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Instruction Manual

**HI 4003**  
**HI 4103**

Cadmium Ion  
Selective Electrode

Half-cell  
Combination

## **HI 4003 Cadmium Half-cell**

## **HI 4103 Cadmium Combination Electrode**

### **I. Introduction:**

The Hanna HI 4003 and HI 4103 are ion selective electrodes designed for the measurement of cadmium ions in aqueous solutions. The HI 4003 is a solid state half-cell sensor that requires a separate reference. The HI 4103 is a combination ion selective electrode.

### **II. Specifications**

Type: Solid State electrode with a Cadmium sulfide/ silver sulfide membrane.

Ion(s) measured: Cadmium ( $\text{Cd}^{2+}$ )

Measurement range: 0.1 M to  $1 \times 10^{-7}$  M  
11,200 to 0.01 ppm

Interfering ions: Silver and mercury must be absent. Any ion that forms a more insoluble sulfide than cadmium sulfide will interfere with the electrode response. These include lead ( $\text{Pb}^{2+}$ ) and cupric ions ( $\text{Cu}^{2+}$ ). Oxidation of the cadmium surface by ferric ion ( $\text{Fe}^{3+}$ ) will severely poison the electrode. Ions that can form complexes with cadmium ions will reduce the measured concentration. Examples include bromide, chloride and EDTA.

Operating Temperature: 0-80°C

Operating pH: 2 to 12 pH  
concentration dependant  
(4.5-7.5 recommended)

Dimensions: 12 mm (OD) X 120 mm  
nominal insertion  
(0.47" X 4.72")

Connection: BNC

### **III. Theory of Operation:**

The HI 4103 or HI 4103 cadmium electrodes are potentiometric devices used for the rapid determination of free cadmium ions in samples and as a detector for the titration of cadmium with EDTA. Cadmium sensors are “electrodes of the third kind” because they detect cations which also form low-solubility salts with sulfide anions that also form low-solubility salts with silver.

The electrode functions as a sensor or ionic conductor. The HI 4003 requires a separate reference electrode to complete its electrolytic circuit. The HI 4103 incorporates a reference electrode. The mixed cadmium sulfide/silver sulfide membrane produces a potential change due to changes in the sample's cadmium ion activity. When the ionic strength of the sample is fixed by the addition of ISA, the voltage is proportional to the concentration of cadmium ions in solution and the electrode follows the Nernst equation.

$$E = E_0 + 2.3 \frac{RT}{nF} \log A_{\text{ion}}$$

E = observed potential

$E_0$  = Reference and fixed internal voltages

R = gas constant (8.314 volt coulomb/K Mole)

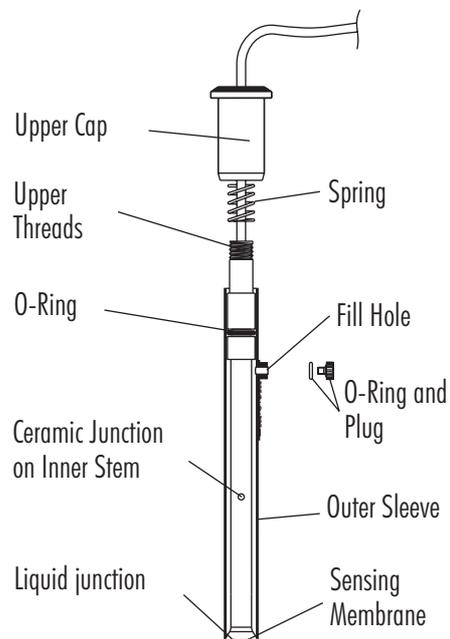
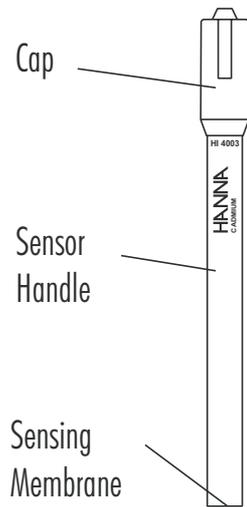
n = Charge on cadmium ion (2+)

$A_i$  = ion activity in sample

T = absolute temperature in K

F = Faraday constant ( $9.648 \times 10^4$  coulomb/mole)

**IV. Design elements of the HI 4003 and HI 4103 electrodes**



#### **V. Equipment required:**

- Hanna HI 5315 Double Junction Reference Electrode with HI 7072 Fill Solution for use with HI 4003 half-cell.
- Hanna HI 4222 pH/ISE/mV meter or other suitable ion or pH/mV meter. (Note: log/linear graph paper is useful if an ISE (ion) meter is not available).
- Hanna HI 180 Magnetic Stirrer or equivalent with TFE coated stirring bars (HI 731320). Note: isolate beakers from stirrer motor heat by placing insulating material such as foam or cork between them.
- Hanna HI 76404 Electrode Holder or equivalent.
- Plastic beakers (HI 740036P) or other suitable measurement vessel.

#### **VI. Solutions Required**

##### For Cadmium Measurements

0.1 M cadmium standard, (500 mL)	HI 4003-01
ISA, (500 mL)	HI 4000-00

For direct cadmium measurements- Using volumetric pipettes and glassware, make dilutions of HI 4003-01 to bracket the concentration of the samples. Note: 0.1M cadmium standard is equivalent to 11,200 ppm. Standards with concentrations  $< 10^{-3}$  M (112 ppm) should be prepared daily. Store in tightly closed plastic bottle. To 100 parts standard or sample add 2 parts of ISA.

Please note: cadmium compounds are toxic by ingestion or skin contact. Take appropriate precautions.

## VII. General Guidelines

- Concentrated samples ( $> 0.10\text{ M}$ ) should be diluted before measurement. Multiply the final result by the corresponding dilution factor.
- Calibration standards and sample solutions should have the same ionic strength.
- For high ionic strength samples, use standard addition or titration methods.
- Calibration standards and sample solutions should be at same temperature.
- The magnetic stirrer may generate heat. Thermally insulate beaker containing standard or sample from magnetic stirrer by placing cork or other insulative sheet between beaker and stirrer plate.
- Calibration standards and sample solutions should be stirred at the same rate using identical sized TFE coated stir bars.
- Rinse electrode pair with distilled or deionized water between samples and gently dab dry with soft disposable absorbent toweling. Do not rub electrodes.
- Avoid  $\text{Cd}(\text{OH})_2$  precipitation or hydrogen ion interference by maintaining pH of samples between 4.5 and 7.5 pH. Use Nitric acid or sodium hydroxide to adjust pH.
- Presoaking the cadmium sensor tip in a dilute standard will optimize response. Use concentrations approximately  $10^{-3}\text{ M}$ .
- Presoaking the cadmium tip in a mild reducing solution such as ascorbic acid for a few minutes may be helpful when oxidation of the membrane surface is an issue between sample measurements.
- A scratched, pitted, or oxidized pellet surface can cause drift, a loss of low level response, or poor repeatability. Optimum response can be restored by removing the damaged surface with the microabrasive strip HI 4000-70. Use gloves to protect skin. Cadmium dust is toxic.
- Avoid large changes in temperature (thermal shock) as it may damage the sensor.

- Gas bubbles may form from solution out-gassing due to temperature change. Gently tap body of sensor to dislodge them from sensing membrane.

#### HI 4003

- Remove protective cover from sensor tip.

#### HI 4103

- Remove the protective plastic wrap that covers the ceramic junction before assembling sensor for the first time.
- HI 7072 reference fill solution should be added daily to electrolyte reservoir before electrode use.
- During measurement always operate electrode with the fill hole open.
- During normal use, fill solution will slowly drain out of the tapered cone junction at the lower portion of the electrode. Excessive loss ( $> 4$  cm drop within 24 hours) is not normal. If this occurs verify cap is tightened and the interface between the internal cone and outer body is free of debris.
- Add fill solution daily to maintain a good head pressure. For optimum response, this level should be maintained and not be allowed to drop more than 2-3 cm (1-inch) below fill hole. Fill solution must cover the ceramic found on the inner stem.
- If an erratic measurement occurs, check to see if foreign matter is seen trapped near the internal cone. Drain, wipe off outer cone while depressing cap, release cap and refill with fresh fill solution.

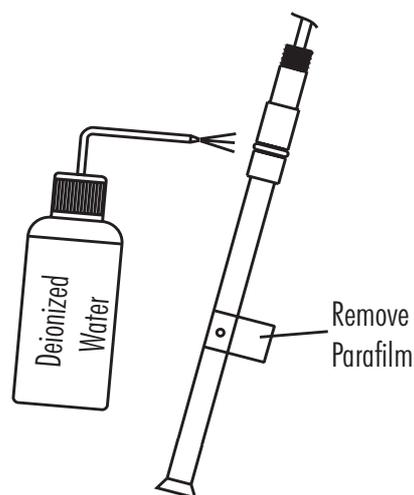
## VIII. Electrode Preparation

### HI 4003

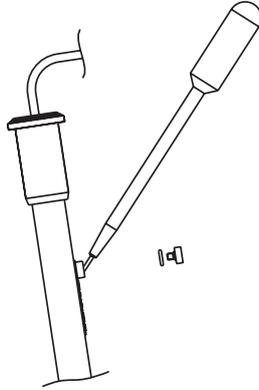
1. Remove protective cover from sensor tip.
2. Prepare reference electrode by filling outer electrolyte reservoir with HI 7072.
3. Place sensor and reference electrodes into electrode holder and connect cable connectors to meter.

### HI 4103

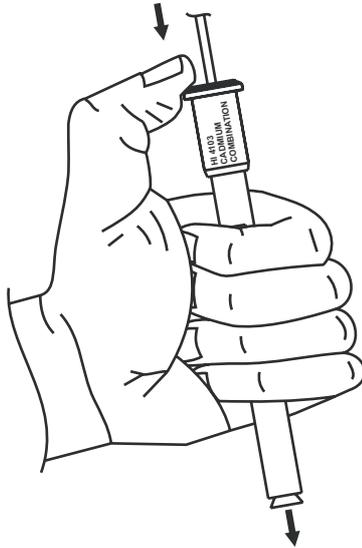
1. Unwrap plastic film seal found over ceramic junction on inner stem and discard. This is only used for shipping and long term storage.
2. Rinse inner stem with deionized water making certain to wet the o-ring found on the inner stem.



3. Reassemble electrode by gently pushing the inner assembly into the outer body, sliding spring down cable, and screwing cap into place.
4. Remove fill hole cover and o-ring on fill hole spout.
5. Using the dropper pipette provided, add a few drops HI 7072 fill solution to the electrode, wetting the o-ring and rinsing out the fill solution chamber.



6. Holding the body of the electrode gently press upper cap with your thumb. This permits the fill solution to drain out of the body. Release cap and verify electrode returns to its original position. (You may need to gently assist for this to occur).



7. Tighten the electrode cap onto the body and fill electrode body until fill solution volume is just below fill hole.
8. Position electrode in a Hanna HI 76404 electrode holder (or equivalent) and connect plug to meter.

### **IX. Quick Check of Electrode Slope**

- Connect sensors to pH/mV/ISE meter
- Place meter in mV mode.
- Place 100 mL of deionized water into a beaker with stir bar and 2 mL of HI 4000-00 ISA. Add stir bar and place on magnetic stirrer.
- Place electrodes into prepared sample.
- Add 1 mL of the stock standard HI 4003-01 (or .01 M or .001 M standard by dilution) to the beaker. Record the mV value when reading has stabilized.
- Add an additional 10 mL of standard HI 4003-01 (or same dilute standard) to the solution. Record the mV when reading has stabilized. This value should be more positive than the previous noted.
- Determine the difference between the two mV values. An acceptable value for this slope is  $+27 \pm 4$  mV near 25°C.

### **X. Corrective action**

- Verify protective cap has been removed (HI 4003).
- Verify plastic film has been removed from inner stem (HI 4103).
- Verify electrodes are connected properly to meter and meter is powered.
- Verify standard has been properly stored. Remake standards if appropriate.
- If the sensor slope just misses the suggested slope window, soaking the sensor in a dilute standard may solve the problem. ( $<10^{-3}$  M standard).
- A scratched, pitted or oxidized sensing surface can be polished with HI 4000-70 polishing strip. Cut off approximately 1 inch of the micro-abrasive strip. Wear protective gloves. Wet the frosted side with deionized water and place against damaged membrane of the electrode. Place your gloved thumb against the shiny backing and slowly rotate back and forth while applying gentle pressure. Continue polishing until you are satisfied with the surface. If dark deposits

appear on polishing strip move the paper slightly and continue polishing.

- If the membrane is damaged, the response becomes extremely sluggish, or the slope of the electrode has decreased significantly, and procedures above have not helped, the sensor should be replaced.

#### **XI. Direct Calibration and Measurement**

This method is a simple procedure for measuring many samples. A direct reading ISE meter (HI 4222 or equivalent) determines concentration of the unknown by a direct reading after calibrating the meter with the standards. The meter is calibrated with two or more freshly made standards that are in the linear measurement range of the unknowns. Two mL of ISA (HI 4000-00) is added to each 100 mL volume of standard or sample. More calibration standards are required in non-linear regions. Unknowns are read directly.

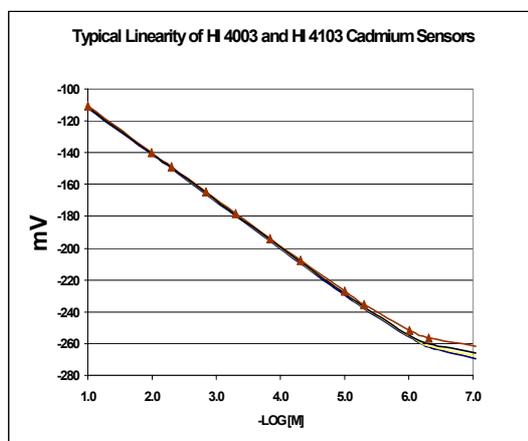
Samples with concentration greater than 0.1 M should be diluted to be within the working range of the electrodes. The final result must be multiplied by the corresponding dilution factor to determine the actual concentration.

A pH/mV meter in mV mode with semi-log graph paper may also be used. Two or more freshly prepared standards that are in the measurement range of the unknowns are measured in mV mode on the meter.

These values are plotted on the semi-log paper and the points are connected to form a straight-line curve. When samples are measured, their mV values are converted to concentration by following the mV to the concentration axis on the semi-log plot.

### Procedure

- 1) Follow sections VIII and IX to prepare sensors for measurement.
- 2) Follow section VI to prepare standards / solution. Standards should bracket and fall within the range of interest.  
Two mL HI 4000-00 ISA is added to 100 mL of both samples and standards. Add stir bar and mix before taking measurements.
- 3) Follow section VII; General Guidelines to optimize test set-up.
- 4) During calibration it is best to start with lower concentration samples first. Wait for a stable measurement before recording values. Slightly longer equilibrations are required at lower concentrations.
- 5) To prevent carry over and contamination of samples, rinse sensors with deionized and dab dry with absorbant laboratory tissue between samples.



## **XII. Other Measurement Techniques**

### Known Addition (for $\text{Cd}^{2+}$ )

An unknown concentration can be determined by adding a known amount (volume and concentration) of measured ion to a known volume of the sample. A mV value is taken before and after the addition of standard, and using the equation provided, the unknown concentration is found.

This technique is called Known Addition. The method can use an ideal sensor slope, but actual determined slopes at the temperature of measurement should be used if known. The volume and concentration of the added standard must cause a mV change of at least 8 mV. This method is preprogrammed in the Hanna HI 4222 pH/ISE/mV meter, which simplifies the method greatly. The method works well for samples with high ionic strengths.

Example: Cadmium ion determination in samples with concentrations less than  $1 \times 10^{-3} \text{ M}$  using known addition.

1. A 50 mL sample of unknown concentration ( $V_{\text{sample}}$ ) is placed in a clean plastic beaker with a cadmium sensor with 1 mL of HI 4000-00 ISA ( $V_{\text{ISA}=1 \text{ mL}}$ ). The stable mV value ( $mV_1$ ) is recorded after the sample is mixed.
2. 5mL ( $V_{\text{std}}$ ) of  $10^{-1} \text{ M}$  standard ( $C_{\text{std}}$ ) is added to the beaker and the mV value increases as does the concentration.  $\Delta E$  is calculated as  $mV_2 - mV_1$ . The unknown cadmium concentration in the original sample ( $C_{\text{sample}}$ ) can then be determined by the following equation.

$$C_{\text{sample}} = \frac{C_{\text{standard}} V_{\text{standard}}}{(V_T) 10^{\Delta E/S} - (V_S)} \left( \frac{V_S}{V_{\text{sample}}} \right)$$

$$(V_{\text{sample}} + V_{\text{standard}} + V_{\text{ISA}}) = V_T$$

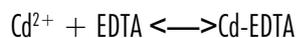
$$(V_{\text{sample}} + V_{\text{ISA}}) = V_S$$

3. The procedure can be repeated with a second standard addition to verify slope and operation of the method.

#### Titration of cadmium

A cadmium electrode may be used as an indicator to follow the progress and detect the endpoint of a complexation titration of cadmium ions with EDTA standard. During the titration the sensor follows the decreasing cadmium concentration while small additions of EDTA titrant are added. The cadmium ion reacts with the EDTA and removes

the free ions from the measurement pool.



The EDTA reacts with the cadmium ion forming a complex. The EDTA also can react with a host of other metals. Working at a pH between 4 and 6 optimizes the pH of the Cd-EDTA complex, and also discourages complexing with other ions that form stable complexes at high pH. Consult a comprehensive Analytical Chemistry Treatise for techniques concerning your particular interferent. The end point is assumed to be at the inflection of the mV versus titrant volume curve. Measurements may be automated by use of the Hanna Titrator HI 901 or titrated manually.

Notes: .

- Addition of ISA is suggested (1 part/50 parts sample).
- Use of the an acetic acid buffer may increase the end point break. Prepare buffer by diluting glacial acetic acid (17.4 M) to 1M and adjust to pH 5 with KOH. Add 1 part buffer to 10 parts sample.
- The EDTA titrant should be 10X more concentrated than the expected cadmium concentration.
- Competing metals will need to be identified and removed or masked.

### **XIII. pH**

HI 4103 and HI 4003 electrodes may be used in solutions with values between 4.5 and 7.5 pH. Samples above pH 7.5 may form  $\text{Cd}(\text{OH})_2$ . Adjust these samples with nitric acid.

### **XIV. Storage and Care of the HI 4003 and HI 4103 sensors**

The HI 4003 and HI 4103 sensor can be stored in very dilute standards ( $<10^{-3}\text{M}$ ) for short periods of time. The HI 4003 should be stored dry with its protective cap on for longer periods. For longer term storage of the model HI 4103 combination electrode; Drain and wash of salts with distilled or deionized water. Unscrew the upper cap and move outer sleeve up cable. Wrap the ceramic junction on the inner stem with Parafilm® or other sealing wrap. Place the protective cap provided over the dried membrane and store in original storage box provided with electrode.

<b>XV. Conversion Tables For <math>\text{Cd}^{2+}</math></b>	<b>Multiply</b>
Moles/L (M) to ppm (mg/L)	$1.124 \times 10^5$
ppm (mg/L) to M (moles/L)	$8.896 \times 10^{-6}$

#### **WARRANTY**

Hanna Instruments Ion Selective Electrodes are warranted to be free of defects in material and workmanship for 6 months from date of purchase when used for their intended purpose and maintained according to instructions. If they fail to work when first used contact your dealer immediately. Damage due to accidents, misuse, misapplication, tampering or lack of prescribed maintenance is not covered.

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Hanna Instruments reserves the right to modify the design, construction or appearance of its products without advance notice.

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