



**Substantiation Testing on Automotive Impressed Current
Protection (ICP) Corrosion Protection System**

Author: James Roselle

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551 Kings Road
Schenectady, NY 12304 (USA)
Ph.: 518-688-2851
Fax: 518-688-2855
E-mail: info@its-inc.com
URL: www.its-inc.com



Report Title: Substantiation Testing on Automotive Impressed Current Protection (ICP) Corrosion Protection System

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CUSTOMER: Warren Camp	CUSTOMER P.O.: N/A
COMPANY: The Auto Saver System, Inc.	CUSTOMER JOB NO: N/A
ADDRESS: 14 Jupiter Lane, Suite 2 Colonie, NY 12205	SPECIMEN SOURCE: Customer
PHONE NO: (800) 072-8155	TEST STAND NO: N/A
	FAX NO: N/A

DESCRIPTION OF WORK REQUESTED:

Conduct laboratory controlled substantiation testing on The Auto Saver System, Inc. supplied automotive impressed current protection device that attaches to the automotive OBD port in accordance to customer approved methodology.

SUMMARY OF TEST RESULTS:

It can be concluded based on the laboratory experiment of one galvanized steel panel fitted with the Auto Saver System, Inc. OBD style corrosion protection device that there is present an cathodic protection that would be required to retard the onset of oxidation or rust of exposed metal to aqueous salt solution.

James Roselle

Report Author

Original Copy Signed in Blue Ink

Lou Fiorini

Laboratory Director

Original Copy Signed in Blue Ink

I HEREBY CERTIFY THAT THE DATA CONTAINED IN THIS REPORT HAVE BEEN GENERATED IN ACCORDANCE WITH AND MEETS THE REQUIREMENTS OF THE PURCHASE ORDERS LISTED.

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1.0 INTRODUCTION

This report pertains to a single laboratory-controlled experiment for the purpose of substantiating the effectiveness of an Automotive OBD port attachment style cathodic protection device that used impressed current protection (ICP) as a corrosion protection measure for use in a typical automotive environment.

The experiment utilized a Galvanized Steel Panel representing the body of an automobile. The panel was partially submerged into a 5% Sodium-Chloride salt solution representing the contact with road salt. The panel was fitted with the ICP device which was powered on and off by a 12V DC power supply representing the automotive battery. The Cathodic Protection impressed upon the panel by the device was measured by use of a Silver / Silver-Chloride Reference Electrode reading the electrical potential of a scribe marked into the panel and submerged into the salt solution.

Cathodic Protection utilizes an applied potential to overcome local anodes on the surface of the material. For impressed current protection devices, the applied potential is derived from an external DC power (vehicle battery) source to maintain a constant electrical flow and artificially decrease the potential between the structure (auto-body) and the electrolyte (road salt).

Below is a table of Redox Equations and the Reduction potentials required for the chemical process of corrosion.

Redox Equations	Reduction Pot.
$\text{Au}^+_{(\text{aq})} + \text{e}^- \rightleftharpoons \text{Au}_{(\text{s})}$	+1.69 V
$\text{Ag}^+_{(\text{aq})} + \text{e}^- \rightleftharpoons \text{Ag}_{(\text{s})}$	+0.80 V
$\text{Cu}^{2+}_{(\text{aq})} + 2\text{e}^- \rightleftharpoons \text{Cu}_{(\text{s})}$	+0.34 V
$\text{Fe}^{2+}_{(\text{aq})} + 2\text{e}^- \rightleftharpoons \text{Fe}_{(\text{s})}$	-0.44 V
$\text{Al}^{3+}_{(\text{aq})} + 3\text{e}^- \rightleftharpoons \text{Al}_{(\text{s})}$	-1.68 V
$\text{O}_{2(\text{g})} + 4\text{H}^+_{(\text{aq})} + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1.23 V
$\text{Fe}^{3+}_{(\text{aq})} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77 V
$2\text{H}^+_{(\text{aq})} + 2\text{e}^- \rightleftharpoons \text{H}_{2(\text{g})}$	0 V
$\text{Zn}^{2+}_{(\text{aq})} + 2\text{e}^- \rightleftharpoons \text{Zn}_{(\text{s})}$	-0.76 V
$\text{Na}^+_{(\text{aq})} + \text{e}^- \rightleftharpoons \text{Na}_{(\text{s})}$	-2.71 V

Table 1: Standard Reduction Potentials E°/V (25 °C). The more positive the E° , the more likely the reduction reaction is to occur at standard conditions (1 M, 1 atm., 25°C). Ref: D.C. Harris: Quantitative Chemical Analysis, 3rd ed., Appendix H, W.H. Freeman and Co., 1991.

2.0 PROCEDURE

A 36" X 48" Galvanized Steel sheet with a thickness of 0.032 inch was washed down, degreased and prepped for the application of automotive primer and paint. The paint layers consisted of a basecoat of R-M Diamont Ford Oxide White (M6887A 4WFAXWA) with R-M LHM Medium Hardener and R-M UR50 Mid-Temp Reducer, and a clearcoat layer of R-M Limco LC4000.

For the test a 1-foot square test panel was cut from the painted 36" X 48" Galvanized Steel Sheet.



Figure 1: The Sectioned 1-foot X 1-foot test panel cut from the painted 36" X 48" panel.

An eight (8) inch long scribe mark was made at a distance of 2.5 inches from the bottom of the panel and centered between the sides. The scribe depth was sufficient to pierce the paint layers and expose the bare metal substrate

The plastic standoff for the Luggin Capillary with Silver/Silver-Chloride reference electrode was adhered to the panel and straddled the scribe mark at center span. The standoff set the distance from the reference electrode to the panel surface at 0.005 inches. The panel was then placed in a circulating bath of 5% Sodium Chloride Salt Solution.

The Reference Electrode was then inserted into the Luggin Capillary and the pair was positioned into the plastic standoff leaving approximately 0.005 inches of distance between the scribe mark and the Luggin Capillary.



Figure 2: The plastic standoff adhered to the test panel.

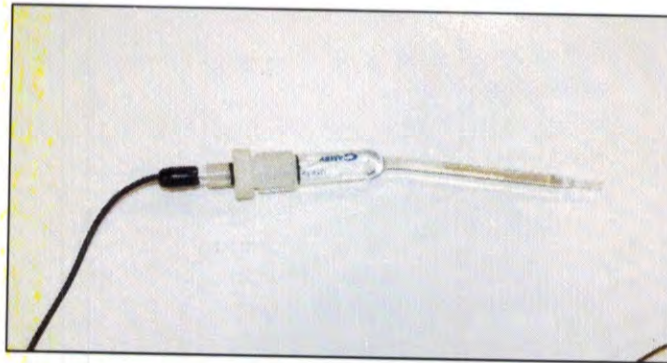


Figure 3: The Silver/Silver-Chloride Reference Electrode inserted into the Luggin Capillary.

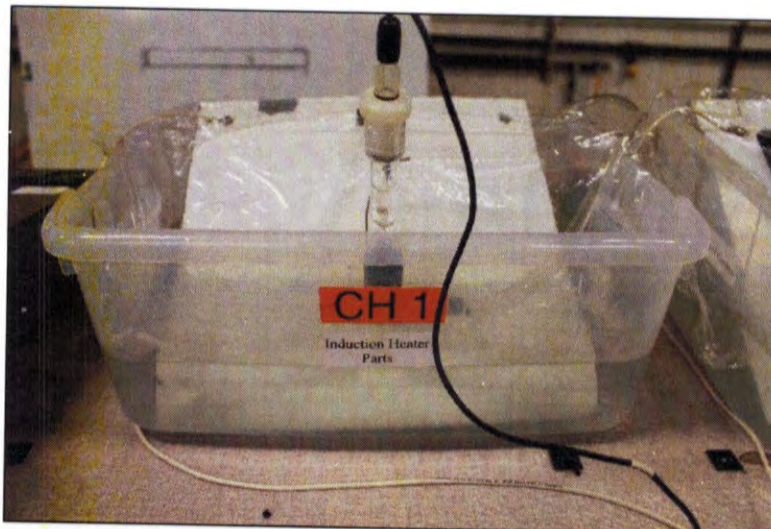


Figure 4: Electrically connected test panel with reference electrode attached shown with scribe mark submerged in 5% sodium-chloride salt solution.

Electrical connections were completed between the power supply, ICP device and measurement device with the connections to the panel made at an inset of 3/4" from the two edges opposite the scribe line. The measurement device was a Keithley DAQ6510. The DC power was produced by a Sorensen LM-18-10 power supply. The ICP Device was from The Auto Saver System, Inc. The Luggin Capillary and Silver/Silver-Chloride Reference Electrode were Gamry Instrument # 930-00015 and 930-00044 respectively.

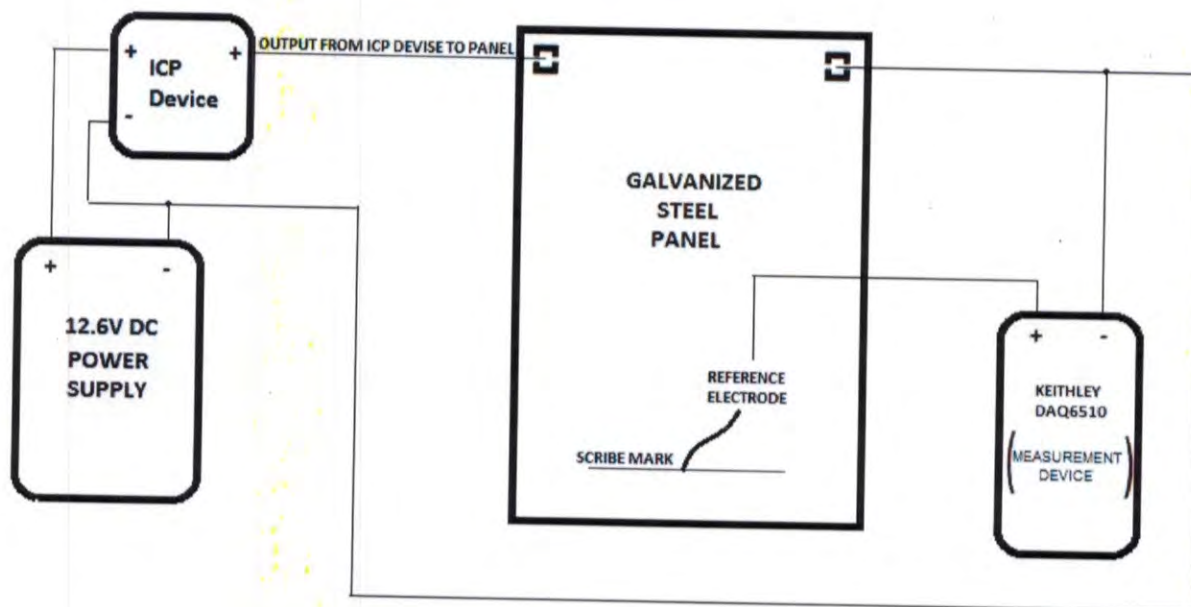


Figure 5: The Circuit Diagram.

The ICP Device was powered off for the first 24 hours of test panel submersion. The test panel then spent approximately 2 weeks with the ICP device turned on and another 2 weeks with the ICP device turned off followed by a period of 1 week with the ICP device activated again. Throughout the 5 week test the panel scribe remained submerged in a circulating bath of 5% sodium-chloride salt solution and voltage readings were collected from the Reference Electrode. The circulator pump output was placed on the scribe mark at the front of the panel, so a constant flow of solution ran across the gap between the scribe mark and Luggin capillary. The return was placed in the plastic tub under the back of the panel.

The DC Power supply provided a constant 12.6 Volts and the current of the circuit was measured at 24.8 mA.

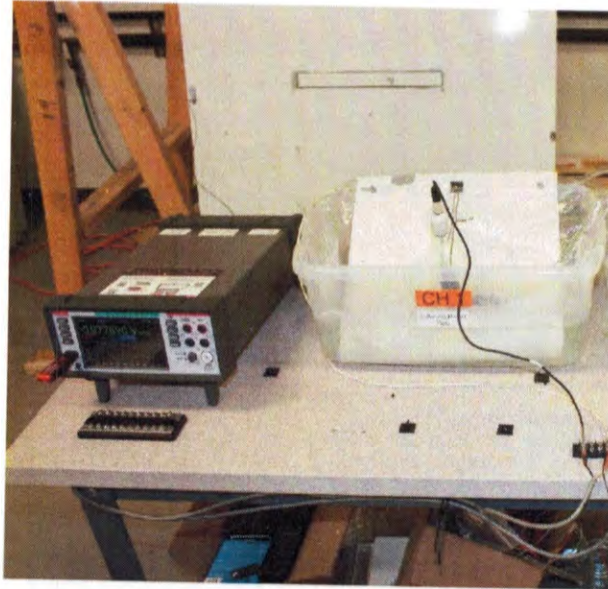


Figure 6: Test Set-up with data recorder

The test set-up was left in a temperature-controlled environment where the temperature was maintained at 72F +/- 5F for the duration of the test. The 5% Salt Solution was continuously circulated in the bath with the panel submerged to a point above the scribe mark. Plastic film was placed over the plastic tub to prevent evaporation of the solution.

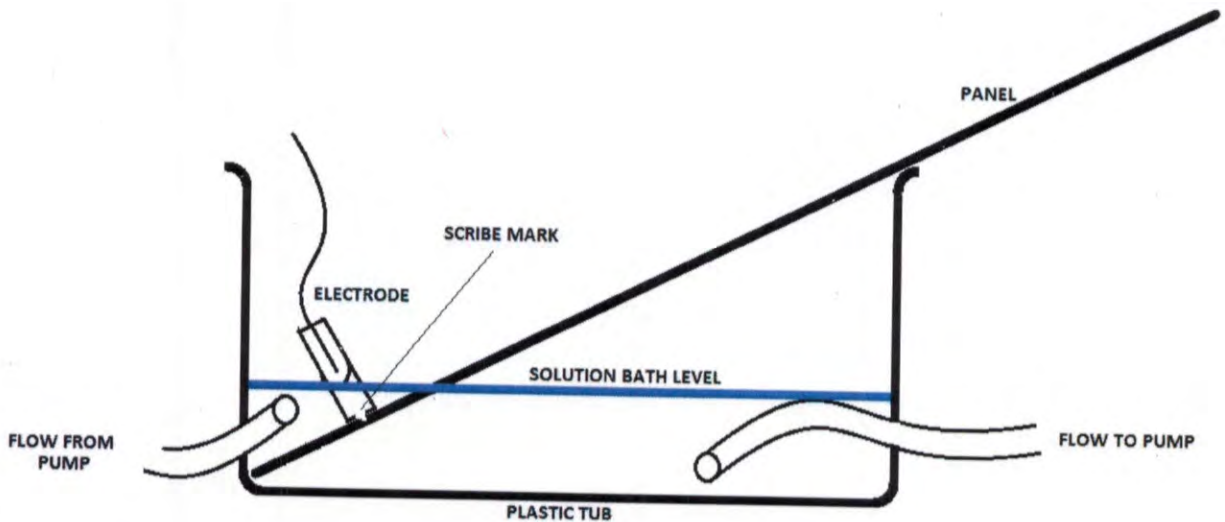


Figure 7: Diagram of panel position within bath of 5% Sodium Chloride solution



3.0 RESULTS

For successful cathodic protection there must be sufficient potential applied to overcome local anodes on the surface of the material. For example, the potential for just raw iron (Fe^2) to corrode to common rust is specified in published literature to be $\sim(-)0.44$ V. For zinc as found in a galvanized panel, the oxidation potential lies near $(-)0.78$ V. In order to protect both the steel substrate of a galvanized panel without consuming excessive current in electrolysis the potential would have to fall between $(-)0.85$ to $(-)1.15$ V.

The reference electrode measured a potential of -1.02 V at the start of the test. The Auto Saver System, Inc. ICP device was activated after an initial 24 hour period of time and the reference electrode showed a shift of 0.01 V less negative ending at a measurement of potential of -1.008 V at the end of 316 hours of an active ICP device. Voltage from the DC power supply was 12.6 V DC and a current of 24.8 mA was measured over the distance from module to the scribe mark.

During the 316 subsequent hours when the ICP device was deactivated, the reference electrode measured a potential shift from a starting voltage of -1.008 V and ending at -0.959 V with greater fluctuation in voltage potential than what was recorded during the IPC device active period that preceded. The highest differential was at 616 hours when the potential was measured at -0.949 V.

The final test period when the ICP device was again initiated the shifting voltage potential reversed trend and was measured at -0.964 V at time of test termination.

The Auto Saver System, Inc. ICP device showed an ability to suppress the voltage potential shift that was seen during the period when the ICP device was disabled.

This suppression indicates that there is present an cathodic protection that would be required to retard the onset of oxidation or rust of exposed metal to aqueous salt solution.

Graphical representations of the recorded data are shown in the Appendix section.



4.0 APPENDIX

Graphical Representations of the data collected during test are shown within this appendix.

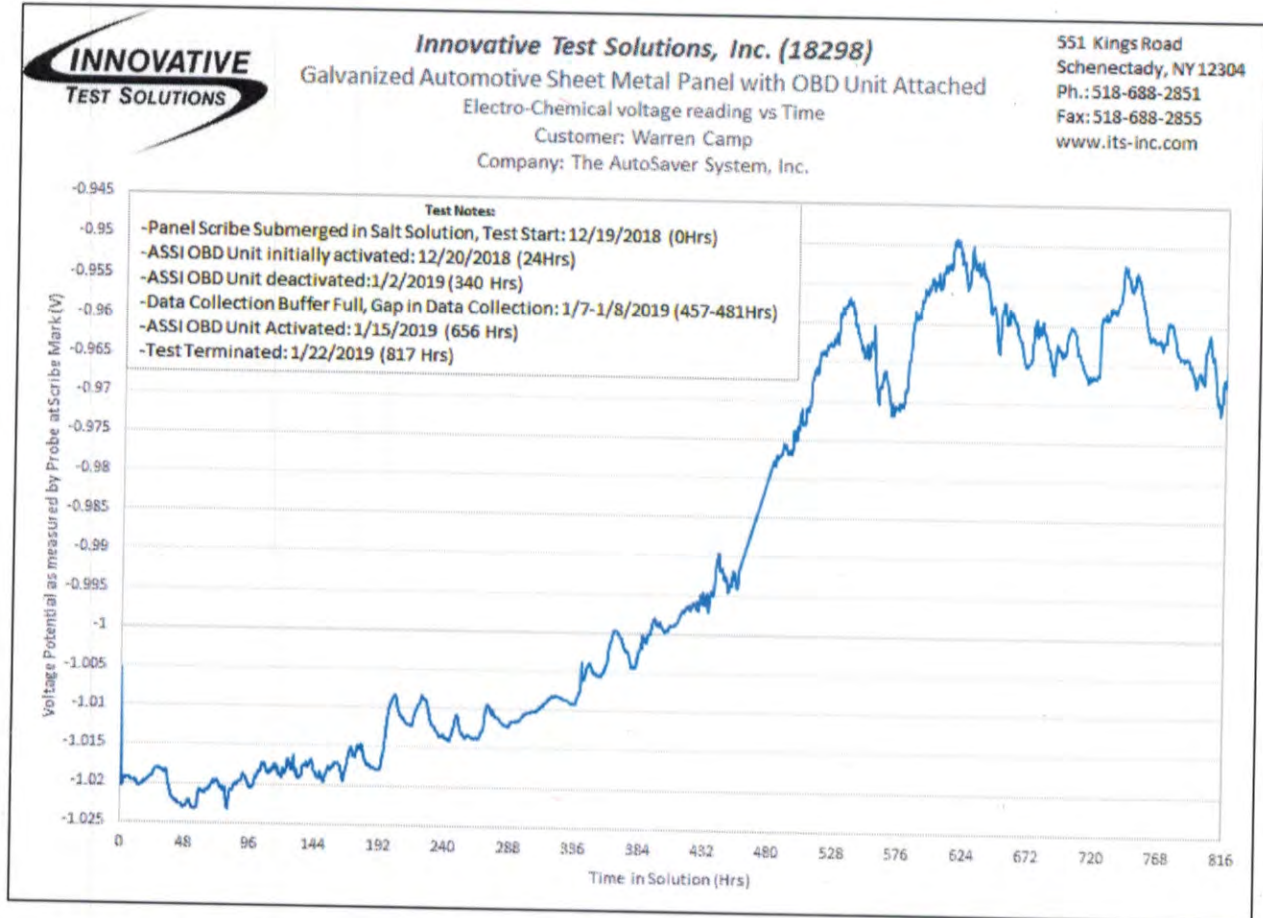


Figure 8: Graph of voltage as measured by the reference electrode vs time panel is submerged in solution.

Test notes box shows hour mark for specific events.

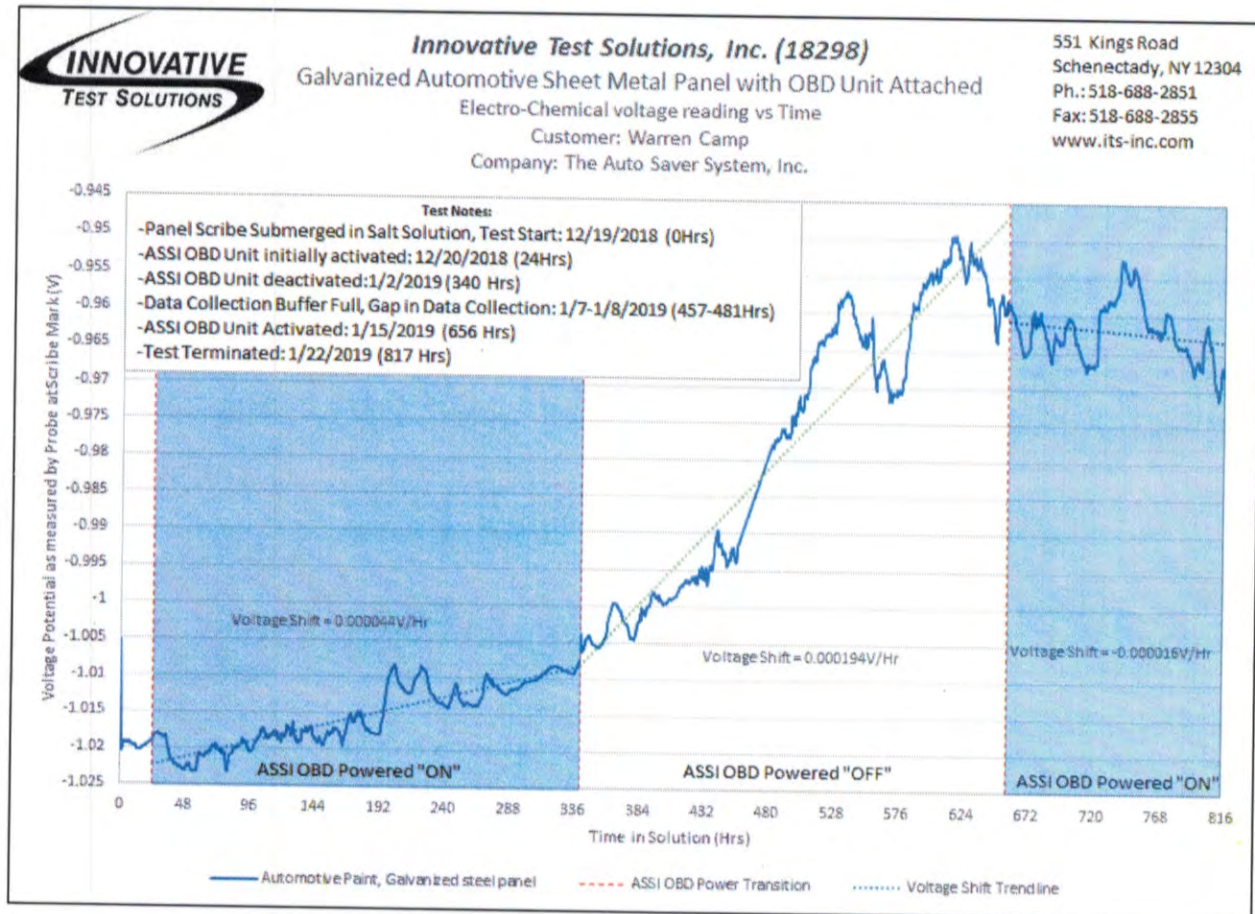


Figure 9: Same graph as previous page with sections of ICP device enabled highlighted in blue and voltage trendlines added for each section.

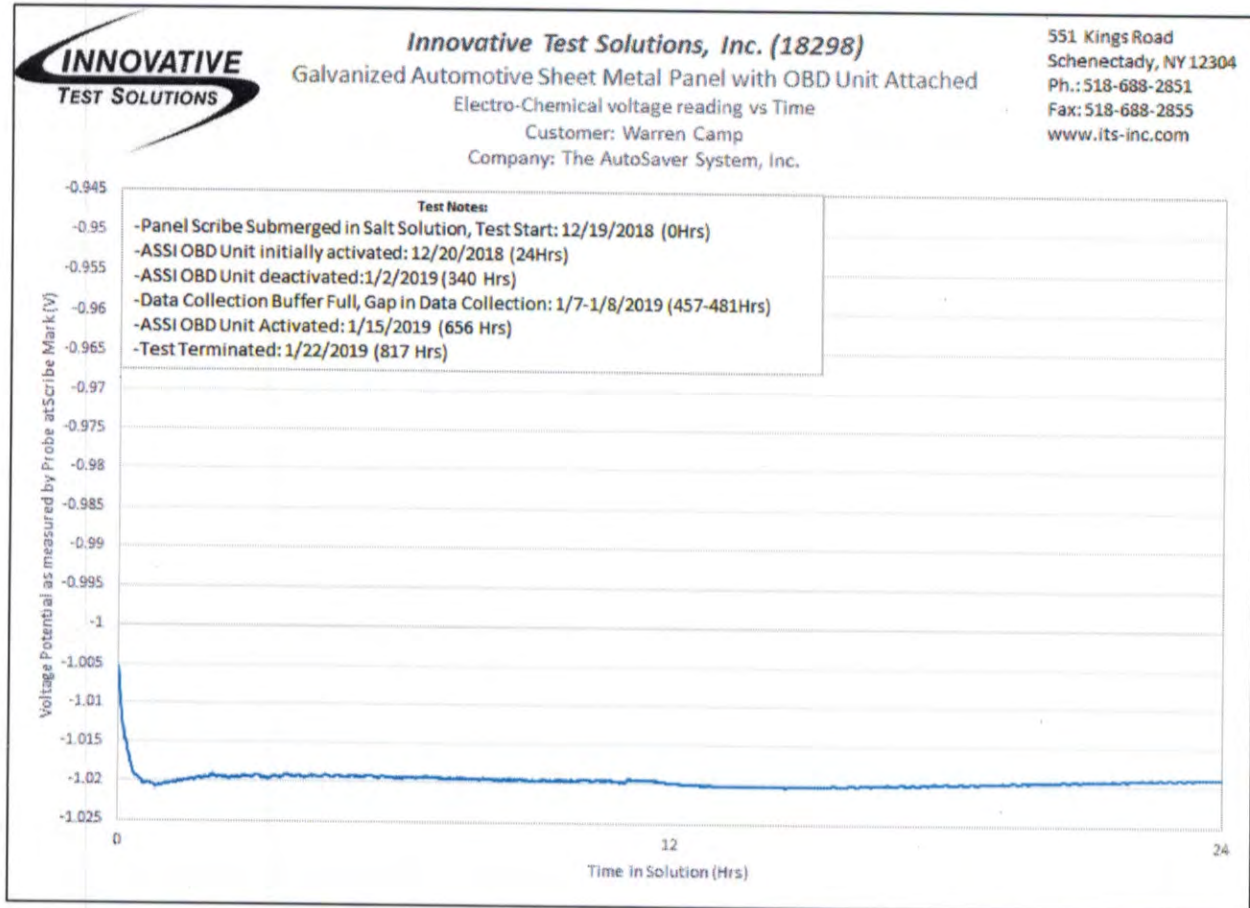


Figure 10: Graph of voltage vs time for initial 24 hour period of solution immersion and ICP device disabled.

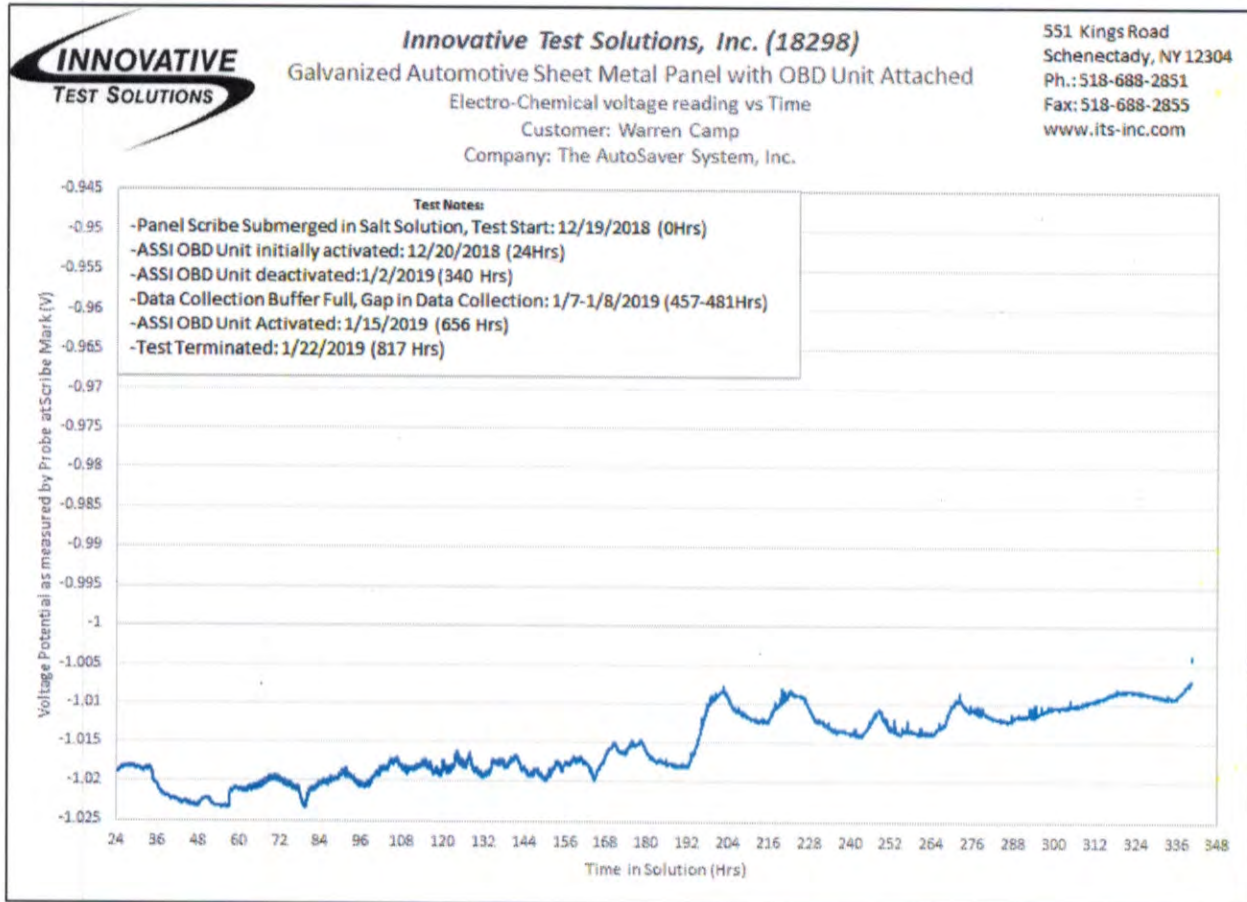


Figure 11: Graph of voltage vs time for initial period when ICP device activated.

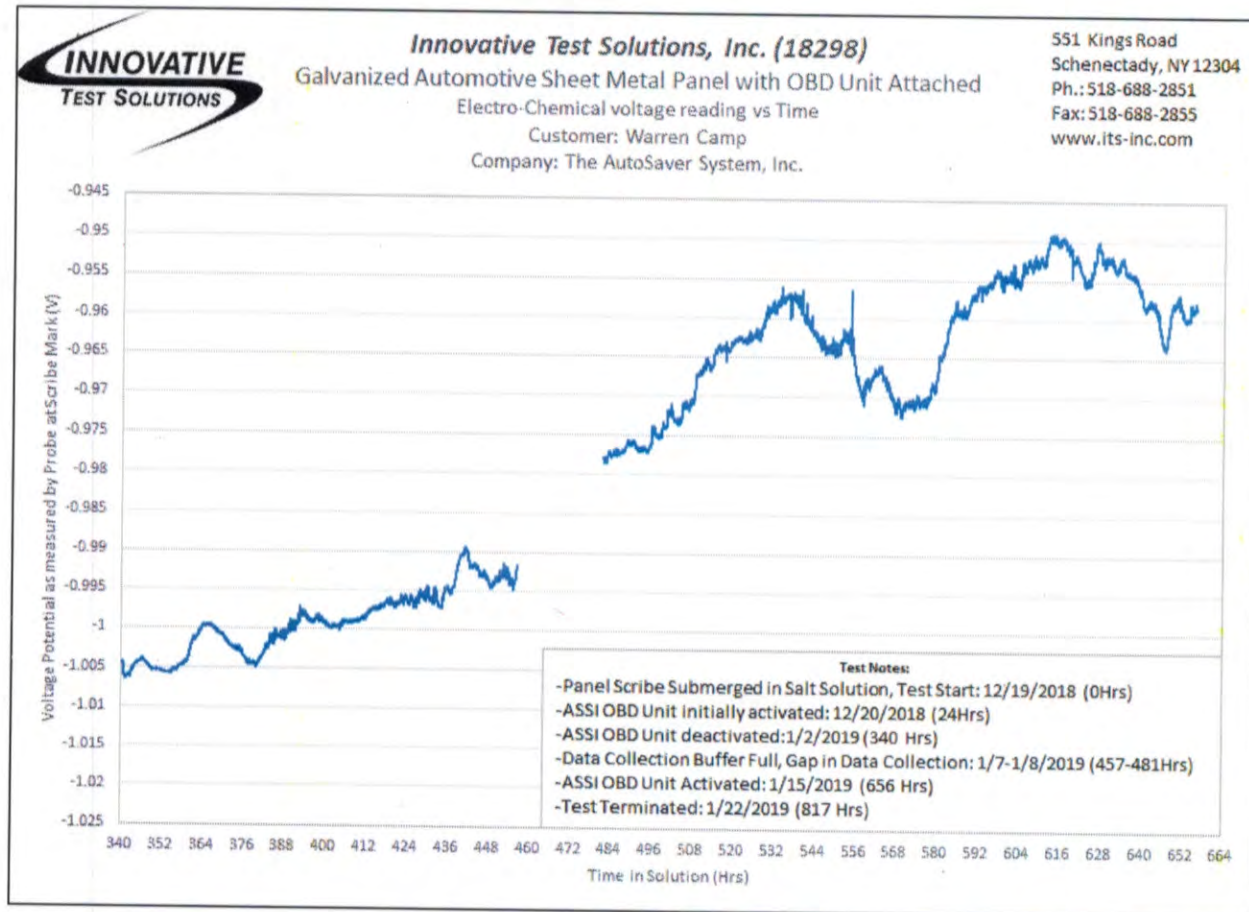


Figure 12: Graph of voltage vs time for the 316 hr period when ICP device disabled following initial ICP device activated period. Note that from 1/7/2019 to 1/8/2019 no voltage readings were collected.

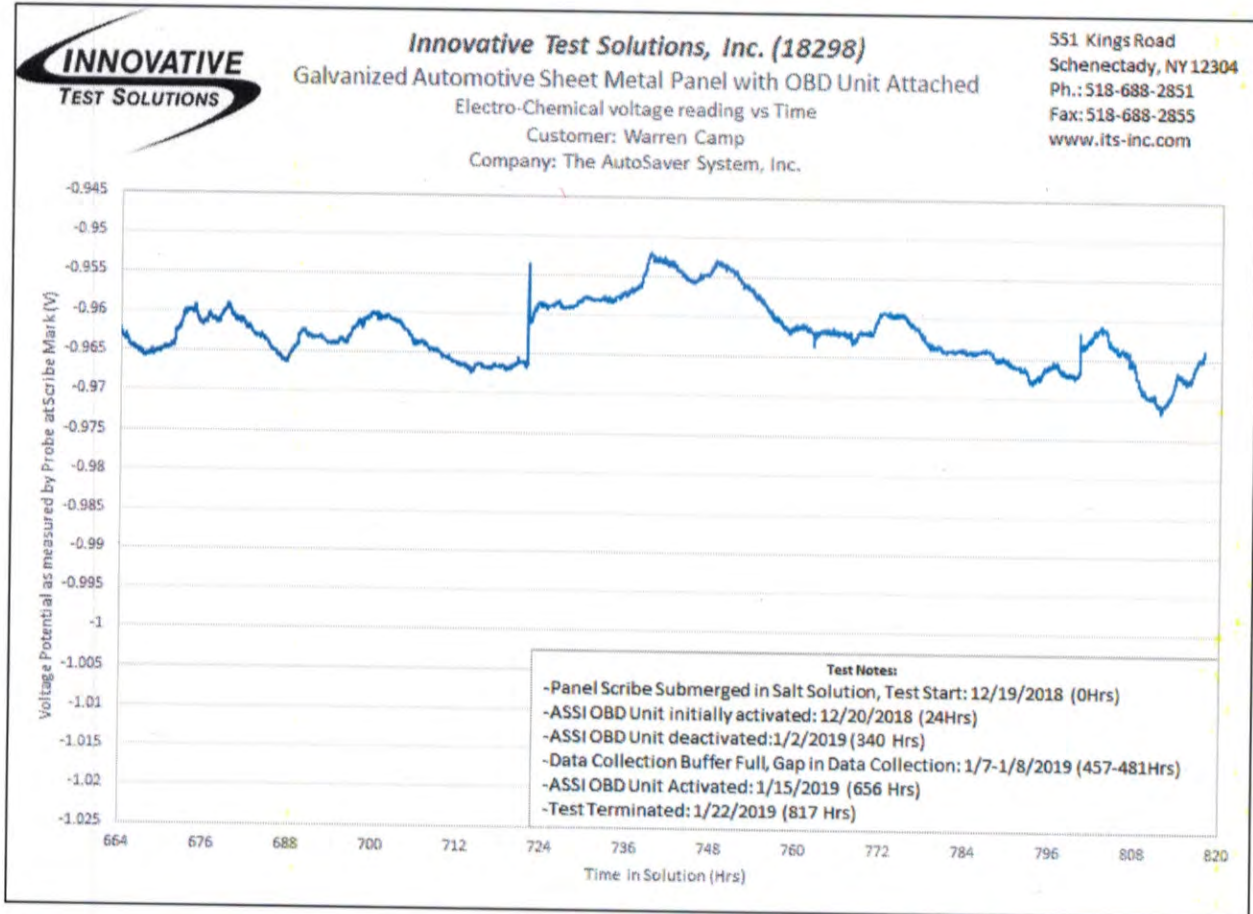


Figure 13: Graph of voltage vs time for final period when ICP device activated. The test was terminated after this period.



Description	Make	Model #	S/N
Laboratory DC Power Supply	Sorensen	LM 18-10	9634016
Water Pump	Greylor	PQM-1/115	115-019563
DAQ/ Multimeter	Keithley	DAQ6510	4402954
Silver/Silver-Chloride Reference Electrode	Gamry	930-00015	-

Table 2: List of essential equipment used during test.