There are several methods for controlling the addition of chlorine into a process. These methods include **flow proportional injection**, **ORP (oxidation reduction potential)** or a **residual chlorine analyzer**. Each method measures a different process characteristic. Depending on the specific type of process being controlled, there generally is a best choice for controlling the injection of either chlorine gas or sodium hypochlorite (liquid bleach, NaOCl).

In order to better understand why one method is preferred over another, it is best to define exactly what the measurement is for each method, what the desired control situation is, the limitations of each system and what routine maintenance is required.

Flow Proportional Injection

In flow proportional control, a volume of chlorine is injected relative to the flow rate (of water) through the system. In most applications, there is a desired resultant concentration of chlorine (i.e., five ppm), and the system is configured to enable the dosing of the chlorine (generally bleach through a metering pump) to achieve this value. Table 1 lists the volumes required per gallon to achieve a one ppm level of chlorine. To achieve a concentration of five ppm, simply multiply these values by five.

The flow proportional control system uses a flow sensor to determine the flow rate of the carrier solution (generally water). Many types of flow sensors are designed to produce a pulse output (per vollume of flow) directly from the sensor. These include multijet meters, paddle wheel, turbine, magnetic, vortex and others. the signal may be taken through an intermediate flow controller (normally required when the pulse rate off the sensor is not adjustable) or directly into a metering pump. The function of the intermediate meter is to ratio a pulse output to that received from the flow sensor. Other functionality such as flow rate monitoring and flow totalization also may be achieved.

Many metering pumps feature an on-board microprocessor-based controller and are capable of multiplying or dividing the pulse signal directly. this eliminates the need for an intermediate controller for flow sensors with non-adjustable pulse outputs and can simplify the overall situation.

The pulse rate required for the application is determined by the amount of bleach required per gallon (generally in ml) and output per stroke (pulse) of the selected metering pump. Adjustment of the stroke length on the pump can enable the pump output (per stroke) to be trimmed to exactly the dose per stroke needed. For example, if five ml of sodium hypochlorite is required for each gallon of water, a pump with an output of six m per stroke can be set at an 80-percent stroke length and programmed to stroke once for each pulse received from a flowmeter generating one pulse per gallon. As the flow rate increases, the pulse output from the flowmeter increases proportionally, achieving a consistent dosing per volume of flow through the system. When selecting a metering pump, using a smaller pump (in ml/stroke) pulsing at a higher rate (i.e., ten strokes per gallon vs. one stroke per gallon) can reduce "slugging" of the chemical into the flow stream. Metering pumps on the market today can stroke at 300 to 360 strokes per minute, virtually eliminating slug feed of the hypochlorite.

Selection of the flowmeter/sensor (pulse generating device) can affect the overall reliability and consistency of the chlorine injection. Hall-effect sensors are generally preferred over mechanical reed switches. The mechanical reed switch should never be used at pulse rates greater than 100 pulses per minute and offers shorter overall life than a Hall-effect sensor. The disadvantage of the Hall-effect sensor is that it requires external power, generally in the range of 6 to 24 VDC. Installation of the sensor should follow manufacturere's guidelines for an upstream straight run to ensure linearity across the flow range.

The flow proportional system for controlling chlorine injection is best used for in-line (one-pass) applications only such as municipal water treatment. In other systems where chlorinated water is recirculated, it is not safe to assume that all chlorine added previously was consumed and requires replacement. For these applications, either an ORP or Residual Chlorine system should be used. the advantage of the flow proportional system is that it is the lowest maintenance, lowest cost option. Once installed and configured correctly, minimal attention is necessary.

Table 1: Chlorination Chart Approximate chemical solution required for chlorination based on 5.25 percent sodium hypochlorite (bleach) at 1 ppm dosage					
WATER FLOW			BLEACH (Sodium Hypochlorite) REQUIRED		
GPM	GPH	m3/h	ml/min	l/hr	GPD
20 30 40	1200 1800 2400	4.542 6.813 9.084	1.51 2.27 3.02	.09 .136 .181	.57 .86 1.15
50 60 70	3000 3600 4200	11.355 13.626 15.897	3.78 4.54 5.30	.227 .272 .318	1.44 1.73 2.01
80 90 100	4800 5400 6000	18.168 20.439 22.71	6.06 6.81 7.57	.364 .409 .454	2.3 2.6 2.88
200 300 400	12000 18000 24000	45.42 68.13 90.84	15.14 22.71 30.28	.908 1.363 1.817	5.76 8.64 11.52
500 750 1000	30000 45000 60000	113.55 170.33 227.10	37.65 56.77 75.71	2.271 3.41 4.54	14.4 21.6 28.8

ORP (Oxidation Reduction Potential)

ORP measures the oxidizing (or reducing) potential or activity that a solution has. Chlorine gas or sodium hypochlorite (bleach) are both strong oxidizers that are effectively monitored with an ORP system. In many applications, the control system is intended specifically to control the oxidation of a species such as cyanide or hydrogen sulflide. In other cases the oxidation is the disinfection of bacteria, such as E. Coli. ORP is generally the best measurement for processes of oxidation or disinfection, because it measures the true oxidizing activity a solution has.

The primary limitation of an ORP system is that it does not provide a direct, repeatable correlation to an exact concentration of chlorine. Two key factors affect this correlation: the pH of the solution and the chloride (salt) concentration. Changes in pH cause a shift in the form of the chlorine in water. With increasing pH, chlorine in water changes from hypochlorous acid (HOCl) to hypochlorite ion (Ocl-). The hypochlorous acid is much more active as an oxidizer (80 to 300 times stronger) than the hypochlorite ion. The result is that as pH increases, the overall oxidizing activity (ORP) of the solution decreases.

To understand the affect of chloride concentration requires evaluation of the Nernst equation. This equation defines the output from the ORP electrode with any oxidizing system:

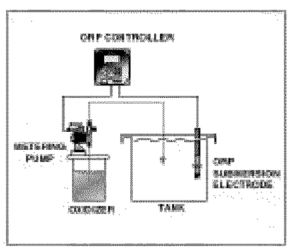
$$E = E^0 + (RT/nF) \ln (a_{ox}/a_{red})$$

This shows that the ORP measurement is made up of the ratio of two concentrations: the concentration of the oxidizing agent and its reduced form. In the case of chlorine, the reduced form is the unreactive chloride ion. Since the ORP is proportional to the ratio of these concentrations (affecting the equilibrium state of the reaction), a greater concentration of chlorides in the solution will also cause the ORP to decrease.

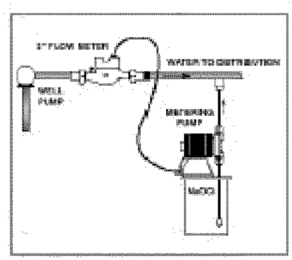
The advantage of using an ORP system is that it measures the true oxidation potential (capability) that a solution has. If the chlorine (or hypochlorite) is being added for the specific purpose to oxidize or disinfect, ORP is the best method for control because it measures the variable that is most important - the solution's actual ability to perform the oxidation. In disinfecting applications for the Pool and Spa Industry, the World Health Organization in Europe has conclusively stated that ORP is preferred over measurements of PPM Chlorine. A minimum ORP value of 650 to 700 mV can guarantee immediate destruction of E. Coli bacteria. However, a given concentration of chlorine may have reduced activity because of high pH or high chloride concentration, and therefore be ineffective at destroying the E. Coli.

ORP is a good choice for any recirculated system. It maintains an oxidizing activity by replacing the oxidizer that has been consumed. Water that is used for spraying foods is often recirculated, and must maintain an oxidation capability to ensure against bacteria in the system or on the food. cooling towers and air scrubbers will also utilize oxidizers to prevent bacteria in the system. the ORP measurement is able to monitor a drop in oxidation activity (oxidizer that has been consumed), and control the addition of replacement chlorine (hypochlorite).

ORP systems require regular maintenance. Generally, the system must be calibrated on a monthly basis using standard solutions, and electrode replacement every 1 to 2 years. With proper maintenance, ORP can provide rapid, on-line measurement of a process, and reliable oxidizing/disinfecting control.



Example of ORP Control



Example of Flow Proportional Control

Residual Chlorine

There are several technologies available for monitoring residual chlorine. These include polarographic, amperometric, and colorimetric. In general, each system may be set up to monitor/control either free residual chlorine (generally in the form of HOCl or OCl-), or total chlorine, consisting of both the free residual chlorine and any "combined" chlorine that may be present. Combined chlorine generally is in the form of chloramines that are very weak oxidizers, and quite ineffective for oxidation.

The advantage of a Residual Chlorine system is that it can provide an exact readout of the actual chlorine present in a solution. If actual chlorine concentration is the key variable for the process and not its oxidizing capability, or if the presence of chlorine can be damaging to a process, than a residual chlorine analyzer should be used. Unfortunately, no one method is accepted as a standard, and all systems are higher in cost than a flow or ORP system and require significantly higher maintenance. Depending on the system selected, maintenance may involve membrane replacement on the sensor (every 4 to 8 weeks), or membrane and electrolyte solution on the sensor (every 4 to 8 weeks), or reagent replacement (every 7 days).

Determining the Best Method for Control

There are many options available for monitoring and controlling chlorine. It is therefore essential to review the application, determine the desired result, and finally, the advantages and limitations for each type of control available. A simplified summary is listed below.

Table 2: Simplified Control Summary		
Application	***Best Method***	***Result***
One-pass/ In-line	Flow Proportional Injection	Consistent Volumetric Addition
Recirculated oxidation / disinfection	ORP	Consistent Oxidation Rate
PPM chlorine monitoring	PPM Chlorine	Actual Chlorine Concentration

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