Gas Absorption Experiment – Draft Standard Operating Procedure

R.Cox 9-2016

Scope

This document is intended to serve as a guide to the operation of the gas absorption experiment located in the Senior Laboratory at the Department of Chemical Engineering, University of Utah.

This procedure details system operation using column # 1 with blower # 2.

Before operating this equipment, all personnel must receive equipment specific training from the lab manager.

Equipment description

In gas absorption a soluble component is absorbed by contact with a liquid phase in which the component is soluble. This system is used for scrubbing gas streams of components such as sulfur dioxide, carbon dioxide and ammonia. In this experiment, the CO2 is injected into the air stream generated by the blower. A mixture of water and sodium hydroxide is used to remove CO2 in the column.

The system demonstrates mass transfer for two-phase systems.

Absorption columns

Column number 1 is packed with ceramic Berl saddles.

Column number 2 is packed with metal Pahl Rings.

Both columns have a six-inch inside diameter and a length of approximately nine and one half feet.

Liquid Circuit

The liquid circuit consists of two 140-gallon tanks, an 80 gallon jacketed mixing tank, and associated pumps and valves. All piping for the liquid circuit is 1-inch schedule 80 PVC, 1-inch schedule 40 PVC or 1-inch 304 stainless steel.

Air circuit

The air circuit consists of two blowers, associated valves and 2-inch schedule 80 PVC rated to 400 PSI.

The gas injection and analysis system consist of a CO2 cylinder and regulator and associated measuring devices.

Gas Analyzers

Inlet and product gas streams are analyzed for CO2 concentration using Alpha gas analyzers.
The 9510 and 9500 gas analyzers measure volumetric percent of gas concentration, the range on both instruments is 0 – 25%. Refer to the instrument documentation for further information.

A detailed list of the equipment incorporated in the gas absorption experiment is included at the end of this document.

**Safety**

- Safety glasses must be worn when operating this equipment.
- Do not operate this equipment alone.
- Note that certain procedures require the coordinated efforts of two people.
- When filling the mixing tank do not exceed the 50-gallon level.
- **Under no circumstances should this equipment be left unattended while in operation.**
- The use of caustic solutions, compressed gas, large volumes of water and multiple sources of electrical power make attention to safety paramount when operating this equipment.
- The floor under the gas absorber is open grate covered by aluminum sheet and rubber mat. Accidental flooding will result in caustic liquid exposure to equipment and personnel working on both floors below the gas absorber experiment. Sodium Hydroxide is extremely corrosive and highly reactive.
- Use Chloroflex gloves and wear safety glasses and a face shield when mixing sodium hydroxide and water.
- Never add water to a corrosive. Always add corrosives to water. When mixing with water, stir in small amounts of corrosives slowly.
- Label containers. All chemical containers must be clearly labeled with the chemical contents and concentrations. Keep containers closed when not in use. Empty containers may contain residues which are hazardous. Triple rinse all empty containers before discarding them to the trash.
- Anytime the basement neutralization tank is in use, a team member must remain in room 2505 to monitor the basement tank system for leaks.
Operating Procedure

This operating procedure details system operation using column # 1 with blower # 2.

Pre-Operational Checklist

1. Verify that tank #2 -located in room 2505 - is empty and that tank #2 drain valve #16L is closed.

2. Verify the liquid level in the feed tank. Both tanks have a sight glass indicating the tank level, however, the sight glass does not read to the bottom of the tank. If the sight glass does not indicate liquid in the tank, it is possible that the tank may contain liquid below the level of the sight glass, which could result in flooding or contamination of your solution. To confirm that the tanks are empty the tank pumps must be operated until no flow is observed as displayed on the flow meter readout on the Opto control system. This procedure must be performed with the assistance of the lab manager.

3. Verify that both the 9500 and 9510 gas analyzer sample bypass valves are set to vent to atmosphere.

4. Open the Blower Vent Valve 100%.

5. Verify that the Validyne pressure transducer module located on the shelf above the gas analyzers is turned on.

Set Valves to fill mixing tank.

A. Close V1L and V2L.

B. Close V16L, basement tank main output valve.

C. Before filling the mixing tank with water:

The water supply line incorporates a totalizing meter, before opening the main water valve note the reading on the totalizer, once you have filled the mixing tank to the 50 gallon level shut of the main water feed valve and again note the reading on the totalizer. Use these totalizer readings to verify the amount of water in the mixing tank. Do not fill the mixing tank above the 50-gallon mark.

2. Fill the mixing tank.

A. Place the water feed hose in the mixing tank, while one person is firmly holding the water hose a second person will slowly open the main water supply valve (green ball valve) located behind and to the left of the mixing tank.

B. Fill the mixing tank to the 50-gallon mark.
Before operating with caustic, the system should be tested with water. Once the correct water and air flow rates are established using water, then the system may be operated with a caustic solution.

**Step #3 should be performed after the system has been evaluated using water without caustic. For evaluating the system with water proceed to step 4.**

3. **Adding sodium hydroxide:**

Never add water to a corrosive. Always add corrosives to water in small amounts.

Wear lab coat, safety glasses, Chloroflex gloves and a face shield when mixing NaOH & water.

Gently mix the solution using the detachable mixer located next to the mixing tank. Consult the lab manager for assistance in operating the mixer.

4. **Set the valves to pump liquid from the mixing tank to the feed tank.**

Open V1L and V3L  
Close V2L

The mixing tank pump is controlled by two switches; 17C (Mixing Tank) located on the rear switch panel located next to the mixing tank and a second 17C switch located on the front switch panel. The 17C (mixing tank switches) must both be in the on position to power the mixing tank pump.

5. **Pump from the mixing tank to the feed tank.**

A. Confirm that the mixing tank pump switch located on the rear panel is in the off position.

B. Turn on the mixing tank pump switch located on the front switch panel.

C. The mixing tank pump may now be controlled by switch 17C (Mixing Tank) on the rear switch panel, this allows the operator to monitor the tank level and stop the pump before the mixing tank runs dry or before the feed tank is over-filled.

D. To pump from the mixing tank to the feed tank. Turn on switch 17C (Mixing Tank) located on the rear switch panel.

E. Stop mixing tank pump as soon as the mixing tank is empty.

F. Repeat procedures 2-4 as needed to fill the feed tank to the desired level.

G. Constantly monitor the level of the feed tank – do not allow the feed tank to fill above the 115 gallon / 43 inch mark at the top of the sight glass.
6. **Log on to the computer control system.**

   The password and username are posted on the computer monitor.

   Double-click on the OPTO GAS ABSORBER icon located on the desktop.

   The event log viewer screen is displayed, you will see a series of about five messages, close the event log viewer.

   The Opto control window should be displayed. Pressure, air velocity and temperature data are displayed in addition to data from the gas analyzers, Tank2 pH and flow and process fluid flowrate. The right side of the window displays the tank level alarms. Alarms will activate when tank levels are too high or too low.

   **When a HIGH ALARM is active immediately stop all pumps and resolve the issue. A high alarm indicates that one of the tanks is about to overflow.**

7. **Set the liquid flow valves to pump liquid from the feed tank to column 1.**

   A. Close 5L recycle valve 100%

   B. Open Tank 1 outlet valve 6L

   C. Set column\textbackslash{}calibrate select valve to feed the columns, not to flow out the clear tubing. The clear tubing flow option allows for flowing into an external vessel. This option is not used under normal operating conditions.

   D. Verify that both column feed sample valves 1L and 2L are closed.

   E. Set the Column Flow Select Valve to feed column #1. The arrow on top of the valve handle should be pointing to the left.

   F. Verify that column 1 and 2 drain valves 14L and 15L are open, these valves must remain open at all times.

   **To feed column # 2 set the Column Flow Select Valve to feed column#2**

8. **Select blower** - Only one air blower may be operated at a time

   A. Adjust the blower select valve (yellow ball valve located between the blowers) to select blower #2. The arrow on the yellow handle indicates air flow.

   B. Before operating the blowers make sure that there are no power cords or materials obstructing the intake side of the blower.

   C. Open the Blower Vent Valve to 100% open.
D. Verify that the blower #2 power switch (13A) and blower #1 power switch, located on the front panel, are in the off position.

E. Insert the Blower #2 power cord into the blower #2 (13A) outlet located on the wall above the blower.

F. If you select blower #1, plug it into the outlet labeled blower #1 and switch the blower select valve to blower #1.

9. Set airflow valves to feed column 1.

Set the Column Airflow Select Valve to flow air to column 1, air flow should go to the right as you face the valve, refer to the arrow located on the valve handle.

10. Set Column Airflow Outlet Valves

A. Verify that Column 1 Air Outlet Valve 14A is open. *This valve should be closed when operating column #2.*

B. Verify that Column 1 Air Outlet Valve 13A is closed. *This valve should be open when operating column #2.*

C. Verify that the Main Air Outlet Valve 15A is open.

D. Verify that the Alternate Air Outlet Valve 16A is closed. The purpose of this valve is to provide an alternative differential pressure measurement of outlet airflow. This option is not used under normal operating conditions.

11. Pump liquid from the feed tank to the column.

A. Verify that the feed tank recycle valve 5L is closed.

B. Before pumping liquid, set the pump control to zero by pressing the decrement button (down arrow) on the pump control panel until 0.0 is displayed.

C. Switch on the feed tank (Tank 1) pump. The switch is located on the front switch panel.

D. Push the Run button on the pump control panel.

E. Push the increment button (up arrow) on the pump control panel until the pump flow set point reads 20.

F. A set point of 20 on the pump control will result in a flowrate of about 0.5 GPM. *The pump control panel displays the frequency of the pump controller, not flowrate.*

G. It will take about 30 seconds for the liquid to reach the top of the column.
H. Constantly monitor the flow as the liquid flows down the column. The flowrate in GPM is displayed on the computer monitor.

12. **Adjusting the liquid feed flow-rate.**

Once stopped, the pump will restart at the last set point.

The pump control procedure is as follows:

A. Using the decrement button, set the set point to zero.
B. Press the run button.
C. Using the increment button set the desired set point.
D. To stop the pump, press the stop button.
E. Before restarting the pump, re-zero the set point.

Always re-zero the pump set point before pressing the run button.

Do not set a flow higher than 25 on the pump speed control.

Air flow will affect the liquid flowrate. Setting the pump control to 20 results in a flow of about 0.5 GPM, without air flow. Once you turn on the blower, the pressure in the column will increase and the liquid flowrate will be reduced.

Watch for flooding at the bottom of the column. If liquid backs up in the bottom of the column to the point where it is about to enter the gas flow inlet, immediately stop the pump and let the liquid drain. Once the liquid has drained start the pump at a low speed and gradually increase the pump speed to the desired set point.

Optional adjustment: Once the flows are reasonably stable, adjust 14L located at the bottom of column #1 to maintain a level of liquid in the bottom of the column that just reaches the wide part of the column, about 4 inches of liquid in the bottom of the column. This will prevent gas from going out the bottom of the column.

**About Flooding**

There are two types of flooding that can occur with this equipment.

The first is the common type of flooding where the water flowing into the column exceeds the ability of the column to drain. In this case liquid will flow into the air inlet pipe and onto the lab
floor. The lab floor area under the experiment is an open grate covered by rubber mat and aluminum sheet. If water should escape the column it will fall through the floor and down two stories on the people and equipment below the lab.

The second type of flooding is where the gas/air flowing up the column is high enough that is impedes the flow of liquid flowing down the column. This type of flooding will inhibit the column efficiency and may result in liquid getting into the air outlet pipe and then leaking from the air outlet pipe onto the lab floor.

13. **Switch on the air blower**

   A. Verify that the Blower Vent Valve is open 100%.

   B. Set both the gas analyzer bypass valves to the vent position.

   C. Once the liquid flows have stabilized at a flow rate less than 2 GPM, switch on the selected air blower.

   D. The blowers are switched on and off from the switches located on the front panel. Make sure you have plugged the blowers into the correct outlet as described in section 9.

   E. Monitor airflow: Air velocity and the pressure drop across orifice plate # 1 are displayed on the monitor.

   F. The system is generally operated at an airflow that is lower than the airflow rotameter range. The rotameter provides a visual indication of airflow; it is not intended to provide accurate measurements. Volumetric airflow measurements are made by measuring the pressure across orifice plate #1. Air velocity as measured before the air reaches the columns is displayed on the monitor.

14. **Adjusting the Air Flow**

   A. Adding air flow to the column will affect the liquid flow. When adjusting the air and liquid flows you must constantly monitor the column for flooding.

   B. The air flow is controlled by venting part of the blower output to atmosphere using the Blower Vent Valve.

   C. Minimum air flow through the column will be achieved when the Blower Vent Valve is open 100%.

   D. To increase the air flow into the column, slowly close the Blower Vent Valve while constantly monitoring the air and liquid flow. Adjust air and liquid flow to the desired set points taking care not to flood the column.
E. Once the air and liquid flows have stabilized, adjust the CO2 flow as described in the next section.

F. Once you have established air and liquid set points, stop the air and liquid flows while you are setting up the CO2 feed.

**Gas sampling instruments - System description**

The 9510 and 9500 gas analyzers measure volumetric percent of gas concentration, the range on both instruments is 0 – 25 %. Refer to the instrument documentation for further information.

Verify that the sample gas pressures and flows are within the operating parameters for the gas analyzers. **Exceeding the maximum pressure or flow will damage the gas analyzers.**

The maximum pressures and flow rates are:

9510 CO2 Monitor: 100-300 ml/min at 2.0 psig (55.35 inches of water) maximum.

9500 O2 & CO2 Monitor: 0.5 – 1.0 L/min at 1 psig (27.68 inches of water) maximum.

The CO2 is fed to the 2 inch blower outlet PVC pipe via a ¼ inch fitting. The CO2 combines with the air from the blower and the mixture is fed to either column 1 or 2.

Downstream from the CO2 injection port is another ¼ inch port fitted with a sample line and needle valve. The gas stream exits this port through poly-tubing where it is fed to the pressure and flow panel.

The top of either column 1 or column 2 is connected via a ¼ inch poly tube to the inlet of the short desiccant cylinder located on the right side of the pressure and flow panel. The outlet of the desiccant connects to the inlet of the 0-50 in/water manometer on the right side of the pressure and flow panel. The outlet of the manometer connects to the inlet of the 0-1000 cc/min rotameter. The outlet of the rotameter connects to the inlet of the 9500 analyzer via a tee fitting located on the back of the instrument.

**About the CO2 Gas Supply**

The column inlet (feed) gas consists of air fed by the blower with the addition of CO2 which is injected into the blower feed stream. The CO2 flowrate is primarily controlled by adjusting the output pressure of the CO2 regulator, additional flow adjustments may be made by adjusting the CO2 needle valve located at the inlet of the CO2 flow rotameter. Note, the CO2 rotameter is not calibrated for CO2 it is calibrated for air.
15. **Setting the vent valve on the Pressure and Flow Panel**

A. The Air/CO2 sample tap connects to the magnehelic and rotameter on the left side of the pressure and flow panel. The gas pressure is displayed on the magnehelic. The gas flows through the rotameter and into the 9510 gas analyzer. Above each magnehelic and flowmeter is a 3-way valve. The valve on the left takes the air sample after it goes through the magnehelic and rotameter and, if the valve is switched to the 7:00 o’clock position, feeds the gas to the 9510 analyzer. With the valve set to the 1:00 o’clock position the gas stream will be vented to atmosphere. The valve positions are labeled on the valve mounting bracket. The bypass valve, magnehelic and rotameter on the right side of the pressure and flow panel feed the gas flowing from the top of column one or two into the 9500 analyzer or to vent in the same manner as previously described.

B. Venting both the column and air feed gasses to atmosphere is the default position for these valve. This ensures that the gas analyzers will not inadvertently be damaged by over pressurizing the gas analyzers.

16. **Setting the CO2 flow rate:**

A. Turn on the CO2 regulator and CO2 gas line heater. Set the heater control to 30%

B. Open the CO2 needle valve 100%. This valve is located at the inlet at the base of the CO2 flow rotameter.

C. Verify that the CO2 regulator outlet pressure adjustment valve is rotated to the left, to the point that the outlet pressure adjustment valve feels loose. This ensures that the outlet pressure and flow will be zero when the main CO2 tank valve is open.

D. Open the main CO2 cylinder valve 1/4 turn.

E. Gradually rotate the regulator outlet pressure adjustment valve to the right while observing the cylinder outlet pressure reading on the gas regulator and the CO2 flow on the CO2 rotameter. Adjust the tank outlet pressure to achieve the desired flow.

F. Periodically check the CO2 regulator and outlet tubing to ensure frost is not forming on the surface. If a film of frost appears on the cooper line, increase the heater output.

G. Once you have set the CO2 flow to achieve the desired percentage of CO2 in the air stream as displayed on the gas analyzers, turn on the blower to feed the column with the Air / CO2 mixture.
17. **Measuring CO2 Concentration in the feed gas.**

   A. Verify that the sample bypass valves are set to vent.

   B. Verify that the blower vent valve is set to the desired setting.

   C. Turn on the blower and observe the pressure and flow readings on the 9510 magnehelic and rotameter. Adjust the needle valve at the base of the rotameter to maintain a flowrate of less than 300 ml/min for the 9510 gas analyzer.

   D. Monitor the pressure reading as displayed on the 9510 magnehelic if the pressure is greater than 55 inches of water reduce the pressure to the measurement system by closing the gas stream sample valve (G1) valve located on the CO2 air sample port. Adjust valve G1 to maintain a pressure reading on the 9510 magnehelic that is below the maximum pressure rating of 55 inches of water.

   E. Once you have set the pressure and flow to within the 9510 specifications, switch the 9510 sample bypass valve from the vent position to the 9510 position. The sample gas should now be fed to the 9510 analyzer. It will take a few minutes for the reading to display.

18. **Measuring CO2 Concentrations in the Column Outlet Gas**

   A. Verify that the poly-tubing that connects the top of either column 1 or 2, whichever one you wish to measure, is connected to the inlet of the small desiccant cylinder labeled column outlet desiccant.

   B. Verify that the 9500 sample bypass valve is set to vent.

   C. Turn on the column blower and observe the pressure reading on the 9500 magnehelic. If it is above 25 inches of water, turn off the blower and contact the lab manager before proceeding.

   D. With the blower running, observe the gas flow reading on the 9500 rotameter, adjust the flow as needed using the needle valve on the rotameter. The flowrate should not exceed 1000 ml/min for the 9500 gas analyzer.

   E. Once you have verified that the flows and pressure are within specification for both the feed gas and column outlet gas; proceed to the next section.
19. Running the column with liquid and gas flow

A. Turn on the pump and establish liquid flow at the desired flowrate. Constantly monitor the column for flooding.

B. Wait a few minutes for the liquid flowrate to stabilize.

C. Now turn on the blower and adjust the air flow as required.

D. Constantly monitor the pressure and flow panel gauges to ensure that all flows and pressure remain within the required limitations. Running liquid and air at the same time will cause the pressure and flow to change.

E. Constantly monitor the column for flooding.

F. Monitor the computer display for high / low level alarms.

Before draining the contents of the basement tank (tank #2) you must verify that the pH of the liquid in tank 2 is between 5 and 10. If the pH is outside of this range the liquid in tank 2 must be neutralized to within the 5-10 range. If you have been operating the system with water, without any caustic additive, you may proceed to the section on draining tank 2.

All procedures involving the tank 2 system in room 2505 require an operator to be present at the tank 2 system when it is in operation. Use walkie-talkies or your cell phone to stay in contact with the computer operator.

Two – person procedure:

Two – person procedure: Coordinate with team members to switch on the basement tank 2 pump. While the pump is on, a team member must remain in room 2505 to monitor the flow of liquid until the tank is empty. Once the tank level has dropped below the sight glass the tank is not empty. Continue draining the tank until the tank 2 flow as displayed on the computer monitor displays zero flow. Once the flow stops, the pump operator that is monitoring the computer must immediately shut off the pump.
18. **Set valves to recycle basement tank 2**

Verify that the pH of the liquid in the basement / neutralization tank is within disposal range (5 – 10 pH).

A. Set neutralization / basement tank valves to recycle the contents of the basement tank.

B. Set V19L flow output to the right; see the flow indication arrow on the valve handle.

C. Open tank 2 drain valve V16L.

D. Switch on the basement / neutralization tank pump. Tank 2 pump is controlled by two switches. One is located on the main switch panel and the other switch (local switch) is located in room 2505, on the wall above the pump. When running the tank 2 pump, the operator must first verify that the local switch is off, then switch on the main tank 2 switch located on the main switch panel and then switch on the local switch to operate the tank 2 pump.

Monitor the pH reading which is displayed on the EUTECH pH meter next to the pump power switch in room 2505. The tank 2 pH is also displayed on the computer monitor.

19. **Neutralizing caustic prior to disposals**

Wear Chloroflex gloves, lab coat and face mask when working with concentrated acid.

Mix all concentrated acid solutions in the fume hood.

A. Set neutralization / basement tank valves to recycle the contents of the basement tank.

B. Set V19L flow output to the right

C. Open V16L

D. Calculate the amount of acid required to lower the pH of the liquid in the basement tank to within the safe disposal range of (5 – 10 pH).

E. Disconnect the acid container from the metering pump located next to the feed tank. Take the acid container to a fume hood and add the required amount of acid.

F. Cap the acid container and return it to the metering pump. Connect the metering pump acid feed line to the acid container.

G. Verify that the metering pump output line is connected to the PVC acid line.

H. Start the basement neutralization pump.

I. Start the acid metering pump at 10 ml/min.
J. Monitor the pH in the basement neutralization tank.

K. Adjust the flow rate of the acid metering pump as required.

L. Stop the acid metering pump as soon as the pH of the neutralization tank drops below a pH of 10.

M. Disconnect the acid metering pump line from the acid container and cap the acid container.

N. Place the acid metering pump feed line and cap on an 8-liter Nalgene container that is 50% full of water.

O. Label the Nalgene container.

P. Store any remaining acid in the 8-liter Nalgene container – remember to label the container with the contents and concentration.

20. Set tank 2 valves to pump the contents to drain

The tank 2 pump is operated by two switches. One is located on the main switch panel, the other is located in room 2505 next to the pH monitor. The purpose of the two switches is to allow the operator in 2505 to have control over the tank 2 pump and also provide the operator at the computer the ability to shut off the tank 2 pump once the flowrate drops to zero.

A. Open V16L

B. Set V19L to flow to the left, towards V20L, refer to the arrow on the valve handle for flow direction.

C. Set V20L to flow to the hose, flow indicator is located on the top of the valve handle.

D. Verify that V16L is open.

E. The operator in 2505 should verify that the tank 2 pump control switch located on the wall by the pH meter is off.

F. The tank 2 operator should then contact the operator at the computer and request that the tank 2 pump switch be turned on.

G. The tank 2 operator should then turn on the tank 2 pump. Constantly monitor the drain flow for leaks and pump failure.

H. While the pump is on, a team member must remain in room 2505 to monitor the flow of liquid until the tank is empty.
I. Once the tank level has dropped below the sight glass the tank is not empty. The operator in 2505 should notify the computer operator that the tank 2 level have dropped below the sight glass. Continue draining the tank until the tank 2 flow, as displayed on the computer monitor, displays zero flow. Once the flow stops, the pump operator that is monitoring the computer must immediately shut off the pump.

J. Once tank 2 is empty the operator in room 2505 should shut off the pump control switch located on the wall next to the pH meter. Both switches that control tank 2 pump should now be switched off.

K. The tank 2 operator should close the basement tank main valve V16L

L. Set basement valve V19L to output flow to the drain. Flow to the left.

M. This concludes the tank 2 drain procedure.

22. **Shutdown:**

   A. Verify that all pump and blower power switches are in the off position
   B. Close the main CO2 tank valve
   C. Switch off the CO2 regulator heater
   D. Close the basement tank main valve V16L
   E. Set basement valve V19L to output flow to the left – drain.
   F. Close Feed tank main valve V6L
   G. Unplug all blowers
   H. Close the mixing tank outlet valves V1L, V2L and V3L
   I. Properly label and store any chemicals in use
   J. Exit the Opto22 control software; do not log off the computer
   K. Save your data to a flash drive
   L. Check out with the lab manager
Equipment Description

Blower #1
Spencer Turbo-Compressor
30 CFM - 64 oz, s/n 51219, lot # 35108
Blower motor: Black & Decker 2 HP, 60 cycles,
240 VAC, 10 Amp, 10,000 RPM, Type CSC
Blower #2
Spencer Turbo-Compressor
12 CFM - 35 oz, s/n 43903, lot # 33662

Rotameter: Air Flow
Omega Engineering FL45200A series
Range: 40 - 240 SCFM
Air velocity transmitter: JLC International model EE66 Range 0-400 ft/min
Orifice Plate #1: 0.814 inches i.d, no bevel - Pipe Size 1.9 inch o.d, 1.5 inch i.d
Orifice Plate # 2: 0.530 inches i.d, no bevel - Pipe size 1.4 inch o.d, 1.0 inch i.d

Liquid Circuit Rotameter: Liquid Flow
Omega Engineering FL46300 series Range: 0 -17 GPM
Mixing tank Capacity: 80 Gal
Capacity of feed & neutralization tanks: 115 Gal
pH transmitter - neutralization tank: Alpha pH 500 transmitter
pH probe: Cole-Parmer p/n 35811-71
Pump data mixing tank pump motor: AMT Model 3696-975-97, Pump head # 3690-002-00
Feed Tank Pump: McMaster ½ hp
Neutralization Tank Pump: Same as feed pump
Metering Pump:
Pulsatron E Plus Series, Maximum flow 630.9 mil/min, Min flow 6.3 mil/min

CO2 Measurement System  Alpha Omega Instruments: Series 9510 CO2 Analyzer

Maximum input sample pressure: < 2.0 psi

Sample flow rate: 100-300 ml/min, 300 ml/min maximum

Range 0 - 25 %

Alpha Omega Instruments: Series 9500 CO2 / O2 monitor:

O2 / CO2 range: 0 - 25 %

Sample flow rate 0.5 - 1.0 L/min

Maximum input sample pressure < 1.0 psi

Calibration standard: 20% CO2 in nitrogen balance

Pressure Measurement: Validyne pressure transducer system

Dwyer Magnehelics

Badger-Meter M2000 Liquid Flow Meter

Temperature Measurement  Type T Thermocouples

Control & data logging  Opto22