TOMCO$_2$ SYSTEMS

WATER TREATMENT SOLUTIONS

Pressurized Solution Feed System (“PSF”)

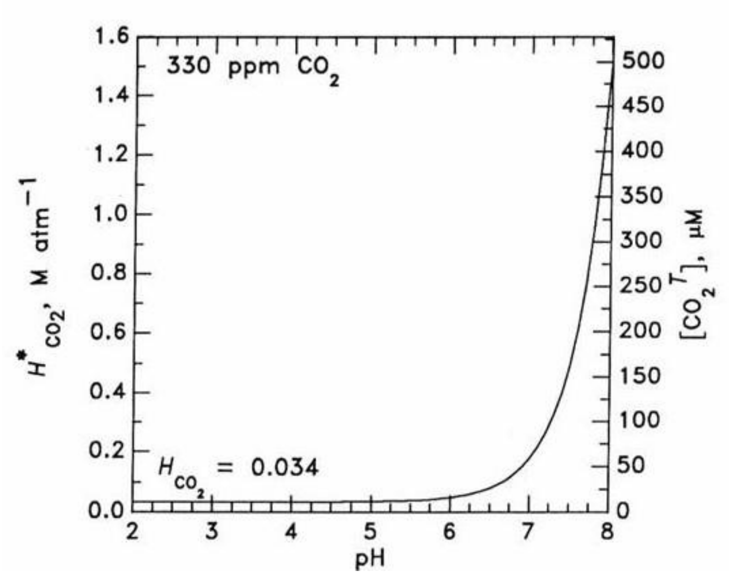
In 1995, Tomco invented and patented a revolutionary advanced carbon dioxide injection system. This system changed how a municipality injected carbon dioxide into drinking water. Our Pressurized Solution Feed System (“PSF”) utilizes a carrier water stream and injects carbon dioxide gas under pressure and controls the injection using our patented Solution Diffuser.

We need to understand the solubility of Carbon Dioxide and how it reacts or dissociates with water and alkalinity. Carbon Dioxide is an electron poor atom. The electron rich oxygen of the water must donate an electron pair to the carbon. Once this transfer occurs, carbonic acid is formed. This reaction between water and dissolved carbon dioxide is very unstable and can reverse back into carbon dioxide gas. Carbonic Acid is only in equilibrium with the bicarbonate anion.

To look at the concentration of the dissolved carbon dioxide, we must look at Henry’s Law of Solubility. This law state that the amount of dissolved gas is proportional to its partial pressure in the gas phase. An everyday example of this law is given by one's experience with carbonated soft drinks, which contain dissolved carbon dioxide. Before opening, the gas above the drink in its container is almost pure carbon dioxide, at a pressure higher than atmospheric pressure. After the bottle is opened, this gas escapes, moving the partial pressure of carbon dioxide above the liquid to be much lower, resulting in degassing as the dissolved carbon dioxide comes out of solution.

This reaction is what we don’t want to happen. We want to prevent the escape of the dissolved carbon dioxide. To prevent this, we must look at the physical make-up of this injection. Key areas are bicarbonate / saturation point, pressure, temperature, and turbulence.

- **Bicarbonate and saturation point:** As we stated, carbonic acid is stable only if a bicarbonate anion is present. With permeate water, the reverse osmosis process removes most of the alkalinity from the water. This leaves pure water state. Therefore, when carbon dioxide is injected directly into the permeate, the carbonic acid is very unstable. Please note that the pH of the permeate is generally between 5.5 and 7.0. If you look at the chart, the solubility is very low. It is only at 6.8, the solubility increases. The injection of excess carbon dioxide will increase this Carbonated Soft Drink effect, when the pressure is lowered, the results are the degassing of the solution. The more bicarbonates present, the higher the solubility of carbon dioxide is.

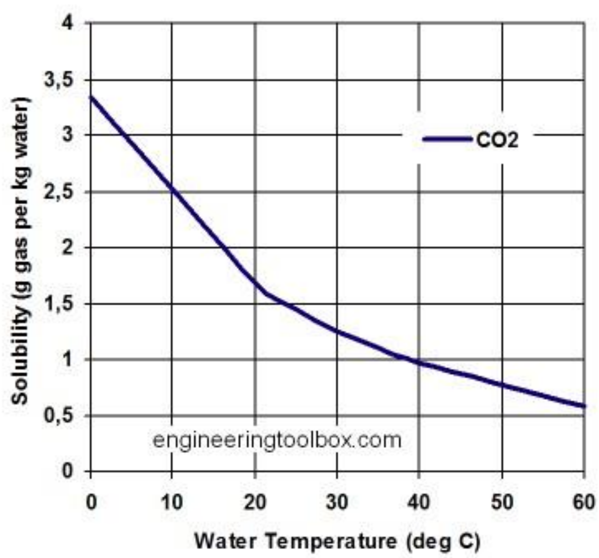


3340 Rosebud Rd., Loganville, Georgia 30052 USA • Phone: 770-979-8000 • www.TOMCOsystems.com

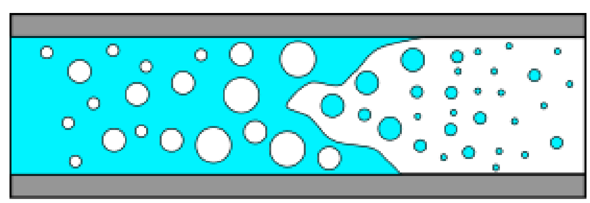
- **Pressure**: If we look at the pressure relationship according to Henry's Law, we will see that pressure has a direct effect on the solubility of carbon dioxide. This is the most important factor in producing Carbonic Acid. Our PSF maintains the pressure during the production of carbonic acid over the pressure of 500 kPa. As we look at this chart, you will the solubility is double or tripled compared to lower pressures. A typical gas injection system will inject carbon dioxide gas into a permeate water (Motive Water) at a low pressure around 50 kPa and 101 kPa. The theoretical solubility is between 30% and 60%. This does not take in consideration of the chemistry of the water. This difference is wasted carbon dioxide.

Temperature (°C)	Solubility of CO in water at various partial pressures (Solubility in mole fraction × 1000, pressure in kPa)			
	50	101.325	200	500
0	0.671	1.355	2.66	6.52
10	0.477	0.963	1.89	4.65
20	0.353	0.713	1.400	3.45
25	0.308	0.622	1.223	3.01
30	0.271	0.548	1.077	2.66
40	0.216	0.437	0.858	2.12
50	0.178	0.359	0.706	1.75
60	0.150	0.304	0.598	1.480

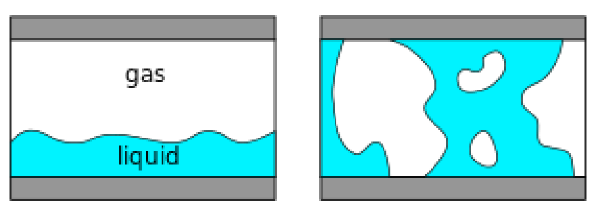
- **Temperature**: Temperature plays an important role in the solubility of the carbon dioxide reaction also. The variation of solubility for a gas with temperature can be determined by examining the graphic on the right. As the temperature increases, the solubility of a gas decreases as shown by the downward trend in the graph. More gas is present in a solution with a lower temperature compared to a solution with a higher temperature. Take the solubility of carbon dioxide between 20°C and 35°C, you should notice a decrease by 50%. The reason for this gas solubility relationship with temperature is very similar to the reason that vapor pressure increases with temperature. Increased temperature causes an increase in kinetic energy. The higher kinetic energy causes more motion in molecules which break intermolecular bonds and escape from solution. This gas solubility relationship can be remembered if you think about what happens to a Carbonated Soft Drink as it sits around at room temperature. The taste is very "flat" since more of the "tangy" carbon dioxide bubbles have escaped.



- **Turbulence:** Turbulent flow is very important for mixing carbon dioxide gas with the water ensures a precise homogenic mix. Most permeate pipeline are straight pipes from point to point causing laminar flow. If gas exist in this pipeline, the unreacted gas bubble will combine with other bubbles causing two phase flows. This two-phase flow could cause internal pipe liquid separation. This leads to gas slugs, which disrupts the permeate flow. To prevent this, static mixers, air vents or degasification equipment is needed. The expelled gas is wasted money and resources.



a) Transient two-phase flow.



b) Separated two-phase flow.

Why is pH control important in the remineralization process? This is simple, to dissolve calcium carbonate to form bicarbonate alkalinity. The permeate water from the reverse osmosis process is typically low in mineral content, hardness, alkalinity and pH. Therefore, permeate water must be remineralized for final distribution and use. The goal of this process is the protect the water distribution system against corrosion and add the essential minerals to meet the World Health Organization Standards.

When permeate water is introduced with calcium carbonate, the reaction increases the pH causing a slow dissolution of the calcium. This react will form calcium carbonate precipitation. This precipitate will adhere to the pipe walls and fittings. This will decrease your alkalinity and your final LSI and leave your water unstable. The additional chemicals to correct this issue will cost more money.

.

Tomco's Pressurized Solution Feed system is engineered to answer these issues which plagues the carbon dioxide gas injection into permeate water. Our process begins with carbon dioxide gas piped from the storage tank vapor space to the vapor heater and then to the carbonic acid pressurized solution feed (PSF) panel. The PSF system utilizes a pH reading strategically placed in the permeate water. The pH of the permeate is controlled by injecting carbonic acid (H_2CO_3) in the process stream and measuring the result of this reaction. The solution concentration is adjusted in the PSF panel prior to being introduced into the process stream by the patented solution diffuser. The solution diffuser is the controlling device for the solution flow in the system. The diffuser has fixed orifices and therefore the solution flow is essentially constant at any given operating pressure. To ensure proper system operation the solution pressure must be maintained above injection pressure in the solution piping system between the PSF panel and the solution diffuser to avoid off-gassing and two-phase flow in the solution piping. The flow of carrier water to the PSF panel should remain essentially constant, varying the amount of CO_2 gas being introduced into the carrier water varies the H_2CO_3 solution/carbonic acid strength.

The PSF panel CO2 flow control valve controls the flow of CO2 gas being introduced. Under normal "feed-back" control the pH probe/sensor inputs a signal to the pH analyzer/controller. The pH analyzer/controller, which has a PID control function, outputs a 4-20 mA control signal to the CO_2 flow control valve for position control. A 4mA signal closes the valve and a 20-mA signal provides the maximum open span position for the valve. If the process flow pH is in the setpoint control range as indicated by the pH probe/sensor input to the pH analyzer/controller, then the CO_2 flow control valve signal is not changed. However, if the process flow pH is above the setpoint control range, as indicated by the pH probe/sensor input to the pH analyzer/controller, then the CO_2 flow control valve signal is increased thus driving the control valve to a more open position, which provides more CO_2 and a stronger acid solution flow. Conversely, if the process flow pH is below the setpoint control range, as indicated by the pH probe/sensor input to the pH analyzer/controller, then the CO_2 flow control valve signal is decreased thus driving the control valve to a more closed position, which provides less CO_2 vapor/gas flow and a weaker acid solution flow.

This process will help minimize the risk of supersaturation on the permeate water while maintain the setpoint pH value. This improved efficiency and control will reduce the amount of carbon dioxide needed for this reaction. The could save over $1,000,000.00 per year in carbon dioxide gas cost.

Cost vs. Efficiency

Cost of CO_2	$ 300.00	Ton
CO2 Dosage	1000	kg/hr.
Total CO2 Used per Day	24,000	Kilograms
Chemical Cost of CO2	$ 2,628,000.00	Year
Direct Gas CO2 Injection (Based on Henry's Law 30°C @ 100 kPa)	54%	Efficiency
Carbonic Acid Solution Injection (Based on Henry's Law 30°C @ 400 kPa)	95%	Efficiency
% Difference between Systems	41%	Efficiency
Estimated Savings using PSF	**$ 1,077,480.00**	**Per Year**

In conclusion, our advance PSF technology:

- **Controls the pH of the permeate, this helps eliminates the risk of supersaturation of the permeate water**
- **Controls the pH of the permeate to increase the dissolution of the calcium -reducing calcium carbonate precipitation.**
- **Controls the pressure during the formation of the Carbonic Acid at the optimal pressure**
- **Minimizes the effect of the temperature by maintaining ideal solubility pressure**
- **Injects Carbonic Acid Counter Flow to the permeate causing a homogenic (Turbulent) mix**
- **Increases the carbon dioxide transfer efficiencies greater than 95% • Will save you operational cost by reducing the wasted carbon dioxide**
- **Has been installed in over 300 water plants worldwide.**

Harvey Swain
Director, International Sales - Water Technologies

3340 Rosebud Rd., Loganville, Georgia 30052 USA • Phone: 770-979-8000 • www.TOMCOsystems.com