WWTP Control System Design in CCRP

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February 22, 2005

Report for
Master of Engineering

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Abstract

This report introduced the Waste Water Treatment Plant control system design in Coleson Cove Refurbishment Project.

This report presented process flow chart, described subsystem process design and control requirement. Subsystem processes were illustrated by many diagrams. Next, control system structure was introduced and analysis was given as well. Several typical logic designs were introduced simply to give reader a glance about industrial logic design example. Finally, the characteristic of WWTP control system design in CCRP was summarized.

Acknowledgement

First of all, I would like to take this opportunity to express my gratitude to my academic supervisor, Dr. Jim H. Taylor, who helped me to obtain the relevant documents for the preparation of this report. Without his help, the completion of this report would be impossible.

Dr. Taylor is a kind, nice, considerate and gentle professor. It is my luck to be directed by Dr. Taylor. I learned not only knowledge but also attitude about life. Dr. Taylor is a distinguished, diligent scholar. His late-off office light is a sound example to every student.

My sincere appreciation also goes to Mr. Kevin Calhoun, Mr. Andrew Duplessis and Mr. Peter Dean. Mr. Kevin Calhoun gave me the chance to work in CPG and started my professional career. The leadership and mentoring from respectful, knowledgeable and sociable Mr. Andrew Duplessis impressed me a lot.

Finally, thanks go to the support from my dear wife, Junping (Grace) Wu and my daughter, Alice Wang. My wife has been supporting me, encouraging and urging me to go ahead.

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1 CCRP / WWTP Project Introduction

Coleson Cove Generating Station is located 12 kilometers southwest of Saint John city, New Brunswick. The installed capacity in this station is 3x350MW. It is a major electricity provider in NB Power electric grid. The boilers were manufactured by Babcock & Wilcox, the turbines and generators were supplied by Hitachi.

This station was built in the early 1970s. Due to evolving environment emission restriction, possible cheap energy source (Orimulsion) and life extension of power generation, the Coleson Cove Refurbishment Project (CCRP) became necessary. CCRP consists of:

- Conversion of boiler burner from burning heavy oil only to burning both Orimulsion and heavy oil
- FGD (Flue Gas Desulphurization)-- treatment of flue gas from boiler
- Refurbishment of Tank Farm area to hold new fuel
- Replace old Bailey and WDPF control system with new Emerson Ovation Distributed Control System (DCS) to implement whole plant process system control
- Limestone handling and storage system
- Gypsum handling system
- Fly ash packing system
- Waste Water Treatment Plant (WWTP)-- process waste water from various sources
- Etc

WWTP is part of whole project. It is located at a corner of the generating station. The Waste Water Treatment System continuously collects and treats waste water from different source. The treated water is stored in a treated recycle tank for reuse inside the station or discharge to outside the station (Fundy Bay).

This report will introduce how the WWTP process and control system was designed.

2 Process Description and Related Control Design

Figure 1.1 shows the WWTP general flow chart. At normal operation, the waste water is from powerhouse, FGD, rain, floor, etc. If the water contains a high percentage of oil, then it will be directed to south and north lagoon and will be treated by Oil-Water separation system. In the event that WWTP fails or in maintenance, or huge incoming waste water, lagoon shall function as a temporary storage. In most cases, the waste water will go to equalization tank. Sometimes ferric sulfate, lime solution will be added to equalization at operator's discretion. Equalization tank will feed the primary reaction tank A/B/C by providing a constant driving pressure. There are three primary reaction tanks. They are connected in series. Ferric sulfate, lime solution and polymer solution shall be added into three reaction tanks to remove heavy metal; as a result suspended solids will be formed. Next after a period of chemical reaction, the water will flow into clarifier by gravity. In clarifier, after a period of settling time, clarified water will flow out of clarifier from top, and high density substance, such as suspended solids, will fall down to bottom. A rake is installed in the bottom of clarifier to collect suspended solid to its bottom center. The sediment will be pumped to the solid holding tank for storage and handling. In the daytime, the sludge stored in the solid holding tank will be pumped to two concurrently working filter presses for dewatering.

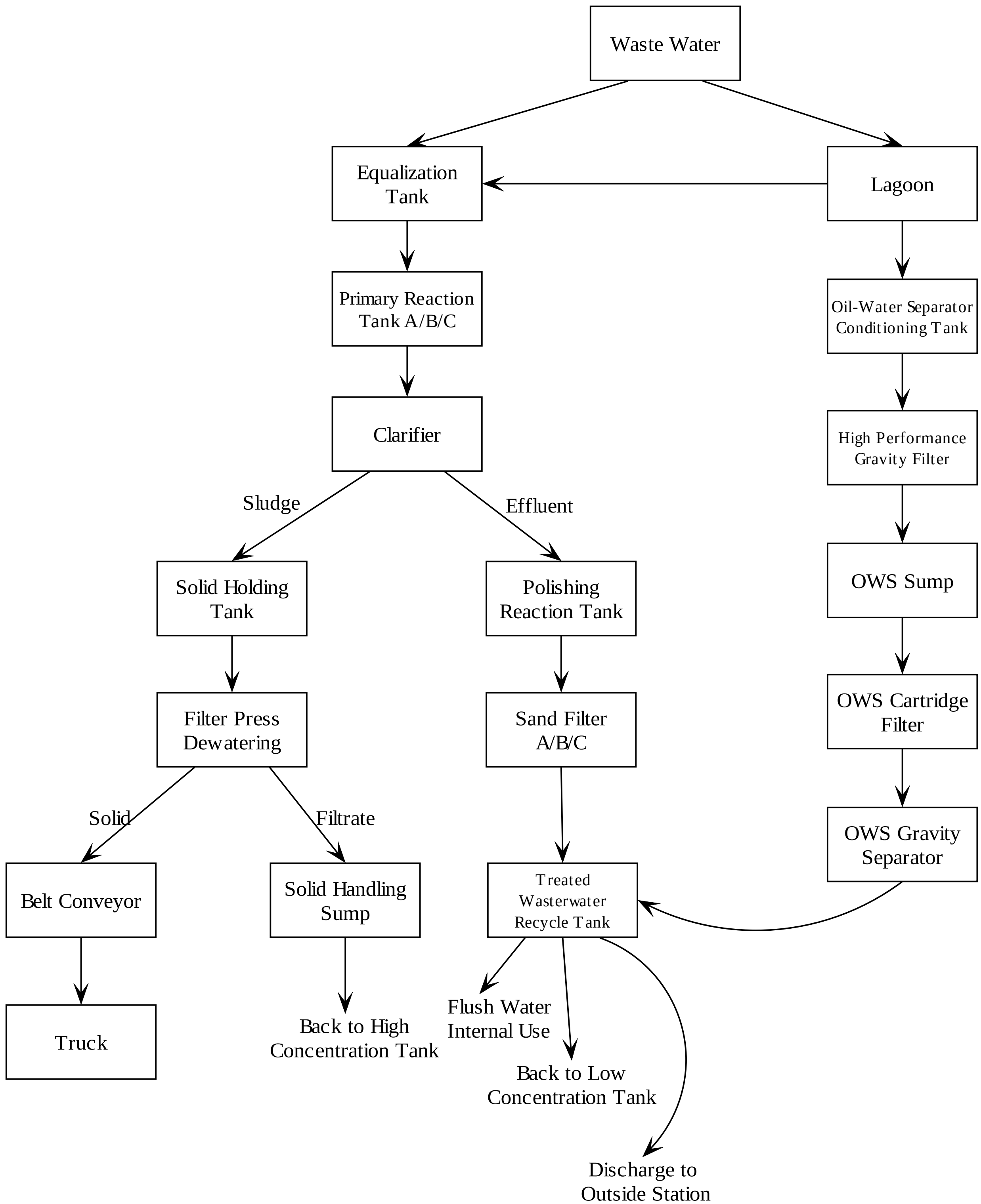

Figure 1.1 WWTP General Flow Chart

The dewatered solid will be transferred to belt conveyors, there truck will be loaded to transport solid to designated area. The filtrate after filter press will be pumped back to high concentration tank for processing again. The effluent from clarifier will flow to polishing tank by gravity. As the name imply, the polishing tank is designed to further remove heavy metal. In order to meet environment discharge requirement, second stage chemical reaction (polishing reaction tank) is critical. Again, ferric sulfate, lime solution and polymer solution are added to water. When water flow out of polishing reaction tank. Its specification almost meets desired value. At different stage (equalization tank, primary reaction tank, polishing reaction tank), metal concentration, PH, turbidity of water are different, the desired amount of substance that will be removed from water are different. Therefore, the amount of ferric sulfate, lime solution and polymer solution that will be added into water are different. After polishing reaction tank, water will be pumped to three sand filters (why?). The three sand filters are connected in parallel form. After sand filter, water will flow by gravity into treated waste water recycle tank. The water stored in treated recycle tank can be used internally for flush water purpose. Based on its lab test result and online monitoring instrument, the water in the treated recycle tank shall be either pumped back to low concentration tank for re-treatment or be discharged outside generating station.

The water containing oil will be directed to lagoon for oil-water separation. A set of oil-water separation system is designed.

Associated with main water flow chart are some auxiliary systems. They are ferric sulfate storage and delivery system, polymer handling and delivery system and lime preparation and storage system respectively.

2.1 Waste Water Equalization Tank System

2.1.1 Waste Water Source

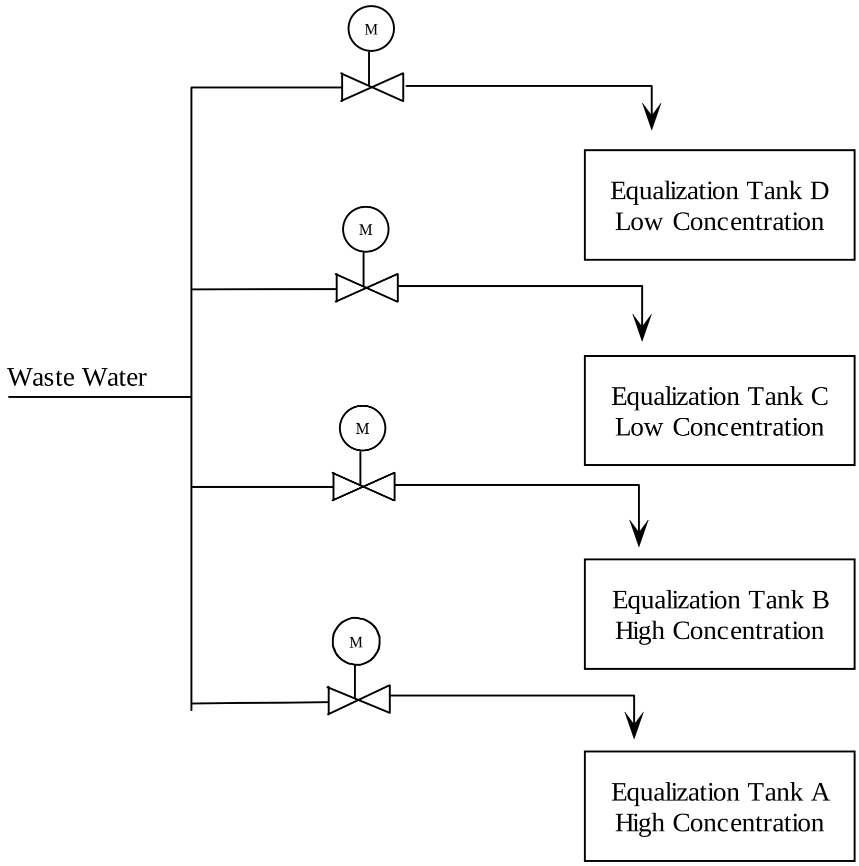

Figure 2.1.1 Equalization Tank incoming waste water

The equalization tanks are used to collect waste water to be treated by WWT process and to equalize both flow and concentration of contaminant. Equalization tanks function as buffering storage device and segregation device. Four equalization tanks are designed. Two of them (A/B) are high concentration tanks, the other two are low concentration tank. During boiler air heater wash period, heavy metal concentration is high; the incoming water will be directed one of the two concentration tanks. The figure 2.1.1 shows how the source water enters the four equalization tanks. It is to the operator to decide which tank needs to be filled. When one high concentration tank is being drawn, the other is ready for fill until full. There are level alarms signal interlock the participating valves to prevent the tanks to be overfilled.

2.1.2 Chemical Addition

Only when operators think the coming water concentration is extremely high, third stage chemical addition will be carried out in the two high concentration equalization tanks in order to reduce the heavy metal removal load undertaken by downstream process and keep the downstream process working at designed operating point.

2.1.2.1 Ferric sulfate solution addition

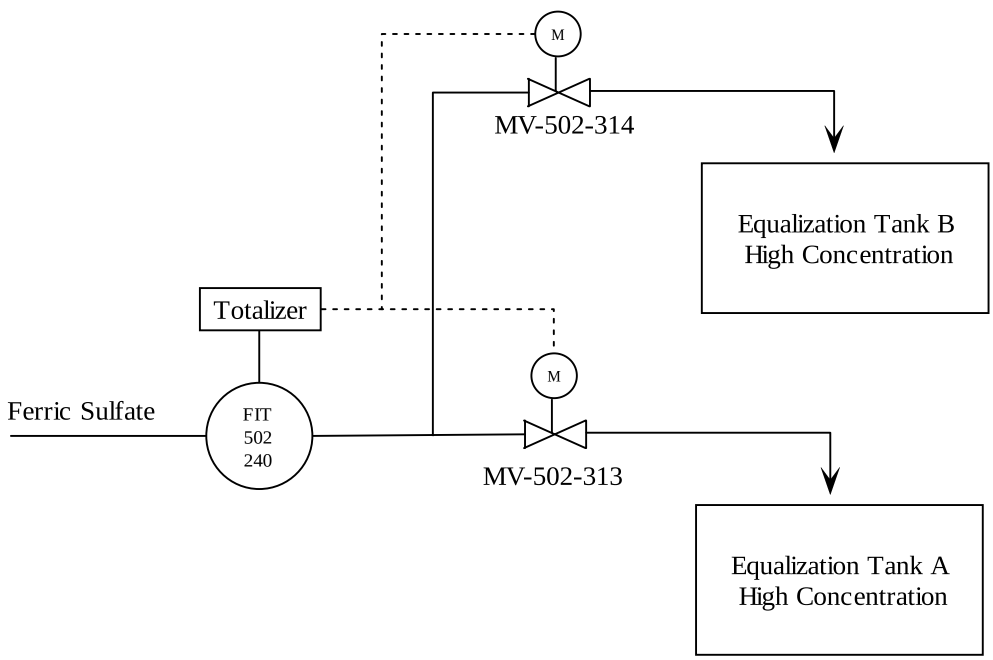

Figure 2.1.2 Equalization Tank Ferric Sulfate Addition

When the operator find that the concentration is high and decide to add Ferric Sulfate, he will calculate the total volume of ferric sulfate solution that should be added to the tank by instructing DCS to obtain it. The calculation formula is as follows:

Volume of ferric sulfate = $f(x1, x2, x3)$

Where x1 represents total volume of wastewater in the tank [USG]

x2 represents concentration of vanadium in wastewater [mg/L] or [ppm]

x3 represents selected iron to vanadium dosage ratio [lb Fe: lb V]

The related coefficient will be determined by chemical calculation and finally tuned at commissioning stage.

The DCS uses flow rate signal and accumulate, once the accumulate total reaches the calculated value, DCS totalizer will closes corresponding valve and shut down corresponding pump, thus the ferric sulfate solution is done.

2.1.2.2 Lime slurry addition

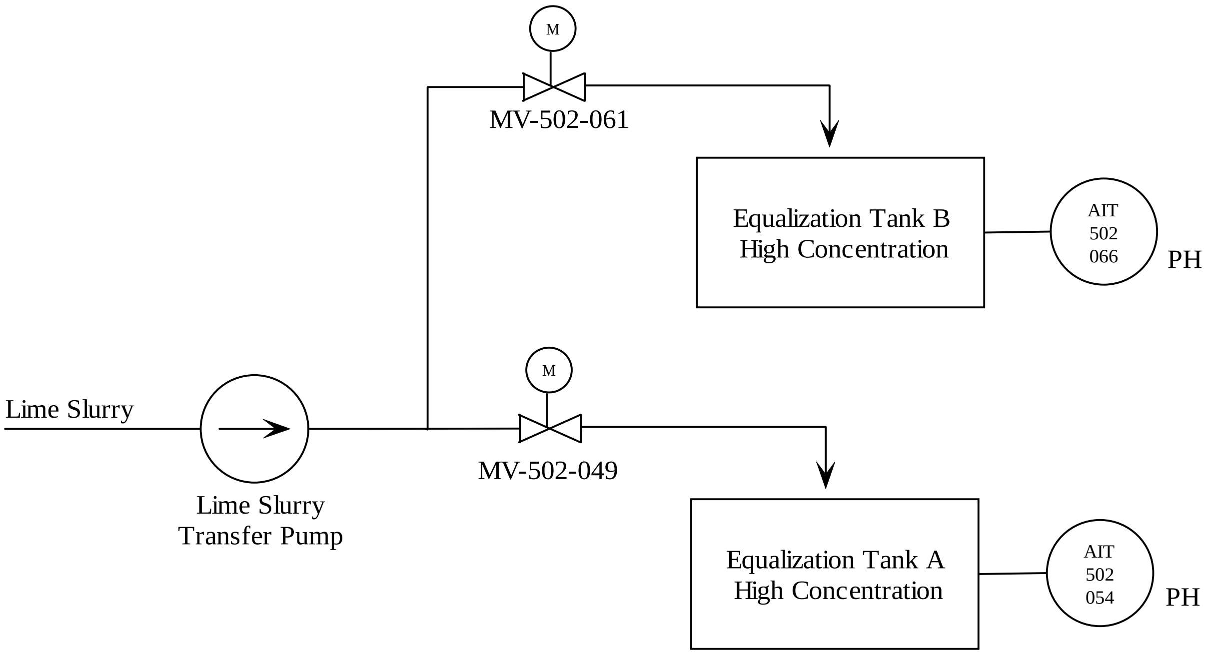

Figure 2.1.3 Equalization Tank Lime Slurry Addition

The Lime Slurry Transfer Pump startup is initiated by operator and shutdown itself upon the set point PH is reached. The analysis instruments monitor the PH value of high concentration equalization tank and send online signal to DCS for decision. The set point is determined by operator. The default value is 4.5.

2.1.3 Recycle pump

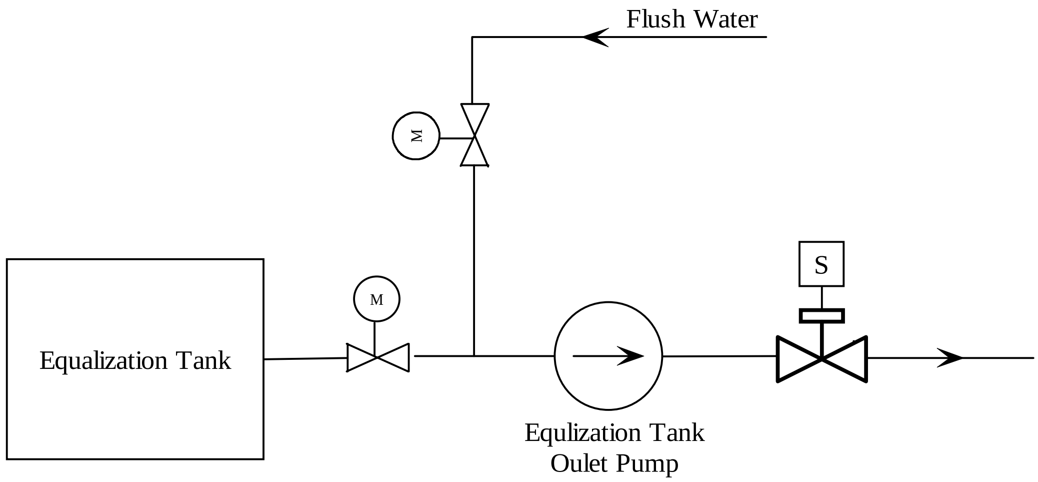

Figure 2.1.4 Equalization Tank Outlet Pump

On each of the four equalization outlet, one set of pump group system is designed. It includes equalization tank outlet pump, pump suction valve, pump discharge valve and pump flush valve. Under normal operating condition, the pump suction and discharge valve are open, flush valve is closed. Every time the pump is shutdown, the suction valve will be closed and flush valve is opened, the pump keeps working for one more minutes, then shutdown. The flush step can be carried out automatically or by operator at any time.

2.1.4 Back Pressure Control Loop

In order to feed primary reaction tank and provide a stable driving force, the back pressure control loop is designed as shown in figure 2.1.5 for each high concentration equalization tank group and low concentration tank group.

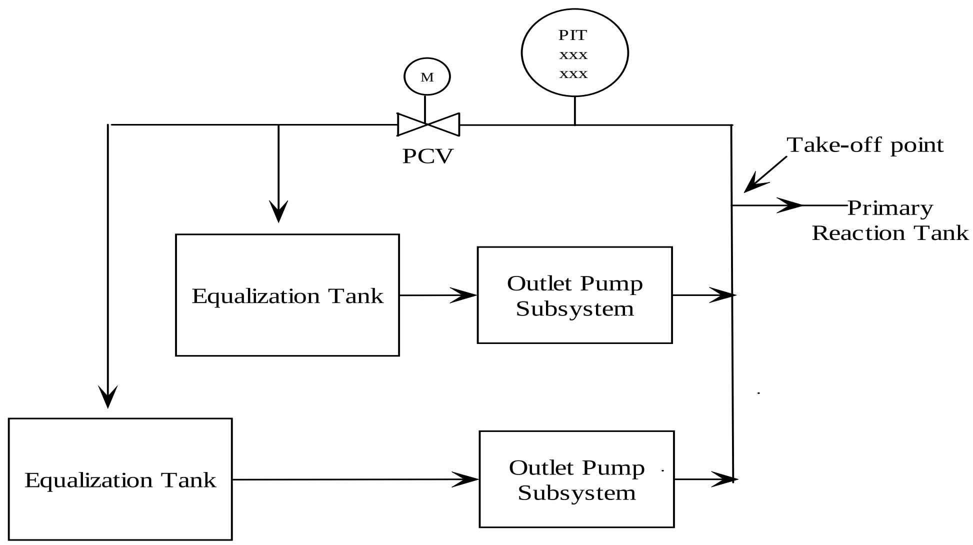

Figure 2.1.5 Equalization Tank Recycle Line Back Pressure Control

The selected outlet pump is centrifugal pump. Its working discharge head is ??? psi.

When downstream take-off point flow rate tends to increase, the recycle line pressure decrease, the pressure transmitter detects the pressure change, DCS forces the PCV(Pressure Control Valve) to move toward close direction until the recycle line pressure increase to desired value (entered by operator). Similarly, When downstream take-off point flow rate tends to decrease, the recycle line pressure increases, the pressure transmitter detects the pressure change, DCS forces the PCV(Pressure Control Valve) to move toward open direction until the recycle line pressure decrease to desired value.

2.1.5 Flow Rate Control

Primary reaction tanks are main equipments to remove heavy metals through the addition of chemicals. Primary reaction tanks are designed to be working continuously. Therefore, the designed operating requirement must be satisfied. One of those parameters is flow rate. So from equalization tank to primary reaction tank feed flow rate control is designed as shown in figure 2.1.6.

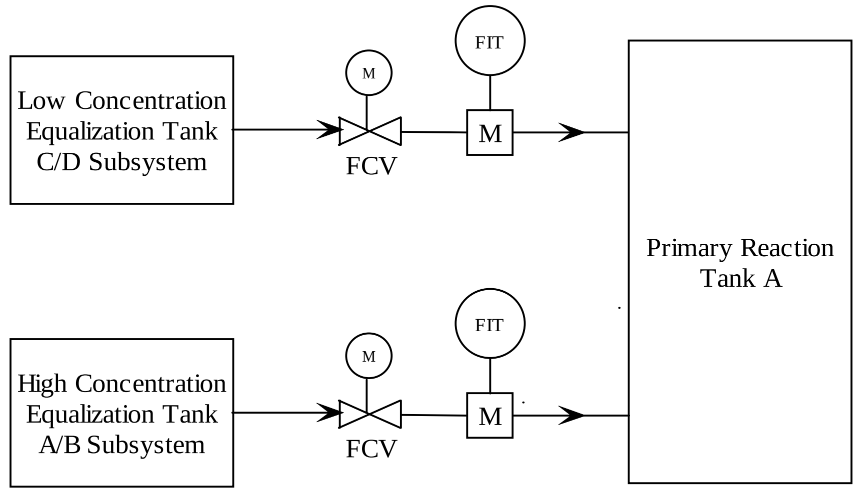

Figure 2.1.6 Equalization Tank to Primary Reaction Tank Feed Flow Rate Control

The total design flow rate is 800USGPM to primary reaction tank. The operator shall enter two separate set points to DCS to make sure the total is equal to 800 USGPM.

2.2 Primary Reaction System

There are three primary reaction tanks (A/B/C) connected in cascade. The lime solution is added only to tank A and B to control PH because controlling the PH of the waste water in the reaction tanks at the designed set point is essential for removing dissolved or soluble contaminants. Ferric sulfate solution is added only to primary reaction tank A for the purpose of precipitating dissolved metals in the waste water. The polymer solution is added only to primary reaction tank C to aid in the flocculation of fine suspended solids to promote accelerated settling in the clarifier. The total settling time in the three primary reaction tanks is designed to be forty five minutes.

In order to quicken reaction time and ensure complete and uniform solid suspension, each primary reaction tank is equipped with agitator. The speed of agitator in primary reaction tank A and B is fixed. The speed of agitator in primary reaction tank C can be adjusted locally or remotely. The operator visually inspect primary reaction tank C to determine agitator speed. if the solids are not suspended completely, or do not appear to be uniformly distributed throughout the tank C, then the set point for the variable agitator speed is increased. If shearing of the flocculation is observed, then the set point for the variable agitator speed is decreased.

2.2.1 Lime Slurry Addition

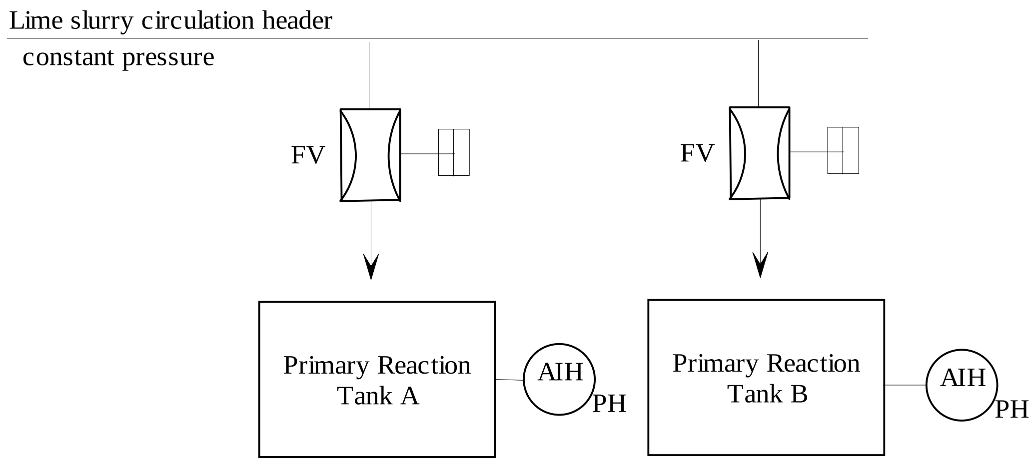

Figure 2.2.1 Primary Reaction Tank A and B lime solution addition

Lime solution preparation system provides a constant pressure in the circulation header to ensure different take-off points have a stable pressure. The PH control in the primary reaction tank A and B is based on duty cycle adjustable control. a cycle is define as a series of steps which begins with the valve (FV) in the fully closed position, followed by the valve in the fully open position, then the valve in the fully closed position again. After that a new cycle begins.

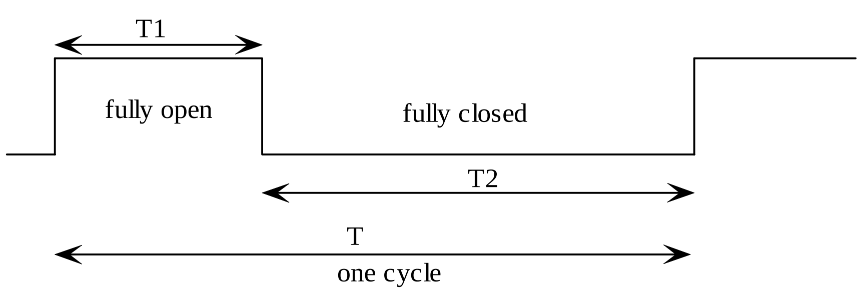

Figure 2.2.2 Primary Reaction Tank A and B PH control

see figure 2.2.2 for illustration. T1 is a preset duration of approximately one to five seconds. T1, T2 and T can be adjusted by operator, and they are designed in DCS configuration stage and finally determined and optimized at commissioning stage. The T1, T2 and T value will be affected by flow rate, reaction lag time, set point PH, online feedback PH, lime solution concentration, etc.

2.2.2 Ferric Sulfate Solution Addition

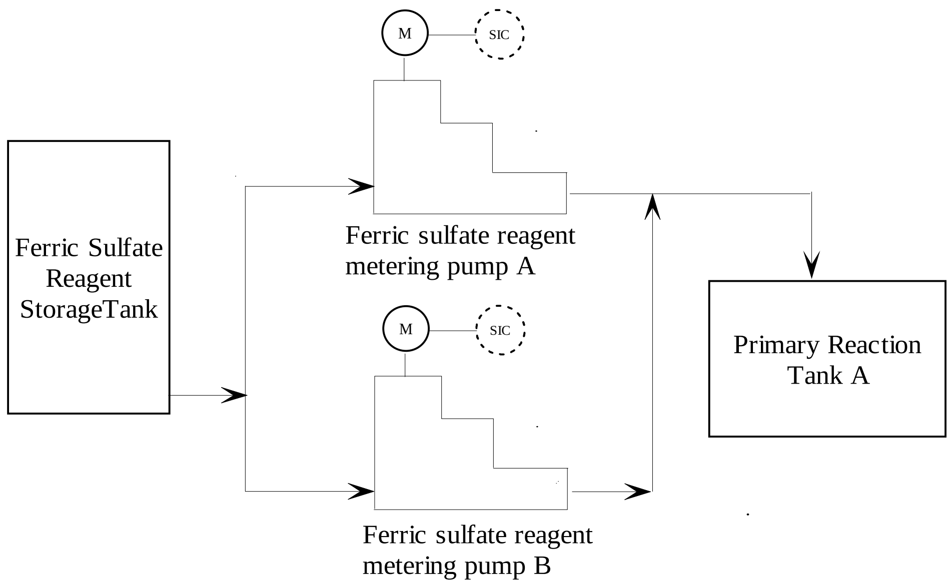

Figure 2.2.3 Primary Reaction Tank A ferric sulfate solution addition

The ferric sulfate solution addition is ratio control. The amount of addition rate is proportional to the total waste water flow rate from equalization to primary reaction tank A. Other factors that affect ferric sulfate addition rate are concentration of vanadium in waste water and selected iron to vanadium ratio. The relation between them can be expressed by the following equation.

addition rate of ferric sulfate reagent = $f(x1, x2, x3)$

Where x1 represents raw wastewater flow rate [USGPM], refer to figure 2.1.6

x2 represents concentration of vanadium in wastewater [mg/L] or [ppm]

x3 represents selected iron to vanadium dosage ratio [lb Fe: lb V] [1]

The formula and corresponding coefficient shall be given by process engineer, preliminarily determined at lab experiment and finally be determined and optimized at commissioning stage.

Because the chemical reaction is undergoing on a continuous basis, the three primary reaction tanks are operating continuously. Therefore, the system design requires the metering pump be highly reliable and be continuously working. the task of heavy metal removal is mainly undertaken by addition of ferric sulfate reagent into primary reaction tank A. Based on the requirement and importance, two metering pumps are designed to deliver ferric sulfate reagent from ferric sulfate reagent storage tank to primary reaction tank A as shown in figure 2.2.3. Both pumps are identical and 100% capacity. When one pump is working, another is in hot standby mode. When working pump fails, the standby pump will startup automatically. Two pumps design allows one pump to be offline for periodical maintenance during a short period of time without stopping WWTP continuous operating.

The flow rate of ferric sulfate reagent metering pump is governed by its stoke rate. When stroke rate increases, metering pump delivers more ferric sulfate reagent to primary reaction tank A. each metering pump comes with an ECC(Electronic Capacity Controller) which receives 4~20mA signal that corresponds to required ferric sulfate reagent flow rate. Each metering pump is supplied with calibration column. Filling a certain volume of reagent to calibration and sending different analog signal to ECC will draw the relationship between pump speed and flow rate. Each calibration exercise will produce a curve relating pump speed to pump output flow rate that will be programmed into the controller to provide the basis for converting the calculated flow rate of ferric sulfate to the required speed of the pump. Under normal operating condition, metering pumps must be calibrated periodically to ensure accuracy.

The set point of the ferric sulfate reagent addition control is not like those closed loop control such as the back pressure control. The latter set point is a fixed value. The former set point will be a variable and change significantly because under nominal operating condition, the flow rate of raw waste water from equalization to primary reaction tank A will be constant at 800USGPM as described before. However, because the concentration of vanadium in the influent can vary significantly, the required range of output flow rates of reagent that the metering pumps must be capable of handling has been estimated as from 0.1 USGPM to 10 USGPM. That wide range of flow rate requires metering pump turndown ratio to be 100:1.

2.2.3 Polymer Solution Addition

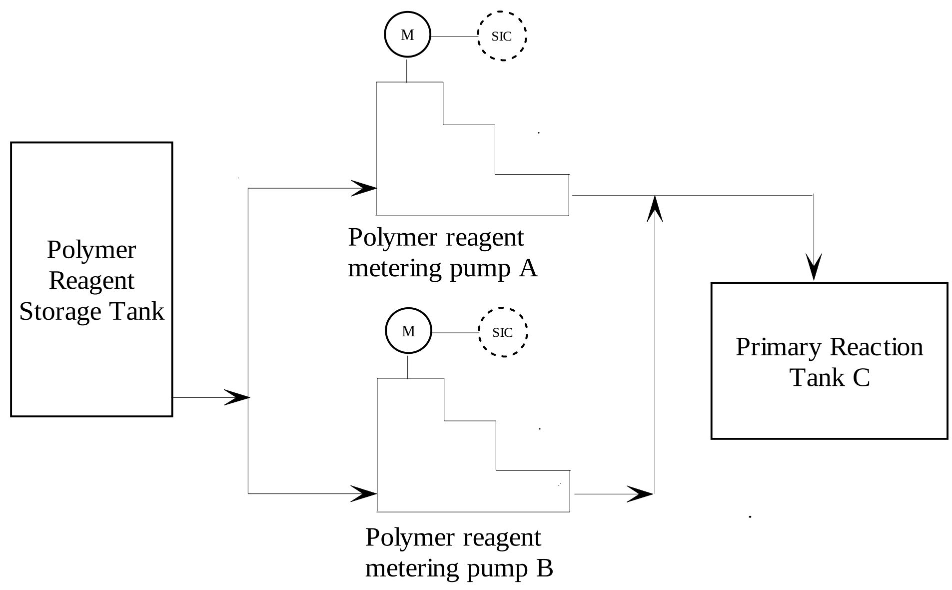

Figure 2.2.5 Polymer solution addition

Addition of polymer to primary reaction tank A is used to flocculate fine suspended solids for the ultimate purpose of improved settling characteristics in the clarifier.

The working principle is similar to ferric sulfate reagent addition except the following.

The required flow rate range of polymer solution is estimated as from 0.025 USGPM to 2.5 USGPM.

The coefficients in $f(x1, x2, x3)$ will be different.

2.3 Clarifier System

After primary reaction tank, the flocculation is formed. The effluent from primary reaction tank C flows to clarifier by gravity. The clarifier is a big container where the flocculation containing contaminants will fall down the bottom, while the treated water will flow out of clarifier to polishing reaction tank. In the bottom middle of clarifier, a rake is installed. The rake is rotating around the axis that stands vertically in the center of clarifier. As a result of rake rotating, the fell down solid is collected and moved toward center bottom well from which sludge will be pumped to solid holding tank.

2.3.1 Clarifier Bed Level Control

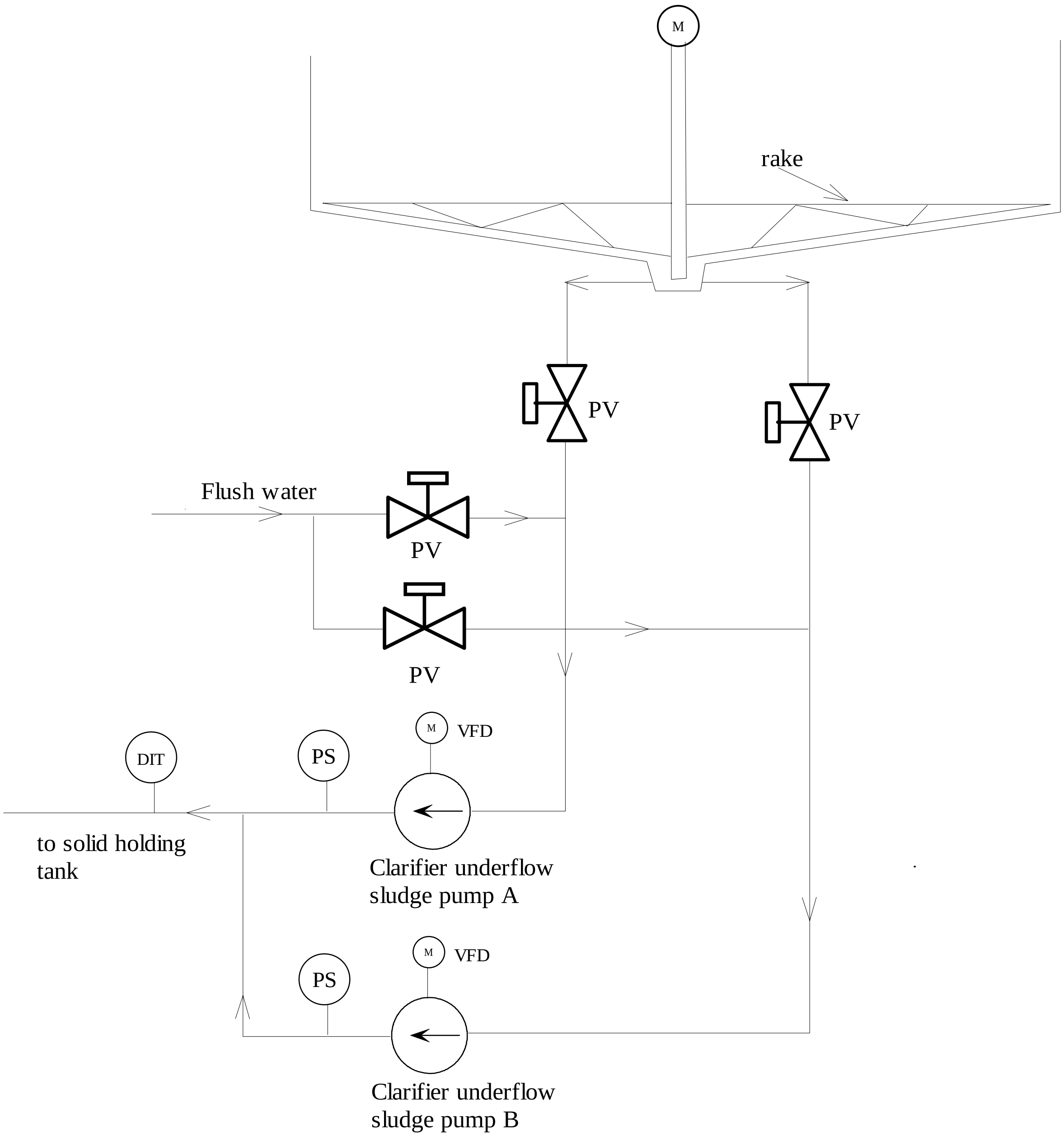

Figure 2.3.1 Clarifier system

Because of instable concentration of raw waste water, thus flocculation form rate, the sludge bed height may vary in a short period of time. Sometimes it may result in sudden shutdown of clarifier; subsequently the continuously working whole WWTP has to be temporarily shutdown to get rid of buildup on the internal surface of clarifier. If the bed level is too low, more percentage of influent from primary reaction tank C will go to solid holding tank rather than supposed to go to polishing reaction tank. Therefore, the clarifier bed level must be controlled at least within some range.

Currently we have not found one kind of commercially proven instrument that can effectively and reliably measure sludge bed level. Therefore, we have to find an alternative way to indirectly reflect the sludge bed level. An inline nuclear density instrument is installed at the outlet of pumps as shown in figure 2.3.1.

The level of the sludge bed in the clarifier will be affected by the degree of formed solids from primary reaction tank C and by the clarifier underflow pumping rate. If clarifier bed level increases, the density measured by instrument DIT will increase, the DCS controller will make underflow sludge pump run fast so that pump can remove more sludge from clarifier, as a result, the sludge bed will decrease. Similarly, if clarifier bed level decreases, the density measured by instrument DIT will decrease, the DCS controller will make underflow sludge pump run slow so that pump can remove less sludge from clarifier, as a result, the sludge bed will increase. By this mean, the clarifier bed level may be effectively controlled.

To provide more information about clarifier bed level, pressure switches are installed at outlet of pumps to alert the operator.

During commissioning stage and maintenance period, the relation between density instrument measuring values, density set point value, pressure switches set point, pump running speed and clarifier bed level must be carefully and repeatedly examined.

2.3.2 Clarifier Underflow Sludge Pump Control

Clarifier is designed to be continuously running. Its proper running is importance to whole system. The underflow sludge must be removed as required rate by underflow sludge pump. Due to underflow sludge characteristic, the pumps will work in harsh environment and easy to have some problems. Therefore, two clarifier underflow sludge pumps are designed to ensure reliability of clarifier system as shown in figure 2.3.1.

To clarifier underflow sludge pumps, there are pump suction valves, pump flush valves, pressure switches and density instrument associated with them. Under normal operating condition, the pump suction valve is open, flush valve is closed. Every time the pump is shutdown, the suction valve will be closed and flush valve is opened, the pump keeps working for one more minutes, then shutdown. The flush step can be carried out automatically or by operator at any time.

2.4 Sludge Dewatering System

Sludge dewatering system is located immediate after clarification system. The sludge dewatering system is designed to working only at day shift 8 or a little more hours to process all of the wastewater sludge produced during a 24 hour period.

Sludge dewatering system can be divided into filter press feed system, filter press system and belt conveyor system.

2.4.1 Filter Press Feed System

Filter press feed system consists of solid holding tank, slurry feed pumps, pressure control valve and flow control valves.

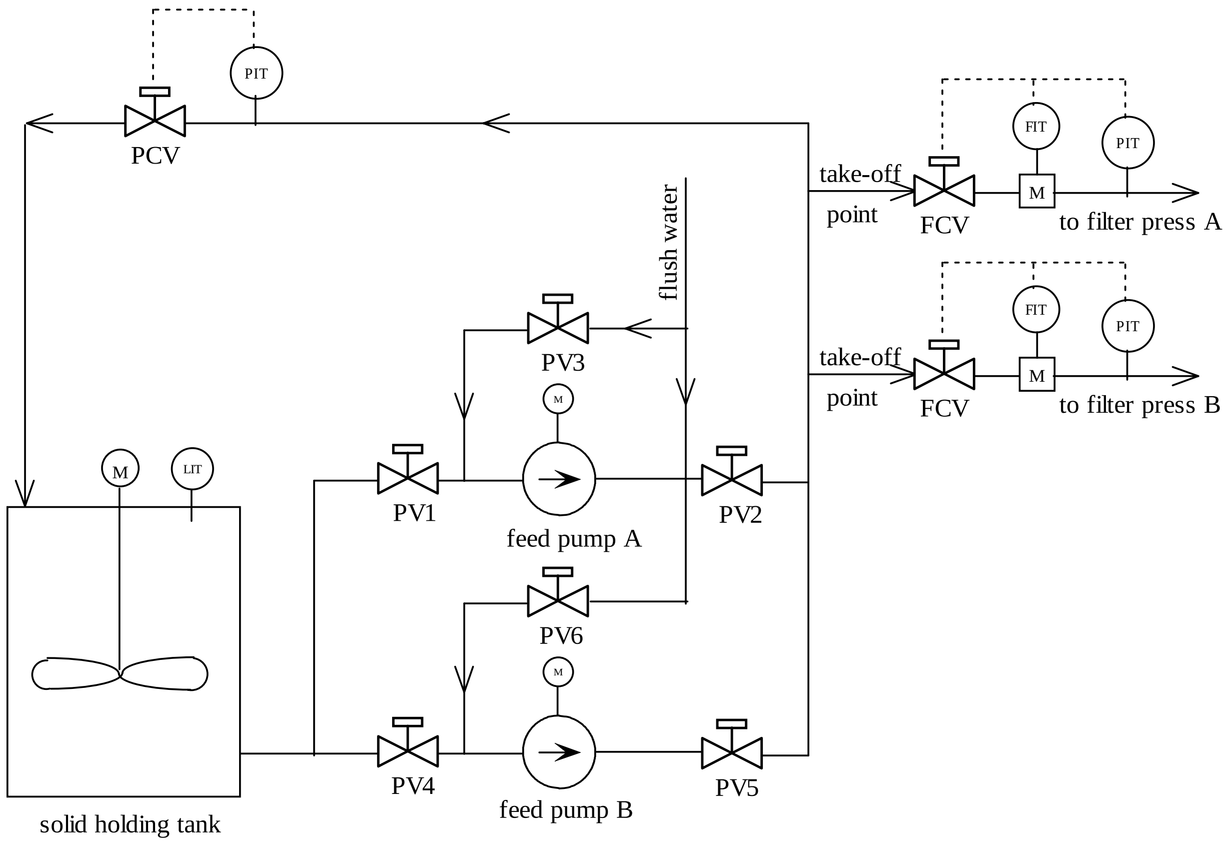

Figure 2.4.1 Filter Press Feed System

Filter press feed system can be further divided into circulation system and flow pressure control system.

2.4.1.1 Circulation System

The plate-in-frame filter press feed pumps will operate on a continuous basis during the filter press operation.

Two redundant pumps with each at 100% capacity are designed to improve pump reliability. Each pump is equipped with suction valve, discharge valve and flush valve. Pump must be flushed prior to normal shutdown. The flush process can be initiated by operator at any time. The pump startup/stop sequence is similar with the previous introduced hot standby pumps with flush, suction and discharge.

A single loop control is designed to maintain constant return header pressure in circulation line.

2.4.1.2 Flow Pressure Control System

Flow pressure control system is basically a flow closed loop control system. But its flow set point is not conventional fixed value entered by operator. It is based on the experiment curve given by vendor or obtained on site commissioning.

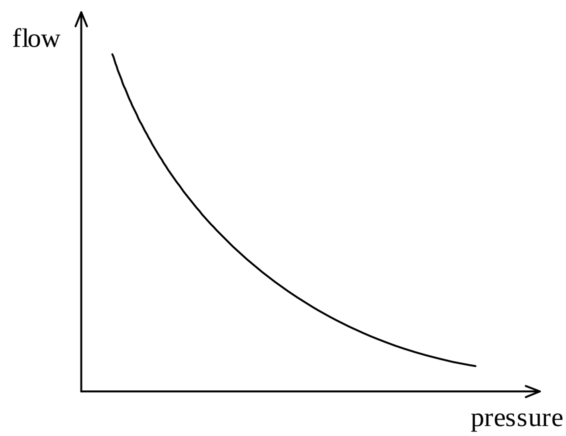

Figure 2.4.2 Filter Press Inlet Pressure-Flow Rate Relation

At the beginning of each filtration cycle, the filter cloths are clean and free of solids and therefore there is no resistance to flow and no back pressure exerted by the filters. As the slurry is pumped through the filters, solids are removed and retained on the filter clothes. As solid cakes are formed on the filter clothes, the resistance to flow increases along an exponential curve similar as that shown in figure 2.4.2 until the maximum operating pressure is reached. The back pressure exerted by the filters as resistance to flow is inversely proportional to the feed flow rate through the filters. A fitting equation between pressure and flow rate can be obtained by repeated experiment. This equation will be programmed into DCS. DCS will use measured pressure signal and calculate corresponding required flow rate based on fitting equation. The required flow rate will be remote set point at flow control loop.

During filter press fill period, the flow rate is variable ranging from 200USGPM at the beginning of fill process to 25 USGPM at the end.

2.4.2 Filter Press System

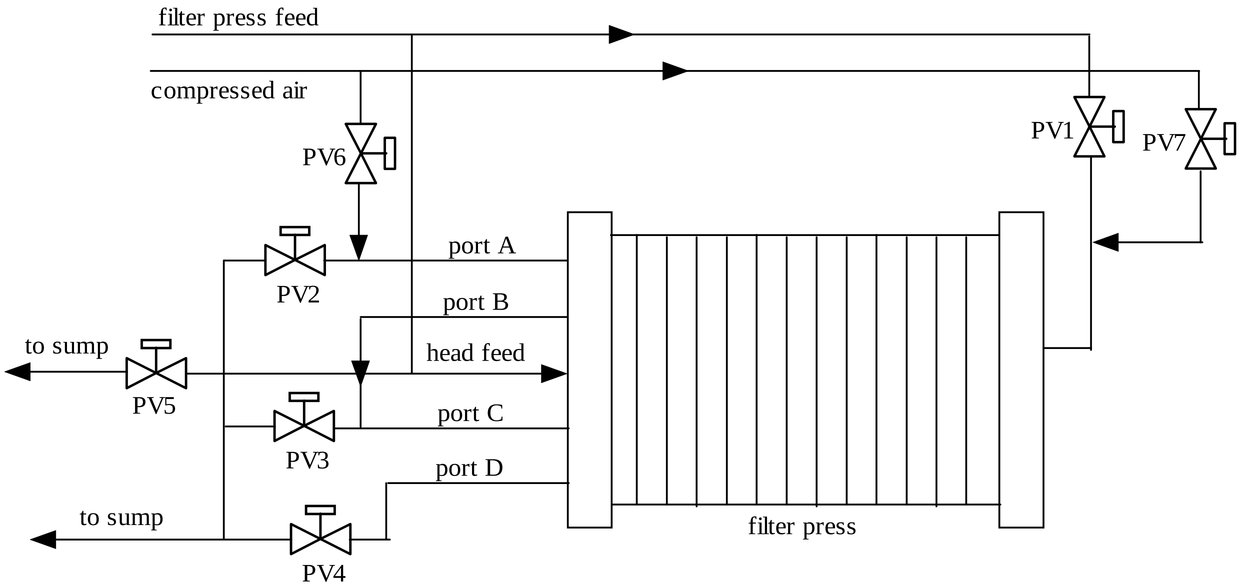

Figure 2.4.3 Filter Press System

Filter press is controlled by vendor supplied PLC. The process and interlock system is complicated. The filter press operating principle is based on sequence-of-events where the time period of each event is staggered. The events are summarized as follows.

1) Initial Fill

The flow of slurry to the press during the initial fill will be at a high rate as a result of a low pressure drop across the bed. The flow will be controlled as a maximum rate to avoid draining of the recycle loop (too low of flow in the recycle loop will result in solid sanding out in the line). During the initial fill, a small amount of fines will be present in the filtrate and as the filter cake forms on the cloth, the cake will improve on the capture of fines. For this reason the filtrate is recycled to the solids holding tank for a short duration.

Note: The duration time for recycle of the filtrate to the solids holding tank will be adjusted periodically based on operating experience. The recycle to the solids holding tank will have a gradual rise in the suspended solids concentration and then a gradual declining and leveling off. The actual time will be determined when the concentration of suspended solids levels off and may range from 5 to 10 minutes.

2) Cake Formation

As the cake forms or builds on the cloth (up to 1/2 inches cake thickness), there will be a gradual increase in pressure and a gradual decrease in the filtration rate. The system automation will detect the increase in pressure and adjust the flow of slurry to match the filtration rate.

3) Cake Buildup

As the cake forms from about 1/2 inch to 1 inch thickness the filtration rate may be considered fairly steady and the flow is controlled to suit the filtration rate.

Note: The control of the fill rate relative to the inlet pressure will require periodical field calibration. Also, the blinding of the filter cloth should be monitored to establish a basis for the cloth life and replacement schedule. As the cloth blinds, the calibration of the flow control may be influenced.

4) Completion of Fill

The cake will gradually fill the filter plate cavity such that there will be rapid rise in the filter press inlet pressure. This will signal that the press is full and feed to the press will be discontinued.

5) Core Blow

For a specified duration of time, air is used to continue filtration of the slurry remaining in the feed line. The core blow will complete the filtration cycle to assure residual slurry is not contained within the press.

6) Cake Blow

To move the residual filtrate from the plates and filtrate lines, air is used for a preset duration of time to clear the system. The duration of the cake blow may also be adjusted to improve on the cake moisture content. The cake blow is also used to dry the cake to improve on cake discharge from the plates.

7) Cake Discharge

At the end of the cake blow cycle, the plates will open, one at a time on the press and should be observed by an operator to assure cake does not build up in chutes.

8) Plate Closing

The plates will close at the end of the discharge cycle. Closing of the plates should be monitored and the operator should check to assure complete cake discharge and that the plates have a minimal build up around the seals.

The filtrate after the initial fill is routed to the equalization tank via the solids handling sump. Filtrate and/or slurry which leaks from the seal of the plates is collected on the drip tray and also routed to the solids handling sump. Occasional washing of the drip trays and plates will be required and both drip trays and area floor drains route all wash water to the equalization tanks via the sump.

Note: During the initial fill, if the seals are worn or the build up of solids prevents a good seal, slurry may be discharged from between the plates under pressure. Operators should monitor sealing during closure of the plates. In the event that sealing is a problem, perimeter curtains should be considered for personnel safety.

The filter cake is discharged to a conveyor system and loaded directly to a transfer truck. All of the dewatered solids are transferred to the on-site waste solids landfill. [1]

Based on the above operation guide, the following operation sequence is developed.

1) Before press begins to fill
   - the cylinder feed valve must be open (PV-503-256)
   - core blow valve must be closed (PV-502-675)
   - cake blow air valve must be closed (PV-502-209)
   - port A filtrate line isolation valve must be open (PV-502-210)
   - port D filtrate line isolation valve must be open (PV-502-679)
   - port B&C filtrate line isolation valve must be open (PV-502-680)
   - core slurry blow isolation valve must be closed (PV-503-258)
2) if any valve changes position during fill, the flow valve into press must be closed and alarm generated
3) Press will continue to fill until pressure transmitter reaches the value set to designate filter full (start at 80 psig). if press does not reach pressure within 3 hours, alarm will be generated.
4) When press reaches this pressure, it will begin an air/core blow to clean the press, as long as the other press is not in a cleaning mode. if the opposite press is in a clean cycle, the clean cycle on this press will be suspended.
5) During the air/core blow cleaning cycle the feed control valve to the press will be closed, the core blow isolation valve will be opened, and the cylinder feed isolation valve will be closed. When the core blow isolation valve and cylinder feed valve reach their position,

the high pressure air valve will open for a preset time as set by operator. At the end of this time, the core blow isolation valve will be closed and the cake air blow step will begin.

6) The core air blow sequence is listed below

- close feed control valve FCV-
- open core blow isolation valve PV-503-258
- close cylinder feed isolation valve PV-503-256
- open core blow valve (timed open) PV-502-675
- close core blow isolation valve PV-503-258

7) The cake air blow cycle will perform as listed below

- filtrate line isolation valve close PV-502-210
- port B&C filtrate isolation valve close PV-502-680
- port D filtrate isolation valve remains open PV-502-679
- cake air blow isolation valve open (for times period) PV-502-209

8) After completion of cake air blow, the appropriate conveyors will start and a signal will be sent to the press to "Start discharge cycle". Conveyors will run for two minutes after the press begins the next fill cycle to ensure all debris is removed from conveyor.

9) When press has completed its discharge cycle, it will send a "ready for slurry" signal to DCS so press can begin to fill. [1]

Che**ck the above operation sequence, replace valve no with this paper diagra**m.

***???This part is copied from

2.4.3 Belt Conveyor System

At the end of dewatering process, cake is formed and will be discharged to the chute, then falls on belt conveyor. The belt conveyor then loads trucks for onsite landfill.

Due to space limitation, three belt conveyors are designed. Belt conveyor A receives discharge from filter press A, while belt conveyor B receives discharge from filter press B.

Each belt conveyor is equipped with pull cord switches and zero speed switches. When operator finds emergency happening, they can use pull cord to trip belt conveyor. Zero speed switches are used to interlock trip belt conveyor. When zero speed is activated, the belt conveyor overload might happen or motor has trouble.

The filter press batch control is undertaken by vendor's supplied PLC while belt conveyor is controlled by DCS. The interface is through hardwired connection. When PLC reaches cake discharge step, it sends "start discharge cycle" to DCS. Upon receiving this signal, DCS will run belt conveyor for two minutes to ensure all debris is removed from conveyor. After that, PLC goes back to initial state, inspecting all controlled devices. If no problem exists, PLC will send a "ready for slurry" signal to DCS and thus next cycle starts.

2.5 Polishing Reaction System

As the name implies, up to this point majority of contaminants have been removed before polishing reaction tank. One polishing reaction tank is designed as final step to accurately treat the waste water to ensure the discharge meet the government requirement.

The primary role of the primary reaction tank is to remove any remaining dissolved metals by increasing PH to 8.5. Again, ferric sulfate reagent, lime solution and polymer reagent is added to treat water in polishing reaction tank as shown in figure 2.5.1. One agitator is installed in the polishing reaction tank to shorten the reaction time and thoroughly mix the water and added reagent.

Three polishing sand filter feed pumps are installed at the downstream outlet of polishing reaction tank to feed three polishing sand filters respectively. Because three polishing sand filters are connected in parallel form, the three feed pump will be working in parallel form as well.

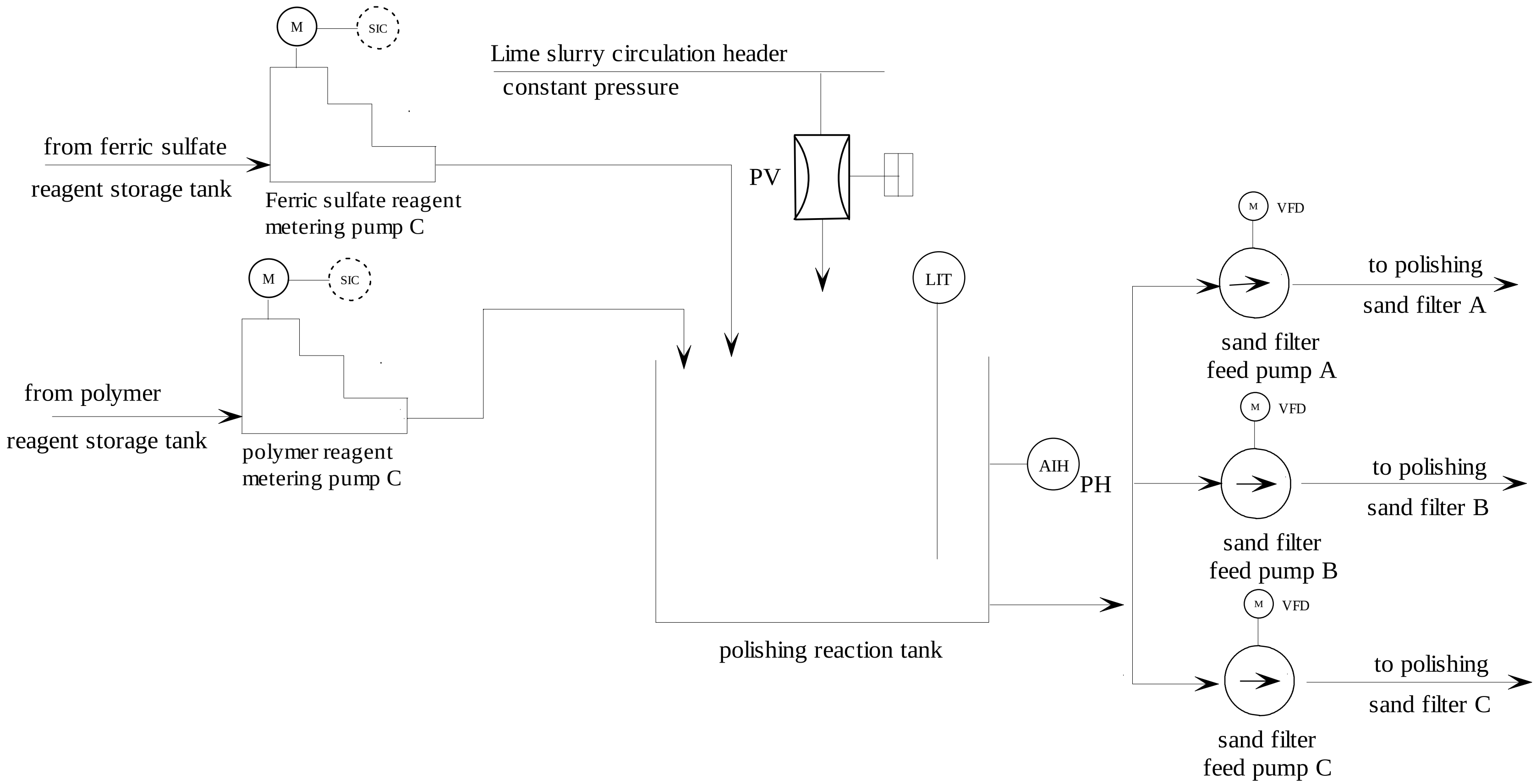

Figure 2.5.1 Polishing reaction system

2.5.1 Polishing Reaction Tank PH Control

Increasing PH in a stage wise way forces the precipitation of remaining dissolved metals. The primary reaction tank A PH design point is 4.5; the primary reaction tank B PH design point is 6.5, while polishing reaction tank PH design point is 8.5. The polishing reaction tank PH control is similar as primary reaction tank.

The lime solution circulation loop provides a constant pressure. The amount of lime required to attain the set point PH will be variable and depends on

- amount of ferric sulfate reagent added to polishing reaction tank
- level of waste water in polishing reaction tank
- set point PH of polishing reaction tank

The lime addition valve works at either fully open or fully closed position. The open time duration and cycle frequency will be governed by the amount of lime required and its parameter can be adjusted by operator. DCS will use a curve (obtained from experiment) to control valve pulse duration and frequency as shown in figure 2.5.2. The curve will be offered by process engineer and programmed into DCS.

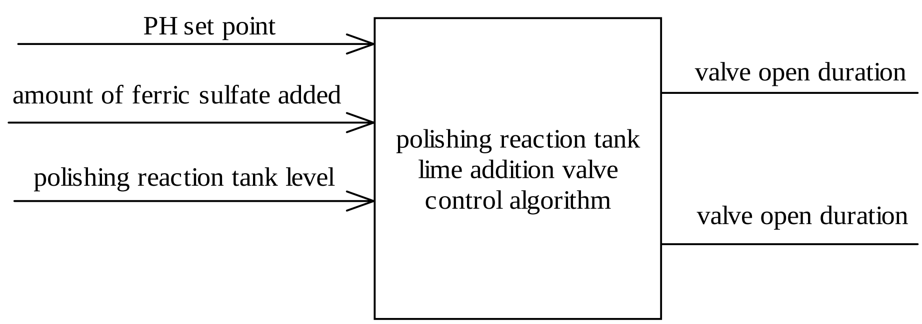

Figure 2.5.2 Polishing reaction tank lime addition valve control algorithm

2.5.2 Polishing Reaction Tank Ferric Sulfate Addition-Flow Control

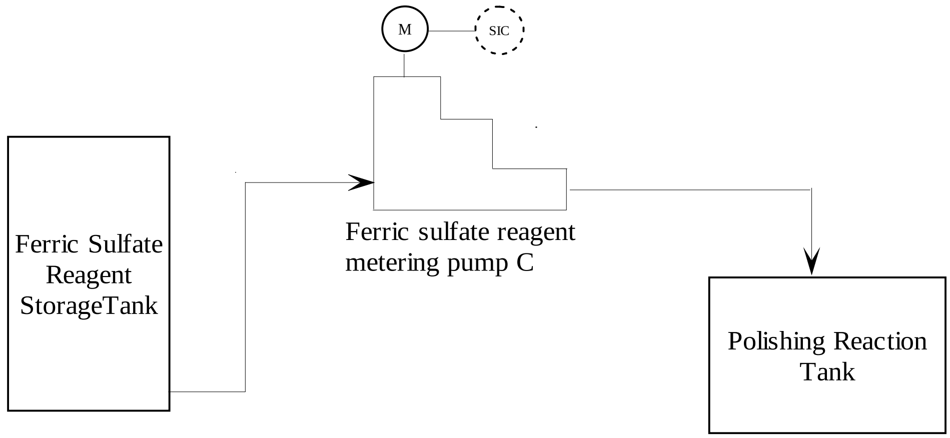

Figure 2.2.3 Polishing Reaction Tank ferric sulfate solution addition

The ferric sulfate solution addition is ratio control. The amount of addition rate is proportional to the total waste water flow rate from equalization to primary reaction tank A. Other factors that affect ferric sulfate addition rate are concentration of vanadium in waste water and selected iron to vanadium ratio. The relation between them can be expressed by the following equation.

Addition rate of ferric sulfate reagent = 5.4275×10^{-6} x1x2x3

Where x1 represents raw wastewater flow rate [USGPM], refer to figure 2.1.6

x2 represents concentration of vanadium in wastewater [mg/L] or [ppm]

x3 represents selected iron to vanadium dosage ratio [lb Fe: lb V] [2]

The formula and corresponding coefficient shall be given by process engineer, preliminarily determined at lab experiment and finally be determined and optimized at commissioning stage.

The flow rate of ferric sulfate reagent metering pump is governed by its stoke rate. When stroke rate increases, metering pump delivers more ferric sulfate reagent to polishing reaction tank. Each metering pump comes with an ECC(Electronic Capacity Controller) which receives 4~20mA signal that corresponds to required ferric sulfate reagent flow rate.

Each metering pump is supplied with calibration column. Filling a certain volume of reagent to calibration and sending different analog signal to ECC will draw the relationship between pump speed and flow rate. Each calibration exercise will produce a curve relating pump speed to pump output flow rate that will be programmed into the controller to provide the basis for converting the calculated flow rate of ferric sulfate to the required speed of the pump. Under normal operating condition, metering pumps must be calibrated periodically to ensure accuracy.

The set point of the ferric sulfate reagent addition control is not like those closed loop control such as the back pressure control. The latter set point is a fixed value. The former set point will be a variable and change significantly because under nominal operating condition, the flow rate of raw waste water from equalization to primary reaction tank A will be constant at 800USGPM as described before. However, because the concentration of vanadium in the influent can vary significantly, the required range of output flow rates of reagent that the metering pumps must be capable of handling has been estimated as from 0.021 USGPM to 0.210 USGPM. That wide range of flow rate requires metering pump turndown ratio to be 10:1.

2.5.3 Polishing Reaction Tank Polymer Addition-Flow Control

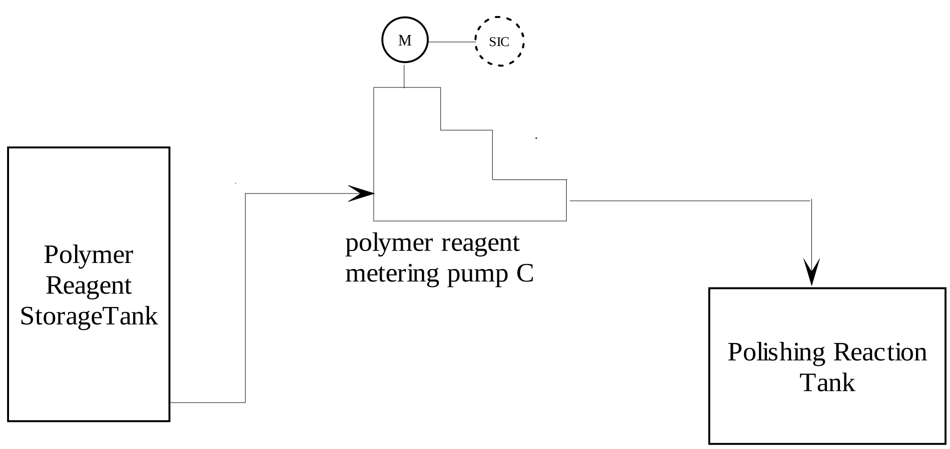

Figure 2.2.5 Polishing reaction tank polymer solution addition

Addition of polymer to polishing reaction tank is used to flocculate fine suspended solids for the ultimate purpose of improved removal efficiency in the polishing backwash sand filters.

Addition rate of polymer reagent = $5.4275 \times 10^{-6} Q_{ww} C_{polymer} R$

Where Q_{ww} represents raw wastewater flow rate [USGPM], refer to figure 2.1.6

$C_{polymer}$ represents selected concentration basis for polymer addition [mg/L]

R represents mix concentration of polymer solution [wt. fraction]

The required polymer addition rate is estimated as 0.00667USGPM to 0.0667USGPM. [1]

2.5.4 Polishing Reaction Tank Level Control

As effluent from polishing reaction tank contains less suspended solids, the pump flush valve and pump isolation valve (for the purpose of temporarily isolating pump from system in the event of solid buildup and maintenance) are not designed.

Polishing sand filter feed pump speed change is undertaken by VFD(Variable Frequency Drive). Allen-Bradley power flex 700 series AC inverter is selected to change motor speed.

The polishing reaction tank level control loop is designed to maintain the water level. The closed loop control is one single loop control. The process variable is tank level given by level transmitter. The set point is entered by operator. The control output is pump speed demand. This demand will drive three identical pumps A/B/C. when level decreases, control signal will decrease, as a result pump run slow, less water will be drawn from tank, feed rate almost no change, level will increase to desired set point. Similarly, when level increases, control signal will increase, as a result pump run fast, more water will be drawn from tank, feed rate almost no change, level will decrease to desired set point.

Polishing reaction tank level control logic is shown in figure (insert figure no here????).

2.5.5 Polishing Reaction Tank Agitator Control

The speed of agitator in polishing reaction tank can be adjusted locally or remotely. The operator visually inspect polishing reaction tank to determine agitator speed. if the solids are not suspended completely, or do not appear to be uniformly distributed throughout the tank C, then the set point for the variable agitator speed is increased. If shearing of the flocculation is observed, then the set point for the variable agitator speed is decreased.

2.6 Continuous Backwash Polishing Sand Filter

Three continuous backwash sand filters are connected in parallel. They are located between polishing reaction tank and treated wastewater recycle tank. They are used to remove any residual particulate and suspended solids that were not removed in the clarification stage as well as any new formed solids that were precipitated in the polishing reaction tank. Each filter is sized at 1/3 capacity and works independently. A filter can be isolated and taken out for maintenance. In that case, WWTP system load must be reduced from 800 USGPM to about 528 USGPM. This is achieved by operator changing two flow control loop set point.

The continuous backwash san filter system is controlled by vendor supplied control panel. However, the following signals from the sand filter control panels are provided to DCS as indication only.

- differential pressure across the san filtration media
- sand filter backwash/reject water weir level
- polishing sand filter service air for sand scouring flow rate

2.7 Recycle Water System

The treated water from continuous backwash polishing sand filter A/B/C will flow into treated wastewater recycle tank by gravity and stay there for a period of residence time to allow adequate time to monitor the quality of stored water. The treated waste water recycle tank functions as a reservoir. The acidity/PH, concentration of suspended solids/turbidity and the concentration of chlorides online analysis instruments are installed at treated recycle waste water tank to monitor the water quality. The measurement data will be used to report to government and route water to different direction as shown in figure 2.7.1.

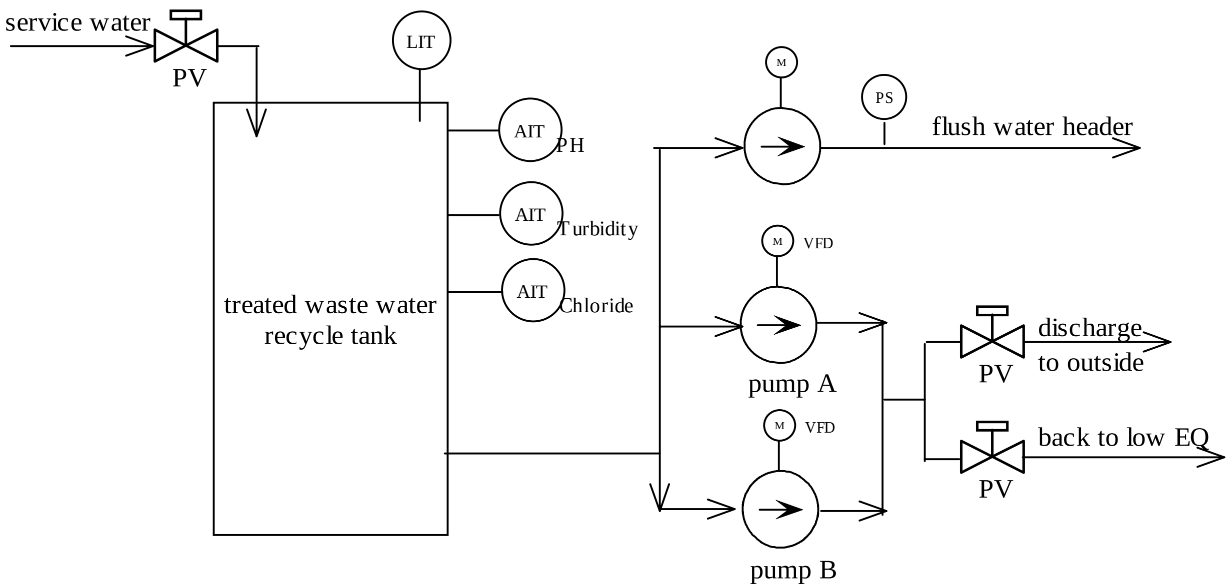

Figure 2.7.1 Treated Waste Water Recycle System

2.7.1 Pump Control for Flush Water

Flush water is used to clean the slurry residual of pumps in equalization tank, clarifier underflow sludge transfer and lime circulation system. According to logic control requirement, a slurry transportation pump must be cleaned with flush water prior to normal shutdown. The treated waste water pump for flushing system is responsible to provide adequate flush pressure. The flush water header will be maintained within a range. The installed pressure switch at pump outlet sends two signals to DCS. The low pressure signal (10 psig) will start pump and high pressure signal (20 psig) will stop pump.

2.7.2 Treated Waste Water Recycle Tank Level Control

The flushing system is designed to be working in intermission way and consumes a little portion of treated water. The remaining treated water will be discharged to outside the plant if quality meets environment discharge requirement. Otherwise, it has be pumped back to low concentration equalization tank for treatment once again. When part of WWTP process has to be temporarily stopped and treated waste water recycle tank level is low, to assure a certain amount of flush water, service water valve will be opened to fill service water into the recycle tank.

To keep the solution at recycle tank an appropriate residence time and get time average analysis of the water quality, it is necessary to maintain a level within the treated wastewater recycle tank. The water level control is through the outlet pump speed control. Each pump motor is equipped with VFD which can effectively change motor speed and further pump speed. When water level is higher than the set point, the DCS control signal increases output, pump speed is increased, more water is drawn from tank, thus water level decreases. When water level is lower than the set point, the DCS control signal decreases output, pump speed is decreased, less water is drawn from tank, thus water level increases.

The WWTP is working continuously. The treated waste water must be drawn away to leave room for more incoming water. And the FGD system has continuous demand for treated water. In order to improve reliability, two pumps are designed. Two pumps will work as lead/lag mode. Operator has to first select which pump is used as lead pump. Once logic sequence needs pump running, the lead pump will startup and become working pump. Once working pump trips, the lag or standby pump will startup automatically without interrupting continuous operation. The lead/lag standby logic can be found in section 4 for typical control logic design.

Control point for operation of liquid level in treated wastewater recycle tank is as follows:

Maximum level (HH)	Alarm operator	14’-0”	87.5% from bottom
Nominal operating level	Modulated by pump	12’-0”	75.0% from bottom
Service water addition	Stop service water (H)	10’-0”	62.5% from bottom
	Fill service water (L)	8’-0”	50.0% from bottom
Level too low (LL)	trip all pumps	3’-0”	18.75% from bottom

2.7.3 Water Quality Monitoring

Online monitoring instruments provide information on the quality of treated waste water and will be used to

- alarm operator
- direct waste water either outside of WWTP or recycle off –spec waste water back to low concentration equalization tank
- prevent discharge off-spec to environment, prevent excess chlorides in the FGD unit

<u>Acidity (PH)</u>

Control points for operation of the effluent valves are as follows:

>9.5	HH	Off-spec wastewater
>9.0	H	Alarm only ph H
<7.0	L	Alarm only ph L
<6.5	LL	Off-spec wastewater

<u>Concentration of suspended solids (turbidity)</u>

Control points for operation of the effluent valves are as follows:

>20 ug/l	HH	Off-spec wastewater
>10 ug/l	H	Alarm only H

Chlorides

Control points for operation of the effluent valves are as follows:

>100 ug/l	HH	Harm to FGD

2.8 Ferric Sulfate Preparation System

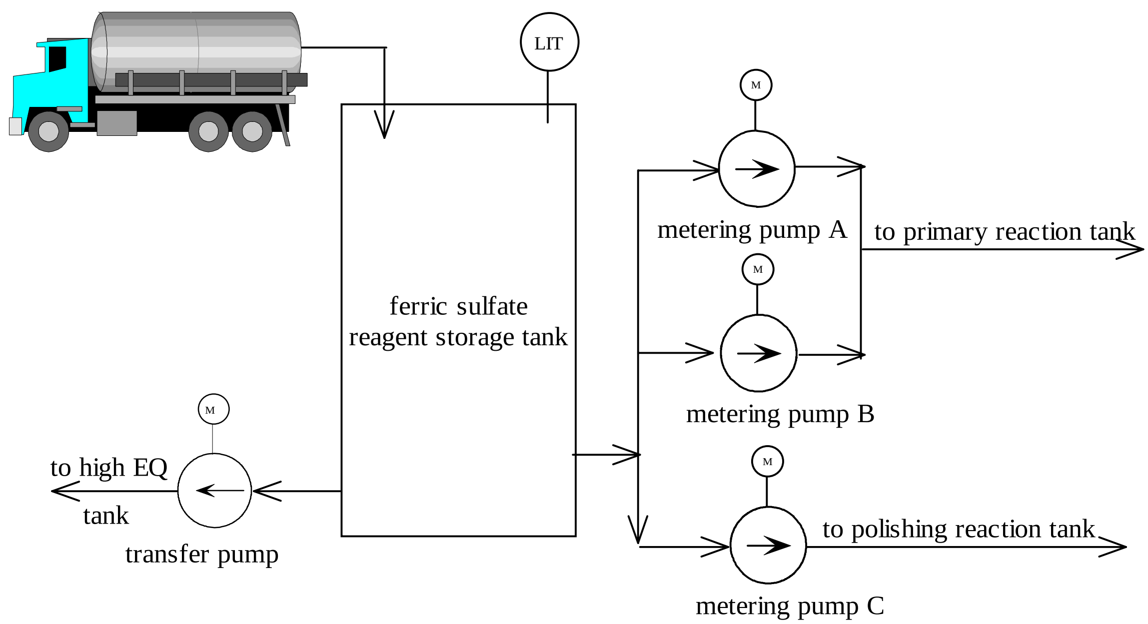

Figure 2.8.1 Ferric Sulfate Reagent Preparation System

Ferric sulfate preparation system is an auxiliary system compared to the previous introduced system. Ferric sulfate is delivered as a bulk solution. The tanker truck will transfer solution to the storage tank through a hose with a quick connect coupling. A level transmitter is installed to monitor storage tank level and provide interlock signal to the associated pumps for pump startup permission and trip protection.

Transfer pump is centrifugal constant speed pump. It pumps ferric sulfate reagent to high concentration tanks only when operators think it is required. It is initially started up by operator and stopped by flow accumulator. The amount of ferric sulfate will be calculated by DCS based on operator entered data and the level of wastewater in the equalization tank to be treated.

Two redundant metering pumps A and B are designed to improve reliability for continuous operation of primary reaction tank. Metering pumps contract were awarded to Milton Roy company, a North America recognized industrial firm. Each metering pump is supplied with an Electronic Capacity Controller (ECC) which is used to control the stroke speed of the pump. DCS calculates needed ferric sulfate flow rate, converts it to needed pump speed and sends demand signal to ECC. By this mean, ferric sulfate reagent is continuously and proportionally delivered to primary reaction tank A and B.

One metering pump C is used to deliver ferric sulfate reagent to polishing reaction tank. The ratio with waste water flow rate control is similar with pump A and B except no lead/lad design.

2.9 Polymer Reagent Preparation System

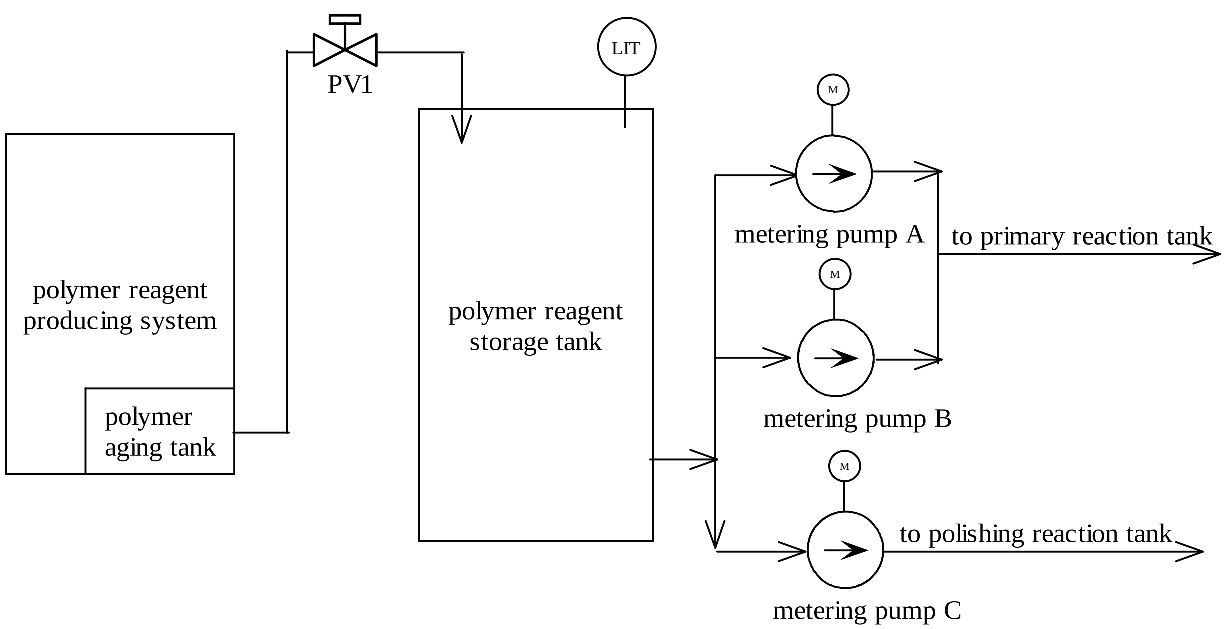

Figure 2.9.1 Polymer Reagent Preparation System

Polymer Reagent Preparation System consists of polymer reagent producing system, polymer reagent storage tank and polymer reagent delivering system.

Polymer reagent preparation system is an auxiliary system compared to the previous introduced system. Polymer is delivered as dry powder form. Polymer must be dissolved into water to form polymer reagent prior to use. The dissolving process and dilution technique is complicated and needs special patent technology. Therefore, the polymer reagent producing system is a fully integral skid-mounted system. This system is controlled by vendor supplied PLC system and stands alone itself. However, DCS can communicate with PLC through Allen-Bradley and Emerson Ovation protocol. Thus polymer producing system operating status can be shown in control room and be available to operators.

A level transmitter is installed to monitor storage tank level and provide interlock signal to the associated pumps for pump startup permission and trip protection. The polymer reagent storage tank level is designed to be within a range. When level transmitter detects level low, DCS will open valve PV1 to draw polymer reagent from producing system. The PV1 keeps open, the level increases. When level transmitter detects level high, DCS will close valve PV1.

Two redundant metering pumps A and B are designed to improve reliability for continuous operation of primary reaction tank. Metering pumps contract were awarded to Milton Roy Company, a North America recognized industrial firm. Each metering pump is supplied with an Electronic Capacity Controller (ECC) which is used to control the stroke speed of the pump. DCS calculates needed polymer reagent flow rate, converts it to needed pump speed and sends demand signal to ECC. By this mean, polymer reagent is continuously and proportionally delivered to primary reaction tank A and B.

2.10 Lime Preparation System

Lime slurry preparation system is an auxiliary system compared to the previous introduced system. This system is controlled by DCS and PLC.

Lime slurry preparation system can be divided into the following subsystem for convenient introduction.

- Lime Storage Silo System
- Lime Transfer System
- Lime Transfer System
- Lime Slurry Circulation System

2.10.1 Lime Storage Silo System

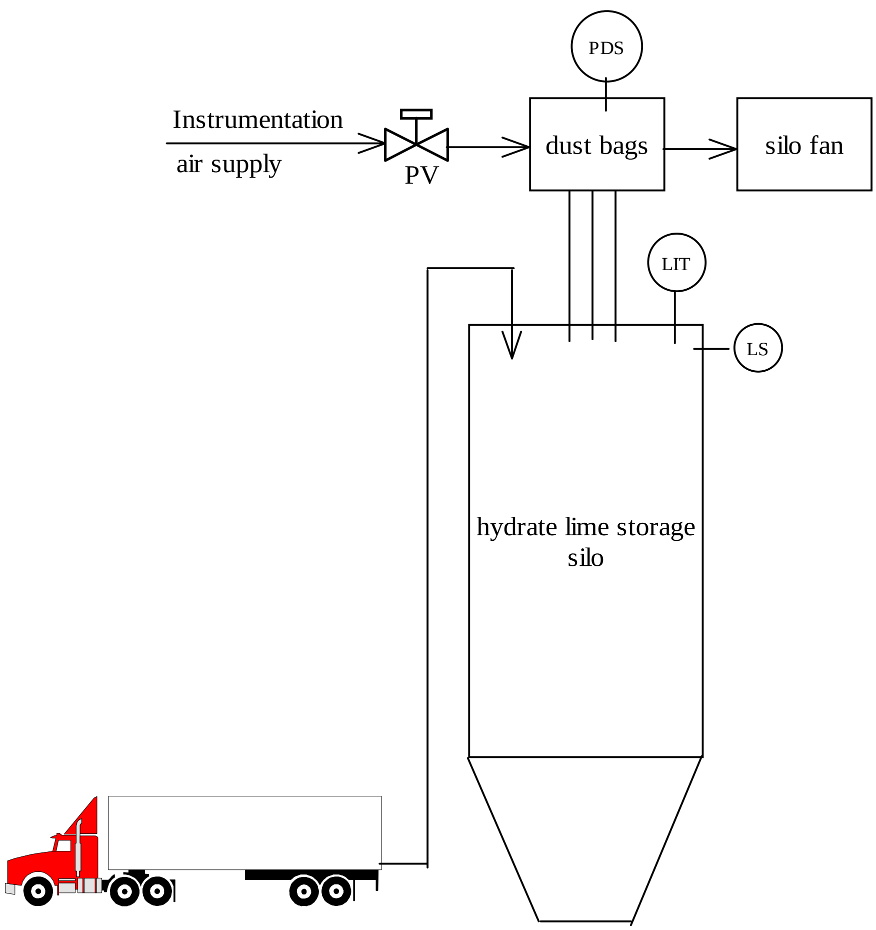

Figure 2.10.1 Lime Storage Silo System

Hydrated lime storage silo is located outside WWTP building. The silo level instrument (LIT) indicates the silo lime level and prompt operator when additional order should be placed. Hydrated lime is delivered in bulk form. The hydrated lime is transferred from the delivery truck to the top of the silo using truck's pneumatic blower system. This transfer process is controlled by truck driver operating a local control panel. Simple pilot lights and switches are mounted in that local control panel. This local control panel is wired and controlled by vendor (Stanco Company) supplied PLC. The high level switch (LS) is used to alarm truck driver.

in order to minimum the emission of lime dust to environment, bag house which holds a lot of bag filters is installed on top portion of lime storage silo. In lime unloading process, silo fan is running, lime dust will be deposited on the surface of bag filters. When pressure difference switch (PDS) indicates a high pressure drop before and after bag filter, it means filter is dirt and needs to be cleaned. Then a clean cycle starts and last 5-10 minutes. The solenoid valve is open, pressured air will clean bag filter.

2.10.2 Lime Transfer from Silo to Hopper System

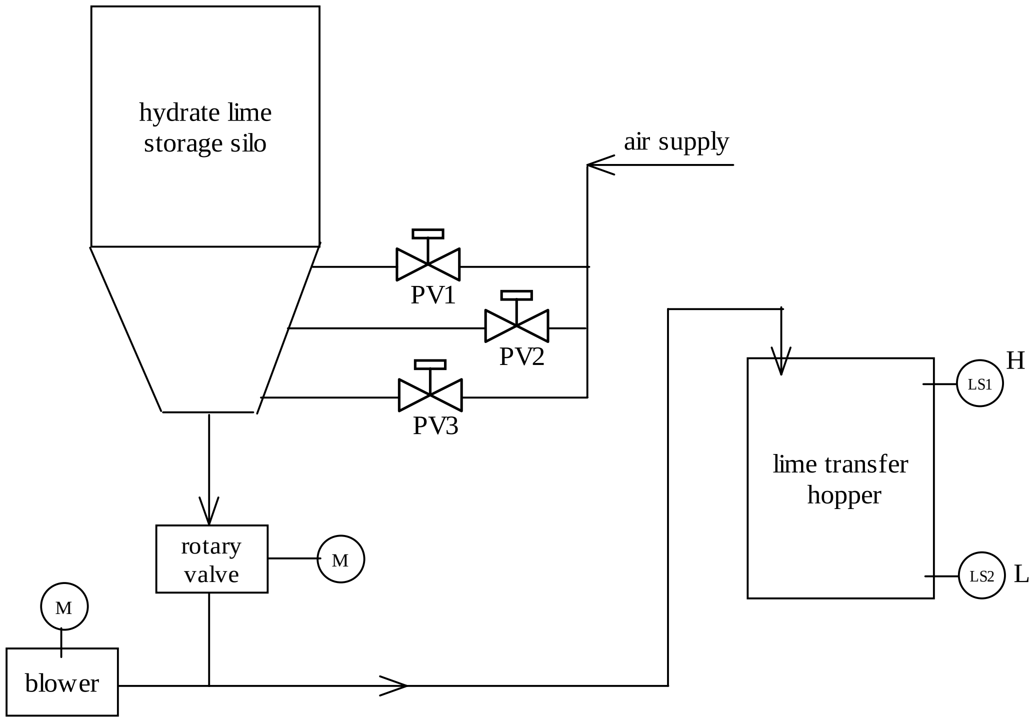

Figure 2.10.2 Lime Transfer from Silo to Hopper System

Lime transfer from silo to hopper cycle is triggered by the detection of lime transfer hopper level low signal (LS2). Once this cycle starts, the blower starts running, 1 minute later, DCS open solenoids valves PV1, PV2 and PV3. The pressured air enters hydrated lime storage silo cone part. The aeration pads are installed in the hydrated lime storage silo cone part for the purpose of lime to fall down easily without blocking. At the same time, rotary valve starts rotating. The falling lime will be blowed pneumatically to lime transfer hopper. When the lime level reaches the desired level point, the level switch LS1 will be acted, and then control system will stop rotary valve and three solenoid valves PV1, PV2 and PV3. The blower continues running for one more minute so that all the residual of fell lime are transported to lime transfer hopper. Thus one transfer cycle is finished. The blower start/stop is on an early start late stop basis in order to minimum the chance of blocking.

2.10.3 Lime Transfer from Transfer Hopper to Screw Feeder Hopper System

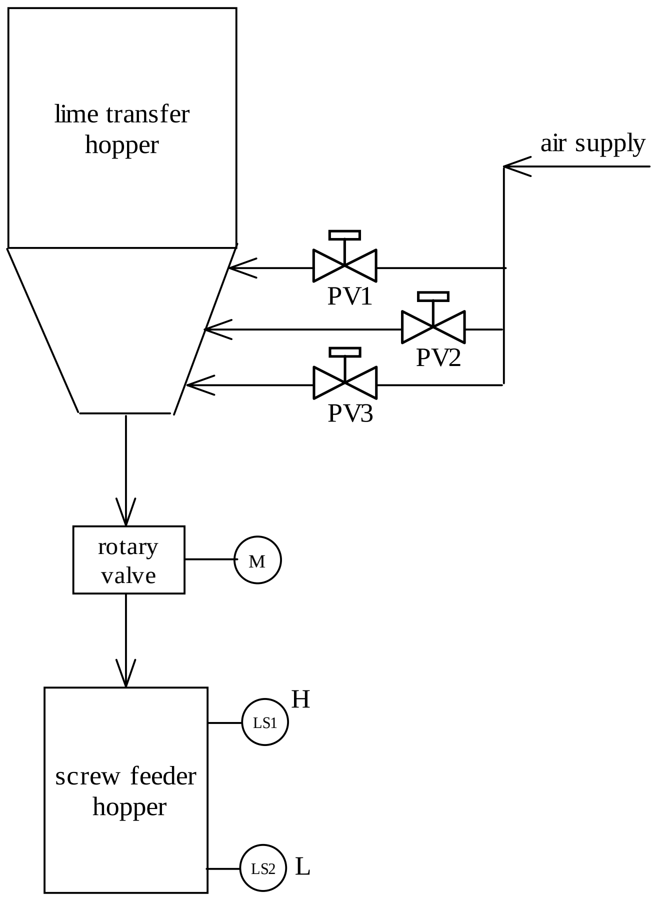

Figure 2.10.3 Lime Transfer from Transfer Hopper to Screw Feeder Hopper System

Lime transfer from transfer hopper to screw feeder hopper cycle is triggered by the detection of screw feeder hopper level low signal (LS2). Once this cycle starts, DCS open solenoids valves PV1, PV2 and PV3. The pressured air enters lime transfer hopper cone part. The impactors are installed in the lime hopper cone part for the purpose of lime to fall down easily without blocking. At the same time, rotary valve starts rotating. The lime will fall to screw feeder hopper. When the lime level reaches the desired level point, the level switch LS1 will be acted, and then control system will stop rotary valve and three solenoid valves PV1, PV2 and PV3. Thus one transfer cycle is finished.

2.10.4 Lime Slurry Producing System

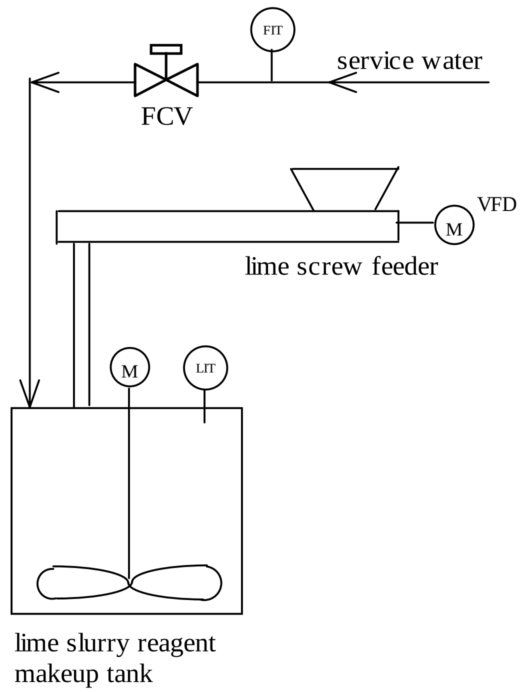

Figure 2.10.4 Lime Slurry Producing System

Lime slurry producing system consists of service water flow transmitter, service water flow control valve, lime screw feeder, lime slurry reagent makeup tank, agitator, and makeup tank level transmitter.

Lime slurry reagent concentration is determined by ratio of service water flow rate and lime screw feeder feed rate. Service water flow control loop is designed to maintain a stable service water flow rate. DCS will calculate the needed volumetric lime and send corresponding signal to control screw feeder speed through VFD.

The calculated ratio and flow control is achieved as follows:

- The operator enters a value for service water flow—in the range of 40 to 100 USGPM. Nominal flow will be 60 USGPM.

- The operator also enters the operating lime concentration and the bulk density of the powder hydrated lime within the screw feeder discharge.
- Based on the operator entered data, both hydrated lime slurry density (specific gravity) and volumetric flow of hydrated lime is calculated by DCS as per the following equations.

$$SGso\ln = ((\frac{x}{2.5} + (1 - x))^{-1}$$

Where SGsoln represents density of hydrated lime solution (specific gravity, no units)

x represents mass faction of lime (16 CaO/lb solution)

$$VHL = \frac{QW \cdot SGso\ln}{DHL} 719.482$$

Where VHL represents volumetric flow of hydrated lime (ft^3/hr)

QW represents volumetric flow of service water (USGPM)

SGsoln represents density of hydrated lime solution (specific gravity, no units)

DHL represents bulk density of hydrated lime (lb/ft^3)

Once the volumetric flow rate of hydrated lime is calculated, control system can use screw feeder calibration curve to get corresponding screw feeder speed. The lime screw feeder will be calibrated periodically to get accurate delivery rate.

The level transmitter (LIT) will be used to indicate online level and interlock agitator, pump screw feeder and service water flow control valve. Different level and its corresponding action is shown in the following table. Reference point is makeup tank bottom.

14 ft	Lime slurry makeup tank level high alarm
7.5 ft	Primary reaction tank lime addition valve close, polishing reaction tank lime addition valve close, high concentration equalization tank lime addition valve close
7.4 ft	Makeup tank low level alarm, transfer pump stop, circulation pump stop
6.5 ft	Makeup tank agitator start

6 ft	Makeup tank agitator stop

2.10.5 Lime Slurry Circulation System

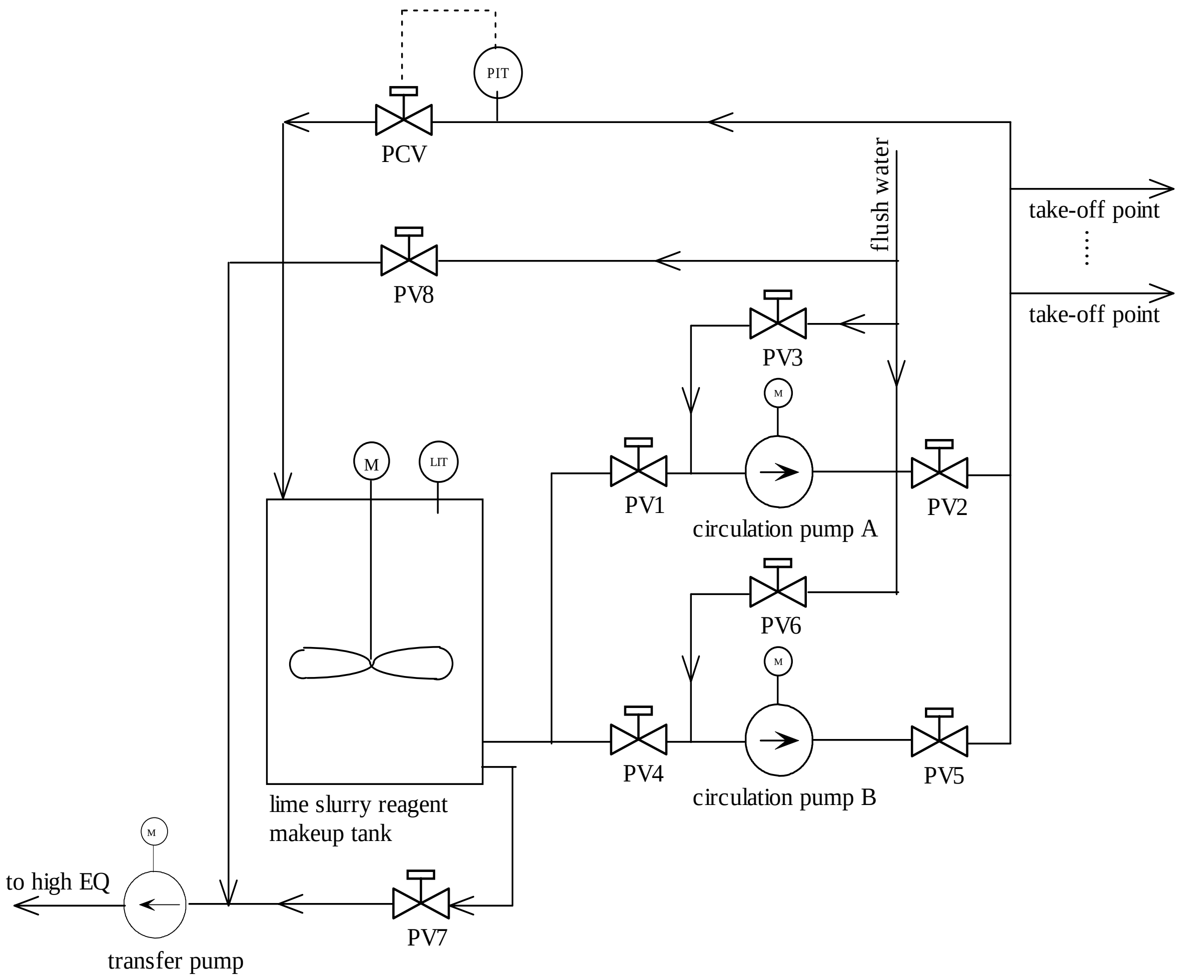

Figure 2.10.5 Lime Slurry Circulation System

To maintain constant feed pressure, lime slurry circulation back pressure control loop is designed as shown in figure 2.10.5. Operator will enter desired back pressure of circulation header. Online mounted pressure transmitter will measure actual back pressure. If measured data is lower than set point, the pressure control valve (PCV) tends to move toward close direction, the header pressure will increase until measured actual pressure is equal to desired pressure. If measured data is greater than set point, the pressure control valve (PCV) tends to move toward open direction, the header pressure will decrease until measured actual pressure is equal to desired pressure.

Lime preparation system is designed to be working continuously. If lime slurry reagent is not available, the continuously running primary reaction tank ph will be very low; as a result, the treated waster water will show high acidity and has to be pumped back for re-treatment. This will increase WWTP system load and efficiency will be affected. Therefore, two lime slurry circulation pumps are designed and work redundantly. They are working in hot lead/lag standby form.

Lime slurry addition to high concentration tank A and B is only necessary when operator finds high heavy metal concentration and already filled with ferric sulfate reagent. The addition is arbitrary and duration is short. So only one lime slurry transfer pump is designed.

Each pump is designed with suction valve, discharge valve and flush valve. Under normal operating condition, the pump suction and discharge valve are open, flush valve is closed. Every time the pump is shutdown, the suction valve will be closed and flush valve is opened, the pump keeps working for one more minutes, then shutdown. The flush step can be carried out automatically or by operator at any time.

2.11 Oil/Water Separation System

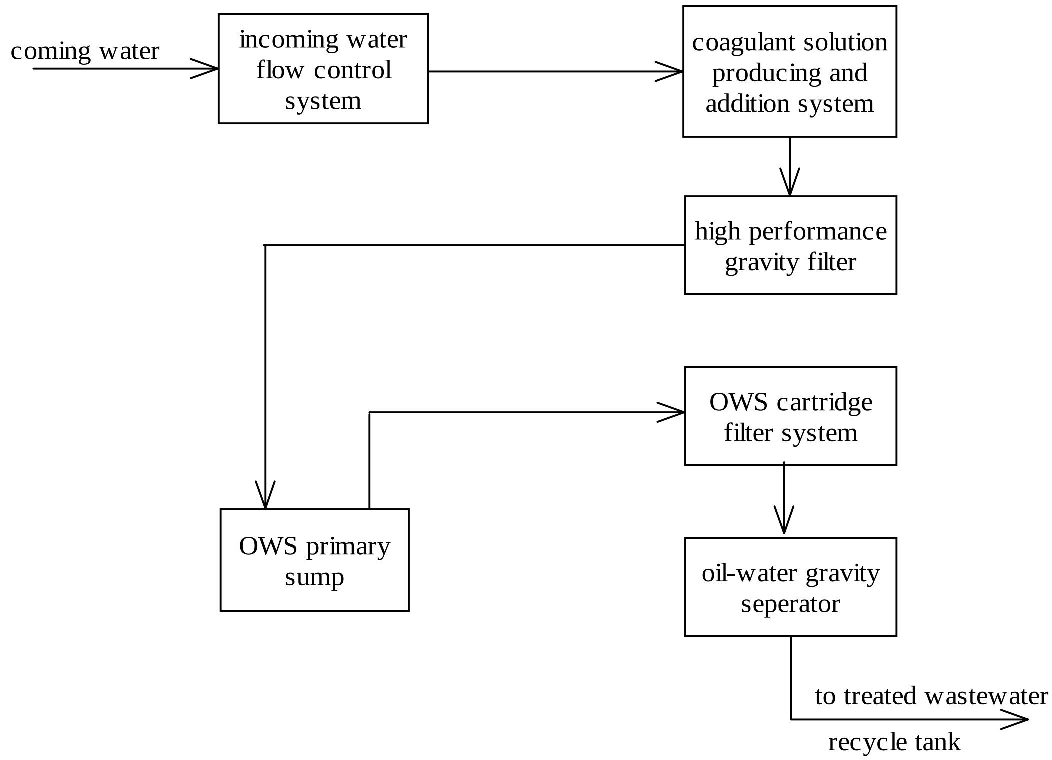

Figure 2.11.1 OWS flow chart

Oil-Water Separation system flow chart is shown in figure 2.11.1. When water contains high percentage of oil/Orimulsion, it must be processed by OWS system. For the purpose of equipment sizing, flow control system is designed to control incoming water flow rate. After flow control system, the water enters coagulant solution producing and addition system where chemical reaction will take place between oil/orimulsion and coagulant. After reaction, the water will flow through high performance gravity filter where coagulated solid will be filtered. Next the filtered water will go to OWS primary sump. After sump, the water will be pumped to oil-water separator cartridge filter system for further filtration. Then, water goes to oil-water gravity separator where oil will be separated and afloat above and water will be lower part of container and be the final OWS product.

2.11.1 Incoming Water Flow Control System

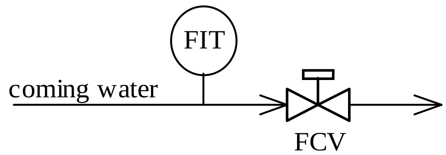

Figure 2.11.2 Incoming Water Flow Control System

A flow control loop is designed to maintain a constant flow rate to OWS system. It consists of a flow transmitter and a flow control valve. The design flow rate is 250 USGPM. DCS will compare the measured flow rate with operator entered set point. If measured flow rate is greater than set point, then DCS will instruct FCV to close a little bit. If measured flow rate is less than set point, then DCS will instruct FCV to open a little bit.

2.11.2 Coagulant Solution Preparation and Addition System

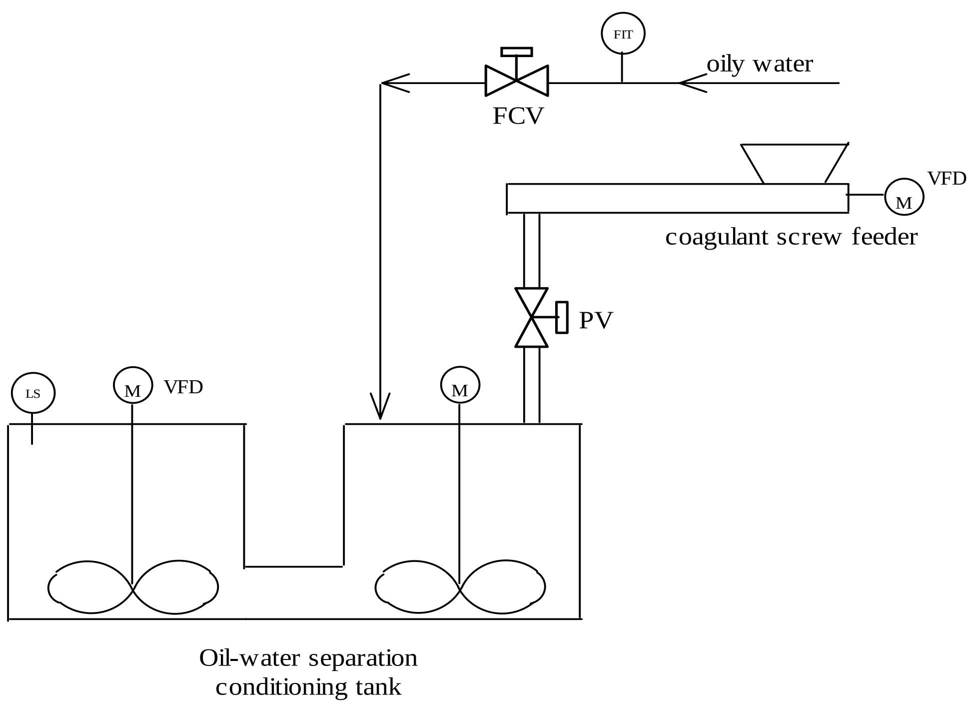

Figure 2.11.3 Coagulant Solution Preparation and Addition System

Coagulant addition rate is in proportion to incoming oily water. Coagulant addition rate will be controlled by coagulant screw feeder speed. Screw feeder speed control is open loop control with no feedback as in practice no speed sensor is installed on rotating shaft. Anyway, practice shows periodical calibration of screw feeder can meet feeding requirement.

The following equation is used to calculate coagulant addition rate and will be programmed into DCS at design stage.

$$Fc = Q_f C_o R_1 (8.9409x10^{-6})$$

Where $Fc =$ calculated coagulant flow to the conditioning tank (ft^3/h)

Q_f = total oily water flow [USGPM]

C_o = concentration of Orimulsion [mg/l] or [ppm]

$R_1 =$ coagulant addition rate constant [lb coagulant: lb oil] [2]

Level switch is used to interlock screw feeder, discharge valve PV, agitator and flow control valve start/stop.

One of the two agitators speed control is achieved using VFD. Operators can locally or remotely changing agitating speed.

2.11.3 OWS Cartridge Filter Feed System

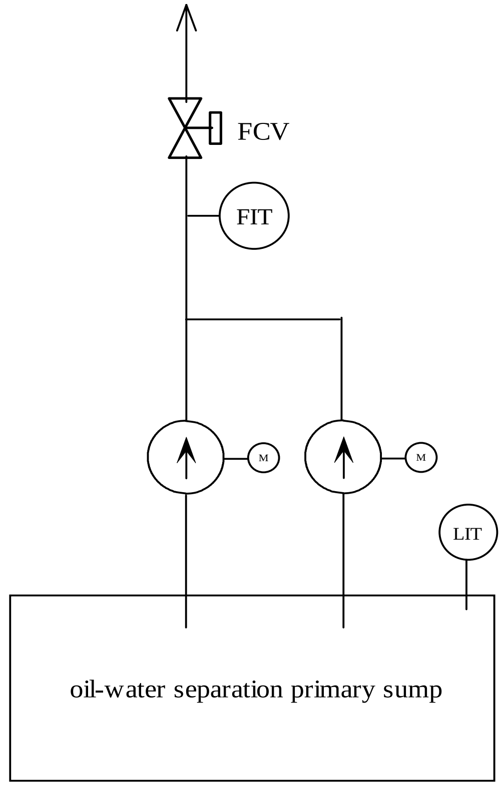

Figure 2.11.4 OWS Cartridge Filter Feed System

In the OWS cartridge filter feed system, two redundant centrifugal pumps are designed to improve reliability. Each pump is sized at 100% capacity.

Level transmitter is used to indicate sump water level and interlock pump start/stop. The following table shows level set point and corresponding action. Reference point is sump bottom.

7 ft	Sump high level alarm, force close incoming flow control valve
6.5 ft	Sump high level alarm
6 ft	Sump pump start interlock
3 ft	Sump pump stop interlock

At the pump outlet, flow control and monitoring devices are designed.

3 Control System Introduction

Coleson Cove Refurbishment Project selected state-of-the-art modern computer control system to control the whole plant. DCS contract was awarded to Emerson Ovation® system. There are 17,000 total I/O points for DCS.

3.1 DCS Control System Architecture

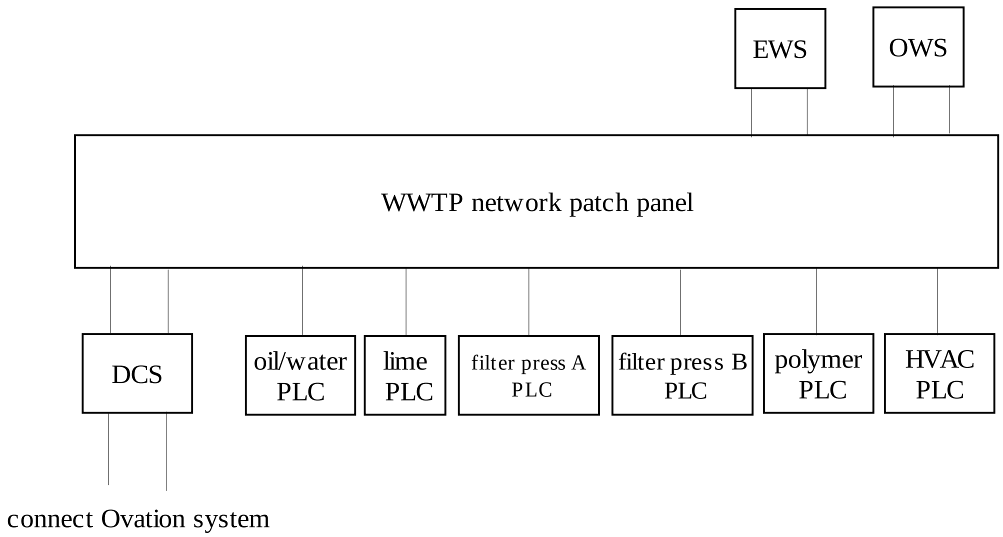

Figure 3.1.1 Control System Architecture

Control system architecture design is very important in big project. It directly affects system efficiency and reliability. Figure 3.1.1 shows WWTP control system block diagram. In WWTP, there are six PLC control system supplied with different subsystem. They are connected through Ethernet network. The EWS(Engineer Work Station) and OWS (Operator Work Station) are also connected to Ethernet network. NIC (Network Interface Card) are provided in EWS, OWS and DCS to make them connected to Ethernet network. The WWTP DCS is connected to other Emerson Ovation system through fiber optical cable.

3.2 Control Room

There is a main control room located between unit 1 and unit2. Most control stations are located there. Operators will use them to control boilers, turbines, generators and their auxiliary system of the three units and some other system.

WWTP is an independent system compared to three unit system and has a lot of equipment. It is necessary to design a control room in WWTP to monitor system running status and inspect on the field conveniently. In the WWTP control room, two ovation work stations and control cabinets are located. One station can be used as engineer station to configure and modify control logic.

3.3 Power Supply

Power supply reliability depends on power source availability and equipment reliability. As far as availability is concerned, we may choose two or three power sources. Once one source is gone, we still have power source available. As far as equipment reliability, usually we choose good quality product.

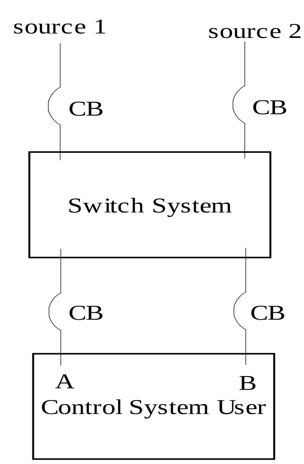

Figure 3.1.1 WWTP Power System for Control Use

Figure 3.1.1 shows Power system supply for control use. Control system power supply needs two reliable power sources from different sections. Under normal condition, switch system connects source 1 to user A and source 2 to user B. Switch system has the capability to switch source 1 to user B and source 2 to user B. Source 1 and source 2 are taken from different places. This design greatly improved power supply reliability.

3.4 Air Supply

One air compressor system is designed in WWTP. In addition to supplying pneumatic valves in WWTP, air compressor system also provides air to fly ash packing system adjacent to WWTP. Air supply to instrument and pneumatic valves must be oil-free and dry. Air pressure should be within a range not a fixed point.

3.5 WWTP Control System Design Features

As a whole project, WWTP control system design is in accordance with other system. However, as an independent system, it has its own features.

- Stand-alone subsystem is controlled by PLC such as filter press, lime system, etc. these subsystem is offered by different vendors and has different operation requirements. In practice, PLC has already become an integral part of entire scope of supply.
- For pumps with VFD, electrical engineer does not need to design protection circuit because VFD already incorporates various protection technologies. The only thing electrical engineer should do is to provide power to VFD.
- Operator can have three options to control some pneumatic valves. They are solenoid body, local control panel and from control room DCS station respectively.
- Some pumps are designed jog switch for the convenience of commissioning. Commissioning staff or maintenance staff does not need the operator’s cooperation any more. In some cases, operator’s time and workstation resource is limited. Pump troubleshooting and fix can be assisted using local switch. Once work is done, put back switch position to remote to enable DCS control.
- Some subsystems are controlled by PLC. However, operator can know all the details about the subsystems. Although communication between different vendor control

system gradually proves to be feasible, effective and reliable, from a conservative design point of view, important signal exchange like interlock signal is still achieved by hard wired communication. For example, in filter press, filter press going to discharge and filter ready to fill is connected through hard wired I/O rather than using soft I/O or communication I/O.

- Motor ready digital signal is added a 20 second delay before it is used by logic. This prevents motor starter engaging again immediately after a trip.
- Motor protection is achieved in MCC and all the details are sent to DCS through communication.
- Each motor accounts for motor ready (DI), motor running (DI) and motor start/stop command (DO). The DO is maintained by DCS.
- Each motorized valve accounts for four I/O points. They are two limit switches, valve opened (DI) and valve closed (DI), valve open command (DO) and valve close (DO).
- Solenoid valve only accounts one DO point. For example, air supply solenoid.
- Each tank agitator is designed with tank level interlock.

4 Typical Control Logic Design

Process control objective is to maximize process automation, reduce manpower to minimum and improve productivity. Therefore, various closed feedback and no feedback control loops are used, complicated logic circuits are designed, communications between different systems are developed. As a result, design drawings are huge and content in drawings are like spider web. No matter how complicated a system is, we can always divide them into drive level, subgroup level and system level. This methodology is useful in I&C design. In the whole design process, there are a lot of changes, thus the drawing revision sometimes can reach 9 or more. But the low level design almost remains no change. They can be made a little adaptation and used in other systems. Here are some typical common logic designs in WWTP.

4.1 Agitator

Agitator control is a basic motor control as shown in figure 4.1.1. Operator should select Auto/Manual first. When in Auto mode, the agitator participates in interlock. When tank level is high enough, agitator starts up automatically. When tank level drops below a specific point, the agitator will stop automatically. Once tank level reaches a specific high point, agitator will start up again automatically. Other signal can be introduced to control agitator start/stop. When in Manual mode, operator can control agitator start/stop manually. When operator presses stop button, agitator work mode will automatically switch to Manual mode. In order to prevent motor start again immediately after trip, a 20 second time delay is designed. When control system set start command to motor, 5 seconds later, if no motor run contact is received, that means start fails, DCS will alarm operator. Similarly, when control system set stop command to motor, 5 seconds later, if motor run contact is still true, that means stop fails, DCS will alarm operator. If motor is not ready, any operation will be disabled.

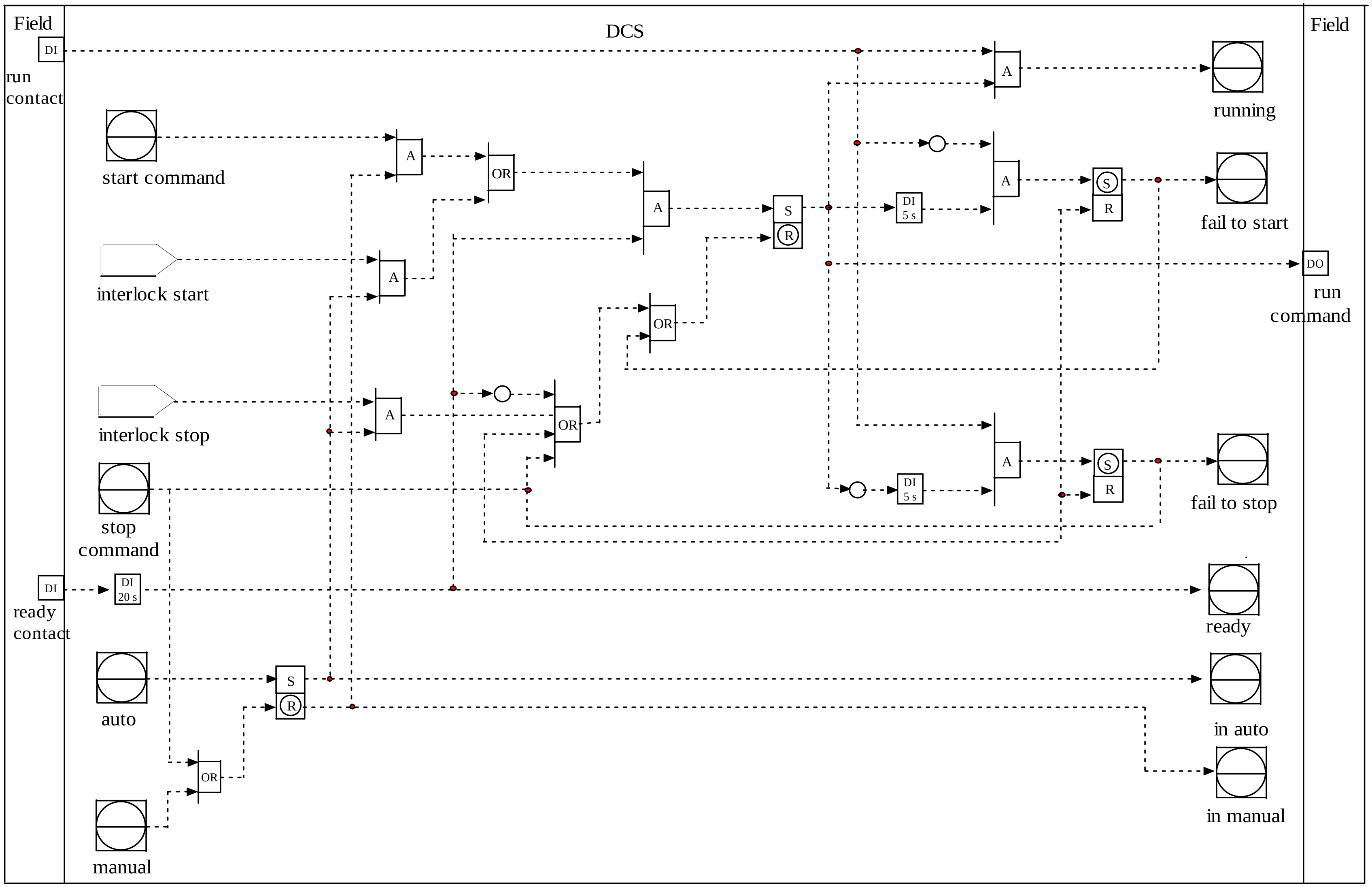

Figure 4.1.1 Agitator control logic

4.2 Single Loop Control

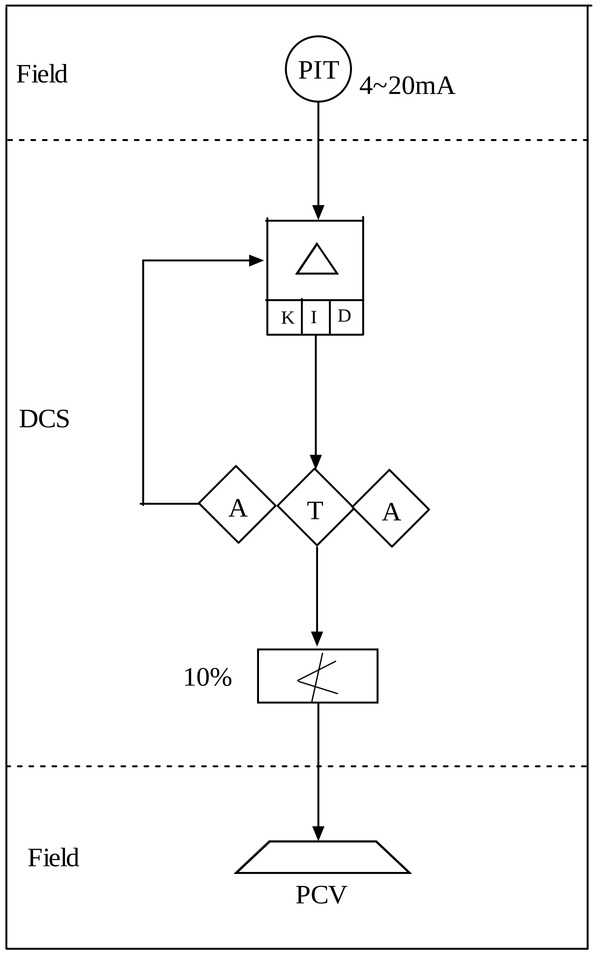

Figure 4.2.1 Back Pressure Loop Control

This is a simple feedback closed loop control. The process variable is lime circulation back pressure. The output variable is pressure control valve. The middle T means Auto/Manual station. In Auto mode, system control valve open automatically. In Manual mode, operator can force an analog output signal to control valve. The right A means operator enter output. The left A means pressure set point. The measured data (PIT) will compare with set point, after that, using appropriate PID algorithm to manipulate error signal, then output an appropriate signal to control valve. In order to prevent when flow rate is low, lime circulation header inline pressure is low, possibility of buildup inline increase, a low pressure restriction (not less than 10%) is designed.

4.3 Lime Solution Producing Screw Feeder and Service Water Flow Control

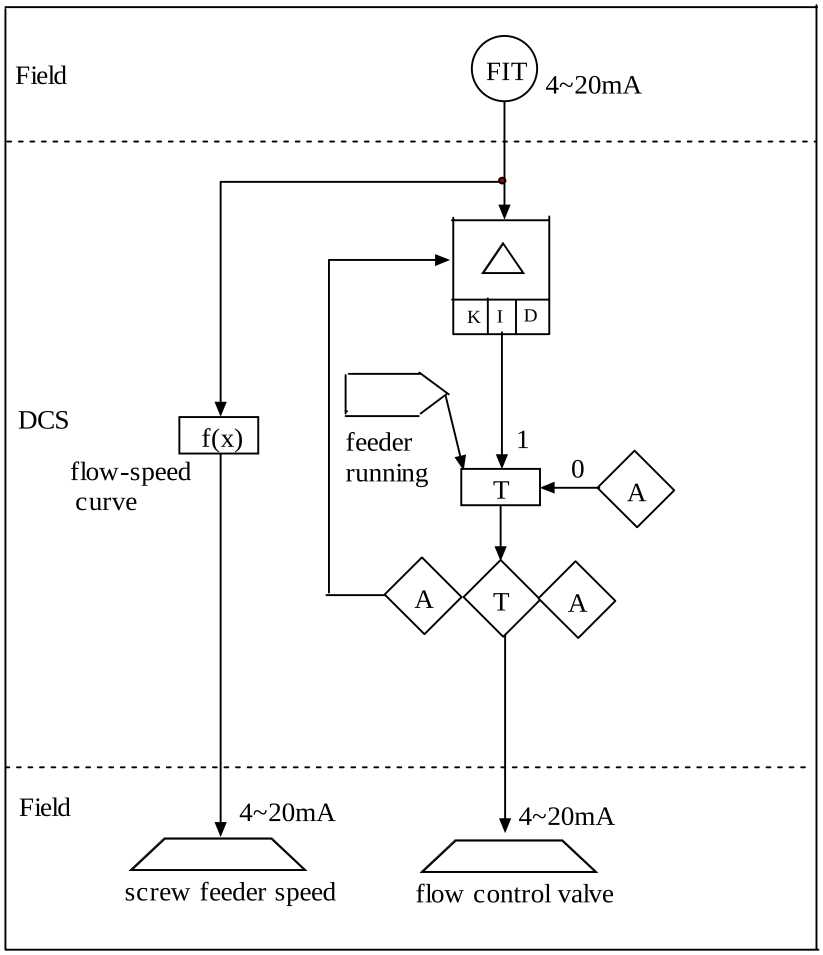

Figure 4.3.1 Lime Solution Producing Screw Feeder and Service Water Flow Control

Screw feeder flow-speed curve will be periodically calibrated and programmed into DCS as f(x). Thus ratio of service water and lime is guaranteed. This example also shows how sequence control enters analog control. Flow control valve from closed position (0%) to open position (100%) is controlled by analog control loop. Here, the A on the right of square T is set 0. When feeder is running, the screw feeder speed is controlled by analog control loop. When feeder has some problem and is not running, sequence control logic will detect the event and through analog control force flow control valve to be closed.

4.4 Polishing Reaction Tank Level Control

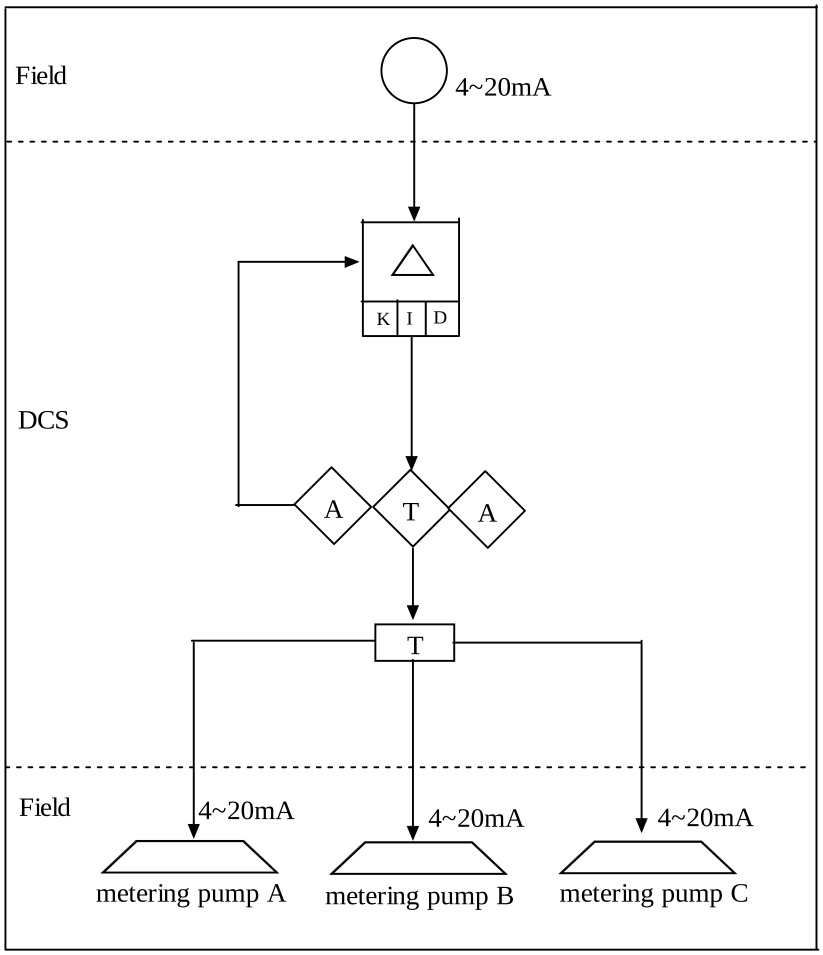

Figure 4.3.1 Polishing Reaction Tank Level Control

This is a typical one process variable with a couple of control output. Under normal operating condition, the three outputs to metering pump A, B and C are equal. The control logic will monitor pump running status. When one pump is taken out of service, the control system will automatically increase the output to the remaining pumps.

4.5 Other Control Logic

The above introduced logic design is the fundamental design in engineering. Complicated system logic design is derivative of the basic logic. There are some other logics that need to be reported as follows:

1) tank level

    Tank level is usually interlocked with agitator start/stop, outlet inlet pump start/stop, and alarm operator.

2) pump flush

    Pump flush is both events triggered and time triggered. When pump needs to be shutdown, it is event triggered. When to terminate flush process is time triggered.

3) dual pump

    Some dual pumps are hot standby. That means when working pump trips, the other pump must startup automatically and immediately. Some dual pumps are not hot standby. That means when working pump trips, the other pump can be started up by operator manually. Therefore, different consideration should be given.

4) sump level

    To important sump, there is possibility that sump will overflow and damage the floor device. The level signal must be reliable and two pumps are designed. When level reaches H, lead pump will start. If level continues to increase and reaches HH, the lag pump must also be started up to draw more water out from sump. If level reaches HHH, an alarm has to be sent to operator.

5) filter press

Filter press is both event triggered and time triggered. There are a lot of interlock in logic design. This belongs to batch logic design.

6) Motorized valve

Motorized valves usually come with gear box. Therefore, they are not like motor or fans start/stop very quickly. The exact open-close time depends on gear-ratio and pipe diameter. The duration may last one minute or longer. When DCS sends control signal out, it will flash until it receive limit switch signal.

5 Control System Design Summary

WWTP involves several subsystems, much equipment and many contractors. To design an efficient control system, designer must be familiar with process operation, relevant standards and codes, equipment operation and maintenance manual, logic design experience and control system characteristic. As a team designer, control engineer has to effectively communicate with engineers in other disciplines. Sometimes, in one area a good idea may be not feasible in other disciplines. Control engineer must optimize control scheme from time to time and give some feedback and suggestion to process engineer to be both practical and apply state-of-the-art control technology.

Due to lack of detailed reference, logic design only suits current control requirement from process engineer and vendors. Some parameter optimization, set point final determination has to be left at commissioning stage. In other words, logic design keeps changing even after normal operation. So far some consideration and suggestion is made here for reference.

- In WWTP, PLC control has already been integrated with some subsystems. If we use DCS instead of vendor supplied PLC, a lot of detailed interface work has to be done at design stage. As some contractors are reluctant to provide detailed logic, they have only operation manual that is not enough to design logic control. But from system integration and cost point of view, only use DCS to control entire WWTP could be more economical.

- So far based on NB Power existing routine, seven I/O points are associated with each motorized valve. Actually, this is not necessary. If we cut three I/O points, the control performance will not be affected, while cost is reduced.
- Local selector switch is necessary for pump commissioning and maintenance purpose.
- For lime slurry addition to high concentration equalization tank, primary reaction tank and polishing reaction tank, currently we select pulse operation. Is there a better control scheme available? This issue needs to be further researched.
- For filter press, pressure-flow conversion, can we design an alternative controller that has a good performance in this situation?

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