



eXact Micro 7+ for Poolside Compliance Testing

By Ivars Jaunakais

Wednesday, October 20, 2010

www.sensafe.com / ivars@sensafe.com



The Importance of Water

- It's the most important natural resource in our environment
- Not pure - contains microorganisms and dissolved minerals which need to be controlled so water can be used safely

Why add Chlorine to Water?

- Effective against a broad range of microorganisms
- Chlorine first used in 1908 for public health
- More than 79,000 tons of chlorine are used per year in the United States and Canada to treat water
- Monitoring chlorine is necessary



Why disinfect pools?

- To protect people, water clarity and equipment
- Several pathogens can be transmitted in water
- Inactivation of pathogens depends on contact time with Chlorine
- Public health requires frequent pool water testing for Hypochlorous acid or free chlorine residual concentration

Germ inactivation time in 1 ppm chlorinated water

GERM	INACTIVATION TIME
E. Coli O157:H7 Bacterium	Less than 1 minute
Hepatitis A Virus	About 16 minutes
Giardia Parasite	About 45 minutes
Cryptosporidium Parasite	About 15,200 minutes (10.5 days)

Some forms of Chlorine

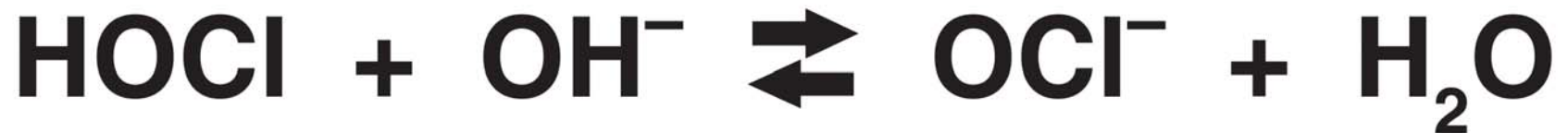
Chemical Name	Chemical Formula	Form	% Chlorine
Chlorine Gas	Cl_2	Gas	100%
Calcium Hypochlorite	$\text{Ca}(\text{OCl})_2$	Solid	65-70%
Sodium Hypochlorite	NaOCl	Liquid	~12%

Properties of Chlorine

- Despite their chemical and physical differences they all form hypochlorous acid
- This change occurs when water is added
- Hypochlorous acid (HOCl) is the actual disinfecting agent

Hypochlorous Acid

- The sum of Hypochlorous acid and Hypochlorite ion is called free chlorine, and the chemical equation or relationship is:



Two chemical reactions impact the performance of Hypochlorous acid as a disinfectant

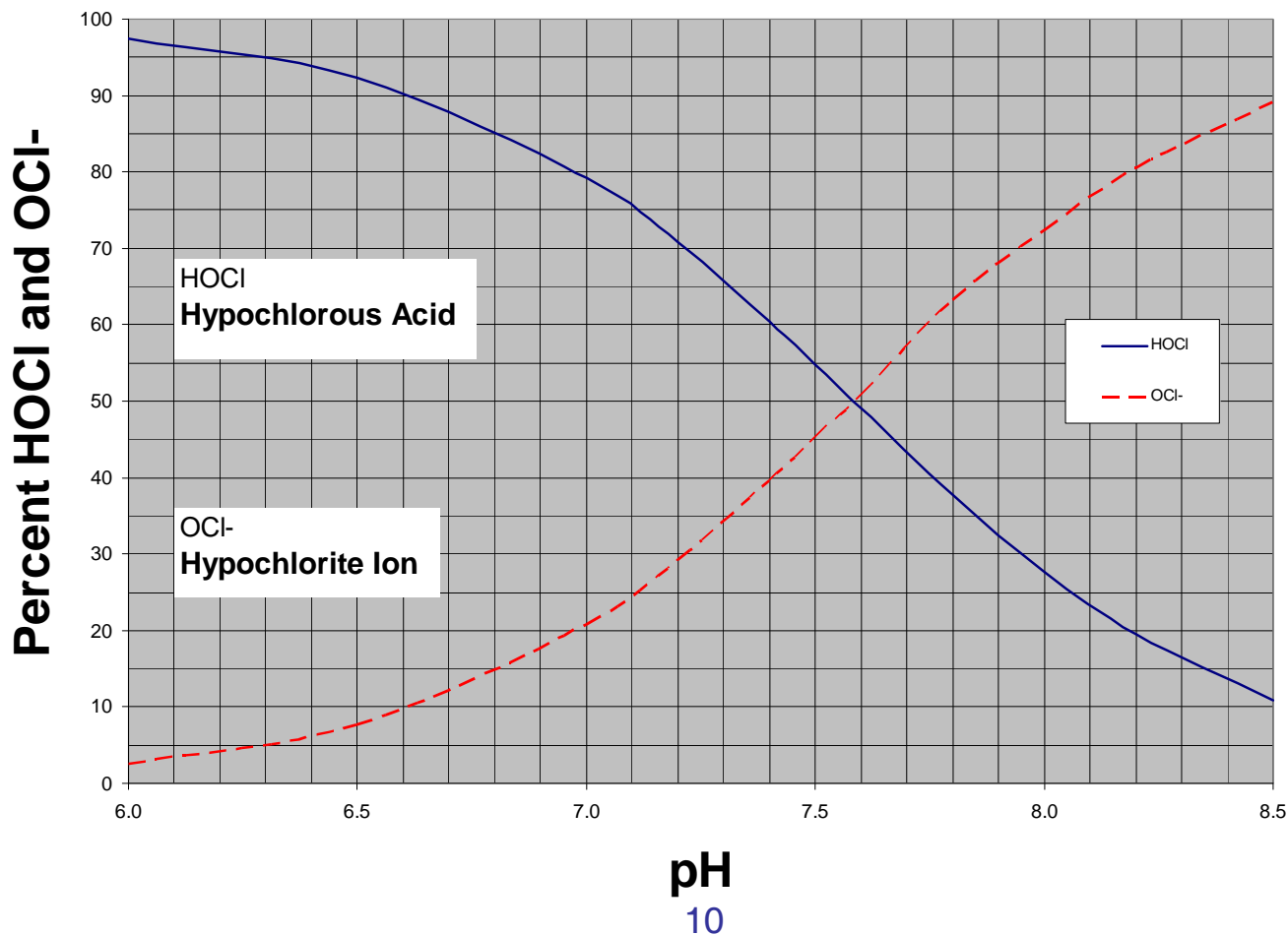
Hypochlorous Acid Reaction

- **First reaction** involves a hydroxide ion (OH^-)
- OH^- is available in aqueous solution especially when pH level is above 7 which causes Hypochlorous acid to form Hypochlorite ion
- Hypochlorite ion is less than one third as effective a disinfectant as Hypochlorous acid
- **Graph 1** shows the relationship between pH versus chlorine species (Hypochlorous acid and Hypochlorite ion)

pH versus chlorine species

Graph 1

Percent HOCl and OCl⁻ vs. pH



Hypochlorous Acid Reaction

- **Second reaction** is with ammonia (NH_3) and organic nitrogen compounds such as proteins and amino acids in the pool
- A series of reactions occur that form chloramines
- Chloramines are less effective as a disinfectant
- Active chlorine can be transferred from inorganic chlorine to amine (organic) containing compounds

Combined Chlorine Equations

- The sum of the chloramine species is called combined chlorine, and chemically created in the pool as follows:



Breakpoint/Shock Chlorination

- The process which eliminates both the combined chlorine and the ammonia problem responsible for creating the chloramine is called Breakpoint Chlorination
- In the pool industry its called “Shock”

Total Chlorine

- Total chlorine is the sum of free chlorine and combined chlorine
- Free chlorine and total chlorine are monitored by automated equipment and confirmed by poolside testing for swimmer protection

$$\text{Total Chlorine} = \text{Free Chlorine} + \text{Combined Chlorine}$$

What makes a good test?

1. Test is acceptable or compliant
2. Test is appropriate for the staff technical ability
3. Test is robust, reagents and equipment are *reliable & stable* in summer heat
4. Test is not affected by interferences
5. Test is accurate when staff performs the test correctly

US EPA accepted on-site methods for Free Residual Chlorine Testing

- DPD-FAS Titrimetric Method
- **DPD Colorimetric Method**
- TMB (3,3',5,5'Tetramethylbenzidine)
SenSafe™ Aperture Colorimetric Test Strip Method
(Approved by the US EPA in 2007)

DPD Chlorine testing

- DPD methods are preferred for chlorine measurement
- The DPD methods determine concentration from the amount of color formed when chlorine reacts with the DPD
- DPD-FAS Titration method determines the chlorine by measuring the number of drops of FAS Titrant needed to bleach out the DPD-chlorine color formed and then multiply the drops by 0.2 or 0.5
- Most state health departments recommend or accept DPD tests because they are quick, enjoy wide acceptance and have US EPA approval

DPD-FAS and Chlorine Photometer Manufacturers

- Taylor Technologies, Inc.
- Industrial Test Systems, Inc.
- Hach Company
- LaMotte Company
- Palintest LTD
- Others



DPD-FAS Free and Total Chlorine Reagent System

- DPD liquid reagents (4: DPD-1, DPD-2, DPD-3 and FAS titrate) or
- DPD two liquid reagents (DPD-3 and FAS titrate) plus DPD powder
- Test Chamber / Tube
Meets 4500-CL G reportable method requirement)



DPD Free and Total Chlorine Tablet Reagent System

- DPD-1 and DPD-3 tablets
- Photocells and caps
- Tablet crusher
- Photometer
- Cell chamber cover

*Meets 4500-CL G reportable
method requirement)*



DPD Free and Total Chlorine Powder Pillow Reagent System

- DPD-1 and DPD-4 powder pillow
- Photocells and caps (2 different sets)
- Photometer
- Cell chamber cover

Meets 4500-CL G reportable method requirement)

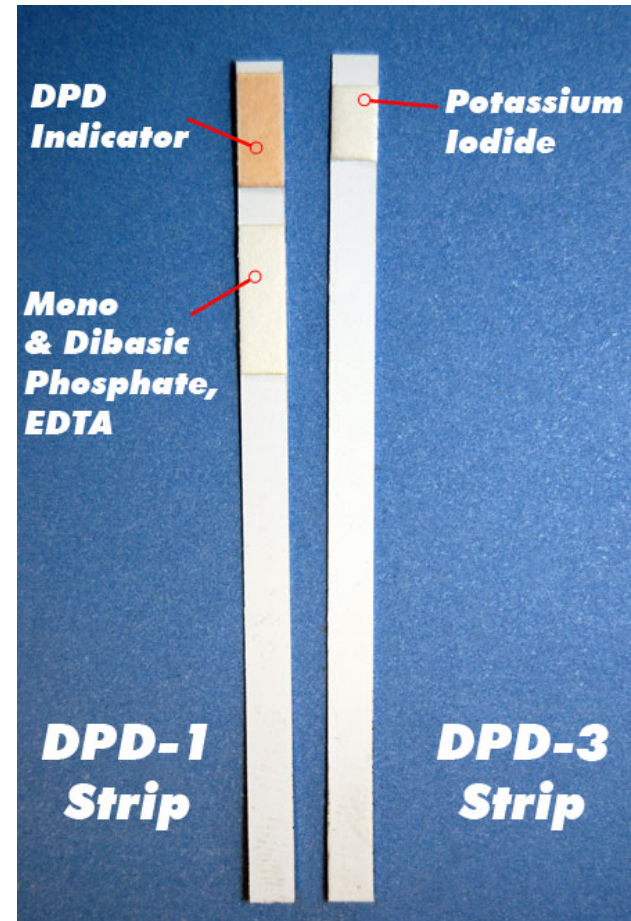


DPD Free and Total Chlorine Reagent Strip System

1. eXact[®] Strip Micro DPD-1, DPD-3
(reagent delivery device)
2. Photometer with built in cell

(Meets 4500-CL G reportable method requirement)

(US Patented 7333194 and 7491546)



DPD Free and Total Chlorine Reagent Strip System

1. eXact® Strip Micro
DPD-1, DPD-3
(reagent delivery
device)
2. Photometer with built
in cell

*(Meets 4500-CL G reportable method
requirement)*

(US Patented 7333194 and 7491546)



eXact[®] Micro 7+ for Poolside Compliance Testing

EXACT PROCEDURE



Fill the built-in cell and zero meter



Dip the strip into cell for 20 seconds with motion



Read value displayed on meter

eXact® Micro 7+ for Poolside Compliance Testing

Step 1: FILL

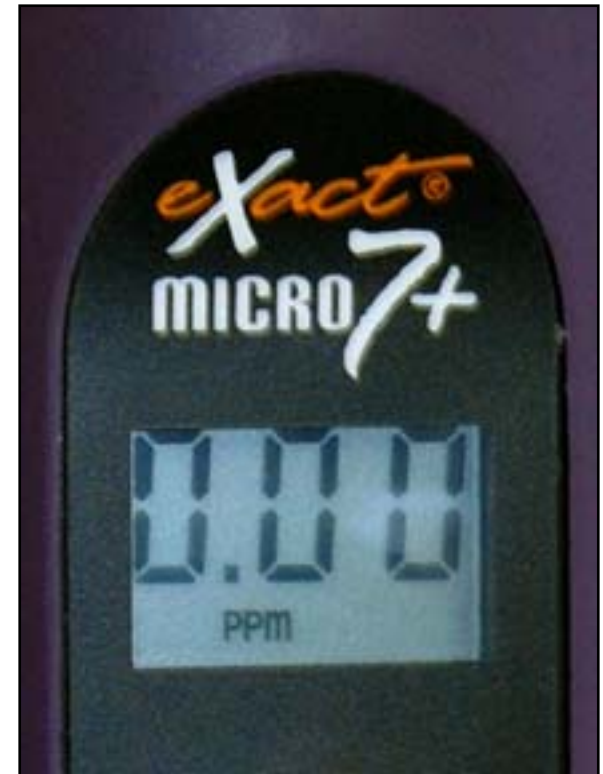
- Press the **“ZERO/ON”** button (powers meter) confirm CL1 on display.
- Rinse meter 3 times and dip meter upside down to elbow length turn meter upright to fill cell with sample pool water and pull meter up.
- Re-press **“ZERO/ON”** button and meter will zero and display 0.00.



eXact® Micro 7+ for Poolside Compliance Testing

Step 1: FILL

- Press the **“ZERO/ON”** button (powers meter) confirm CL1 on display.
- Rinse meter 3 times and dip meter upside down to elbow length turn meter upright to fill cell with sample pool water and pull meter up.
- Repress **“ZERO/ON”** button and meter will zero and display 0.00.



eXact® Micro 7+ for Poolside Compliance Testing

Step 2: DIP DPD-1 Strip

- Press “**READ**” button and immediately dip eXact® Strip Micro DPD-1 into cell for the 20 second count down. During the 20 seconds constantly move the strip back and forth, which releases the DPD and buffer reagents from the test strip while mixing the sample.
- At the end of the 20 second countdown when “1” disappears you remove and discard the strip and the meter automatically displays the **Free Chlorine** concentration, and stores the result in memory.

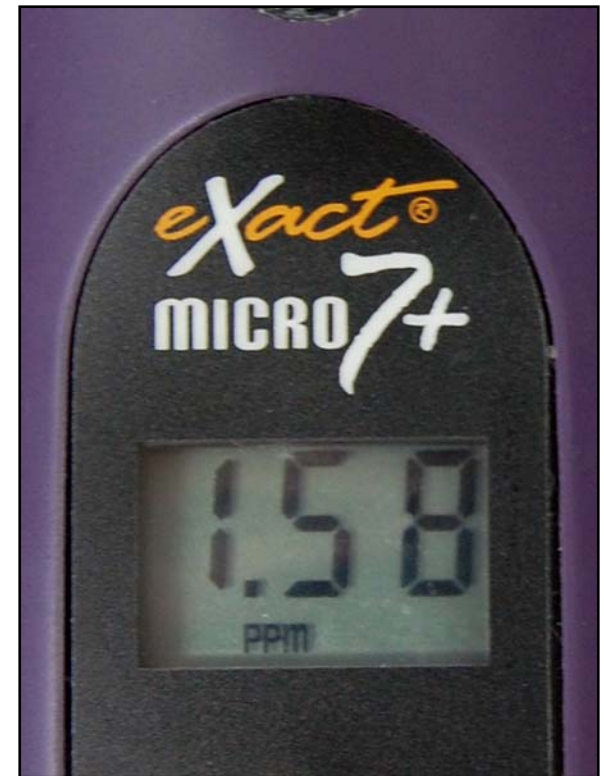


eXact® Micro 7+ for Poolside Compliance Testing

Step 3: READ

- Read display result
- This value is also stored in memory for later retrieval

FREE CHLORINE = 1.58 PPM



eXact® Micro 7+ for Poolside Compliance Testing

Step 4: DIP DPD-3 strip

- For Total Chlorine test continue: Press “**READ**” button and immediately dip eXact® Strip Micro DPD-3 into cell for the 20 second count down. During the 20 seconds constantly move the strip back and forth, which releases the KI reagent from the test strip while mixing the sample.
- At the end of the 20 second countdown when “1” disappears you remove and discard the strip and the meter automatically displays the **Total Chlorine** concentration, and stores the result in memory.



eXact® Micro 7+ for poolside compliance testing

Step 5: READ

- Discard sample and rinse with water before storage.
- This DPD test method is compliant for health department and US EPA requirements for Free and Total Chlorine testing

Total Chlorine = 1.89 ppm



Total Chlorine (TC) = Free Chlorine (FC) + Combined Chlorine

- Combined chlorine = TC - FC
- Free chlorine = 1.58 ppm (FC)
- Total chlorine = 1.89 ppm (TC)
- Combined chlorine = $1.89 - 1.58 = 0.31$ ppm
- Combined chlorine is over the recommend level of 0.20 ppm and pool needs to be “shocked”: in this example ($10 \times 0.31 = 3.1$) this pool can be “shocked” by increasing the pool chlorine level by 3.1 ppm
- Spa and Hot Tub shock is required when level is above 0.50 ppm

Benefits of eXact® Micro 7+

- No cell or test tube to handle
- Safe and easy to use DPD delivery device
- The eXact® DPD Strip is stable in summer conditions individual foil packet(s) available for greater integrity



Benefits of eXact[®] Micro 7+

- No drops to count or colors to match
- Simple (Fill, Dip, Read) procedure
- Tolerates 15 ppm without color loss
- Quick
- Accurate (minimum combined Chlorine interference because test is completed quickly)

eXact Strip Micro CL (DPD-1/DPD-3/DPD-4) Interferences

(Typical DPD interferences as found with all DPD tests)

Interfering Substance	Interfering Levels & Treatments
Acidity	If sample has acidity above 150mg/L CaCO ₃ test may not develop full color. Neutralize to pH 6.0 to 7.0 with 0.5N Sodium hydroxide.
Alkalinity	If sample has alkalinity above 200mg/L CaCO ₃ test may not develop full color. Neutralize to pH 6.0 to 7.0 with 0.5N Sulfuric acid.
Bromine & Bromamines, Br ₂	Color similar to free chlorine reaction at all levels.
Chlorine Dioxide, ClO ₂	Color similar to free chlorine reaction at all levels.
Copper, Cu ⁺²	Color development is reduced above 10 ppm (mg/L).
Iodine, I ₂	Color similar to free chlorine reaction at all levels.
Manganese, oxidized (Mn ⁺⁴ , Mn ⁺⁷) or Chromium, oxidized (Cr ⁺⁶)	See AWWA procedure 4500-CL F, 1(d) for removal of interferences.
Monochloramines (NH ₂ Cl) (applies to DPD-1 only)	Monochloramine interferences are known to occur in free chlorine DPD methods. This interference is dependent on temperature and monochloramine concentration.
Ozone, O ₃	Color similar to free chlorine reaction at all levels.
Peroxides	Interference is possible.
pH	Typical pH samples of potable water with a pH of 6.0 to 9.0 are OK. If outside this range adjust to pH 6.0 to 7.0 using acid (0.5N Sulfuric acid) or base (0.5N Sodium hydroxide).

Monochloramine Interference on Free Chlorine DPD Analysis

“The DPD indicator immediately reacts with the free available Chlorine – hypochlorous acid or hypochlorite ion – to form a pink color, which is proportional to the Chlorine concentration. However some DPD test results may be misleading because monochloramine residual interferes with DPD free analysis, creating a false positive ...”

“Do you really have a Free Chlorine Residual?” by Robert Spon AWWA Opflow magazine
June 2008 pg 24-27

Monochloramine Interference on Free Chlorine DPD Analysis

“Sample temperature and relative concentration of monochloramine to free chlorine (if present), and the time required to perform the analysis are primary risk factors to the intensity of interference”

“Do you really have a Free Chlorine Residual?” by Robert Spon AWWA Opflow magazine
June 2008 pg 24-27

Monochloramine Interference on Free Chlorine DPD Analysis

Sample temperature influences interference levels from monochloramine residual. Below are typical interference levels after a one minute hold time for color development

Monchloramine Level (ppm) as Cl ₂	Water Temperature			
	40°F	50°F	68°F	86°F
1.2	0.15	0.19	0.29	0.30
2.5	0.35	0.38	0.55	0.61
3.5	0.38	0.56	0.69	0.73
5.0	0.68	0.75	0.93	1.05

“Do you really have a Free Chlorine Residual?” by Robert Spon AWWA Opflow magazine

June 2008 pg 24-27

For best results with **eXact[®] Micro 7+ System be sure**

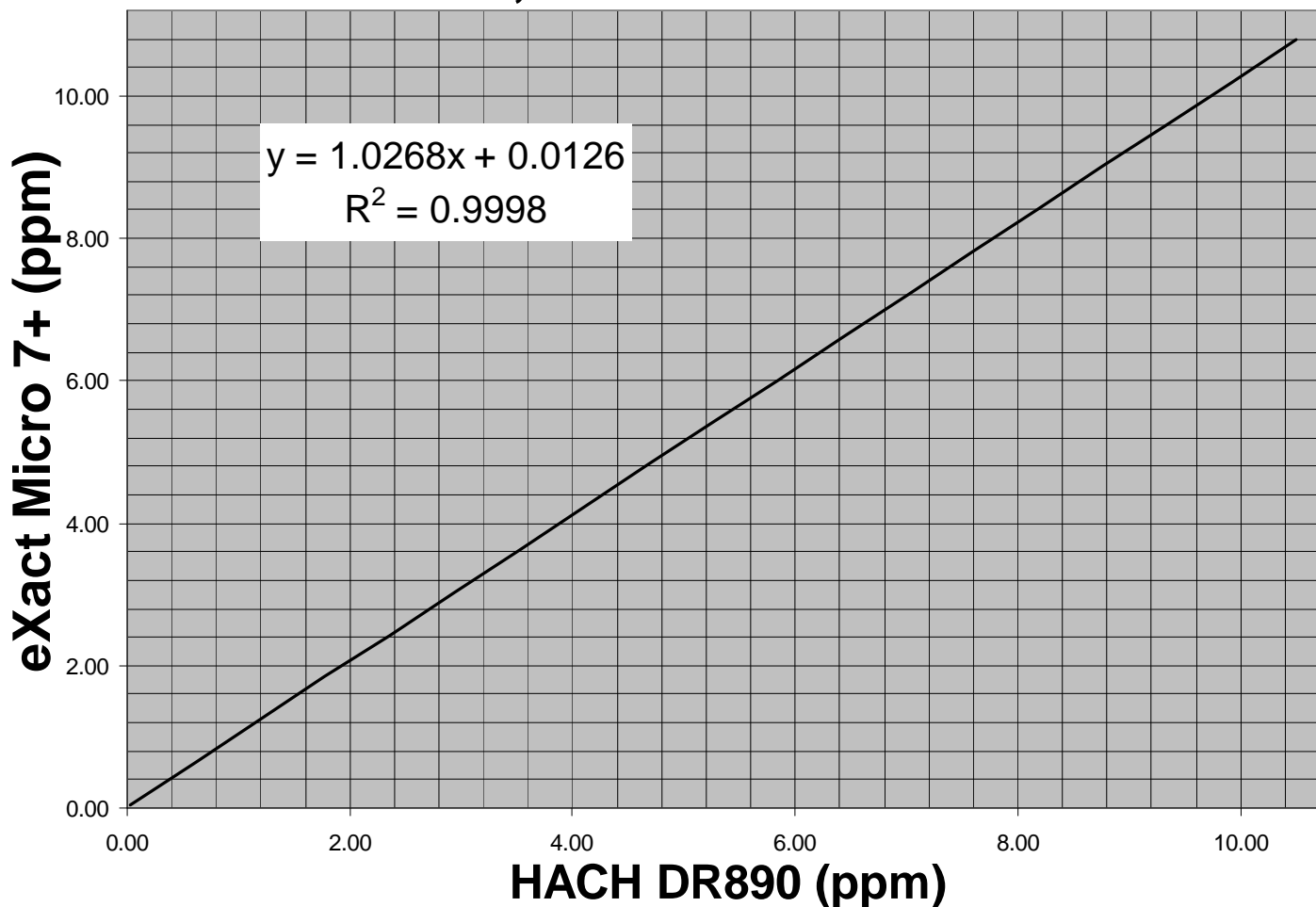
- Strip touches bottom of cell during dip
- To avoid retrieving strip with wet hands from bottle
- To use only eXact[®] Micro strips
- Strips are NOT expired
- To rinse cell immediately after completion of each test

Comparison of Chlorine Photometer eXact[®] Micro 7+ and HACH DR890

METER	MENU	RANGE (PPM)	RESOLUTION
eXact [®] Micro 7+	CL1	0.00 – 5.99	0.01
	auto range	6.0 – 11.0	0.1
HACH DR890	Program 9	0.00 – 2.20	0.01
	Program 12	0.0 – 11.0	0.1

Graph 2

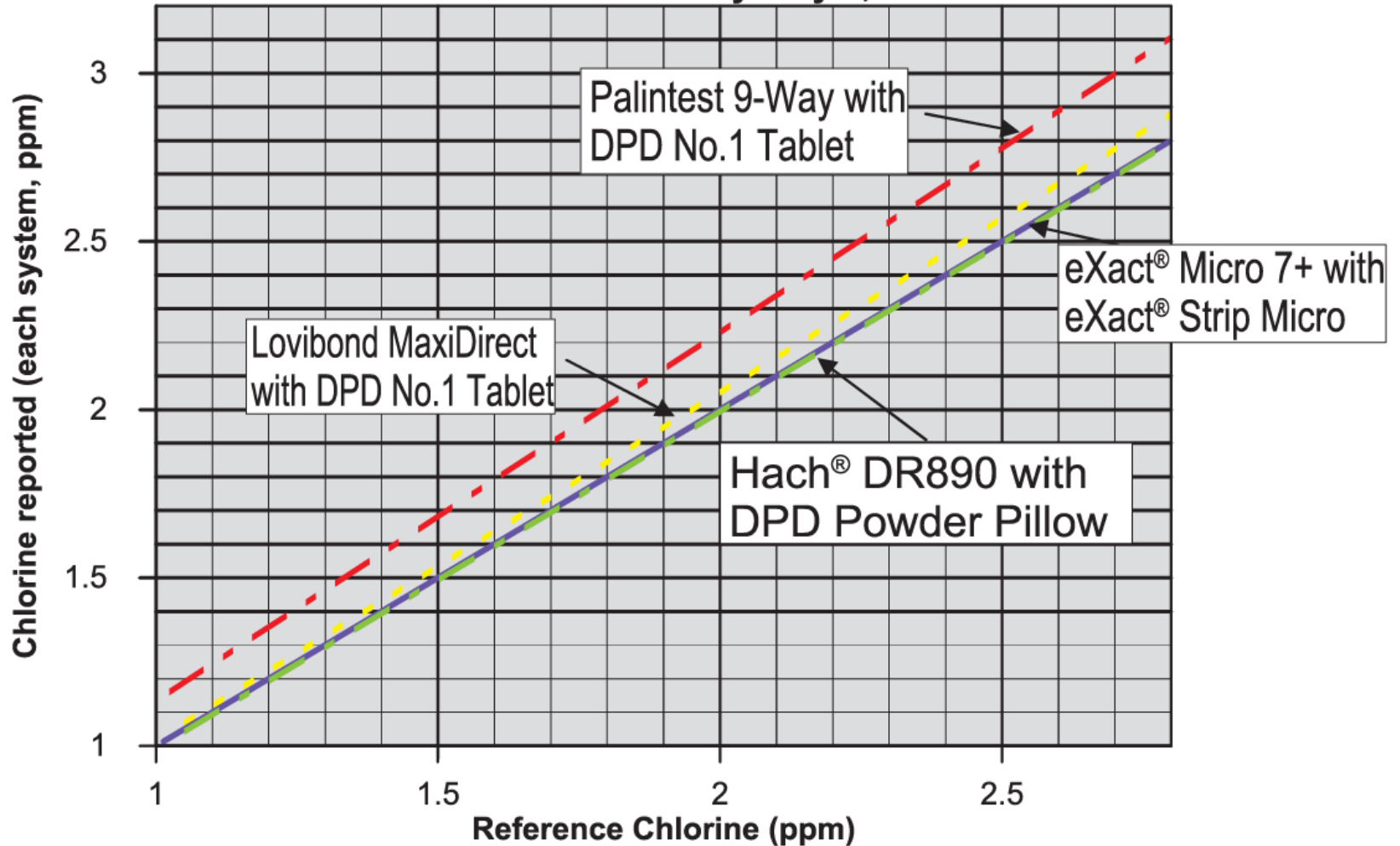
Regression equation with correlation coefficient (R^2)
Free Chlorine, Hach DR890 vs. eXact Micro 7+



MICRO 7+ COMPARISON STUDY WITH OTHER DPD PHOTOMETER SYSTEMS

(FOR ADDITIONAL INFORMATION ABOUT THIS STUDY - VISIT OUR WEBSITE)

DPD Chlorine Study July 8, 2010



eXact Micro 7+ Accuracy

- The algorithms in the software reflect the best correlation of the eXact® Micro 7+ System against the AWWA, US EPA, DIN, and ISO reference test methods for chlorine. Studies show that the eXact® Micro 7+ System repeatedly agrees with an EPA Compliant reference method greater than 99%
- The eXact® Micro 7+ is factory calibrated for convenience
- You can expect the fixed calibrations in the meter to be valid for the life of the meter because of the quality, Long-Life LED, the photo cell, and the software as written into the meter
- 2.00 PPM Standard permits verification of meter performance where government regulation requires meter accuracy to be verified
- 5-year warranty



eXact Micro 7+ Compliance Testing for Free and Total Chlorine

- This DPD test system is accepted by most state health departments because this test is USEPA accepted for testing requirements for Free and Total Chlorine for water and wastewater. eXact Strip DPD-1 formula is identical to AWWA 4500-CL G.

Component (Free Chlorine)	AWWA 4500-CL G	eXact[®] DPD-1
Anhydrous DPD sulfate	1.5%	1.5%
Anhydrous Na ₂ HPO ₄	33.4%	33.4%
Anhydrous KH ₂ PO ₄ Na ₂	64.0%	64.0%
EDTA	1.1%	1.1%

eXact Micro 7+ Specifications

Menu	Tests for	Range	Resolution	Accuracy	Ideal Levels
CL1	Free Chlorine (DPD-1) Total Chlorine (DPD-3)	0.00-5.99 ppm	0.01	0.02	1.0 to 3.0 ppm (combined less than 0.2 ppm)
		6.0-11.0 ppm	0.1	0.1, or 4%	
PH2	pH	6.1-8.4 pH	0.1	0.3	7.4 – 7.6
BR3	Bromine (DPD-1)	0.00-2.99 ppm	0.01	0.03	For spas 3.0 – 6.0 ppm
		3.0-14.0 ppm	0.1	0.1, or 4%	
AL4	Total Alkalinity	20-240 ppm	5	25	80 – 140 ppm
CA5	Calcium as CaCO ₃	20-990 ppm	10	20 or 7%	200 – 400 ppm
CU6	Copper (Cu ⁺²)	0.00-1.99 ppm	0.01	0.02	0.0
		2.0-8.0 ppm	0.1	0.1 or 4%	
TR7	Transmission	99.9-10.0 %T	0.1	0.1	For Nitrate and other tests
		9.99-0.01 %T	0.01	0.01	
TR7	Cyanuric Acid	5 – 60 ppm	0.1	0.1	In Transmission mode

Available next month



eXact Micro 10 Specifications

eXact[®] Micro 10 Direct Read Specifications No Look-up Tables Required

Menu	Tests for	Range	Resolution	+/- Accuracy
AL1	Total Alkalinity	20 - 180 ppm	1	25
PH2	pH	6.2 - 8.4 pH	0.1	0.3
CL3	Free Chlorine (DPD-1) & Combined Chlorine (DPD-3)[†]	0.00 - 11.0 ppm	0.01 (0.00 - 5.99 ppm)	0.02
			0.1 (6.0 - 11.0 ppm)	0.1, or 10%
CL3	Ozone (DPD-4)	0.00 - 11.0 ppm	0.01 (0.00 - 5.99 ppm)	0.02
			0.1 (6.0 - 11.0 ppm)	0.1, or 10%
PO4	Phosphate	0.04 - 3.20 ppm	0.01	0.02
CA5	Calcium as CaCO₃	20 - 990 ppm	10	20 or 7%
CH6	Chloride / Salt (as NaCl)	1000 - 9990 ppm	100	5%
CY7	Cyanuric Acid	3 - 90 ppm	1	5%
TR8	Transmission (30 other test parameters)	99.9 - 0.01 %T	0.1 (99.9 - 10.0 %T)	0.1
			0.01 (9.99 - 0.01 %T)	0.01

[†]Bromine easily obtained by multiplication factor using CL3 menu