**Bulk Dispense System User Guide**

**Table of Contents**

1. **System Overview**
2. **Setup and Configuration**
   * **Hardware Setup**
   * **Network Configuration**
3. **System Commands**
   * **Command Overview**
   * **Complete Command List**
   * **Commonly Used Commands for Normal Operation**
4. **Step-by-Step Workflows**
   * **Get Help**
   * **Prime Reagent Lines**
   * **Dispense Reagents**
   * **Stop Dispensing**
   * **Fill and Stop Filling Troughs**
   * **Drain and Stop Draining Troughs**
   * **Get System State**
   * **Set System to Idle**
5. **Monitoring and Troubleshooting**
   * **System State Monitoring**
   * **Real-Time Serial Output Example**
   * **Common Issues and Resolutions**
6. **Maintenance**
   * **Daily Checks**
   * **Post-Experiment Cleaning**
   * **Configuration Adjustments**
   * **Caution**

**1. System Overview**

The **Bulk Dispense System** is a prototype instrument designed to enable automated workflows on a liquid handling robotic system that requires bulk reagent for their process. This system is designed to integrates with liquid handlers to streamline fluid operations, including:

* **Dispensing Reagents**: Automatically dispenses specified volumes of reagents into troughs on liquid handler decks.
* **Waste Management**: Utilizes vacuum-assisted waste bottles for efficient drainage and disposal of liquid waste.
* **Real-Time Monitoring**: Operated via an intuitive command-line interface (CLI) to track system states, issue commands, and manage workflows.

Several containers with wires

Description automatically generated with medium confidence

Figure 1: "Bulk Dispense System Positioned under a Liquid Handling Robot."

**2. Setup and Configuration**

**Hardware Setup**

Before using the Bulk Dispense System, verify the following hardware connections and configurations:

1. **Reagent System Setup**:
   * Fill the reagent bottles with the desired reagents.
   * Secure the bottle caps and ensure all tubing is free of kinks or blockages to maintain consistent reagent flow.
   * Connect the system to a compressed air source capable of providing up to 100 PSI.
2. **Waste Management System**:
   * Ensure waste bottles are empty and securely attached to the system.
   * Verify that waste bottle overflow sensors are correctly installed.
   * Connect the vacuum port to an external vacuum source to enable waste drainage.
3. **Power Connection**:
   * Connect the system to a stable power source using the AC/DC Desktop Adapter (24V, 120W).
4. **Liquid Handler Integration**:
   * Position reagent troughs on the liquid handler deck.

Several white rectangular objects on a table

Description automatically generated

Figure 2: Reagent troughs positioned on the liquid handler deck, ready for operation.

**Network Configuration**

To access the Bulk Dispense System remotely, configure your network and connect via the following steps:

1. **Network Identification**:
   * **IP Address**: 192.168.0.13 (Port 8080).
   * **MAC Address**: 00:01:FC:8D:CF:CE.
2. **Command-Line Access**:
   * Use a terminal application (e.g., PuTTY) to connect to the system via Serial or TCP/IP communication.
   * Enter the system's IP address and port to establish a connection.

**3. System Commands**

**Command Overview**

The Bulk Dispense System operates using a command-line interface (CLI), which allows users to execute various commands for monitoring and controlling the system. Below are two tables summarizing the full list of available commands:

**Complete List of Commands**

| **Command** | **Syntax** | **Description** |
| --- | --- | --- |
| **Dispense Reagent** | D <1-4> [volume] | Dispenses reagent into a trough (volume optional for continuous dispensing). |
| **Drain Trough** | DT <1-4> | Drains the specified trough into the waste system. |
| **Stop Draining** | SDT <1-4> or SDT all | Stops draining the specified trough or all troughs. |
| **Fill Trough** | F <1-4> or F all | Starts filling the specified trough or all troughs. |
| **Stop Filling** | SF <1-4> or SF all | Stops filling the specified trough or all troughs. |
| **Set Reagent Valve** | R <1-4> <0/1> | Opens or closes reagent valves for manual control. |
| **Set Media Valve** | M <1-4> <0/1> | Opens or closes media valves for manual control. |
| **Set Waste Valve** | W <1-4> <0/1> | Opens or closes waste valves for manual control. |
| **Prime Valves** | P <1-4> or P all | Primes valves by flushing liquid through the system until liquid is detected. |
| **Check System State** | SS | Retrieves the current state of the system, including valve and sensor states. |
| **Set Pressure Valve** | PV <percentage> | Sets the position of the pressure control valve (0% to 100%). |
| **Reset Flow Sensor** | RF <1-4> or RF all | Resets the flow sensor for the selected valve(s). |
| **Idle System** | idle | Puts the system in a safe idle state. |
| **Check Trough State** | TS <1-4> | Checks whether the specified trough is full or not. |
| **Log Frequency** | LF <milliseconds> | Sets the logging interval for system. |
| **Print Help** | H, h, help | Displays a list of available commands and their usage. |
| **Device Info** | DI | Prints system device information (e.g., IP address, MAC address). Only available for Serial communication |

**Commonly Used Commands for Normal Operation**

| **Command** | **Syntax** | **Description** |
| --- | --- | --- |
| **Dispense Reagent** | D <1-4> [volume] | Dispenses reagent into a specified trough. |
| **Drain Trough** | DT <1-4> | Drains the specified trough. |
| **Stop Draining** | SDT <1-4> | Stops draining for the specified trough. |
| **Idle System** | idle | Puts the system in a safe idle state. |
| **Check System State** | SS | Retrieves the current system state, including valve statuses. |
| **Prime Valves** | P <1-4> or P all | Primes valves by flushing liquid until liquid is detected. |
| **Print Help** | H, help | Displays a list of available commands and their usage. |
| **Fill Trough** | F <1-4> or F all | Starts filling the specified trough or all troughs. |
| **Stop Filling** | SF <1-4> or SF all | Stops filling the specified trough or all troughs. |

**4. Step-by-Step Workflows**

**4.1 Getting Help**

**Command:** H or help  
**Action:** Displays a list of all available system commands and their usage examples.

**Example:**  
**Command:** H  
**Output:** Provides a detailed list of commands and their functionalities.

**4.2 Prime Reagent Lines**

**Command:** P <1-4> or P all  
**Action:** Flushes reagent lines until liquid is detected, ensuring lines are free of air bubbles.

**Examples:**

1. **Prime Reagent Line for Trough 1**  
   **Command:** P 1  
   **Action:** Starts priming the reagent line connected to Trough 1.
2. **Prime All Reagent Lines**  
   **Command:** P all  
   **Action:** Flushes all reagent lines until liquid is detected.

**4.3 Dispensing Reagent**

**Command:** D <1-4> [volume]  
**Action:** Dispenses reagent into the specified trough. Volume can be specified (in mL) or omitted for continuous dispensing.

**Examples:**

1. **Dispense 50 mL into Trough 1**  
   **Command:** D 1 50  
   **Action:** Dispenses 50 mL of reagent into Trough 1.
2. **Continuous Dispensing into Trough 2**  
   **Command:** D 2  
   **Action:** Starts continuous dispensing into Trough 2.

**4.4 Stop Dispensing**

**Command:** SD <1-4> or SD all  
**Action:** Stops dispensing for the specified trough or all troughs.

**Examples:**

1. **Stop Dispensing into Trough 3**  
   **Command:** SD 3  
   **Action:** Stops dispensing into Trough 3.
2. **Stop Dispensing for All Troughs**  
   **Command:** SD all  
   **Action:** Stops dispensing for all active troughs.

**4.5 Filling Troughs**

**Command:** F <1-4> or F all  
**Action:** Starts filling the specified trough or all troughs.

**Examples:**

1. **Fill Trough 4**  
   **Command:** F 4  
   **Action:** Begins filling Trough 4 with reagent.
2. **Fill All Troughs**  
   **Command:** F all  
   **Action:** Starts filling all connected troughs.

**4.6 Stop Filling Troughs**

**Command:** SF <1-4> or SF all  
**Action:** Stops filling the specified trough or all troughs.

**Examples:**

1. **Stop Filling Trough 2**  
   **Command:** SF 2  
   **Action:** Stops filling Trough 2.
2. **Stop Filling All Troughs**  
   **Command:** SF all  
   **Action:** Stops filling all troughs.

**4.7 Draining Troughs**

**Command:** DT <1-4>  
**Action:** Drains liquid waste from the specified trough into the waste system.

**Examples:**

1. **Drain Trough 3**  
   **Command:** DT 3  
   **Action:** Drains liquid waste from Trough 3.
2. **Stop Draining Trough 1**  
   **Command:** SDT 1  
   **Action:** Stops draining operations for Trough 1.
3. **Stop All Draining Operations**  
   **Command:** SDT all  
   **Action:** Stops draining operations for all active troughs.

**4.8 Check Current System State**

**Command:** SS  
**Action:** Outputs the current state of all valves, sensors, and other system components.

**Example:**  
**Command:** SS  
**Output:** Displays detailed system state information, including valve positions, sensor statuses, and system activity.

**4.9 Put System in Idle State**

**Command:** idle  
**Action:** Puts the system in a safe idle state by halting all operations, closing all valves, and ensuring safety.

**Examples:**  
**Command:** idle  
**Action:** Stops all ongoing activities and resets the system to its idle state.

1. .

**5. Monitoring and Troubleshooting**

**5.1 System State Monitoring**

The Bulk Dispense System can be monitored to track valve states, sensor readings, and operational status. This is achieved using the SS (System State) command, which provides detailed information about the system's current state, including states such as **Idle**, **Dispensing**, **Filling**, **Draining**, or a combination of these operational modes.

**System State Output Details**

* **Valve States**: Displays the open/closed status of reagent, media, and waste valves.
* **Sensor Readings**: Outputs the status of overflow sensors, vacuum sensors, and pressure sensor feedback.
* **Operational Status**: Indicates if the system is dispensing, filling, or draining.

**Example System State Output:**  
*Command:* SS  
*Action:* Displays the current system state.

System State: Idle

=== Additional System Info ===

Pressure Valve (PV%): 0.13%

Pressure Sensor (PS1): 0.00 psi - Pressure Level: Insufficient

Reagent Valves:

1: Closed 2: Closed 3: Closed 4: Closed

Media Valves:

1: Closed 2: Closed 3: Closed 4: Closed

Waste Valves:

1: Closed 2: Closed 3: Closed 4: Closed

Trough Fill Mode State:

1: Not in Fill Mode 2: Not in Fill Mode 3: Not in Fill Mode 4: Not in Fill Mode

Trough Dispensing State:

1: Not Dispensing 2: Not Dispensing 3: Not Dispensing 4: Not Dispensing

Trough Draining State:

1: Not Draining 2: Not Draining 3: Not Draining 4: Not Draining

Trough State:

1: Not Full 2: Not Full 3: Not Full 4: Not Full

Bubble Sensors (Primed Status):

1: Primed 2: Primed 3: Primed 4: Primed

Waste Bottle Liquid Level Status:

Bottle 1: Not Full

Bottle 2: Not Full

Waste Bottle Vacuum State:

Bottle 1: No Vacuum

Bottle 2: No Vacuum

**Note**: The example above is an idle system. Active states will show valves opening or closing, filling or draining statuses, and pressure sensor activity.

**5.2 Monitoring Methods**

System monitoring varies based on the connection type:

1. **Serial RS-232 Communication**
   * **Configuration**:
     + Baud Rate: 115200
     + Line Ending: LF (Line Feed)
     + Data Bits: 8
     + Stop Bits: 1
     + Parity: None
   * **Functionality**:
     + Displays a live running log of system activity in the serial stream.
     + Allows sending the SS command for detailed system status.
   * **Example Serial Log:**  
     [12:34:15:123] ---- Sent utf8 encoded message: "D 1 50\n" ---- [12:34:15:567] Reagent valve 1 opened. Dispensing 50 mL into Trough 1. [12:34:16:891] LOG,STATE,2,RV,1000,MV,0000,WV,0000,BS,1111,OV,0000,PV,1.20,PV%,15.0,PS1,20.00,DS,1000,TDS,1000,WLS,00,WBS,00,WBVS,00
2. **TCP/IP Connection**
   * **Configuration**:
     + IP Address: 192.168.0.13
     + Port: 8080
   * **Functionality**:
     + System state can only be queried by sending the SS command.
     + No continuous logging available via TCP/IP.

**5.3 Common Issues and Resolutions**

1. **Reagent Line Not Primed**
   * **Issue**: Reagent line has air bubbles or is not dispensing correctly.
   * **Solution**: Run the P <trough> or P all command to prime the affected lines.
2. **Overflow Detected**
   * **Issue**: Waste bottle is full, preventing further draining or dispensing operations.
   * **Solution**: Check and empty the waste bottles if necessary.
3. **Commands Not Executing**
   * **Issue**: CLI commands are unresponsive or not functioning as expected.
   * **Solution**: Power cycle the system.

**6. Maintenance**

**Daily Checks**

1. Inspect all tubing and connections for any signs of leaks or blockages.
2. Ensure that reagent bottles contain enough solution to complete your experiment without interruptions.
3. Verify that waste bottles have sufficient capacity to handle the waste generated by your experiment to avoid issues during drainage operations.

**Post-Experiment Cleaning**

* For experiments using viscous reagents or solutions containing salts or sugars:
  + Fill the reagent troughs with warm water.
  + Execute the drain command (DT <trough>) at least twice to flush the troughs, drain lines, and valves, preventing crystallization or clogging.

**Configuration and Setup Recommendations**

1. **Origin Adjustments**:
   * Perform origin adjustments for all reagent lines that will be used for an experiment. Detailed instructions can be found in the *System Flow Sensor Configuration with NQ Sensor Monitor Software* section of the System Wiring Diagram.
2. **Kinematic Viscosity Configuration**:
   * For fluids that are significantly more viscous than water, set the appropriate kinematic viscosity parameters. Instructions for this process are also outlined in the System Wiring Diagram.

**Caution**

* The glass reagent bottles used in the Bulk Dispense System are specially rated for pressure-based dispensing. These bottles are designed to handle the pressures required during dispense operations. **Do not substitute with non-rated bottles**, as they may fail under pressure, leading to system damage or safety hazards.

**Appendix**

**Plumbing and Wiring**

* **Plumbing Diagrams**:
  + Reagent Dispense Line
  + Waste Line
* **Wiring Diagrams**:
  + Bulk Dispense System Wiring

**Bill of Materials**

Refer to the provided BOM document for detailed component specifications.