Utilizing A Phosphate Analyzer To Monitor And Control Chemical Feed Reduces Operating Costs And Improves Reliability

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Introduction

Phosphates have many uses in the treatment of potable (drinking) water. They are used to prevent:

1. Colored water such as "red" water from iron and "black" water from manganese.
2. Prevent and/or remove scale formed from minerals.
3. Prevent corrosion due to low pH and/or dissimilar metals in the distribution system.
4. Reduce soluble lead and copper in potable water delivered to the consumer's tap.

The Environmental Protection Agency (EPA) administers the Safe Drinking Water Act (SDWA), which provides for the enhancement of the safety of public drinking water supplies through the establishment and enforcement of nationwide drinking water regulations. Congress gave the primary responsibility for establishing regulations to the U. S. EPA. Until 1990, the EPA administered a certification process for chemicals, including phosphates, to be used for potable water treatment.

In 1990, the National Sanitation Foundation International (NSF) assumed responsibility for the total certification process which involves several steps. The toxicology database and impurity profiles are thoroughly reviewed by NSF's toxicology staff. NSF then audits all manufacturing locations. Samples are taken and analyzed to confirm impurity data submitted on certification applications. Raw materials used in the process are verified against submitted lists and any gaps must be filled. The raw material suppliers are also required to submit detailed information similar to the product application.

Phosphates have many properties that are beneficial to potable water. There are a number of phosphate products that can be employed however they fall into three main categories; 1) phosphoric acids, 2) orthophosphates, and 3) condensed phosphates. Each product has a maximum concentration established by the NSF.

Many utilities use phosphate for the benefits it provides. Often they manually feed the phosphate based on their typical flow and perform manual grab sample testing to verify proper chemical feed to ensure the desired phosphate residual is maintained. However, as the flow changes the phosphate residual changes in proportion to the flow change. Employing a continuous phosphate analyzer provides many advantages:

1. Ensures proper phosphate residuals are maintained.

2. Alerts operator when residuals are out of range.
3. Reduces operating cost by not overfeeding product when flow decreases.

Properties of Phosphates Beneficial to Potable Water

There are many properties of phosphate that are beneficial to potable water such as:

1. Safety
   a. The National Sanitation Foundation certifies the use of products for potable water.
2. Chlorine stability
   a. Ortho and polyphosphates are stable in the presence of chlorine at the levels found in chlorinated potable water. There are no interactions that reduce the levels or effectiveness of either the chlorine or polyphosphate. In addition, iron and manganese that is sequestered as colorless complexes before chlorination will remain colorless after chlorination.
3. Sequestration
   a. Phosphates react with metal ions to form colorless soluble complexes and reacts with hardness ions to prevent excessive scale build up.
4. Deflocculation
   a. Polyphosphates tend to coat the small particles and reduce their attraction to each other by changing the surface charge distribution. These coated particles tend to repel rather than attract one another – hence deflocculation. Deflocculated particles are suspended in water and show little or no tendency to settle in standing water. This property is important for the removal of existing hardness scale deposits (CaCO3) and iron oxides.
5. Hydrolytic stability
   a. Phosphates hydrolyze slowly therefore they are stable and do not break down.
6. Threshold activity
   a. Many polyphosphates can accomplish the desired effect at levels far below that which would seem to be required for a stoichiometric (molar equivalent) reaction. For example, water containing 200 parts per million (ppm) hardness (as calcium carbonate, or $CaCO_3$) would theoretically require about 500 ppm of sodium hexametaphosphate (SHMP) to sequester the available calcium. Actually, only 2-4 ppm of SHMP is typically used to inhibit scale formation. This "threshold effect" of SHMP apparently occurs by interfering with early crystal growth.

Phosphate Products Employed

Phosphate products for potable water treatment can be broadly classified into three groups: phosphoric acid, orthophosphates, and condensed phosphates. The application of each phosphate product depends upon the specific properties or treatment desired. Phosphates for potable water treatment along with their National Sanitation Foundation (NSF) designated maximum use levels are listed in the table below.

Phosphate	National Sanitation Foundation (NSF) Maximum Use Level
Phosphoric Acids:	
36% Phosphoric Acid	27.0 mg/l
75% Phosphoric Acid	13.0 mg/l
80% Phosphoric Acid	12.0 mg/l
85% Phosphoric Acid	12.0 mg/l
Orthophosphates:	
Monosodium Phosphate (MSP)	13.0 mg/l
Disodium Phosphate (DSP)	15.0 mg/l
Trisodium Phosphate (TSP)	17.0 mg/l
Monopotassium Phosphate (MKP)	14.0 mg/l
Dipotassium Phosphate (DKP)	36.0 mg/l
Tricalcium Phosphate (TCP)	12.0 mg/l
Condensed Phosphates:	
Sodium Acid Pyrophosphate (SAPP)	12.0 mg/l
Sodium Trimetaphosphate (STMP)	11.0 mg/l
Tetrasodium Pyrophosphate (TSPP)	14.0 mg/l
Sodium Tripolyphosphate (STP)	13.0 mg/l
Tetrapotassium Pyrophosphate (TKPP)	17.0 mg/l
Tetrapotassium Pyrophosphate, 60% Solution	29.0 mg/l
Sodium Hexametaphosphate (SHMP)	12.0 mg/l

The use of polyphosphates at concentrations as low as 2 – 4 ppm is sufficient to mitigate color, tastes due to metals, and scale formation. The optimal product to use is influenced by the pH, and the optimal concentration is influenced by the properties of the water. Therefore the product of choice and optimal feed concentration are site specific.

Phosphate Feed

Many municipalities choose to manually feed their treatment chemicals based on mass balance calculations. However, due to variables such as flow, pump capacity, metals and hardness concentration maintaining a proper phosphate residual without over or under feeding is challenging. Large systems can achieve substantial cost savings by automatically dosing their treatment chemicals. Manual chemical feed requires the operator to set the chemical feed rate based on some selected flow rate to achieve the desired phosphate residual. If the flow or demand changes the phosphate residual also changes.

This often results in over feed of chemicals to ensure the system is protected. If continuous phosphate monitoring is employed the feed rate of the phosphate can be adjusted to consistently maintain the desired residual.

Table 1 illustrates the potential savings when continuous monitoring is employed to automatically control the chemical feed with only an average 10% reduction in flow from the flow used to establish the feed rate. The product feed rate for the example is 3 ppm and the cost is $2.00 per pound. An average of 33.5% as PO_4 was also used to calculate the phosphate as PO_4 residual.

Cost Savings Employing Phosphate Monitoring and Automatic Dosing					
MGD	**3 - PPM Product Feed Rate lb./day**	**Actual Targeted Conc. as PO_4, PPM @ 33.5% PO_4**	**Manual Dosing Annual Cost @ $2/lb.**	**Automatic Dosing Annual Cost @10% Flow Variation**	**Annual Savings per 10% Total Flow Variation**
10	250	1.0	$182,646	$164,381	$18,265
50	1251	1.0	$913,230	$821,907	$91,323
75	1877	1.0	$1,369,845	$1,232,861	$136,985
100	2502	1.0	$1,826,460	$1,643,814	$182,646

Table 1: Potential Savings Employing Automatic Dosing

In addition to cost savings the operator can be alerted to the low phosphate residual concentration due to issues such as:

1. Chemical feed pump failure.
2. Feed tank is empty.
3. Anything impacting chemical delivery such as:
   a. Line leak or break
   b. Plugged line
   c. Closed valve

The risk of over feed conditions resulting in exceeding the NSF maximum level is also mitigated.

Figure 1 compares the phosphate residual with automatic versus manual control when the flow changes. As illustrated, automatic feed provides more consistent phosphate residuals.

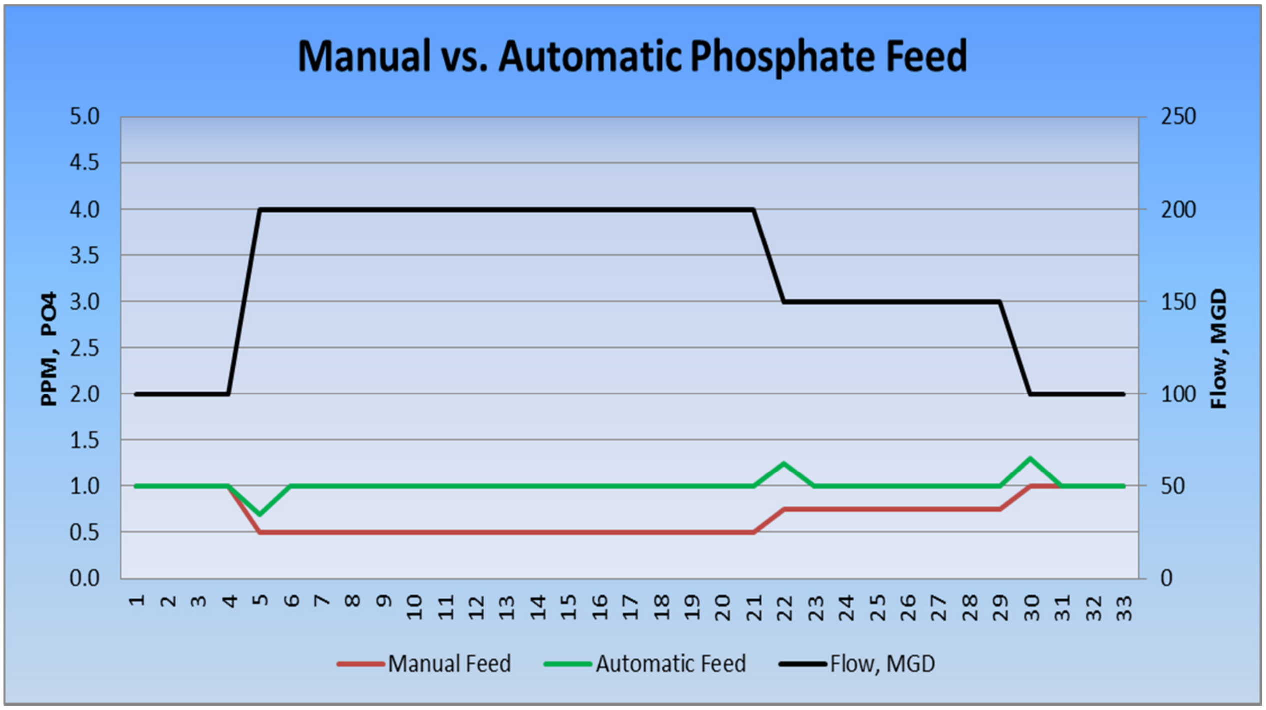
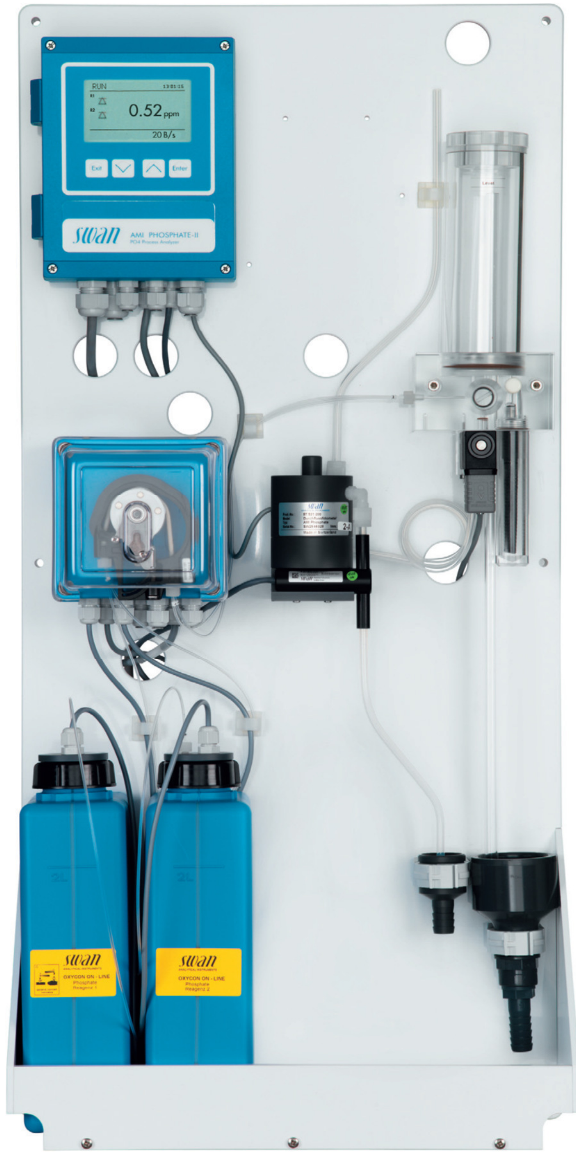


Figure 1: Automatic versus Manual Phosphate Feed

<u>**Summary**</u>

The use of continuous monitoring of phosphate to control chemical feed provides operational, technical, and economic benefits that can greatly exceed the cost of the analyzer and annual O&M costs. The risk of underfeed of phosphate resulting aesthetically unpleasing water, and tastes due to metals, as well as scaling issues is greatly mitigated. The risk of exceeding NSF guidelines is mitigated minimizing the regulatory risks. The cost savings of avoiding over feeding phosphate during reduced flow periods can result in substantial cost savings. This is true for chlorine and fluoride as well.



Swan AMI Phosphate II Analyzer

[Swan AMI Phosphate II Datasheet]

References:

1. The Phosphate Forum of America Educational Document