “Config Main” is used to set up the primary sensors needed for operation of the Apex
    - “Config Extra” is used to set up additional sensors for which data should be collected, logged, etc.
- Select “Gas Lift Configuration” to set up sensors used for Gas Lift
- Select “DHG Configuration” to set up acquisition of Flowco Down Hole Gauge data
- Check the “Latching Mode” check box next to the “A Valve” and “B Valve” labels to keep the valve outputs on for the entire duration of the plunger cycle. Clear these check boxes to keep the outputs on for only 1 second during valve transitions.
- Select “Sales Throttle Valve” to set up the AO1 analog output for Sales Flow Throttling
- Select “Injection Valve” to set up the AO2 analog output for Gas Injection and Gas Lift

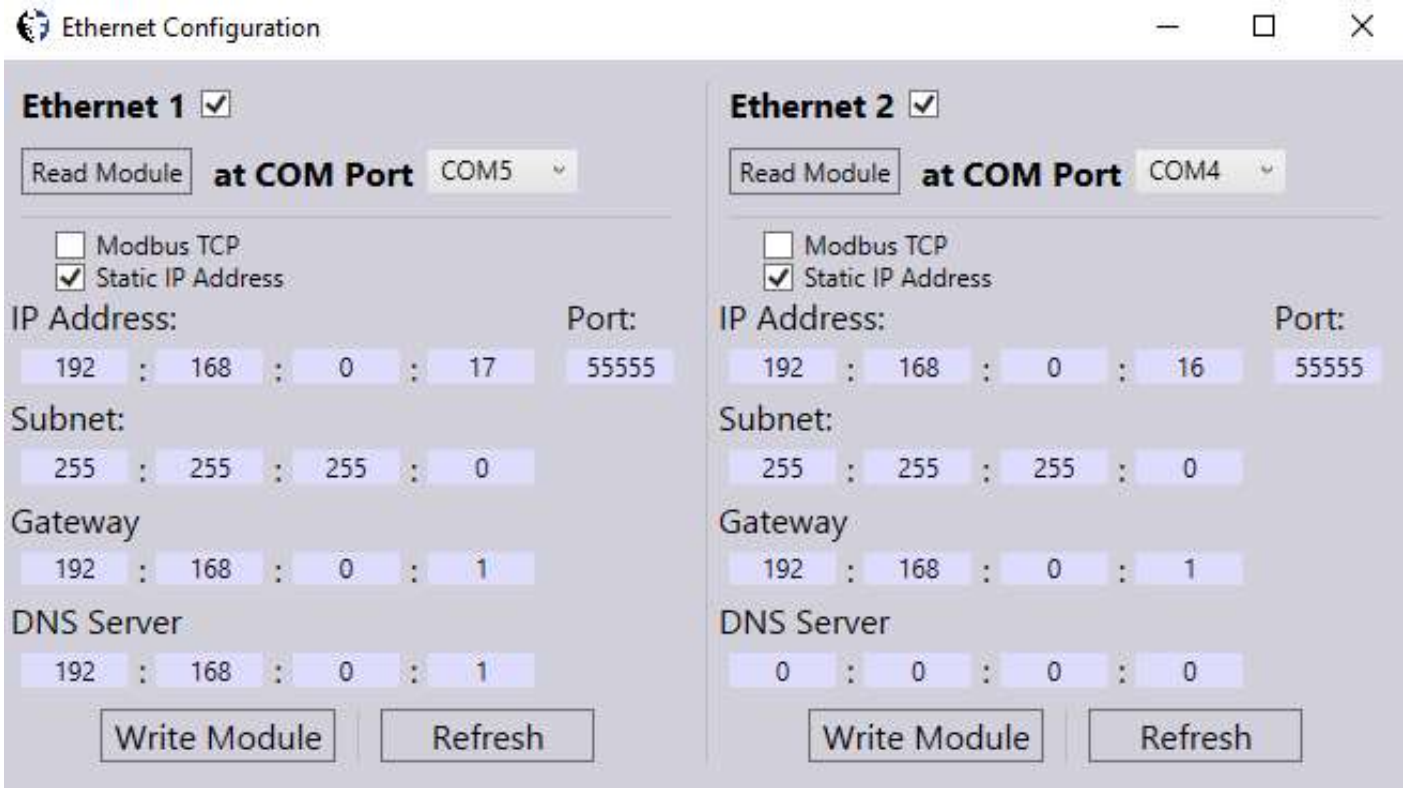
5.4.b.i COM Configuration Window

System->Port Configuration



- Each COM port can be individually configured. The configuration options are:
  - Slave ID: 1-255 **(Slave ID)**
  - Baud Rate: Supports 9600, 19200, 38400, 57600, 115200, and 230400 **(Baud Rate)**
  - Parity: supports None, Even, Odd **(Parity)**
  - Stop Bits: supports 0.5, 1, 1.5, 2 **(Stop Bits)**
  - Data Bits: supports 7, 8, 9 **(Data Bits)**
  - Selectable Master or Slave mode **(Master yes/no)**
  - the DB9 Debug port cannot be set to Master mode.
- When the system is in Multi-Well mode and well 1 is selected, this window configures the Apex's COM ports. The Slave IDs selected here will be the base slave IDs for the Multi-Well system on each port.
  - When wells 2-16 are selected, this window configures the relevant Expander's COM ports for access by and of other Modbus RTU devices
- The Refresh button at the bottom of the window will read the COM settings for all ports
- The Apply and Refresh buttons below each COM port will write or read settings for that particular port only.
- Do not to set all ports to Master mode, as this would prevent access by other masters (including the Utility).

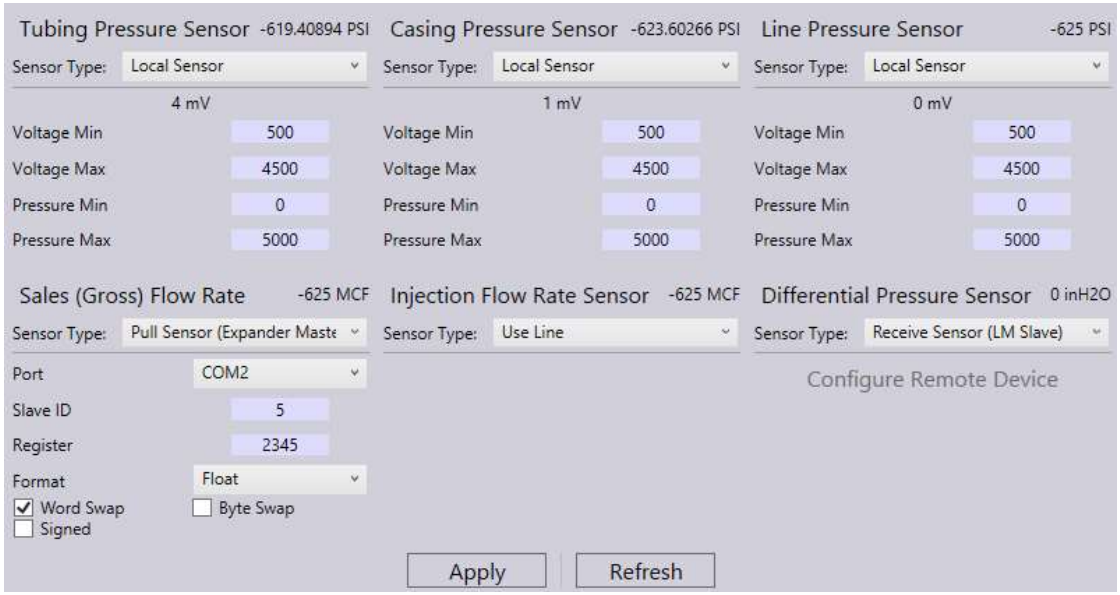
5.4.b.ii Ethernet Configuration Window



- Click the Read Module button to have the Apex attempt to read information from the Ethernet module located on the COM port selected in the dropdown menu. The information will be populated in the fields below.
- Make whatever changes desired to the settings in the window and then click the Write Module button to have the Apex update the Ethernet module with the new settings.
- Click the Refresh button to have LiftLink refresh the window information with the latest data from the Apex without reading from the module. (Used to determine what COM port the Apex thinks the Ethernet module is at, or to cancel and refresh LiftLink settings before clicking Write Module.)

5.4.b.iii Main Sensor Configuration Window

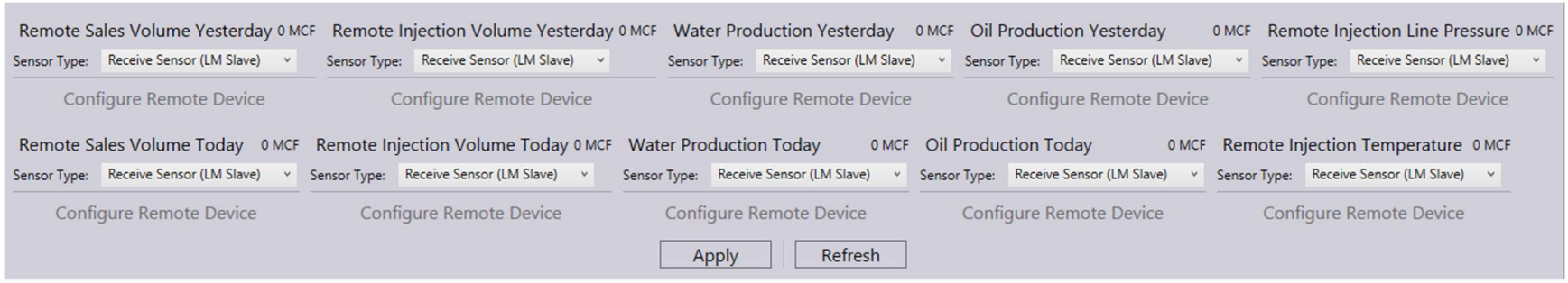
System->Calibration



- Each sensor can be individually configured. **(Sensor Name, Sensor Type)**
- Local Sensor: The sensor is read from the Apex or Expander analog input
    - Configure the sensor span by setting the full-scale voltage and pressure. Set the minimum voltage to the reading observed when the sensor is exposed to atmospheric pressure unless the sensor's spec sheet indicates otherwise
- Use Line:
    - Special option for Sales Flow Rate and Injection Flow Rate.
    - When selected, data will be pulled from the sensor wired into the line pressure sensor connector.
    - Must also select Line Pressure as local sensor for this option.
- Receive Sensor: Sensor data will be sent to the Apex or Expander by a Modbus RTU master; no further configuration options are available.
- Pull Sensor: Sensor data will be retrieved from a Modbus RTU slave by the Apex or Expander
    - Select the COM port on which to access the Modbus slave device
    - Enter the Slave ID of the target device

- Enter the starting register at which to access the sensor data
- Select the data type
- Word and/or Byte Swapping may be necessary, depending on the device that is being accessed
- Integer data can be interpreted as signed or unsigned (default)

5.4.b.iv Extra Sensor Configuration Window



- Each sensor can be individually configured. **(Sensor Name, Sensor Type)**
- All Extra Sensors are configured in the same way as Main Sensors; see the previous page for details

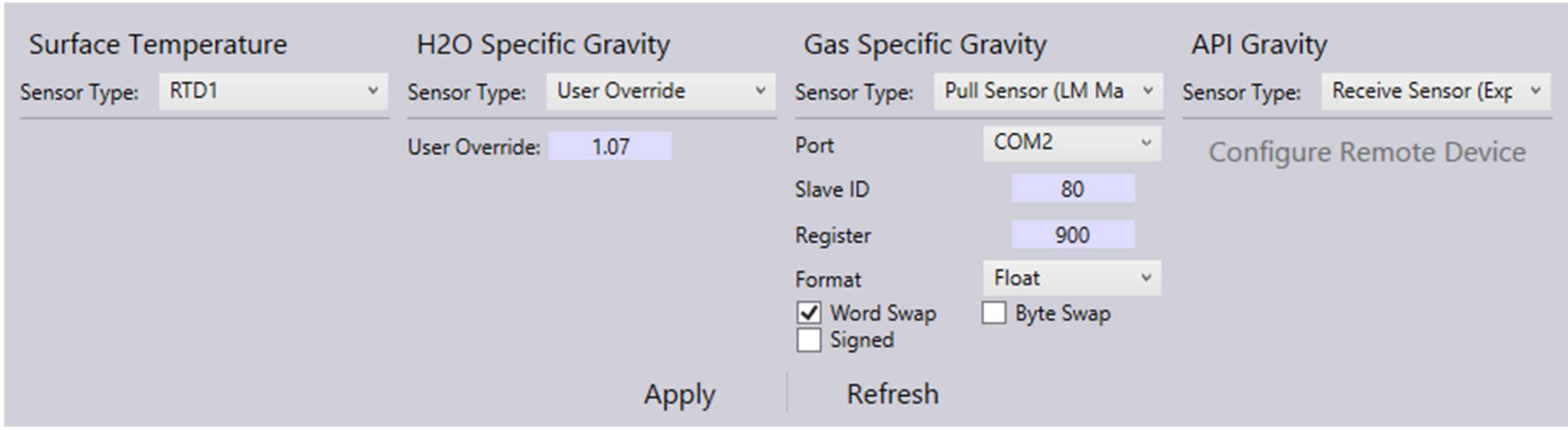
5.4.b.v Down Hole Gauge Configuration Window

System->Gauge Calibration->Downhole Gauge

- COM Port: Select the COM port on which to access the Modbus slave device when sensor type is set to Pull.
- ID: Enter the Slave ID of the target device when sensor type is set to Pull.
- Sensor Type:
    - Receive Sensor: DHG data will be sent to the Apex or Expander by a Modbus RTU master; no further configuration options are available.
    - Pull Sensor: Sensor data will be retrieved from a Modbus RTU slave by the Apex or Expander
- Register: Enter the starting register at which to access the sensor data
- Format: Select the data type
- Word and/or Byte Swapping may be necessary, depending on the device that is being accessed.
- Integer data can be interpreted as signed or unsigned (default)
- Acquisition of each data point can be enabled or disabled. For example, if there is no Annulus gauge present, the Annulus Pressure and Annulus Temperature data points should be disabled.
- DHG Failsafe:
    - Timeout: If DHG tubing pressure doesn't change over a period of time corresponding to "Timeout", the DHG gauge will be declared stuck, and action will be taken depending on the value of Recovery Mode.
    - Recovery Mode:
        - Off: no action will be taken for a stuck DHG gauge.
        - Critical Rate: gas lift will transition to critical rate when the DHG gauge is declared stuck.
        - Static Value: the injection flow setpoint will be set to "Default Value" if the DHG gauge is declared stuck.

5.4.b.vi Gas Lift Acquisition Configuration Window

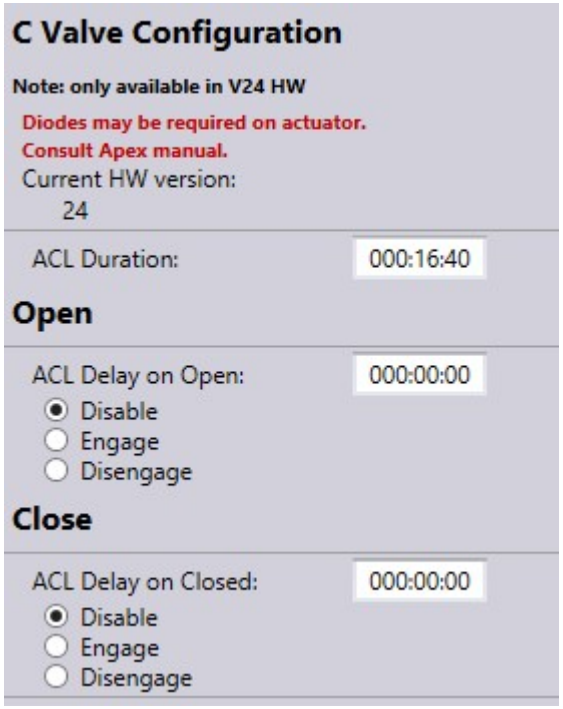
System->Gauge Calibration->Gas Lift Params



- User Override: The data is a known constant and is entered by the user
- Receive Sensor: same as previous sections
- Pull Sensor: same as previous sections
- For Surface Temperature only:
    - Internal Apex: Acquire temperature from onboard temperature sensor
    - RTD1, RTD2: Acquire temperature from the RTD inputs. Note that the Expander only features one RTD input

5.4.b.vii C Valve / ACL Configuration

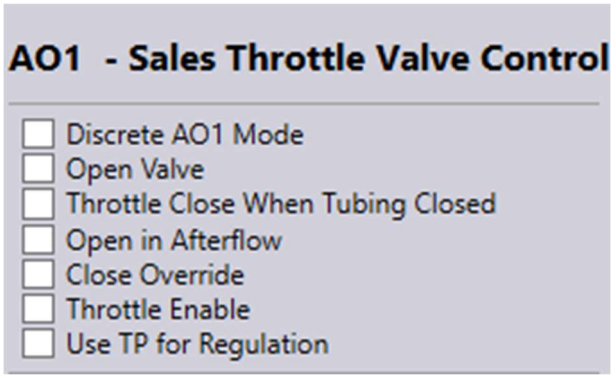
- See 6.4.1 for hardware description and connection information.
- ACL Duration: Time during which ACL is engaged/disengaged (motor CW or CCW).
- ACL Delay on Open: Delay after well enters Open State before ACL is engaged/disengaged.
    - Select disable to disable ACL operation on well transition to open state.
    - Select engage for ACL to engage for a time corresponding to “ACL Duration” after the “Delay on Open” timer expires.
    - Select disengage for ACL to disengage for a time corresponding to “ACL Duration” after the “Delay on Open” timer expires.
- ACL Delay on Closed: Delay after well enters Closed State before ACL is engaged/disengaged.
    - Select disable to disable ACL operation on well transition to closed state.
    - Select engage for ACL to engage for a time corresponding to “ACL Duration” after the “Delay on Closed” timer expires.
    - Select disengage for ACL to disengage for a time corresponding to “ACL Duration” after the “Delay on Closed” timer expires.



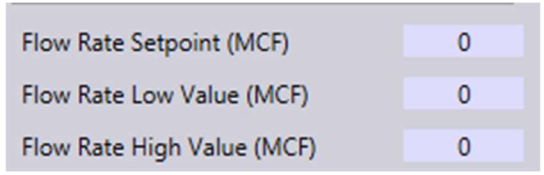
5.4.b.viii Sales Throttle Valve Configuration Window

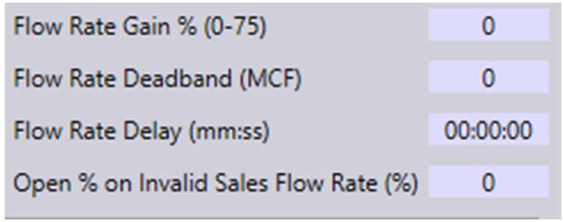
Set->Flow Rate Settings->AO1 Sales Flow

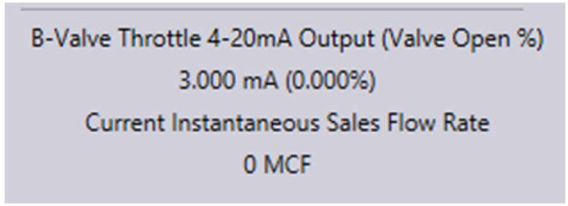
- Discrete AO1 Mode **(AO1 Discrete Mode)**
  - If checked, AO1 output will be 3 mA when the A valve is closed and 21 mA when the A valve is open. The following options will be ignored.
  - If unchecked, AO1 operation is dictated by the following options
- Open Valve **(AO1 Rate ENABLED)**
  - If checked, enables AO1 flow rate controls based on Sales EFM flow rate
- Throttle Closed when Tubing Closed **(CLS ON TBG CLS)**
  - If checked, AO1 will output 3 mA when the main sales valve is closed.
  - If unchecked, AO1 flow rate control will continue during the closed state
- Open in Afterflow **(AO1 RATE OPN AFLW)**
  - If checked, AO1 flow rate control will continue after plunger arrival
  - If unchecked, AO1 will output 3 mA after plunger arrival
- Close Override **(AO1 OVERRIDE)**
  - If checked, AO1 will output 3 mA if the well enters ESD
  - If unchecked, AO1 flow rate control will continue even in ESD
- Throttle Enable **(AO1 Throttle En)**
  - If checked, the AO1 throttling feature is enabled
- Use TP for Regulation
  - If checked, the AO1 control loop will use Tubing Pressure instead of Sales Flow Rate to control



- Flow Rate Setpoint (MCF) **(AO1 RATE SET)**
  - The target sales flow rate
- Flow Rate Low Value (MCF) **(AO1 RATE LOW)**
  - The expected sales flow rate when the valve is set to 4 mA (0%)
- Flow Rate High Value (MCF) **(AO1 RATE HIGH)**
  - The expected sales flow rate when the valve is set to 20 mA (100 %)
- Flow Rate Gain **(AO1 RATE GAIN)**
  - Scaling factor applied to the error between the Flow Rate Setpoint and the actual Sales Flow Rate
- Flow Rate Deadband **(AO1 RATE DBAND)**
  - If the error between the Flow Rate Setpoint and Sales Flow Rate exceeds this value, then a valve adjustment will occur
- Flow Rate Delay **(AO1 DELAY)**
  - If the error between the Flow Rate Setpoint and Sales Flow Rate remains outside of the above Deadband for this duration, then a valve adjustment will occur
- Open % on Invalid Sales Flow Rate **(AO1 RATE INVALID)**
  - This option is not implemented on the Apex
- B-Valve Throttle 4-20 mA Output (Valve Open %) **(AO1 mA OUT)**
  - Displays the valve output in both mA and % open
  - Note that the Apex will set the output to 3 mA and 21 mA for fully closed and fully open, respectively
- Current Instantaneous Sales Flow Rate **(SALES FLOW RATE)**
  - Displays the Sales Flow Rate reported to the Apex by the EFM





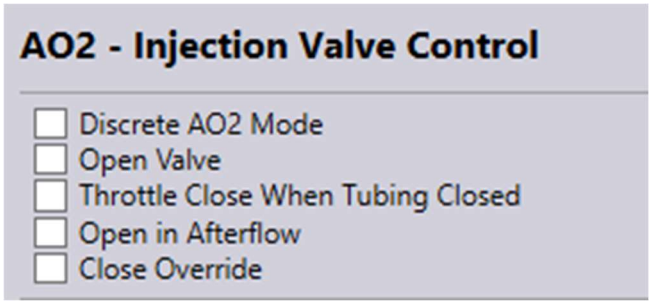


- Initial % Open **(AO1 RATE INIT)**
  - When opening the AO1 valve, immediately go to this percent open
- Control Time **(CTL TIME)**
  - Once this time elapses, the throttling procedure will end and the sales flow rate will be controlled to the above Flow Rate Setpoint
- Step % **(AO1 RATE STEP)**
  - For the duration of the above control time, the AO1 valve will step open by this percentage until either the above Control Time or Flow Rate Setpoint has been reached
- Max Time **(MAX TIME)**
  - Once this time elapses, the AO1 valve will go to either the fully open or fully closed state according to the below End State setting
- End State (Open or Closed) **(AO1 RATE END)**
  - The AO1 valve will go to this state following the above Max Time period

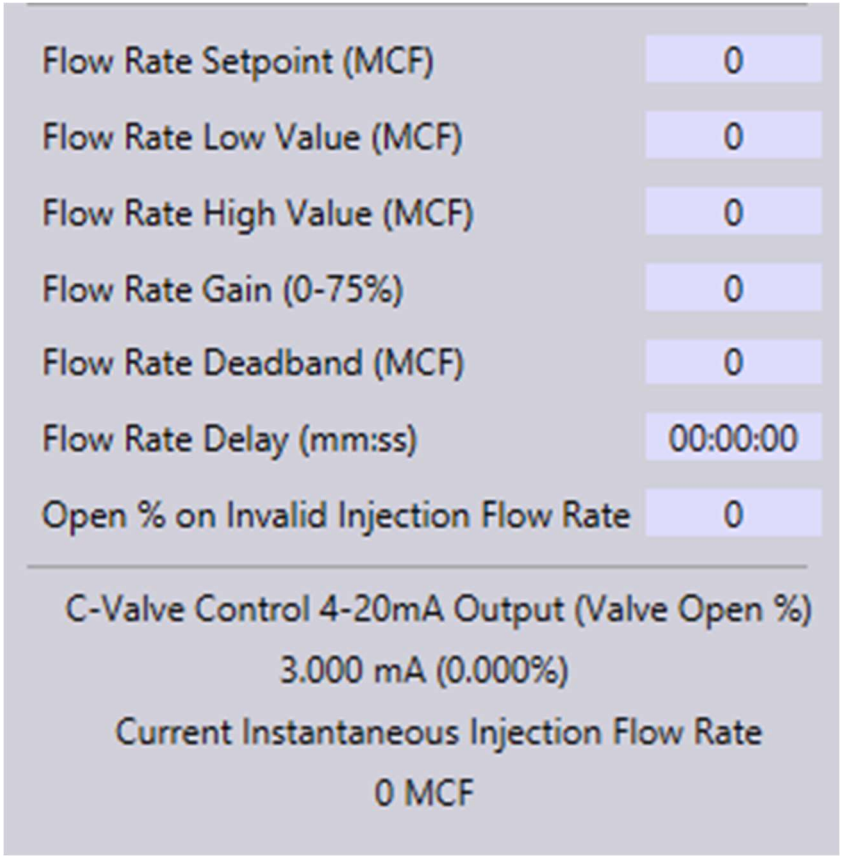
5.4.b.ix Injection Valve Configuration Window

Set->Flow Rate Settings->AO2 INJ FLOW/GAPL

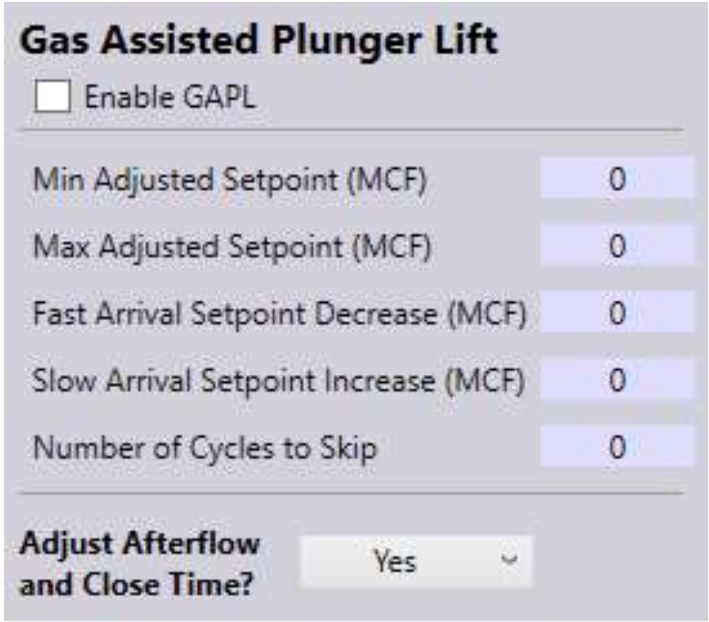
- Discrete AO2 Mode **(AO2 Discrete Mode)**
  - If checked, AO2 output will be 3 mA when the A valve is closed and 21 mA when the A valve is open. The following options will be ignored.
  - If unchecked, AO2 operation is dictated by the following options
- Open Valve **(AO2 VALVE Open/Close)**
  - If checked, enables AO2 flow rate controls based on Sales EFM flow rate
- Throttle Closed when Tubing Closed **(CLS ON TBG CLS)**
  - If checked, AO2 will output 3 mA when the main sales valve is closed.
  - If unchecked, AO2 flow rate control will continue during the closed state
- Open in Afterflow **(AO2 RATE OPN AFLW)**
  - If checked, AO2 flow rate control will continue after plunger arrival
  - If unchecked, AO2 will output 3 mA after plunger arrival
- Close Override **(AO2 OVERRIDE)**
  - If checked, AO2 will output 3 mA if the well enters ESD
  - If unchecked, AO2 flow rate control will continue even in ESD



- Flow Rate Setpoint (MCF) **(AO2 RATE SET)**
  - The target injection flow rate
- Flow Rate Low Value (MCF) **(AO2 RATE LOW)**
  - The expected injection flow rate when the valve is set to 4 mA (0%)
- Flow Rate High Value (MCF) **(AO2 RATE HIGH)**
  - The expected injection flow rate when the valve is set to 20 mA (100 %)
- Flow Rate Gain **(AO2 RATE GAIN)**
  - Scaling factor applied to the error between the Flow Rate Setpoint and the actual Injection Flow Rate
- Flow Rate Deadband **(AO2 RATE DBAND)**
  - If the error between the Flow Rate Setpoint and Injection Flow Rate exceeds this value, then a valve adjustment will occur
- Flow Rate Delay **(AO2 DELAY)**
  - If the error between the Flow Rate Setpoint and Injection Flow Rate remains outside of the above Deadband for this duration, then a valve adjustment will occur
- Open % on Invalid Injection Flow Rate **(AO2 RATE INVALID)**
  - The valve open percentage if a new injection flow rate hasn't been received within 1 minute.
- C-Valve Throttle 4-20 mA Output (Valve Open %) **(AO2 mA OUT)**
  - Displays the valve output in both mA and % open
  - Note that the Apex will set the output to 3 mA and 21 mA for fully closed and fully open, respectively
- Current Instantaneous Injection Flow Rate **(INJ FLOW RATE)**
  - Displays the Injection Flow Rate reported to the Apex by the EFM. The word "STALE" will appear if the flow rate hasn't changed for ~30 seconds.



- Enable GAPL **(GAPL ENABLED)**
  - If checked, enable Gas-Assisted Plunger Lift control
- Min Adjusted Setpoint (MCF) **(GAPL MIN)**
  - Minimum value that the above Flow Rate Setpoint can be adjusted to by the GAPL routine
- Max Adjusted Setpoint (MCF) **(GAPL MAX)**
  - Maximum value that the above Flow Rate Setpoint can be adjusted to by the GAPL routine
- Fast Arrival Setpoint Decrease (MCF) **(GAPL FST (-))**
  - If a fast arrival occurs, decrease the above Flow Rate Setpoint by this amount
- Slow Arrival Setpoint Increase (MCF) **(GAPL SLW (+))**
  - If a slow arrival occurs, increase the above Flow Rate Setpoint by this amount
- Number of Cycles to Skip **(GAPL SKIP)**
  - Set to 0 to adjust every plunger cycle
  - Set to 1 to adjust every other plunger cycle, etc.
- Adjust Afterflow and Close Time **(GAPL OPT)**
  - Yes: adjust afterflow and closed times as they would normally be in Plunger mode upon fast or slow arrivals
  - No: afterflow and closed times will not be adjusted upon fast or slow arrivals
  - At Limit: afterflow and closed times are only adjusted upon fast or slow arrivals if the above Min or Max Adjusted Setpoints have been met or exceeded.



- Open Inj Sales Low Threshold
    - Open injection valve when sales flow falls below this threshold (disabled when set to 0).
- Open Inj Sales Low Delay
    - Time that must expire on state change before Open Inj Sales Low Threshold takes effect.
- Open Inj Sales High Threshold
    - Open injection valve when sales flow goes above this threshold (disabled when set to 0).
- Open Inj Sales High Delay
    - Time that must expire on state change before Open Inj Sales High Threshold takes effect.
- Close Inj Sales Low Threshold
    - Close injection valve when sales flow falls below this threshold (disabled when set to 0).
- Close Inj Sales Low Delay
    - Time that must expire on state change before Close Inj Sales Low Threshold takes effect.
- Close Inj Sales High Threshold
    - Close injection valve when sales flow goes above this threshold (disabled when set to 0).
- Close Inj Sales High Delay
    - Time that must expire on state change before Close Inj Sales High Threshold takes effect.
- Injection Sales Override Enable
    - Must be checked for the above threhsolds to take effect.

5.4.c Controls Configuration Tab

System->Control Options

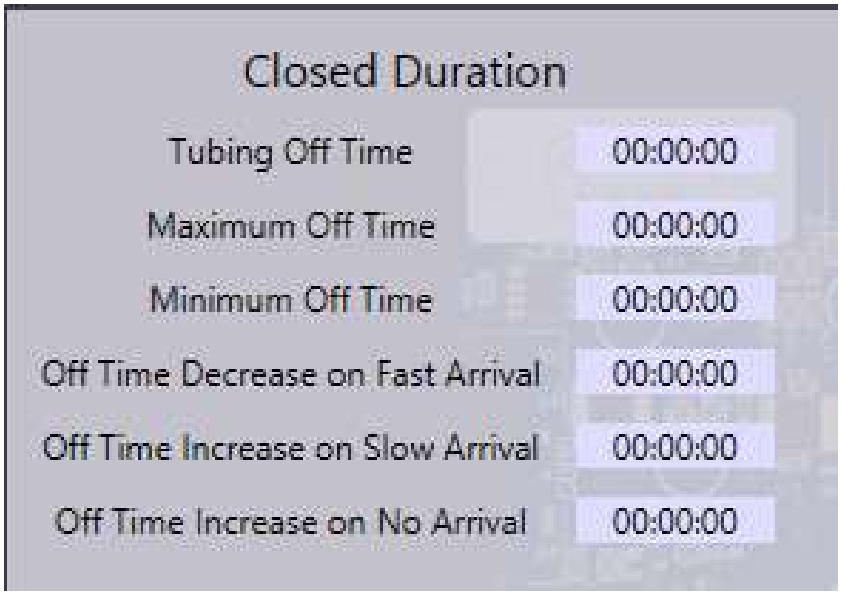
- Control Mode **(Ctl Mode)**
  - Disabled: The well will not operate; sales valve remains closed. Useful for configuring the well settings without disrupting anything.
  - Timer: The well will not perform auto adjustments or use pressure overrides
  - Plunger: The well will operate with all options enabled, including pressure overrides and plunger arrival auto adjustments
- Pressure Overrides Enable **(Prs Ovrd Enabled)**
  - Set to disabled to prevent pressure overrides from causing well state changes
- B-Valve Enable **(B Vlv Enabled)**
  - Enable to allow per-state B-Valve settings to be applied
- Afterflow on Slow Arrival Enable **(Set->Afterflow Settings->Slw Arr Aflw)**
  - If disabled, the well will enter closed instead of afterflow upon the occurrence of a slow arrival
- Contract Time **(Cntrct Tim)**
  - Set the time at which the well should consider a new contract day to have begun
- Plunger Arrival Adjustment Enable **(PLNG ARRIVAL ADJ)**
  - Set to disabled to prevent automatic adjustment of parameters following fast, slow, or no arrivals
- Plunger Sensor On **(PLNG SNS ENABLED)**
  - Set to disabled to prevent the well from entering afterflow upon plunger arrival

5.4.d Closed Configuration Tab

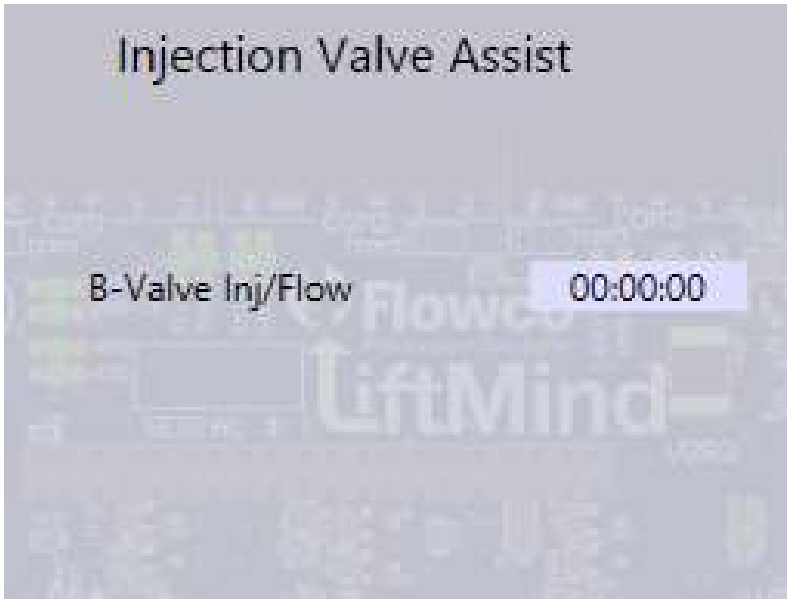
Set->Closed Settings

5.4.d.i Closed Duration

- Tubing Off Time **(TBG CLOSE)**
  - The amount of time that the sales valve will remain closed for before moving to the open state
- Maximum Off Time **(MAX CLOSE)**
  - The maximum that the closed duration can be adjusted to by the auto-adjust routines
- Minimum Off Time **(MIN CLOSE)**
  - Overrides will be ignored for this long during the closed state
  - The minimum that the closed duration can be adjusted to by the auto-adjust routines
- Off Time Decrease on Fast Arrival **(OFF FST -)**
  - If a fast arrival occurs, the closed duration will be decreased by this amount
- Off Time Increase on Slow Arrival **(OFF SLW +)**
  - if a slow arrival occurs, the closed duration will be increased by this amount
- Off Time Increase on No Arrival **(OFF N/A +)**
  - if no arrival occurs, the closed duration will be increased by this amount



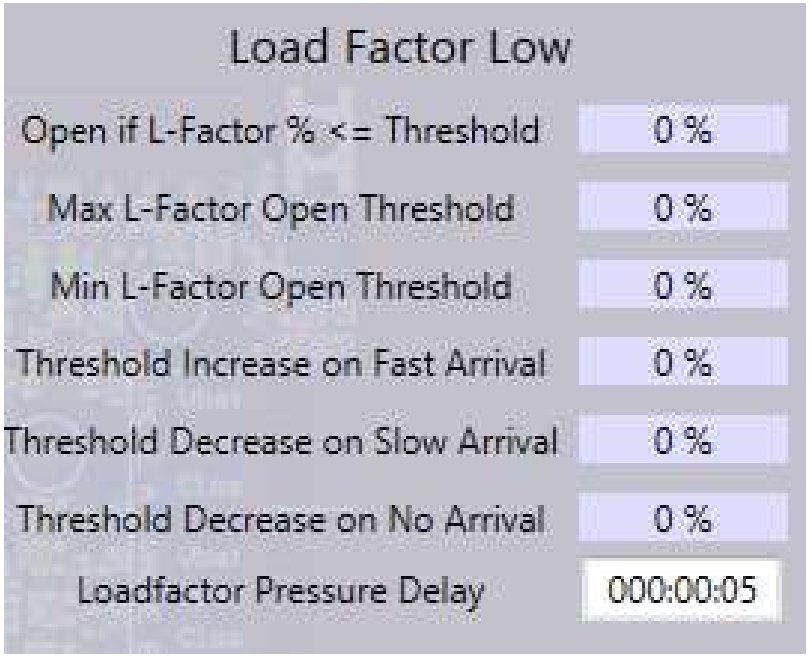
5.4.d.ii Closed Injection Valve Assist



- B-Valve Inject/Flow **(BVLV INJFLO)**
  - The B-Valve will open this amount of time before the well is scheduled to open to assist in building pressure

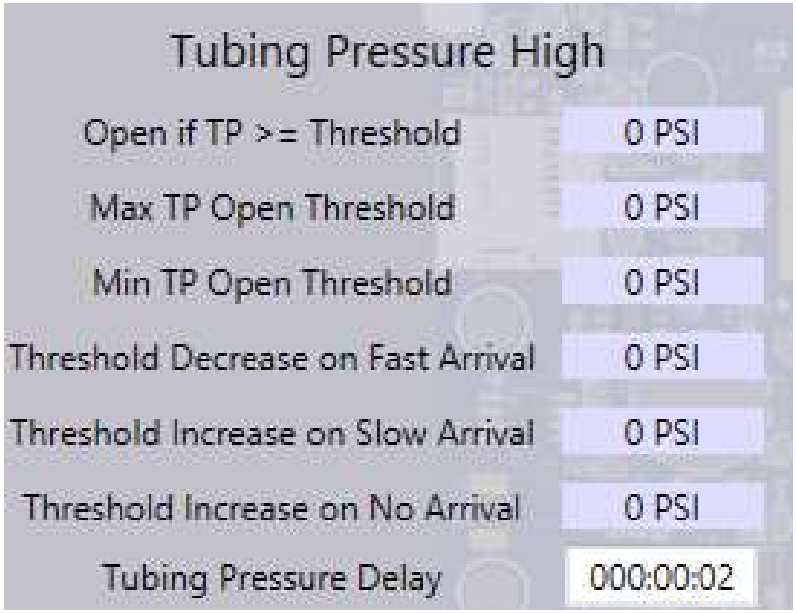
5.4.d.iii Closed Load Factor Low Threshold

- Open if Load Factor ≤ Threshold **(OPN IF LFACT%<)**
  - if the load factor falls below this threshold while closed and after min closed time, go to opened
- Max Load Factor Open Threshold **(MAX OPN LFACT%)**
  - the maximum value that the closed low loadfactor threshold can be adjusted to by the auto adjustments
- Min Load Factor Open Threshold **(MIN OPN LFACT%)**
  - the minimum value that the closed low loadfactor threshold can be adjusted to by the auto adjustments
- Threshold Increase on Fast Arrival **(OP FS LFACT%<+)**
  - if a fast arrival occurs, increase the closed low loadfactor threshold by this amount
- Threshold Decrease on Slow Arrival **(OP SL LFACT%<-)**
  - if a slow arrival occurs, decrease the closed low loadfactor threshold by this amount
- Threshold Decrease on No Arrival **(OP NA LFACT%<-)**
  - if a no arrival occurs, decrease the closed low loadfactor threshold by this amount
- Loadfactor Pressure Delay **(LFACT DLY)**
  - Time that must expire before this threshold can trigger a change to the opened state.



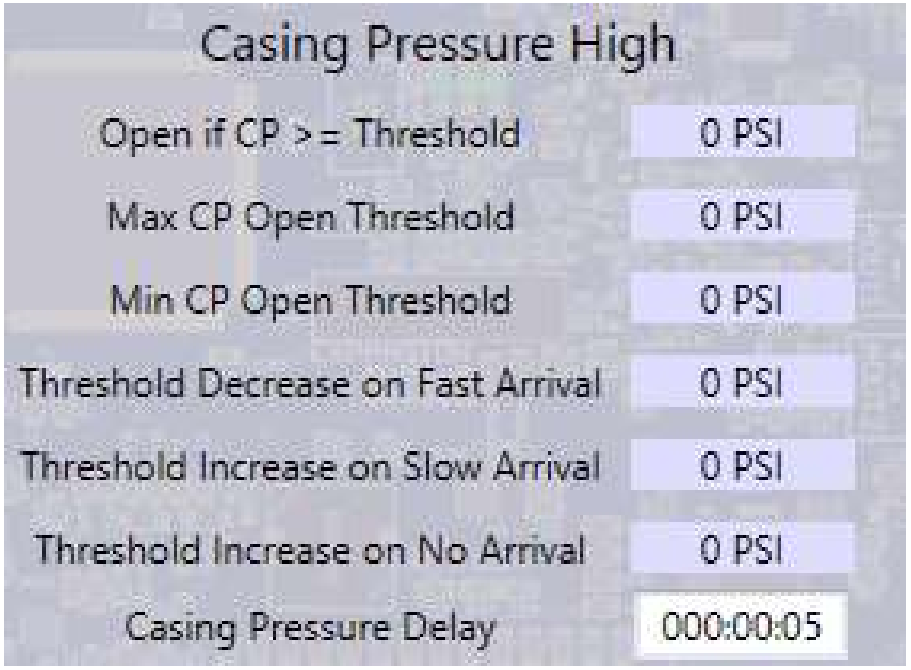
5.4.d.iv Closed Tubing Pressure High Threshold

- Open if Tubing Pressure ≥ Threshold **(OPN IF TP >=)**
  - if tubing pressure exceeds this threshold while closed and after min closed time, go to opened
- Max Tubing Pressure Open Threshold **(MAX OPN TP)**
  - the maximum value that the closed high tubing pressure threshold can be adjusted to by the auto adjustments
- Min Tubing Pressure Open Threshold **(MIN OPN TP)**
  - the minimum value that the closed high tubing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(OPN FST TP -)**
  - if a fast arrival occurs, decrease the closed high tubing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(OPN SLW TP +)**
  - if a slow arrival occurs, increase the closed high tubing pressure threshold by this amount
- Threshold Increase on No Arrival **(OPN N/A TP +)**
  - if no arrival occurs, increase the closed high tubing pressure threshold by this amount
- Tubing Pressure Delay **(TP DLY)**
  - Time that must expire before this threshold can trigger a change to the opened state.



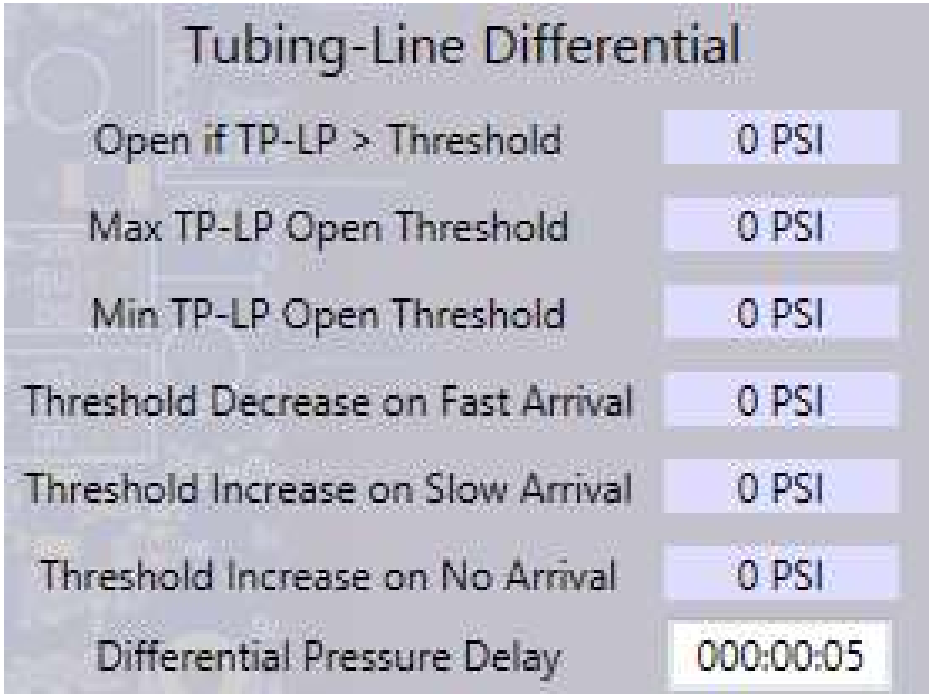
5.4.d.v Closed Casing Pressure High Threshold

- Open if Casing Pressure ≥ Threshold **(OPN IF CP >=)**
  - if casing pressure exceeds this threshold while closed and after min closed time, go to opened
- Max Casing Pressure Open Threshold **(MAX OPN CP)**
  - the maximum value that the closed high casing pressure threshold can be adjusted to by the auto adjustments
- Min Casing Pressure Open Threshold **(MIN OPN CP)**
  - the minimum value that the closed high casing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(OPN FST CP -)**
  - if a fast arrival occurs, decrease the closed high casing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(OPN SLW CP +)**
  - if a slow arrival occurs, increase the closed high casing pressure threshold by this amount
- Threshold Increase on No Arrival **(OPN N/A CP +)**
  - if no arrival occurs, increase the closed high casing pressure threshold by this amount
- Casing Pressure Delay **(CP DLY)**
  - Time that must expire before this threshold can trigger a change to the opened state.



5.4.d.vi Closed Tubing-Line Differential Pressure High Threshold

- Open if Tubing Pressure – Line Pressure > Threshold **(OPN IF TP-LP >)**
    - if the difference between tubing and line pressure exceeds this threshold while closed and after min closed time, go to opened
- Max Tubing Pressure – Line Pressure Open Threshold **(MAX OPN TP-LP)**
    - the maximum value that the closed high tubing-line differential pressure threshold can be adjusted to by the auto adjustments
- Min Tubing Pressure – Line Pressure Open Threshold **(MIN OPN TP-LP)**
    - the minimum value that the closed high tubing-line differential pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(OP FS TP-LP -)**
    - if a fast arrival occurs, decrease the closed high tubing-line differential pressure threshold by this amount
- Threshold Increase on Slow Arrival **(OP SL TP-LP +)**
    - if a slow arrival occurs, increase the closed high tubing-line differential pressure threshold by this amount
- Threshold Increase on No Arrival **(OP NA TP-LP +)**
    - if no arrival occurs, increase the closed high tubing-line differential pressure threshold by this amount
- Differential Pressure Delay **(DP DLY)**
    - Time that must expire before this threshold can trigger a change to the opened state.



5.4.e Open Configuration Tab

Set->Opened Settings

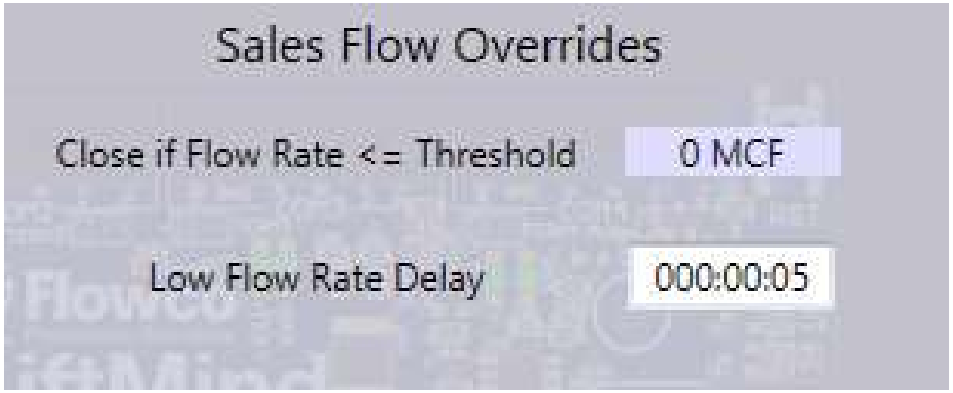
5.4.e.i Plunger Arrival Thresholds

- Fast Arrival Time **(FAST TIME)**
  - if a plunger arrives before this time, it is considered fast
- Slow Arrival Time **(SLOW TIME)**
  - if a plunger arrives after this time, it is considered slow
- Tubing On Time **(TBG OPEN)**
  - The maximum amount of time that the well will wait for the plunger to arrive
  - If the plunger does not arrive after this time, it is considered a no arrival

5.4.e.ii Opened Vent Valve Assist

- B-Valve Delay **(BVLV DELAY)**
  - if the plunger does not arrive after this duration, the b valve will be opened to assist
  - After the sales valve has opened, the well will wait this long before opening the B-valve
- B-Valve Open **(BVLV OPEN)**
  - the b valve will be opened for this amount of time if the above condition is met

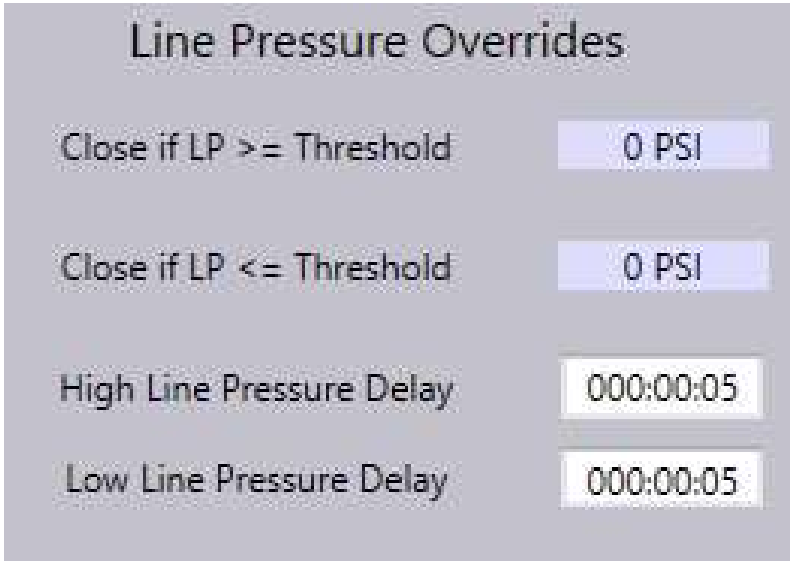
5.4.e.iii Opened Sales Flow Overrides



- Close if Flow Rate ≤ Threshold **(CLS IF FLW <=)**
  - if the flow rate falls below this threshold while opened, go to closed
- Low Flow Rate Delay **(LOW FLW DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.

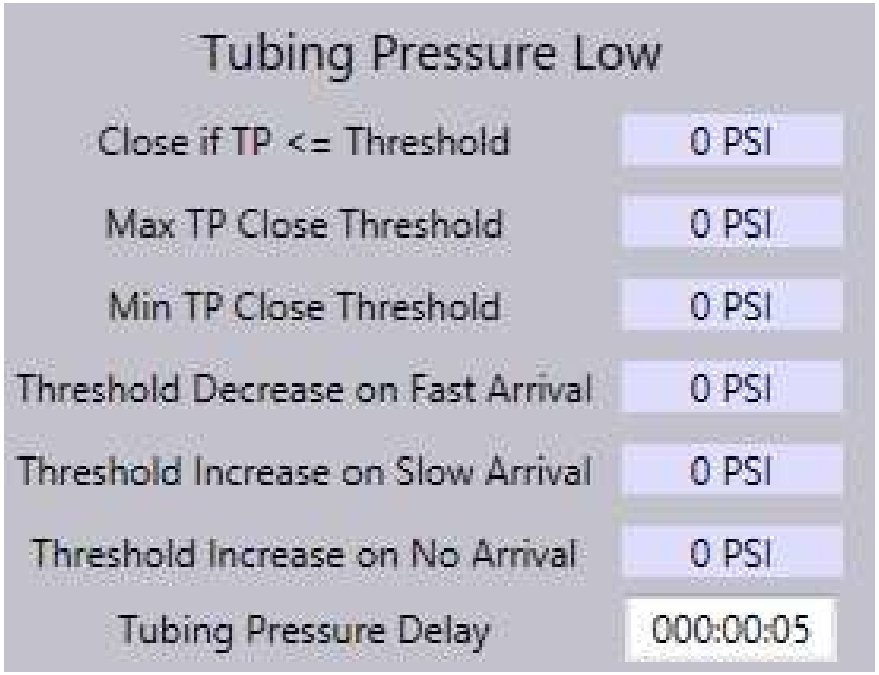
5.4.e.iv Opened Line Pressure Overrides

- Close if Line Pressure ≥ Threshold **(CLS IF LP >=)**
  - if the line pressure exceeds this threshold while opened, go to closed
- Close if Line Pressure ≤ Threshold **(CLS IF LP <=)**
  - if the line pressure falls below this threshold while opened, go to closed
- High Line Pressure Delay **(H-L DELAY)**
  - Time that must expire before this threshold triggers a change to the closed state.
- Low Line Pressure Delay **(L-L DELAY)**
  - Time that must expire before this threshold triggers a change to the closed state.



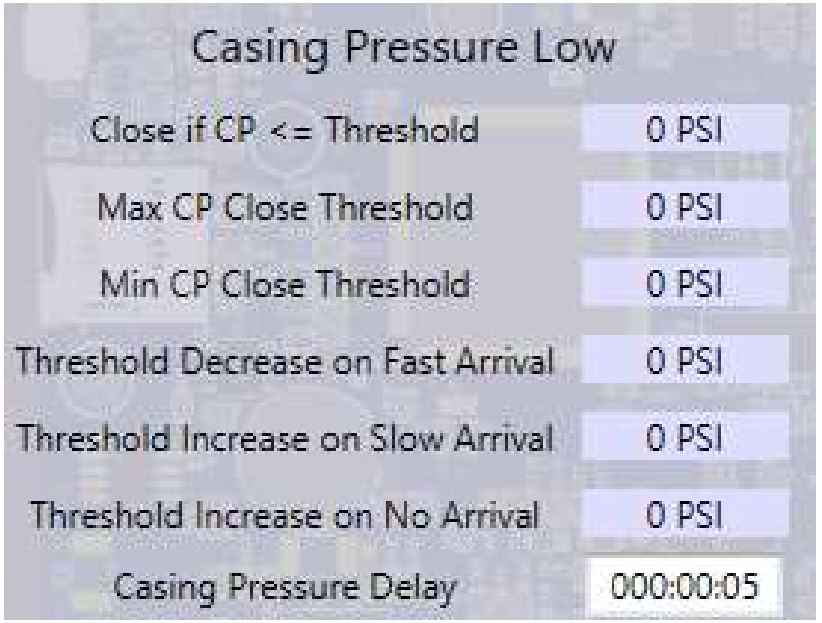
5.4.e.v Opened Tubing Pressure Low Threshold

- Close if Tubing Pressure ≤ Threshold **(CLS IF TP <=)**
  - if tubing pressure falls below this threshold while open, go to closed
- Max Tubing Pressure Close Threshold **(MAX CLS TP)**
  - the maximum value that the opened low tubing pressure threshold can be adjusted to by the auto adjustments
- Min Tubing Pressure Close Threshold **(MIN CLS TP)**
  - the minimum value that the opened low tubing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST TP -)**
  - if a fast arrival occurs, decrease the opened low tubing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW TP +)**
  - if a slow arrival occurs, increase the opened low tubing pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A TP +)**
  - if no arrival occurs, increase the opened low tubing pressure threshold by this amount
- Tubing Pressure Delay **(TP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



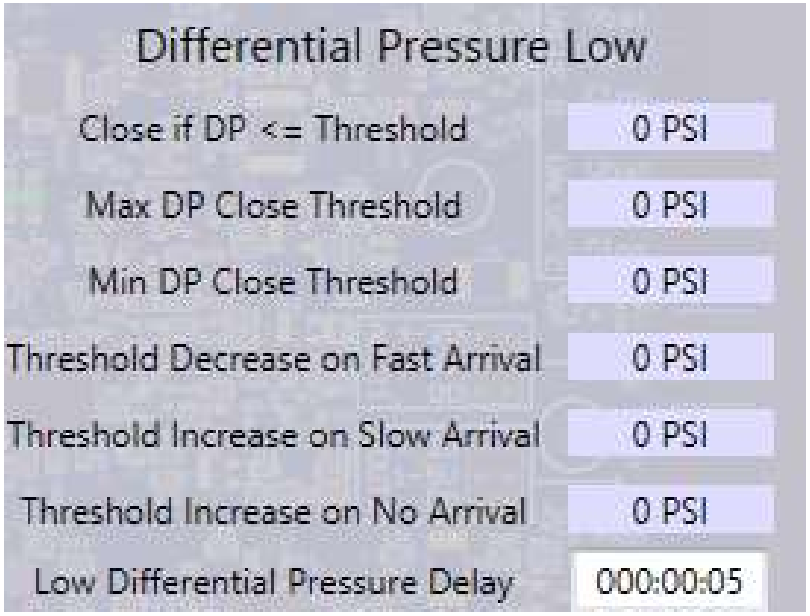
5.4.e.vi Opened Casing Pressure Low Threshold

- Close if Casing Pressure ≤ Threshold **(CLS IF CP <=)**
  - if casing pressure falls below this threshold while open, go to closed
- Max Casing Pressure Close Threshold **(MAX CLS CP)**
  - the maximum value that the opened low casing pressure threshold can be adjusted to by the auto adjustments
- Min Casing Pressure Close Threshold **(MIN CLS CP)**
  - the minimum value that the opened low casing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST CP -)**
  - if a fast arrival occurs, decrease the opened low casing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW CP +)**
  - if a slow arrival occurs, increase the opened low casing pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A CP +)**
  - if no arrival occurs, increase the opened low casing pressure threshold by this amount
- Casing Pressure Delay **(CP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



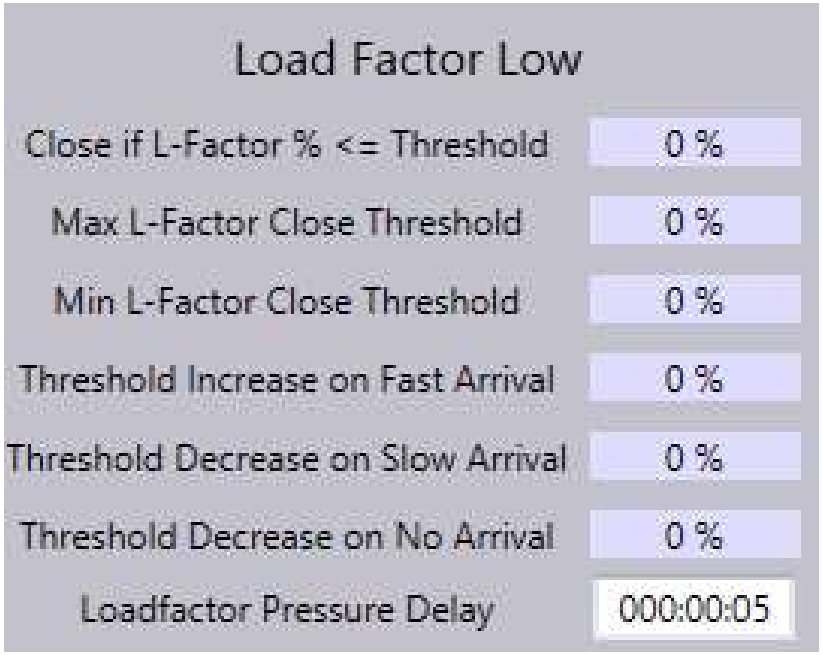
5.4.e.vii Opened Remote Differential Pressure Low Threshold

- Close if Differential Pressure ≤ Threshold **(CLS IF DP <=)**
  - if the remote differential pressure falls below this threshold while open, go to closed
- Max Differential Pressure Close Threshold **(MAX CLS DP)**
  - the maximum value that the opened low remote differential pressure threshold can be adjusted to by the auto adjustments
- Min Differential Pressure Close Threshold **(MIN CLS DP)**
  - the minimum value that the opened low differential pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST DP -)**
  - if a fast arrival occurs, decrease the opened differential pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW DP +)**
  - if a slow arrival occurs, increase the opened differential pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A DP +)**
  - if no arrival occurs, increase the opened differential pressure threshold by this amount
- Low Differential Pressure Delay **(LOW DP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



5.4.e.viii Opened Load Factor Pressure Low Threshold

- Close if Load Factor ≤ Threshold **(CLS IF LFACT%<)**
  - if the load factor falls below this threshold while opened, go to closed
- Max Load Factor Close Threshold **(MAX CLS LFACT%)**
  - the maximum value that the opened low loadfactor threshold can be adjusted to by the auto adjustments
- Min Load Factor Close Threshold **(MIN CLS LFACT%)**
  - the minimum value that the opened low loadfactor threshold can be adjusted to by the auto adjustments
- Threshold Increase on Fast Arrival **(CLS FS LFACT%+)**
  - if a fast arrival occurs, increase the opened low loadfactor threshold by this amount
- Threshold Decrease on Slow Arrival **(CLS SL FLACT%-)**
  - if a slow arrival occurs, decrease the opened low loadfactor threshold by this amount
- Threshold Decrease on No Arrival **(CLS NA LFACT%-)**
  - if a no arrival occurs, decrease the opened low loadfactor threshold by this amount
- Loadfactor Pressure Delay **(LFACT DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.

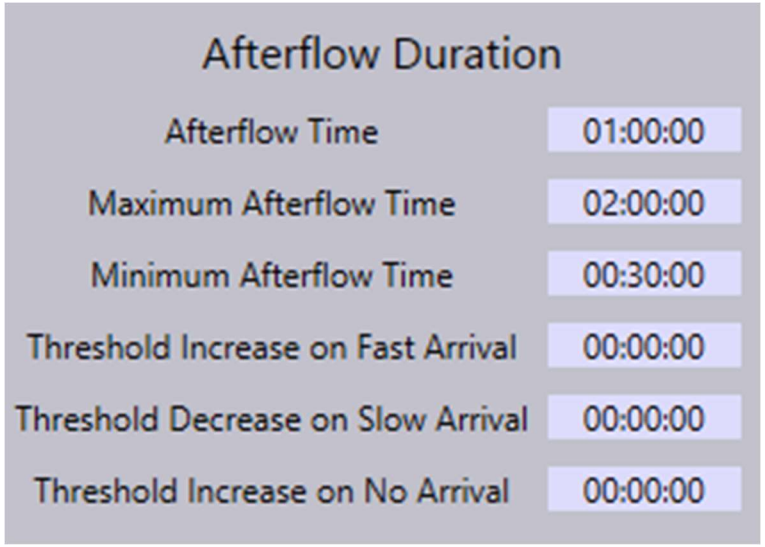


5.4.f Afterflow Configuration Tab

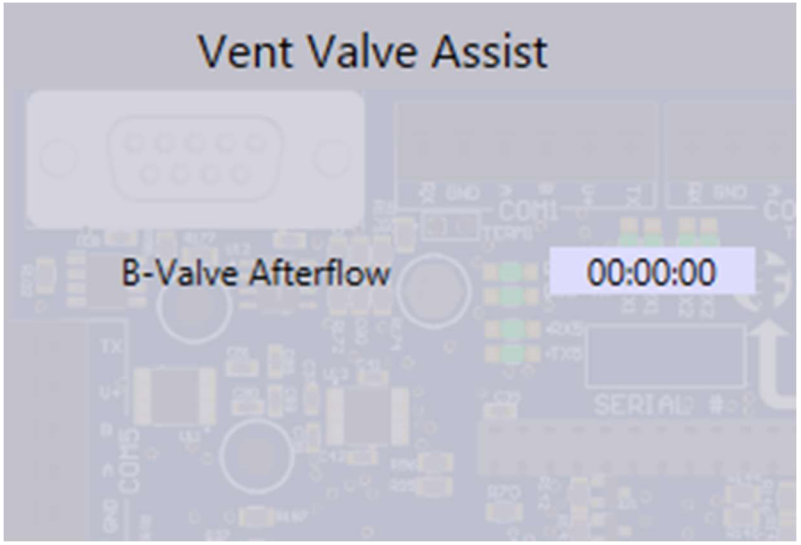
Set->Afterflow Settings

5.4.f.i Afterflow Duration

- Afterflow Time **(AFTFLW)**
  - the amount of time that the sales valve will remain open for after the plunger has arrived
- Maximum Off Time **(MAX AFLW)**
  - The maximum that the afterflow duration can be adjusted to by the auto-adjust routines
- Minimum Off Time **(MIN AFLW)**
  - Overrides will be ignored for this long during the afterflow state
  - The minimum that the afterflow duration can be adjusted to by the auto-adjust routines
- Afterflow Time Increase on Fast Arrival **(A/F FST +)**
  - If a fast arrival occurs, the afterflow duration will be increased by this amount
- Afterflow Time Decrease on Slow Arrival **(A/F SLW -)**
  - if a slow arrival occurs, the afterflow duration will be decreased by this amount
- Afterflow Time Decrease on No Arrival **(A/F N/A -)**
  - if no arrival occurs, the afterflow duration will be decreased by this amount



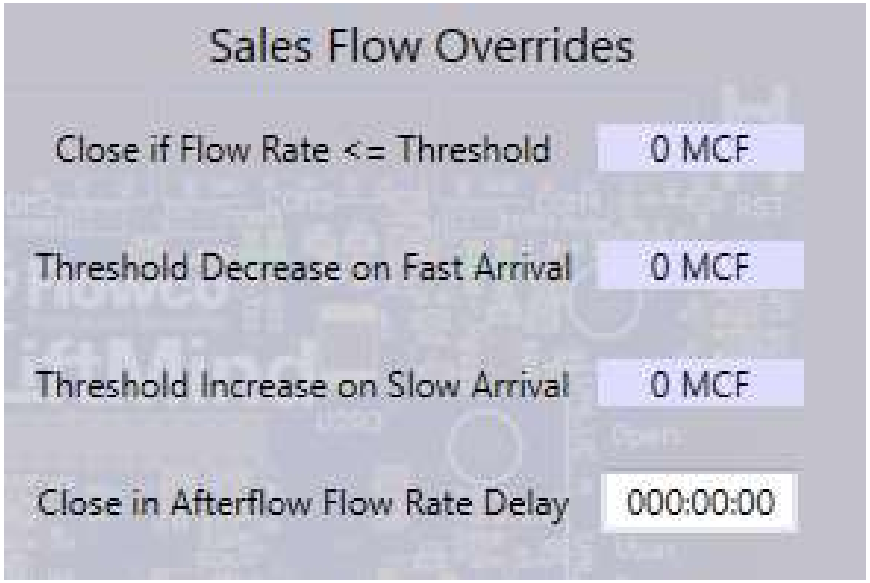
5.4.f.ii Afterflow Vent Valve Assist



- B-Valve Afterflow **(BVLV AF)**
  - the amount of time that the b valve will remain open after the plunger has arrived

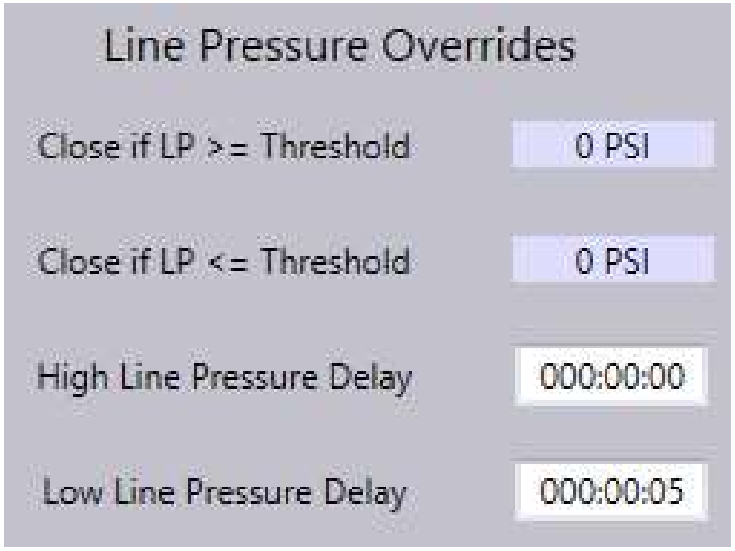
5.4.f.iii Afterflow Sales Flow Overrides

- Close if Flow Rate ≤ Threshold **(CLS IF FLW <=)**
  - if the flow rate falls below this threshold while in afterflow, go to closed
- Threshold Decrease on Fast Arrival **(CLS FST FLW -)**:
  - On plunger fast arrival, decrease the sales low flow threshold by this amount.
- Threshold Increase on Slow Arrival **(CLS SLW FLW +)**:
  - On plunger slow arrival, increase the sales low flow threshold by this amount.
- Low Flow Rate Delay **(LOW FLW DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



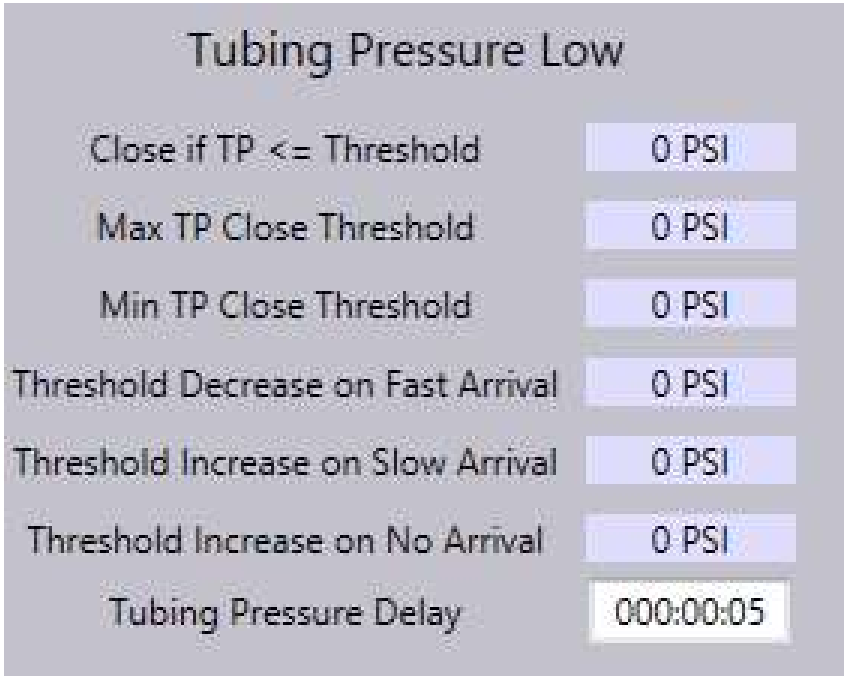
5.4.f.iv Afterflow Line Pressure Overrides

- Close if Line Pressure ≥ Threshold **(CLS IF LP >=)**
  - if the line pressure exceeds this threshold while in afterflow, go to closed
- Close if Line Pressure ≤ Threshold **(CLS IF LP <=)**
  - if the line pressure falls below this threshold while in afterflow, go to closed
- High Line Pressure Delay **(H-L DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.
- Low Line Pressure Delay **(L-L DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



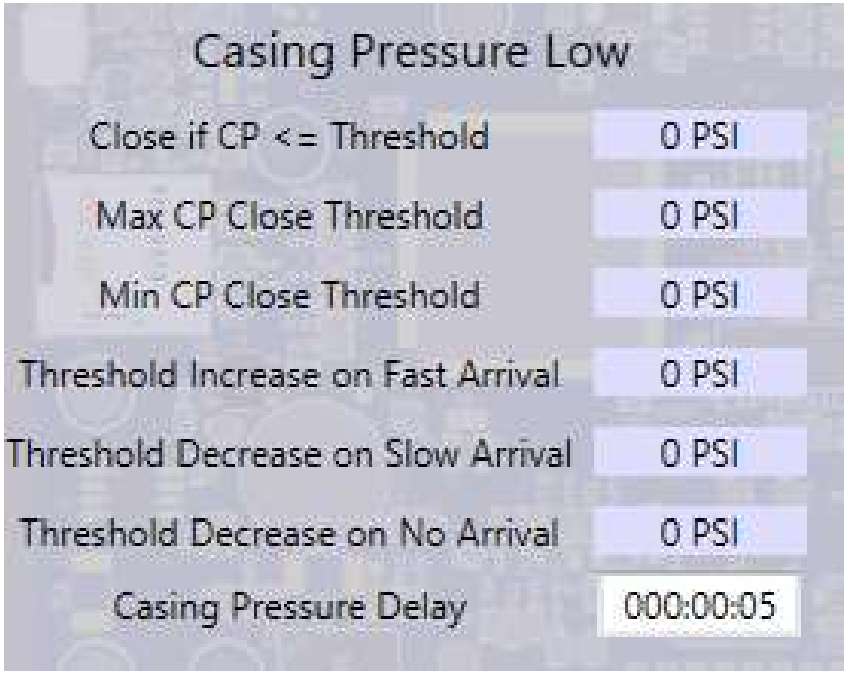
5.4.f.v Afterflow Tubing Pressure Low Threshold

- Close if Tubing Pressure ≤ Threshold **(CLS IF TP <=)**
  - if tubing pressure falls below this threshold while in afterflow, go to closed
- Max Tubing Pressure Close Threshold **(CLS MAX TP)**
  - the maximum value that the afterflow low tubing pressure threshold can be adjusted to by the auto adjustments
- Min Tubing Pressure Close Threshold **(CLS MIN TP)**
  - the minimum value that the afterflow low tubing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST TP -)**
  - if a fast arrival occurs, decrease the afterflow low tubing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW TP +)**
  - if a slow arrival occurs, increase the afterflow low tubing pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A TP +)**
  - if no arrival occurs, increase the afterflow low tubing pressure threshold by this amount
- Tubing Pressure Delay **(TP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



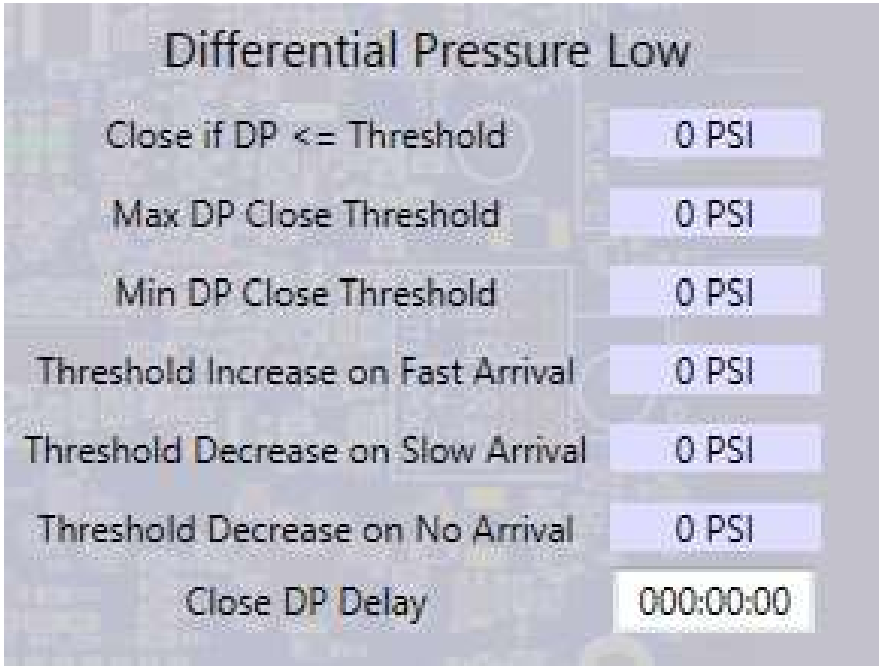
5.4.f.vi Afterflow Casing Pressure Low Threshold

- Close if Casing Pressure ≤ Threshold **(CLS IF CP <=)**
  - if casing pressure falls below this threshold while in afterflow, go to closed
- Max Casing Pressure Open Threshold **(CLS MAX CP)**
  - the maximum value that the afterflow low casing pressure threshold can be adjusted to by the auto adjustments
- Min Casing Pressure Open Threshold **(CLS MIN CP)**
  - the minimum value that the afterflow low casing pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST CP -)**
  - if a fast arrival occurs, decrease the afterflow low casing pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW CP +)**
  - if a slow arrival occurs, increase the afterflow low casing pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A CP +)**
  - if no arrival occurs, increase the afterflow low casing pressure threshold by this amount
- Casing Pressure Dleay **(CP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



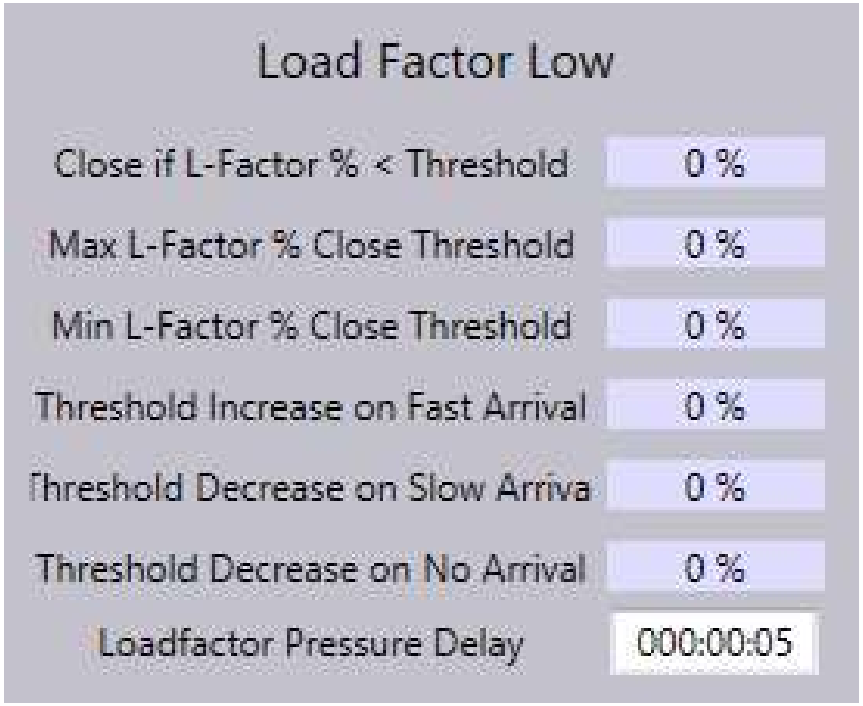
5.4.f.vii Afterflow Remote Differential Pressure Low Threshold

- Close if Differential Pressure ≤ Threshold **(CLS IF DP <=)**
  - if the remote differential pressure falls below this threshold while in afterflow, go to closed
- Max Differential Pressure Close Threshold **(CLS MAX DP)**
  - the maximum value that the afterflow low remote differential pressure threshold can be adjusted to by the auto adjustments
- Min Differential Pressure Close Threshold **(CLS MIN DP)**
  - the minimum value that the afterflow low differential pressure threshold can be adjusted to by the auto adjustments
- Threshold Decrease on Fast Arrival **(CLS FST DP -)**
  - if a fast arrival occurs, decrease the afterflow differential pressure threshold by this amount
- Threshold Increase on Slow Arrival **(CLS SLW DP +)**
  - if a slow arrival occurs, increase the afterflow differential pressure threshold by this amount
- Threshold Increase on No Arrival **(CLS N/A DP +)**
  - if no arrival occurs, increase the afterflow differential pressure threshold by this amount
- Close DP Delay **(LOW DP DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



5.4.f.viii Afterflow Load Factor Pressure Low Threshold

- Close if Load Factor ≤ Threshold **(CLS IF LFACT%<)**
  - if the load factor falls below this threshold while opened, go to closed
- Max Load Factor Close Threshold **(CLS MAX LFACT%)**
  - the maximum value that the opened low loadfactor threshold can be adjusted to by the auto adjustments
- Min Load Factor Close Threshold **(CLS MIN LFACT%)**
  - the minimum value that the opened low loadfactor threshold can be adjusted to by the auto adjustments
- Threshold Increase on Fast Arrival **(CLS FS LFACT%+)**
  - if a fast arrival occurs, increase the opened low loadfactor threshold by this amount
- Threshold Decrease on Slow Arrival **(CLS SL LFACT%-)**
  - if a slow arrival occurs, decrease the opened low loadfactor threshold by this amount
- Threshold Decrease on No Arrival **(CLS NA LFACT%-)**
  - if a no arrival occurs, decrease the opened low loadfactor threshold by this amount
- Loadfactor Pressure Delay **(LFACT DLY)**
  - Time that must expire before this threshold triggers a change to the closed state.



5.4.g Recovery Configuration Tab

Set->Recovery Settings

5.4.g.i Recovery Times

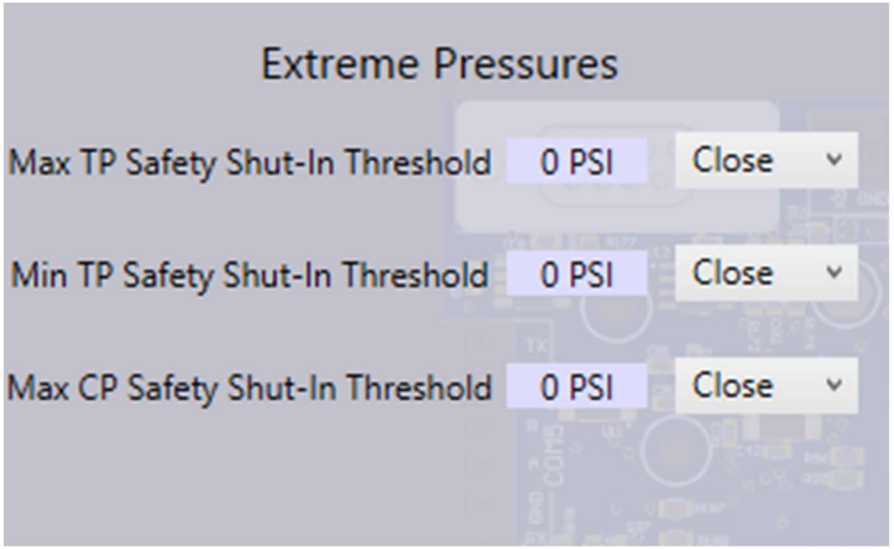
- Recovery Enable **(RECOV EN)**
  - If set to 1, the well will use the recovery state to build additional pressure if the recovery no arrival threshold is met
- Recovery Time **(RECOV CLOSE)**
  - the amount of time that the sales valve will remain closed for if recovery mode has been triggered
  - After this time, the well will being the closed state
- Initial Recovery Counter **(RECOV SETPOINT)**
  - when this threshold is reached, the well will move to recovery
- Current Recovery Counter **(RECOV CURRENT)**
  - The number of no arrivals that have occurred in a row

5.4.h Emergency Shutdown Configuration Tab

Set->ESD Settings

5.4.h.i Extreme Pressures

-
-
- Max Tubing Pressure Safety Shut-In Threshold **(MAX TP SHUT IN)**
    - If tubing pressure exceeds this maximum threshold, the well will go to ESD mode and wait for user intervention
    - Sales valve state is selectable between open and closed upon ESD entry due to this condition **(MAX TP AVLV)**
- Min Tubing Pressure Safety Shut-In Threshold **(MIN TP SHUT IN)**
    - If tubing pressure falls below this minimum threshold, the well will go to ESD mode and wait for user intervention
    - Sales valve state is selectable between open and closed upon ESD entry due to this condition **(MIN TP AVLV)**
- Max Casing Pressure Safety Shut-In Threshold **(MAX CP SHUT IN)**
    - If casing pressure exceeds this maximum threshold, the well will go to ESD mode and wait for user intervention.
    - Sales valve state is selectable between open and closed upon ESD entry due to this condition **(MAX CP AVLV)**

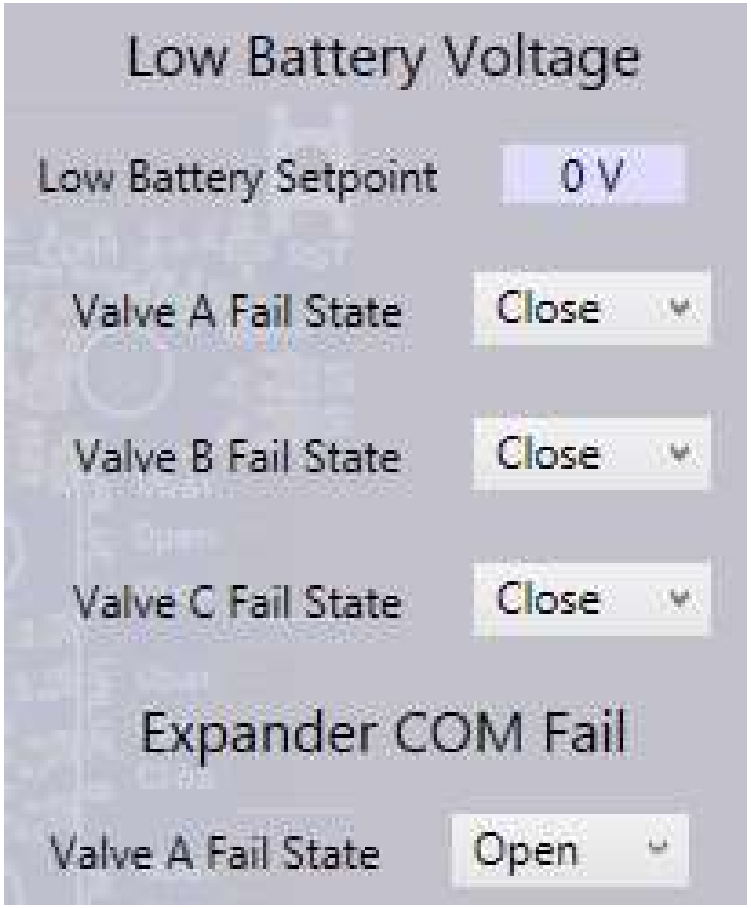


5.4.h.ii Unsafe Arrival Overrides

- Too Fast Arrival Time **(SAFE TIME)**
  - If a plunger arrives faster than this time, it is considered to be too fast and therefore unsafe due to the potential of lubricator/plunger damage
- Safety Shutdown Count **(MAX SAFE COUNT)**
  - If this many too fast arrivals occur in a row, the well will go to ESD mode and wait for user intervention
  - Sales valve state is selectable between open and closed upon ESD entry due to this condition **(SHUTDOWN MODE)**
- Current Safety Shutdown Count **(CURR SAFE COUNT)**
  - The number of too fast arrivals that have occurred in a row

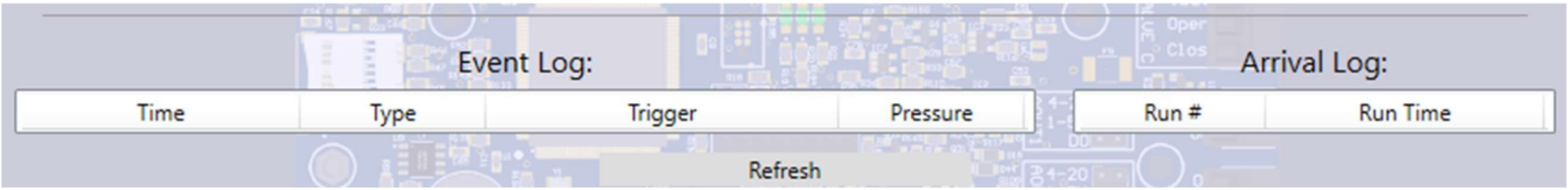
5.4.h.iii Low Battery Voltage / Expander COM Fail

- Low Battery Setpoint **(LOW BATT V)**
  - If the battery voltage falls below this setpoint, the well will go to ESD mode and wait for user intervention
  - The state of each digital valve is selectable between open and closed upon ESD entry due to this condition **(LOW BATT AVLV, LOW BATT BVLV, LOW BATT CVLV)**
- Expander COM Fail **(COM FAIL AVLV)**
  - If communication is lost with the expander, the expander's valve A will default to this state.



5.4.i Logging Configuration Tab

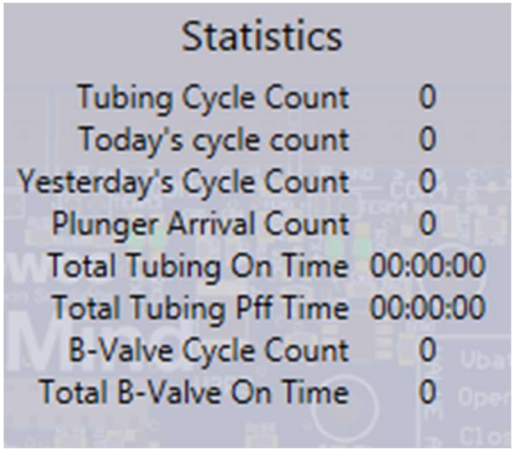
5.4.i.i Event and Arrival Logs



- The Event Log will display the last 25 events that have occurred, including power on and all state changes.
    - The date and time, event type, and trigger will be displayed for each event.
    - If a state change occurs because of a pressure override, the pressure value that triggered the override will be displayed.
- The Arrival Log will display the last 15 plunger run times, meaning the duration between the opening of the sales valve and the detection of the plunger by the arrival sensor.

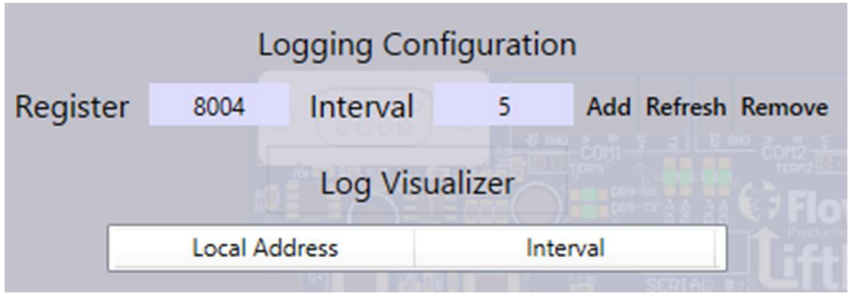
5.4.i.ii Statistics and Arrival History

- Tubing Cycle Count
  - Displays the total number of tubing cycles, as well as the number of cycles that have occurred so far in the current contract day and the number of cycles that occurred in the previous contract day
- Plunger Arrival Count
  - Displays the total number of arrivals that have occurred
- Total Tubing/B-Valve On/Off Time
  - Displays the total amount of time that the sales and B valves have been open and closed
- B-Valve Cycle Count
  - Displays the total number of B-Valve cycles



- Arrival History
  - Displays the number of fast, good, slow, and no arrivals that have occurred
- Average Run time
  - Displays the average of the last 15 plunger run times

5.4.i.iii Configurable Logging



The Apex offers configurable logging for any and all variables. Logging is simple to configure:

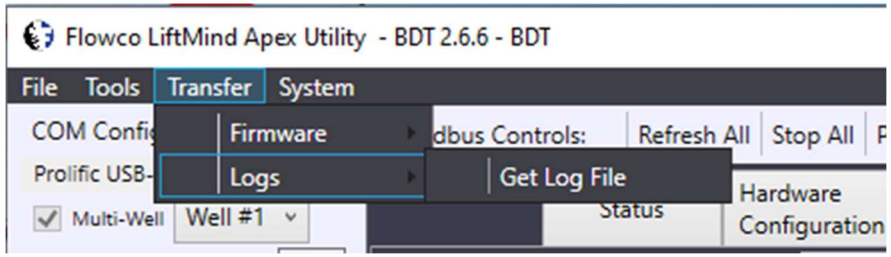
1. Simply enter the Modbus register of the data you would like to log
2. The interval (in seconds) at which to log the data.
3. Click the “Add” button.
4. Then, click “Refresh” button will display all registers that are configured to be logged for this well. To remove a variable from the logging configuration, simply enter the Modbus register number and click “Remove”.

A new log file is generated for each well each day. All logged variables are written to the same log file, allowing for easy analysis of simultaneously logged data.

The above example shows the Apex being configured to log Tubing Pressure every 5 seconds.

5.4.i.iv Log Visualization

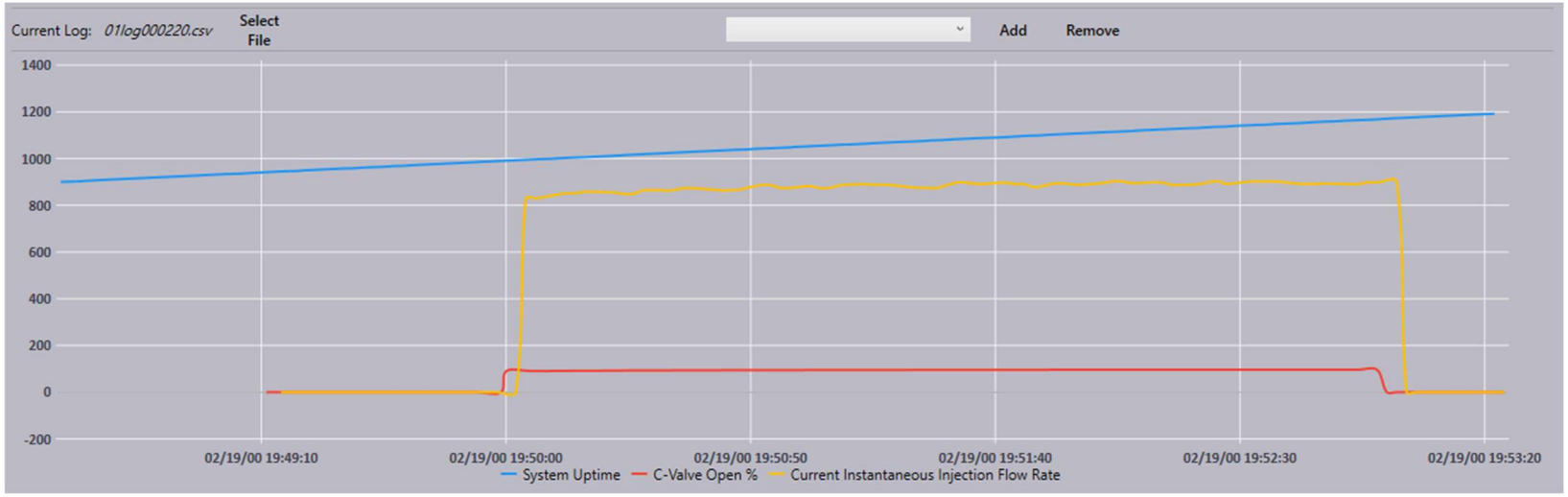
Before we try to visualize the data that the LM has recorded, we need to import the file on to our computer:



1. In the tool bar at the top right of the Utility App, go to Transfer/Logs/Get Log File.
2. Click the “Next File” button until you see the file that you want to download.
3. Once you have identified the file you want to grab from the LM, click the “Get This Log” button.
4. Select a folder to save it to.
5. You now have the CSV file saved to your computer.

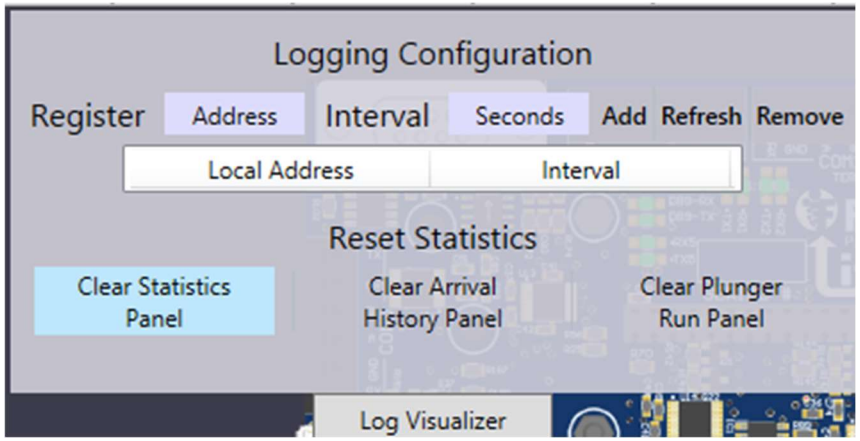
Log files can be graphed by using the Log Visualizer feature. The following steps will instruct you on how to configure this:

1. Click the “Log Visualizer” button.
2. Click the “Select File” button to select an Apex log file and graph its contents.
3. Individual variables can be added to or removed from the plot using the box at the top center of this window.



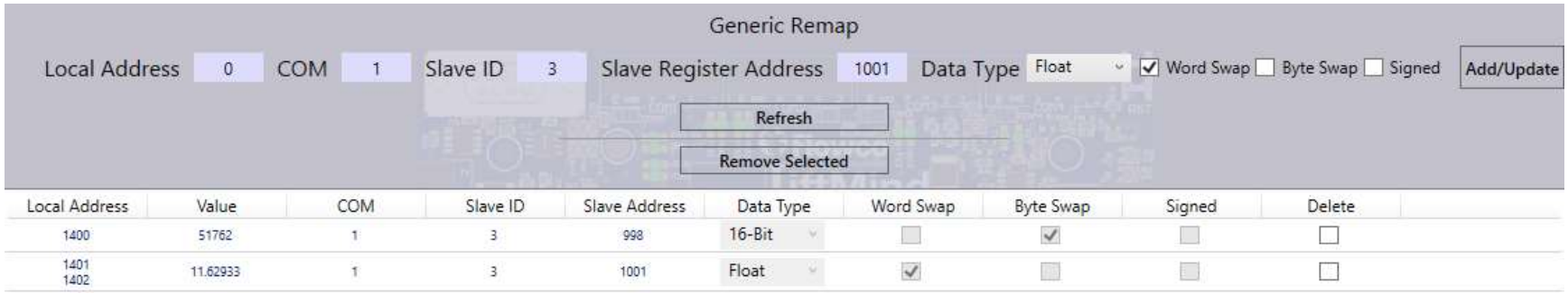
Here, a graph of logged data including System Uptime, C-Valve Open %, and Current Instantaneous Injection Flow Rate can be seen.

Log graphs can be zoomed in or out in time by scrolling the mouse wheel up or down. Hovering the cursor over a data point on the graph will display the precise value and timestamp of that data point.



Here is a picture of the Log Visualizer button located in the Logging Configuration panel.

5.4.j Register Mapping Configuration Tab



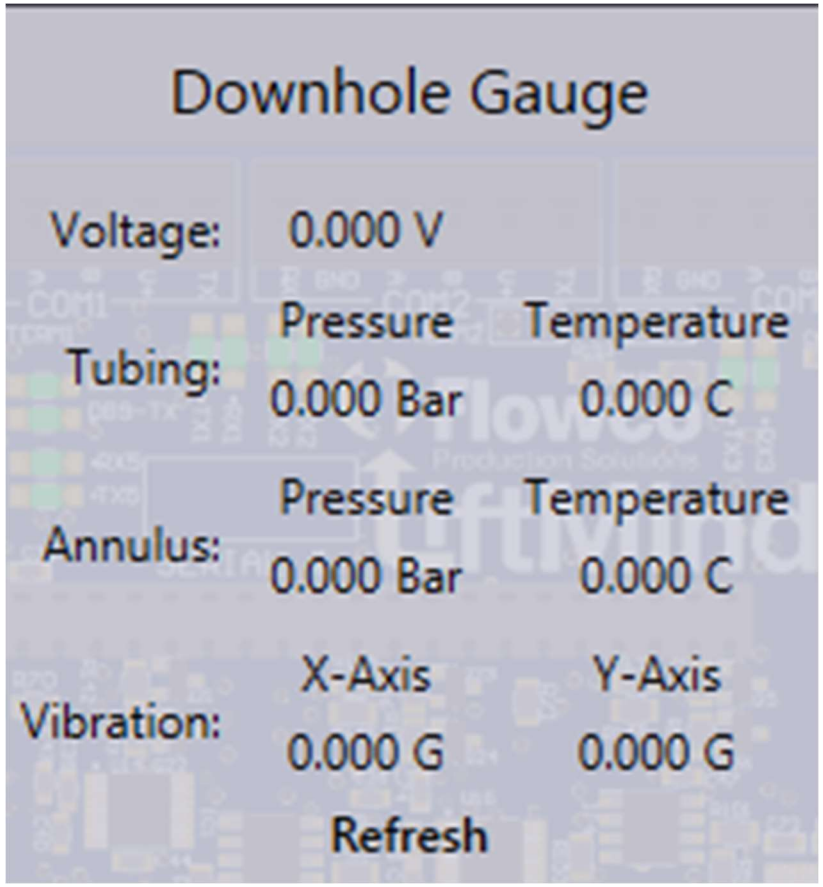
In addition to the numerous variables that can be acquired by the Apex as a Modbus RTU master, 100x general holding registers are available per well for logging and monitoring by Flowco's LiftSight SCADA platform or other devices. These registers can be read from the Apex for each well from registers 1400-1499.

Similar to the configurable logging functionality, these generic registers are configured by entering the register from the range above, COM port on which to find the target device, Modbus RTU slave ID of the target device, and the register to request from the slave. Options for data type / format are also provided. Click Add/Update to add a new remappable register or to modify an existing one. (Double-click on a grid row to autofill the entries for easier modification.) Clicking "Refresh" will display a list of all currently configured generically remappable register associations, while the "Remove Selected" button will remove the association from all the rows in which the "Delete" checkbox is checked.

If the data type selected is 32-bit or Float, two addresses will appear in a single cell in the Local Address column in the grid (as seen above with 1401 and 1402).

5.4.k Downhole Gauge Data Tab

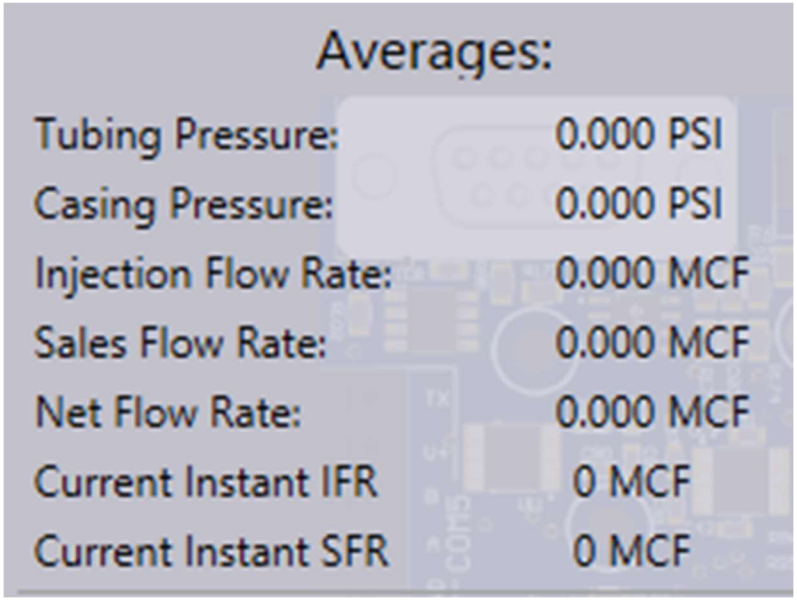
This tab displays real-time data retrieved from the Flowco Down Hole Gauge, including TEC Voltage, Tubing and Annulus Pressures and Temperatures, and X- and Y- Axis Vibration.



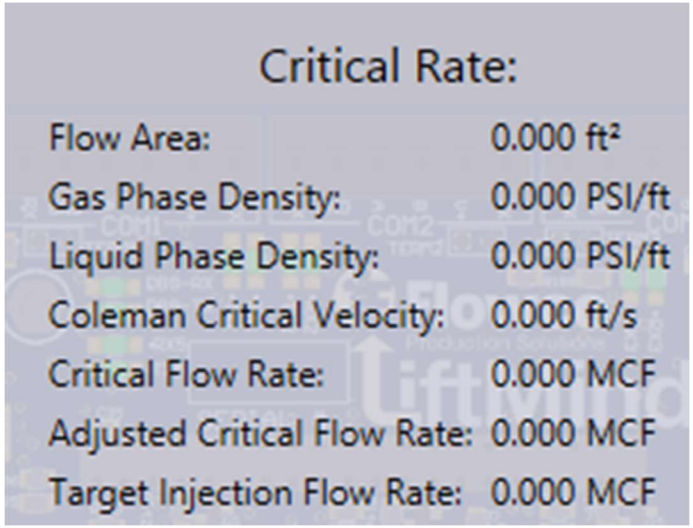
5.4.l Gas Lift Data/Configuration Tab

5.4.l.i Average Gas Lift Data

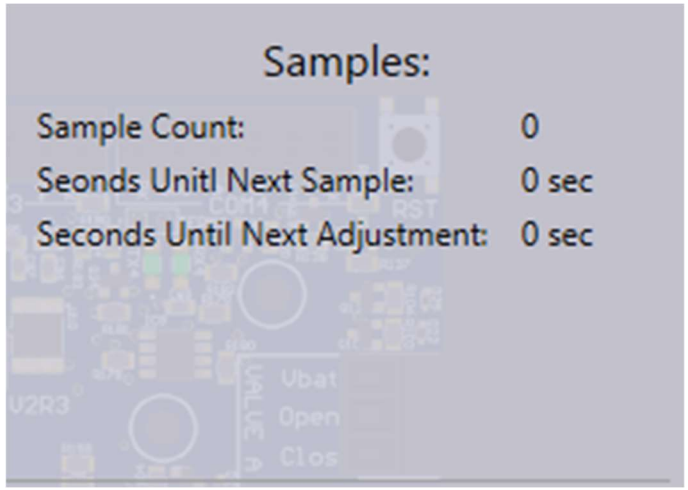
- This section displays the current running averages for variables relevant to Gas Lift operation



5.4.I.ii Critical Rate Gas Lift Data



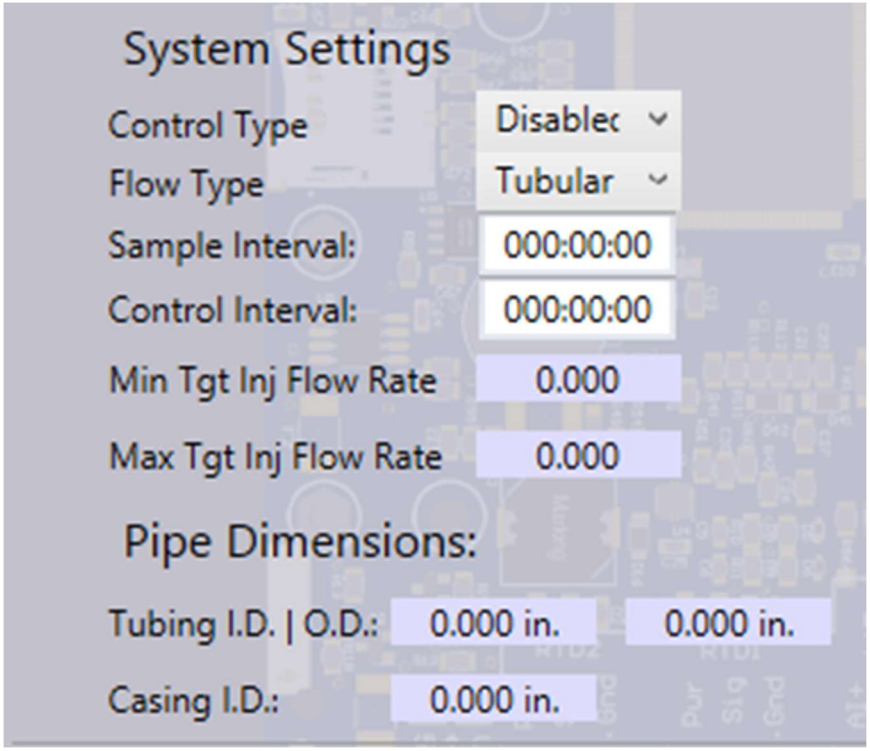
- This section displays live calculated data and parameters related to Gas Lift Optimization performed via the Flowco Critical Rate method.



- In addition, Sample Count and time remaining before the next sample and adjustment are also displayed here

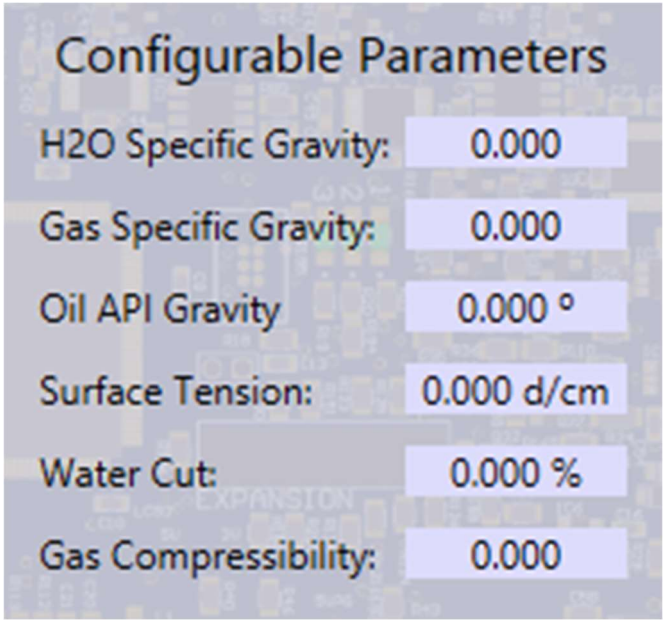
5.4.I.iii Gas Lift Main Configuration

- The Gas Lift control type can be selected between Disabled, Critical Rate, and Downhole
- Flow Type
  - Can be specified as Tubular or Annular
- Sample Interval
  - The amount of time that will elapse between consecutive gas lift data acquisition samples
- Control Interval
  - The amount of time that will elapse between consecutive gas injection rate adjustments
- A minimum and maximum flow rate can be specified in order to limit the adjustment that can be performed by the algorithm.
- Pipe Dimensions must be entered for the system to determine flow area. This is vital information for the Critical Rate Gas Lift optimization algorithm.

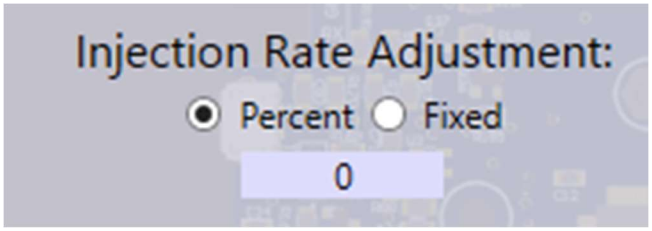


5.4.l.iv Gas Lift Critical Rate Configuration

-
-
-
-
- Specific Gravity of Water
    - Can be entered here or configured as a remote sensor on the Hardware tab
- Specific Gravity of Gas
    - Can be entered here or configured as a remote sensor on the Hardware tab
- API Gravity of Oil
    - Can be entered here or configured as a remote sensor on the Hardware tab
- Surface Tension
- Water Cut
- Gas Compressibility (Z Factor)

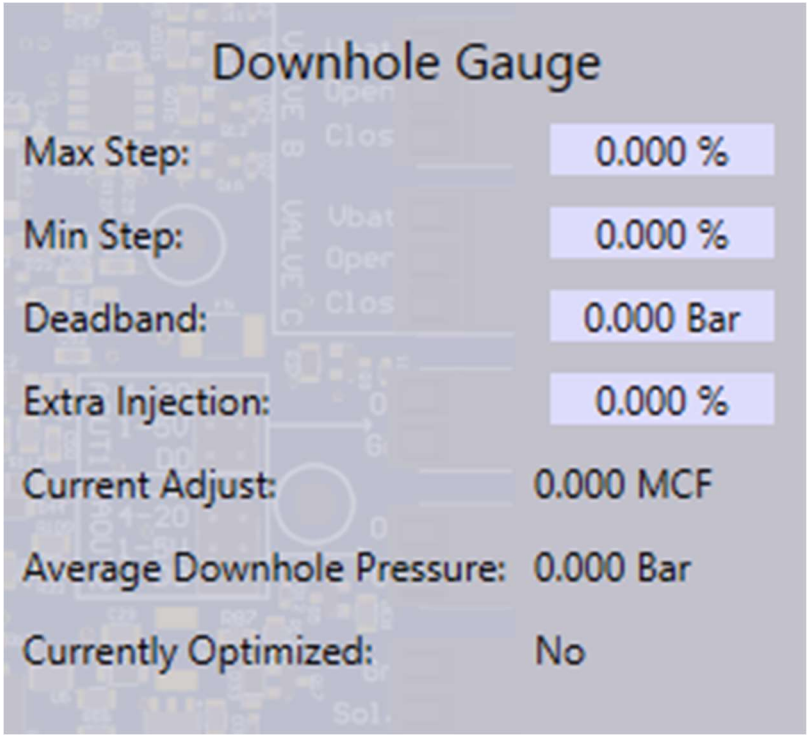


- Injection Rate Adjustment
    - Used to increase the calculated Flowco Critical Flow Rate to ensure well stability
    - Can be set as a percentage rate adjustment (i.e., inject an extra 10%) or a fixed adjustment (i.e., inject an extra 50 MCF)

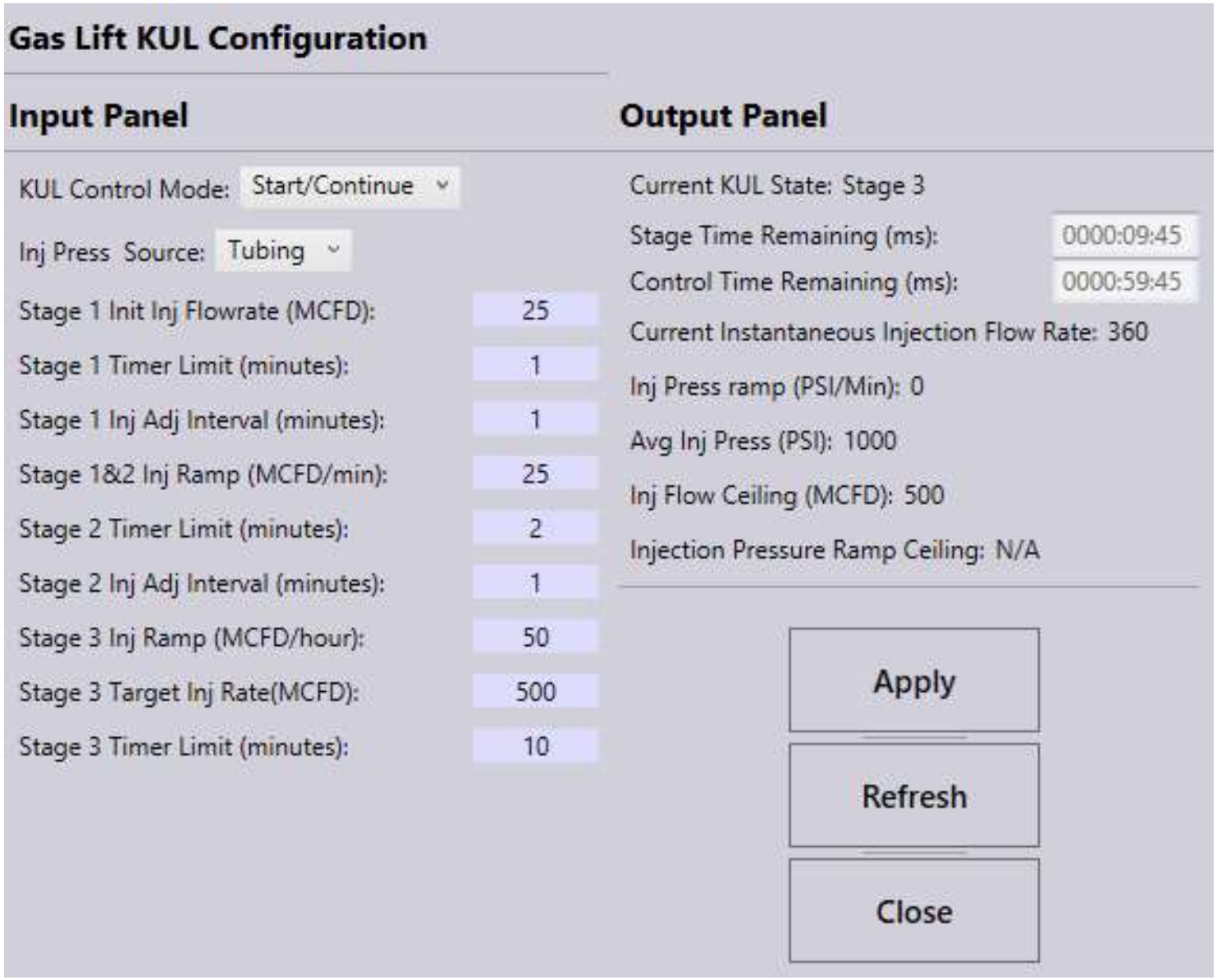


5.4.I.v Gas Lift Downhole Configuration

- Maximum Adjustment Step
  - The largest change that the well will make to the injection flow rate while searching for minimum bottomhole pressure
  - Recommended starting value is 50 % for rapid optimization
- Minimum Adjustment Step
  - The smallest change that the well will make to the injection flow rate while searching for minimum bottomhole pressure
  - Recommended value is 5% for minimum oscillation
- Deadband
  - Once the Gas Lift has been optimized using the downhole method, the optimization is considered to be lost if the bottomhole pressure deviates from the previously located minimum by this amount
- Extra Injection
  - Once the Gas Lift has been optimized using the downhole method, an additional injection percentage can be applied to ensure well stability on the Tubing Performance Curve
- Current Adjustment Step
  - Shows the current adjustment step percentage size
- Average Downhole Pressure
  - Shows the average bottomhole pressure during this averaging period
- Optimization Status
  - Shows whether the minimum bottomhole pressure has been achieved



5.4.l.vi Kick-Off / Unloading "KUL" Procedure Configuration



- KUL Control Mode (input):
    - Disable: Select to disable the KUL procedure. This option will also be automatically selected after completion of the KUL procedure to allow the normal gas lift algorithm to begin.
    - Reset: Default state. Will prevent normal gas lift algorithm from beginning while waiting for user to select Disable or Start.
    - Start/Continue: Begins the KUL process; also continues after pausing.
    - Pause: Pauses the KUL process. All timers are paused and no adjustments to the injection setpoint are made. Values used for injection pressure average and ramp calculations are preserved as-is across a paused period. Current injection flow and pressure are ignored during pause and are not used in average/ramp pressure calculations or as fulfilling conditions for transition to the next state.
- Inj Press Source (input): Choose Casing or Tubing as source for injection pressure for KUL procedure. During the KUL procedure only, the injection pressure will be read from modbus register 8002 or 8004 based on this selection, allowing user to either hardwire the injection pressure transducer into the casing/tubing analog input port or else update the modbus registers remotely.
- Current KUL State (output):
    - Not Started: KUL procedure has not been started. Transition to Stage 1 will begin after Control Mode is set to Start/Continue.
    - Stage 1: Designates that the KUL procedure is in Stage 1. Injection setpoint will be adjusted every control interval until the pressure ramp ceiling or flow ceiling is met. Will proceed to Stage 2 only after at least one of these ceilings has been met and the Stage 1 timer has expired.
    - Stage 2: KUL procedure in Stage 2. Same as Stage 1 except for potentially different values for the ceilings, control interval, and timer limit. Proceeds to Stage 3 when finished.
    - Stage 3: KUL procedure in Stage 3. Injection setpoint adjusted every hour until flow ceiling is met or until the injection line pressure has stabilized. The Done state will be entered after either of these conditions is met.
    - Done: KUL procedure finished. Control Mode will be automatically set to disabled which will allow the selected gas lift optimization mode (or fixed-setpoint mode) to begin.
- Stage Time Remaining (output): The amount of time remaining before the current stage timer expires. For Stages 1 and 2, this time must equal zero before transition to the next stage (provided the flow or pressure ramp ceiling has also been met). For Stage 3, when this time equals zero a determination will begin to be made on whether the injection pressure has stabilized. However, it is possible to transition to the Done state before this time equals zero in Stage 3 if the Stage 3 flow ceiling has been met.
- Control Time Remaining (output): The amount of time remaining before the next potential adjustment to the injection flow setpoint is made.

- Current Instantaneous Injection Flow Rate (output): The current injection flow rate as given by modbus register 8016: “remote injection flow rate”.
- Inj Flow Ceiling (output): The current injection flow ceiling. 250 MCFD for Stage 1, 350 MCFD for Stage 2, and a user-configurable amount for Stage 3 (Default 500 MCFD).
- Avg Inj Press (output): The average injection pressure (psi) as calculated from samples of the injection pressure taken every second. For Stages 1 and 2, the average pressure is updated at the end of every control interval provided that the injection pressure ramp ceiling has not been met. For Stage 3, the average pressure is updated at the end of every sample interval (every second) because the control interval timer for stage 3 is one hour long. For Stages 1 and 2, the last value after the ramp ceiling has been met is retained until overridden by the next Stage. For Stage 3, the last value after the pressure has stabilized is retained.
- Inj Press Ramp (output): For Stages 1 and 2 (provided the pressure ramp ceiling has not been met), corresponds to the current injection pressure ramp (psi/min) as calculated by subtracting the average injection pressure of the previous control interval from the average injection pressure of the current control interval and dividing by the control interval time. The first update during Stage 1 occurs on completion of the 2nd control interval. The first update during Stage 2 occurs on completion of the 1st control interval of Stage 2 (by using the average value from the last control interval of Stage 1 and dividing by the average of the control interval times of Stages 1 and 2). The last value after the ramp ceiling has been met is retained. Displays “N/A” for Stage 3.
- Injection Pressure Ramp Ceiling (output): The injection pressure ramp ceiling for Stages 1 and 2. Displays 3 psi/min for Stage 1, and 6 psi/min for Stage 2. Displays “N/A” for Stage 3.
- Stage 1 Init Inj Flowrate (input): The initial injection flow setpoint of the KUL procedure. Default: 25 MCFD. Resolution: 1MCFD. Max: 65535 MCFD (16 bits)
- Stage 1 Timer Limit (input): Guaranteed minimum time spent in Stage 1. Default: 180min = 3 hours. Resolution: 1min. Max: 65535 minutes (16 bits) = ~1092 hours = ~45 days.
- Stage 1 Inj Adj Interval (input): Stage 1 Control Interval. Time between potential adjustments to the injection flow setpoint during Stage 1. Default: 1min. Resolution: 1min. Max: 65535 minutes (16 bits) = ~1092 hours = ~45 days.
- Stage 1 & 2 Injection Ramp (input): The effective amount by which the injection flow setpoint is potentially adjusted each control interval during Stages 1 and 2. For example, if the control interval is set to 2 minutes, and the injection ramp is set to 25 MCFD/min, then every 2 minutes the injection flow setpoint will be potentially increased by 50 MCFD. Default: 25MCFD/min. Resolution: 1MCFD/min. Max: 65535 MCFD/min (16 bits).
- Stage 2 Timer Limit (input): Guaranteed minimum time elapsed from beginning of KUL procedure before exiting Stage 2. Default: 1440min = 24 hours. Resolution: 1min. Max: 65535 minutes (16 bits) = ~1092 hours = ~45 days.
- Stage 2 Inj Adj Interval (input): Stage 2 Control Interval. Time between potential adjustments to the injection flow setpoint during Stage 2. Default: 1min. Resolution: 1min. Max: 65535 minutes (16 bits) = ~1092 hours = ~45 days.

- Stage 3 Inj Ramp (input): The amount by which the injection flow setpoint is potentially adjusted each control interval during Stage 3. (The control interval for Stage 3 is fixed at 1 hour). For example, if the injection ramp is set to 50 MCFD/hour, then every hour the injection flow setpoint will be potentially increased by 50 MCFD. Default: 50MCFD/hour. Resolution: 1MCFD/hour Max: 65535 MCFD/hour (16 bits).
- Stage 3 Timer Limit (input): Minimum amount of time spent in Stage 3 for determining whether the injection pressure has stabilized. The injection pressure is considered stabilized if the currently measured injection pressure is within 5% of the average Stage 3 injection pressure and if Stage 3 has been active for an amount of time that is greater than or equal to the Stage 3 Timer Limit. Default: 360min = 6 hours. Resolution: 1min. Max: 65535 minutes (16 bits) = ~1092 hours = ~45 days.
- Stage 3 Target Inj Rate (input): The injection flow ceiling for Stage 3. The measured injection flow (as reported by modbus register 8016 “remote injection flow rate”) is compared against this ceiling.

5.6 Menu Bar

The Utility's Menu Bar allows the user to perform main system configuration, including Multi-Well setup, setting the onboard Real-Time Clock/Calendar, firmware upgrades, and downloading log files stored on the Apex's SD card.

5.5.a File Menu

Configuration Import/Export

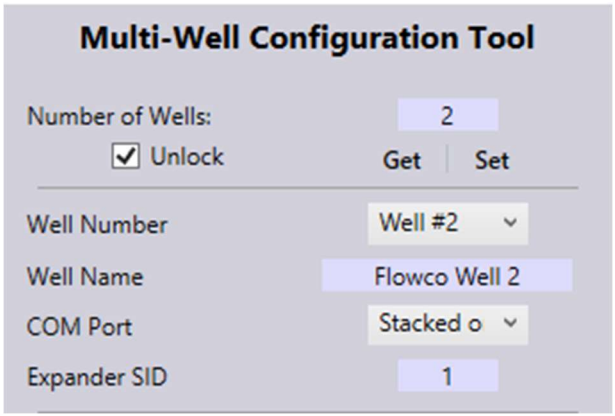
A configuration file can be exported for the current well by going to File > Import/Export > Export Well. The Utility will refresh all registers from the current well, and when done will save any registers that are not read-only, are not communication hardware related, and not a historical statistic or log entry. This file can be saved anywhere as a backup or to speed up the bring-up of similar wells by creating a template.

A configuration file can be loaded onto a well by going to File > Import/Export > Import Well. A file selection window will appear, and the user can navigate to where the backup/template configuration file is located. The Utility will load in the file and apply the register values to the current well. Note that COM port settings will need to be configured, as these settings are truly well-specific.

5.5.b Tools Menu

5.5.a.i Multi-Well Configuration

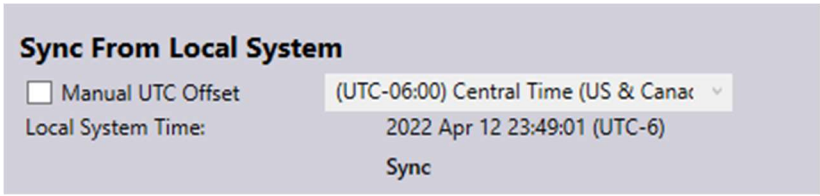
- Number of Wells: Sets the number of wells that will run on this Apex



- Subwell Configuration:
  - Well Number: Select the well to configure settings for
  - Well Name: Set the name of the well that will appear on the display
  - COM Port: Select the location of the expander associated with this well. Note that the selected Apex COM port must be configured as a Modbus RTU master with COM settings matching the Expander
    - Alternate options are “Stacked on Apex” for expanders connected directly to the Apex’s Expansion connector and “Virtual” for subwells that do not have a physical expander associated with them
  - Expander SID: Enter the Slave ID of this subwell’s expander. Typically, this will be set via the rotary switch on each expander.

5.5.a.ii Clock Configuration

- This window allows the Apex's onboard Real Time Clock and Calendar to be synchronized with the connected PC's current time and date.
- A manual UTC offset can be entered for installations that are in time zones different from the one the PC is configured in.
    - This would be especially relevant for wells that are being configured remotely in a different time zone.
- Upon connection to an Apex, the PC application will check the Apex's current RTC time. If the time is out of sync with the PC's clock by more than 10 minutes, the user will be prompted to synchronize the clock.



5.5.c Transfer Menu

5.5.b.i Firmware Updates

The Firmware item in the Transfer Menu allows the Utility to upload firmware updates to an Apex and its connected expanders.

To update the Apex:

- Ensure that you have the latest Apex binary file saved to an easily accessible location on your computer. **The file must not be in a compressed or zipped folder!**
- Click Transfer->Firmware->Update Apex. A file selection dialog will open, allowing you to select only binary files.
- Navigate to the new firmware file and click Open
- The transfer will now begin and a progress bar will appear. After several minutes, the window will show “Transfer Complete” or “Transfer Failed”. If the transfer has failed, simply retry. If the transfer completed, reboot the Apex to apply the update.

To update Expanders connected to the Apex:

- Follow the steps above, except click Transfer->Firmware->Update Apex Expander.
- This will transfer the new expander firmware to the Apex’s storage, which will then automatically forward and apply the update to each connected expander. No further action is required from the user.
- Due to the limited connection bandwidth and other ongoing Modbus RTU traffic, Expander firmware updates take approximately **30-60 minutes per expander** AFTER the progress bar indicates that the transfer has completed. It is recommended that no further configuration be performed until confirming that all expanders have been successfully updated.

Following a firmware update, use the System menu for each subwell to confirm that the updates have applied successfully.

5.5.d System Menu

5.5.d.i Device Management

- Clicking “Reboot Device Now” will cause LiftLink to issue a command to the Apex to reboot.
- Check “Display Sleep Enable” to enable sleep mode on the Apex. When enabled, the Apex will turn off the display to save power. Pressing any key (except open/close) on the HMI, will cause the display to turn back on for a duration corresponding to “Sleep Delay”
- Uncheck “AO1 1-5V Enable” or “AO2 1-5V Enable” to disable the Apex AO1 1-5V or AO2 1-5V Analog Out circuitry. Provided the 1-5V analog output is not needed, disabling it can reduce power consumption considerably.

6. Hardware overview

Please see I/O port drawings for each board for detailed connector pinout and location.

6.2 Analog Input Ports

There are 3 analog inputs. (Tubing, Casing and Line) These ports have 3 pins, and provide power and ground to the sensor, as well as a return for the analog signal representing pressure. The pin labeled “AI+” is the power pin to the analog sensor and can be selected via the “AI-PWR” jumper to be either 5V regulated or system voltage (battery). The pin labeled “Sig” is the analog signal return. Each port must be connected to its corresponding sensor for correct operation.

6.3 Plunger Arrival Input Port

The plunger arrival sensor port should be connected the plunger arrival sensor. It provides battery power on the “Vbat” pin and the return signal on “Sig”. The signal input is compatible with open collector type arrival sensors, including the Flowco Magnetic arrival sensor and tri coil sensor families.

6.4 Valve Output Ports

The valve output ports are intended to be used with a latching valve. Each port has a Vbat pin for providing system power to the valve, as well as an open and close pin which is an open collector to ground. The ports can sink up to 1A of current.

6.4.1 Auto-Catcher Latch (ACL) Port

The Valve-C output port on V24 hardware can also be used for ACL functionality. The pin labelled “2” corresponds to “OPEN Valve-C/ENGAGE ACL” and the pin labelled “1” corresponds to “CLOSE Valve-C/DISENGAGE ACL”.

The pin labelled “+” has different functions depending on whether the jumper “ACL PWR” is installed or not. With the jumper **installed**, the “+” pin acts just as the “Vbatt” pin on Valve-A/B (described above in 6.3). With the jumper **removed**, external power for driving the ACL motor can be applied to the “+” pin. If using external power, the external power ground wire should be connected to an available Apex ground connection.

ONLY APPLY EXTERNAL POWER IF THE JUMPER IS REMOVED. DO NOT APPLY EXTERNAL POWER IF THE JUMPER IS INSTALLED OR DAMAGE MAY RESULT.

Max external power voltage: 24V. Max current: 1A.

Diodes may need to be wired into the ACL actuator for proper operation. Consult FlowCo for actuator-specific wiring/compatibility.

6.5 Analog Output Ports

The analog output port is intended to be used with 4-20mA valves, but can also be used for 1-5V output or as an additional DO valve output. The AO1 and AO2 jumpers select the mode of each output pin (1 and 2) on the port.

6.6 RTD

The RTD port is a standard 3 wire PT-100 RTD input port. It provides 3.3V on the power pin and monitors the return on the Sig pin.

6.7 Serial Ports

There are 3 COM ports on each Expander. These COM ports can be used in either RS-232 or RS-485 modes. Either mode can be entered by connecting the wires the correct terminals on the 6 pin COM Port. Only 1 mode can be used at any given time per port. These ports can be operated at baud rates from 9600 to 230400. Full configuration of what each port is connected to is done through the PC utility. The Apex features 2 additional COM ports as well as a sixth RS-232-only port available on the DB9 connector.

6.8 Expander Port

The expander port on the Apex is for use with Flowco Expander boards for additional local well control. No other devices should be used in this port.

6.9 Memory

6.9.1 SD Card

The Apex has a single micro-SD card slot. This memory card (if installed) can be used for logging well data. Logging configuration can be performed with the Flowco LiftLink.

6.9.2 Internal Memory

The internal memory of the Apex can also be used for data storage. 4MB of data can be stored to the internal memory. The data stored to the internal memory is configurable by the user in the logging menu of the Flowco LiftLink.

6.10 DC Power Input

6.10.1 Battery Power

The Apex can be powered from a 6V, 12V, or 24V cell through the 4 pin power connector using the Gnd and Batt pins.

If using a 6V or 12V power system, the on board battery charger can be used. **Batt Sel** should be selected at the correct voltage level. This jumper sets the on board battery voltage for the batter charger if used.

6.10.2 Solar Power

The Apex has an on board solar charger, intended for small solar plants/battery banks. It is only recommended for use in single well applications. An external solar charger should be used if more power is required.

Solar Panel Voc : 18V

Apex Charger Imax: 2A