ORP CONTROL IN POOLS AND SPAS

By J. Steininger D. Sc.
Santa Barbara Control Systems

Principle of Operation

ORP (Oxidation-Reduction Potential) control of sanitizers in pools and spas has been used all over the world with great success for over 30 years.

Our understanding of ORP technology is based on numerous studies by scientists and health authorities in the U.S. and other countries. It has been confirmed in the field by thousands of pool and spa operators who use ORP controllers every day to monitor the activity of chlorine, bromine or ozone.

ORP standards have been recognized by the *World Health Organization (WHO)*, by the *Center for Disease Control (CDC)* in Atlanta, Georgia, by state and local health departments and by the *National Spa and Pool Association (NSPI)* in Washington, DC. ORP control is required by code in several states and more states (such as California and Florida) are planning to add it to their new revisions.

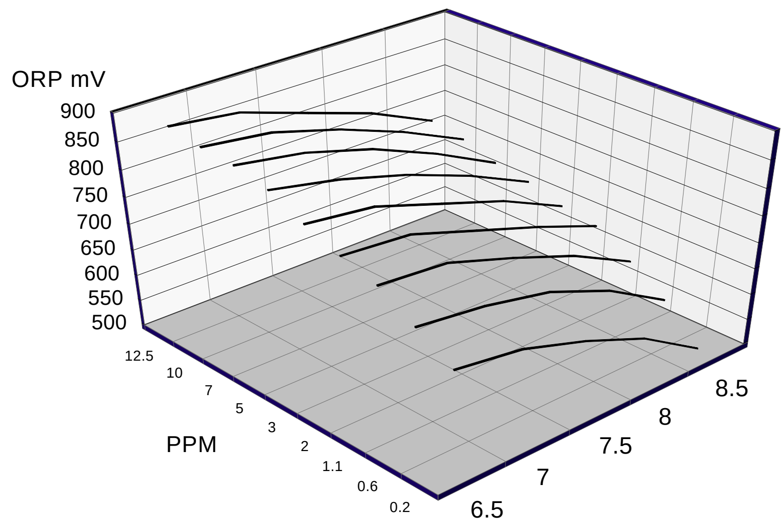

Figure 1 - **Variations of ORP with PPM and pH**

ORP and PPM Test Kits

Pool and spa operators must realize that test kit measurements differ fundamentally from ORP readings. The relationship between ORP and PPM readings is quite complex, as show in Figure 1, a computer-generated three-dimensional representation of ORP vs PPM and pH readings.

OTO and DPD test kits have been traditionally used for monitoring sanitizers. They differ from ORP readings because they are designed to estimate the **concentration of sanitizer** in water (PPM of chlorine or bromine).

On the other hand, ORP measures the ***chemical activity of the sanitizer**,* more specifically its oxidizing power . For water treatment applications, ORP is the most relevant measurement since sanitizers are used for their biological activity, i.e. their ability to kill germs and bacteria, which has been shown in many studies to be related to their oxidizing activity.

Test Kits

Pool and spa operators must realize that **test kit readings are subject to significant errors** resulting both from variations in reagent properties and user errors.

Figure 2 shows the results of laboratory testing of chlorinated water with two well-known DPD test kits for free chlorine and with a colorimeter calibrated by amperometry. It can be seen that there are wide differences - more than 50% - between baseline colorimeter and test kits readings. For 1 ppm of free chlorine, the DPD test kits show values of 1.2 and 2.4 respectively. For 2 ppm, the test kit readings range from 2.4 to 3.0.

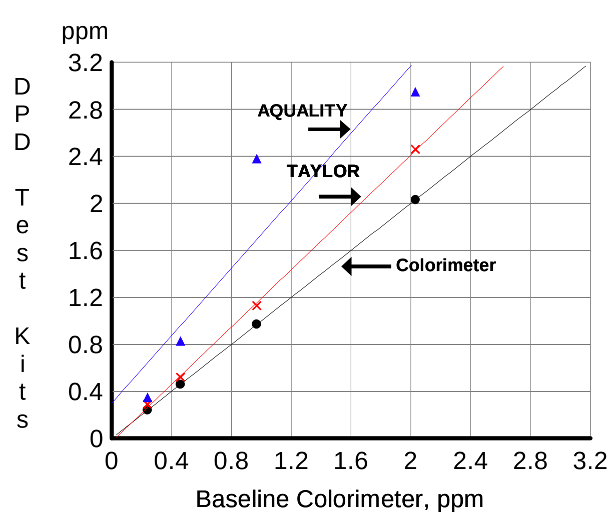

Figure 2 - **Comparison of DPD Test Kits**

In addition, errors are also caused by individual users due to the **differences in color perception**. Statistical analysis of test kit readings by 10 different individuals showed differences as high as 50% to 100% of the readings. For consistent results therefore, tests kits should be read by the same person.

These results confirm that the DPD test kits are qualitative, or at best semi-quantitative. In other words, they can indicate the presence or absence of free chlorine, and the approximate concentration levels but not with the degree of accuracy that is generally expected.

Another frequent problem with test kits is caused by **bleaching of the reagents at high chlorine levels**. The operator is led to believe that there is no chlorine or that the pH is very low when in fact there is too much chlorine. If this happen, the ORP reading will be determinant.

ORP / PPM Conversion

In clean and relatively clean water, the ORP and test kits methods are complementary because the activity of a sanitizer depends primarily on its concentration. In other words ORP and PPM can be correlated. The curves representing the variations of ORP as a function of PPM and pH were first determined by Uniloc in the 70's. They have been used for many years in older analog type controllers for graphical determination of PPM values from ORP readings. Figure 3 shows a recent redetermination under controlled conditions in the CHEMTROL$_{TM}$ chemistry laboratory. Modern controllers with microprocessors use different algorithms to represent these curves.

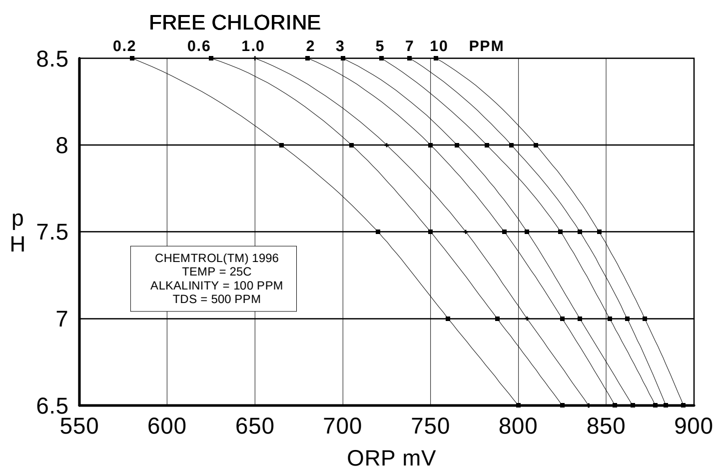

Figure 3 **- PPM Readings vs. ORP and pH**

As shown in Figure 3, the most important factor affecting sanitizer activity is pH, because it changes the concentration of the active form of free chlorine, hypochlorous acid, HOCl. As a result, chlorine and bromine become less effective at higher pH. This is why it is essential to maintain a **stable pH value of 7.4 to 7.5**.

Besides concentration and pH, there are other significant factors which can greatly influence the activity of a sanitizer. Although difficult to define, they are known to include many of the organic and inorganic contaminants that are found in pools and spas.

This can be confusing to pool and spa operators because each test kit reacts differently to these contaminants**. In contaminated water, it's very difficult to obtain reliable readings from any test kit.** At best, they can be used to detect the presence or absence of chlorine.

With stabilized pools, the HOCl concentration and therefore the ORP readings can vary daily as a result of exposure to the UV rays in the sun. Due to the slow rate of chlorine release from the cyanurate compound, the HOCl concentration decreases during the day and increases after sunset, **even though no chlorine is added.** This does not show on test kits.

Another problem arises with organic bromine (dihalo or bromine sticks), known by its chemical name as *1-bromo-3-chloro-5,5-Dimethylhydantoin*. Besides bromine and chlorine, the formula shows an organic part that remains in the water and accumulates progressively. The accumulation of organic material reduces the effectiveness of the sanitizer. This is why it is **strongly recommended to use bromine only in conjunction with ozone** in order to oxidize and eliminate these organic contaminants.

A systematic study of chemical and biological conditions in commercial spas by the Oregon Health Department has proved conclusively that ORP testing provides the most reliable index of sanitary conditions in heavily used pools and spas, regardless of sanitizer concentration, pH level and contaminants.

Pool and spa operators must therefore learn to trust ORP readings. If there is a disagreement between ORP-derived PPM values and test kit readings, it's usually due to the effects of contaminants.

Using ORP control

The recommended ORP level for pools and spas is between 650 and 750 mV. It can be even higher in very clean water.

The absolute minimum of 650 mV applies to both chlorine and bromine. In contaminated water however, the controller will call for larger concentrations of chlorine or bromine to maintain the ORP level. **The more contaminated the water is, the more sanitizer is required to generate the required ORP reading**. This is fundamental to the understanding of water treatment.

There are no commercially available calibration solutions for ORP in the range of 650 to 750 mV that is recommended for water treatment. However, Figure 4 shows that CHEMTROL$_{TM}$ sensors give consistent readings. In this test, 10 sensors showed readings within + or - 2 mV after reaching full equilibrium.

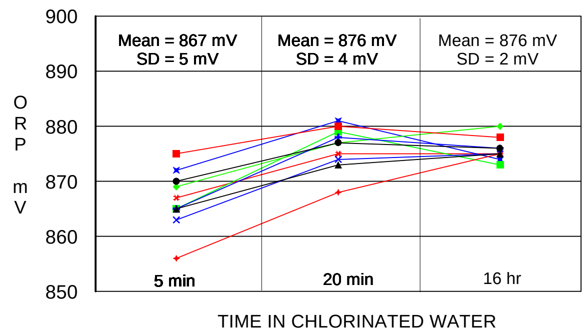

Figure 4 **- Reproducibility of ORP Sensors**

Since ORP sensors can't be calibrated, ORP control must be based on the selection of a proper ORP level corresponding to the recommended chlorine or bromine levels in clean water. This level may vary for different facilities.

In no case, should the ORP setpoint be below 650 mV. After the proper ORP setpoint has been selected, it should not be changed to accommodate varying sanitizer readings, except for superchlorination.

PPM calibration

The theoretical relatioonship between PPM and ORP can be derived from the chemical equilibrium equations for free chlorine. Equation (1) below shows that PPM varies exponentially with ORP.

$$PPM / Reducer = \exp[ORP * nF / RT] \qquad (1)$$

This is in general agreement with the experimental data from the Uniloc and CHEMTROL$_{TM}$ studies, which are shown in Figure 5 for a constant pH value of 7.5.

Because of the exponential relationship between PPM and ORP, **small changes in ORP readings result in large variations in PPM** values at free chlorine concentrations above 2ppm. In other words, a change of 1.0 ppm is significant at 0.5 ppm but much less so at 5.0 ppm. The same goes for bromine.

As the water becomes loaded with contaminants, **the ORP controller calls for increasing PPM** values to offset the decreasing effectiveness of chlorine. If the PPM readings exceed the values allowed by the health department, the water should be replaced or the contaminants destroyed with a strong oxidizer. This is particularly important with bromine or with cyanuric acid-stabilized chlorine.

In summary, PPM readings are more accurate at low sanitizer levels and in cleaner water.

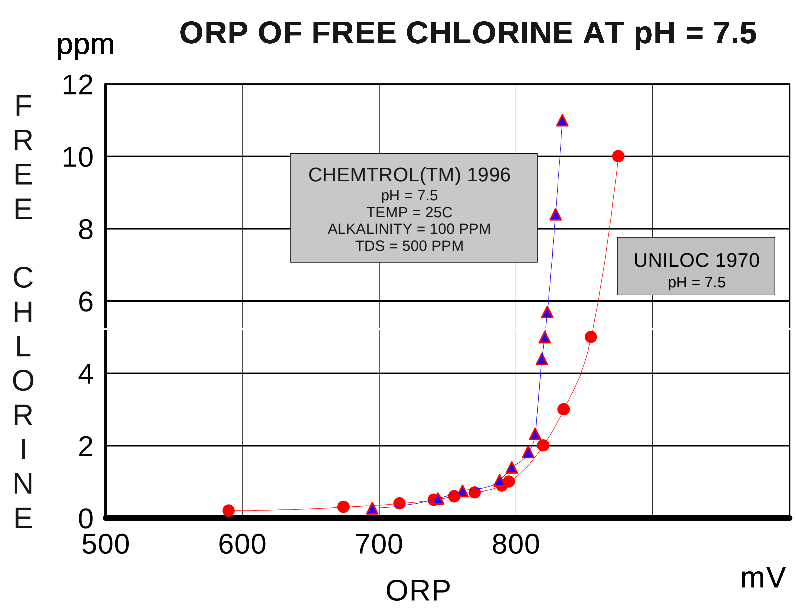

Figure 5 **- Variation of PPM with ORP**

ORP Controller Procedure

The recommended procedure for operation of an ORP controller is as follows.

1. Start with clean water, preferably early in the day before use by bathers.
2. Adjust the pH to 7.4 to 7.5.
3. Adjust the chlorine level to 1 to 2 ppm (2 to 4 ppm for bromine).
4. Let the recirculation pump run for several minutes.
5. Read the ORP value and use it as set point.
6. Verify readings after 1 hour.
7. Keep **calibration changes to a minimum**, preferably by the same operator and at the same time of the day.
8. Adjust the chemical feeders if they are constantly overfeeding or underfeeding.

PPM calibration

The controller should automatically display the PPM values corresponding to the ORP and pH readings in clean water.

If the displayed PPM value differs slightly from test kit readings, it can be re-calibrated using the programmed calibration procedure.

Large variations in PPM readings should be seen as **evidence that the water is contaminated** and should be replaced or shocked with an oxidizer.

Sensor Testing - The Acid Test

A simple test can be used to verify that the ORP sensor is operating properly. It is called The Acid Test.

Just add a little bit of acid in the intake of the recirculation line and watch the ORP readings. Because of the increased activity of the sanitizer at low pH, the ORP reading should increase dramatically. If there is no reaction, the sensor should be replaced.

Chemical Feeders

Proper operation of a controller requires adequate feed equipment. The chemical feeders should be sized so that they respond rapidly to the commands of the controller. If the feeders are undersized, they will have to run for very long periods of time, leading to chemical imbalance and triggering of the overfeed safety timers.

It is important to use **proper settings for the Overfeed Safety Timers**. Properly sized chemical feeders should not have to run continuously for more than 15 minutes for a spa or 1 hour for a pool. This is as important for pH as for the sanitizer.

Replacement of Spa Water

Unlike pools, commercial spas require replacement of water on a frequent basis due to the evaporation caused by the high water temperature and air jets. The formula recommended by health departments for replacement of the water in commercial spas is:

Bathers = Gallons / 3

This means that for a 600-gallon spa, the water should be replaced when the accumulated number of bathers over any period of time exceeds 200.

In addition, the water should also be replaced when the Total Dissolved Solids (TDS) concentration exceeds 2,000 ppm.