

## SECTION 11020

### BIOLOGICAL TREATMENT SYSTEM – FUNCTIONAL DESCRIPTIONS

#### PART 1 – GENERAL

##### 1.1 DESCRIPTION

###### A. Definition:

1. This Section describes the control philosophy and control system approach for the new Upper Hocking Water Pollution Control Facility, in regards to the biological treatment system (BTS) and its interaction with other processes at the plant. Included in this Section are monitoring requirements, scenario-based control capabilities, expected hardware capabilities, Operator Interface Terminal (OIT) display functions, and data logging requirements.
2. Control System Configuration: The Upper Hocking Water Pollution Control Facility programmable logic controllers (PLCs), human-machine interface (HMI), and OIT components shall be as shown on the Control System Configuration Diagram, with input and output signals as listed in the schedule at the end of Specification Schedule 13451.

###### B. Related Sections:

1. Section 11010, Biological Treatment System – General Provisions.
2. Section 11011, Membrane Bioreactor System.
3. Section 11012, Process Aeration Equipment.
4. Section 11013, Residuals Reduction System.
5. Section 11014, Sodium Hypochlorite and Citric Acid Feed Equipment.
6. Section 11015, Compressed Air System.
7. Section 11016, Filtrate Pumps.
8. Section 11017, Biological Treatment System – Valves.
9. Section 11018, Biological Treatment System – Instrumentation.
10. Section 11019, Biological Treatment System – Controls, Interface, and Hardware.
11. Division 13, Applicable Sections on Instrumentation and Controls.

- ###### C.
- This Section describes the minimum anticipated control programming that shall be provided by the biological treatment system Supplier in order to provide a fully functional system. Additional functionality may be required to provide a completely operable system and to meet the specific requirements of this installation and shall be provided by the biological system Supplier at no additional cost. The specific procedures, modes, setpoints, durations, etc. may be amended to optimize and customize the system operation upon approval of the Engineer.

## 1.2 SUBMITTALS:

- A. PLC and OIT Application Software Documentation: Prepare and submit one electronic and five (5) hard copies of preliminary software documentation two (2) weeks prior to expected initiation of factory testing as specified herein and at each application programming review meeting. Electronic copy shall be in CD-R format. Submittal shall be for review and comment only and not be subject to formal approval action. Software documentation shall include the following as a minimum:
1. Complete electronic and hard copy printouts of OIT screen displays. Provide documentation for each display identifying configuration parameters, dynamic symbols with controlling elements, and operator adjustable values.
  2. Complete electronic and hard copies of PLC listing of external and internal I/O address assignments, register assignments, and preset constant values. Also list all unused/undefined I/O and data table registers available.
- B. Operations and Maintenance Manuals:
1. Provide one electronic and three (3) hard copies of O&M manuals for the PLC and OIT application program in accordance with the requirements below. The O&M manuals shall include the following:
    - a. Name, address, and telephone number of the BTS Supplier and each software manufacturer's local service representative.
    - b. Copy of all approved submittal information as specified herein with corrections made to reflect all review comments and the actual system as tested and delivered to the site for installation.
    - c. Standard technical documentation covering the procedures for programming, start-up, and shutdown of the PLC equipment including instruction set descriptions and programming procedures.
    - d. The O&M Manuals shall conform to the requirements of Section 01781, Operation and Maintenance Data.
    - e. The O&M Manuals shall include electronic and hard copy of the final software documentation.
  2. Final versions of OIT screens, in the file format readable by the OIT software language shall be made available on CD to the Owner, so that the Owner's designated programmer can incorporate the BTS graphics into the main HMI display.
- C. Application Programming Review Meetings:
1. Application programming review meetings shall be scheduled by the Engineer. Contractor and of representative of the BTS Supplier shall be required to attend a minimum of 2 meetings at the Owner's site.
  2. The BTS Supplier shall provide five (5) color printouts/copies of the OIT graphics and other relevant deliverables to be discussed. The BTS Supplier shall provide the color printouts/copies to the Engineer and

Owner five (5) business days prior to the review meeting in which the material is discussed.

3. The purpose of the meetings shall be to insure that the PLC and OIT programs are in compliance with the intent of the specifications, and to allow the Owner to modify proposed screen graphics to match Owner's preferences.
4. Representatives at the meeting shall have the competence and authority to make any and all necessary decisions. Decisions and statements made at the meetings shall commit the Contractor and BTS Supplier to agreed procedures and schedules.

### 1.3 REQUIREMENTS

- A. The following points are necessary for successful integration of the control system with the plant.
  1. Provide PLC programming and network configuration necessary to communicate to and from the various process equipment PLCs, drives, and other networked equipment.
  2. Setpoints, alarm limits, timer ranges, and other values specified herein shall be for initial setting and use. These values shall be adjusted during field start-up to coordinate with actual equipment operating conditions.
  3. All digital and analog inputs as listed in the Input/Output Schedule in Section 13451 (equipment on Network 'A') shall be displayed on one or more process graphic displays. Other signals referred to in this document or necessary in the program but retrieved from the Network B PLC shall also be displayed the graphic displays.
  4. All operator entered setpoints shall be tested for appropriate range both at the HMI entry field and in the PLC. The HMI shall flag any setpoint that is out of range and prompt the operator to enter a valid number. The PLC shall not accept any setpoint that is out of range.
  5. The PLC shall generate a "Fail to Run" alarm if the PLC calls for any motor to run and running feedback is not received within 10 seconds. The alarm shall be annunciated at the HMI and the OIT.
  6. The PLC shall generate a "Fail to Open" or a "Fail to Close" alarm if the PLC calls for any non-modulating valve or gate to operate and position feedback is not received within 125% of the full travel time. The alarm shall be annunciated at the HMI and the OIT.
  7. The PLC shall generate a "Position Deviation" alarm for modulating valves and gates if the position feedback differs from the position control output by more than 5% for more than 60 seconds. The alarm shall be annunciated at the HMI and the OIT.
  8. The PLC shall not generate a command output to any process equipment that is not controllable from the PLC (equipment not in Remote mode or in alarm).

### 1.4 GENERAL CONTROL PHILOSOPHY

A. Control System Description:

1. The Biological Treatment System Control System shall consist of the following components:
  - a. A main control panel (Biological Treatment System Control Panel) which houses PLCs, additional I/O racks, and an OIT. This control panel shall be located in the Secondary Control Building Control Room.
  - b. An additional control panel (Biological Treatment System Remote I/O Panel) which houses I/O racks, an OIT, and some relay logic functions for the RAS Screen and Compactor. This control panel shall be located in the Screening and Dewatering Building Electrical Room.
  - c. A control panel located in the Residuals Reduction Tunnel, although provided under Division 13, contains remote I/O racks dedicated to the Biological Treatment System and is a node on the BTS network.
2. The control panels provided under Section 11019 also house an additional PLC, as well as additional remote I/O racks. This is depicted on the Drawings as "Network B." The additional equipment shall not be programmed by the Biological Treatment System Supplier; rather, the Owner's designated programmer is responsible for programming this equipment. It is on a separate network from the BTS PLC.
3. The PLC shall be configured to operate all equipment manually or automatically based on monitored data, commands, and setpoints entered by operators at the OIT or SCADA system. All equipment shall also be controlled locally from the corresponding Variable Frequency Drive (VFD), actuator, or local control station.
4. The OITs shall provide detailed, user-friendly information on all equipment, and shall allow the operator to initiate process changes, alter setpoints, and respond to alarm conditions.
5. The PLC system shall be programmed to be standalone. The PLC shall control the attached equipment even in the event that communications with the OIT are severed. In such a case, the PLC shall control the BTS based on the most recently entered setpoints.

B. Local Control Mode:

1. All equipment shall have local manual control capability at or near the equipment. This shall allow operators to use the equipment for testing, maintenance, and other such purposes.
2. Equipment relevant to the primary process (i.e. Filtrate Pumps, RAS Screen, etc.) shall be installed with Local-Off-Remote selector switches (provided under Division 16) to denote control location. If the switch is in the Local position, local manual control is enabled and PLC control is disabled. If the switch is in the Off position, the equipment shall not operate.

C. Remote Control Mode:

1. Equipment with selector switches in the Remote position shall have an additional layer of control if the equipment is VFD driven.
  - a. A VFD/PLC selector switch on the VFD determines whether control shall be from the VFD machine interface, or remotely from the PLC.
  - b. Stop functionality shall be available at the VFD in any mode.
2. Equipment powered from the MCC for the BTS process shall be controlled by the PLC when the selector switch is in the Remote position.
3. Equipment under the control of the PLC can either operate in a completely automatic manner, PLC-Auto, or manually via operator input to an OIT or OIT screen, OIT-Manual.
  - a. OIT-Manual Control: This mode of operation requires operator action at the OIT to change the operating status of pieces of equipment. Buttons located on the graphic displays shall allow for starting, stopping, changing speed, and other such functionality. Equipment safety interlocks shall be provided when in manual mode. For example, the PLC shall not allow pumping into a closed valve for an extended period of time, or to draw from an empty wet well.
  - b. PLC-Auto Control: This mode of operation allows the PLC to control equipment based upon measured process variables, operator adjustable and fixed internal setpoints, and the selected control schemes.

## PART 2 – PROCESS CONTROL DESCRIPTIONS

### 2.1 VERTICAL LOOP REACTORS

A. Influent Feed to VLRs:

1. The influent flow to the VLR is controlled by the VLR Influent Control Valve. This valve is automatically controlled by the “Network B” PLC, and is used to limit the flow to the VLRs to below 6 MGD. A PID control algorithm maintains the flow setpoint and will be programmed by the Owner’s designated programmer.
  - a. The operator is permitted to assign a flow setpoint below 6 MGD.
  - b. Interlocks will be performed between the valve and downstream equipment to stop flow upon alarm conditions. This data shall be coordinated between BTS programmer and Owner’s designated programmer.
2. The flow rate is monitored by the “Network B” PLC, and this data will be made available to the BTS PLC through a network PLC.

B. VLR Blowers:

1. If the DO and ORP setpoints in the VLR tanks can be maintained by the disc aerators alone, then the PLC shall shut off the VLR Blowers. If oxygen supplied by the disc aerators alone is not adequate to achieve the desired DO and ORP setpoints in the VLR tanks, then the VLR Blowers shall be switched on as required.
2. When the VLR Blowers are operating, the number of blowers in service and the speed of the blowers shall be automatically controlled via a PID algorithm to maintain the pressure in the common blower manifold within a pre-selected deadband.
3. The VLR Blowers Operating Procedure:
  - a. The first blower in operation adjusts its speed to maintain a pressure setpoint within the common header. As the pressure drops, the blower shall increase in speed. Should the pressure demand push the blower to 100% speed for a short time, a second blower shall start.
  - b. The first blower shall maintain 100% speed until the second blower reaches a point at which the pressure meets the setpoint. At this stage, both running blowers shall match speed as they attempt to maintain the pressure.
  - c. The same process as described in parts 'a' and 'b' shall be used to start a third blower.
  - d. If the pressure builds too high, the blowers shall slow down. Once they have reached a predetermined speed, the first one that was started shall stop. The remaining running blowers shall then ramp back up to maintain the pressure. This shall continue until the pressure has been met.
  - e. Every time no blowers are running, and one is required to start, the one that was started the longest time ago shall start first. Provisions shall be created on the OIT screens to make changes to this system for customization purposes.

C. Aeration Discs:

1. The PLC shall automatically vary the speed of the Aeration Discs to maintain the desired DO and ORP setpoints in each VLR tank.
2. The PID loop governing the Aeration Discs shall be dampened so that it does not interfere with the VLR Blower controls.

D. VLR Air Flow Control Valves:

1. When the VLR Blowers are running, the position of the VLR Air Flow Control Valves shall be varied to control DO and ORP. The valves shall be limited to opening at pre-defined settings, rather than infinitely variable.
2. The PID loops for VLR Air Flow Control Valves and Aeration discs are cascaded.

## 2.2 MEMBRANE BIOREACTORS

A. General:

1. Modes of Operation:
  - a. Online: The Membrane Tank can begin the filtration process.
  - b. Offline: The Membrane Tank has been shutdown or a Clean-in-Place (CIP) is in operation.
2. Tank Rotation – Membrane Tanks shall automatically be placed in service based on the flow conditions described in one of the following sections. When flow drops down in the system, all available Membrane Tanks will not be required for filtration and Membrane Tanks shall be rotated. Methods are:
  - a. Last On, Last Off: If a Membrane Tank enters a maintenance clean, clean in place, or standby, or if the system enters Shutdown, the tank that has been in standby for the longest shall come online when a tank is required by the system for filtration.
  - b. Caterpillar: When a Membrane Tank goes into relaxation another Membrane Tank shall start filtration if there is a tank in standby.
3. Tank Prioritization – The prioritization of different operating states in the membrane operating system is required due to the use of the filtrate pipe work for multiple purposes.
  - a. Relaxation: If a Membrane Tank is requesting relaxation it shall enter this before any other operations.
  - b. CIP Fill / Filtrate Clean Water: If a Membrane Tank is empty and requesting to fill from other tanks then it will start after relaxation has completed.
  - c. Recirculation – Turbidity: If a Membrane Tank is requiring to go into recirculation due to a turbidity spike this shall occur after a CIP Fill request is completed. Relaxation on other tanks has no effect on this request.
  - d. Maintenance Clean: The Maintenance Clean shall be delayed until CIP Fill, Recirculation Turbidity, and Recirculation CIP are completed. If Relaxation occurs on another tank then the timer shall continue after Relaxation is completed.
  - e. Recirculation – Storage in Place (SIP): If the Membrane Tank is requesting to perform the weekly recirculation or initial recirculation for SIP, it shall be queued behind all other tasks. Relaxation on the other tanks has no effect on this request.
4. Manual Entry – The Membrane Operating System shall have nine manual push buttons (on OIT screen) per Membrane Tank that can be initiated by the operator. The operator can press buttons whether the membrane is in the online or offline state. The PLC shall automatically check that the necessary resources are available before the required sequence is initiated:
  - a. Offline: This shall shutdown everything associated with the Membrane Tank including the Membrane Feed Pump and the Membrane Blower.

- b. Filtration / Start-up: If the Membrane Tank is standing by or shut down, this shall make the tank available for service.
  - c. Clean in Place: Places the Membrane Tank into CIP by the operator. The CIP sequence shall then proceed automatically after resources are available.
  - d. Maintenance Clean (MC): Maintenance Clean is an automatic operation but the operator can perform a manual MC by using this pushbutton.
  - e. Extended Relaxation / Standby: The operator can be manually place the Membrane Tank in this mode, which shall take the tank offline.
  - f. Draindown Rinse: The operator can manually drain down the Membrane Tank for maintenance.
  - g. Storage in Place: Used to protect and prepare the Membrane Tank for extended periods of low flow. The SIP sequence shall then proceed automatically when resources become available.
  - h. Clean Water Fill: Used for bubble tests, maintenance, and removal of the membrane modules. It shall run through a Draindown Rinse and Filtrate Fill, which is described in the next section.
  - i. Recirculation: Used for manually putting a Membrane Tank into a recirculation loop, drawing water through the membranes and being discharged from the Filtrate Pump back into the tank.
5. Online Operating States:
- a. Standby / Extended Relaxation: Standby is an active state that a Membrane Tank enters from Filtration when:
    - 1) The plant incoming flow is low and the Filtrate Pump cannot run below the minimum speed required for continuous operation.
    - 2) The mixed liquor level in the tank is below a minimum set level.
    - 3) A low mixed liquor feed flow alarm has been activated. A warning alarm shall be an operator entered setpoint.
    - 4) If the Membrane Tank is filtering and the transmembrane pressure exceeds the preset value for a preset time. A shutdown alarm shall be set.
    - 5) A low air flow / pressure alarm is activated. A warning alarm shall be set for this.
    - 6) Placed in Standby manually. The Membrane Tank shall then remain in Standby – Manual until it is manually restarted or is shut down. If restarted, the tank shall enter Fixed Filtration then Filtration.
      - a) The Membrane Feed Pump and Membrane Blower run continuously when in Standby less than 24 hours.
      - b) The Membrane Feed Pump and Membrane Blower run 10 minutes every hour when in Standby between 24 and 36 hours.

- c) The Membrane Feed Pump does not run, and the Membrane Blower runs 10 minutes every hour when in Standby over 36 hours.
- 6) When the demand increases due to incoming water, the Membrane Tank shall change from Standby and enter Startup if the system did not enter Standby because of alarm. If a tank has been put into Standby because of alarm, it must be cleared and manually put back into Startup by the operator.
- b. Startup: When the membrane system is started, the PLC shall control the start-up sequence. In Startup, the Membrane Feed Pump is called to run and the Membrane Tank is filled until the level in the membrane weir overflows. The vacuum system then primes the modules and filtrate piping in preparation for filtration. Once the Filtrate Pump is primed, it will start and the tank enters Fixed Filtration.
- c. Filtration: Filtrate is drawn from the Membrane Tank through the membrane by suction pressure. Particles that do not enter the membrane fibers overflow the tank and re-enter the Vertical Loop Reactors. The measured suction pressure required to draw the necessary flow through the membranes is the trans-membrane pressure (TMP). The TMP gauges the fouling on the membrane surface. The membrane system flow control is as follows:
  - 1) The Filtrate Pump flow rate for each tank is based upon the number of tanks online and the level in the VLR wet well. Tanks are unavailable for filtration if they are:
    - a) In Standby – Manual mode.
    - b) In Offline mode.
    - c) In Shutdown Alarm mode.
    - d) In Maintenance Clean mode.
  - 2) On completion of the Startup sequence, the membrane system enters Fixed Filtration. In this mode, the Filtrate Pump ramps to a predetermined position based on the previous cycle VFD setting and maintains this speed for a preset duration. This allows filtrate flow to stabilize close to the flow set point before starting proportional control.
  - 3) The membrane system enters Filtration Initialize ones the Fixed Filtration period ends. During this mode, the Filtrate Pump maintains the level in the VLR wet well. The PLC shall monitor filtrate flow, TMP, and VLR wet well level for a set period to provide an initial filtration reference point for these variables. The reference point determines when another Relaxation or CIP is required.
  - 4) Normal Filtration mode consists of controlling the Filtrate Pump to maintain the VLR wet well level.
- d. Relaxation: Relaxation of the membrane fiber is used to remove caked solids accumulated during Filtration. The Filtrate pump shall

stop while the Membrane Blower and Membrane Feed Pump continue to run. Relaxation cycles on for 60 seconds for every 12 minutes of Filtration when flow conditions are at or below the maximum sustained flow. For flows above the maximum sustained flow, the Relaxation duration is 30 seconds every 6 minutes of Filtration. These parameters are default but shall be field adjustable.

- 1) Only one Membrane Tank should be in Relaxation at one time. This control is implemented to remove false variations in VLR wet well level due to multiple Membrane Tanks relaxing at the same time.
  - 2) Membrane tanks are queued for Relaxation. The membrane requests a Relaxation period through the PLC program, and it is required that no other tanks are in Relaxation, and no Shutdown Alarm is present. Membranes shall continue in Filtration until the option to enter Relaxation is available.
- e. Maintenance Clean (MC):
- 1) Maintenance Clean provides interim disinfection of the membrane modules and filtrate piping, useful to control biological growth and membrane fouling. The MC is a fully automated backwash and aeration cycle. When a MC is performed the tank is in Standby with the Membrane Feed Pump and Membrane Blower still flowing into the tank. For initiation of MC, the required number of tanks for the flow shall be available for service. This allows maintaining throughput while performing an MC. Steps of a cycle are as follows:
    - a) The Filtrate Pump is called to run while dosing Sodium Hypochlorite for 5 minutes.
    - b) A 15 minute Relaxation.
    - c) The Filtrate Pump is called to run while dosing Sodium Hypochlorite for 5 minutes.
    - d) A 15 minute Relaxation.
    - e) Recirculation.
    - f) Filtration begins again.
  - 2) Maintenance Clean Request and Resources: An automatic MC request is set by the PLC as part of the program. This is an adjustable parameter with a default of 7 days of Filtration. An MC can be started manually by the operator. An automatic MC shall also occur following a peak event, when the flow drops below the maximum sustained flow. The following is required before initiating an MC:
    - a) No high flow warning is present.
    - b) No Shutdown Alarm present.
    - c) The VLR is above the Start MC or CIP fill level (also an adjustable parameter).

- d) Total filtrate flow from the plant is greater than required for MC with one tank out of service. If not, the filtrate flow on the on-line Membrane Tanks shall be forced to the flow required.
  - e) Sufficient Membrane Tanks are in service so that the peak flow rate for an individual tank is not exceeded.
  - f) No other Membrane Tank is in MC, CIP Fill, or Drawdown Rinse.
- 3) Maintenance Clean Sodium Hypochlorite Transfer Pump: The dosing pump shall start automatically. The pump shall be available to run when:
- a) The PLC is functional.
  - b) The chemical storage tank is above the low level setpoint.
  - c) The tank about to MC is not in Shutdown Alarm mode.
- f. Recirculation – High Turbidity: If high turbidity is alarmed, the Membrane Tank with the high turbidity shall automatically go into recirculation per priority level. The Recirculation mode shall pull filtrate through the membranes and back to the Membrane Tank instead of the discharge line. The PLC continues to monitor turbidity. When the turbidity is within allowable limits for a preset amount of time, the system transfers back into Filtration mode. If the filtrate stays above limits for a preset amount of time, the Membrane Tank shall shutdown. If another tank is available, the PLC shall bring it online.
- g. Recirculation – Tank Startup: At the end of an MC or CIP the system shall step through a Recirculation mode to remove any residual chemicals in the membranes and filtrate lines. The Recirculation mode pulls filtrate through the membranes and back into the Membrane Tank instead of the discharge line. The PLC shall close a valve isolating the turbidimeter during this procedure to protect the instrument from corrosion. At the end of this step the program continues with MC, CIP, or enters Filtration.
6. Offline Operating States:
- a. Shutdown Alarm: If this mode is achieved, the Membrane Tank stops the process. The tank cannot be started until the alarm condition is rectified and the Shutdown Alarm has been reset.
  - b. Draindown and Rinse: Draindown and Rinse needs to be performed for inspection and maintenance of membrane and associated pipework, as part of CIP sequences or as part of Bubble Test.
    - 1) Primary Operation:
      - a) The tank drain valve opens allowing liquid to drain to the Plant Drain Wet Well.
      - b) The tank is filled with filtrate from the common discharge header using the Filtrate Pump.
      - c) The Membrane Blower runs for a preset period of time.

- d) The tank drain valve opens again allowing liquid to drain to the plant drain wet well.
- 2) Manual Draindown Rinse (DDR): The DDR can also be initiated manually by the operator if the Membrane Tank is Offline. In this case, the DDR sequence is normally used prior to removing module racks from the tank, placing the tank into SIP mode, or for inspection or maintenance of other tank components.
- 3) Draindown Rinse Completion: At the end of the DDR, a screen shall appear on the OIT, prompting the operator if another DDR is required. If Yes is selected, then another DDR shall be performed. If No is selected, then the PLC shall carry out the next step in the sequence. After 5 minutes of inactivity, the PLC will consider the selection to be No.
- 4) Draindown Rinse Resources, CIP: Before a DDR takes place as part of CIP, the PLC shall ensure that all resources are available. See the following sections.
- 5) Draindown Rinse Resources, Single: For DDR as a single sequence, the following conditions shall be present:
  - a) No High Flow Warning Alarm.
  - b) No Shutdown Alarm
  - c) VLR wet well is above the Start DDR level (field adjustable)
  - d) Total filtrate flow from the plant is greater than required for Membrane Tank fill. If not, the filtrate flow on the on-line tanks should be forced to the flow required.
  - e) Sufficient Membrane tanks are in service so that the peak flow rate for an individual tank is not exceeded.
  - f) No other Membrane tanks are in CIP Fill, MC, or DDR.
- 6) Draindown Rinse Scheduling: If the DDR Resource is not immediately available when the request is initiated, the Membrane Tank continues in normal operation cycles. Once the DDR commences, Draindown and Rinse shall appear in the OIT display. If the DDR is halted and unable to fill with filtrate so that the membrane modules are exposed to air for a set period of time, the tank shall be filled with mixed liquor automatically.
- c. Filtrate Fill: The Filtrate Fill sequence follows directly after the Draindown Rinse when a clean water fill is initiated.
  - 1) Primary Operation:
    - a) The Membrane Tank shall fill from the common discharge header using the Filtrate Pump until the level is at the top of the membrane header.
    - b) The Membrane Blowers are turned off.
  - 2) Filtrate Fill Required Resources:

- a) Total filtrate flow from the plant shall be greater than required for Membrane Tank fill. If not, the filtrate flow for the online tanks shall be forced to the required flow.
  - b) Sufficient Membrane Tanks are in service so that the peak flow rate for an individual tank is not exceeded.
  - c) No other Membrane Tank is in CIP Fill.
- d. Bubble Test: The Bubble Test is used to assist in the detection of leaks within a Membrane Tank. This procedure is a manual operation, and the operator first places the tank in Offline mode.
  - 1) The operator then presses the Clean Water Fill push button.
  - 2) A Draindown Rinse is automatically initiated.
  - 3) A Filtrate Fill follows the Draindown Rinse.
  - 4) Low pressure air is used to drain the membrane fibers of liquid. The test air remains on for the duration of the test period.
  - 5) If the TMP exceeds 9 psig, the Membrane Integrity Test Solenoid Valve shall close.
- e. Clean in Place: Cleaning is necessary to remove the contaminants that cannot be removed by Relaxation.
  - 1) General:
    - a) The OIT prompts the operator for the type of cleaning that shall be performed – Sodium Hypochlorite, Citric Acid, or both. When both are selected, Citric Acid is used first.
    - b) The OIT prompts the operator what action the membrane should take once the CIP has finished – either Storage in Place or Online.
    - c) If the influent flow is high enough, the PLC shall put another tank online if one is available for service.
  - 2) Clean in Place Request: OIT displays a warning alarm when a CIP is required. This may happen if any of the following conditions occur:
    - a) A preset maximum filtration time has been reached.
    - b) The permeability of the membranes has decreased to a preset minimum value.
  - 3) Clean in Place Required Resources: The CIP Request shall be set when the operator manually initiates a CIP after ensuring that there is the appropriate amount of downtime available for the CIP. Before the CIP, the PLC determines if the following is available:
    - a) The filtrate discharge flow rate is greater than the flow rate required for a CIP fill. The filtrate flow rate is greater than 980 gpm.
    - b) The influent flow is at a rate that can be managed by the other tanks.
    - c) There is sufficient chemical available to perform the CIP.
    - d) The VLR wet well is above the Start CIP Fill Level.
    - e) No shutdown alarms are in action.

- 3) Clean in Place Cycle: The CIP cycle runs through the steps automatically. During a CIP, all of the steps and time to completion shall be displayed on the OIT. Steps are as follows:
- a) A Draindown Rinse is performed.
  - b) Once able to proceed, the tank is filled with filtrate from the tanks online using the Filtrate Pump. At the same time, chemical is dosed directly in the CIP fill line, mixing with the filtrate to produce the desired concentration.
  - c) The CIP solution is recirculated through the membranes via the Filtrate Pump and back into the Membrane Tank in CIP mode.
  - d) The membranes are soaked in cleaning solution, which is timed and can be extended to improve cleaning efficiency.
  - e) The soak is divided into blocks of time typically 20 minutes with aeration and soak cycles. For the acid clean, the system aerates the membranes to mix chemical for 5 minutes (adjustable) with 15 minutes of soak. This process is repeated until the end of the soak time. For Sodium Hypochlorite cleaning, the system does not require aeration, but it shall be an option selectable from the OIT.
  - f) Soak time is calculated based upon the water temperature, input from the discharge temperature transmitter. The minimum soak time is three (3) hours. The soak time can be extended if desired by updating a parameter on the OIT display for the particular Membrane Tank.
  - g) At the conclusion of the soak, the Membrane Tank drain valve opens and the wasted CIP solution is discharged to the Plant Drain Wet Well. An alarm is highlighted on the OIT that waste is currently being discharged.
  - h) If the Membrane Tank is entering storage next, the program automatically changes to a Storage in Place.
  - i) If the membrane is coming back online, a rinse sequence is performed. The Membrane Tank is filled and continuously fed with mixed liquor feed and the Membrane Blower is used to remove any remaining chemical residuals.
  - j) Upon restarting the system, the Membrane Tank is placed into Filtration Recirculation. The Filtrate is returned to the tank and not discharged.
  - k) If both chemicals are used to clean, then a Draindown Rinse is completed with includes 10 minutes of recirculation to remove acid residual.

- l) On completion of the CIP cycle, the Membrane Tank shall enter Standby and enter Filtration when required.
- 3) Clean in Place Halt: If a CIP cycle is stopped before completion, the Membrane Tank enters CIP Halt mode. The PLC retains all current timing information and program step numbers. Halts occur if any of the following occur:
  - a) A valve failure for the Membrane Tank being cleaned.
  - b) A chemical transfer pump fails.
  - c) If CIP flow is not available to fill Membrane Tank during the fill procedure.
  - d) A shutdown alarm occurs.
  - e) The operator manually initiates CIP Halt.
  - f) Power Failure.
  - g) Emergency Stop activated.
- 3) Clean in Place Resume: When a shutdown alarm is present, the tank shall be placed in Shutdown Alarm mode. To resume a CIP cycle from CIP Halt mode, the following is required:
  - a) The membrane should be in CIP Halt mode with alarms reset.
  - b) There are no CIP system alarms.
- 4) Clean in Place Waste Disposal:
  - a) The CIP chemical solution shall be drained to the Plant Drain Wet Well and shall be metered back to the VLR by the Membrane Tank Drain Pump. Prior to the chemical drain the wet well will be pumped to the low level using the Plant Drain Pumps, controlled by the "Network B" PLC. The Membrane Tank Drain Pump shall start upon indication that the Membrane Tank Drain Pump Influent Valve is open.
  - b) The Membrane Tank Drain Pump shall be initiated by the chemical drain procedure. Other drains around the plant, as well as the DDR drain procedure, shall be pumped by the Plant Drain Pumps. No other CIP should be initiated until the Plant Drain Wet Well reached the low level.
- 5) Chemical Transfer Pumps: The pumps associated with the chemical transfer to the Membrane Tank are piped into the CIP Fill line for in-line dosing. The dosing pump starts automatically, for a preset period of around 20 minutes. Chemical transfer pumps are as follows:
  - a) NaOCl Metering Pump 1.
  - b) NaOCl Metering Pump 2.
  - c) Citric Acid Metering Pump 1.
- 6) Sodium Hypochlorite Metering Pump Operation: The transfer pump is permitted to operate at any time that:
  - a) The PLC is running.
  - b) The Membrane Tank is not in Shutdown Alarm mode.

- 7) Citric Acid Metering Pump Operation: The transfer pump is permitted to operate at any time that:
  - a) The PLC is running.
  - b) The Membrane Tank is not in Shutdown Alarm mode.
  - c) The Citric Acid Storage Tank is above the low level setpoint.
- e. Storage in Place: Storage in Place (SIP) function is used to protect a Membrane Tank during periods of low flow. The SIP can be a standalone function or performed at the end of a CIP.
  - 1) General Operation: The sequence drains the tank using the Draindown Rinse function. The following then takes place:
    - a) The tank is filled with discharge filtrate using the Filtrate Pump.
    - b) The dosing pump shall run for 5 minutes to give a low concentration of chlorine as the water flows into the Membrane Tank.
    - c) The filtrate shall be recirculated through the membranes back into the Membrane Tank for 20 minutes.
    - d) The valves to the Membrane Tank are closed.
    - e) The PLC runs a recirculation loop once per week for 20 minutes.
  - 2) Storage in Place Request: An SIP Request is set when the operator selects Storage in Place on the OIT or selects Storage Following CIP.
  - 3) Storage in Place Resources: The resources required to start an SIP cycle include the following:
    - a) The filtrate discharge flow rate is greater than the flow rate required for a CIP fill.
    - b) The influent flow rate is at a rate that can be managed by other Membrane Tanks that are Online.
    - c) No shutdown alarms are active.
  - 4) Storage in Place Auto Restart Requirements: As the influent flow is subject to both seasonal and diurnal flow there may be a time when one or two Membrane Tanks are in SIP at the start of a peak event. In order to manage flow, tanks in SIP may be automatically brought back online if required. The requirements to bring online a membrane in SIP include the following:
    - a) The filtrate flow rate of Membrane Tank(s) in service is at peak hourly flow rate; and
    - b) The VLR wet well level transmitter is at the HI-HI level setpoint.
  - 5) Storage in Place Auto Restart Sequence: The Membrane Tank returning to service shall run through the following procedure:
    - a) The Membrane Tank is filled and continuously fed mixed liquor, to dilute the chemical solution.

- b) The Membrane Blower is started.
- c) The Membrane Tank is placed into Filtration Recirculation, the filtrate is returned to the tank and not discharged.
- d) After 10 minutes of recirculation the discharge valve is opened and normal Filtration commences.

B. Flow Control:

1. The Membrane Operating System is started automatically by a start signal from the PLC. Once started, is shall operated automatically under the control of the PLC. No operator input is required for control of Filtration and Relaxation cycles and the Biological System PLC shall automatically adjust its operation to suit the incoming flow and the level in the VLR wet well.
2. Membrane Start Sequence: The MOS is only available for starting when:
  - a. The main power is ON.
  - b. PLC communications are OK.
  - c. Liquid levels in the VLR are OK.
  - d. Membrane Blowers are available.
  - e. Membrane Feed Pumps are available.
  - f. No shutdown alarms are present.
3. A Membrane Tank is placed in Auto Mode after Standby Mode will automatically enter Startup and go directly to Online Mode when required by the PLC. The operations of Membrane Tanks are as follows:
  - a. The Membrane Tanks shall be called to service as required by the level in the VLR wet well. When a Membrane Tank is requested, the tank that has been offline for the longest period shall be called to run in a Last On / Last Off configuration. The Membrane Tanks shall operates as generally shown in the Table below.

# of Cells in service	Filtrate Pump Flow (gpm)			Influent Flow (MGD)		
	Min. Flow	Max. Sustained Flow	Max 3 day sustained Flow	Min. Flow	Max. Sustained Flow	Max 3 day sustained Flow
1	756	845	1,506	0.99	1.11	1.98
2	1,512	1,690	3,012	1.98	2.22	3.96
3	2,268	2,667	4,518	2.98	3.50	5.94

- b. If the flow drops below a minimum flow the system shall attempt to take a tank out of service after a 2 hour delay.
- c. Maximum sustained flow is the flow at which the MOS can operate on a continuous basis with no time constraint.
- d. Maximum 3 day sustained flow is the maximum flow rate that the MOS can be maintained at for 3 days before it should be returned to the maximum sustained flow.
- e. If the flow rate is at or above 1512 gpm per Membrane Tank at any time, the system shall bring an additional tank online. If no

additional tanks are available, a warning alarm shall be displayed on the OIT.

4. **Peak Daily Flow Control:** If the filtrate flow to a given Membrane Tank is above the maximum sustained flow and at or below the 3 day sustained flow, then a timer shall start. If the flow stays above the maximum sustained flow for 24 hours, and there is a tank in Standby, then it shall be called to service. When a tank is put back into Standby, it should be the tank that ran for 24 hours at the elevated flow. When the filtrate flow has been above the maximum sustained flow for 70 hours continuously or 140 hours over a 30 day rolling period, then a warning alarm shall be displayed on the OIT.
5. **Minimum Flow Filtrate Setpoint:** If the filtrate flow from the plant is less than 756 gpm, the Filtrate Pump is set up for a batch mode of operation. The low flow rate on the pump is fixed and switches on and off based on the VLR wet well level. In this configuration the MOS shall go in and out of Filtrate Standby based on the levels in the VLR wet well. When multiple tanks are in service, the minimum flow filtrate setpoint shall be used to take a tank offline after a 2 hour delay.
6. **Level in the VLR Wet Well:** The Filtrate Pumps for the MOS are controlled by monitoring the level in the VLR Wet Well. The range of level in the wet well is between 12 ft and 18 ft. Outside of this range an alarm shall activate.
  - a. The Filtrate Pump shall have preset limits on what maximum flow rates the membranes can see.
  - b. If the high level alarm activates, the Filtrate Pump shall be run at maximum flow of 1506 gpm until the level drops to 13.5 ft, then it shall maintain the level at 15 ft with PID control algorithms.
  - c. If level drops below 12 ft, the Filtrate Pumps shall stop. The pumps shall not be called to run until the level is at 17.5 ft. Upon restart after a low level pump stoppage, the pump shall begin operating at the previous flow until the level is seen to increase further, then is shall control around the level with PID control algorithms.
  - d. The Filtrate Pump VFD shall adjust proportionally to the level in the VLR wet well. Between the Start and Stop setpoints, the Filtrate Pump shall modulate using proportional control to maintain the level in the VLR wet well. As the level increases in the tank, the Filtrate Pump shall ramp up and as the level decreases in the tank, the Filtrate Pump shall ramp down.
7. **Membrane Blowers:** The Membrane Blowers provide low pressure air to scour the membrane surface. The supply of air is continuous in Filtration and Relaxation modes. During Maintenance Clean, CIP, or Standby modes, the need for air is intermittent.
  - a. The blowers are VFD driven and the BTS PLC monitors and controls the speed to maintain flow setpoints.
  - b. There are 3 duty Membrane Blowers. The air discharged enters a common header leading to a Thermal Mass Flowmeter for each

Membrane Tank. The PLC calculates the difference between the actual reading and a setpoint to adjust a modulating valve to provide the flow as required.

- c. Required air flow is based upon filtrate flow rates:

Tanks in service	Average Flow			Peak Flow		
	Flow per tank (scfm)	Total system flow (scfm)	# of blowers operating	Flow per tank (scfm)	Total system flow (scfm)	# of blowers operating
1	1,470	1,470	1	2,308	2,308	1
2	1,470	2,940	2	2,308	4,616	2
3	1,470	4,410	3	2,308	6,924	3

- d. The blower speed is controlled by a PID algorithm to maintain a set flow range in the header; the set flow range is + 10% the set valve in the table.
- e. The air flow is based on the number of membrane modules installed.

7. Membrane Feed Pumps: The mixed liquor flow is variable based on the allowed mixed liquor concentration in the tank for a given filtrate flow. This can be transferred to a basic equation:

$y = mx + b$ , where  $y$  = mixed liquor flow and  $x$  = net filtrate flow. Using the table below:

Filtrate Flow Range (gpm)	ML Flow (gpm)	gradient for equation (m)	y-intercept for equation (b)
756 to 844	2,290	N/A	N/A
845 to 1506	3,800	$m = 2.16659$	$b = 1987.41384$

- a. During non-peak conditions (up to 845 gpm) the mixed liquor feed flow rate shall utilize the Mixed Liquor Suspended Solids (MLSS) concentration in VLR 1C and the filtrate flow rate to determine the most efficient set point. This set point shall be base on maintaining a mixed liquor concentration of 12,500 mg/L in the MOS overflow channel.
- b. The PLC calculates the mixed liquor feed flow rate based on the filtrate flow rate reading of the filtrate flowmeter and the reading of the MLSS sensor. The mixed liquor concentration in the MOS overflow is set to 12,500 mg/L which is the allowable concentration for sustainable operation.
- c. In the event of low MLSS concentrations in the VLR tank and/or low filtrate flows, there is a minimum mixed liquor feed flow rate which is based on maintaining a minimum velocity in the mixed liquor distribution laterals in the Membrane Tank. This minimum flow rate is 2,290 gpm.

- C. Effluent Flow Control Calculation:
1. Clean water required for the MC, CIP, or SIP, which comes from the common effluent line, passes through the filtrate flow meter for each respective tank being cleaned prior to entering the tank. This rate is subtracted from the totalized flow.
  2. During a recirculation mode, the flow rate measured by the filtrate flowmeter is not added or subtracted from the totalized effluent flow.

### 2.3 RESIDUALS REDUCTION SYSTEM

- A. General:
1. Modes of Operation:
    - a. The two Interchange Tanks alternate daily on the process carried out.
      - 1) During Day 1, Tank 1 shall withdraw and fill and Tank 2 shall react.
      - 2) During Day 2, Tank 1 shall react and Tank 2 shall withdraw and fill.
    - b. This cycle repeats until the process is taken offline.
  2. Interchange Tank Return Cycle:
    - a. A timer triggered in the BTS PLC begins the return cycle for Interchange Tank 1.
    - b. The PLC calculates the required fill amount based on a sludge reduction time (SRT) calculation or a predetermined level, which is operator adjustable.
    - c. If SRT mode is selected, then the PLC calculates the decant amount.
    - d. The Interchange Tank 1 Decant Valve opens and a preset quantity of clear liquid is transferred to the VLR tanks. The operator can adjust the quantity of clear liquid withdrawn to modify the total suspended solids (TSS) concentration in the Interchange Tanks.
    - e. Interchange Mixer 1 starts when the first set point level is reached.
    - f. Interchange Tank 1 indicates the final set point level has been reached. This is determined either by preset levels, or a decant amount entered in the OIT.
    - g. Interchange Tank 1 Decant Valve is closed.
    - h. This step is also carried out by Tank 2 on days that Tank 1 is reacting.
  3. Solids Flow to Interchange Tank:
    - a. The Interchange Mixer 1 continues to run during flow to the Interchange Tank.
    - b. The BTS PLC begins the wasting phase of operation based on maintaining a SRT calculation or a predetermined level.
      - 1) PLC calculates plant inventory using the MLSS probe in the VLR tank. The MLSS concentration multiplied by the volume of the VLR tanks equals the sludge inventory. The totalizer

goal for interchange flow is then a setpoint fraction of the VLR tank inventory.

- 2) Interchange Mass, in pounds = MLSS (in mg/L) x VLR volume (in millions of gallons) x 8.34 x setpoint fraction.
  - 3) If the SRT for the system is 10 days, then the set point fraction would be 1/10<sup>th</sup>.
  - 4) The SRT set point is adjustable by the operator at the OIT. The Interchange Mass cannot exceed the design loading.
  - 5) High level indication in the Interchange Tank prevents the sequence and an alarm is triggered on the OIT.
- c. The Interchange Tank 1 Feed Valve is opened directing flow to Interchange Tank 1. If the SRT mode is selected by the operator, the PLC begins totalizing mass flow using signals from the VLR MLSS probe and Interchange Tank level transmitter.
  - d. The Interchange Reactor reaches the set point.
  - e. The Interchange Tank 1 Feed Valve closes.
  - f. The Interchange Mixer 1 stops.
  - g. This step is also carried out by Tank 2 on days that Tank 1 is reacting.
4. Interchange Tank Environment Control: Periodically, when the Return Cycle and Solid flow are not in progress, other functions are carried out in the Interchange Tanks:
- a. Interchange Tank Mixer starts.
  - b. The BTS PLC starts a timer, and after 15 minutes (or entered setpoint) the PLC accepts the signal from the tank's ORP probe.
  - c. If the ORP signal is below the setpoint, a Residuals Blower starts, and the PLC starts a timer.
  - d. At the end of this timer, the Interchange Tank Mixer and Residuals Blower stops.
  - e. If the pH drops below a setpoint prior to the Residuals Blower timer expiring, this shall also cause the Interchange Tank Mixer and Residuals Blower to stop.
  - f. Blowers are controlled by PLC timers which shall signal the start of the Interchange Tank Mixer and Residuals Blower for a pre-determined period of time.

**B. Solids Separation Module Operation:**

1. RAS Screen and RAS Screenings Compactor:
  - a. During normal operation, the RAS Pumps continuously direct flow to the RAS Screen.
  - b. If the RAS Pumps are off, then the PLC shuts down the RAS Screen process train.
  - c. If the float switch mounted in the RAS Screen discharge chute closes, then the PLC shall stop the RAS Pumps and shut down the RAS Screen process train.
2. Spray Water:

- a. If the RAS Screen is running, then the internal and external spray water solenoid valves shall open.
  - b. If the RAS Screenings Compactor is running, then the spray water solenoid valves shall open periodically as determined by a timer.
  - c. If the RAS Screen and RAS Screenings Compactor are ready to be back on service after a maintenance stop, then the spray system shall start before running the equipment for a preset period of time.
  - d. If the pressure switch on the spray water line detects low pressure, then the PLC shall shut off the RAS Pumps immediately and sounds an alarm. The RAS Screen and RAS Screenings Compactor shall also shut off after preset delay intervals.
  - e. The spray water system shall have the ability to be controlled from the BTS OIT screens for manual operations. Manual shutdown shall close the spray water solenoid valves.
3. Grit Cyclones:
- a. A PLC timer signals the start of the RAS Grit Pump, and opening of the RAS Grit Pump Dilution Water Solenoid Valve. A second PLC timer begins counting. When the second timer has finished, the pump is stopped and the solenoid valve is closed.
  - b. The inerts removal can be adjusted at the OIT by set point. The frequency of the inerts removal operation is adjustable.
  - c. The Grit Cyclone can only operate if the RAS Screen is in operation.

## PART 3 – OPERATOR INTERFACE

### 3.1 GENERAL

- A. Operator Interface Terminals:
1. The OIT stations shall provide detailed information on the operation of plant equipment. From the OIT stations, plant operators shall receive a complete picture of the plant processes.
- B. Process Graphic Displays:
1. The graphic displays that reside on the OIT stations shall be the operator's primary window into the process. All monitored and calculated data points in the BTS PLC shall be available for display via graphic symbol color changes, text messages, animation, or other display action.
  2. The graphic displays shall allow the operator to enter control set points and initiate manual commands (i.e., PLC auto/manual selection, manual start/stop control). All set points and operator inputs shall be tested for validity at both the PLC and OIT level. Out of range inputs shall be rejected and the system shall prompt the operator for a valid input.

3. Graphic displays shall utilize dynamic symbols, text messages, and pop-up window as applicable to effectively display the information. The color conventions used on the OIT shall be as follows:
  - a. Green: Running, Open.
  - b. Red: Stopped, Closed.
  - c. Gray: Non-Monitored Equipment.
  - d. Amber: Malfunction, Alarm.
  - e. Two-position valves/gates symbols, with positive feedback, shall be green when open, red when closed, and mixed while in transition.
  - f. Modulating control valves/gates symbols shall have a percent open indication value displayed next to the symbol. The percent open control shall be used to determine symbol color if positive feedback is not available. The symbol shall be green if the valve/gate is greater than or equal to five percent (5%) open, and red if the valve/gate is less than five percent (5%) open.
4. Main Graphic Displays:
  - a. At a minimum, the main graphic displays shall contain the following information:
    - 1) Graphic Display Title.
    - 2) Current Date and Time.
    - 3) OVERVIEW button – takes the operator to the BTS overview graphic display.
    - 4) ALARM SUMMARY button – takes the operator to the alarm summary graphic display.
    - 5) TREND button – takes the operator to the historical trend associated with the graphic display.
    - 6) RUNTIMES button – takes the operator to the runtime graphic display.
    - 7) HELP button – takes the operator to an informational screen with OIT assistance and equipment manuals.
  - b. Main graphic displays list:
    - 1) Alarm Summary: Displays a list of the current active alarms and also gives the operator the ability to acknowledge the active alarms.
    - 2) System Configuration: Displays the current status of the PLC system.
    - 3) VLR Tank Overview: Displays tank status, flows, levels, and analytical values, etc.
    - 4) Membrane Tank Overview: Displays tank status, flows, levels, analytical values, modes, valve positions, etc.
    - 5) Residuals Reduction System: Displays tank status, flows, levels, analytical values, modes, RAS equipment statuses, grit system, blower status, valve positions, etc.
    - 6) Citric Acid Feed System: Displays tank levels, equipment status, etc.

- 7) Sodium Hypochlorite Feed System: Displays equipment status, etc.
  - 8) Process Air Supply Systems: Displays equipment status, pressure in manifolds, flow rates to Membrane Tanks, valve positions, etc.
  - 9) Compressor System: Displays equipment status, valve positions, pressure switch statuses, etc.
5. Trend Graphic Displays:
- a. The OIT shall be capable of producing real-time or historical trends for any monitored or calculated variable.
  - b. Fixed trends (with variables permanently assigned to the pens) can be provided for the more commonly accessed trend displays and individually assignable trends (with operator assigned variables for each pen) can be provided for custom trending.
  - c. Trends graphics shall be configured as described below for the signals connected to the PLC system. Trend graphics shall be contained in trend windows that are smaller pop-up windows, separate from the main window that contains the main graphic displays.
  - d. Trend graphics shall display historical data (allowing the operator to pan back in time and see the trend data).
  - e. Common trend values shall be grouped on the same trend graphic, with different colors for each value.

C. Historical Data Collection:

1. All process data monitored or calculated by the OIT shall be logged and stored on disk.
2. Analog data shall be logged for trending purposes and the OIT shall calculate averages, minimums, maximums, flow totals, and other statistical information needed for process monitoring and reporting.
3. Process alarms shall be logged along with the date and time the alarm became active, was acknowledged, and cleared. Discrete information can be logged if there is benefit to having the data available for future access.

D. Alarming:

1. The OIT shall receive all alarm conditions monitored or generated by the PLC and shall calculate alarms based on other monitored variables as necessary.
2. The alarms shall be conspicuously displayed on the stations in a dedicated area of each graphic display, in a dedicated window which shall automatically appear whenever the alarm becomes active, or in another intuitive fashion.
3. Alarms shall be grouped by priority on a common display that shall list all active alarms.

E. Security:

1. Operators that wish to control the equipment shall need to log in to the OIT with a username and password, based upon level of access (i.e. Supervisor, Operator, Maintenance, etc).

++ END OF SECTION ++