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AUTOMATIC ALKALINITY CONTROLLER

Theory of Operation

The Lyons Filter Co. Automatic Alkalinity Controller provides a simple and reliable means of automatically control lime treatment of water from variable sources. These sources can vary in quantity, quality, or temperature.

Impurities in water change with the source. In general, surface waters are high in dissolved oxygen and suspended solids and low in hardness and dissolved solids. Ground waters are usually high in carbon dioxide, dissolved solids and hardness, and low in suspended solids.

The hardness of most water supplies is caused by the presence of calcium and magnesium compounds in solution. The associated anions of these bivalent ions are principally the bicarbonate and sulfate ions, although chlorides and nitrates of calcium and magnesium do occur. The lime softening process removes a part of these calcium and magnesium salts from the water. Calcium and magnesium bicarbonates are called carbonate hardness and sulfate, chloride, and nitrate compounds are called non-carbonate hardness.

The alkalinity of most natural water supplies is caused by dissolved bicarbonate (HCO_3^-) salts.

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^-$$

Most source waters have a total alkalinity content greater than 50 ppm, usually in the form of bicarbonates that are very soluble in water. The most common forms of bicarbonate alkalinity are calcium bicarbonate and magnesium bicarbonate. These compounds are formed when calcium or magnesium is bound to the bicarbonate to form $Ca(HCO_3)_2$ or $Mg(HCO_3)_2$.

When lime ($Ca(OH)_2$) is added to water having bicarbonate alkalinity, it will react with the calcium bicarbonate to form calcium carbonate ($CaCO_3$), small particles that precipitate from the water. The lime also reacts with the magnesium bicarbonates to form magnesium carbonate ($MgCO_3$.) An additional amount of lime will react with the magnesium carbonate to form magnesium hydroxide ($Mg(OH)_2$) that will precipitate.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2\,CaCO_3 \downarrow + 2H_2O$$
$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + MgCO_3 + 2H_2O$$
$$MgCO_3 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + Mg(OH)_2 \downarrow$$

Other reactions also occur which create a lime demand yielding carbonates and hydroxides of heavy metals that will precipitate. Examples of these are zinc carbonate *($ZnCO_3$)*, zinc hydroxide *($Zn(OH)_2$)*, cadmium carbonate *($CdCO_3$)*, cadmium hydroxide *($Cd(OH)_2$)*, copper carbonate *($CuCO_3$)*, and copper hydroxide *($Cu(OH)_2$).*

Free carbon dioxide reacts with lime to form calcium carbonate and water.

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$$

Historically, metal coagulants (alum and iron salts) have been most widely used in water clarification. These products function as both coagulants and flocculent. When added to water, they form positively charged species in the typical pH range for clarification. This hydrolysis produces insoluble gelatinous aluminum or ferric hydroxide.

The most often used coagulants are form of metal salts, usually ferric sulfate $Fe_2(SO_4)_3$ or alum $Al_2(SO_4)_3$. The reaction with lime forms a metal hydroxide $X(OH)_3$ and calcium sulfate $CaSO_4$.

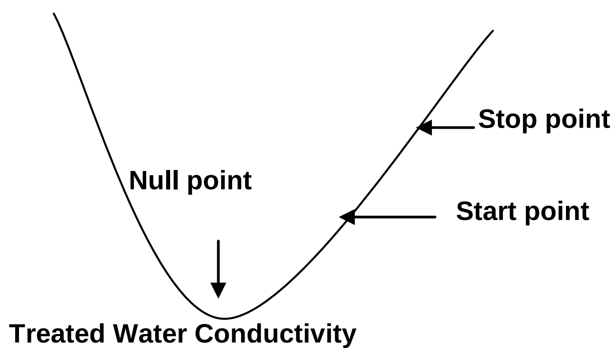
$$Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4$$
$$Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4$$

The metal hydroxides forms the gelatinous floc to which the precipitated particles cling. This dense floc easily settles out of the water to form sludge.

As these reactions occur the total alkalinity and dissolved heavy metals decrease. Conductivity is a measure of the ability of a fluid to conduct electricity. Conductivity decreases as dissolved solids are removed from the fluid.

Lime is usually fed as a slurry in proportion to the raw water flow rate. This requires accurate feeders and rate of flow controls that are high in maintenance and initial costs. Precise control of chemical feed becomes even more important when the quality of the source water is in a constant state of change. When a source water changes in quality the proper amount of lime required for satisfactory treatment also varies and manual adjustments of feed rates must be made. The amount of the adjustments are normally determined by chemical tests of the treated water.

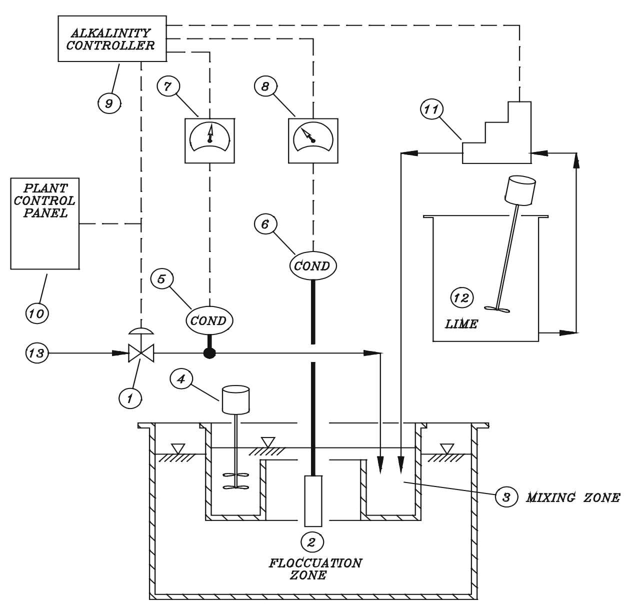
A graph of the conductivity plotted against lime addition to water containing precipitable dissolved solids shows a continuous decrease to a minimum point. At this point all the bicarbonates and dissolved metals have been precipitated. Further addition causes an excess of lime and a corresponding increase in the conductivity of the water. These relationships remain true even with changes in the mineral and sodium salt content of the water.



These concepts form the basis for the Alkalinity Controller. The controller utilizes two conductivity measurements, one of the incoming water and one of the treated water. These measurements supply signals to a microprocessor, where they are used in controlling the process.

The microprocessor calculates the ratio of treated water to raw water conductivity. It also calculates the rate of change of the conductivity. Utilizing both the ratio and the slope allows precise control on any part of the curve.

The Lyons Filter Co. AUTOMATIC ALKALINITY CONTROLLER package consists of a control panel with equipment to monitor two points in the water treatment system. The panel includes a microprocessor that controls the lime feed pump. Also included is an interface module which allows the operator to enter set points and various other operating parameters.



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Untreated water (13) enters through a control valve (1) and is mixed with chemicals in the mixing zone (3). Chemicals are added from a chemical storage tank (12) utilizing a feed pump (11). The water and chemicals overflow to the downcomer to enter the flocculation zone (2). This system represents a typical arrangement of rapid mixing and flocculation. The exact configuration can vary from that shown.

The Automatic Alkalinity Controller system monitors the conductivity of the untreated water (5 & 7) and of the treated water (6 & 8). The conductivity meters (7 & 8) generate 4-20 ma signals proportional to the values of conductivity. These signals are transmitted to the processor in the Alkalinity Controller. The controller also receives a signal from the plant control panel (10) to determine if the plant is running and sends a signal to the chemical pump (11) to start and /or stop it. This system can also be set up to modulate the chemical pump instead of on-off control.

Operation

The alkalinity controller must determine the shape and values of the conductivity curve of the treated water as lime is introduced to the mixing zone. It accomplishes this by performing a NULL PROCEDURE.

When an initial plant run signal is received (raw water valve open), the unit will start. Raw water, ferric sulfate, chlorine and sludge from the air lift will enter the mixing chamber.

The lime pump is off for a period of time equal to the retention time in the mixing chamber. This is usually 1 to 2 minutes. This delay is to ensure that the controller has a known starting condition. After the delay time, the microprocessor will determine the value of the treated water conductivity.
The pump will then start to run while the microprocessor determines the direction and slope of the conductivity curve.

Since conductivity is being measured at all times, the microprocessor will determine when the conductivity of the water passes through its lowest point and starts to increase. The increase is caused by excess lime.

This lowest point is the NULL POINT. Once the null point is determined the lime pump will cycle on and off at the points selected in the PUMP STOP and PUMP START set points. The on and off set points determine the 2P - M = A value.