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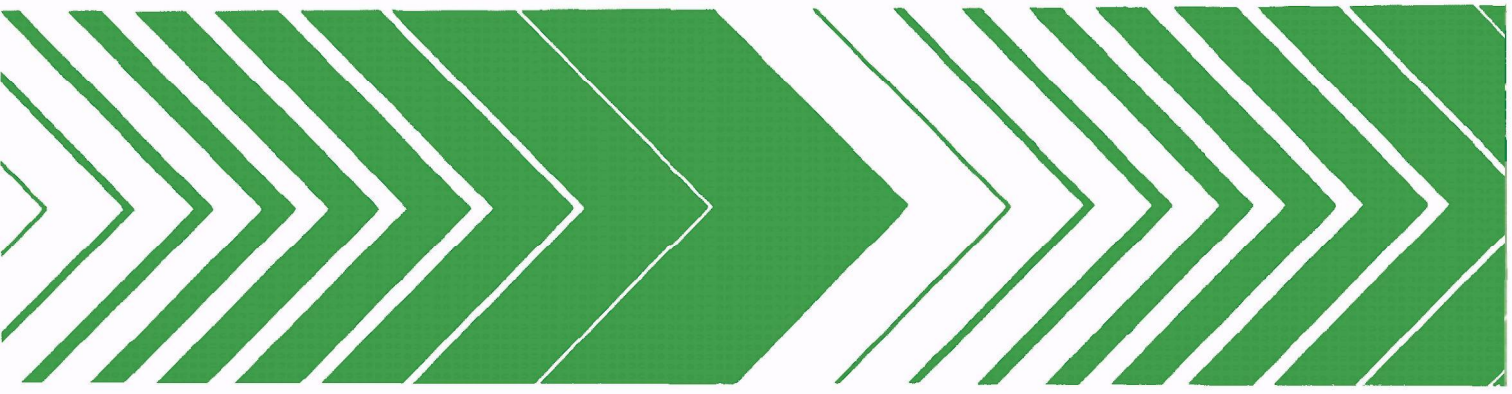
# The Use of pH and Chloride Electrodes for the Automatic Control of Flue Gas Desulfurization Systems



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# The Use of pH and Chloride Electrodes for the Automatic Control of Flue Gas Desulfurization Systems

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## ABSTRACT

The goal of this study was to determine the applicability of chloride and pH electrodes in automated control systems. Included in this study was a survey of chloride and pH electrode use in different flue gas desulfurization (FGD) systems and an evaluation test of an industrial pH electrode system.

The survey revealed that chloride ion measurements were only necessary where high chloride values corresponded with FGD unit corrosion and when chloride values were used as correction factors in pH calculations. Chloride ion measurements were not considered necessary for the majority of the surveyed companies.

The survey found that all surveyed companies use pH measurements to control scaling and/or to attain optimum performance in FGD units. The most common pH electrode problem described was residue buildup (scaling) around the electrode, a condition due to the use of non-self-cleaning (standard type) pH electrodes.

The performances of a self-cleaning and standard-type industrial pH electrodes were evaluated at the EPA/TVA Shawnee Test FGD facility.

The electrodes were tested during a seven week period with varying durations of continuous operation. The pH electrode evaluation test uncovered the following observations. The performances of the self-cleaning and standard-type electrodes were nearly identical. The benefits of a self-cleaning pH electrode can only be realized if electrode scaling is a problem and a long continuous period (>2 weeks) of pH electrode operation is maintained.

CONTENTS

## ACKNOWLEDGMENTS

The cooperation among the Tennessee Valley Authority, Bechtel Corporation, the Environmental Protection Agency, and Electrofact was greatly appreciated.

William Sensing of EPA, Gina Dallabetta, and Dave Rabb of Bechtel, Don Ford of TVA, Paul Schaff of Electrofact, and Toby Acciani and Ray Maddalone of TRW were key personnel responsible for the successful completion of this study.

# SECTION 1

# INTRODUCTION

This study was performed under the terms of the Environmental Protection Agency Contract No. 68-02-2165, Task No. 62. "pH and Chloride Sensitive Electrodes." The effort was directed by William Sensing in the Process Measurement Branch, Industrial Environmental Research Laboratory of the EPA.

The goal of this study was to determine the applicability of chloride and and pH electrodes in automated control systems. Included in this study was a survey of chloride and pH electrode use in different flue gas desulfurization (FGD) systems and an evaluation test of an industrial pH electrode system.

The study was conducted in the following manner. The survey reviewed companies utilizing pH and chloride measurements. The methodology and more important, the utility of the measurements were evaluated. When the utility of either electrode's measurements was judged necessary for the majority of the surveyed companies, an evaluation test of the appropriate electrode was to be planned. The purpose of the evaluation test was to determine the applicability of the electrode(s) in automated control systems. The criteria for evaluation were in the areas of maintenance, maintenance schedule, accuracy, precision, reliability, and durability. Of these criteria maintenance was the most critical factor.

The following utilities and sponsoring companies, grouped according to the type of FGD unit employed, were surveyed for pH and chloride electrode use.

Ash Scrubber

- Colstrip - Montana Power Company

Dual Alkali (Sodium/Calcium) Scrubber

- Scholz Electric - Southern Company Services

Lime Scrubber

- Bruce Mansfield - Pennsylvania Power Company
- Cane Run - Louisville Gas and Electric (Carbide - Lime)
- Green River Power Station - Kentucky Utilities

Limestone Scrubber

- Lawrence No. 4 - Kansas Power and Light Company
- Shawnee Test Facility - EPA/TVA
- Sherbourne County - Northern States Power

This report is organized in the following manner. Section 2 lists the conclusions and recommendations of this study. Section 3 and 4 respectively describe the results of the chloride and pH measurements survey. Section 5 outlines the pH electrode evaluation test and Section 6 describes the results.

## SECTION 2

## CONCLUSIONS AND RECOMMENDATIONS

The results of the chloride measurements survey indicated that:

- The majority of utilities surveyed did not make chloride measurements
- The utilities that made chloride measurements used the data to identify FGD corrosion problems (high chloride values) or to correct calculations of pH values.

The results of the pH measurements survey indicated that:

- All utilities surveyed made pH measurements
- The pH data were used to control scaling and to attain optimum scrubbing performance in an FGD unit.

Evaluation of the pH electrode test data revealed the following facts:

- The accuracy and precision of the self-cleaning and standard type electrode were nearly identical during the duration of the test.
- Scaling was a confirmed maintenance problem with the standard-type electrode.
- Clogging of the screen surrounding the electrode was a maintenance problem with the self-cleaning electrode used in slurry streams.
- The overall maintenance of both the self-cleaning and standard type pH electrode during continuous periods of operation less than two weeks were equal in slurry streams.
- For continouous periods of operation greater than two weeks in slurry streams, the self-cleaning electrode required slightly less maintenance.

The following recommendations are made for the application of chloride and pH electrodes to automated control systems in FGD units (slurry streams):

- Chloride measurements are not necessary unless FGD corrosion (high chloride values) is a problem or accurate pH calculations are required.
- For continuous periods of operation less than two weeks the use of either the standard type or self-cleaning pH electrode is recommended.
- For continuous periods of operation greater than two weeks, the self-cleaning electrode is recommended and should require less maintenance.
- If the self-cleaning pH electrode is selected, the required maintenance should be significantly reduced when the wire screen surrounding the electrode is removed or the screen mesh size is increased.
- Additional comparisons at different FGD sites.
- Longer, uninterrupted periods of comparison.

## SECTION 3

## CHLORIDE ELECTRODE SURVEY

### SCOPE OF SURVEY

The potential application of chloride measurement equipment to automated systems was evaluated in this survey. A representative number of power plants equipped with FGD's were asked whether or not they were making chloride measurements. The tabulated responses to this question provided a measure of the industry's interest in chloride measurements. Due to the low interest in chloride measurements found by the survey, it was decided not to field test a chloride electrode.

### SURVEY RESULTS AND DISCUSSION

The most significant finding was that six out of eight utilities surveyed did not make chloride measurements. High chloride concentrations (as HCl) may cause internal FGD unit corrosion. The companies at Cane Run, Colstrip, Green River, Lawrence, Scholz and Sherbourne reported low chloride values and the absence of chloride related corrosion problems. At these sites, monitoring chloride concentration was not necessary for the normal FGD unit operation.

However, monitoring chloride concentrations is necessary at sites where chloride levels are high and corrosion is a potential problem. The companies at Bruce Mansfield and Shawnee reported high chloride levels and made routine chloride measurements as part of the normal FGD unit maintenance schedule. These measurements were made on grab samples in the laboratory.

At Shawnee, chloride measurements also were used to calculate pH values. High chloride and magnesium values significantly alter the results of pH calculations. Thus, if a solid or slurry stream is added to an existing

stream, the resultant pH value cannot be accurately calculated without original and resultant chloride and magnesium concentration values. The equation for calculating the resultant pH values is:

$$pH = pHR + 1.60\ (MgR - Mg + Cl - ClR),$$

where,

Cl = Expected or new Cl value (g-eq/l) in resultant stream

ClR = Original Cl value (g-eq/l) in stream

Mg = Expected or new Mg value (g-eq/l) in resultant stream

MgR = Original Mg value (g-eq/l) in stream

pH = Expected or new pH in resultant stream

pHR = Original pH in stream

The integration of a chloride electrode into an automated system is only necessary where high chloride concentration is a problem. The applicability of the electrode for automation may take two directions. In one method, chloride measurements are used as a warning device such that operators are notified of high concentration levels and manual operations are used to correct the situation. The alternate approach is to completely integrate chloride measurements into an automated system such that high concentrations will be automatically corrected by the control devices.

Although the potential exists for chloride electrode application in automated control systems, the limited interest of surveyed companies in chloride measurements did not merit a pursuit of a chloride electrode evaluation test.

## SECTION 4

## PH ELECTRODE SURVEY

### SCOPE OF SURVEY

The purpose of this survey was to describe the application of pH electrodes toward the operation of an FGD unit. The surveyed companies were asked about their use of pH data and problems encountered while obtaining this data. Among the topics covered were:

- Type of Scrubber
- Type of pH Electrode
- Location of pH Electrode
- Desired pH or pH Range
- Maintenance of pH Electrodes
- Problems with pH Electrodes
- Use of pH Data
- Use of pH Electrode in Automated Control System

### SURVEY RESULTS AND DISCUSSION

All of the survey companies use a standard-type, non-self-cleaning pH electrode. Seven utilities use the Uniloc electrodes. Cane Run and Scholz use Uniloc plus Leeds and Northrup electrodes. Colstrip uses only Great Lake electrodes. Sherbourne was employing the Uniloc standard type pH electrode and testing the Electrofact self-cleaning electrode. Unfortunately detailed results and their recommendations of the self-cleaning electrode were not completed or available at the time of this report.

The location of the pH electrodes and the desired pH or pH range varied considerably among the companies surveyed. The Shawnee Facility makes pH measurements only at the slurry inlet to the FGD. Lawrence, Scholz, and Sherbourne located the electrodes at the outlet FGD slurry stream.

Colstrip makes pH measurements at the recycle pump discharge whereas Bruce Mansfield measures at the scrubber and absorber discharge. Cane Run and Green River take measurements at three FGD slurry locations (inlet, middle, and outlet) Cane Run, Green River, and Shawnee take inlet measurements and the respective desired pH (range) values are 8.0-8.5, 8.0-8.5, and 5.5. Cane Run and Green River "middle" desired values are 6.0-7.0 and 7.5-8.0. Cane Run, Green River, Lawrence, Scholz, and Sherbourne make outlet measurements and the desired values are 6.0-7.0, 5.5-7.0, 5.0-7.0, 5.5, and 4.0-6.0. Bruce Mansfield requires 7.0 and Colstrip 4.5-5.5 at their respective slurry discharge locations.

All electrodes except Electrofact require an acid wash at least once a week. The Bruce Mansfield and Shawnee sites require acid washings three times a week. All the other sites require acid washing once a week or when necessary. According to site personnel at Cane Run, Lawrence, and Sherbourne, ultrasonic cleaning shortens the electrode life and was not the preferred method.

The most common problem shared by all three limestone and one lime scrubber site was residue buildup on the pH electrodes. Cane Run, Lawrence, and Shawnee have problems with hard scale forming on the electrodes. Sherbourne has a coating problem which has been identified not to be gypsum. Colstrip and Scholz have electrode erosion problems associated with their highly abrasive (undissolved solids) FGD unit. Bruce Mansfield and Green River did not mention any problems with the electrodes.

The most common use of pH data was to control FGD unit scaling at Bruce Mansfield, Cane Run, Colstrip, Green River, and Shawnee. Bruce Mansfield, Scholz, and Shawnee used the pH data to optimize performance (scrubbing) in the FGD unit. Sherbourne used pH data to monitor chemical corrosion and erosion relative to the additive feed. Lawrence was the only site that did not use pH data for control or monitoring.

The three lime scrubber sites, Bruce Mansfield, Cane Run, and Green River, were the only sites that utilized the pH electrodes for an automated system. This highlights the fact that lime has a much more consistent chemical composition and dissolves faster than limestone. A system utilizing materials with consistent and

predictable chemical compositions is much easier to automate than a system with chemically inconsistent materials. Thus, it is expected that automated lime scrubbing systems would be more prevalent than automated limestone systems. The Lawrence Facility, a limestone site, has provisions for automation; however, this system is not utilized.

In summary, the goal of this survey was to assess the use of pH electrodes and data and to apply these findings toward an effective electrode evaluation test. Due to the fact that all the survey companies used a non-self-cleaning electrode, scaling on the electrode was the major maintenance problem.

It was found that accurate pH measurement of slurry streams is very important for proper operation and prevention of scaling, corrosion, $SO_2$ removal and erosion in an FGD unit. Paramount to successful pH electrode operation is the prevention of residue buildup and erosion of the electrode, clearly the most common problems among the utilities. The field evaluation test of a self-cleaning and standard-type electrode was designed to solve these problems and to evaluate the applicability of the electrode in an automated system.

# SECTION 5

# PH ELECTRODE TEST

## INTRODUCTION

The purpose of this pH electrode test is twofold. One aspect of the test is to determine if the self-cleaning electrode will solve the most common problem of scaling or residue buildup. The results of this test plus evaluation by other criteria will then be used to determine the applicability of a self-cleaning electrode in an automated system.

This section describes the nature and procedures of the test. The most important aspect of this test is a description of the criteria for evaluation. Specific areas of equipment performance related to applicability in automated systems are listed in order of importance. The equipment tested, both standard-type and self-cleaning electrodes, are described. The test location and equipment placement were chosen and arranged to facilitate maintenance. The test plan provides a detailed description of the recommended procedures for the test.

## CRITERIA FOR EVALUATION

Before actual testing is initiated, the criteria for evaluating a pH electrode's applicability in an automated FGD unit must be delineated. Specific areas of equipment performance which determine successful automated operation are emphasized. Thus, certain equipment qualities which are minor considerations in a nonautomated system are major factors in an automated system and likewise, the reverse may be true. The criteria by which a pH electrode is to be evaluated are listed in the order of importance:

- Maintenance and maintenance schedule
- Reliability and durability
- Accuracy and precision
- Transient response

The nearly unanimous opinion of the surveyed companies is that maintenance is the single most important criteria by which a new electrode is to be evaluated. The problems of residue buildup and erosion of the electrode account for the most time and money lost for a pH measurement system. Not only is "what has to be done" important but also "how often it has to be done" (maintenance schedule) is critical during an evaluation.

Reliability depends both on the maintenance and durability of the electrode. Careful evaluation should identify and differentiate a reliability problem caused by the lack of maintenance or inherent weaknesses. Durability depends on maintenance and quality of materials and workmanship. Lack of maintenance should not be construed as a durability problem.

Carefully made buffer solutions can be used to evaluate accuracy and precision in the laboratory; however, accurate and precise measurements in dynamic slurry streams containing percent ranges of total dissolved solids is very difficult. Judgments that one pH system is correct and another incorrect are difficult to substantiate when pH differences are small (+0.1 pH). In addition, the basic principles and materials used for the manufacture of pH electrodes are fairly common throughout the industry. Any flaw in workmanship or materials should be a subject for reliability and durability. Thus, accuracy and precision are extremely important parameters; however, these qualities would be very difficult to assess under conditions of these test evaluations.

Transient response is another very difficult parameter to evaluate in a constantly changing slurry stream. Judgments in this area must be made with much discretion with respect to where the electrode was placed, and when the measurements were made. It was impossible to assess the exact effect of transient response based on the data uncovered in this program.

## PH ELECTRODE TEST

This subsection describes the equipment, test location and test plan.

Equipment Description

The focus of this test is on the electrode, the most critical link in any pH measurement system. The criteria for equipment performance were selected to evaluate the electrodes or the primary equipment. Auxiliary or secondary equipment such as pre-amplifiers (increases signal strength of pH electrode output), transmitters (modifies pre-amplified signals to be sent over long distances), meters (provides a visual readout of the pH measured by the electrode), and chart recorders (makes permanent record of pH measurements) are still important and are evaluated by the same criteria.

In order to avoid confusion the following definitions of terms used in the remainder of this report are made:

| | |
|---|---|
| Electrode: | Refers to the piece of equipment placed in the liquid stream. Thus, pH measurements are not possible with only one electrode |
| Chart Recorder: | Refers to equipment recording the pH measurements on chart paper. |
| Chart Recorder Readings: | Refers to the pH measurements (in chart units or adjusted to pH units) recorded on the chart paper. |
| Meter: | Refers to equipment that provides visual readouts of instantaneous pH measurements. |
| Meter Readings: | Refers to the pH measurements recorded by a technician reading the meter. |

In this evaluation, both a self-cleaning and a standard-type (non-self-cleaning) pH electrodes were tested. Except during equipment failures, meter and chart recorder readings were made for both self-cleaning and standard-type electrodes.

A pH electrode manufactured by Electrofact was specified as the self-cleaning electrode to be tested and evaluated. This electrode was selected because it was designed to reduce maintenance and lengthen maintenance schedule intervals as compared to the standard-type electrode.

The Electrofact 135 G/Z electrode is composed of the electrode assembly, preamplifier, and transmitter which contains the pH meter and output for a strip chart recorder. Special features of the electrode assembly are automatic temperature compensation and the self-cleaning electrode mechanism. Once every seven seconds, the electrode is wiped by a moving viton diaphragm or nylon brush. This constant wiping motion is designed to prevent the buildup of any deposits in the electrode. The range of the meter is from 4.5 to 6.5 pH units which corresponds to a 4-20 ma output. With a 28.7 $\Omega$ + 0.01% resistor connected in parallel, the chart recorder output ranged from 114.8 to 574.0 mV.

Meter and chart recorder readings were taken from a standard-type pH electrode placed in the same slurry stream. A Uniloc pH electrode connected to an EMC meter and control room chart recorder was the arrangement used by the utility at the test site. In addition to meter and chart recorder readings, laboratory pH measurements were made for the slurry stream. A separate slurry line is fed into the control room when a grab sample is taken. A standard laboratory pH meter capable of being read to $\pm$0.01 pH unit was utilized for these measurements.

## Test Location

The test site was the Shawnee Test facility operated by the Tennessee Valley Authority under the direction of Bechtel Corporation and the Environmental Protection Agency. The self-cleaning electrode was placed in an external slurry pot fed by a rubber hose from the venturi slurry stream. (Originally the test was to be conducted at a turbulent contact absorber (TCA); however, the unit was down at the time of this test). A baffle deflected the incoming slurry stream to prevent breakage of the glass electrodes by solid materials. The Uniloc (referred as "standard") electrode was placed in a similar apparatus fed by the same slurry line. The "standard" pH electrode measurements were recorded by a chart recorder and displayed on a meter.

Test Plan

Under normal operating conditions at the Shawnee facility, laboratory measurements and meter readings are used to monitor the slurry stream. Thus, this evaluation will base its results on laboratory and meter readings from both self-cleaning and standard pH electrodes. When meter readings are absent, chart recorder readings are adjusted to correspond to meter readings. This adjustment is accomplished by determining the average arithmetic differences between corresponding meter and chart recorder readings and adding/subtracting this difference to/from the chart recorder readings.

The complete test plan is contained in Appendix A. A brief summary of the test plan is given below:

- Every two hours the following pH measurements were made:
  - Laboratory pH readings
  - Meter and chart recorder readings for both self-cleaning and standard pH electrodes
- Both self-cleaning and standard pH electrode systems were recalibrated under the following conditions:
  - Differences between the self-cleaning and standard pH electrode meter readings were greater than 0.2 pH unit
  - Differences between the self-cleaning pH electrode meter readings and the laboratory measurements were greater than 0.5 pH unit (a common range used by the Shawnee facility)
- All laboratory pH measurements of the slurry stream were made within 15 minutes after the sample was taken.

## SECTION 6

## PH ELECTRODE EVALUATION

### DATA DESCRIPTION AND CALCULATIONS

The raw data recorded during the field test included:

- Self-cleaning pH electrode meter and chart recorder readings
- Standard-type pH electrode meter and chart recorder readings
- Laboratory measurements by conventional pH meter.

This data is presented in Table B (Appendix). All meter readings and laboratory measurements were recorded directly in pH units. All chart recorder readings were initially recorded in chart paper units and were later converted to pH units.

The equation used to convert the self-cleaning pH electrode chart recorder readings into pH units is:

$$pH = (X)(0.21777) + 4.00 \text{ where}$$

X = Chart paper units

The equations used to convert the standard pH electrode chart recorder readings into pH units are:

$$pH = (X)(0.06) + 4.00 \text{ for 4-10 pH paper}$$

$$= (X)(0.10) + 2.00 \text{ for 2-10 pH paper where}$$

X = Chart paper units

All pH data were rounded off to the nearest 0.01 pH unit.

Because the standard procedures at Shawnee utilized the meter readings

and laboratory measurements of pH to monitor the FGD unit, comparisons involving the self-cleaning and standard-type pH electrode were based on the meter readings. When meter readings were not available, the chart recorder readings were adjusted to correspond to the meter readings. This adjustment is made by computing arithmetic averages of the numbers appearing in the ΔpH column for each type of electrode. The ΔpH figures represent the differences between the meter and chart recorder readings. A negative ΔpH value represents a higher meter reading. Performance comparisons among the self-cleaning pH electrode, standard-type pH electrode and laboratory measurements were listed in the following columns in Table B:

- The column labeled "ΔpH ± (#2 - #1)" represents the differences between the standard and self-cleaning meter readings. In the absence of meter readings, the arithmetic ΔpH (chart-meter) averages are added/subtracted from the chart readings. For example: The standard meter readings average a higher reading (0.04 pH) than the chart readings. On 3-24 at 500 the standard meter reading is extrapolated to be 6.32 (6.28 - (-0.04)). Note: -0.04 is negative because of the way the calculations for ΔpH were arranged. The ΔpH (#2 - #1) is equal to 0.02 (6.32-6.30). A negative number for the column ΔpH (#2 - #1) represents a higher self-cleaning meter reading.
- The column labeled "ΔpH ± (#3 - #1)" represents the difference between the lab measurements and the self-cleaning meter readings. A negative number indicates a higher meter reading.
- The column labeled "ΔpH ± (#3 - #2)" represents the difference between the lab measurements and the standard meter readings. A negative number indicates a higher meter reading.

Table 1 summarizes the data representing differences between the chart and meter readings of the self-cleaning pH electrode. In this table only the absolute values of the pH data are averaged. This calculation reveals the magnitude of the reading differences. The real values are averaged in Table 6. This real value average will indicate a positive or negative value bias of the data. The calculated values in Table 1 are listed in two columns. One column is a running average or cumulative average of the absolute value differences. The second column is the absolute value averages for each group.

A group represents a continuous, uninterrupted set of data. At the start of each group the instruments are recalibrated. This set of absolute value "group" averages can indicate a proper calibration or malfunction of the instrument. In addition, Table 1 lists the down time, both cumulative and group, between continuous readings.

Tables 2 through 5 present data in a similar style as Table 1. Table 6 summarizes Tables 1 through 5 and includes the real value averages of the ΔpH values. Table 7 lists the significant events during the test. In summary, the tables are:

Table 1. Self Cleaning pH Electrode: Chart Readings vs Meter Readings.

Table 2. Standard pH Electrode: Chart Readings vs Meter Readings.

Table 3. Self Cleaning vs Standard pH Electrode Meter Readings.

Table 4. Self Cleaning pH Electrode Meter Readings vs Laboratory Measurements.

Table 5. Standard pH Electrode Meter Readings vs Laboratory Measurements.

Table 6. Summary of Tables 1 through 5.

Table 7. Chronological Listing of Events During pH Electrode Test.

TABLE 1. SELF-CLEANING pH ELECTRODE: CHART READINGS vs. METER READINGS

| Time of Readings Hour (Date) | | Number of Testing Hours | | ΔpH-Absolute Value Average | | Hours Down Time | | |
|---|---|---|---|---|---|---|---|---|
| From | To | Cumulative | Per Group | Cumulative (Std Dev) | Per Group (Std Dev) | Cumulative | Per Group | Comment |
| 1300(3-13) | 1500(3-14) | 26 | 26 | 0.10(0.13) | 0.10(0.13) | | | |
| 1500(3-14) | 1100(3-15) | | | | | 20 | 20 | A |
| 1100(3-15) | 2300(3-16) | | | | | 56 | 36 | B |
| 2300(3-16) | 0500(3-21) | 128 | 102 | 0.05(0.08) | 0.03(0.05) | | | |
| 0500(3-21) | 1300(3-22) | | | | | 88 | 32 | B |
| 1300(3-22) | 0900(3-28) | 268 | 140 | 0.04(0.06) | 0.04(0.02) | | | |
| 0900(3-28) | 1500(3-28) | | | | | 94 | 6 | B |
| 1500(3-28) | 0100(3-30) | 302 | 34 | 0.04(0.05) | 0.04(0.01) | | | |
| 0100(3-30) | 1700(3-30) | | | | | 110 | 16 | B |
| 1700(3-30) | 1900(4-1) | 350 | 48 | 0.04(0.05) | 0.04(0.04) | | | |
| 1900(4-1) | 1500(4-3) | | | | | 154 | 44 | B |
| 1500(4-3) | 1300(4-12) | 564 | 214 | 0.04(0.04) | 0.03(0.02) | | | |
| 1300(4-12) | 1500(4-16) | | | | | 252 | 98 | C |
| 1500(4-16) | 2100(4-18) | | | | | 306 | 54 | B |
| 2100(4-18) | 0900(4-19) | | | | | 318 | 12 | D |
| 0900(4-19) | 1600(4-20) | | | | | 349 | 31 | C |
| *1600(4-20)* | *0900(5-3)* | | | | | 654 | 305 | E |
| Overall Total | | | | 0.04(0.04) | | | | |

A - Cage surrounding pH electrode plugged
B - Scrubber unit down
C - Meter and chart recorder inoperable
D - Meter readings only — Chart recorder inoperable
E - Meter readings only — not calibrated

TABLE 2. STANDARD pH ELECTRODE: CHART READINGS vs. METER READINGS

| Time of Readings Hour (Date) | | Number of Testing Hours | | ΔpH-Absolute Value Average | | Hours Down Time | | |
|---|---|---|---|---|---|---|---|---|
| From | To | Cumulative | Per Group | Cumulative (Std Dev) | Per Group (Std Dev) | Cumulative | Per Group | Comment |
| 1300(3-13) | 1100(3-15) | 46 | 46 | 0.06(0.02) | 0.06(0.02) | | | |
| 1100(3-15) | 2300(3-16) | | | | | 36 | 36 | A |
| 2300(3-16) | 0500(3-21) | 148 | 102 | 0.04(0.02) | 0.03(0.02) | | | |
| 0500(3-21) | 1300(3-22) | | | | | 68 | 32 | A |
| 1300(3-22) | 0300(3-24) | 186 | 38 | 0.04(0.03) | 0.05(0.05) | | | |
| 0300(3-24) | 1500(3-27) | | | | | 152 | 84 | B |
| 1500(3-27) | 0900(3-28) | 204 | 18 | 0.04(0.03) | 0.03(0.01) | | | |
| 0900(3-28) | 1500(3-28) | | | | | 158 | 6 | A |
| 1500(3-28) | 0100(3-30) | 238 | 34 | 0.04(0.03) | 0.03(0.01) | | | |
| 0100(3-30) | 1700(3-30) | | | | | 174 | 16 | A |
| 1700(3-30) | 1900(4-1) | 286 | 48 | 0.04(0.03) | 0.04(0.04) | | | |
| 1900(4-1) | 1500(4-3) | | | | | 218 | 44 | A |
| 1500(4-3) | 1500(4-16) | 598 | 312 | 0.05(0.04) | 0.05(0.05) | | | |
| 1500(4-16) | 2100(4-18) | | | | | 272 | 54 | A |
| 2100(4-18) | 1300(4-22) | 686 | 88 | 0.05(0.04) | 0.04(0.03) | | | |
| 1300(4-22) | 1100(4-25) | | | | | 360 | 88 | B |
| 1100(4-25) | 2300(4-29) | | | | 0.22(0.24) | 469 | 109 | C |
| 2300(4-29) | 2300(5-3) | | | | 0.24(0.17) | 565 | 96 | D |

A - Scrubber Unit down
B - Chart readings only — Meter inoperable
C - Meter and chart recorder not working properly
D - Replaced chart recorder

TABLE 3. SELF-CLEANING vs. STANDARD pH ELECTRODE METER READINGS*

| Time of Readings Hour (Date) | | Number of Testing Hours | | ΔpH-Absolute Value Average | | Hours Down Time | | |
|---|---|---|---|---|---|---|---|---|
| From | To | Cumulative | Per Group | Cumulative (Std Dev) | Per Group (Std Dev) | Cumulative | Per Group | Comment |
| 1300(3-13) | 1500(3-14) | 26 | 26 | 0.11(0.11) | 0.11(0.11) | | | |
| 1500(3-14) | 1100(3-15) | | | | | 20 | 20 | A |
| 1100(3-15) | 2300(3-16) | | | | | 56 | 36 | B |
| 2300(3-16) | 0500(3-21) | 128 | 102 | 0.06(0.07) | 0.04(0.03) | | | |
| 0500(3-21) | 1300(3-22) | | | | | 88 | 32 | B |
| 1300(3-22) | 0900(3-28) | 268 | 140 | 0.07(0.06) | 0.07(0.05) | | | |
| 0900(3-28) | 1500(3-28) | | | | | 94 | 6 | B |
| 1500(3-28) | 0100(3-30) | 302 | 34 | 0.07(0.06) | 0.10(0.04) | | | |
| 0100(3-30) | 1700(3-30) | | | | | 110 | 16 | B |
| 1700(3-30) | 1900(4-1) | 350 | 48 | 0.07(0.06) | 0.07(0.04) | | | |
| 1900(4-1) | 1500(4-3) | | | | | 154 | 44 | B |
| 1500(4-3) | 1300(4-12) | 564 | 214 | 0.10(0.08) | 0.16(0.10) | | | |
| 1300(4-12) | 1500(4-16) | | | | | 252 | 98 | C |
| 1500(4-16) | 2100(4-18) | | | | | 306 | 54 | B |
| 2100(4-18) | 0900(4-19) | 576 | 12 | 0.10(0.09) | 0.19(0.12) | | | |
| 0900(4-19) | 1600(4-20) | | | | | 337 | 31 | C |
| 1600(4-20) | 0900(5-3) | | | | 0.36(0.30) | 642 | 305 | D,E |

*In cases when there were no meter readings, the ΔpH arithmetic average (difference between the meter vs. chart readings) was added/subtracted from the chart readings.

A - Cage surrounding self-cleaning pH electrode plugged
B - Scrubber unit down
C - Self-cleaning pH electrode meter and chart recorder inoperable
D - Self-cleaning pH electrode meter could not be calibrated. Chart recorder inoperable
E - Standard pH electrode meter and chart recorder not operating properly.

TABLE 4. SELF-CLEANING pH ELECTRODE METER READINGS vs. LABORATORY MEASUREMENTS*

| Time of Readings Hour (Date) | | Number of Testing Hours | | ΔpH-Absolute Value Average | | Hours Down Time | | | |
|---|---|---|---|---|---|---|---|---|---|
| From | To | Cumulative | Per Group | Cumulative (Std Dev) | Per Group (Std Dev) | Cumulative | Per Group | Comment | |
| 1300(3-13) | 1500(3-14) | 26 | 26 | 0.35(0.12) | 0.35(0.12) | | | | |
| 1500(3-14) | 1100(3-15) | | | | | 20 | 20 | A | |
| 1100(3-15) | 2300(3-16) | | | | | 56 | 36 | B | |
| 2300(3-16) | 0500(3-21) | 128 | 102 | 0.24(0.10) | 0.21(0.08) | | | | |
| 0500(3-21) | 1300(3-22) | | | | | 88 | 32 | B | |
| 1300(3-22) | 0900(3-28) | 268 | 140 | 0.26(0.13) | 0.28(0.15) | | | | |
| 0900(3-28) | 1500(3-28) | | | | | 94 | 6 | | |
| 1500(3-28) | 0100(3-30) | 302 | 34 | 0.27(0.13) | 0.33(0.07) | | | | |
| 0100(3-30) | 1700(3-30) | | | | | 110 | 16 | B | |
| 1700(3-30) | 1900(4-1) | 350 | 48 | 0.27(0.12) | 0.27(0.08) | | | | |
| 1900(4-1) | 1500(4-3) | | | | | 154 | 44 | B | |
| 1500(4-3) | 1300(4-12) | 564 | 214 | 0.29(0.15) | 0.33(0.19) | | | | |
| 1300(4-12) | 1500(4-16) | | | | | 252 | 98 | C | |
| 1500(4-16) | 2100(4-18) | | | | | 306 | 54 | B | |
| 2100(4-18) | 0900(4-19) | 576 | 12 | (0.31)(0.18) | 0.92(0.19) | | | | |
| 0900(4-19) | 1600(4-20) | | | | | 337 | 31 | C | |
| 1600(4-20) | 0900(5-3) | | | | 0.30(0.17) | 642 | 305 | D | +0.29 (0.18) |

*In cases when there were no meter readings, the ΔpH arithmetic average (difference between the meter vs. chart readings) was added/subtracted from the chart readings.
A - Cage surrounding self-cleaning pH electrode plugged
B - Scrubber unit down
C - Self-cleaning pH electrode meter and chart recorder inoperable
D - Self-cleaning pH electrode meter could not be calibrated. Chart recorder inoperable.

TABLE 5. STANDARD pH ELECTRODE METER READINGS vs. LABORATORY MEASUREMENTS*

| Time of Readings Hour (Date) | | Number of Testing Hours | | ΔpH-Absolute Value Average | | Hours Down Time | | |
|---|---|---|---|---|---|---|---|---|
| From | To | Cumulative | Per Group | Cumulative (Std Dev) | Per Group (Std Dev) | Cumilative | Per Group | Comment |
| 1300(3-13) | 1100(3-15) | 46 | 46 | 0.30(0.11) | 0.30(0.11) | | | |
| 1100(3-15) | 2300(3-16) | | | | | 36 | 36 | A |
| 2300(3-16) | 0500(3-21) | 148 | 102 | 0.23(0.10) | 0.20(0.08) | | | |
| 0500(3-21) | 1300(3-22) | | | | | 68 | 32 | A |
| 1300(3-22) | 0900(3-28) | 288 | 140 | 0.25(0.14) | 0.26(0.17) | | | |
| 0900(3-28) | 1500(3-28) | | | | | 74 | 6 | A |
| 1500(3-28) | 0100(3-30) | 322 | 34 | 0.24(0.13) | 0.23(0.07) | | | |
| 0100(3-30) | 1700(3-30) | | | | | 90 | 16 | A |
| 1700(3-30) | 1900(4-1) | 370 | 48 | 0.25(0.13) | 0.26(0.09) | | | |
| 1900(4-1) | 1500(4-3) | | | | | 134 | 44 | A |
| 1500(4-3) | 2300(4-13) | 618 | 248 | 0.31(0.13) | 0.41(0.13) | | | |
| 2300(4-13) | 0100(4-15) | | | | | 160 | 26 | B |
| 0100(4-15) | 1500(4-16) | 656 | 38 | 0.32(0.16) | 0.56(0.08) | | | |
| 1500(4-16) | 2100(4-18) | | | | | 214 | 54 | A |
| 2100(4-18) | 1100(4-25) | 832 | 176 | 0.32(0.19) | 0.27(0.30) | | | |
| 1100(4-25) | 2300(5-3) | | | | 0.30(0.21) | 418 | 204 | C |

*In cases when there was no meter readings, the ΔpH arithmetic average (difference between the meter vs. chart readings) was added/subtracted from the chart readings.
A - Scrubber unit down.
B - Laboratory measurements were not made.
C - Standard pH electrode meter and chart recorder not working properly.

TABLE 6. SUMMARY OF TABLES 1 THROUGH 5

| Item | Total Number of Hours Tested | ΔpH-Absolute Value Average (Std Dev.) | ΔpH-Arithmetic Average (Std Dev.) |
|---|---|---|---|
| TABLE 1. Self-Cleaning Electrode: Meter vs. Chart | 564 | 0.04 (0.04) | +0.03 (0.05)[1] |
| TABLE 2. Standard Electrode: Meter vs. Chart | 686 | 0.05 (0.04) | -0.04 (0.05)[1] |
| TABLE 3. Self-Cleaning vs. Standard | 576 | 0.10 (0.09) | 0.00 (0.13)[2] |
| TABLE 4. Self-Cleaning vs. Laboratory Measurements | 576 | 0.31 (0.18) | -0.30 (0.19)[3] |
| TABLE 5. Standard vs. Laboratory Measurements | 832 | 0.32 (0.19) | -0.30 (0.22)[3] |

[1]A positive number indicates the chart recorder indicated a higher pH value and vice versa.

[2]Self-cleaning pH electrode meter tended to have higher values during the first half of the test and the standard meter had higher values during the second half.

[3]Lab measurements tended to have lower readings than the on-line meters.

TABLE 7. CHRONOLOGICAL LISTING OF EVENTS DURING pH ELECTRODE TEST

| Time Period Hour (Date) From | To | Effective Down Time (Hours) Scrubber | pH Electrodes S.C./Std | Remarks |
|---|---|---|---|---|
| 1300 (3-13) | End of test | | | Initiation of test |
| 1500 (3-14) | 1100 (3-15) | | 20/ | Self-cleaning electrode screen clogged |
| 1100 (3-15) | 2300 (3-16) | 36 | | Scrubber unit down |
| 0500 (3-21) | 1300 (3-22) | 32 | | Scrubber unit down |
| 0300 (3-24) | 1500 (3-27) | | /84 | Standard pH electrode meter failed |
| 0300 (3-28) | 0900 (3-28) | | / 6 | Standard pH electrode meter failed |
| 0900 (3-28) | 1500 (3-28) | 6 | | Scrubber unit down |
| 0100 (3-30) | 1700 (3-30) | 16 | | Scrubber unit down |
| 1900 (4-1) | 1500 (4-3) | 44 | | Scrubber unit down |
| 1300 (4-12) | 1500 (4-16) | | 98/ | Self-cleaning pH electrode meter could not be calibrated |
| 1500 (4-16) | 2100 (4-18) | 54 | | Scrubber unit down |
| 2300 (4-18) | End of test | | | Self-cleaning pH electrode operating without calibration |
| 0900 (4-19) | 1600 (4-20) | | 31/ | Self-cleaning pH electrode meter chart recorder inoperable |
| 2300 (4-19) | 0700 (4-20) | | / 8 | Standard pH electrode meter failed |
| 1500 (4-22) | End of test | | | Standard pH electrode meter not operating properly |
| Total Down Times | | 188 | 149/98 | |

## DISCUSSION OF RESULTS

Before a discussion of results is undertaken, it must be noted that cumulative calculations involving pH values represent selected periods of time. The reasons for these time period restrictions are as follows. The cumulative calculations in Table 1, 3, and 4 were stopped after 4-20-79 because the self-cleaning pH electrode meter controls were inoperative and calibration was not possible. The calculations in Table 2 and 5 were stopped after 4-25-79 because the following groups pH average values demonstrated a 550% change.

Agreement between the meter and chart readings was very good for both self cleaning and standard pH electrodes. The self-cleaning pH meter tested to show (0.03 pH) lower readings than the chart recorder. The standard pH meter tended to show (0.04 pH) higher readings than the chart recorder.

Over a period of 576 hours, the real average ΔpH value between the meter reading of self-cleaning and standard pH electrodes demonstrated 0.00 pH unit agreement, even though the magnitude of the absolute value averages was 0.10 pH unit. It is interesting to note that the self-cleaning pH electrode meter tended to show higher values during the first half of the test and the standard pH electrode pH meter tended to show higher values during the second half of the test. These results should be evaluated in view of the fact that the pH electrode meter accuracy is typically +0.02 pH unit.

Both self-cleaning and standard pH meters tended to show a 0.30 pH unit higher reading than the laboratory measurements. The self-cleaning electrode demonstrated a 0.32 pH absolute value ΔpH difference from the laboratory measurements whereas the standard electrode demonstrated a slightly lower, 0.31 pH unit, variation.

The most obvious problem that Table 7 reveals is the down time experienced by the FGD unit. Almost 190 hours during the testing period were not used for evaluating the electrodes.

CRITERIA FULFILLMENT

In review, the criteria of electrode evaluation include the following areas of performance:

- Maintenance and Maintenance Schedule
- Reliability and Durability
- Accuracy and Precision
- Transient Response

Maintenance and Maintenance Schedule

The evaluation of the maintenance and maintenance schedule of a pH electrode involves both objective data and subjective opinions. Although difficult, this report will differentiate these two potentially conflicting observations.

The most common maintenance complaint about the standard (non-self-cleaning) electrode is the effort for cleaning. For example, an initially clean electrode is placed in a slurry stream. Within a few hours, a thin coating develops around the electrode. Between three to seven days after immersion, a hard scale develops around the electrode and impairs pH performance. The design of the self-cleaning electrode is to wipe the electrode (every seven seconds) before a crust can develop.

The initial impression about the self-cleaning electrode was that it required the same amount of maintenance as the standard electrode. However, the required maintenance was quite different. A wire screen cage surrounding the self cleaning electrode was susceptible to plugging. This problem can be eliminated by the use of a larger mesh screen. The recalibration of this electrode required as much or more effort than the standard electrode. This opinion could be due to the operator's unfamiliarity with the equipment.

Although the overall comments about maintenance indicated little difference between the two electrodes, these comments reflect the number of recalibrations during the test. The frequency of pH electrode calibration averaged to more than once per week during the testing period. This unusually

high number is caused by the frequency of down time of the FGD unit, a problem beyond the control of this test. The test plan required that the pH electrodes be recalibrated if an interruption of service was experienced. During the test, the FGD unit was inoperative several times. As a result, an impression of significant maintenance may have been caused by the problems with the FGD unit.

During the longer periods of continuous operation (214 and 140 hours), the self-cleaning electrode required less electrode maintenance than the standard electrode. The wire screen had to be frequently checked for clogging and as a result, this effort was nearly equal to the effort of cleaning the standard electrodes.

The number of problems associated with the FGD unit made evaluation of the maintenance schedule very difficult. However, it can be extrapolated that during longer periods of continuous operation (200+ hours) and if the wire screen was removed, the self-cleaning electrode would have a longer period of time between maintenance.

Reliability and Durability

During the duration of the test, no reliability or durability problems occurred with either the self-cleaning or standard-type pH electrode. However both self-cleaning and standard-type pH electrode meters developed electrical problems. During the middle of the test, the EMC meter (connected to the standard electrode) was inoperable. The meter was repaired and placed back into service. Toward the end of the test, the Electrofact meter (connected to the self-cleaning electrode) developed problems with the calibration controls. These controls affect the slope and asymmetry of the calibration curve. This problem was probably caused by the combination of fragile controls and the unfamiliarity of the operators with the meter. In summary, the meters for both pH electrodes caused reliability problems in the measurement systems.

Accuracy and Precision

The precision between both pH measurement systems (self-cleaning and standard-type) appear to be good. Although the overall pH difference (arithmetic average) was 0.00 pH unit, the standard deviation was 0.13 pH unit, an indication of the variation between the two systems. This large

standard deviation supports observations that the self-cleaning pH electrode measurement system tended to have higher readings during the first half of the test and lower readings during the last half of the test.

The accuracy of the pH measurement systems is a very difficult parameter to assess. The constant dynamics of a slurry stream in combination with different reference positions of the electrodes and laboratory measurements complicate the assessment. Nevertheless, comparisons among both electrode systems and the laboratory results reveal certain trends. As mentioned before, the agreement between the two pH meter systems is good, the overall average difference being 0.00 pH unit with a standard deviation of 0.13 pH unit. However, when the data of either self-cleaning or standard pH electrode were compared to the laboratory measurements, both comparisons revealed nearly identical results. The laboratory measurements had an overall 0.30 pH unit lower reading than either of the on-line pH meters. This obvious systematic error indicates problems with the location of the measurement systems or equipment problem.

This discrepancy between the on-line meter readings and the laboratory measurements indicates a systematic error in operating procedures or equipment performance. The most obvious error is the difference of operating procedures. The on-line pH meters measure the instantaneous pH of the slurry stream. Because of the undissolved solids, flue gases, turbulence, and rapid flow rates, the slurry steam is in a state of non equilibrium at the time of an on-line pH measurement. On the other hand, when a grab sample for laboratory measurement is taken, the slurry aliquot may undergo equilibrium changes before the pH test. Depending on the original conditions (temperature, pressure, stoichiometry, etc.) of the slurry stream, supersaturated solutions will precipitate and non saturated solutions will dissolve solids and gases immediately after the aliquot is taken. Thus the difference in taking a pH measurement (on-line vs. laboratory) may account for the discrepancies in the results.

## Transient Response

Transient response is the ability of an instrument to handle change of the measurement parameters. The constant dynamics and unpredictable nature of a slurry stream does not allow an accurate assessment of transient response. Thus no conclusions or observations could be made about this parameter during the test.

## AUTOMATION

The goal of this evaluation test was to determine the applicability of the self-cleaning electrode in automated FGD control systems. This applicability was determined in the study by equipment performance in the areas of

- Maintenance and maintenance schedule
- Reliability and durability
- Accuracy and Precision
- Transient response

and comparing these findings with the results of a standard-type pH electrode.

It was found that the performance of the self-cleaning pH electrode system was nearly identical to the standard-type pH electrode system. The reliability problems were similar and the maintenance requirements, although different, were also similar in effort expended. The frequency of FGD unit problems created an unexpected variable in the test. This variable, because of the frequency of meter recalibration, made the maintenance requirements higher than normal for both pH measuring systems. These requirements could conceal any significant maintenance differences between the two systems, and make a false impression of frequent maintenance.

Under certain conditions, the self-cleaning electrode might have reduced maintenance requirements and would then be more applicable in automated FGD control systems. These conditions would include a larger mesh size or complete removal of the screen surrounding the electrode assembly. With this modification, and during periods of long continuous operation (>2 weeks), the self-cleaning electrode would require less maintenance.

## REFERENCES

1. Rowland, C., "Correction of Liquor pH for Dissolved Mg and Cl Concentrations," Bechtel Corporation Inter-Office memorandum, February 10, 1976.

# APPENDIX A

# TEST PLAN

# TEST PLAN FOR TLE TASK # 62

## I. INTRODUCTION

The purpose of this task is to test an industrial pH electrode used to monitor limestone slurry streams. Equipment manufactured by Electrofact was selected to be used in the Unit #10 TCA at the Shawnee Power Plant facility.

## II. INSTALLATION AND EQUIPMENT SETUP

The installation of the Electrofact pH equipment is to be arranged and performed by the TVA personnel at the Shawnee Power Plant. The basic pH equipment and electrical connections will be supplied by EPA. Any additional mounting equipment will be supplied by the TVA facility.

The Electrofact pH electrode will be placed in an external slurry pot fed by auxiliary slurry lines. Laboratory measurements are made by standard pH measurements of grab samples from a slurry line fed directly into the laboratory.

The pH equipment to be tested is composed of the pH electrode, mechanical electrode wiper assembly, sender unit, pH meter, transmitter, and strip chart recorder. The range of the pH meter is from 4.5 to 6.5. The recorder. The range of the pH meter is from 4.5 to 6.5. The output of the transmitter is 4 milliamperes at pH 4.5 and 20 milliamperes at pH 6.5. A 23.7 ohm resistor is placed across the current source in order to create a voltage source for the strip chart recorder. Table 1 summarizes the corresponding pH readings, the output current and voltages of the transmitter, and predicted strip chart recorder readings. These data are important for calibration of this equipment.

The pH electrode and meter are factory adjusted and calibrated. However, the strip chart recorder does not give readings in pH units and must be calibrated. A column in Table A-1 gives approximate strip chart recorder deflections in chart paper divisions for various ph readings. The following procedure must be used to calibrate the strip chart recorder.

STRIP CHART RECORDER pH CALIBRATION PROCEDURE

1. For normal operation, set the chart paper speed to 2.5 cm/hr. For calibration, set the chart paper speed to 2.5 cm/min.
2. Place the pH electrodes in a pH 5.0 buffer.
3. Go to the strip chart recorder and mark on the chart paper the pH of the buffer and when (time and date) the electrodes were placed in the buffer.
4. Repeat Steps #2 and #3 with a pH 6.0 buffer.
5. Reset the chart paper speed to 2.5 cm/hr.

III. TEST PROCEDURE

The following procedures are to be used for proper evaluation of the pH electrode.

1. Make sure the strip chart recorder was calibrated by the procedures outlined in Section II. Set the chart paper speed to 2.5 cm/hr.
2. Use the "FIELD FORM FOR pH MEASUREMENT TEST" to record all data.
3. Every two hours or when the normal slurry pH measurement is made by the technician, enter the date and time onto the form.
4. Enter in the column, "Laboratory pH Meter Readings," the pH of the slurry as determined by the technician.
5. Enter in the column, " Electrofact pH Meter Reading," the reading of the Electrofact pH meter at the time of the laboratory measurement.
6. Enter in the column, "Strip Chart Recorder Reading," the number of chart divisions that the recorder pen is deflected. Maximum deflection is 10 units. Give reading to nearest 0.1 chart units.

7. Initial the last column.

8. Continue Steps #2 through #7 for one month or approximately 30 days.

9. If the differences between the laboratory measurements and the Electrofact pH meter is greater than 0.2 pH units,

   a. Pull the Electrofact electrodes from the system.

   b. Thoroughly clean the electrodes.

   c. Recalibrate the strip chart recorder, Section II.

   If these steps are performed and the difference is still greater than 0.2 pH units, try to troubleshoot the system. If the troubleshooting is unsuccessful, resume the test, write down appropriate comments, and contact Clinton Ung, (213) 536-2448.

10. If equiment failure and/or breakage occurs,

    a. Replace the damaged equipment.

    b. Recalibrate the strip chart recorder, Section II.

    c. Resume test.

    If the equipment cannot be repaired immediately, notify Clinton Ung, (213) 536-2448.

11. At the end of the test, (i.e., after approximately 30 days) thoroughly clean the Electrofact electrodes and recalibrate the strip chart recorder according to Section II. This is very important because correlation beween the Electrofact pH meter readings and the transmitter milliampere output values must be made.

Table A-1

| pH | ma Output | mV w/28.7Ω | Chart Paper Division Units (0-600 mV Span) |
|---|---|---|---|
| 4.5 pH | 4.0 | 114.8 | 2.3 |
| 4.6 | 4.8 | 137.8 | 2.8 |
| 4.7 | 5.6 | 160.7 | 3.2 |
| 4.8 | 6.4 | 183.7 | 3.7 |
| 4.9 | 7.2 | 206.6 | 4.1 |
| 5.0 | 8.0 | 229.6 | 4.6 |
| 5.1 | 8.8 | 252.6 | 5.1 |
| 5.2 | 9.6 | 275.5 | 5.5 |
| 5.3 | 10.4 | 298.5 | 6.0 |
| 5.4 | 11.2 | 321.4 | 6.4 |
| 5.5 | 12.0 | 344.4 | 6.9 |
| 5.6 | 12.8 | 367.4 | 7.3 |
| 5.7 | 13.6 | 390.3 | 7.8 |
| 5.8 | 14.4 | 413.3 | 8.3 |
| 5.9 | 15.2 | 436.2 | 8.7 |
| 6.0 | 16.0 | 459.2 | 9.7 |
| 6.1 | 16.8 | 482.2 | 9.6 |
| 6.2 | 17.6 | 505.1 | 10.1 |
| 6.3 | 18.4 | 528.1 | 10.6 |
| 6.4 | 19.2 | 551.0 | 11.0 |
| 6.5 | 20.0 | 574.0 | 11.5 |

FIELD FORM FOR pH MEASUREMENT TEST

Recorder Calibration: pH ___ Buffer = ____ Chart paper divisions
pH ___ Buffer = ____ Chart paper divisions

| Date | Time | Laboratory pH Meter Reading (pH Units) | Electrofact pH Meter Reading (pH Units) | Strip Chart Recorder Reading Chart Divisions | Performed by (Initials) |
|---|---|---|---|---|---|
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# APPENDIX B

## DATA FOR pH ELECTRODE EVALUATION

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-13 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | 5.95 | 5.99 | 0.04+ | 5.57 | 5.50 | 0.07- | 5.65 | 0.38- | 0.30- | 0.08+ |
| | 1500 | 5.44 | 5.82 | 0.38+ | 5.31 | 5.26 | 0.05- | 5.80 | 0.13- | 0.36+ | 0.49+ |
| | 1700 | 5.33 | 5.71 | 0.38+ | 5.44 | 5.41 | 0.03- | 5.70 | 0.11+ | 0.37+ | 0.26+ |
| | 1900 | 5.60 | 5.66 | 0.06+ | 5.43 | 5.39 | 0.04- | 5.35 | 0.17- | 0.25- | 0.08- |
| | 2100 | 5.50 | 5.55 | 0.05+ | 5.32 | 5.37 | 0.05+ | 5.07 | 0.18- | 0.43- | 0.25- |
| | 2300 | 5.37 | 5.44 | 0.07+ | 5.29 | 5.26 | 0.03- | 5.00 | 0.08- | 0.37- | 0.29- |
| 3-14 | 100 | 5.30 | 5.33 | 0.03+ | 5.25 | 5.20 | 0.05- | 4.95 | 0.05- | 0.35- | 0.30- |
| | 300 | 5.33 | 5.34 | 0.01+ | 5.30 | 5.20 | 0.10- | 4.95 | 0.03- | 0.38- | 0.35- |
| | 500 | 5.35 | 5.38 | 0.03+ | 5.36 | 5.28 | 0.08- | 4.98 | 0.01+ | 0.37- | 0.38- |
| | 700 | 5.60 | 5.33 | 0.27- | 5.33 | 5.28 | 0.05- | 4.90 | 0.27- | 0.70- | 0.43- |
| | 900 | 5.25 | 5.28 | 0.03+ | 5.26 | 5.20 | 0.06- | 5.01 | 0.01+ | 0.24- | 0.25- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-14 cont | 1100 | 5.25 | 5.28 | 0.03+ | 5.27 | 5.21 | 0.06- | 5.04 | 0.02+ | 0.21- | 0.23- |
| | 1300 | 5.20 | 5.23 | 0.03+ | 5.14 | 5.08 | 0.06- | 5.00 | 0.06- | 0.20- | 0.14- |
| | 1500 | 5.15 | 5.20 | 0.05+ | 5.05 | 5.02 | 0.03- | 4.84 | 0.10- | 0.31- | 0.21- |
| | 1700 | 5.90 | 5.79 | 0.11- | 5.16 | 5.08 | 0.08- | 4.79 | 0.74 | 1.11- | 0.37- |
| | 1900 | 6.20 | 6.21 | 0.01+ | 5.20 | 5.14 | 0.06- | 4.94 | 1.00- | 1.26- | 0.26- |
| | 2100 | 6.40 | 6.43 | 0.03+ | 5.20 | 5.16 | 0.04- | 4.95 | 1.20- | 1.45- | 0.25- |
| | 2300 | 6.32 | 6.37 | 0.05+ | 5.25 | 5.20 | 0.05- | 4.87 | 1.07- | 1.45- | 0.38- |
| 3-15 | 100 | 6.27 | 6.31 | 0.04+ | 5.27 | 5.21 | 0.06- | 4.84 | 1.00- | 1.43- | 0.43- |
| | 300 | 6.18 | 6.22 | 0.04+ | 5.30 | 5.26 | 0.04- | 4.94 | 0.88- | 1.24- | 0.36- |
| | 500 | 6.10 | 6.12 | 0.02+ | 5.33 | 5.28 | 0.05- | 5.00 | 0.77- | 1.10- | 0.33- |
| | 700 | 6.10 | 6.11 | 0.01+ | 5.32 | 5.26 | 0.06- | 4.85 | 0.78- | 1.25- | 0.47- |
| | 900 | 6.10 | 6.11 | 0.01+ | 5.32 | 5.26 | 0.06- | 4.96 | 0.78- | 1.14- | 0.36- |
| | 1100 | 5.20 | 5.20 | | 5.25 | 5.17 | 0.08- | 5.04 | 0.05+ | 0.16- | 0.21- |
| | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-15 cont | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 3-16 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |
| | 2100 | | | | | | | | | | |
| | 2300 | 5.40 | 5.44 | 0.04+ | 5.44 | 5.37 | 0.07- | 5.21 | 0.04+ | 0.19- | 0.23- |
| 3-17 | 100 | 5.85 | 5.89 | 0.04+ | 5.85 | 5.80 | 0.05- | 5.66 | 0.0 | 0.19- | 0.19- |
| | 300 | 5.90 | 5.95 | 0.05+ | 5.89 | 5.87 | 0.02- | 5.54 | 0.01- | 0.36- | 0.35- |
| | 500 | 5.95 | 5.97 | 0.02+ | 5.91 | 5.88 | 0.03- | 5.56 | 0.04- | 0.39- | 0.35- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-17 cont | 700 | 6.00 | 6.05 | 0.05+ | 5.99 | 5.98 | 0.01- | 5.80 | 0.01- | 0.20- | 0.19- |
| | 900 | 5.90 | 5.96 | 0.06+ | 5.91 | 5.86 | 0.05- | 5.77 | 0.01+ | 0.13- | 0.14- |
| | 1100 | 5.90 | 5.94 | 0.04+ | 5.91 | 5.88 | 0.03- | 5.79 | 0.01+ | 0.11- | 0.12- |
| | 1300 | 5.55 | 5.81 | 0.26+ | 5.80 | 5.80 | 0 | 5.43 | 0.25+ | 0.12- | 0.37- |
| | 1500 | 5.90 | 5.93 | 0.03+ | 5.86 | 5.86 | 0 | 5.70 | 0.04- | 0.20- | 0.16- |
| | 1700 | 5.91 | 5.94 | 0.03+ | 5.95 | 5.93 | 0.02- | 5.72 | 0.04+ | 0.19- | 0.23- |
| | 1900 | 5.95 | 5.94 | 0.01+ | 5.95 | 5.93 | 0.02- | 5.74 | 0 | 0.21- | 0.21- |
| | 2100 | 5.95 | 5.96 | 0.01+ | 5.97 | 5.97 | 0 | 5.73 | 0.02+ | 0.22- | 0.24- |
| | 2300 | 5.95 | 5.96 | 0.01+ | 5.99 | 5.96 | 0.03- | 5.86 | 0.04+ | 0.09- | 0.13- |
| 3-18 | 100 | 5.93 | 5.95 | 0.02+ | 5.99 | 5.97 | 0.02- | 5.75 | 0.06+ | 0.18- | 0.24- |
| | 300 | 5.95 | 5.97 | 0.02+ | 6.00 | 5.99 | 0.01- | 5.75 | 0.05+ | 0.20- | 0.25- |
| | 500 | 5.95 | 5.96 | 0.01+ | 5.99 | 5.96 | 0.03- | 5.73 | 0.04+ | 0.22- | 0.26- |
| | 700 | 5.95 | 5.96 | 0.01+ | 5.97 | 5.94 | 0.03- | 5.84 | 0.02+ | 0.11- | 0.13- |
| | 900 | 5.95 | 5.96 | 0.01+ | 5.96 | | | 5.77 | 0.01+ | 0.18- | 0.19- |
| | 1100 | 5.90 | 5.94 | 0.04+ | 5.97 | 5.91 | 0.06- | 5.72 | 0.07+ | 0.18- | 0.25- |
| | 1300 | 5.90 | 5.94 | 0.04+ | 5.90 | 5.86 | 0.04- | 5.71 | 0 | 0.19- | 0.19- |
| | 1500 | 5.90 | 5.93 | 0.03+ | 5.88 | 5.83 | 0.05- | 5.70 | 0.02- | 0.20- | 0.18- |
| | 1700 | 5.95 | 5.96 | 0.01+ | 5.85 | 5.84 | 0.01- | 5.72 | 0.10- | 0.23- | 0.13- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-18 cont | 1900 | 5.95 | 5.96 | 0.01+ | 5.90 | 5.86 | 0.04- | 5.74 | 0.05- | 0.21- | 0.16- |
| | 2100 | 5.90 | 5.93 | 0.03+ | 5.89 | 5.86 | 0.03- | 5.70 | 0.01- | 0.20- | 0.19- |
| | 2300 | 5.90 | 5.92 | 0.02+ | 5.88 | 5.85 | 0.03- | 5.72 | 0.02- | 0.18- | 0.16- |
| 3-19 | 100 | 5.85 | 5.88 | 0.03+ | 5.84 | 5.80 | 0.04- | 5.52 | 0.01- | 0.33- | 0.32- |
| | 300 | 5.87 | 5.91 | 0.04+ | 5.85 | 5.82 | 0.03- | 5.68 | 0.02- | 0.19- | 0.17- |
| | 500 | 5.90 | 5.89 | 0.01- | 5.85 | 5.81 | 0.04- | 5.58 | 0.05- | 0.32- | 0.27- |
| | 700 | 5.85 | 5.88 | 0.03+ | 5.89 | 5.86 | 0.03- | 5.63 | 0.04+ | 0.22- | 0.26- |
| | 900 | 5.90 | 5.93 | 0.03+ | 5.90 | 5.86 | 0.04- | 5.69 | 0 | 0.21- | 0.21- |
| | 1100 | 5.89 | 5.91 | 0.02+ | 5.86 | 5.81 | 0.05- | 5.66 | 0.03- | 0.23- | 0.20 |
| | 1300 | 6.03 | 6.00 | 0.03- | 5.92 | 5.93 | 0.01+ | 5.84 | 0.11- | 0.19- | 0.08- |
| | 1500 | 5.95 | 5.98 | 0.03+ | 5.97 | 5.94 | 0.03- | 5.79 | 0.02+ | 0.16- | 0.18- |
| | 1700 | 5.96 | 5.98 | 0.02+ | 5.94 | 5.90 | 0.04- | 5.76 | 0.02- | 0.20- | 0.18- |
| | 1900 | 5.75 | 6.00 | 0.25+ | 5.96 | 5.92 | 0.04- | 5.77 | 0.21+ | 0.02+ | 0.19- |
| | 2100 | 5.95 | 5.99 | 0.04+ | 5.90 | 5.85 | 0.05- | 5.75 | 0.05- | 0.20- | 0.15- |
| | 2300 | 5.95 | 5.96 | 0.01+ | 5.88 | 5.85 | 0.03- | 5.74 | 0.07- | 0.21- | 0.14- |
| 3-20 | 100 | 5.97 | 5.96 | 0.01- | 5.92 | 5.87 | 0.05- | 5.78 | 0.05- | 0.19- | 0.14- |
| | 300 | 5.93 | 5.95 | 0.02+ | 5.89 | 5.86 | 0.03- | 5.60 | 0.04- | 0.33- | 0.29- |
| | 500 | 5.95 | 5.97 | 0.02+ | 5.91 | 5.86 | 0.05- | 5.61 | 0.04- | 0.34- | 0.30- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-20 cont | 700 | 5.95 | 5.97 | 0.02+ | 5.90 | 5.87 | 0.03- | 5.85 | 0.05- | 0.10- | 0.05- |
| | 900 | 5.95 | 5.96 | 0.01+ | 5.88 | 5.84 | 0.04- | 5.82 | 0.08- | 0.13- | 0.06- |
| | 1100 | 5.95 | 5.96 | 0.01+ | 5.85 | 5.80 | 0.05- | 5.73 | 0.10- | 0.22- | 0.12- |
| | 1300 | 5.90 | 5.93 | 0.03+ | 5.82 | 5.80 | 0.02- | 5.69 | 0.08- | 0.21- | 0.13- |
| | 1500 | 5.82 | 5.88 | 0.06+ | 5.83 | 5.80 | 0.03- | 5.50 | 0.01+ | 0.32- | 0.33- |
| | 1700 | 5.85 | 5.86 | 0.01+ | 5.80 | 5.80 | 0 | 5.55 | 0.05- | 0.30- | 0.25- |
| | 1900 | 5.90 | 5.93 | 0.03+ | 5.84 | 5.80 | 0.04- | 5.61 | 0.06- | 0.29- | 0.23- |
| | 2100 | 5.95 | 5.93 | 0.02- | 5.85 | 5.80 | 0.05- | 5.65 | 0.10- | 0.30- | 0.20- |
| | 2300 | 5.90 | 5.93 | 0.03+ | 5.88 | 5.84 | 0.04- | 5.12 | 0.02- | 0.28- | 0.26- |
| 3-21 | 100 | 5.95 | 5.95 | 0 | 5.88 | 5.86 | 0.02- | 5.66 | 0.07- | 0.29- | 0.22- |
| | 300 | 5.96 | 5.99 | 0.03+ | 5.92 | 5.89 | 0.03- | 5.85 | 0.04- | 0.11- | 0.07- |
| | 500 | 5.95 | 5.97 | 0.02+ | 5.89 | 5.86 | 0.03- | 5.81 | 0.06- | 0.14- | 0.08- |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-21 cont | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |
| | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 3-22 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | 5.95 | 5.81 | 0.14- | 6.26 | 6.01 | 0.25- | 6.07 | 0.31+ | 0.12+ | 0.19- |
| | 1500 | 6.07 | 6.11 | 0.04+ | 6.25 | 6.23 | 0.02- | 5.75 | 0.18+ | 0.32- | 0.50- |
| | 1700 | 6.13 | 6.18 | 0.05+ | 6.29 | 6.28 | 0.01- | 5.80 | 0.16+ | 0.33- | 0.49- |
| | 1900 | 6.30 | 6.22 | 0.08- | 6.32 | 6.25 | 0.07- | 6.01 | 0.02+ | 0.27- | 0.31- |
| | 2100 | 6.25 | 6.29 | 0.04+ | 6.38 | 6.34 | 0.04- | 5.08 | 0.13+ | 1.17- | 1.30- |
| | 2300 | 6.30 | 6.33 | 0.03+ | 6.42 | 6.39 | 0.03- | 6.28 | 0.12+ | 0.02- | 0.14- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-23 | 100 | 6.30 | 6.33 | 0.03+ | 6.42 | 6.40 | 0.02- | 6.10 | 0.12+ | 0.20- | 0.32- |
| | 300 | 6.30 | 6.32 | 0.02+ | 6.44 | 6.42 | 0.02- | 6.08 | 0.14+ | 0.22- | 0.36+ |
| | 500 | 6.30 | 6.34 | 0.04+ | 6.47 | 6.46 | 0.01- | 6.12 | 0.17+ | 0.18- | 0.25- |
| | 700 | 6.35 | 6.36 | 0.01+ | 6.45 | 6.43 | 0.02- | 5.95 | 0.10+ | 0.40- | 0.50- |
| | 900 | 6.33 | 6.36 | 0.03+ | 6.45 | 6.40 | 0.05- | 6.00 | 0.12+ | 0.33- | 0.45- |
| | 1100 | 6.35 | 6.40 | 0.05+ | 6.44 | 6.40 | 0.04- | 5.98 | 0.09+ | 0.37- | 0.46- |
| | 1300 | 6.35 | 6.41 | 0.06+ | 6.38 | 6.34 | 0.04- | 6.07 | 0.03+ | 0.28- | 0.31- |
| | 1500 | 6.40 | 6.37 | 0.03- | 6.23 | 6.35 | 0.12+ | 6.20 | 0.17- | 0.20- | 0.03- |
| | 1700 | 6.30 | 6.36 | 0.06+ | 6.32 | 6.28 | 0.04- | 6.02 | 0.02+ | 0.28- | 0.30- |
| | 1900 | 6.32 | 6.37 | 0.05+ | 6.36 | 6.33 | 0.03- | 6.03 | 0.04+ | 0.29- | 0.33- |
| | 2100 | 6.31 | 6.36 | 0.05+ | 6.41 | 6.39 | 0.02- | 6.09 | 0.10+ | 0.22- | 0.32+ |
| | 2300 | 6.30 | 6.36 | 0.05+ | 6.38 | 6.34 | 0.04- | 6.15 | 0.08+ | 0.15- | 0.23- |
| 3-24 | 100 | 6.30 | 6.36 | 0.06+ | 6.36 | 6.34 | 0.02- | 6.13 | 0.06+ | 0.17- | 0.23- |
| | 300 | 6.35 | 6.37 | 0.02+ | 6.36 | 6.31 | 0.05- | 6.16 | 0.01+ | 0.19- | 0.20- |
| | 500 | 6.30 | 6.37 | 0.07+ | * | 6.28 | | 6.09 | 0.02+ | 0.21- | 0.23- |
| | 700 | 6.35 | 6.38 | 0.03+ | * | 6.28 | | 6.01 | 0.03- | 0.34- | 0.31- |
| | 900 | 6.35 | 6.40 | 0.05+ | * | 6.31 | | 6.11 | 0.06- | 0.24- | 0.24- |
| | 1100 | 6.38 | 6.40 | 0.02+ | * | 6.32 | | 6.10 | 0.02- | 0.28- | 0.26- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-24 cont | 1300 | 6.40 | 6.43 | 0.03+ | * | 6.32 | | 6.17 | 0.04- | 0.23- | 0.19- |
| | 1500 | 6.44 | 6.44 | 0 | * | 6.35 | | 6.17 | 0.05- | 0.27- | 0.22- |
| | 1700 | 6.45 | 6.46 | 0.01+ | * | 6.37 | | 6.15 | 0.04- | 0.30- | 0.26- |
| | 1900 | 6.35 | 6.48 | 0.13+ | * | 6.24 | | 6.05 | 0.07- | 0.30- | 0.23- |
| | 2100 | 6.35 | 6.35 | 0 | * | 6.24 | | 6.12 | 0.07- | 0.23- | 0.16- |
| | 2300 | 6.30 | 6.34 | 0.04+ | * | 6.22 | | 6.22 | 0.04- | 0.08- | 0.04- |
| 3-25 | 100 | 6.32 | 6.35 | 0.03+ | * | 6.22 | | 6.12 | 0.06- | 0.20- | 0.14- |
| | 300 | 6.30 | 6.37 | 0.07+ | * | 6.23 | | 6.07 | 0.03- | 0.23- | 0.20- |
| | 500 | 6.30 | 6.36 | 0.06+ | * | 6.22 | | 6.07 | 0.04- | 0.23- | 0.19- |
| | 700 | 6.40 | 6.36 | 0.04- | * | 6.26 | | 6.15 | 0.10- | 0.25- | 0.15- |
| | 900 | 6.40 | 6.42 | 0.02+ | * | 6.28 | | 6.13 | 0.08- | 0.27- | 0.19- |
| | 1100 | 6.40 | 6.43 | 0.03+ | * | 6.29 | | 6.06 | 0.07- | 0.34- | 0.27- |
| | 1300 | 6.40 | 6.43 | 0.03+ | * | 6.28 | | 6.05 | 0.08- | 0.35- | 0.27- |
| | 1500 | 6.40 | 6.45 | 0.05+ | * | 6.28 | | 6.07 | 0.08- | 0.33- | 0.25- |
| | 1700 | 6.36 | 6.43 | 0.07+ | * | 6.27 | | 6.15 | 0.05- | 0.21- | 0.16- |
| | 1900 | 6.33 | 6.38 | 0.05+ | * | 6.24 | | 6.09 | 0.05- | 0.24- | 0.19- |
| | 2100 | 6.34 | 6.38 | 0.04+ | * | 6.22 | | 6.10 | 0.08- | 0.24- | 0.16- |
| | 2300 | 6.35 | 6.38 | 0.03+ | * | 6.21 | | 6.13 | 0.10- | 0.22- | 0.12- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements #3 | ΔpH ± (#2-#1) | ΔpH ± (#3-#1) | ΔpH ± (#3-#2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | | | | |
| 3-26 | 100 | 6.30 | 6.36 | 0.06+ | * | 6.22 | | 6.11 | 0.04- | 0.19- | 0.15- |
| | 300 | 6.35 | 6.36 | 0.01+ | * | 6.22 | | 6.15 | 0.09- | 0.20- | 0.11- |
| | 500 | 6.30 | 6.34 | 0.04+ | * | 6.22 | | 6.08 | 0.04- | 0.22- | 0-18- |
| | 700 | 6.35 | 6.36 | 0.01+ | * | 6.22 | | 6.00 | 0.09- | 0.35- | 0.26- |
| | 900 | 6.30 | 6.32 | 0.02+ | * | 6.26 | | 5.93 | 0.00 | 0.37- | 0.37- |
| | 1100 | 6.33 | 6.36 | 0.03+ | * | 6.25 | | 6.12 | 0.04- | 0.21- | 0.17- |
| | 1300 | 6.36 | 6.40 | 0.04+ | * | 6.27 | | 6.02 | 0.05- | 0.34- | 0.29- |
| | 1500 | 6.35 | 6.38 | 0.03+ | * | 6.27 | | 6.12 | 0.04- | 0.23- | 0.19- |
| | 1700 | 6.34 | 6.38 | 0.04+ | * | 6.24 | | 6.07 | 0.06- | 0.27- | 0.21- |
| | 1900 | 6.40 | 6.36 | 0.04- | * | 6.28 | | 6.02 | 0.08- | 0.38- | 0.30- |
| | 2100 | 6.40 | 6.40 | 0 | * | 6.30 | | 6.04 | 0.06- | 0.36- | 0.30- |
| | 2300 | 6.32 | 6.37 | 0.05+ | * | 6.29 | | 6.15 | 0 | 0.17- | 0.18- |
| 3-27 | 100 | 6.32 | 6.35 | 0.03+ | * | 6.28 | | 6.08 | 0.00 | 0.24- | 0.24- |
| | 300 | 6.30 | 6.34 | 0.04+ | * | 6.28 | | 6.04 | 0.02+ | 0.26- | 0.28- |
| | 500 | 6.30 | 6.34 | 0.04+ | * | 6.23 | | 6.04 | 0.03- | 0.26- | 0.23- |
| | 700 | 6.29 | 6.33 | 0.04+ | * | 6.23 | | 5.98 | 0.02- | 0.31- | 0.29- |
| | 900 | 6.33 | 6.36 | 0.03+ | * | 6.22 | | 6.03 | 0.07- | 0.30- | 0.23- |
| | 1100 | 6.35 | 6.36 | 0.01+ | * | 6.22 | | 6.02 | 0.09- | 0.33- | 0.24- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-27 cont | 1300 | 6.30 | 6.34 | 0.04+ | * | 6.22 | | 5.91 | 0.04- | 0.39- | 0.35- |
| | 1500 | 6.30 | 6.35 | 0.05+ | 6.25 | 6.24 | 0.01- | 5.98 | 0.05- | 0.32- | 0.27- |
| | 1700 | 6.30 | 6.34 | 0.04+ | 6.23 | 6.22 | 0.01- | 5.90 | 0.07- | 0.40- | 0.33- |
| | 1900 | 6.29 | 6.33 | 0.04+ | 6.22 | 6.18 | 0.04- | 6.02 | 0.07- | 0.27- | 0.20- |
| | 2100 | 6.32 | 6.34 | 0.02+ | 6.23 | 6.19 | 0.04- | 6.06 | 0.09- | 0.16- | 0.17- |
| | 2300 | 6.30 | 6.32 | 0.02+ | 6.20 | 6.16 | 0.04- | 6.05 | 0.10- | 0.25- | 0.15- |
| 3-28 | 100 | 6.30 | 6.34 | 0.04+ | 6.22 | 6.19 | 0.03- | 6.09 | 0.08- | 0.21- | 0.13- |
| | 300 | 6.30 | 6.34 | 0.04+ | 6.23 | 6.19 | 0.04- | 6.11 | 0.07- | 0.19- | 0.12- |
| | 500 | 6.30 | 6.33 | 0.03+ | * | 6.18 | | 6.04 | 0.08- | 0.26- | 0.18- |
| | 700 | 6.33 | 6.36 | 0.03+ | * | 6.18 | | 5.42 | 0.11- | 0.91- | 0.80- |
| | 900 | 6.30 | 6.36 | 0.06+ | 6.21 | 6.17 | 0.04- | 6.02 | 0.09- | 0.28- | 0.19- |
| | 1100 | | | | | | | | STOP | STOP | STOP |
| | 1300 | | | | | | | | | | |
| | 1500 | 6.39 | 6.42 | 0.03+ | 6.28 | 6.24 | 0.04- | 6.07 | 0.11- | 0.32- | 0.21- |
| | 1700 | 6.35 | 6.40 | 0.05+ | 6.26 | 6.23 | 0.03- | 6.09 | 0.09- | 0.26- | 0.17- |
| | 1900 | 6.40 | 6.43 | 0.03+ | 6.28 | 6.25 | 0.03- | 5.99 | 0.12- | 0.41- | 0.29- |
| | 2100 | 6.40 | 6.45 | 0.05+ | 6.30 | 6.27 | 0.03- | 6.04 | 0.10- | 0.36- | 0.26- |
| | 2300 | 6.55 | 6.49 | 0.06+ | 6.34 | 6.31 | 0.03- | 6.10 | 0.21- | 0.45- | 0.24- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-29 | 100 | 6.45 | 6.48 | 0.03+ | 6.34 | 6.30 | 0.04- | 6.11 | 0.11- | 0.34- | 0.23- |
| | 300 | 6.45 | 6.47 | 0.02+ | 6.33 | 6.30 | 0.03- | 6.15 | 0.12- | 0.30- | 0.18- |
| | 500 | 6.45 | 6.48 | 0.03+ | 6.34 | 6.32 | 0.02- | 6.14 | 0.11- | 0.31- | 0.20- |
| | 700 | 6.45 | 6.49 | 0.04+ | 6.36 | 6.33 | 0.03- | 6.18 | 0.09- | 0.27- | 0.18- |
| | 900 | 6.50 | 6.52 | 0.02+ | 6.38 | 6.34 | 0.04- | 6.19 | 0.12- | 0.31- | 0.19- |
| | 1100 | 6.45 | 6.49 | 0.04+ | 6.35 | 6.31 | 0.04- | 6.21 | 0.10- | 0.24- | 0.14- |
| | 1300 | 6.38 | 6.46 | 0.08+ | 6.36 | 6.34 | 0.02- | 6.20 | 0.02- | 0.18- | 0.16- |
| | 1500 | 6.42 | 6.46 | 0.04+ | 6.36 | 6.36 | 0 | 6.04 | 0.06- | 0.38- | 0.32- |
| | 1700 | 6.40 | 6.45 | 0.05+ | 6.34 | 6.33 | 0.01- | 6.08 | 0.06- | 0.32- | 0.26- |
| | 1900 | 6.41 | 6.45 | 0.04+ | 6.33 | 6.30 | 0.03- | 6.13 | 0.08- | 0.28- | 0.20- |
| | 2100 | 6.39 | 6.44 | 0.05+ | 6.30 | 6.28 | 0.02- | 6.10 | 0.09- | 0.29- | 0.20- |
| | 2300 | 6.37 | 6.41 | 0.04+ | 6.29 | 6.29 | 0 | 5.91 | 0.08- | 0.46- | 0.38- |
| 3-30 | 100 | 6.40 | 6.44 | 0.04+ | 6.31 | 6.28 | 0.03- | 5.98 | 0.09- | 0.42- | 0.33- |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 3-30 cont | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | 6.45 | 6.28 | 0.17- | 6.29 | 6.18 | 0.17- | 6.07 | 0.16- | 0.38- | 0.22- |
| | 1900 | 6.30 | 6.33 | 0.03+ | 6.22 | 6.20 | 0.02- | 6.01 | 0.08- | 0.29- | 0.21- |
| | 2100 | 6.35 | 6.36 | 0.01+ | 6.25 | 6.23 | 0.02- | 6.13 | 0.10- | 0.22- | 0.12- |
| | 2300 | 6.33 | 6.35 | 0.02+ | 6.25 | 6.23 | 0.02- | 6.07 | 0.08- | 0.26- | 0.18- |
| 3-31 | 100 | 6.28 | 6.29 | 0.01+ | 6.20 | 6.18 | 0.02- | 6.00 | 0.08- | 0.28- | 0.20- |
| | 300 | 6.22 | 6.25 | 0.03+ | 6.19 | 6.16 | 0.03- | 5.89 | 0.03- | 0.33- | 0.30- |
| | 500 | 6.13 | 6.15 | 0.02+ | 6.11 | 6.08 | 0.03- | 5.79 | 0.02- | 0.34- | 0.32- |
| | 700 | 6.05 | 6.06 | 0.01+ | 5.97 | 5.96 | 0.01- | 5.65 | 0.08- | 0.40- | 0.32- |
| | 900 | 5.90 | 5.84 | 0.06- | 5.81 | 5.78 | 0.03- | 5.47 | 0.09- | 0.43- | 0.34- |
| | 1100 | 5.57 | 5.59 | 0.02+ | 5.64 | 5.67 | 0.03+ | 5.25 | 0.07+ | 0.27- | 0.34- |
| | 1300 | 5.60 | 5.63 | 0.03+ | 5.68 | 5.64 | 0.04- | 5.29 | 0.08+ | 0.31- | 0.39- |
| | 1500 | 5.55 | 5.58 | 0.03+ | 5.65 | 5.63 | 0.02- | 5.39 | 0.10+ | 0.16- | 0.26- |
| | 1700 | 5.55 | 5.57 | 0.02+ | 5.61 | 5.57 | 0.04- | 5.39 | 0.06+ | 0.16- | 0.22- |
| | 1900 | 5.53 | 5.55 | 0.02+ | 5.66 | 5.61 | 0.05- | 5.26 | 0.13+ | 0.27- | 0.40- |
| | 2100 | 5.57 | 5.60 | 0.03+ | 5.58 | 5.57 | 0.01- | 5.37 | 0.01+ | 0.20- | 0.21- |
| | 2300 | 5.65 | 5.67 | 0.02+ | 5.62 | 5.62 | 0 | 5.33 | 0.03- | 0.32- | 0.29- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-1 | 100 | 5.65 | 5.79 | 0.14+ | 5.80 | 5.74 | 0.06- | 5.47 | 0.15+ | 0.18- | 0.33- |
| | 300 | 5.78 | 5.77 | 0.01- | 5.73 | 5.68 | 0.05- | 5.56 | 0.05- | 0.22- | 0.17- |
| | 500 | 5.75 | 5.76 | 0.01+ | * | 5.74 | | 5.57 | 0.03+ | 0.18- | 0.17- |
| | 700 | 5.66 | 5.69 | 0.03+ | 5.72 | 5.68 | 0.04- | 5.37 | 0.06+ | 0.29- | 0.35- |
| | 900 | 5.65 | 5.75 | 0.10+ | 5.76 | 5.73 | 0.03- | 5.37 | 0.11+ | 0.28- | 0.39- |
| | 1100 | 5.70 | 5.75 | 0.05+ | 5.73 | 5.68 | 0.05- | 5.60 | 0.03+ | 0.10- | 0.13- |
| | 1300 | 5.90 | 5.87 | 0.03- | 5.87 | 5.74 | 0.13- | 5.68 | 0.03- | 0.22- | 0.19- |
| | 1500 | 5.91 | 5.92 | 0.01+ | 5.88 | 5.85 | 0.03- | 5.65 | 0.03- | 0.26- | 0.23- |
| | 1700 | 5.84 | 5.95 | 0.11+ | 5.76 | 5.86 | 0.10+ | 5.67 | 0.08- | 0.17- | 0.09- |
| | 1900 | 6.00 | 6.00 | 0 | 5.95 | 5.92 | 0.03- | 5.65 | 0.05- | 0.35- | 0.30- |
| | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 4-2 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-2 cont | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |
| | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 4-3 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | | | | | | | | | | |
| | 1500 | 5.82 | 5.81 | 0.01- | 6.01 | 5.92 | 0.09- | 5.88 | 0.19+ | 0.06+ | 0.13- |
| | 1700 | 5.90 | 5.91 | 0.01+ | 6.03 | 5.98 | 0.05- | 5.79 | 0.13+ | 0.11- | 0.24- |
| | 1900 | 5.95 | 5.99 | 0.04+ | 6.14 | 6.09 | 0.05- | 5.77 | 0.19+ | 0.18- | 0.37- |
| | 2100 | 6.05 | 6.05 | 0 | 6.18 | 6.11 | 0.07- | 5.85 | 0.13+ | 0.25- | 0.38- |
| | 2300 | 6.00 | 6.06 | 0.06+ | 6.11 | 6.07 | 0.04- | 5.78 | 0.11+ | 0.22- | 0.33- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-4 | 100 | 6.10 | 6.05 | 0.05- | 6.19 | 6.10 | 0.09- | 5.71 | 0.09+ | 0.39- | 0.48- |
| | 300 | 6.10 | 6.11 | 0.01+ | 6.20 | 6.10 | 0.10- | 5.89 | 0.10+ | 0.21- | 0.31- |
| | 500 | 6.06 | 6.08 | 0.02+ | 6.17 | 6.11 | 0.06- | 5.89 | 0.11+ | 0.17- | 0.28- |
| | 700 | 6.05 | 6.08 | 0.03+ | 6.15 | 6.11 | 0.04- | 5.87 | 0.10+ | 0.18- | 0.28- |
| | 900 | 6.10 | 6.09 | 0.01- | 6.17 | 6.16 | 0.01- | 5.87 | 0.07+ | 0.23- | 0.30- |
| | 1100 | 6.06 | 6.09 | 0.03+ | 6.19 | 6.15 | 0.04- | 5.91 | 0.13+ | 0.15- | 0.28- |
| | 1300 | 6.05 | 6.09 | 0.04+ | 6.18 | 6.06 | 0.12- | 5.87 | 0.13+ | 0.18- | 0.31- |
| | 1500 | 6.13 | 6.15 | 0.02+ | 6.25 | 6.20 | 0.05- | 6.15 | 0.12+ | 0.02+ | 0.10- |
| | 1700 | 6.10 | 6.13 | 0.03+ | 6.21 | 6.19 | 0.02- | 5.94 | 0.11+ | 0.16- | 0.27- |
| | 1900 | 6.10 | 6.16 | 0.06+ | 6.25 | 6.22 | 0.03- | 5.91 | 0.15+ | 0.19- | 0.34- |
| | 2100 | 6.15 | 6.19 | 0.04+ | 6.26 | 6.23 | 0.03- | 5.92 | 0.11+ | 0.23- | 0.34- |
| | 2300 | 6.15 | 6.17 | 0.02+ | 6.28 | 6.24 | 0.04- | 5.89 | 0.13+ | 0.26- | 0.39- |
| 4-5 | 100 | 6.15 | 6.19 | 0.04+ | 6.29 | 6.27 | 0.02- | 5.98 | 0.14+ | 0.17- | 0.31- |
| | 300 | 6.15 | 6.18 | 0.03+ | 6.29 | 6.25 | 0.04- | 5.79 | 0.14+ | 0.36- | 0.50- |
| | 500 | 6.17 | 6.21 | 0.04+ | 6.32 | 6.28 | 0.04- | 5.85 | 0.15+ | 0.32- | 0.47- |
| | 700 | 6.20 | 6.19 | 0.01- | 6.30 | 6.26 | 0.04- | 6.00 | 0.10+ | 0.20- | 0.30- |
| | 900 | 6.15 | 6.15 | 0 | 6.25 | 6.22 | 0.03- | 5.93 | 0.10+ | 0.22- | 0.32- |
| | 1100 | 6.15 | 6.17 | 0.02+ | 6.25 | 6.20 | 0.05- | 5.92 | 0.10+ | 0.23- | 0.33- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements #3 | ΔpH ± (#2-#1) | ΔpH ± (#3-#1) | ΔpH ± (#3-#2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | | | | |
| 4-5 cont | 1300 | 6.10 | 6.13 | 0.03+ | 6.23 | 6.22 | 0.01- | 5.88 | 0.13+ | 0.22- | 0.35- |
| | 1500 | 6.10 | 6.12 | 0.02+ | 6.22 | 6.19 | 0.03- | 5.86 | 0.12+ | 0.24- | 0.36- |
| | 1700 | 6.00 | 6.06 | 0.06+ | 6.14 | 6.10 | 0.04- | 5.82 | 0.14+ | 0.18- | 0.32- |
| | 1900 | 6.00 | 6.05 | 0.05+ | 6.13 | 6.11 | 0.02- | 5.81 | 0.13+ | 0.19- | 0.32- |
| | 2100 | 6.05 | 6.07 | 0.02+ | 6.17 | 6.09 | 0.08- | 5.85 | 0.12+ | 0.20- | 0.32- |
| | 2300 | 6.02 | 6.04 | 0.02+ | 6.08 | 6.13 | 0.05+ | 5.76 | 0.06+ | 0.26- | 0.32- |
| 4-6 | 100 | 5.96 | 6.00 | 0.04+ | 6.08 | 6.04 | 0.04- | 5.80 | 0.12+ | 0.16- | 0.28- |
| | 300 | 6.00 | 5.99 | 0.01- | 6.06 | 6.03 | 0.03- | 5.80 | 0.06+ | 0.20- | 0.26- |
| | 500 | 5.90 | 5.96 | 0.06+ | 6.01 | 5.98 | 0.03- | 5.70 | 0.11+ | 0.20- | 0.31- |
| | 700 | 5.69 | 5.77 | 0.08+ | 5.82 | 6.06 | 0.24+ | 5.47 | 0.13+ | 0.22- | 0.35- |
| | 900 | 5.35 | 5.40 | 0.05+ | 5.52 | 5.44 | 0.08- | 5.16 | 0.17+ | 0.19- | 0.36- |
| | 1100 | 5.20 | 5.21 | 0.01+ | 5.36 | 5.41 | 0.05+ | 5.00 | 0.16+ | 0.20- | 0.36- |
| | 1300 | 5.35 | 5.34 | 0.01- | 5.48 | 5.44 | 0.04- | 5.20 | 0.13+ | 0.15- | 0.28- |
| | 1500 | 4.95 | 5.07 | 0.12+ | 5.12 | 5.44 | 0.32- | 4.72 | 0.17+ | 0.23- | 0.40- |
| | 1700 | 5.35 | 5.40 | 0.05+ | 5.51 | 5.46 | 0.05- | 5.03 | 0.16+ | 0.32- | 0.48- |
| | 1900 | 5.55 | 5.54 | 0.01- | 5.73 | 5.73 | 0.00 | 5.30 | 0.18+ | 0.25- | 0.43- |
| | 2100 | 5.80 | 5.76 | 0.04- | 5.92 | 5.88 | 0.04- | 5.53 | 0.12+ | 0.27- | 0.39- |
| | 2300 | 5.70 | 5.74 | 0.04+ | 5.83 | 5.80 | 0.03- | 5.38 | 0.13+ | 0.32- | 0.45- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-7 | 100 | 5.55 | 5.57 | 0.02+ | 5.68 | 5.63 | 0.05- | 5.24 | 0.13+ | 0.32- | 0.44- |
| | 300 | 5.31 | 5.34 | 0.03+ | 5.50 | 5.44 | 0.06- | 5.05 | 0.19+ | 0.25- | 0.45- |
| | 500 | 5.16 | 5.21 | 0.05+ | 5.38 | 5.34 | 0.04- | 4.78 | 0.22+ | 0.38- | 0.60- |
| | 700 | 5.30 | 5.30 | 0 | 4.98 | | | 5.07 | 0.32- | 0.23- | 0.09+ |
| | 900 | 5.25 | 5.27 | 0.02+ | 5.43 | 5.38 | 0.05- | 5.03 | 0.18+ | 0.22- | 0.40- |
| | 1100 | 5.40 | 5.40 | 0 | 5.53 | 5.49 | 0.04- | 5.11 | 0.13+ | 0.29- | 0.42- |
| | 1300 | 5.53 | 5.51 | 0.02- | 5.63 | 5.56 | 0.07- | 5.31 | 0.10+ | 0.22- | 0.32- |
| | 1500 | 5.65 | 5.67 | 0.02+ | 5.77 | 5.74 | 0.03- | 5.36 | 0.12+ | 0.29- | 0.41- |
| | 1700 | 5.70 | 5.72 | 0.02+ | 5.76 | 5.65 | 0.11- | 5.40 | 0.06+ | 0.30- | 0.36- |
| | 1900 | 5.30 | 5.31 | 0.01+ | 5.41 | 5.36 | 0.05- | 5.07 | 0.11+ | 0.23- | 0.34- |
| | 2100 | 5.37 | 5.37 | 0 | 5.52 | 5.49 | 0.03- | 5.78 | 0.15+ | 0.41+ | 0.26+ |
| | 2300 | 5.50 | 5.49 | 0.01- | 5.64 | 5.58 | 0.06- | 5.16 | 0.14+ | 0.34- | 0.48- |
| 4-8 | 100 | 5.47 | 5.50 | 0.03+ | 5.63 | 5.59 | 0.04- | 5.16 | 0.16+ | 0.31- | 0.47- |
| | 300 | 5.50 | 5.48 | 0.02- | 5.70 | 5.64 | 0.06- | 5.07 | 0.20+ | 0.43- | 0.63- |
| | 500 | 5.37 | 5.38 | 0.01+ | 5.58 | 5.53 | 0.05- | 5.01 | 0.21+ | 0.36- | 0.57- |
| | 700 | 5.35 | 5.39 | 0.04+ | 5.55 | 5.50 | 0.05- | 5.10 | 0.20+ | 0.25- | 0.45- |
| | 900 | 5.33 | 5.33 | 0 | 5.52 | 5.47 | 0.05- | 5.11 | 0.19+ | 0.41- | 0.60- |
| | 1100 | 5.35 | 5.40 | 0.05+ | 5.57 | 5.50 | 0.07- | 5.16 | 0.22+ | 0.19- | 0.41- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-8 cont | 1300 | 5.45 | 5.47 | 0.02+ | 5.62 | 5.58 | 0.04- | 5.22 | 0.17+ | 0.23- | 0.40- |
| | 1500 | 5.45 | 5.48 | 0.03+ | 5.64 | 5.58 | 0.06- | 5.49 | 0.19+ | 0.04+ | 0.15- |
| | 1700 | 5.50 | 5.52 | 0.02+ | 5.64 | 5.58 | 0.06- | 5.36 | 0.14+ | 0.14- | 0.28- |
| | 1900 | 5.45 | 5.49 | 0.04+ | 5.63 | 5.57 | 0.06- | 5.19 | 0.18+ | 0.26- | 0.44- |
| | 2100 | 5.30 | 5.35 | 0.05+ | 5.54 | 5.50 | 0.04- | 5.06 | 0.24+ | 0.24- | 0.48- |
| | 2300 | 5.45 | 5.47 | 0.02+ | 5.65 | 5.58 | 0.07- | 5.11 | 0.20+ | 0.34- | 0.54- |
| 4-9 | 100 | * | 5.47 | | * | 5.61 | | 5.12 | 0.21+ | 0.32- | 0.53- |
| | 300 | 5.50 | 5.52 | 0.02+ | 5.73 | 5.68 | 0.05- | 5.12 | 0.23+ | 0.38- | 0.61- |
| | 500 | 5.55 | 5.58 | 0.03+ | 5.76 | 5.73 | 0.03- | 5.14 | 0.21+ | 0.41- | 0.62- |
| | 700 | 5.50 | 5.55 | 0.05+ | 5.73 | 5.69 | 0.04- | 5.18 | 0.23+ | 0.32- | 0.55- |
| | 900 | 5.60 | 5.60 | 0 | 5.73 | 5.68 | 0.05- | 5.39 | 0.13+ | 0.21- | 0.34- |
| | 1100 | 5.65 | 5.67 | 0.02+ | 5.78 | 5.73 | 0.05- | 5.42 | 0.13+ | 0.23- | 0.36- |
| | 1300 | 5.65 | 5.67 | 0.02+ | * | 5.73 | | 5.41 | 0.12+ | 0.24- | 0.36- |
| | 1500 | 5.65 | 5.68 | 0.03+ | 5.77 | 5.73 | 0.04- | 5.28 | 0.12+ | 0.37- | 0.49- |
| | 1700 | 5.65 | 5.69 | 0.04+ | 5.80 | 5.74 | 0.06- | 5.32 | 0.15+ | 0.33- | 0.48- |
| | 1900 | 5.55 | 5.57 | 0.02+ | 5.67 | 5.63 | 0.04- | 5.31 | 0.12+ | 0.24- | 0.36- |
| | 2100 | 5.45 | 5.46 | 0.01+ | 5.55 | 5.51 | 0.04- | 5.18 | 0.10+ | 0.27- | 0.37- |
| | 2300 | 5.35 | 5.37 | 0.02+ | 5.49 | 5.44 | 0.05- | 5.18 | 0.14+ | 0.17- | 0.31- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-10 | 100 | 5.25 | 5.28 | 0.03+ | 5.42 | 5.38 | 0.04- | 5.04 | 0.17+ | 0.21- | 0.38- |
| | 300 | 5.25 | 5.27 | 0.02+ | 5.41 | 5.38 | 0.03- | 4.95 | 0.16- | 0.30- | 0.46- |
| | 500 | 5.30 | 5.33 | 0.03+ | 5.43 | 5.38 | 0.05- | 5.02 | 0.13+ | 0.28- | 0.41- |
| | 700 | 5.35 | 5.38 | 0.03+ | * | 5.44 | | 5.04 | 0.13+ | 0.31- | 0.44- |
| | 900 | 5.43 | 5.44 | 0.01+ | 5.53 | 5.49 | 0.04- | 5.11 | 0.10+ | 0.32- | 0.42- |
| | 1100 | 5.55 | 5.51 | 0.04- | 5.62 | 5.56 | 0.06- | 5.15 | 0.07+ | 0.40- | 0.47- |
| | 1300 | 5.95 | 6.00 | 0.05+ | 5.66 | 5.62 | 0.04- | 5.14 | 0.29- | 0.81- | 0.52- |
| | 1500 | 6.27 | 6.33 | 0.06+ | 5.66 | 5.63 | 0.03- | 5.32 | 0.61- | 0.95- | 0.34- |
| | 1700 | 5.92 | 5.94 | 0.02+ | 5.67 | 5.65 | 0.02- | 5.37 | 0.25- | 0.55- | 0.30- |
| | 1900 | 5.85 | 5.89 | 0.04+ | 5.81 | 5.77 | 0.04- | 5.26 | 0.04- | 0.59- | 0.55 |
| | 2100 | 5.85 | 5.86 | 0.01+ | 5.85 | 5.80 | 0.05- | 5.37 | 0 | 0.48- | 0.48- |
| | 2300 | 5.94 | 5.97 | 0.03+ | 5.96 | 5.92 | 0.04- | 5.52 | 0.02+ | 0.42- | 0.44- |
| 4-11 | 100 | 6.02 | 6.07 | 0.05 | 6.03 | 5.99 | 0.04- | 5.57 | 0.01+ | 0.45- | 0.46- |
| | 300 | 6.15 | 6.15 | 0 | 6.07 | 6.04 | 0.03- | 5.71 | 0.08- | 0.44- | 0.36- |
| | 500 | 6.15 | 6.16 | 0.01+ | 6.10 | 6.08 | 0.02- | 5.73 | 0.05- | 0.42- | 0.37- |
| | 700 | 6.15 | 6.17 | 0.02+ | 6.14 | 6.11 | 0.03- | 5.72 | 0.01- | 0.43- | 0.42- |
| | 900 | 5.95 | 5.97 | 0.02+ | 5.97 | 5.94 | 0.03- | 5.48 | 0.02+ | 0.47- | 0.49- |
| | 1100 | 5.97 | 6.00 | 0.03+ | 5.97 | 5.94 | 0.03- | 5.61 | 0 | 0.36- | 0.36- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-11 cont | 1300 | 6.15 | 6.07 | 0.08- | 5.98 | 5.98 | 0 | 5.69 | 0.17- | 0.46- | 0.29- |
| | 1500 | 6.05 | 6.06 | 0.01+ | 6.01 | 5.97 | 0.04- | 5.42 | 0.04- | 0.63- | 0.59- |
| | 1700 | 6.30 | 6.34 | 0.04+ | 6.05 | 6.02 | 0.03- | 5.59 | 0.25- | 0.71- | 0.46- |
| | 1900 | 6.32 | 6.35 | 0.03+ | 6.08 | 6.07 | 0.01- | 5.71 | 0.24- | 0.61- | 0.37- |
| | 2100 | 6.25 | 6.33 | 0.08+ | 6.16 | 6.15 | 0.01- | 5.74 | 0.09- | 0.51- | 0.42- |
| | 2300 | 6.42 | 6.46 | 0.04+ | 6.20 | 6.17 | 0.03- | 5.79 | 0.22- | 0.63- | 0.41- |
| 4-12 | 200 | 6.50 | 6.54 | 0.04+ | 6.19 | 6.16 | 0.03- | 5.82 | 0.31- | 0.68- | 0.37- |
| | 400 | 6.45 | 6.48 | 0.03+ | 6.20 | 6.16 | 0.04- | 5.80 | 0.25- | 0.65- | 0.40- |
| | 600 | 6.50 | 6.57 | 0.07+ | 6.21 | 6.15 | 0.06- | 5.82 | 0.29- | 0.68- | 0.39- |
| | 700 | 6.60 | 6.60 | 0.0 | 6.21 | 6.18 | 0.03- | 5.66 | 0.39- | 0.94- | 0.55- |
| | 900 | 6.55 | 6.60 | 0.05+ | 6.20 | 6.16 | 0.04- | 5.83 | 0.35- | 0.72- | 0.37- |
| | 1100 | 6.35 | 6.41 | 0.06+ | 6.00 | 5.92 | 0.08- | 5.65 | 0.35- | 0.76- | 0.35- |
| | 1300 | 6.10 | 6.15 | 0.05+ | 5.52 | 5.46 | 0.06- | 5.08 | 0.58- | 1.02- | 0.44- |
| | 1500 | | | | 5.46 | 5.39 | 0.07- | 5.04 | | | 0.42- |
| | 1700 | | | | 5.63 | 5.60 | 0.03- | 5.22 | | | 0.41- |
| | 1900 | | | | 5.65 | 5.63 | 0.02- | 4.90 | | | 0.75- |
| | 2100 | | | | 5.82 | 5.85 | 0.03+ | 5.02 | | | 0.80- |
| | 2300 | | | | 6.06 | 6.09 | 0.03+ | 5.77 | | | 0.29- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-13 | 100 | | | | 6.08 | 6.03 | 0.05- | 5.42 | | | 0.66- |
| | 300 | | | | 6.09 | 6.04 | 0.05- | 5.56 | | | 0.53- |
| | 500 | | | | 6.00 | 5.97 | 0.03- | 5.47 | | | 0.53- |
| | 700 | | | | 5.95 | 5.94 | 0.05- | 5.52 | | | 0.43- |
| | 900 | | | | 5.98 | 5.56 | 0.42- | 5.11 | | | 0.87- |
| | 1100 | | | | 5.57 | 5.52 | 0.05- | 5.12 | | | 0.45- |
| | 1300 | | | | 5.99 | 5.54 | 0.05- | 5.09 | | | 0.50- |
| | 1500 | | | | 5.62 | 5.57 | 0.05- | 5.03 | | | 0.59- |
| | 1700 | | | | 5.87 | 5.80 | 0.07- | 5.43 | | | 0.44- |
| | 1900 | | | | 5.70 | 5.67 | 0.03- | 5.11 | | | 0.59- |
| | 2100 | | | | 5.69 | 5.66 | 0.03- | 5.02 | | | 0.67- |
| | 2300 | | | | 5.91 | 5.56 | 0.35- | 5.26 | | | 0.65- |
| 4-14 | 100 | | | | 5.98 | 5.92 | 0.06- | | | | |
| | 300 | | | | 5.99 | 5.92 | 0.07- | | | | |
| | 500 | | | | 5.76 | 5.68 | 0.08- | | | | |
| | 700 | | | | 5.63 | 5.57 | 0.06- | | | | |
| | 900 | | | | 5.66 | 5.61 | 0.05- | | | | |
| | 1100 | | | | 5.74 | 5.71 | 0.03- | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | ΔpH ± (#2-#1) | ΔpH ± (#3-#1) | ΔpH ± (#3-#2) |
| 4-14 cont | 1300 | | | | 5.74 | 5.79 | 0.05+ | | | | |
| | 1500 | | | | 5.79 | 5.75 | 0.04- | | | | |
| | 1700 | | | | 5.73 | 5.68 | 0.05- | | | | |
| | 1900 | | | | 5.76 | 5.72 | 0.04- | | | | |
| | 2100 | | | | 5.89 | 5.87 | 0.02- | | | | |
| | 2300 | | | | 6.01 | 5.93 | 0.08- | | | | |
| 4-15 | 100 | | | | 5.96 | 5.92 | 0.04- | 5.43 | | | 0.53- |
| | 300 | | | | 5.68 | 5.67 | 0.01- | 5.14 | | | 0.54- |
| | 500 | | | | 5.78 | 5.73 | 0.05- | 5.24 | | | 0.54- |
| | 700 | | | | 5.81 | 5.77 | 0.04- | 5.19 | | | 0.62- |
| | 900 | | | | 5.78 | 5.73 | 0.05- | 5.27 | | | 0.51- |
| | 1100 | | | | 5.81 | 5.75 | 0.06- | 5.33 | | | 0.48- |
| | 1300 | | | | 5.61 | 5.56 | 0.05- | 5.15 | | | 0.46- |
| | 1500 | | | | 5.62 | 5.59 | 0.03- | 5.08 | | | 0.54- |
| | 1700 | | | | 5.71 | 5.67 | 0.04- | 5.02 | | | 0.69- |
| | 1900 | | | | 5.83 | 5.79 | 0.04- | 5.29 | | | 0.54- |
| | 2100 | | | | 5.90 | 5.86 | 0.04- | 5.37 | | | 0.53- |
| | 2300 | | | | 5.76 | 5.74 | 0.02- | 5.05 | | | 0.71- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-16 | 100 | | | | 5.82 | 5.80 | 0.02- | 5.33 | | | 0.51- |
| | 300 | | | | 5.78 | 5.76 | 0.02- | 5.32 | | | 0.46- |
| | 500 | | | | 5.66 | 5.62 | 0.04- | 5.17 | | | 0.49- |
| | 700 | | | | 5.68 | 5.63 | 0.05- | 5.04 | | | 0.64- |
| | 900 | | | | 5.78 | 5.75 | 0.03- | 5.22 | | | 0.56- |
| | 1100 | | | | 5.96 | 5.93 | 0.03- | 5.30 | | | 0.66- |
| | 1300 | | | | 5.80 | 5.74 | 0.06- | 5.20 | | | 0.60- |
| | 1500 | 5.87 | | | 5.68 | 5.62 | 0.06- | 5.01 | | | 0.67- |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |
| | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 4-17 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-17 cont | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | | | | | | | |
| | 2100 | | | | | | | | | | |
| | 2300 | | | | | | | | | | |
| 4-18 | 100 | | | | | | | | | | |
| | 300 | | | | | | | | | | |
| | 500 | | | | | | | | | | |
| | 700 | | | | | | | | | | |
| | 900 | | | | | | | | | | |
| | 1100 | | | | | | | | | | |
| | 1300 | | | | | | | | | | |
| | 1500 | | | | | | | | | | |
| | 1700 | | | | | | | | | | |
| | 1900 | | | | 7.60 | | | | | | |
| | 2100 | | | | 6.13 | 6.10 | 0.03- | 5.45 | | | 0.68- |
| | 2300 | 6.30 | | | 6.27 | 6.22 | 0.05- | 5.56 | 0.03- | 0.74- | 0.71- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| | | Self-Cleaning | | | Standard | | | Lab Measurements | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | ΔpH ± (#2-#1) | ΔpH ± (#3-#1) | ΔpH ± (#3-#2) |
| 4-19 | 100 | 6.35 | | | 6.31 | 6.28 | 0.03- | 5.47 | 0.04- | 0.88- | 0.84- |
| | 300 | 6.40 | | | 6.17 | 6.18 | 0.01+ | 5.58 | 0.23- | 0.82- | 0.59- |
| | 500 | 6.45 | | | 6.21 | 6.22 | 0.01+ | 5.68 | 0.24- | 0.77- | 0.53- |
| | 700 | 6.55 | | | 6.29 | 6.22 | 0.07- | 5.45 | 0.26- | 1.10- | 0.84- |
| | 900 | 6.55 | | | 6.24 | 6.22 | 0.02- | 5.36 | 0.31- | 1.19- | 0.88- |
| | 1100 | OUT | | | 6.24 | 6.22 | 0.02- | 5.55 | | | 0.69- |
| | 1300 | OUT | | | 6.24 | 6.21 | 0.03- | 5.49 | | | 0.75- |
| | 1500 | OUT | | | 6.22 | 6.21 | 0.01- | 5.66 | | | 0.56- |
| | 1700 | | | | 6.21 | 6.18 | 0.03- | 5.59 | | | 0.62- |
| | 1900 | | | | 6.24 | 6.22 | 0.02- | 5.52 | | | 0.72- |
| | 2100 | | | | 6.33 | 6.29 | 0.04- | 5.52 | | | 0.81- |
| | 2300 | | | | 6.31 | 6.29 | 0.02- | 5.50 | | | 0.81- |
| 4-20 | 100 | | | | * | 6.34 | | 5.53 | | | 0.85- |
| | 300 | | | | * | 6.35 | | 5.60 | | | 0.79- |
| | 500 | | | | * | 6.07 | | 5.56 | | | 0.55- |
| | 700 | | | | 6.07 | 6.05 | 0.02- | 5.49 | | | 0.58- |
| | 900 | | | | 5.58 | 5.44 | 0.14- | 5.66 | | | 0.92- |
| | 1100 | | | | 5.51 | 5.47 | 9.04- | 5.14 | | | 0.37- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-20 cont | 1300 | | | | 5.49 | 5.44 | 0.05- | 5.55 | | | 0.06+ |
| | 1600 | 5.50 | | | 5.47 | 5.44 | 0.03- | 5.58 | 0.03- | 0.08+ | 0.11+ |
| | 1700 | 5.36 | | | 5.47 | 5.43 | 0.04- | 5.52 | 0.11+ | 0.16+ | 0.05+ |
| | 1900 | 5.45 | | | 5.49 | 5.46 | 0.03- | 5.56 | 0.04+ | 0.11+ | 0.07+ |
| | 2100 | 5.60 | | | 5.49 | 5.45 | 0.04- | 5.55 | 0.11- | 0.05- | 0.06+ |
| | 2300 | 5.50 | | | 5.45 | 5.40 | 0.05- | 5.48 | 0.05- | 0.02- | 0.03+ |
| 4-21 | 100 | 5.30 | | | 5.41 | 5.35 | 0.06- | 5.45 | 0.11+ | 0.15+ | 0.04+ |
| | 300 | 5.05 | | | 5.40 | 5.35 | 0.05- | 5.45 | 0.35+ | 0.40+ | 0.05+ |
| | 500 | 5.10 | | | * | 5.29 | | 5.39 | 0.23+ | 0.29+ | 0.06+ |
| | 700 | | | | 5.30 | 5.26 | 0.04- | 5.22 | | | 0.08- |
| | 900 | | | | 5.28 | 5.25 | 0.03- | 5.18 | | | 0.10- |
| | 1100 | | | | 5.58 | 5.53 | 0.05- | 5.13 | | | 0.45- |
| | 1300 | 5.15 | | | 5.25 | 5.21 | 0.04- | 5.25 | 0.10+ | 0.10+ | 0 |
| | 1500 | 5.10 | | | 5.20 | 5.16 | 0.04- | 5.26 | 0.10+ | 0.16+ | 0.06+ |
| | 1700 | 5.10 | | | 5.18 | 5.14 | 0.04- | 5.15 | 0.08+ | 0.05+ | 0.03- |
| | 1900 | 5.05 | | | 5.21 | 5.13 | 0.08- | 5.07 | 0.16+ | 0.02+ | 0.14- |
| | 2100 | 4.90 | | | 5.29 | 5.18 | 0.11- | 5.23 | 0.39+ | 0.33+ | 0.06- |
| | 2300 | 5.10 | | | 5.32 | 5.27 | 0.05- | 5.05 | 0.22+ | 0.05- | 0.27- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-22 | 100 | 5.10 | | | 5.35 | 5.32 | 0.03- | 5.16 | 0.25+ | 0.06+ | 0.19- |
| | 300 | 5.05 | | | * | 5.35 | | 5.35 | 0.34+ | 0.30+ | 0.04- |
| | 500 | 4.95 | | | * | 5.27 | | 5.26 | 0.36+ | 0.31+ | 0.05- |
| | 700 | 4.85 | | | 5.30 | 5.21 | 0.09- | 5.20 | 0.45+ | 0.35+ | 0.10- |
| | 900 | 4.85 | | | 5.15 | 5.14 | 0.01- | 5.21 | 0.30+ | 0.36+ | 0.06+ |
| | 1100 | 4.92 | | | 5.15 | 5.11 | 0.04- | 5.05 | 0.23+ | 0.13+ | 0.10- |
| | 1300 | 4.84 | | | 5.20 | 5.20 | 0 | 5.02 | 0.36+ | 0.18+ | 0.18- |
| | 1500 | 4.95 | | | * | 5.37 | | 5.16 | 0.46+ | 0.21+ | 0.25- |
| | 1700 | 5.19 | | | * | 5.43 | | 5.22 | 0.28+ | 0.03+ | 0.25- |
| | 1900 | 5.20 | | | * | 5.50 | | 5.56 | 0.34+ | 0.36+ | 0.02+ |
| | 2100 | 5.15 | | | * | 5.49 | | 5.54 | 0.38+ | 0.39+ | 0.01+ |
| | 2300 | 5.10 | | | * | 5.47 | | 5.59 | 0.41 | 0.49+ | 0.08+ |
| 4-23 | 100 | 5.15 | | | * | 5.47 | | 5.45 | 0.36+ | 0.30+ | 0.06- |
| | 300 | 5.10 | | | * | 5.40 | | 5.35 | 0.34+ | 0.25+ | 0.09- |
| | 500 | 5.00 | | | * | 5.39 | | 5.36 | 0.43+ | 0.36+ | 0.07- |
| | 700 | 4.91 | | | *5.25 | 5.35 | | 5.39 | 0.48+ | 0.48+ | 0.00 |
| | 900 | 4.92 | | | *5.82 | 6.22 | | 5.26 | 1.34+ | 0.34+ | 1.00- |
| | 1100 | 4.95 | | | *5.81 | 5.40 | | 5.51 | 0.49+ | 0.56+ | 0.07+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements #3 | ΔpH ± (#2-#1) | ΔpH ± (#3-#1) | ΔpH ± (#3-#2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | | | | |
| 4-23 cont | 1300 | 4.95 | | | *5.82 | 5.35 | | 5.40 | 0.44+ | 0.45+ | 0.01+ |
| | 1500 | 4.90 | | | *5.83 | 5.31 | | 5.40 | 0.45+ | 0.50+ | 0.05+ |
| | 1700 | 4.80 | | | *5.86 | 5.27 | | 5.33 | 0.51+ | 0.53+ | 0.02+ |
| | 1900 | 4.90 | | | *5.91 | 5.32 | | 5.07 | 0.46+ | 0.17+ | 0.29- |
| | 2100 | 5.00 | | | *5.96 | 5.42 | | 5.15 | 0.46+ | 0.15+ | 0.31- |
| | 2300 | 5.05 | | | *6.01 | 5.38 | | 5.33 | 0.37+ | 0.28+ | 0.09- |
| 4-24 | 100 | 5.07 | | | *6.08 | 5.38 | | 5.23 | 0.35+ | 0.16+ | 0.19- |
| | 300 | 5.00 | | | *6.09 | 5.35 | | 5.33 | 0.39+ | 0.33+ | 0.06- |
| | 500 | 4.95 | | | *6.08 | 5.27 | | 5.25 | 0.36+ | 0.30+ | 0.06- |
| | 700 | 4.80 | | | *6.04 | 5.15 | | 5.21 | 0.39+ | 0.41+ | 0.02+ |
| | 900 | 4.90 | | | *6.04 | 4.96 | | 5.43 | 0.10+ | 0.53+ | 0.43+ |
| | 1100 | 5.05 | | | *6.11 | 5.37 | | 5.34 | 0.36+ | 0.29+ | 0.07- |
| | 1300 | 5.20 | | | *6.14 | 5.50 | | 5.47 | 0.34+ | 0.27+ | 0.07+ |
| | 1500 | 5.20 | | | *6.06 | 5.50 | | 5.58 | 0.34+ | 0.38+ | 0.04+ |
| | 1700 | 5.20 | | | *6.08 | 5.50 | | 5.67 | 0.34+ | 0.47+ | 0.13+ |
| | 1900 | 5.15 | | | *6.06 | 5.49 | | 5.59 | 0.38+ | 0.44+ | 0.06+ |
| | 2100 | 5.15 | | | *6.14 | 5.47 | | 5.54 | 0.35+ | 0.39+ | 0.03+ |
| | 2300 | 5.12 | | | * | 5.45 | | 5.52 | 0.34+ | 0.40+ | 0.06+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-25 | 100 | 5.00 | | | *6.11 | 5.37 | | 5.41 | 0.41+ | 0.41+ | 0.00 |
| | 300 | 4.92 | | | *6.00 | 5.32 | | 5.28 | 0.44+ | 0.36+ | 0.08- |
| | 500 | 4.90 | | | * | 5.47 | | 5.22 | 0.61+ | 0.32+ | 0.29- |
| | 700 | 5.00 | | | * | 5.39 | | 5.33 | 0.40+ | 0.33+ | 0.07- |
| | 900 | 5.05 | | | * | 5.75 | | 5.36 | 0.74+ | 0.31+ | 0.43- |
| | 1100 | 5.15 | | | 6.06 | 5.94 | 0.08- | 5.66 | 0.91+ | 0.51+ | 0.40- |
| | 1300 | 5.10 | | | 6.16 | 5.94 | 0.22- | 5.58 | 1.06+ | 0.48+ | 0.58- |
| | 1500 | 5.15 | | | 6.24 | 5.95 | 0.29- | 5.52 | 1.09+ | 0.37+ | 0.72- |
| | 1700 | 5.05 | | | 6.26 | 5.97 | 0.29- | 5.47 | 1.21+ | 0.42+ | 0.79- |
| | 1900 | 4.85 | | | 6.27 | 5.99 | 0.28- | 5.39 | 1.42+ | 0.54+ | 0.88- |
| | 2100 | 4.70 | | | 6.10 | 6.02 | 0.08- | 5.30 | 1.40+ | 0.60+ | 0.80- |
| | 2300 | 4.70 | | | 6.03 | 6.10 | 0.07+ | 5.06 | 1.33+ | 0.36+ | 0.97- |
| 4-26 | 100 | 4.75 | | | 5.99 | 5.86 | 0.13- | 5.15 | 1.24+ | 0.40+ | 0.84- |
| | 300 | 4.90 | | | 5.95 | 5.86 | 0.09- | 5.48 | 1.05+ | 0.58+ | 0.47- |
| | 500 | 5.05 | | | 5.89 | 5.89 | 0 | 5.53 | 0.84+ | 0.48+ | 0.36- |
| | 700 | 4.95 | | | 5.75 | 5.92 | 0.17+ | 5.37 | 0.80+ | 0.42+ | 0.38- |
| | 900 | 5.00 | | | 5.67 | 5.48 | 0.19- | 5.45 | 0.67+ | 0.45+ | 0.22- |
| | 1100 | 5.10 | | | 5.61 | 5.51 | 0.10- | 5.66 | 0.51+ | 0.56+ | 0.05+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-26 cont | 1300 | 5.15 | | | 5.64 | 5.54 | 0.10- | 5.71 | 0.49+ | 0.56+ | 0.07+ |
| | 1500 | 5.15 | | | 5.75 | 5.41 | 0.34- | 5.49 | 0.60+ | 0.34+ | 0.26- |
| | 1700 | 4.85 | | | 5.86 | 5.23 | 0.63- | 5.42 | 1.01+ | 0.57+ | 0.44- |
| | 1900 | 4.70 | | | * | 5.15 | | 5.16 | 0.49+ | 0.46+ | 0.03- |
| | 2100 | 4.65 | | | * | 5.11 | | 5.24 | 0.50+ | 0.59+ | 0.09+ |
| | 2300 | 4.58 | | | 5.12 | 5.08 | 0.04- | 4.98 | 0.54+ | 0.40+ | 0.14- |
| 4-27 | 100 | 4.52 | | | 5.11 | 5.05 | 0.06- | 5.19 | 0.59+ | 0.67+ | 0.08+ |
| | 300 | 4.45 | | | 5.03 | 4.98 | 0.05- | 5.08 | 0.58+ | 0.63+ | 0.05+ |
| | 500 | 4.54 | | | 5.12 | 5.05 | 0.07- | 5.09 | 0.58+ | 0.55+ | 0.03- |
| | 700 | 4.55 | | | 5.13 | 5.09 | 0.04- | 5.12 | 0.58+ | 0.57+ | 0.01- |
| | 900 | 4.70 | | | 5.27 | 5.20 | 0.07- | 5.32 | 0.57+ | 0.62+ | 0.05+ |
| | 1100 | 4.80 | | | 5.26 | 5.20 | 0.06- | 5.20 | 0.46+ | 0.40+ | 0.06- |
| | 1300 | | | | | | | | | | |
| | 1500 | | | | 6.22 | 5.32 | 0.90- | 6.62 | | | 0.40+ |
| | 1700 | 5.76 | | | 6.17 | 6.16 | 0.01- | 6.34 | 0.41+ | 0.58+ | 0.17+ |
| | 1900 | 6.00 | | | 6.08 | 6.10 | 0.02+ | 6.46 | 0.08+ | 0.46+ | 0.38+ |
| | 2100 | 5.70 | | | 5.85 | 6.10 | 0.25+ | 6.23 | 0.15+ | 0.53+ | 0.38+ |
| | 2300 | 5.40 | | | 5.87 | 5.89 | 0.02+ | 5.89 | 0.47+ | 0.49+ | 0.02+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-28 | 100 | 5.25 | | | 5.32 | 5.98 | 0.66+ | 5.66 | 0.07+ | 0.41+ | 0.34+ |
| | 300 | 5.85 | | | 5.87 | 6.04 | 0.17+ | 6.02 | 0.02+ | 0.17+ | 0.15+ |
| | 500 | 6.00 | | | 5.94 | 6.16 | 0.22+ | 6.18 | 0.06- | 0.18+ | 0.24+ |
| | 700 | 6.41 | | | 6.84 | 6.25 | 0.59- | 6.66 | 0.43+ | 0.25+ | 0.18- |
| | 900 | 5.98 | | | 6.33 | 6.40 | 0.07+ | 6.30 | 0.35+ | 0.32+ | 0.03- |
| | 1100 | 5.85 | | | * | 6.40 | | 6.33 | 0.59+ | 0.48+ | 0.11- |
| | 1300 | 5.85 | | | 5.89 | 6.19 | 0.30+ | 6.20 | 0.04+ | 0.35+ | 0.31+ |
| | 1500 | 5.50 | | | 5.48 | 5.89 | 0.41+ | 5.88 | 0.02- | 0.38+ | 0.40+ |
| | 1700 | 6.00 | | | 6.05 | 6.16 | 0.11+ | 6.25 | 0.05+ | 0.25+ | 0.20+ |
| | 1900 | 6.27 | | | 6.44 | 6.04 | 0.44- | 6.55 | 0.17+ | 0.28+ | 0.11+ |
| | 2100 | 5.30 | | | 5.37 | 5.92 | 0.55+ | 5.69 | 0.07+ | 0.39+ | 0.32+ |
| | 2300 | | | | 5.74 | 6.16 | 0.42+ | 5.80 | | | 0.06+ |
| 4-29 | 100 | | | | 7.30 | 6.22 | 1.12- | 6.79 | | | 0.51- |
| | 300 | | | | 5.01 | 4.96 | 0.05- | 5.46 | | | 0.45+ |
| | 500 | 5.90 | | | 5.92 | 5.91 | 0.01- | 6.12 | 0.02+ | 0.22+ | 0.20+ |
| | 700 | 5.70 | | | 6.06 | 5.92 | 0.06- | 6.02 | 0.36+ | 0.32+ | 0.04- |
| | 900 | 5.05 | | | 5.40 | 5.26 | 0.14- | 5.58 | 0.35+ | 0.53+ | 0.18+ |
| | 1100 | 6.35 | | | 6.7 | 6.10 | 0.6- | 6.50 | 0.35+ | 0.15+ | 0.20- |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 4-29 cont | 1300 | 5.40 | | | 5.72 | 5.80 | 0.08+ | 5.70 | 0.32+ | 0.30+ | 0.02- |
| | 1500 | 5.25 | | | 5.59 | 5.74 | 0.15+ | 5.83 | 0.34+ | 0.58+ | 0.24+ |
| | 1700 | 6.05 | | | 6.16 | 6.16 | 0 | 6.23 | 0.11+ | 0.18+ | 0.07+ |
| | 1900 | 5.90 | | | 6.00 | 6.10 | 0.10+ | 6.05 | 0.10+ | 0.15+ | 0.05+ |
| | 2100 | 5.65 | | | 5.80 | 6.10 | 0.30+ | 6.00 | 0.15+ | 0.35+ | 0.20+ |
| | 2300 | 6.00 | | | 6.21 | 6.34 | 0.13+ | 6.25 | 0.21+ | 0.25+ | 0.04+ |
| | | | | | NEW RECORDER | | | | | | |
| 4-30 | 100 | 5.60 | | | 5.83 | 5.90 | 0.07+ | 5.98 | 0.23+ | 0.38+ | 0.15+ |
| | 300 | 6.20 | | | 6.16 | 6.00 | 0.16- | 6.33 | 0.04- | 0.13+ | 0.17+ |
| | 500 | 6.30 | | | 6.29 | 5.85 | 0.44- | 6.45 | 0.01- | 0.15+ | 0.16+ |
| | 700 | 6.50 | | | 6.26 | 6.21 | 0.05- | 6.46 | 0.30- | 0.04- | 0.26+ |
| | 900 | 6.05 | | | 6.20 | 6.28 | 0.08+ | 6.25 | 0.15+ | 0.20+ | 0.05+ |
| | 1100 | 5.60 | | | 5.50 | 5.43 | 0.07- | 5.94 | 0.10- | 0.34+ | 0.44+ |
| | 1300 | 6.35 | | | 6.34 | 6.15 | 0.19- | 6.57 | 0.01- | 0.22+ | 0.23+ |
| | 1500 | 6.55 | | | 6.75 | 6.40 | 0.35- | 6.88 | 0.20+ | 0.33+ | 0.13+ |
| | 1700 | 6.00 | | | 5.82 | 5.60 | 0.22- | 6.14 | 0.18- | 0.14+ | 0.32+ |
| | 1900 | 5.90 | | | 5.72 | 5.60 | 0.12- | 5.99 | 0.18- | 0.09+ | 0.27+ |
| | 2100 | 5.90 | | | 5.87 | 5.70 | 0.17- | 6.15 | 0.03- | 0.25+ | 0.28+ |
| | 2300 | 5.80 | | | 5.55 | 5.55 | 0 | 5.98 | 0.25- | 0.18+ | 0.43+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 5-1 | 100 | 5.50 | | | 5.28 | 5.50 | 0.22+ | 5.63 | 0.22- | 0.13+ | 0.35+ |
| | 300 | 5.85 | | | 5.99 | 6.30 | 0.31+ | 5.77 | 0.14+ | 0.08- | 0.22- |
| | 500 | 5.75 | | | 5.66 | 5.49 | 0.17- | 6.04 | 0.09- | 0.29+ | 0.38+ |
| | 700 | 5.90 | | | 5.69 | 5.50 | 0.19- | 6.25 | 0.21- | 0.35+ | 0.56+ |
| | 900 | 5.75 | | | 5.83 | 6.35 | 0.48- | 5.92 | 0.08+ | 0.17+ | 0.09+ |
| | 1100 | 6.11 | | | 5.97 | 5.21 | 0.76- | 6.39 | 0.14- | 0.28+ | 0.42+ |
| | 1300 | 6.04 | | | 5.89 | 5.73 | 0.16- | 6.20 | 0.15- | 0.16+ | 0.31+ |
| | 1500 | 6.20 | | | 5.92 | 5.70 | 0.22- | 6.24 | 0.28- | 0.04+ | 0.32+ |
| | 1700 | 6.20 | | | 5.73 | 5.50 | 0.23- | 6.13 | 0.47- | 0.07- | 0.40+ |
| | 1900 | 6.05 | | | 5.47 | 5.30 | 0.17- | 6.16 | 0.58- | 0.11+ | 0.69+ |
| | 2100 | 6.00 | | | 5.54 | 5.37 | 0.17- | 5.95 | 0.46- | 0.05- | 0.41+ |
| | 2300 | 5.75 | | | 5.60 | 5.45 | 0.15- | 6.02 | 0.15- | 0.27+ | 0.42+ |
| 5-2 | 100 | 5.85 | | | 5.51 | 5.50 | 0.01- | 6.05 | 0.34- | 0.20+ | 0.54+ |
| | 300 | 5.95 | | | 5.89 | 5.60 | 0.29- | 6.03 | 0.06- | 0.08+ | 0.14+ |
| | 500 | 6.10 | | | 6.05 | 5.80 | 0.25- | 6.23 | 0.05- | 0.13+ | 0.18+ |
| | 700 | 6.10 | | | 5.97 | 5.97 | 0 | 6.13 | 0.13- | 0.03+ | 0.16+ |
| | 900 | 5.90 | | | 5.73 | 5.31 | 0.42- | 6.10 | 0.17- | 0.20+ | 0.37+ |
| | 1100 | 5.93 | | | 5.54 | 5.47 | 0.07- | 6.06 | 0.39- | 0.13+ | 0.52+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

TABLE B. DATA FROM pH ELECTRODE EVALUATION TEST (pH UNITS) (Continued)

| Date | Time | Self-Cleaning | | | Standard | | | Lab Measurements | ΔpH ± | ΔpH ± | ΔpH ± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Meter #1 | Chart #1 | ΔpH ± | Meter #2 | Chart #2 | ΔpH ± | #3 | (#2-#1) | (#3-#1) | (#3-#2) |
| 5-2 cont | 1300 | 5.79 | | | 5.42 | 5.70 | 0.28+ | 6.03 | 0.37- | 0.24+ | 0.61+ |
| | 1500 | 5.80 | | | 5.45 | 5.40 | 0.05- | 5.93 | 0.35- | 0.13+ | 0.48+ |
| | 1700 | 6.10 | | | 6.10 | 5.87 | 0.23- | 6.38 | 0 | 0.28+ | 0.28+ |
| | 1900 | 6.05 | | | 5.81 | 5.60 | 0.21- | 6.13 | 0.24- | 0.08+ | 0.32+ |
| | 2100 | 6.00 | | | 5.85 | 5.50 | 0.35- | 6.18 | 0.15- | 0.18+ | 0.33+ |
| | 2300 | 5.70 | | | 5.42 | 5.25 | 0.17- | 5.80 | 0.28- | 0.10+ | 0.38+ |
| 5-3 | 100 | 5.90 | | | 5.70 | 5.57 | 0.27- | 6.04 | 0.20- | 0.14+ | 0.34+ |
| | 300 | 6.35 | | | 6.40 | 5.80 | 0.60- | 6.49 | 0.05+ | 0.14+ | 0.09+ |
| | 500 | 6.30 | | | 6.47 | 5.95 | 0.52- | 6.19 | 0.17+ | 0.11- | 0.28- |
| | 700 | 5.75 | | | 5.45 | 5.40 | 0.05- | 5.95 | 0.30- | 0.20+ | 0.50+ |
| | 900 | 5.97 | | | 5.69 | 5.20 | 0.49- | 5.93 | 0.28- | 0.04- | 0.24+ |
| | 1100 | | | | 6.18 | 5.60 | 0.58- | 6.62 | | | 0.44+ |
| | 1300 | | | | 5.33 | 5.20 | 0.13- | 5.63 | | | 0.30+ |
| | 1500 | | | | 5.72 | 5.40 | 0.32- | 6.16 | | | 0.44+ |
| | 1700 | | | | 5.37 | 5.80 | 0.43+ | 5.86 | | | 0.49+ |
| | 1900 | | | | 6.27 | 6.15 | 0.12- | 6.47 | | | 0.20+ |
| | 2100 | | | | 5.41 | 5.20 | 0.21- | 6.04 | | | 0.63+ |
| | 2300 | | | | 5.44 | 5.70 | 0.26+ | 6.05 | | | 0.61+ |

*In cases with no meter readings, the ΔpH arithmetic average (difference between meter vs. chart readings) was added/subtracted from the chart readings.

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-600/2-79-202 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| The Use of pH and Chloride Electrodes for the Automatic Control of Flue Gas Desulfurization Systems | November 1979 |
| | 6. PERFORMING ORGANIZATION CODE |

| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
|---|---|
| Clinton Ung, Toby Acciani, and Ray Maddalone | |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
|---|---|
| TRW Defense and Space Systems Group<br>One Space Park<br>Redondo Beach, California 90278 | INE624 |
| | 11. CONTRACT/GRANT NO. |
| | 68-02-2165, Task 220 |

| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
|---|---|
| EPA, Office of Research and Development<br>Industrial Environmental Research Laboratory<br>Research Triangle Park, NC 27711 | Task Final; 9/78 - 7/79 |
| | 14. SPONSORING AGENCY CODE |
| | EPA/600/13 |

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Frank E. Briden, Mail Drop 62, 919/541-2557.

16. ABSTRACT The report gives results of a study to determine the applicability of chloride and pH electrodes in automated control systems. It included a survey of chloride and pH electrodes in different flue gas desulfurization (FGD) systems and an evaluation of an industrial pH electrode system. The survey showed that chloride ion measurements were necessary only where high chloride values correspond with FGD unit corrosion and when chloride values were used as correction factors in pH calculations. Chloride ion measurements are unnecessary for most of the surveyed companies. All surveyed companies use pH measurements to control scaling or to attain optimum performance in FGD units. The most common pH electrode problem was residue buildup (scaling) around the electrode, caused by the use of non-self-cleaning (standard) pH electrodes. The performance of self-cleaning and standard industrial pH electrodes was evaluated at the EPA/TVA Shawnee FGD test facility. The electrodes were tested during a 7-week period with varying durations of continuous operation. The tests showed that: the performance of self-cleaning and standard electrodes was nearly identical, and the benefits of a self-cleaning pH electrode can only be realized if electrode scaling is a problem and if a long (2-week) continuous period of pH electrode operation is maintained.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Pollution<br>Flue Gases<br>Desulfurization<br>Automatic Control<br>Electrodes<br>pH<br>Chlorides<br>Corrosion Prevention | Pollution Control<br>Stationary Sources | 13B 07B<br>21B 13H<br>07A, 07D<br>14B<br>09A |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
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| | Unclassified | |

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