**PAA CT Dosing Calculations (3/29/2019)**

**Overview**

**PAA iCT Dosing Algorithm:** PAA dosing for this control scheme is adjusted to maintain a target integrated concentration x time (iCT) value with lower and upper concentration clamps. This strategy will adjust the target PAA dosing concentration to maintain a constant input iCT based on the current contact basin detention time (DT).

**PAA Variables:**

* FlowN = FI-F2 for North flow; backup flow meter is FI-F350
* FlowS = Greater of FY-K100 and FY-F230 for South flow; backup flow meter is FY\_S100
* iCTN = XC\_KXXX DCS Input for North iCT Target SP

iCTS = XC\_KXXX DCS Input for South iCT Target SP

kN = operator adjustable north decay constant input from DCS

Dinst,N = instantaneous calculated demand

Davg,N = week running average D

Tup,N = time at upstream analyzer

Ttotal,N = total disinfection time

Cup,N = concentration from upstream analyzer

CD,N = calculated dose concentration in north

CDset,N = dose set point for north

* CPAA,Low,N = XC\_KXXX DCS Input low concentration clamp for north plant PAA dose
* CPAA,Low,S = XC\_KXXX DCS Input low concentration clamp for south plant PAA dose
* CPAA,High,N = XC\_KXXX DCS Input high concentration clamp for north plant PAA dose concentration
* CPAA,High,S = XC\_KXXX DCS Input high concentration clamp for south plant PAA dose concentration
* CPAA,Dose,N = Current PAA dose in north
* CPAA,Dose,S = Current PAA dose in south
* MPAA,N = Mass of PAA feed in north
* MPAA,S = Mass of PAA feed in south
* QPAA,N = Calculated flow for north PAA feed system
* QPAA,S = Calculated flow for south PAA feed system

**PAA iCT Dosing Calculations:**

1. Calculate current hydraulic total retention time (Ttotal,N, minutes);
   1. Ttotal,N = 2775\*(FlowN + FlowS)^(-0.9588)
2. Calculate current hydraulic retention time to upstream analyzer (Tup,N, minutes);
   1. Tup,N = 395.8813\*(FlowN + FlowS)^(-0.982)+12.2
3. Set current value of kN from DCS input
4. Grab previous value for concentration dose set point (CDset,N, minutes)
5. Estimate instantaneous demand from analyzer data and hydraulic retention time (Dinst,N, mg/L)
   1. Dinst,N = CDset,N –Cup,N / (exp (-kN \* Tup,N))
6. Calculate the Target Dose Concentration (CD,N, mg/l) to maintain target CT
   1. CD,N = iCTN \* kN / (1 – exp (-kN \* Ttotal,N)) + Dinst,N
7. Step 4: Determine whether dose concentration set point is within clamps (CDoseN, mg/l) using high and low concentration clamps
   1. If (CTarget,N < CPAA,Low,N), CPAA,Dose,N = CPAA,Low,N, else if (CTarget,N > CPAA,High,N), CPAA,Dose,N = CPAA,High,N, elseCPAA,Dose,N = CTarget,N
   2. If (CTarget,S < CPAA,Low,S), CPAA,Dose,S = CPAA,Low,S, else if (CTarget,S > CPAA,High,S), CPAA,Dose,S = CPAA,High,S, elseCPAA,Dose,S = CTarget,S
8. Step 5: Calculate the mass of PAA required for target dose concentration:
   * MPAA,N (lbs/day) to add to North = FlowN (MGD) \* CPAA,Dose,N (mg/l) \* 8.34 (l-lb/MG-mg)
   * MPAA,S (lbs/day) to add to South = FlowS (MGD) \* CPAA,Dose,S (mg/l) \* 8.34 (l-lb/MG-mg)
9. Step 6: Convert mass feed rate (lbs PAA /Day) calculated in Step 5 to volumetric flow rate (gpm) for PAA dosing pumps
   * QPAA,N (gpm) in North= MPAA,N (lbs/day) \* 1 gallon/1.43 lbs PAA \* 1 day/24 hours \* 1 hour/60 minutes
   * QPAA,S (gpm) in South = MPAA,S (lbs/day) \* 1 gallon/1.43 lbs PAA \* 1 day/24 hours \* 1 hour/60 minutes
     + PAA mass per gallon was calculated using the manufacturer-provided (EnviroTech Peragreen 15%) PAA solution specific gravity of 1.14 or 9.5 lbs/gallon. The product used at MWRD is 15% which results in a PAA density of 9.5 \* 0.15 = 1.43 lbs PAA/gal.

**PAA fail safes:**

1. Effluent Flow Meters
   1. North Effluent Flow Meter
      1. If FI-F2 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FI-F350) and send an alarm that the primary flow meter (FI-F2) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.
   2. South Effluent Flow Meter
      1. If FY-F230 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FY\_S100) and send an alarm that the primary flow meter (FY-F230) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.
2. Detecting Flush of ChemScan

**PAA Dosing fail safes (all values listed below were current as of 10/18/2017. These variables are adjustable by Operations Management):**

1. North dose low set point clamp set at 0.03 gpm.
2. North dose high set point clamp set at 2.8 gpm
3. South dose low set point clamp set at 0.03 gpm
4. North dose high set point clamp set at 2.8 gpm

**SBS Dosing Calculations for PAA with Dose Decay (2/21/2018)**

**Overview**

**SBS Strategy B – PAA Dose with Decay Paced Algorithm:** Start-up SBS dosing is calculated using the initial PAA dose concentration minus an input observed initial decay, assuming stoichiometric ratios of SBS:PAA. An operator adjustable safety factor is included.

**SBS Variables:**

1. CPAA,Dose,N = Current PAA dose setpoint in the north.
2. CPAA,Dose,S = Current PAA dose setpoint in the south.
3. CDecay,S = Initial decay of PAA in the south.
4. CDecay,N = Initial decay of PAA in the north.
5. FlowN = FI-F2 for North flow; backup flow meter is FI-F350.
6. FlowS = FY-F230 for South flow; backup flow meter is FY\_S100.
7. MSBS,N = Mass of SBS to add to north for quenching.
8. MSBS,S = Mass of SBS to add to south for quenching.
9. SBSSF, N = Operator adjustable safety factor (Treatment Superintendent). Ratio of calculated SBS dose.
10. SBSSF, S = Operator adjustable safety factor (Treatment Superintendent). Ratio of calculated SBS dose.
11. QSBS,N = Calculated flow for north SBS feed system
12. QSBS,S = Calculated flow for south SBS feed system

**SBS Dosing Calculations:**

1. Step 1: Use the current PAA dose setpoint and current plant flow to calculate the mass of PAA to remove (lbs/day)
   * Mass of PAA to remove in north (lbs/day) MPAA,N = FlowN (MGD) \* (CPAA,Dose,N (mg/l) – Cdecay, N (mg/L)) \* 8.34 (l-lb/MG-mg)
   * Mass of PAA to remove in south (lbs/day) MPAA,S = FlowS (MGD) \* (CPAA,Dose,S (mg/l) – Cdecay,S (mg/L)) \* 8.34 (l-lb/MG-mg)
2. Step 2: Calculate SBS mass required to remove PAA mass calculated in Step 1 (jar tests indicated 1.6 mg SBS per mg PAA which is greater than the stoichiometric ratio)
   * MSBS,N (lbs/day) = MPAA,N \* 1.6 \* SBSSF
   * MSBS,S (lbs/day) = MPAA,S \* 1.6 \* SBSSF
3. Step 3: Convert mass feed rate (lbs SBS /Day) in Step 2 to gpm for SBS dosing
   * QSBS,N (gpm) = MSBS,N \* 1 gallon/4.21 lbs SBS \* 1 day/24 hours \* 1 hour/60 minutes
   * QSBS,S (gpm) = MSBS,S \* 1 gallon/4.21 lbs SBS \* 1 day/24 hours \* 1 hour/60 minutes
     + SBS content per gallon was calculated using the manufacturer-provided (Chemtrade Logistics) SBS solution density of 10.8-11.7 lbs gallon. The product used at MWRD is 38% which results in an SBS density of 10.8 \* 0.38 = 4.1 lbs SBS/gal.

**SBS Plant Flow fail safes:**

1. Effluent Flow Meters
   1. North Effluent Flow Meter
      1. If FI-F2 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FI-F350) and send an alarm that the primary flow meter (FI-F2) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.
   2. South Effluent Flow Meter
      1. If FY-F230 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FY\_S100) and send an alarm that the primary flow meter (FY-F230) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.

**SBS dosing fail safes:**

1. Low flow SP threshold is set at 0.05 gpm for north and south
2. High flow SP threshold is set at 1.5 gpm for the north and south

**PAA Dosing Calculations (10/18/2017)**

**Overview**

**PAA Strategy A - Flow Paced Algorithm:** PAA dosing for this control scheme is adjusted based on a manually input PAA dose setpoint.

**PAA Variables:**

1. FlowN = FI-F2 for North flow; backup flow meter is FI-F350
2. FlowS = FY-F230 for South flow; backup flow meter is FY\_S10
3. CPAA,input,N = manual input north plant dose from DCS
4. CPAA,input,S = manual input south plant dose from DCS
5. CPAA,Dose,N = Current PAA dose in north
6. CPAA,Dose,S = Current PAA dose in south
7. CPAA,High,N = manual input high dose from DCS for north plant high flow cases. Overrides CPAA,input,N
8. CPAA,High,S = manual input high dose from DCS for south plant high flow cases. Overrides CPAA,input,S
9. MPAA,N = Mass of PAA feed in north
10. MPAA,S = Mass of PAA feed in south
11. QPAA,N = Calculated flow for north PAA feed system
12. QPAA,S = Calculated flow for south PAA feed system

**PAA Dosing Calculations:**

1. Step 1: Determine CPAA, Dose:
   1. If (FlowN >145 (mgd) and CPAA,Input,N < CPAA,High,N), CPAA,Dose,N = CPAA,High,N else CPAA,Dose,N = CPAA,Input,N
   2. If (FlowS > 135 (mgd) and CPAA,Input,S < CPAA,High,S), CPAA,Dose,S = CPAA,High,S  else CPAA,Dose,S = CPAA,Input,S
2. Step 2: Calculate the mass of PAA required for target dose concentration:
   * MPAA,N (lbs/day) to add to North = FlowN (MGD) \* CPAA,Dose,N (mg/l) \* 8.34 (l-lb/MG-mg)
   * MPAA,S (lbs/day) to add to South = FlowS (MGD) \* CPAA,Dose,S (mg/l) \* 8.34 (l-lb/MG-mg)
3. Step 3: Convert mass feed rate (lbs PAA /Day) calculated in Step 2 to volumetric flow rate (gpm) for PAA dosing pumps
   * QPAA,N (gpm) in North= MPAA,N (lbs/day) \* 1 gallon/1.43 lbs PAA \* 1 day/24 hours \* 1 hour/60 minutes
   * QPAA,S (gpm) in South = MPAA,S (lbs/day) \* 1 gallon/1.43 lbs PAA \* 1 day/24 hours \* 1 hour/60 minutes
     + PAA mass per gallon was calculated using the manufacturer-provided (EnviroTech Peragreen 15%) PAA solution specific gravity of 1.14 or 9.5 lbs/gallon. The product used at MWRD is 15% which results in a PAA density of 9.5 \* 0.15 = 1.43 lbs PAA/gal.

**PAA fail safes:**

1. Effluent Flow Meters
   1. North Effluent Flow Meter
      1. If FI-F2 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FI-F350) and send an alarm that the primary flow meter (FI-F2) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.
   2. South Effluent Flow Meter
      1. If FY-F230 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FY\_S100) and send an alarm that the primary flow meter (FY-F230) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.

**PAA Dosing fail safes (all values listed below were current as of 10/18/2017. These variables are adjustable by Operations Management):**

1. North dose low set point clamp set at 0.08 gpm.
2. North dose high set point clamp set at 2.8 gpm
3. South dose low set point clamp set at 0.08 gpm
4. North dose high set point clamp set at 2.8 gpm

**PAA System Operator Adjustable Inputs**

|  |  |  |  |
| --- | --- | --- | --- |
| INPUT | DESCRIPTION | RANGE | INITIAL VALUE |
| PAA Dose SP | CPAA,input,N  CPAA,input,S | 0.5 – 5.0 mg/L | 3.0 mg/L |
| PAA High Dose SP | CPAA,High,N  CPAA,High,S | 0.5 – 5.0 mg/L | 2.0 mg/L |
| Dose Low SP Clamp | Min allowable flow at each PAA dosing system (N and S) | 0.03 – 1.0 gpm | 0.03 gpm |
| Dose High SP Clamp | Max allowable flow at each PAA dosing system (N and S) | 1.0 – 3.0 gpm | 2.8 gpm |

**PAA System Alarms**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ALARM | DESCRIPTION | TAGS (NORTH) | TAGS (SOUTH) | AVAILABLE RANGE | VALUE | DELAY  (sec) |
| Pump Fail | Not in remote, not available for control, not achieving SP (within X%), low pressure, high pressure | PMP-K811, K812, K813 | PMP-K861, K862, K863 | - | - | 0 |
| Dose Discrepancy | Total delivered dose not within 5% of SP. Operator adjustable | SUM (FIT-K811, K812, K813) | SUM (FIT-K861, K862, K863) | 0-10% | +/- 5% dose SP | 0 |
| PAA Flow Meter Fail | Not in remote, not available, not achieving SP | FIT-K811, K812, K813 | FIT-K861, K862, K863 | - | - | 0 |
| Tank Level Lo | Operator adjustable | LIT-K801, K802 | LIT-K851, K852 | 0.5 – 2.5 ft | 1.5 ft | 5 |
| Tank Level Lo Lo | Operator adjustable | LIT-K801, K802 | LIT-K851, K852 | 0.5 – 1.5 ft | 1.0 ft | 5 |
| Tank Level Hi | Operator adjustable | LIT-K801, K802 | LIT-K851, K852 | 12.0 - 14.5 ft | 13.5 ft | 5 |
| Tank Level Hi Hi | Operator adjustable | LIT-K801, K802 | LIT-K851, K852 | 11.0 – 13.5 ft | 13.0 ft | 5 |
| Tank Temperature | High temperature indicates impurities causing PAA decay. Operator adjustable | TIT-K801, K802 | TIT-K851, K852 | 120 -145 degF | 120 degF | 5 |
| Flow Lo | Operator adjustable – fail safe override | SUM (FIT-K811, K812, K813) | SUM (FIT-K861, K862, K863) | 0.05 – 1.0 gpm | 0.08 gpm | 30 |
| Flow Hi | Operator adjustable – fail safe override | SUM (FIT-K811, K812, K813) | SUM (FIT-K861, K862, K863) | 1.0 – 3.0 gpm | 2.8 gpm | 30 |
| Initial Residual Hi | Operator adjustable | AIT-K822 | AIT-K872 | 0.5 - 5.0 mg/L | 3.5 mg/L | 10 |
| Initial Residual Lo | Operator adjustable | AIT-K822 | AIT-K872 | 0.0 – 1.0 mg/L | 0.5 mg/L | 10 |
| Final Residual Hi | Operator adjustable | AIT-K832 | AIT-K882 | 0.4 – 2.0 mg/L | 1.0 mg/L | 10 |
| Final Residual Lo | Operator adjustable | AIT-K832 | AIT-K882 | 0.0 – 0.5 mg/L | 0 mg/L | 10 |
| Sec Eff Flow Meter Fail | Flow not available | FI-F2 | FY-F230 | - | - | 0 |

**SBS Dosing Calculations for PAA (10/11/2017)**

**Overview**

**SBS Strategy A – PAA Dose Paced Algorithm:** Start-up SBS dosing is calculated using the initial PAA dose concentration assuming stoichiometric ratios of SBS:PAA. An operator adjustable safety factor is included.

**SBS Variables:**

1. CPAA,Dose,N = Current PAA dose setpoint in the north.
2. CPAA,Dose,S = Current PAA dose setpoint in the south.
3. FlowN = FI-F2 for North flow; backup flow meter is FI-F350.
4. FlowS = FY-F230 for South flow; backup flow meter is FY\_S100.
5. MSBS,N = Mass of SBS to add to north for quenching.
6. MSBS,S = Mass of SBS to add to south for quenching.
7. SBSSF, N = Operator adjustable safety factor (Treatment Superintendent). Ratio of calculated SBS dose.
8. SBSSF, S = Operator adjustable safety factor (Treatment Superintendent). Ratio of calculated SBS dose.
9. QSBS,N = Calculated flow for north SBS feed system
10. QSBS,S = Calculated flow for south SBS feed system

**SBS Dosing Calculations:**

1. Step 1: Use the current PAA dose setpoint and current plant flow to calculate the mass of PAA to remove (lbs/day)
   * Mass of PAA to remove in north (lbs/day) MPAA,N = FlowN (MGD) \* CPAA,Dose,N (mg/l) \* 8.34 (l-lb/MG-mg)
   * Mass of PAA to remove in south (lbs/day) MPAA,S = FlowS (MGD) \* CPAA,Dose,S (mg/l) \* 8.34 (l-lb/MG-mg)
2. Step 2: Calculate SBS mass required to remove PAA mass calculated in Step 1 (jar tests indicated 1.6 mg SBS per mg PAA)
   * MSBS,N (lbs/day) = MPAA,N \* 1.6 \* SBSSF
   * MSBS,S (lbs/day) = MPAA,S \* 1.6 \* SBSSF
3. Step 3: Convert mass feed rate (lbs SBS /Day) in Step 2 to gpm for SBS dosing
   * QSBS,N (gpm) = MSBS,N \* 1 gallon/4.21 lbs SBS \* 1 day/24 hours \* 1 hour/60 minutes
   * QSBS,S (gpm) = MSBS,S \* 1 gallon/4.21 lbs SBS \* 1 day/24 hours \* 1 hour/60 minutes
     + SBS content per gallon was calculated using the manufacturer-provided (Chemtrade Logistics) SBS solution density of 10.8-11.7 lbs gallon. The product used at MWRD is 38% which results in an SBS density of 10.8 \* 0.38 = 4.1 lbs SBS/gal.

**SBS Plant Flow fail safes:**

1. Effluent Flow Meters
   1. North Effluent Flow Meter
      1. If FI-F2 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FI-F350) and send an alarm that the primary flow meter (FI-F2) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.
   2. South Effluent Flow Meter
      1. If FY-F230 is not functioning (flow values change too fast), the DCS will use the backup flow meter (FY\_S100) and send an alarm that the primary flow meter (FY-F230) is not being used so that a Priority One Work Order can be generated. The primary flow meter will not be used again until Operations resets the alarm in the alarm faceplate.

**SBS dosing fail safes:**

1. Low flow SP threshold is set at 0.05 gpm for north and south
2. High flow SP threshold is set at 1.5 gpm for the north and south

**SBS System Operator Adjustable Inputs**

|  |  |  |  |
| --- | --- | --- | --- |
| INPUT | DESCRIPTION | RANGE | INITIAL VALUE |
| SBS Safety Factor | SBSSF, N  SBSSF, S | 0.0 – 1.0 | 1.0 |
| Dose Low SP Clamp | Min allowable flow at each SBS dosing system (N and S) | 0.0 – 1.0 gpm | 0.05 gpm |
| Dose High SP Clamp | Max allowable flow at each SBS dosing system (N and S) | 0.5 – 2.0 gpm | 1.5 gpm |

**SBS Alarms - (Maintain Existing)**