Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 70-25

Chlorine Sequenced Vacuum System – Control Function Description

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REVISION 1

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REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	**VER./ REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
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DESIGN STANDARD DS 70-25
Chlorine Drum Sequence Vacuum Systems – Control Function Description

CONTENTS

1 Definitions

DCIP	Drum Controller Interface Panel
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition (system)
RTU	Remote Terminal Unit
PID	Proportional, Integral and Derivative (controller)
Modbus	Generic Communications Protocol

2 Introduction

Chlorine sequence systems are used widely within the Water Corporation at chlorine facilities with high chlorine gas demands. In the past a number of variants of PLC logic have been implemented at different sites. This document has been written to bring consistency to all the future chlorine sequence vacuum system designs.

3 Scope

The scope of this document is to outline the functionality of the chlorine drum/cylinder sequence system within the chlorine storage room and its interaction with other system parts within the chlorine storage room. This document is not intended to be used as a user manual, but rather describes how the control of each piece of equipment should operate within the chlorine storage room of a chlorine sequenced vacuum system.

The functionality of the chlorine sequence system is applicable to both drum and cylinder configurations. Sequenced vacuum chlorine cylinder systems are rarely used as the tendency is to use drums when the chlorine demand is higher than a single chlorine cylinder can supply, but in specific circumstances buffer considerations may favor the use of a sequenced cylinder system.

It should be noted that this standard has been written for a system consisting of 12 drums. The actual number of drums (or cylinders) is determined according to the project needs. Similar logic/terminology can be applied for systems comprising either fewer or more than 12 drums.

Chlorine storage room heaters can be used to reduce the number of drums or cylinders required, although this is not covered in this standard.

4 Reference Documents

The tag numbers used in this functional specification have been taken from the Water Corporation's Design Standard P&IDs for Chlorination Systems with the following drawing numbers:

- EO28-60-80.12
- EO28-60-80.13

The following logic diagrams are also referred to within this document:

- EO28-61-10.1
- EO28-61-10.2
- EO28-61-10.3
- EO28-61-10.4
- EO28-61-10.5

- EO28-61-10.6
- EO28-61-10.7

5 Communications Interface (SCADA RTU)

The standard chlorination package has a communications interface to provide indication and control to clear SCADA. For Ethernet connected devices Modbus protocol is used.

All indications are always available at the SCADA HMI but control of the drum store can either be local or remote controlled. A selector on the DCIP toggles between local and remote. When in local mode all control operations are changed or initiated from the DCIP. In local mode the system will ignore commands from SCADA HMI. When in remote mode control operations are changed or initiated from the SCADA HMI. In remote mode the system will ignore commands from the DCIP (other than the local / remote toggle).

6 Analogue Values

Table 6-1 summarizes the analogue inputs from the chlorine drum storage room that will be connected to the PLC and scaled internally. The PLC analogue input is configured for 4 to 20 mA. Should the analogue signal drop below 3.5mA for 60 seconds an analogue failure alarm is generated for the specific input. The analogue input signal is also damped using a first order filter.

Table 6-1: Analogue Inputs

Tag Number	Item
AE80140A	Cell 1 leak detector – chlorine store
AE80140B	Cell 2 leak detector – chlorine store
AE80140C	Cell 3 leak detector (5-100ppm) – chlorine store
AE80140D	Cell 4 leak detector – chlorination room
WE80101	Drum 1 weight
WE80102	Drum 2 weight
WE80103	Drum 3 weight
WE80104	Drum 4 weight
WE80105	Drum 5 weight
WE80106	Drum 6 weight
WE80201	Drum 7 weight
WE80202	Drum 8 weight
WE80203	Drum 9 weight
WE80204	Drum 10 weight
WE80205	Drum 11 weight
WE80206	Drum 12 weight
PIT80111	Chlorine Manifold Vacuum
PIT80211	Chlorine Manifold Vacuum

7 Drum Sequencing

7.1 System Description

The chlorine storage consists of multiple drums manifolded together on a common header so that any combination of drums can supply any combination of chlorinators (Refer EO28-60-80.12 and EO28-60-80.13).

Table 7-1 describes the equipment, instrumentation and valves in chlorine drum set 1. For drum sets 2 to 6 on P&ID EO28-60-80.12, the same equipment, instrumentation and valves but with sequential tag numbers applies. Similar numbering is used for drum sets 7 to 12 (as shown on EO28-60-80.13).

Table 7-1: Drum 1 Tag Numbers and Equipment / Instrumentation / Valve List

Tag Number	Item for Chlorine Drum 1
VA80121	Drum Isolation Valve– manual valve utilized during drum replacement and purging operations
VA80131	Vacuum Regulator Valve– regulates vacuum pressure for delivery of chlorine gas
VA80101	Drum Changeover Valve– motorized valve that operates to isolate the drum and vacuum regulator.
PI80101 PSL80101	Drum Gas Pressure Indicator (with integrated Low Drum Gas Pressure Switch) – provides visual indication of drum gas pressure whilst the pressure switch initiates on low pressure, reflecting an empty drum.
WE80101	Drum Weighing Scale – provides visual indication of contents of drum and is also used to optimize the number of drums online where chlorine supply exceeds demand.
FI80101	Drum Outlet Flow Indicator – rotameter providing indication of gas flow.
ZZL80121	Drum emergency shutoff device – closes Drum Isolating Valve VA80121 in the event of a 5ppm leak alarm.
HS80101A	Drum Online/Standby toggle
HS80101B	Drum Disable/Enable toggle

Each drum has four states, as follows:

- DISABLED: Drum off-line, the respective drum changeover valve is closed and not available for automatic control. When in DISABLED state, the drum is isolated from the perspective of the control system and ignored in any sequences.
- STANDBY: Drum offline, the respective drum changeover valve is closed but is available for automatic control if the controller determines that the drum is required to be brought online (or the drum is manually brought online using the respective Online/Standby toggle switch). The STANDBY state is one of the three ‘ENABLED’ states.
- ONLINE: Drum changeover valve is open and under automatic control. The ONLINE state is one of the three ‘ENABLED’ states.
- EMPTY: Drum off-line, drum changeover valve is closed and under automatic control, however the low pressure switch on the vacuum regulator has latched indicating that the drum is empty. The EMPTY state is one of three ‘ENABLED’ states.

7.2 Chlorine Manifold & Supply Lines

The following equipment and valves are associated with the chlorine manifold lines:

Tag Number	Item for Chlorine Drum 1
VA80141 VA80142 VA80241 VA80242	Drum Bank Isolation Valves– manual valves that provide flexibility and redundancy in the manifold lines for chlorine gas delivery. Also allows for double isolation for maintenance on the run.
PIT80111 PIT80211	Pressure Indicators Transmitters– Indicates and transmits the pressure (vacuum) within the manifold. This pressure value will be used to bring an additional drum online if required or Initiating a 'Manifold Vacuum High' Alarm.
VA80144 VA80244	Pressure Transmitter Isolation Valves.
VA80143 VA80245	Drum Bank Isolation Valves– manual valves that enable isolation of drums 1 to 6 Also enables the isolation of PIT 80111.
VA80243 VA80246	Drum Bank Isolation Valves– manual valves that enable isolation of drums 7 to 12 Also enables the isolation of PIT 80211.

7.3 Process Description

The duty chlorinator is initiated when a 'call for water' is received. When the duty chlorinator operates it generates a vacuum at the chlorine manifold which automatically pulls open the vacuum regulators on the "Online" chlorine drums allowing chlorine to flow to the chlorinators.

The Drum Gas Pressure Indicators monitor the pressure in each chlorine drum. An empty chlorine drum will trigger its respective low pressure switch which is interpreted by the PLC as an indication that the drum is empty. The PLC will then close that drums changeover valve.

Pressure transmitters PIT80111 and PIT80211 monitor the vacuum level in the manifold. If a 'High Vacuum' is detected by either manifold pressure transmitter then the PLC will bring the next "Standby" drum "Online".

7.3.1 Start-up Sequence

1. Chlorination system is called to start
2. When 'Call for Water' is received, PLC will bring the last drum(s) which had 'ONLINE' status to be 'ONLINE' again. If none of the drums were 'ONLINE' then PLC will follow the sequence described below in point 3.
3. Once the process water flow starts PIT80111 or PIT80211 will register a high vacuum condition. If high vacuum continues for 10 seconds the PLC will open the changeover valve of the first available drum. If the high vacuum condition continues to be active for another 10 seconds, the PLC will put the next available drum 'ONLINE'. The process will keep repeating until the high vacuum condition ceases or when the maximum number of drums are 'ONLINE'.

Note: If the high vacuum condition is not resolved within 60 seconds then a 'DRUM MANIFOLD HIGH VACUUM' alarm (PAL 80111/PAL 80211) will be generated.

Note: If chlorine demand significantly outstrips supply, it is possible that the chlorinators may trip requiring another restart attempt.

7.3.2 Additional Drum Request

As chlorine demand increases, the vacuum in the manifold also increases. If the manifold vacuum increases to more than the pre-set value, for 10 seconds, then the PLC will initiate a Low Pressure pulse. The PLC will open the automatic changeover valve of the next available drum (in numerical sequence

order) to put it 'ONLINE'. If the high vacuum condition is still active then the next available drum will be put 'ONLINE'.

The process will keep repeating until the high manifold vacuum condition ceases (i.e. the requisite number of drums is supplying the chlorine demand) or the maximum number of drums are 'ONLINE'.

Note: If the high vacuum condition is not resolved within 60 seconds then a 'DRUM MANIFOLD HIGH VACUUM' alarm will be generated.

Alternatively if a low pressure state occurs from an 'ONLINE' drum (ie. From the low pressure switch on the vacuum regulator of that drum) then the drum will be placed into an 'EMPTY' state and the changeover valve for the drum will be closed. If the maximum number of drums are not 'ONLINE', then this will call the next available drum 'ONLINE'.

7.3.3 Drum Usage Prioritization

The PLC shall maintain a circular queue of all 12 drums. When searching for a chlorine drum to transition from "Standby" to "Online" the PLC shall select the next available standby drum from the circular queue.

If chlorination stops and then restarts due to a fault in the system, then the PLC will bring the same drums 'ONLINE' that were previously 'ONLINE' before the shutdown.

Please refer to logic drawings EO28-61-10.1 to 4 for more details on the drum changeover logic.

7.3.4 Maximum Drums Online Input

The Maximum number of drums 'ONLINE' can be configurable through DCIP and SCADA using HC80201. This functionality is to take account of the different number of drums required for different seasons.

7.3.5 Manual Drum Changeover

The ONLINE/STANDBY toggle button (HS 8010*A/ HS 8020*A) on the DCIP and SCADA for each drum can be used to place any drum 'ONLINE' or in 'STANDBY' irrespective of its priority. In this way the number of drums online can be increased manually, provided that there are sufficient full drums to do so.

7.3.6 Drum Changeover Valve Faults

Should a Drum Changeover Valve fail to open within a preset time of it being requested to open by the PLC then the Drum * Changeover Valve Opening Fault (ZA 8010*A/ ZA 8020*A) / Drum * Changeover Valve Closing Fault alarm (ZA 8010*B/ ZA8020*B) will be generated on SCADA and the DCIP. The fault itself will cause no further action to the valves/drums – someone must physically intervene to work on the drums / valve.

Should a Drum Changeover Valve fail to close within a preset time of it being requested to close by the PLC then the Drum * Changeover Valve Closing Fault alarm (ZA 8010*B/ ZA8020*B) will be generated on SCADA and the DCIP. The fault itself will cause no further action to the valves/drums – someone must physically intervene to work on the drums / valve otherwise the drum will eventually become exhausted.

7.3.7 Drum Availability Control

Each drum can be enabled or disabled for use through the 'Drum * ENABLE/DISABLE' toggle buttons (HS 8010*B/HS 8020*B). Drums that are enabled will default to standby status until called online (refer to Section 7.3.3) or 'toggled ONLINE' (refer to Section 7.3.5)

7.3.8 Drum Evacuate

The 'Drum Evacuate' functionality is used at the time of drum replacement to facilitate an 'EMPTY' drum being completely emptied before being replaced with a full drum. To initiate the 'Drum Evacuate'

sequence, the operator manually selects an "Empty" drum to be placed 'ONLINE' using the Online/Standby (toggle) button for that drum. The PLC (detecting that an "Empty" status drum is being manually brought "Online") initiates the following Drum Evacuate sequence:

1. The drum changeover valves for all ONLINE drums are closed.
2. The drum changeover valve of the drum to be replaced is opened for 10 seconds and manifold vacuum will suck the remaining chlorine gas in the drum. The change in the pressure gauge reading on the drum will provide visual indication that this has occurred.
3. After 10 seconds (This value needs to be configured in the PLC at the time of commissioning) the drum changeover valve of the drum to be replaced will be closed and changeover valves are re-opened on the drums which were 'ONLINE' before the sequence was initiated.

Note: The Drum Evacuate sequence can be initiated by the operator either with the drum valve open or with the drum valve closed. With the drum valve open, the evacuate sequence can be used to confirm that a drum is empty. With the drum valve closed the evacuate sequence can be used to minimize any small release of chlorine into the chlorine store when the vacuum regulator is removed from the drum.

7.3.9 Shut-Down Sequence

When the water flow rate falls below the initiate chlorine dosing setpoint, the 'Call for Water' is de-registered, and the flow pacing signals indicate to the chlorinators to set the chlorine gas flow to zero. The chlorine gas delivery automatically ceases when the chlorine ejector isolation valves close because there is no vacuum to draw the chlorine gas. The position of the drum changeover valves remain unchanged.

7.3.10 Fault resetting

The Drum Manifold Fault Reset button (HS 80112), can be used to reset the following conditions:

- Changeover valve failed to close
- Changeover valve failed to open
- Manifold High Vacuum

8 Chlorine Leak Detection

8.1 Digital Leak Detection

There are three digital inputs for chlorine leak detection in the Chlorine store:

- 5ppm Chlorine Leak detected
- 1ppm Chlorine Leak detected
- Chlorine Leak Detector Cell Fail

There are three digital inputs for chlorine leak detection in the Chlorination room:

- 5ppm Chlorine Leak detected
- 1ppm Chlorine Leak detected
- Chlorine Leak Detector Cell Fail

8.1.1 20ppm Chlorine Leak

The 20 ppm chlorine leak alarms are derived from the analogue signals from each cell and provide indication on SCADA immediately when the 20 ppm concentration is reached.

8.1.2 5 ppm Chlorine Leak

A 5 ppm leak detected at any of the cells across the chlorine building will activate the 5 ppm external flashing lights on the chlorine building and the flashing red light in the internal drum room. Separate alarms for the chlorine store and chlorination room chlorine leaks are displayed on SCADA.

Similarly, 5 ppm leak detection will result in the sounding of the chlorine leak audible alarm siren. The siren sounds for 2 minutes continuously before silencing. It is also possible to silence the siren immediately by pressing the Alarm Acknowledge button located on the chlorination control cubicle. The alarm cannot be silenced from the SCADA.

The 5ppm leak detection will also activate the containment functionality and emergency shutdown device as described in Section 10.

The 1ppm alarm activates the general audible alarm but does not sound the chlorine leak audible alarm siren nor activate the external flashing lights.

8.1.3 Chlorine Leak Detector Cell Fail

The chlorine leak detector cell fail alarms provide immediate indication on SCADA.

If the security system is off, then the chlorine leak detector cell fail alarm is sent to the SCADA after fifteen minutes.

8.2 Analogue Leak Detection Range

Analogue signal ranges shall be in accordance with DS 70.2, Clause 3.2.

8.3 Fault Resetting

The leak detection switches (ASL 80140 A/B (cell fail), ASH 80140 A/B (1 ppm chlorine leak detected), and ASHH 80140 A/B (5 ppm chlorine leak detected)) can be reset using the local button HS 80140 on the chlorine leak detector controller.

9 Chlorine Store

9.1 Multiple Drum Empty Indication (VA 80112)

This alarm is raised when the system reports # drums have completed changeover (i.e. are in EMPTY state). This is an advisory alarm to suggest drum replacement is required, and that a reorder should be immediately placed.

Note: The number '#' needs to be adjusted depending on the site needs and number of drums in the system. This may range from 3 to 5 drums.

9.2 Drum Weights

Each chlorine drum will be fitted with the weigh scale and weights will be displayed locally and on SCADA.

9.3 Manifold Vacuum High Alarm (PIT80111 and PIT80211)

Pressure transmitters transmits vacuum values in the chlorine manifold line to the PLC/SCADA which will result in more drums being bought 'ONLINE' to supply more chlorine gas to match the demand for gas from the chlorinators. If any of the vacuum transmitters registers a vacuum value more than the pre-set value (default = 60 seconds), a 'Manifold Vacuum High' alarm will be transmitted to the

PLC/SCADA, alerting the operators that there is a problem with the supply of chlorine gas from the manifold.

Please refer to Section 7.3 Process Description for more information on the functionality, prioritization and controls for the drums.

9.4 Power Failure

Loss of power, indicated by the phase failure relay, produces a power failure alarm on the OIP and to the SCADA if the condition remains for a configurable time (default = 60 seconds, maximum = 15 minutes). When the power is restored the chlorinator delays resumption of normal operation for a configurable time (default = 60 seconds).

9.5 General Audible Alarm

The general audible alarm is separate from the chlorine leak audible alarm. The general audible alarm is sounded if the security system is disabled, and any of the general alarms below become active for at least 1 second.

The general audible alarm is automatically silenced after 5 minutes but can be silenced immediately from the OIP or SCADA.

9.5.1 General Alarm (Chlorine Store)

A general chlorination alarm is displayed on SCADA if any of the following alarms are activated from the chlorine storage room:

- PLC/RTU communication fail
- PLC status
- # Drums Empty (Number of drums (#) to be determined on project. # may range from 3-5)
- Manifold Vacuum High (Alarm)
- Chlorine store 5ppm chlorine leak detected
- Chlorination room 5ppm chlorine leak detected
- Chlorine leak detector 20 ppm leak chlorine store
- Chlorine leak detector 20ppm leak chlorination room
- Chlorine leak detector cell fail chlorination room
- Chlorine leak detector cell fail chlorine store
- Containment Alarm
- Containment Alarm Doors Open
- ESD battery volts low
- ESD Activated

A general chlorination alarm is displayed on the DCIP and SCADA if any of the following alarms are activated from the chlorine storage room:

- Drum 1 Changeover Valve Opening Fault
- Drum 2 Changeover Valve Opening Fault
- Drum 3 Changeover Valve Opening Fault
- Drum 4 Changeover Valve Opening Fault
- Drum 5 Changeover Valve Opening Fault

- Drum 6 Changeover Valve Opening Fault
- Drum 7 Changeover Valve Opening Fault
- Drum 8 Changeover Valve Opening Fault
- Drum 9 Changeover Valve Opening Fault
- Drum 10 Changeover Valve Opening Fault
- Drum 11 Changeover Valve Opening Fault
- Drum 12 Changeover Valve Opening Fault
- Drum 1 Changeover Valve Closing Fault
- Drum 2 Changeover Valve Closing Fault
- Drum 3 Changeover Valve Closing Fault
- Drum 4 Changeover Valve Closing Fault
- Drum 5 Changeover Valve Closing Fault
- Drum 6 Changeover Valve Closing Fault
- Drum 7 Changeover Valve Closing Fault
- Drum 8 Changeover Valve Closing Fault
- Drum 9 Changeover Valve Closing Fault
- Drum 10 Changeover Valve Closing Fault
- Drum 11 Changeover Valve Closing Fault
- Drum 12 Changeover Valve Closing Fault

10 Chlorine Risk Mitigation Measures (Mandatory)

Risk mitigation measures need to be included at sequenced vacuum chlorine facilities because of their offsite risk profile. Chlorine store risk mitigation measures include:

- Containment
- Leak Detectors/Alarms
- Emergency Shutdown Device

10.1 Enabled Containment Operation

Under normal operation, the chlorine room fan(s) will switch on based on initiation from a switch adjacent to the personnel door. This provides a safer environment for any personnel working in the chlorine store. When a chlorine store door is open, after fifty five minutes an audible warning alarm is generated locally (containment buzzer wall mounted in the chlorine store), and after sixty minutes a door open alarm is generated to SCADA. Alarms are reset when the door is closed. The containment buzzer acknowledge button (HS 80148) can also be used to acknowledge the containment alarm buzzer (YA 80148) and resets the timer to 0.

With containment operation, the fan(s) is inhibited from operation in the event of chlorine gas detection above 5 ppm. The fan inhibit system can be overridden using the SCADA by selecting the ‘Fan Inhibit Override’ function on the SCADA and then entering a special password which prevents unauthorized use of this function. This function has to be authorized by a site (incident) manager for use.

If the 'Fan Inhibit Override' function is activated the fan will run for a set time and then turn off. This fan run time is configurable through the SCADA but limited to a maximum of 5 minutes. During this period it can be turned off on the SCADA if required. Each time the 'Fan Inhibit Override' function is used the special password must be re-entered before the fans will operate.

10.2 Enabled Emergency Shutdown Device Operation

The emergency shutdown device (ESD) is a safety system which closes the chlorine drum/cylinder valves in the event of a 5ppm chlorine leak being detected. The device and its I/O are detailed in DS 70.3.

The ESD can be activated manually using HS 80120A or using the optional buttons HS 80120B and HS 80120C.

11 Configurable Set points and Settings Default Values (Drum Room)

11.1 Control Setpoints

Setpoint Group	Setpoint Item	Units	Range	Value (*)	Access Level
Drum Changeover	Manifold Vacuum	kPag	0 to -50	-10	Technician
Maximum Drums Online Input	Maximum Number of Drums	-	0-12	6	Technician

(*) Values provided here are for guidance only and may change from site to site. Setpoint values for each site must be documented during the commissioning phase.

11.2 Module Enables and Disables

Module	1	0	Value
Containment	Enable	Disable	0
Emergency Shutdown Device	Enable	Disable	0

11.3 Analogue Ranges

Analogue Input	Units	Range	Low	High
Leak Detector Cell 1 (Chlorine Store)	ppm	0-20	0	20
Leak Detector Cell 2 (Chlorine Store)	ppm	0-20	0	20
Leak Detector Cell 3 (Chlorine Store)	ppm	5-100	0	20
Leak Detector Cell 4 (Chlorination Room)	ppm	0-20	0	20
Drum 1 Weight	kg	0-1000	0	920
Drum 2 Weight	kg	0-1000	0	920
Drum 3 Weight	kg	0-1000	0	920
Drum 4 Weight	kg	0-1000	0	920
Drum 5 Weight	kg	0-1000	0	920

Analogue Input	Units	Range	Low	High
Drum 6 Weight	kg	0-1000	0	920
Drum 7 Weight	kg	0-1000	0	920
Drum 8 Weight	kg	0-1000	0	920
Drum 9 Weight	kg	0-1000	0	920
Drum 10 Weight	kg	0-1000	0	920
Drum 11 Weight	kg	0-1000	0	920
Drum 12 Weight	kg	0-1000	0	920
Manifold Vacuum A (PIT 80111)	kPA	0 - (-50)	-2	-10
Manifold Vacuum B (PIT 80211)	kPA	0 - (-50)	-2	-10

12 Appendix

To supplement the information in this standard and for further information, refer to Drum Sequence Vacuum System Functional Description Overview.

END OF DOCUMENT