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Iron and Lead Corrosion in WIPP-Relevant Conditions: 12 Month Results

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DEFINITION OF ABREVIATIONS, ACRONYMS AND INITIALISMS

Abbreviation or Acronym	Definition
ASTM	American Society for Testing and Materials
CH	contact handled
CH_4	methane
CO_2	carbon dioxide
CPR	cellulosic, plastic, and rubber
CRA	compliance recertification application
DAS	data acquisition system
DI	de-ionized
DOE	Department of Energy
EDS	energy dispersive spectroscopy
EDTA	ethylenediaminetetraacetic acid
EPA	Environmental Protection Agency
ERDA-6	Energy Research and Development Administration (WIPP Well) 6, a Synthetic Castile Formation brine
ES&H	Environmental Safety and Health
f_{CO2}	fugacity of carbon dioxide
FMT	Fracture-Matrix Transport, a geochemical speciation and solubility code
GWB	Generic Weep Brine, a synthetic Salado Formation brine.
H_2	hydrogen gas
H_2S	hydrogen sulfide
HSLA	high-strength, low-alloy
ISO	International Standards Organization
m	molal (mol/kg)

Abbreviation or Acronym	Definition
M	molar (mol/L)
MFGCS	mixed-flow gas control system
N_2	nitrogen gas
NACE	National Association of Corrosion Engineers
NP	Nuclear Waste Management Procedure
PA	performance assessment
QA	quality assurance
PABC	(WIPP) performance assessment baseline calculations
RH	remote handled
SEM	scanning electron microscopy
SNL	Sandia National Laboratories
TP	test plan
TRU	Transuranic
TSP	Trisodium phosphate
WIPP	Waste Isolation Pilot Plant
XRD	X-ray diffractometer

1 INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is a deep geologic repository developed by the U.S. Department of Energy (DOE) for the disposal of transuranic (TRU) radioactive waste. The WIPP repository is located within the bedded salts of the Permian Salado Formation, which consists of interbedded halite and anhydrite layers. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to requirements set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with containment requirements by means of performance assessment (PA). WIPP PA calculations are used to estimate the probability and consequence of radionuclide releases from the repository to the accessible environment for a period of 10,000 years after facility closure.

The WIPP PA includes modeling the consequences of future inadvertent human intrusions into the repository by drilling for resources. Such intrusions could lead to a postulated release of radionuclides to the accessible environment before the end of the 10,000 year regulatory period. To accomplish this, the DOE has examined different drilling scenarios, which involve the penetration of the repository by one or more drill holes; some of the scenarios also involve the possibility of the penetration of a pressurized Castile brine reservoir (U.S. DOE, 2009). The estimated quantity of radionuclides released to the accessible environment following penetration of the repository depends on the chemistry of these radioelements. For example, plutonium (Pu) is less soluble when it speciates in lower oxidation states, such as Pu(III) and Pu(IV), than in higher oxidation states, such as Pu(VI). Thus it follows that in order to minimize the release of such radionuclides from the repository it is desirable to maintain all such species in their least-soluble form (i.e., low oxidation states).

The nature of the environment within the WIPP following closure will, to a large extent, control the speciation of the radionuclides within the waste. More specifically, there are components contained within the waste that can impact the oxidative or reductive nature of the environment, such as metals undergoing active corrosion. If metals undergo active corrosion within the WIPP, the corrosion process will serve to maintain electrochemically reducing conditions. The predominant metals within the WIPP will be iron (Fe) in the form of low-carbon steel and lead (Pb). These metals are present within the waste itself, as well as the containers used to hold the waste during emplacement. The current inventory predicts that 280 and 599 kg/m^3 of Fe and Fe-base alloys will be present in the contact handled (CH) and remote handled (RH) wastes, respectively. Also 0.013 and 420 kg/m^3 of Pb will be present in the CH and RH wastes, respectively (Crawford 2005). The corrosion behavior of these materials, specifically the kinetics of the corrosion reaction, will be controlled by the availability of water (in brine) at the metal surface, as well as the internal atmosphere within the WIPP.

In addition to Fe and Pb, the waste disposed within WIPP contains significant quantities of cellulosic, plastic and rubber (CPR) materials. With time, microbial activity may consume some portion of the CPR materials, resulting in generation of significant quantities of carbon dioxide (CO_2), hydrogen sulfide (H_2S), hydrogen (H_2), nitrogen (N_2) and methane (CH_4). Some of these gasses, namely CO_2 and H_2S, may interact with the metallic Fe and Pb, altering their electrochemical behavior. Elevated concentrations of both gasses have been demonstrated to passivate Fe under certain conditions due to the formation of corrosion products on the surface of the metal (Telander and Westerman, 1993; 1997). If Fe and Pb within the WIPP are passivated, the corrosion process will be stifled and electrochemically reducing conditions will no longer be maintained by the corrosion process. Under these conditions, Fe and Pb would not be available to prevent oxidation of the radionuclides, although other reductants may still be available.

The microbially-produced CO_2 also has the potential to significantly affect the mobility of actinides in other ways. The presence of CO_2 will acidify any brine present in the repository and increase the solubilities of the actinides (Appendix SOTERM, U.S. DOE, 2009). For this reason the DOE emplaces magnesium oxide (MgO) into the repository to buffer the f_{CO2} and pH within ranges that favor lower actinide solubilities. The f_{CO2} of the WIPP environment will be buffered by the MgO carbonation reaction:

$$5\ Mg(OH)_2\,(s) + 4\ CO_2\,(aq \text{ or } g) \Leftrightarrow Mg_5(CO_3)_4(OH)_2 \cdot 4\ H_2O\,(s) \quad (1)$$

where $Mg(OH)_2$ (brucite) is the main hydration product of the mineral periclase (MgO) expected in the WIPP and $Mg_5(CO_3)_4(OH)_2 \cdot 4\ H_2O$ is the form of the mineral hydromagnesite predicted by the repository models. The pH of brines possibly present in the WIPP is buffered by the brucite dissolution reaction:

$$Mg(OH)_2\,(s) \Leftrightarrow Mg^{2+}\,(aq) + 2\ OH^-\,(aq) \quad (2)$$

Laboratory and modeling studies (Appendix MgO, Table MgO-6, U.S. DOE, 2009) indicate that reaction (1) will buffer the f_{CO2} in the WIPP at a value of $10^{-5.50}$ atm and that reaction (2) will buffer pH in the WIPP at a Pitzer scale value of 8.69 in Generic Weep Brine (GWB) and 8.94 in Energy Research and Development Administration (WIPP Well) 6 Synthetic Castile Formation brine (ERDA-6). The Pitzer scale is an unofficial pH scale consistent with pH values calculated using single-ion activity coefficients based on the Pitzer activity-coefficient model for brines and evaporite minerals of Harvie et al. (1984). The term "Pitzer scale" was proposed unofficially by T. J. Wolery of Lawrence Livermore National Laboratory (LLNL) in Livermore, CA. The large quantities of Fe and Pb present in WIPP may also contribute to the consumption of microbially generated gases, primarily through the formation of carbonates and sulfides. After the limited concentration of O_2 trapped within the repository at the time of closure is depleted via the corrosion process and the aerobic microbial consumption of CPR materials, it has been hypothesized that anoxic corrosion of Fe and Pb will occur (Brush, 1990). The WIPP-specific experiments of Telander and Westerman (1993, 1997) have verified this hypothesis.

The experimental work reported in this document assesses the corrosion behavior of carbon steel and Pb alloys used to contain CH and RH waste under WIPP-relevant conditions. The objective of this work is to determine to what extent these alloys consume CO_2 through the formation of carbonates, potentially supporting MgO in its role of CO_2 sequestration. This work is being conducted under the test plan "Iron and Lead Corrosion in WIPP-Relevant Conditions, Test Plan TP 06-02" (Wall and Enos, 2006). The following report documents the 12-month results from this two-year experimental work. This report is a follow up to Roselle (2009) in which the results from the six month experiments were presented.

2 EXPERIMENTAL APPROACH

The purpose of these experiments is to assess the corrosion behavior of carbon steel and Pb alloys used to contain CH and RH waste under WIPP-relevant conditions. Specifically, the experiments aim to determine the corrosion rates of these metals and the nature of the corrosion products that will form. The environmental conditions and samples used for this set of experiments are set up to be representative of the conditions that are expected in the WIPP following its closure. During these experiments steel and lead coupons will be immersed in different WIPP-relevant brines or hung in WIPP-relevant atmospheric conditions for a period of two years. A subset of samples will be removed from the experiments for analysis at six month intervals. The range of experimental variables is summarized in Table 2-1. This combination of experimental conditions, material types and time segments results in 288 unique experiments. In addition, three replicate coupons are used for each of the experimental conditions resulting in a total of 864 coupons (432 for lead and 432 for steel). A detailed discussion of the types of metal coupons used and the environmental conditions employed in the experiments is given in Roselle (2009).

Also shown in Table 2-1 are the matrix identifiers used in formulating unique sample numbers. The naming convention used follows this format: Aa-Bb-#### - X – Yz, where Aa is the material type, Bb the brine (or "Atm" for humid samples), #### the atmosphere, X the time segment, Y the replicate number (1 to 3) and z the sample position (left blank for humid position). Thus, sample number Fe-Go-1500-12-1f indicates the first replicate of a steel coupon fully inundated in GWB organic brine in a 1500 ppm CO_2 atmosphere for 12 months.

Table 2-1 Experimental Test Matrix

Condition	Variable	Matrix Identifier
Material Type	ASTM A1008 Steel	Fe
	QQ-L-171e Grade C Lead	Pb
Brine	GWB	G
	GWB with organics	Go
	ERDA-6	E
	ERDA-6 with organics	Eo
Sample Positioning	Fully Submerged	f
	Partially Submerged	p
	Humid Atmosphere	Atm
Atmosphere	0 ppm CO_2 (balance N_2)	0000
	350 ppm CO_2 (balance N_2)	0350
	1500 ppm CO_2 (balance N_2)	1500
	3500 ppm CO_2 (balance N_2)	3500
Time Segment	6 months	6
	12 months	12
	18 months	18
	24 months	24
Fixed Properties (constant for all experiments)	Temperature – 26 °C	--
	Relative Humidity – 75% ± 10%	--
	O_2 concentration < 5 ppm	--

Note: [2 Material types × 4 Brines × 2 Positions (wet) × 4 Atmospheres × 4 Time segments] + [2 Material type × 1 Position (humid) × 4 Atmospheres × 4 Time segments] = 288 experiments

3 EXPERIMENTAL METHODS

3.1 Mixed Flow Gas Control System

Previous corrosion experiments (e.g., Telander and Westerman, 1993; 1997) have been conducted in closed systems in which the atmosphere in the experiments changes as a function of corrosion. This method uses measurements of the head gas composition to estimate the amount and type of corrosion occurring in the experiments. However, such experiments result in head space gas compositions that change over time and may not reflect the expected conditions in the WIPP after closure. Therefore, the current Fe/Pb corrosion experiments are being conducted in a continuous flow setup that allows the atmospheric composition to be fixed at constant values. A specially-built gas flow system known as the Mixed Flow Gas Control System (MFGCS) is being used to house the experiments. The MFGCS is a continuous flow system designed to create and maintain a controlled environment for the Fe/Pb corrosion experiments. The variables controlled by the MFGCS include the oxygen level, humidity level and N_2/CO_2 gas concentrations. The system is continuously monitored real time by a data acquisition system (DAS) to continuously assess various experimental and operational parameters. The specific details of the MFGCS can be found in the six month experimental report (Roselle, 2009) and the MFGCS System Pressure Safety Package (Schuhen, 2007).

3.2 Coupon Preparation

Prior to emplacement in the experiments each coupon was measured, cleaned and pre-weighed. All measurements were recorded in the appropriate scientific notebook. Coupons were measured to an accuracy of ±0.025 mm. For each coupon three measurements of the width, length and thickness were made. The averages of these three measurements were then used to calculate the surface area for each coupon (see Appendix A). The pre-cleaning processes used for the steel and lead coupons were based on recommendations in ASTM G1-03 (ASTM, 2003). Steel coupons were cleaned by degreasing with a commercially available TSP (trisodium phosphate) substitute followed by rinsing with de-ionized (DI) water. Coupons were then rinsed with ethanol and allowed to air dry. Lead coupons were cleaned by degreasing with the TSP substitute solution and then immersed in a solution of boiling 1% acetic acid for two minutes. After boiling, the coupons were submerged in a beaker of DI water until all coupons had been cleaned in the acid solution. The beaker containing the submerged coupons was then placed into an anoxic glovebox. The lead coupons were then removed from the DI water and allowed to air dry under anoxic conditions. This step was necessary because air drying in the laboratory produced immediate oxidation of the lead coupons. Once the coupons were dry they could then be removed from the glovebox for further preparation. After cleaning, the mass of all coupons was determined to an accuracy of 0.0001 grams. Coupons were then photographed front and back. Figure 3-1 shows the typical appearance of steel and lead coupons after cleaning. All coupons were stored inside a desiccator in the anoxic glovebox until loaded in a sample test chamber.

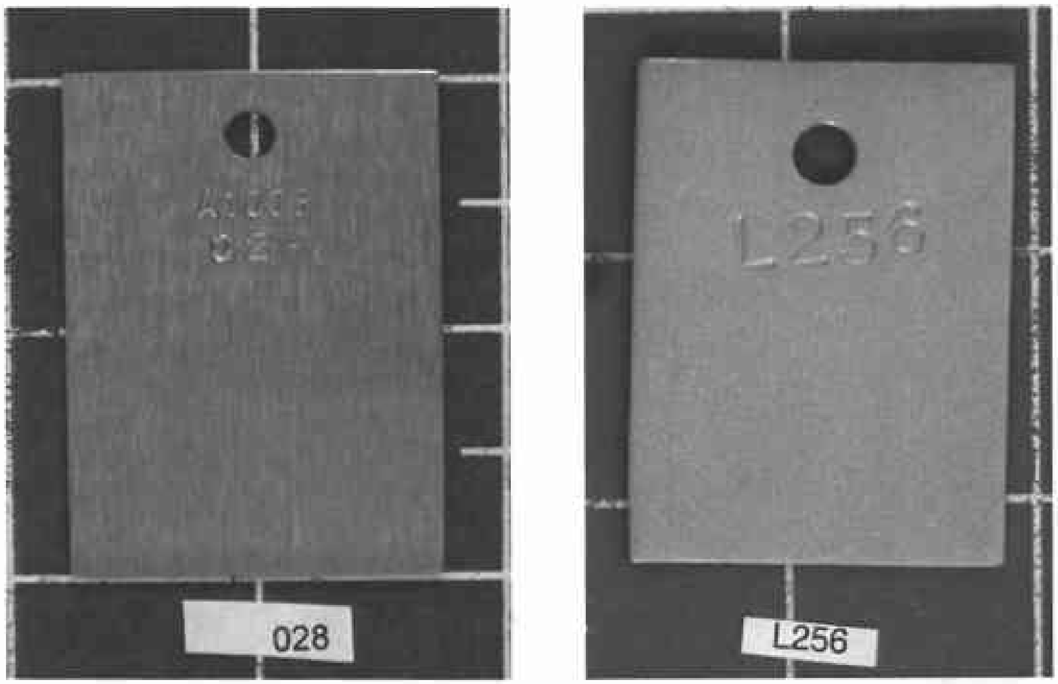


Figure 3-1 Typical appearance of steel (left) and lead (right) coupons after cleaning.

3.3 Sample Loading

After the preparation steps outlined in Section 3.2, the coupons are ready to be placed into the sample test chambers described in Roselle (2009). The sample test chambers are placed into the anoxic glovebox with the coupons and all loading/unloading operations are done inside the glove box. There are eight sample chambers used for each of the four experimental gas streams (e.g. 0 ppm CO_2, 350 ppm CO_2, etc.): four chambers for Pb coupons (one for each of the four time segments) and four for steel coupons. Each test chamber includes eight HDPE containers for the brines (four for fully immersed and four for partially submerged coupons). The three replicate coupons for each setup are separated by nylon spacers and attached to an acrylic hanger with a nylon machine bolt. Each set of replicate coupons is placed into the same brine container. The brine containers are filled with approximately 120 mL of the appropriate brine for the fully immersed replicates and 75 mL of brine for the partially submerged replicate sets. The humid atmosphere set of replicates are hung from the top of the chamber at the end of the brine buckets. A typical setup of a sample test chamber is shown in Figure 3-2. Once the chamber has been loaded the end cap is sealed into place and the chamber is removed from the glove box and attached to the MFGCS.

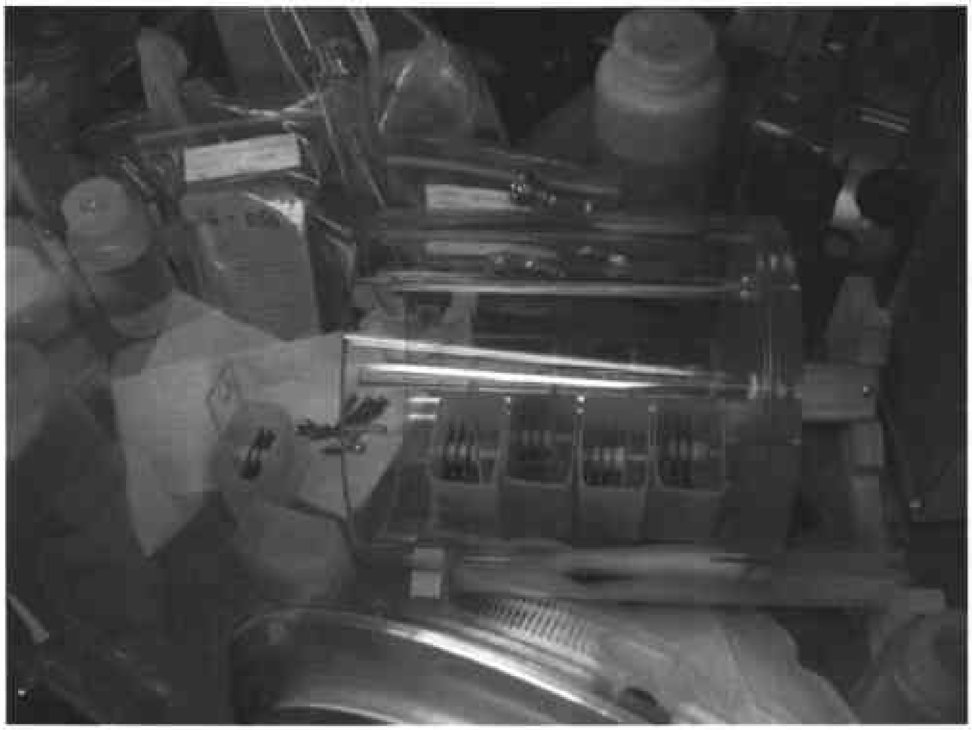


Figure 3-2 Partially loaded sample chamber inside the anoxic glove box. A second row of brine containers will be placed into the chamber and then the humid atmosphere replicates will be hung at the end of the chamber.

3.4 Removal and Unloading of Sample Chambers

At the conclusion of the experiment a sample chamber is disconnected from the MFGCS and placed into the anoxic glove box. Once the chamber is in the glove box its end cap is removed and the brine containers with the coupon hangers are taken out of the sample test chamber. The coupon replicate set is then removed from the brine and given a light rinse with DI water to remove any residual brine on the coupons. The hanger with the replicate coupons is then set aside and allowed to air dry inside the glove box for several hours. Once the coupons are removed from the brine container the pH of the brine is measured. The brine is then poured in a glass serum bottle and the bottle is sealed and crimped. All brine bottles are stored in the glove box for later chemical analysis.

After the replicate coupon sets have dried the three coupons are removed from the hangers. Two of the three replicates will be used to determine the weight loss during the experiments. The process used to determine weight loss is discussed below in Section 4.4. The third replicate coupon is used for characterizing the corrosion products that formed. Each coupon is photographed prior to being cleaned for the weight loss measurements or material characterization activities. Coupons are stored inside the glove box until needed for analysis.

4 EXPERIMENTAL RESULTS

4.1 Steel Coupon Post-Experimental Appearance

After 12 months of exposure in the various brines and atmospheres most of the coupons show clear signs of corrosion. The following figures illustrate the general trends observed among the different experimental conditions. Regardless of the CO_2 concentration, none of the coupons that were exposed only to the humid environment show any clear sign of corrosion. Figure 4-1 shows that there is no obvious change in appearance over the 12 month exposure period.

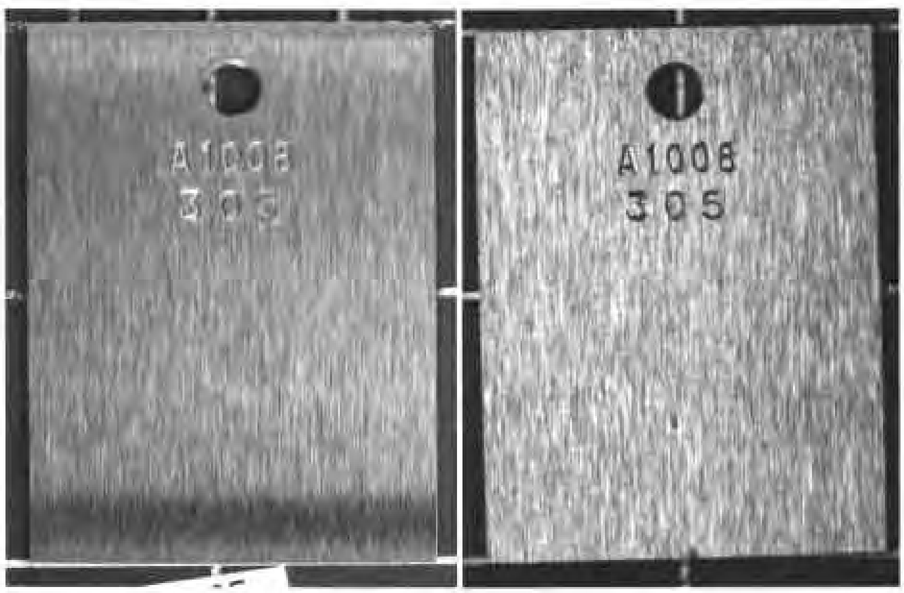


Figure 4-1 Images of steel coupon exposed to humid 1500 ppm CO_2 atmosphere. Left image shows coupon prior to experiments, right image shows coupon after 12 months exposure.

Figure 4-2 shows a series of coupons that were fully immersed in different brine types at 1500 ppm CO_2 for 12 months. The trends seen in this series of coupons are broadly similar to all four of the different atmospheres used. Although there is no visible corrosion product forming on either of the coupons immersed in GWB brines (upper left and right of Figure 4-2), the coupons do have a "hazy" appearance. The hazy appearance and apparent lack of corrosion products is also characteristic of the coupon that was immersed in ERDA-6 containing organic ligands (lower right of Figure 4-2). Coupon 293 shown on the lower left of Figure 4-2 was immersed in ERDA-6 without organic ligands. The appearance of this coupon is different from the others in that dark green patches of corrosion products can be seen in addition to the hazy appearance of the bulk of the coupon surface. The white blotches also visible on coupon 293 are salt crystals that formed on the coupon either during the experiment or after rinsing. As seen in the six month experiments (Roselle, 2009), the formation of corrosion products on the coupon hangers was seen in all brines and at all CO_2 concentrations. The corrosion products were removed from the hangers using a razor blade and are stored for later analysis.

In contrast to the fully immersed coupons, the partially submerged coupons show more pronounced formation of corrosion products. Figure 4-3 shows a series of coupons that were partially submerged in the different brine types at 1500 ppm CO_2 for 12 months. As with the fully immersed coupons the trends seen in this series of partially submerged coupons are broadly similar in all four of the different atmospheres used. In all cases shown in Figure 4-3 the most significant corrosion product formation occurred at the brine/atmosphere interface. This is consistent with observations made by Telander and Westerman (1993, 1997). From Figure 4-3 it is apparent that those coupons exposed to GWB brines exhibit far less corrosion product formation at the brine/atmosphere interface than those exposed to the ERDA-6 brines. The coupons placed in GWB show only a thin band of greenish corrosion products forming at the interface, whereas coupons in ERDA-6 show a wider band of dark green corrosion products.

For those portions of the coupons that were below the brine/atmosphere interface the formation of corrosion products appears to be limited. As with the fully immersed coupons, there is no visible corrosion product forming on either of the coupons immersed in GWB brines (upper left and right of Figure 4-3) and the coupons have a "hazy" appearance. The same observation can be made for the coupon that was immersed in ERDA-6 without organic ligands (lower left of Figure 4-3). The portion of the coupon immersed in ERDA-6 with organic ligands shows the appearance of some dark green patches of corrosion products in addition to the hazy appearance on the bulk of the coupon surface. No corrosion products formed on the acrylic hangers used in these experiments because the hangers did not extend into the brine. However, corrosion product formation was observed on the sides of the brine containers.

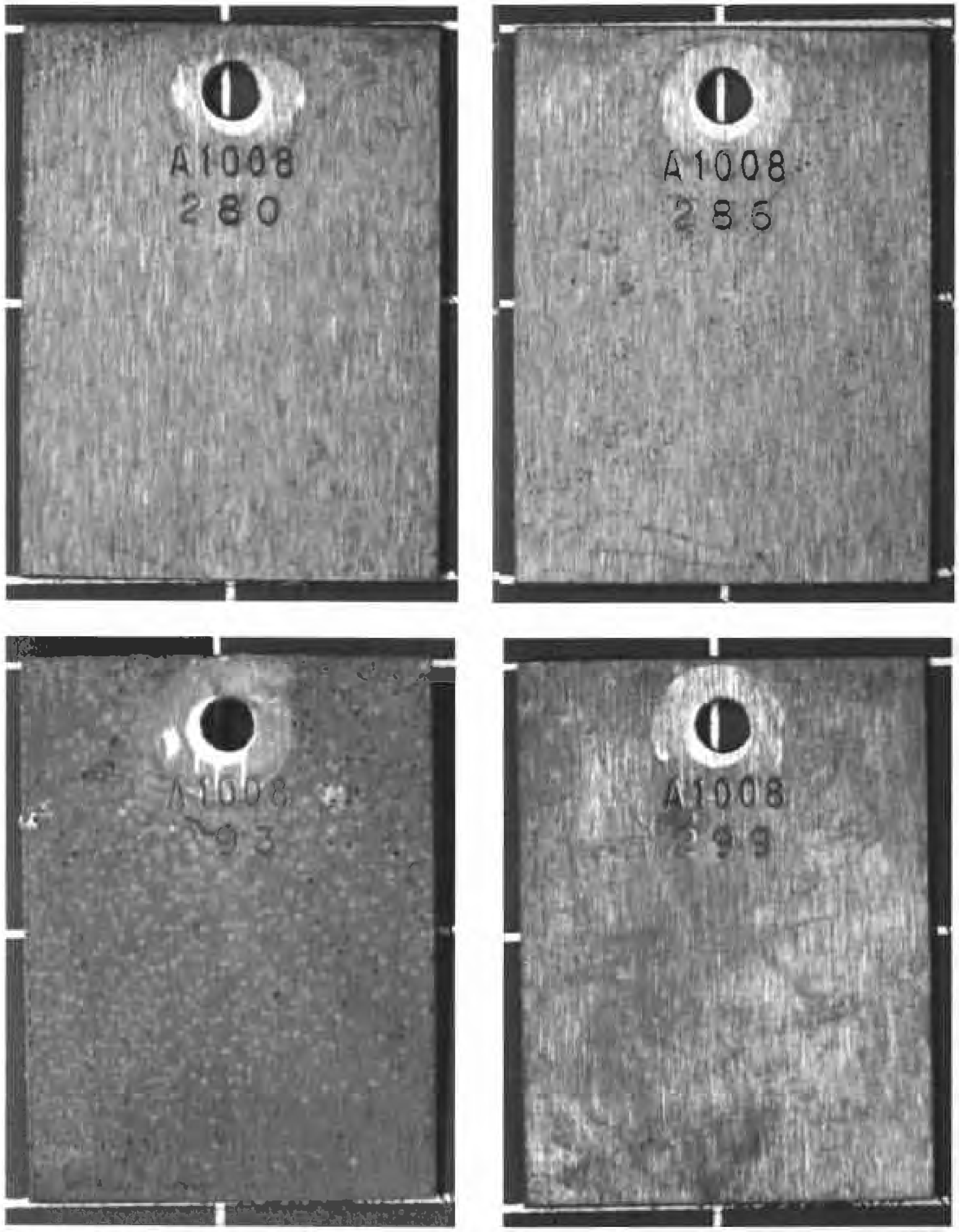


Figure 4-2 Photographs of fully immersed steel coupons after 12 months exposure in a 1500 ppm CO_2 atmosphere. Coupon 280 (top left) submerged in GWB without organics. Coupon 286 (top right) submerged in GWB with organic ligands. Coupon 293 (bottom left) submerged in ERDA-6 without organics. Coupon 299 (bottom right) submerged in ERDA-6 with organic ligands.

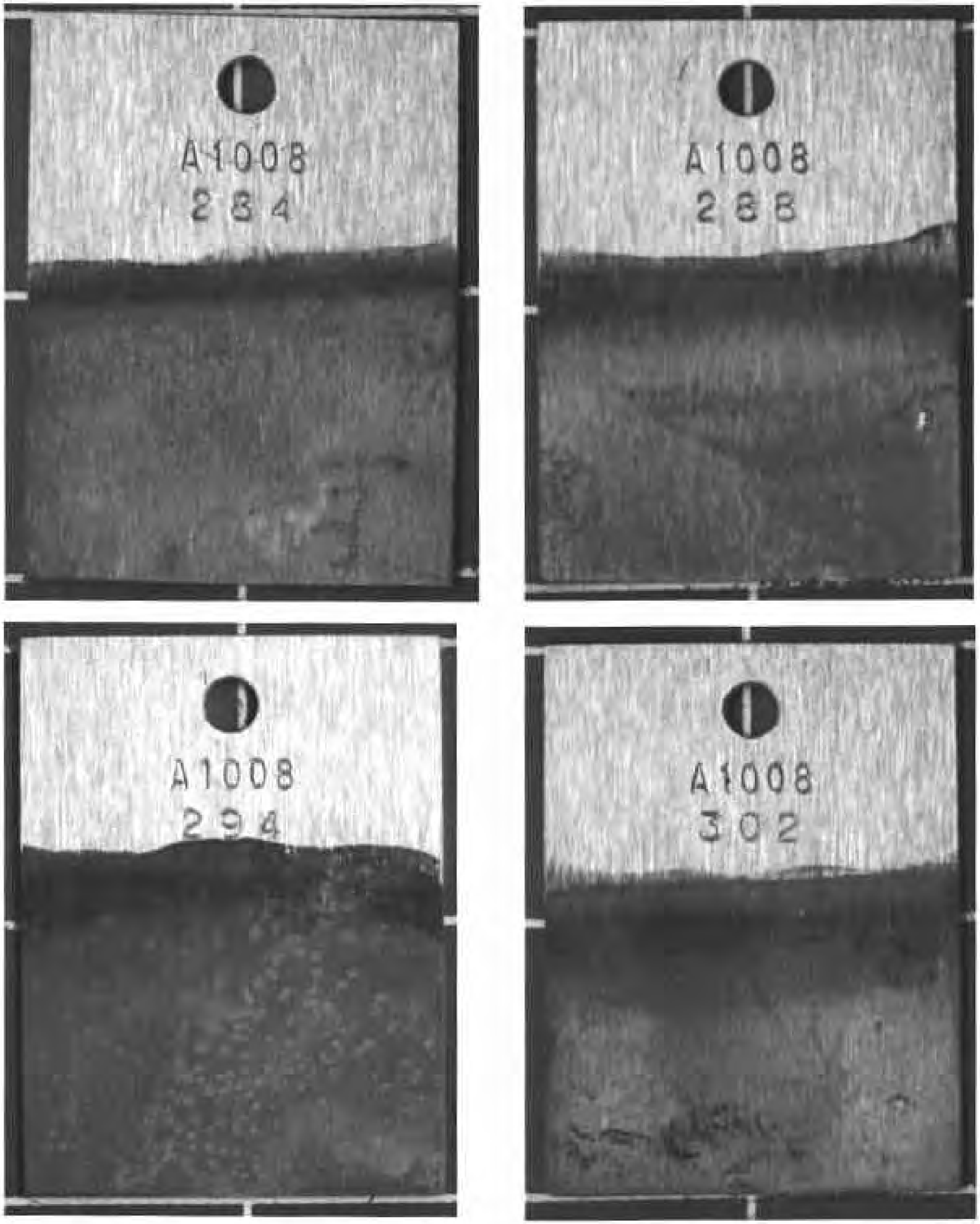


Figure 4-3 Photographs of partially submerged steel coupons after 12 months exposure in a 1500 ppm CO_2 atmosphere. Coupon 284 (top left) submerged in GWB without organics. Coupon 288 (top right) submerged in GWB with organic ligands. Coupon 294 (bottom left) submerged in ERDA-6 without organics. Coupon 302 (bottom right) submerged in ERDA-6 with organic ligands.

4.2 Lead Coupon Post-Experimental Appearance

Lead coupons show little macroscopic evidence of corrosion in any of the experiments. In general, the only visible change in many of the coupons is a discoloration in those parts of the coupons exposed to the humid atmosphere. This is evident at the edges of the coupon shown in Figure 4-4, which shows before and after pictures of a coupon exposed to the 3500 ppm CO_2 humid atmosphere. The discoloration forms in all of the experimental atmospheres used. This same discoloration is also observed on the upper portion of coupons that were partially submerged. Figure 4-5 shows a series of lead coupons that were partially submerged in the different brine types at 1500 ppm CO_2 for 12 months. Unlike the steel coupons, there seems to be no corrosion product formation occurring at the brine/atmosphere interface. There also appears to have been little corrosion product formation on coupon surfaces exposed to the brine beneath the brine/atmosphere interface. From Figure 4-5 it can be seen that those portions of the coupons within the brine appear much the same as they did before the experiments (compare with Figure 4-4).

Coupons that were fully immersed in the brines show similar traits to those observed in the partially submerged coupons (Figure 4-6). Again, there is no visible corrosion product formation on the coupons regardless of the brine type in which they were immersed. As with the partially submerged coupons some of the fully immersed coupons show growth of salt crystals on the coupon surface.

Figure 4-4 Images of lead coupon exposed to humid 3500 ppm CO_2 atmosphere. Left image shows coupon prior to experiments, right image shows coupon after 12 months exposure.

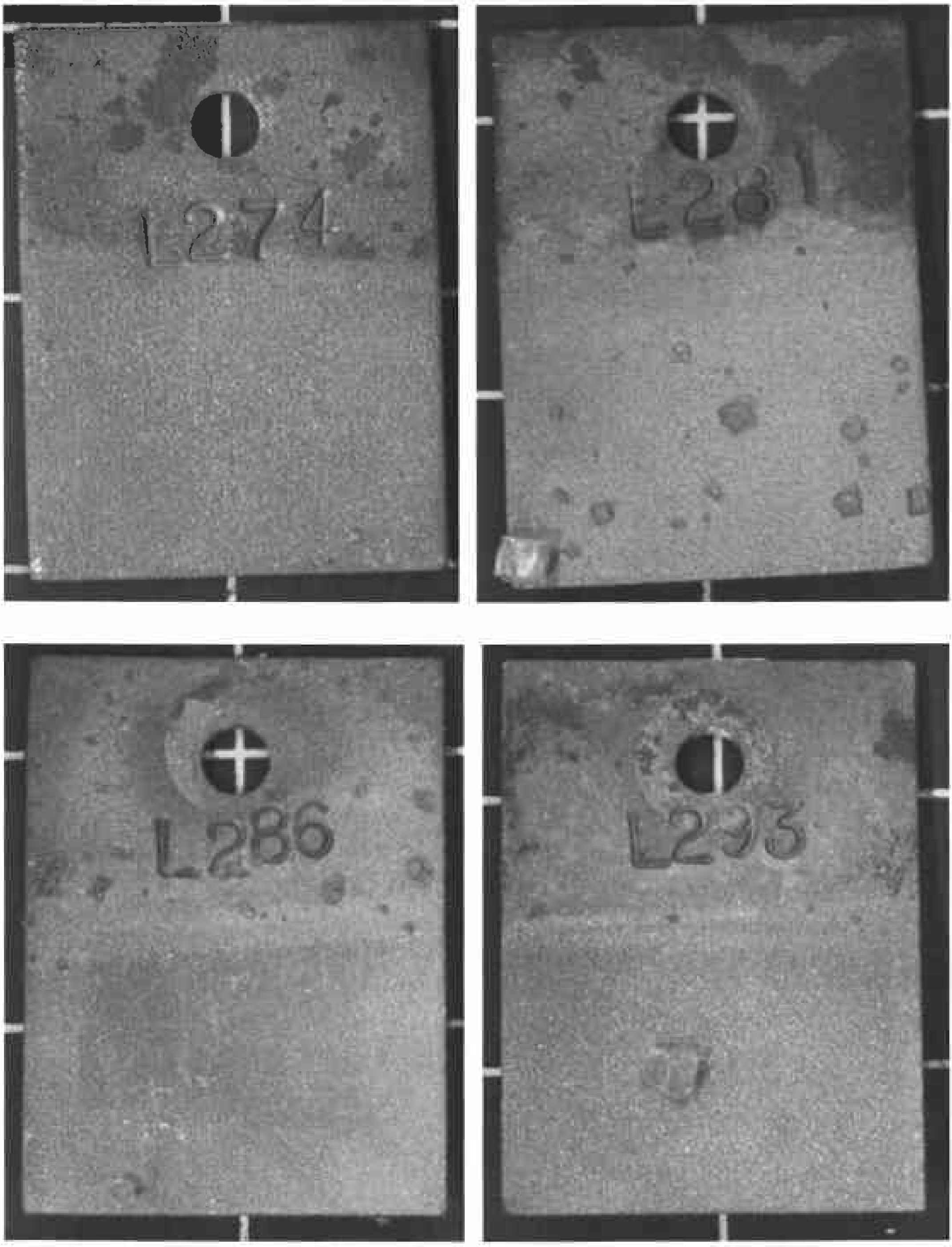


Figure 4-5 Photographs of partially submerged lead coupons after 12 months exposure in a 1500 ppm CO_2 atmosphere. Coupon L274 (top left) submerged in GWB without organics. Coupon L281 (top right) submerged in GWB with organic ligands. Coupon L286 (bottom left) submerged in ERDA-6 without organics. Coupon L293 (bottom right) submerged in ERDA-6 with organic ligands.

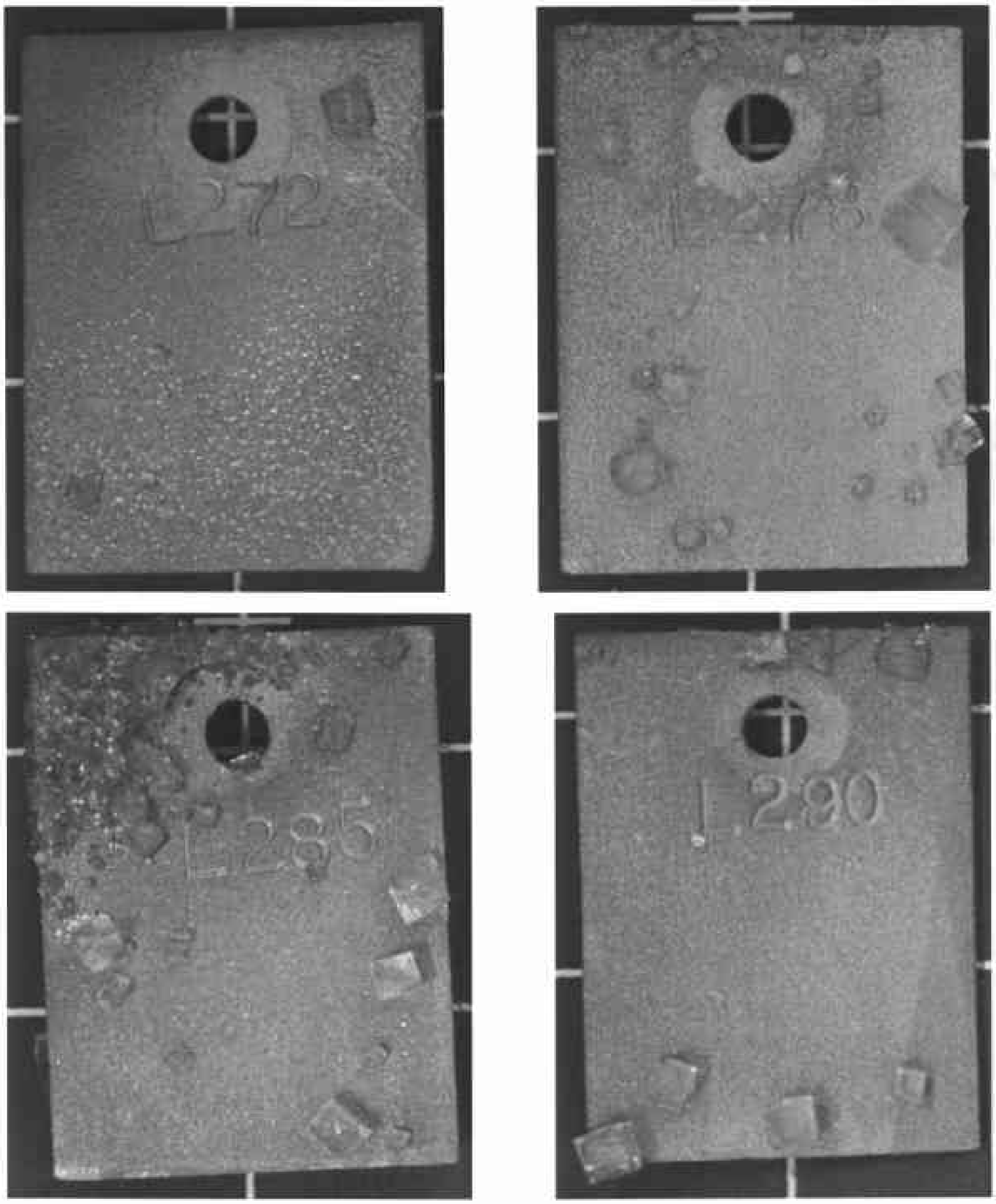


Figure 4-6 Photographs of fully immersed lead coupons after 12 months exposure in a 1500 ppm CO_2 atmosphere. Coupon L272 (top left) submerged in GWB without organics. Coupon L278 (top right) submerged in GWB with organic ligands. Coupon L285 (bottom left) submerged in ERDA-6 without organics. Coupon L290 (bottom right) submerged in ERDA-6 with organic ligands.

4.3 Scanning Electron Microscopy

Scanning electron microscopy (SEM) combined with energy dispersive spectroscopy (EDS) was used to characterize the corrosion products on the coupons. Due to the limited amount of products formed many characterization techniques such as X-ray diffraction (XRD) and electron backscatter diffraction (EBSD) have not yet yielded a positive identification of the different phases. Thus, the SEM imaging and EDS analysis provide an important tool with which to classify, at least qualitatively, the different types of corrosion products.

For each of the test conditions one of the three replicate coupons was used for corrosion product characterization. Each of these coupons was removed from the anoxic glovebox and quickly photographed and then placed into the SEM in order to minimize exposure to air. Coupons were mounted in a large sample holder without any coating. SEM images and EDS spectra were taken using a JEOL JSM-5900LV with a ThermoNORAN Energy Dispersive Spectroscopy system. At the conclusion of the SEM analysis the coupons were quickly placed back into the anoxic glovebox.

4.3.1 Steel Coupons

The appearance of an unreacted steel coupon is shown in Figure 4-7. The surface of the coupon is smooth showing only linear striations due to the surface finishing at the supplier. The EDS spectrum of this coupon is not shown but indicates only the presence of iron. The minor constituents of the steel (see Table 2-1 in Roselle, 2009) are not present in high enough concentration to be detected. This image serves as a baseline for comparison with other coupons. Although SEM imaging and EDS analysis was completed for one replicate coupon from every test condition, this section will only present a few examples that illustrate the general trends seen in corrosion product formation.

The SEM imaging of coupons exposed only to the humid environments yields results that are consistent with the macroscopic observations in that almost no corrosion product formation is observed. Figure 4-8 shows a SEM image and EDS spectra for one of the coupons exposed to the humid 1500 ppm CO_2 atmosphere. The appearance of the coupon shows little change from an unreacted coupon (compare with Figure 4-7) and the EDS spectra shows only an iron peak. Some of the humid condition coupons, however, do show incipient signs of very limited corrosion product formation. These corrosion products tend to form at the interface between the coupon and the nylon spacer used for hanging. It is likely that condensation in this space promoted the formation of some corrosion products. The observed corrosion products in this case are similar to those observed at the brine/atmosphere interface in the partially submerged coupons (discussed below).

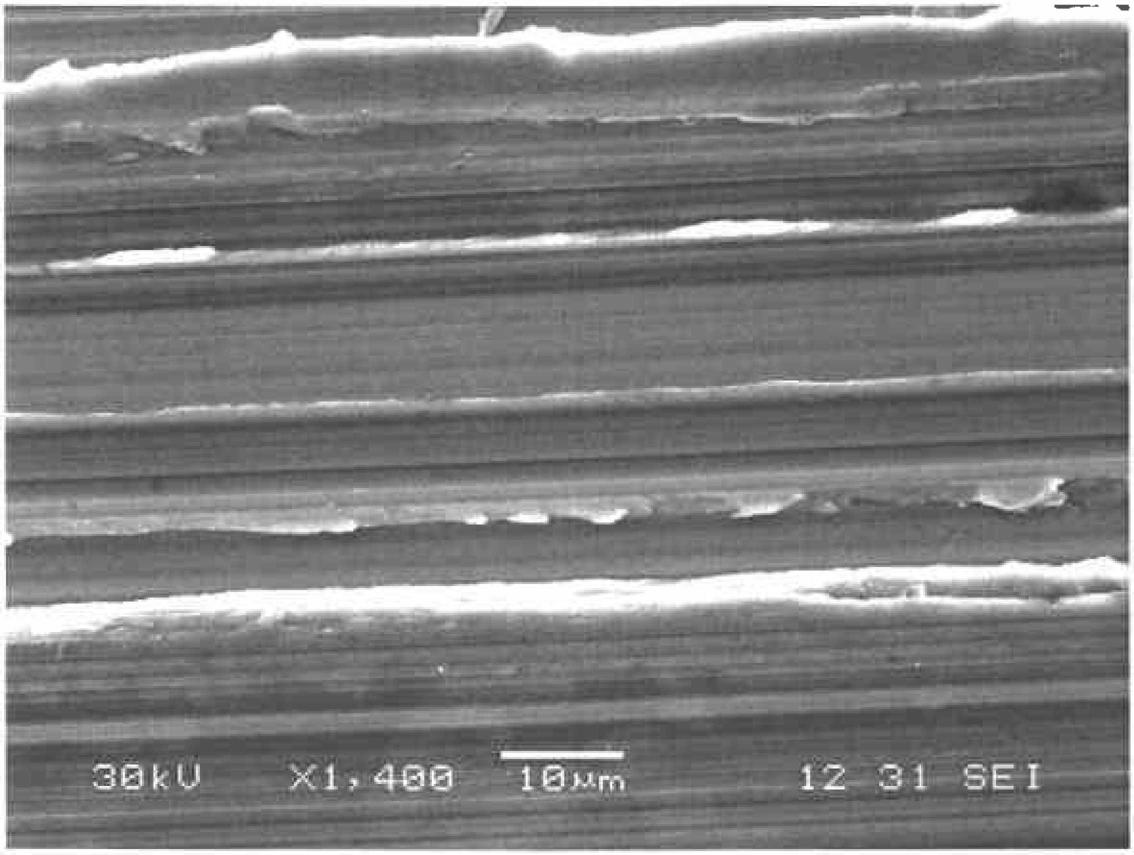


Figure 4-7 SEM image of unreacted portion of steel coupon 110. Image source: *110E_1.BMP* located on disk in "WIPP-FePb-3 Supplemental Binder D".

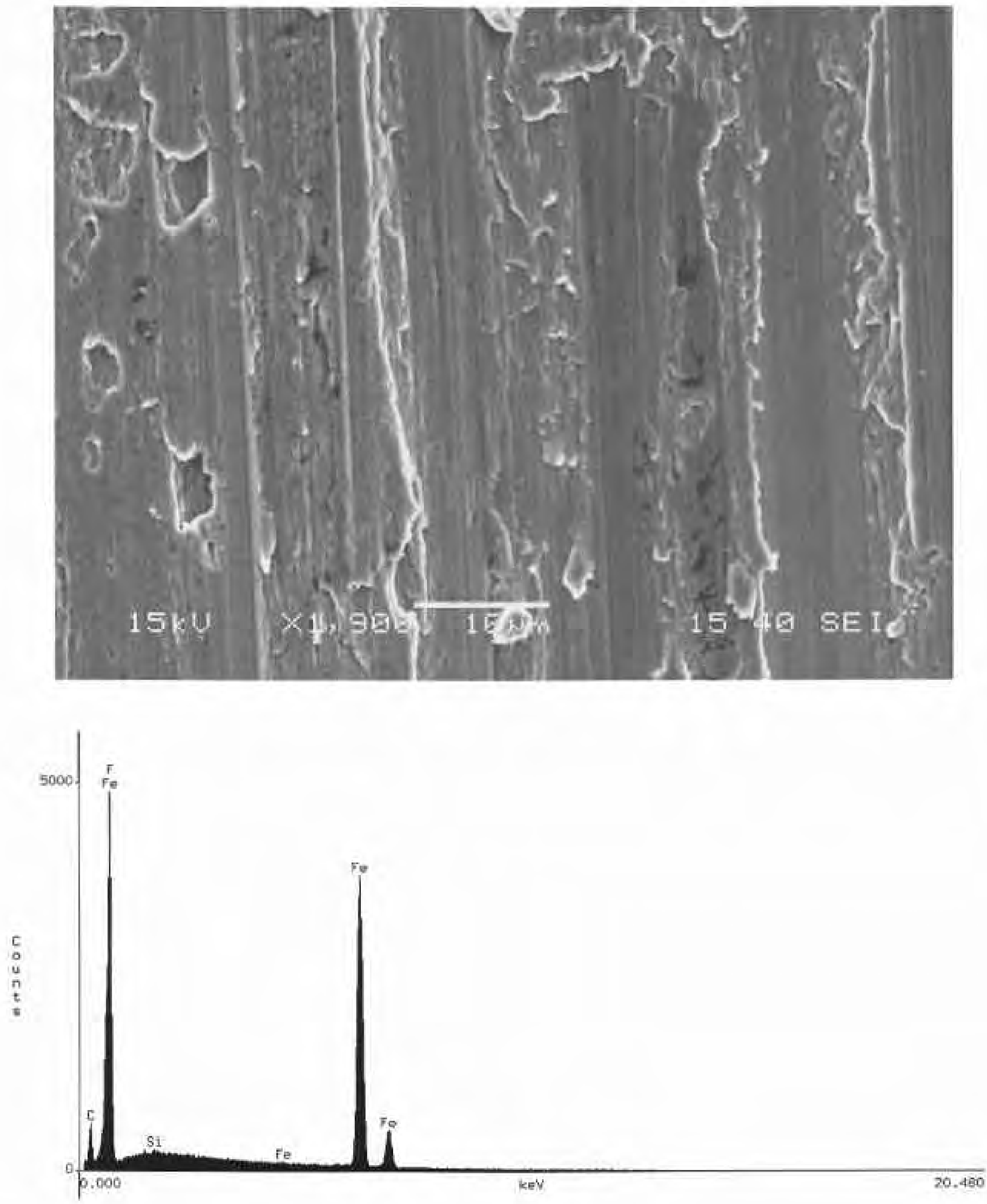


Figure 4-8 SEM image (top) and EDS spectra (bottom) of steel coupon 303 reacted in a humid 1500 ppm CO_2 atmosphere for 12 months. EDS spectra indicates the presence of only iron. Sources: image file *303_1.BMP* and EDS spectra file *303_1.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

Steel coupons that were immersed in brines exhibit several different types of corrosion products. Although the mineralogical identification of the phases has not yet been possible, they can be distinguished by their habit and EDS spectra. Table 4-1 lists each of the major phases with its identifying habit and qualitative composition. The occurrence of each of these phases in the different test conditions is summarized in Table 4-2. Iron chloride 1 is the phase that forms the green bands at the brine/ atmosphere interface in the partially submerged experiments (see Figure 4-3). It is observed in all of the partially submerged coupons regardless of the brine type or exposure atmosphere. In contrast to the six month experiments (Roselle, 2009), the iron chloride 1 phase is found on most of the fully immersed coupons in both ERDA-6 and GWB brines. A SEM image of the typical appearance of the iron chloride 1 phase is shown in Figure 4-9. This phase always exhibits this characteristic angular or blocky habit and often forms columns with a triangular symmetry. Energy dispersive spectroscopy (EDS) of this corrosion product shows that it is likely an iron/magnesium-chlori-hydroxide. The EDS spectrum of this phase is also shown in Figure 4-9 for this same coupon. The pattern seen here is typical of all occurrences of this phase in both the six and 12 month experiments.

The corrosion product phase, iron chloride 2, is found on only a few samples. There is not a consistent pattern for its occurrence as it is observed on both partially and fully submerged samples in all brine types. However, it does seem to be restricted to samples exposed to CO_2 levels of 350 ppm or less. It often occurs comingled with the iron chloride 1 phase as can be seen in Figure 4-10. This phase consistently appears as aggregates of spherical rosettes of plate-like crystals. Iron chloride 2 often forms along linear features of the steel coupon that are likely sites of high surface energy. It also tends to form on the coupon surface beneath the brine/atmosphere interface in partially submerged coupons. The chemistry of iron chloride 2 as determined by EDS analysis (Figure 4-10) shows that it is also an iron-chlori-hydroxide. It differs from iron chloride 1 in that it has little or no magnesium and the chlorine peak tends to be larger than the oxygen peak.

In addition to the phases described in Table 4-1 some samples exhibit phases denoted as "Other" in Table 4-2. These phases are typically composed of potassium, sulfur, and calcium. It is likely that these phases are not corrosion products but represent precipitates of the brine that formed after the samples were removed from the experimental chambers.

Table 4-1 Corrosion Product Phases Observed on Steel Coupons

Phase	Habit	Chemistry
Iron chloride 1	angular, blocky columns	Fe-Cl-Mg-O (O peak > Cl peak)
Iron chloride 2	fuzzy aggregates of plates	Fe-Cl-O±Mg (Cl peak > O peak)
Carbonate 1	large ovoid rosettes	Ca-C-O
Carbonate 2	smaller spherical rosettes	Ca-Fe-Mg-C-O

Table 4-2 Occurrence of Steel Coupon Corrosion Product Phases in Different Test Conditions

Test ID	Coupon	Iron chloride 1	Iron chloride 2	Carbonate 1	Carbonate 2	Other
Humid Samples						
Fe-Atm-0000-12-3	086	--	--	--	--	--
Fe-Atm-0350-12-3	224	--	--	--	--	X
Fe-Atm-1500-12-1	303	--	--	--	--	--
Fe-Atm-3500-12-3	414	--	--	--	--	X
GWB Brines						
Fe-G-0000-12-3f	062	X	--	--	--	--
Fe-Go-0000-12-3f	068	X	--	--	--	X
Fe-G-0350-12-1f	189	X	--	--	--	--
Fe-Go-0350-12-1f	204	--	--	--	--	--
Fe-G-1500-12-1f	279	--	?	--	--	--
Fe-Go-1500-12-1f	285	X	--	--	--	--
Fe-G-3500-12-3f	390	X	--	--	--	X
Fe-Go-3500-12-3f	396	X	--	--	X	--
Fe-G-0000-12-3p	065	X	X	--	--	--
Fe-Go-0000-12-3p	071	X	--	--	--	--
Fe-G-0350-12-3p	203	X	--	--	--	--
Fe-Go-0350-12-3p	209	X	X	--	X	X
Fe-G-1500-12-1p	282	X	--	--	--	--
Fe-Go-1500-12-1p	288	X	--	X	--	--
Fe-G-3500-12-3p	393	X	--	--	X	--
Fe-Go-3500-12-3p	399	X	--	--	X	--
ERDA-6 Brines						
Fe-E-0000-12-3f	074	X	X	--	--	--
Fe-Eo-0000-12-3f	080	X	X	--	--	X
Fe-E-0350-12-2f	211	X	X	--	--	--
Fe-Eo-0350-12-1f	216	X	--	--	--	--
Fe-E-1500-12-1f	291	X	--	X	X	--
Fe-Eo-1500-12-1f	297	--	--	X	X	--
Fe-E-3500-12-3f	402	--	--	X	X	--
Fe-Eo-3500-12-3f	408	--	--	X	X	--
Fe-E-0000-12-3p	077	X	X	--	--	--
Fe-Eo-0000-12-3p	083	X	--	--	--	--
Fe-E-0350-12-3p	215	X	--	X	--	--
Fe-Eo-0350-12-1p	219	X	--	--	--	--
Fe-E-1500-12-1p	294	X	--	X	X	X
Fe-Eo-1500-12-1p	300	X	--	--	X	--
Fe-E-3500-12-3p	405	X	--	X	X	X
Fe-Eo-3500-12-3p	411	X	--	--	X	--

Note: ? indicates that the phase is likely present but the results are ambiguous.

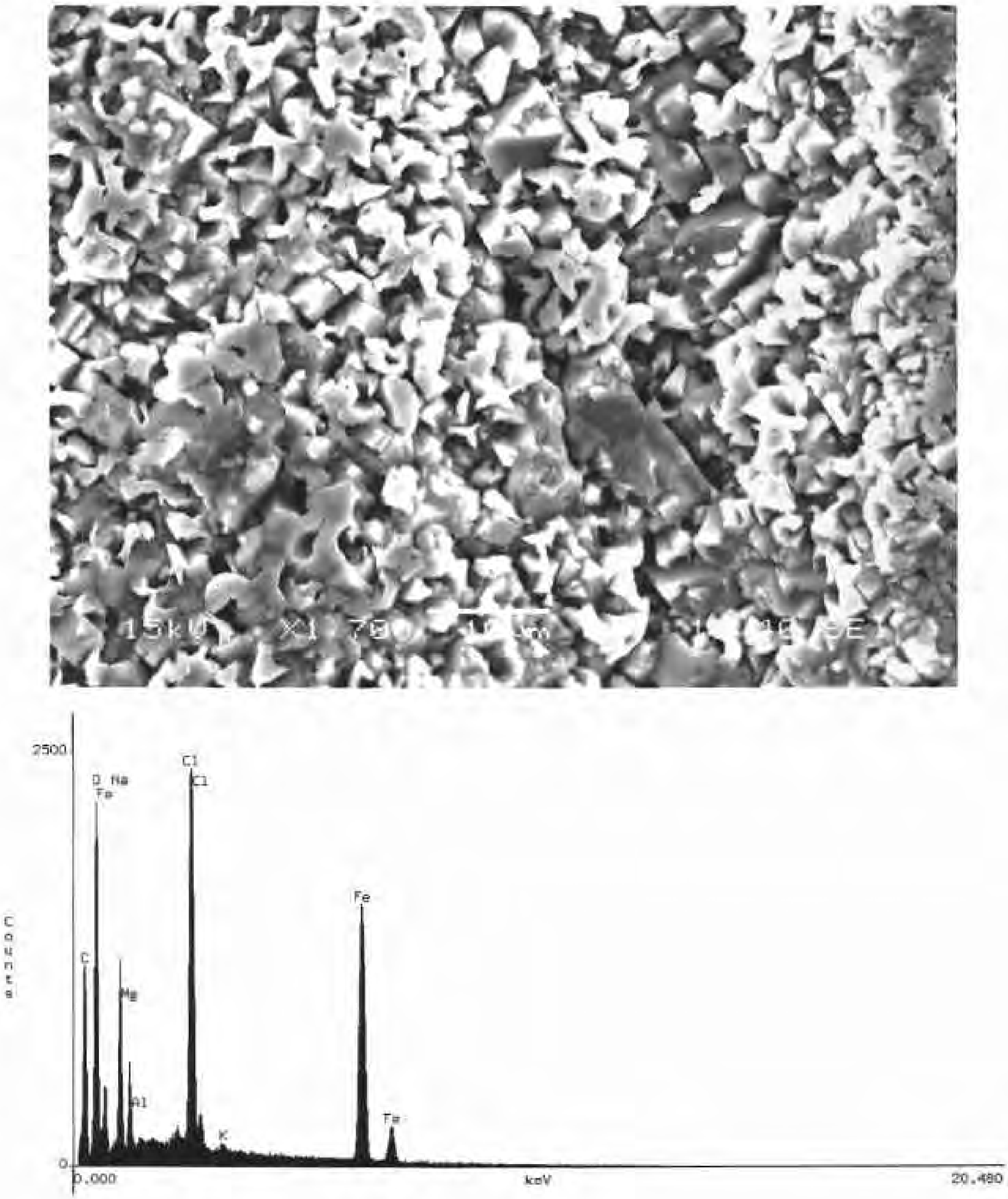
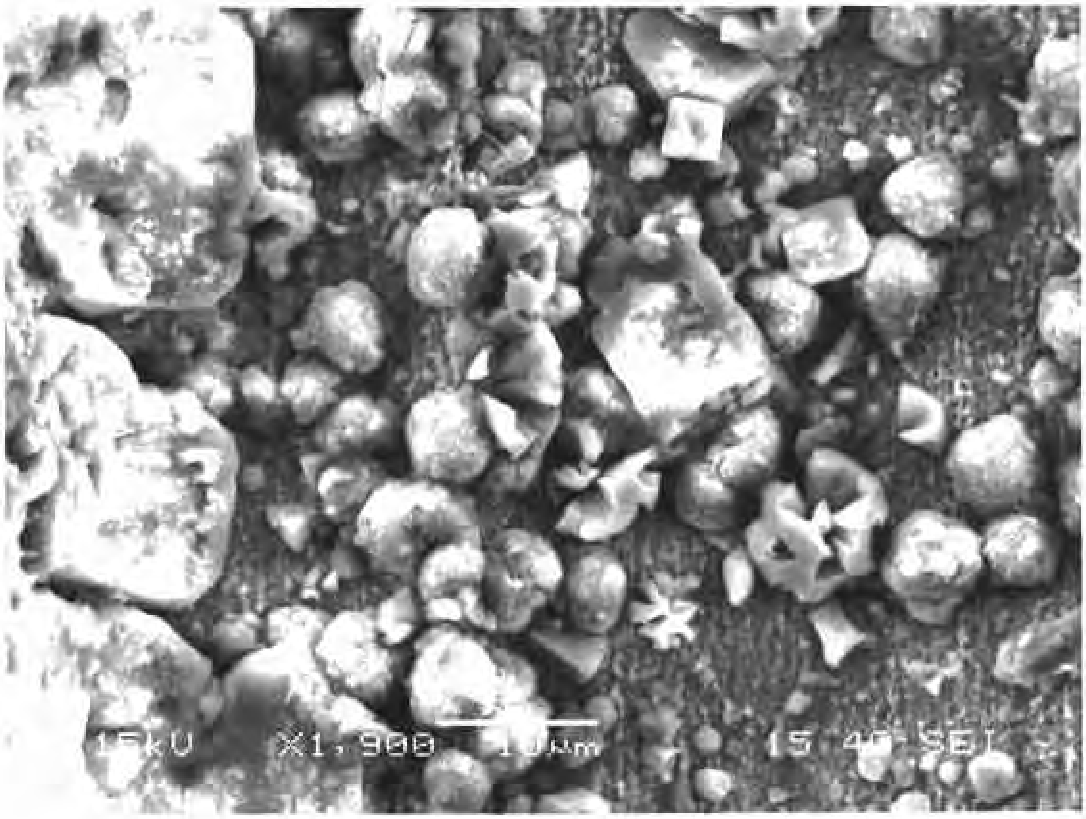


Figure 4-9 SEM image (top) and EDS spectra (bottom) of corrosion product "iron chloride 1" formed on partially submerged coupon 077. This phase forms the green band on partially submerged samples at the brine/atmosphere interface in all brine types and CO_2 concentrations. Sources: image file *077_1.BMP* and EDS spectra file *077_1.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".



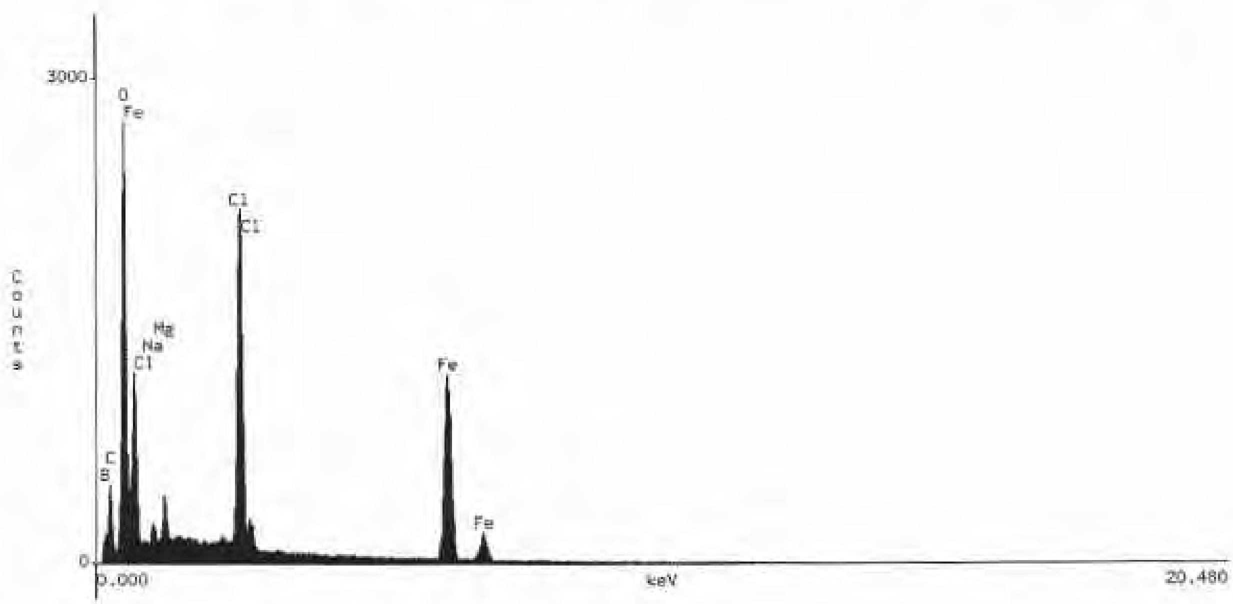


Figure 4-10 SEM image (top) of both iron chloride phases on steel coupon 077. The angular blocks are iron chloride 1, whereas the spherical rosettes are iron chloride 2. Heavy pitting of the underlying steel surface can also be observed. Typical EDS spectra (bottom) of corrosion product iron chloride 2 is also shown. Sources: image file *077_2.BMP* and EDS spectra file *077_2.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

In experiments conducted in atmospheres that contained CO_2 two different phases are observed on the coupons. The phases have been labeled as carbonate 1 and carbonate 2 based on their morphology and EDS spectra. The phase carbonate 1 forms large spheres that have a blocky or stepped appearance. Often these spheres occur in pairs making them look ovoid in shape. Figure 4-11 shows an SEM image of coupon 408 that was fully immersed in ERDA-6 with organic ligands in a 3500 ppm CO_2 atmosphere. A typical EDS spectrum for carbonate 1 is shown in Figure 4-12 and indicates that it is most likely a calcium carbonate phase. The phase carbonate 1 forms only in ERDA-6 brines (both with and without organic ligands) at CO_2 concentrations greater than 1500 ppm (see Table 4-2). The phase carbonate 1 is likely a precipitate from brine that has equilibrated with the higher CO_2 concentrations in these experiments. Therefore, it should not be considered a corrosion product in the strictest sense.

The phase labeled carbonate 2 occurs in most experiments conducted in ERDA-6 brines that contain CO_2 atmospheres (Table 4-2). It is also present in some GWB experiments at the higher CO_2 concentrations. This phase also appears as spherical aggregates of blocky or stepped crystals. The spheres of carbonate 2 are consistently smaller and more abundant than carbonate 1 when they occur together (Figure 4-11). Although they appear to have much the same habit as carbonate 1, the EDS spectra for carbonate 2 is markedly different. The EDS spectrum of carbonate 2 in Figure 4-13 shows that this phase is likely an iron-calcium-magnesium carbonate. Based on its chemistry carbonate 2 can be considered the actual corrosion product in these experiments.

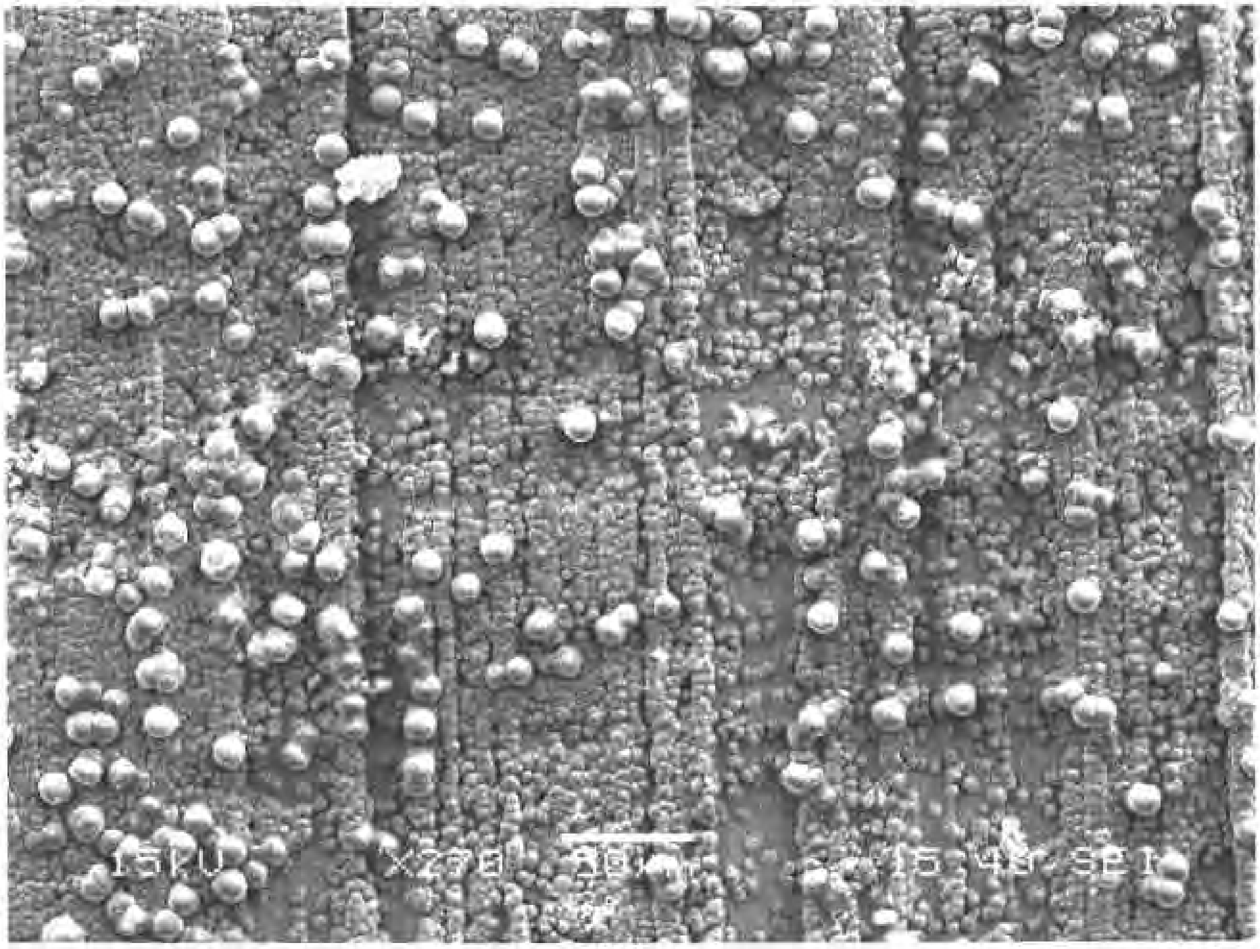


Figure 4-11 SEM image of carbonate corrosion products formed on fully immersed coupon 408. The larger ovoid phases are carbonate 1. The smaller spherical aggregates are carbonate 2. Image source: *408_3.BMP* located on disk in "WIPP-FePb-3 Supplemental Binder D".

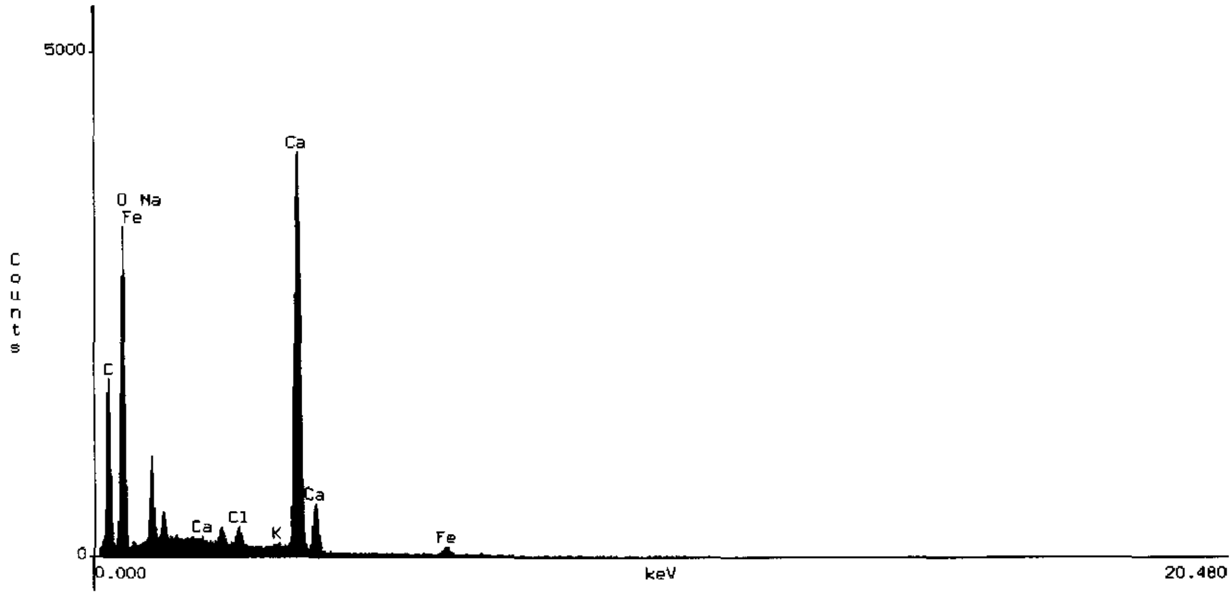


Figure 4-12 EDS spectra carbonate 1 phase as found on coupon 408. EDS spectra source: file *408_2.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

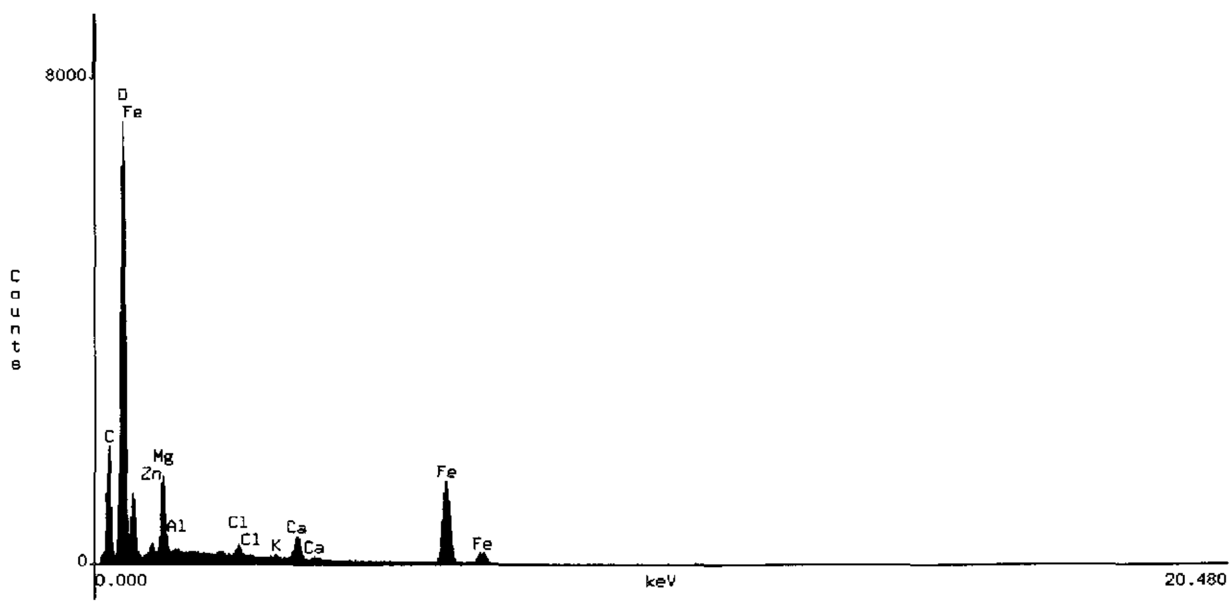


Figure 4-13 EDS spectra carbonate 2 phase as found on coupon 408. EDS spectra source: file *408_3a.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

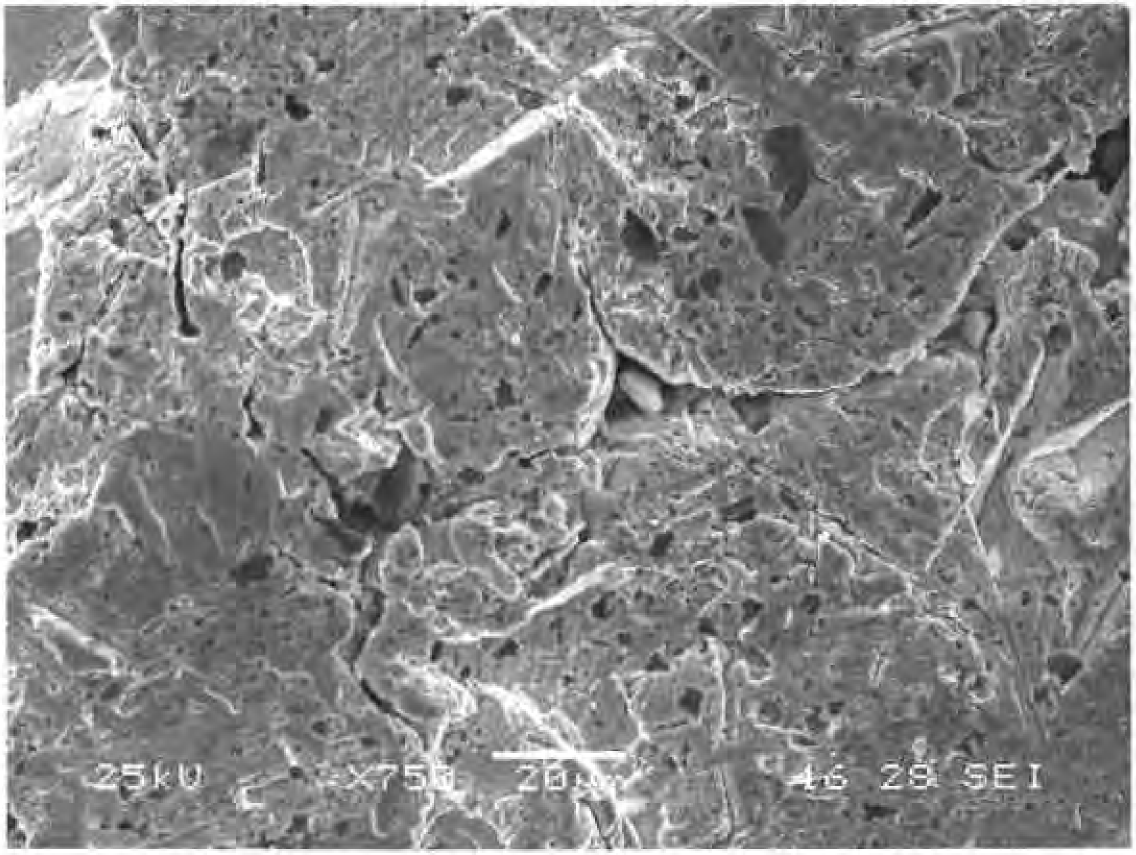
4.3.2 Lead Coupons

The appearance of an unreacted lead coupon is shown in Figure 4-14. The surface of the lead coupons is rough and pitted. The EDS spectrum of this coupon also shown in Figure 4-14 indicates only the presence of lead. The minor constituents of the lead (see Table 2-2 in Roselle, 2009) are not present in high enough concentration to be detected. The image in Figure 4-14, however, shows that the lead coupons contain inclusions of an unknown mineral phase. EDS analysis of these inclusions shows that they are a calcium-sodium silicate phase (Roselle, 2009). These inclusions are likely a contaminant from the process used to produce the lead coupons, either in their casting or the surface finishing. They are only a minor inclusion but have been observed in all coupons.

The SEM imaging of lead coupons shows a limited amount of corrosion product formation in experiments conducted in atmospheres that contained CO_2. In contrast to the six month experiments where only one corrosion product phase was identified (Roselle, 2009), the 12 month experiments show the presence of an additional phase on a few samples. Both of the corrosion product phases identified on the 12 month samples appear to be carbonate phases. The phases have been labeled as Pb-Ca carbonate and Pb carbonate based on their morphology and EDS spectra. The distribution of the two phases in the different experiments is shown in Table 4-3.

The Pb-Ca carbonate phase is similar in crystal habit to the carbonate 1 phase identified in the steel coupons. Figure 4-15 shows an SEM image of coupon L409 that was partially immersed in ERDA-6 with organic ligands in a 3500 ppm CO_2 atmosphere. A typical EDS spectrum for this phase is also shown in Figure 4-15 and indicates that it is most likely a lead-calcium carbonate phase. The Pb-Ca carbonate phase typically forms only in ERDA-6 brines (both with and without organic ligands) at CO_2 concentrations of 1500 ppm or greater. Although there is one occurrence of this phase at 350 ppm CO_2 and in one of the samples immersed in GWB (see Table 4-3).

The Pb carbonate phase has an elongated prism habit and Table 4-3 shows that the formation of this phase is limited to only a small number of experiments. Figure 4-16 shows an SEM image of coupon L294 that was partially immersed in ERDA-6 with organic ligands in a 1500 ppm CO_2 atmosphere. A typical EDS spectrum for this phase is also shown in Figure 4-15 and indicates that it is most likely a lead carbonate phase.



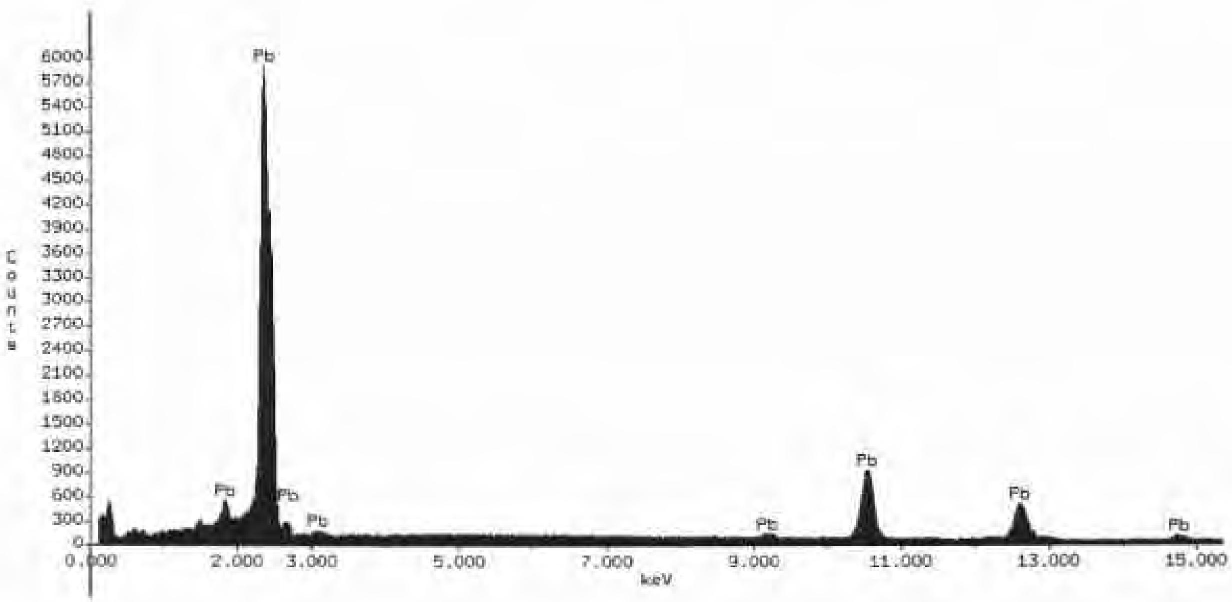


Figure 4-14 SEM image (top) and EDS spectra (bottom) of unreacted lead coupon L456. Sources: image file L*456E_1.BMP* and spectra file *L456_1b.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

Table 4-3 Occurrence of Lead Coupon Corrosion Product Phases in Different Test Conditions

Test ID	Coupon	Ca-Pb Carbonate	Pb Carbonate
Pb-Atm-0000-12-3	L081	--	--
Pb-Atm-0350-12-3	L216	--	--
Pb-Atm-1500-12-3	L298	--	--
Pb-Atm-3500-12-3	L412	--	--
Pb-G-0000-12-3f	L057	--	--
Pb-Go-0000-12-3f	L063	--	--
Pb-G-0350-12-3f	L192	--	--
Pb-Go-0350-12-2f	L197	--	--
Pb-G-1500-12-1f	L271	--	--
Pb-Go-1500-12-3f	L279	--	--
Pb-G-3500-12-3f	L388	?	--
Pb-Go-3500-12-3f	L394	--	--
Pb-G-0000-12-3p	L060	--	--
Pb-Go-0000-12-3p	L066	--	--
Pb-G-0350-12-1p	L193	--	--
Pb-Go-0350-12-3p	L201	--	--
Pb-G-1500-12-1p	L274	--	--
Pb-Go-1500-12-3p	L282	--	X
Pb-G-3500-12-3p	L391	--	--
Pb-Go-3500-12-3p	L397	--	--
Pb-E-0000-12-1f	L067	--	--
Pb-Eo-0000-12-1f	L073	--	--
Pb-E-0350-12-1f	L202	X	--
Pb-Eo-0350-12-1f	L208	--	--
Pb-E-1500-12-2f	L284	X	--
Pb-Eo-1500-12-1f	L289	X	--
Pb-E-3500-12-3f	L400	X	--
Pb-Eo-3500-12-3f	L406	X	--
Pb-E-0000-12-1p	L070	--	--
Pb-Eo-0000-12-3p	L078	--	--
Pb-E-0350-12-2p	L206	--	--
Pb-Eo-0350-12-3p	L213	--	X
Pb-E-1500-12-3p	L288	X	X
Pb-Eo-1500-12-3p	L294	--	X
Pb-E-3500-12-3p	L403	X	--
Pb-Eo-3500-12-3p	L409	X	--

Note: ? indicates that the phase is likely present but the results are ambiguous.

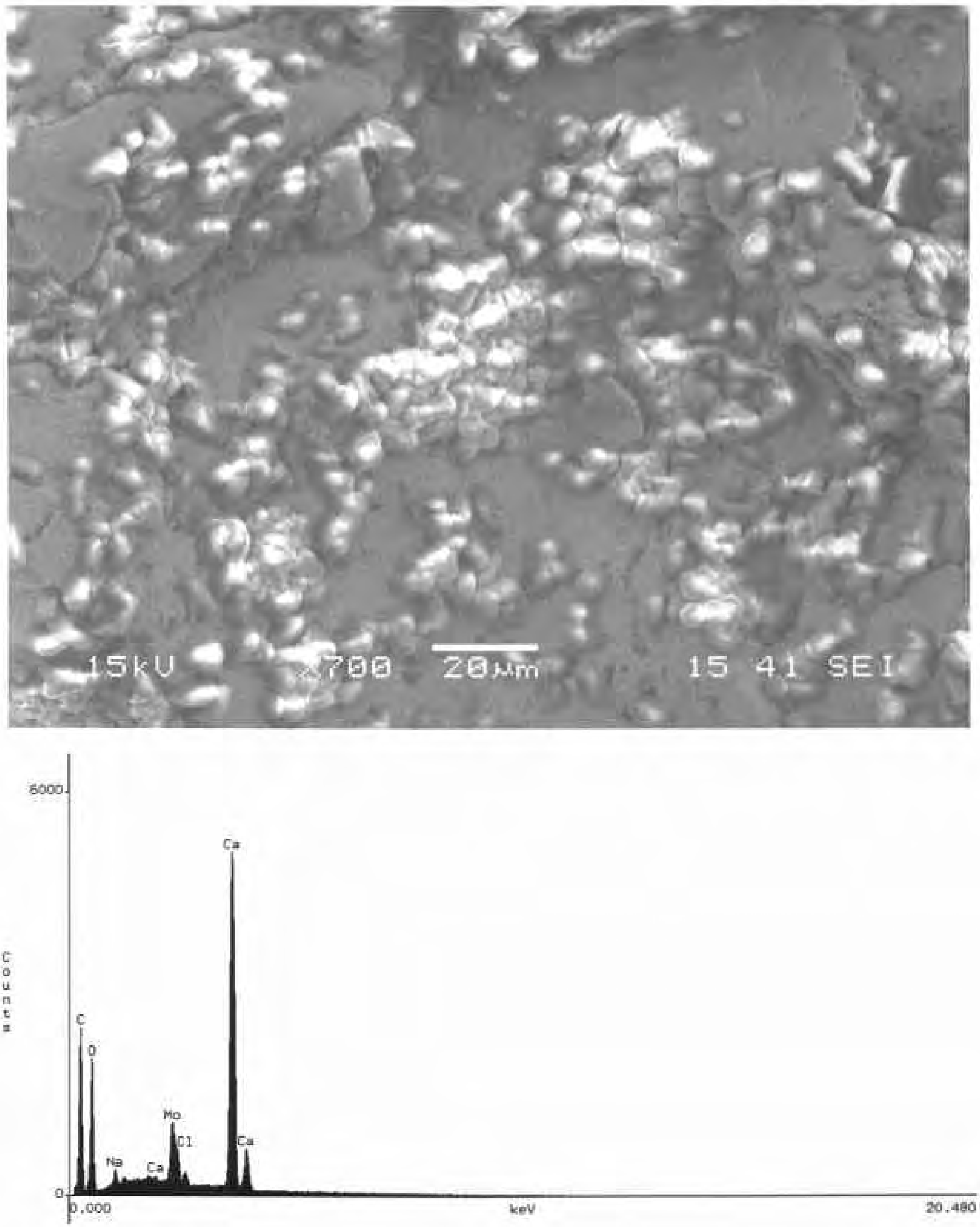


Figure 4-15 SEM image (top) and EDS spectra (bottom) of Pb-carbonate corrosion products formed on partially submerged coupon L409. Sources: image file *L409_4.BMP* and spectra file *L409_4.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

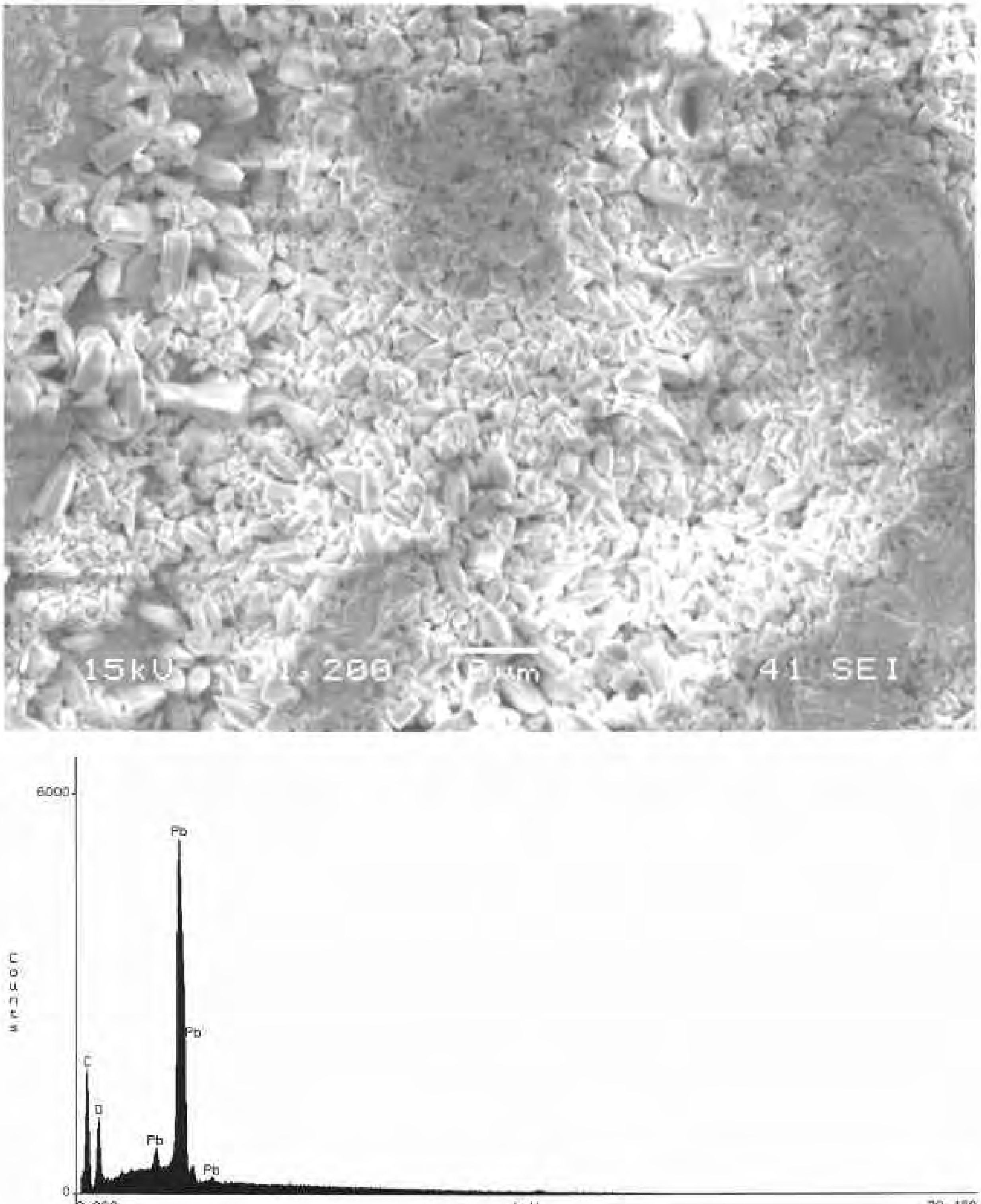


Figure 4-16 SEM image (top) and EDS spectra (bottom) of Pb-carbonate corrosion products formed on partially submerged coupon L294. Sources: image file *L294_2.BMP* and spectra file *L294_1.doc* located on disk in "WIPP-FePb-3 Supplemental Binder D".

4.4 Determination of Mass-Loss and Corrosion Rates

After the corrosion tests have been completed, two of the three replicate coupons for each test condition were chemically cleaned in order to remove all of the corrosion products. The mass of the coupons after cleaning is compared to the initial mass and the difference represents the loss of material to corrosion. The mass loss can then be used to calculate a corrosion rate.

There are numerous standard procedures that outline requirements for the cleaning of corrosion samples: ISO 8407:1991, NACE Standard TM0169-2000 and ASTM G 1 – 03. For the most part, each of these standard procedures outlines nearly identical requirements and all coupons were cleaned per the requirements outlined in these standards. Where there are differences between the standards, the source for a particular requirement that was used is noted. The cleaning process included multiple cycles of chemical etching, brushing with a nonmetallic soft bristle brush followed by rinsing with deionized water. Following each cleaning cycle the coupons were dried and weighed with the weight for each cycle being recorded in the scientific notebook. A minimum of five cleaning cycles was performed for each coupon. The details of the chemical cleaning process for each material type are given in detail in Roselle (2009).

Because the above cleaning procedures remove some amount of base metal in addition to the corrosion products a procedure needs to be employed that corrects the weight loss measurements for the base metal loss. This study uses a procedure of graphical analysis based on multiple cleaning cycles in order to extrapolate the actual weight loss due to corrosion from the total measured weight loss. The graphical analysis method is outlined in ISO 8407:1991 and discussed in Roselle (2009). Corrosion rates are calculated from the mass loss data according to the following formula (NACE, 2000):

$$rate = \frac{W \times 87.6}{SA \times t \times \rho} \times 1000 \qquad (3)$$

where *rate* is the corrosion rate in µm/yr, W the mass loss (mg), SA the exposed surface area of the coupon (cm^2), t the exposure duration (hours), ρ the metal density (g/cm^3) and 1,000 converts the rate from mm/yr to µm/yr. The details of the surface area determination for each coupon are described in Appendix A. Metal densities of 7.872 g/cm^3 and 11.340 g/cm^3 were used for steel and lead, respectively (MatWeb, 2009). A summary of the weight loss data for each coupon is given in Appendix B. The raw cleaning cycle data and graphical analysis results for each coupon are given in Appendix C (steel) and Appendix D (lead).

Table 4-4 gives the steel coupon average corrosion rates calculated from the weight-loss and surface area measurements for each brine type and the humid samples for the 12 month experiments. The average corrosion rates for the different brine types are calculated using the results for both the fully immersed and partially submerged coupons for each brine type. This was done because the calculated corrosion rates do not seem to be dependent on the coupon placement. The average steel corrosion rates are plotted as a function of CO_2 concentration in Figure 4-17. From this plot it can be seen that for both brine types the corrosion rate appears to be a function of the CO_2 concentration, regardless of the presence or absence of organic ligands. However, there are differences in the corrosion rates between the different brine types. The ERDA-6 brines appear to be more corrosive than the GWB brines by a factor of nearly 3 at the higher CO_2 concentrations. It also appears that the addition of organic ligands to the ERDA-6 brine results in significantly less corrosion than the organic free ERDA-6. This does not appear to be the case for GWB. From Figure 4-17 it can be seen that there is little to no difference in the corrosion rates for the two GWB brine types. The humid samples show no corrosion regardless of the CO_2 concentration.

Table 4-4 Average Corrosion Rate (μm/yr) for 12 Month Steel Samples

Brine	CO_2 Concentration (ppm)			
	0	350	1500	3500
GWB	0.19 ± 0.03	0.22 ± 0.02	0.17 ± 0.05	0.31 ± 0.01
GWB org	0.19 ± 0.04	0.23 ± 0.03	0.22 ± 0.03	0.26 ± 0.02
ERDA-6	0.25 ± 0.03	0.18 ± 0.03	0.58 ± 0.14	0.92 ± 0.18
ERDA-6 org	0.13 ± 0.02	0.18 ± 0.05	0.21 ± 0.04	0.54 ± 0.09
Humid	0.02 ± 0.02	0.05 ± 0.03	0.00 ± 0.00	0.01 ± 0.01

Source: Averages calculated from data in Appendix B. Note that negative corrosion rates given in Appendix B are considered as 0.0 for calculation of averages.

The trends seen in the 12 month experiments are consistent with the results obtained in the six month experiments. For comparison, the results of the six month experiment are given in Table 4-5. Comparison of the rates in the six and 12 month experiments indicates that the corrosion rates may be slowing down as a function of time. In particular the experiments at CO_2 concentrations of 1500 and 3500 ppm appear to be approximately 20% lower in the 12 month results as compared to the six month experiments. The reduction in corrosion rates with time could be an indication that the samples are beginning to shows signs of passivation. However, the two sets of corrosion rates are still within error of each other and the observed trends may be the result of experimental variations in the data as opposed to passivation. Additional data from the longer duration experiments (18 and 24 months) will be needed.

Table 4-5 Average Corrosion Rate (μm/yr) for 6 Month Steel Samples

Brine	CO_2 Concentration (ppm)			
	0	350	1500	3500
GWB	0.08 ± 0.07	0.19 ± 0.04	0.24 ± 0.04	0.40 ± 0.03
GWB org	0.14 ± 0.09	0.20 ± 0.01	0.26 ± 0.06	0.39 ± 0.07
ERDA-6	0.08 ± 0.04	0.02 ± 0.02	0.53 ± 0.03	1.20 ± 0.25
ERDA-6 org	0.19 ± 0.11	0.02 ± 0.03	0.26 ± 0.07	0.65 ± 0.07
Humid	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01

Source: Roselle (2009)

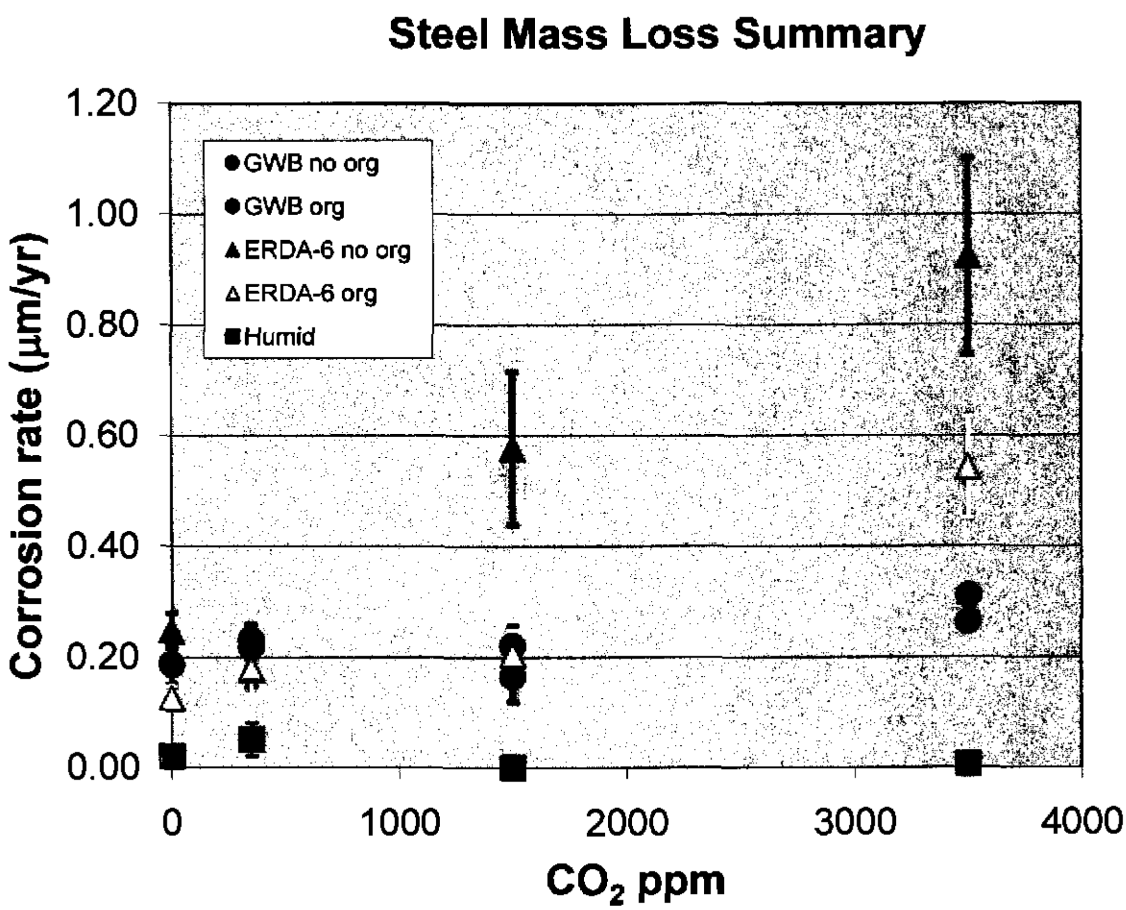


Figure 4-17 Average corrosion rates for steel coupons in the various brines plotted as a function of the atmospheric CO_2 concentration. Bars indicate one standard deviation for the average corrosion rates.

Table 4-6 gives the Pb coupon average corrosion rates calculated from the weight-loss and surface area measurements for each brine type and the humid samples. As with the steel coupons, the average Pb corrosion rates are calculated using the results for both the fully immersed and partially submerged coupons for each brine type. The average lead corrosion rates are plotted as a function of CO_2 concentration in Figure 4-18. From this plot it can be seen that the data for the lead coupons does not present as clear a picture as for the steel coupons. There may be a slight dependence on corrosion rates with the CO_2 concentration. However, given the relatively large standard deviation in the averages it is difficult to determine if there is an actual dependence on CO_2 concentration. Unlike the steel data, there does not appear to be differences in the corrosion rates between the different brine types. However, from Figure 4-18 it can be seen that there may be a slight difference in the corrosion rates for both brine types with the addition of organic ligands. The organic free brines appear to have slightly higher corrosion rates at CO_2 concentrations of 1500 and 3500 ppm. The humid samples show measureable mass loss regardless of the CO_2 concentration. However, it is not certain if the magnitude of the mass loss is within the measurement uncertainty of the graphical analysis method (Appendix B).

Table 4-6 Average Corrosion Rate (μm/yr) for 12 Month Lead Samples

Brine	CO_2 Concentration (ppm)			
	0	350	1500	3500
GWB	0.34 ± 0.16	0.21 ± 0.01	0.46 ± 0.25	0.30 ± 0.15
GWB org	0.41 ± 0.18	0.24 ± 0.08	0.35 ± 0.21	0.19 ± 0.05
ERDA-6	0.30 ± 0.19	0.11 ± 0.14	0.38 ± 0.30	0.28 ± 0.23
ERDA-6 org	0.33 ± 0.21	0.16 ± 0.15	0.35 ± 0.22	0.21 ± 0.10
Humid	0.11 ± 0.02	0.10 ± 0.00	0.11 ± 0.05	0.09 ± 0.01

Source: Averages calculated from data in Appendix B. Note that negative corrosion rates given in Appendix B are considered as 0.0 for calculation of averages.

As with the steel coupons there appears to be a difference in the corrosion rates between the six month (Roselle, 2009) and the 12 month experiments at the highest CO_2 concentration. The six month corrosion rate data for the Pb coupons are shown in Table 4-7 for comparison. The twelve month corrosion rates at 3500 ppm CO_2 are nearly 50% lower than those in the six month experiments. However, given the large uncertainties on these rates it is difficult to say if this represents a true reduction in the corrosion rates with time. Data from the longer term experiments will be necessary for any conclusions to be drawn.

Table 4-7 Average Corrosion Rate (μm/yr) for Six Month Lead Samples

Brine	CO_2 Concentration (ppm)			
	0	350	1500	3500
GWB	0.54 ± 0.16	0.31 ± 0.33	0.91 ± 0.82	0.60 ± 0.28
GWB org	0.33 ± 0.12	0.36 ± 0.09	0.95 ± 0.56	0.62 ± 0.34
ERDA-6	0.41 ± 0.22	0.19 ± 0.04	0.47 ± 0.37	0.73 ± 0.51
ERDA-6 org	0.32 ± 0.18	0.33 ± 0.06	0.51 ± 0.31	0.46 ± 0.17
Humid	0.06 ± 0.05	0.00 ± 0.00	0.15 ± 0.05	0.06 ± 0.02

Source: Roselle (2009)

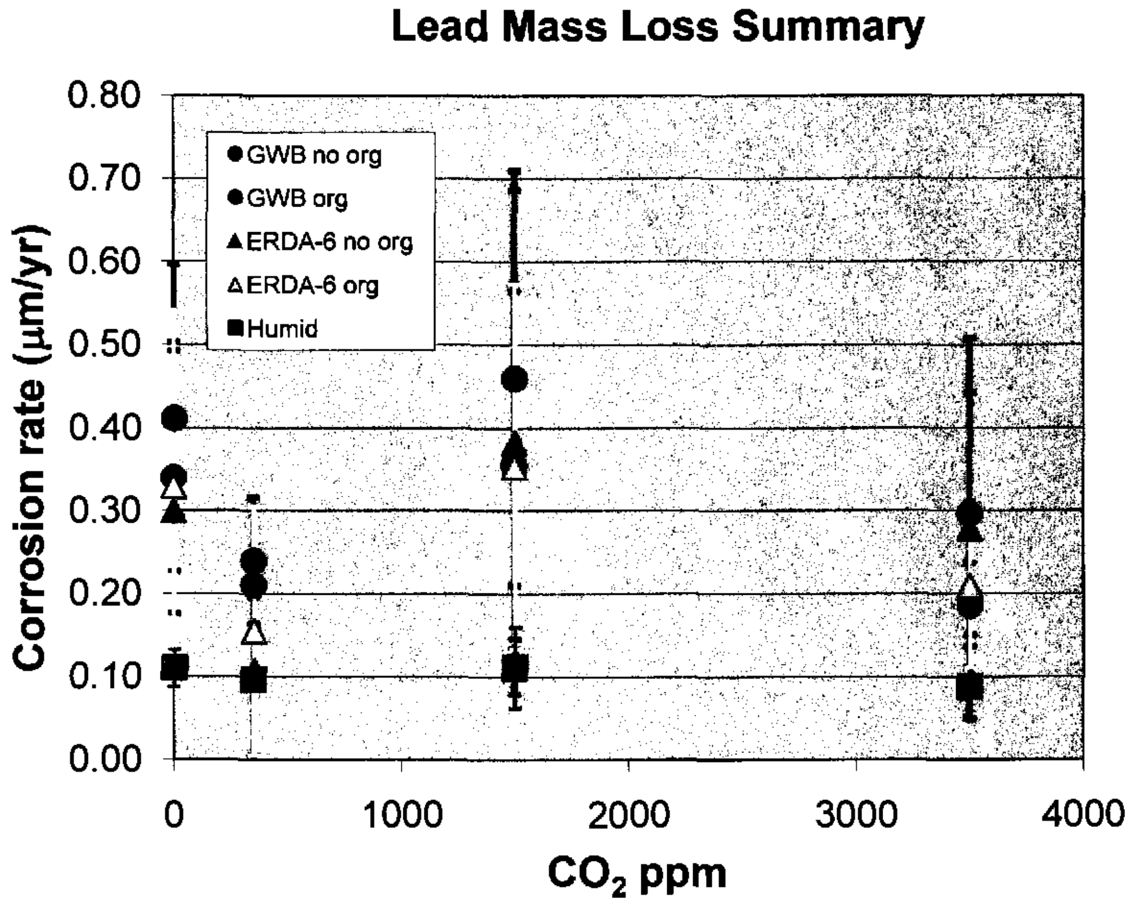


Figure 4-18 Average corrosion rates for lead coupons in the various brines plotted as a function of the atmospheric CO_2 concentration. Bars indicate one standard deviation for the average corrosion rates.

4.5 Brine Chemistry - pH

The initial pH for each of the brines used in the Fe/Pb corrosion experiments was measured at the time the brines were synthesized (Table 4-8). However, the measurement of pH in concentrated solutions using standard pH electrodes is problematic due to variations in the activity coefficients, formation of species such as HSO_4^- or $H_2B_4O_7$ that can consume protons during standardization, and potentially large liquid junction potentials (Rai et al., 1994). As a result, the pH values measured using standard pH electrodes need to be corrected to account for these effects. Several different methods have been proposed for determining the correction needed to convert measured pH values into meaningful hydrogen ion concentrations (Knauss et al., 1990, 1991; Mesmer, 1991; Rai et al., 1994). Each of these methods requires an empirical calibration of the pH electrode with the brines to be measured. At this time, the correction factor for the brines used in these experiments has not been determined. Therefore, the pH values reported here are done so as "measured" values and should not be used to calculate quantitative hydrogen ion concentrations. They are, however, valid measurements for qualitative comparisons of observed pH values among the different experiments.

Table 4-8 Initial Brine pH as Measured

Brine	pH_{meas}
GWB[1]	7.595
GWB[2] with organics	7.605
ERDA-6[1]	7.955
ERDA-6[2] with organics	7.915

[1] WIPP-FePb-3 p. 51
[2] WIPP-FePb-3 p. 52
Source: Average of values given in WIPP FePb-3 p. 65 (ERMS 550783)

At the conclusion of an experiment the brine pH is measured using a combination glass electrode. All pH measurements were conducted inside the anoxic glove box immediately after the coupons were removed from the brine. The final measured pH values for each of the 12 month experiments are given in Table 4-9. The data are shown plotted as a function of experimental duration in Figures 4-19A through 4-19D. Also shown in these plots are the pH data from the six month experiments as reported in Roselle (2009). From these plots it can be seen that there is almost no difference in the final measured pH values between the Pb and the steel experiments in the 0 ppm and 350 ppm CO_2 atmospheres (Figures 4-19A and 4-19B). In addition, there is no significant change in the pH over the duration of the experiments in the 0 ppm CO_2 atmosphere (Figure 4-19A). In the experiments conducted in the 350 ppm, 1500 ppm and 3500 ppm CO_2 atmospheres there is a noticeable trend in the measured pH values towards lower values (Figures 4-19B, 4-19C and 4-19D). The differences in measured pH values between GWB and ERDA-6 have virtually disappeared in the 1500 ppm and 3500 ppm CO_2 atmospheres. It can also be seen in Figures 4-19C and 4-19D that after 12 months the observed pH in brines from the lead experiments are trending lower than those observed in the steel experiments. The observed trends to lower pH values over time are due to equilibration of the experimental brines with the CO_2 concentration of the atmospheres. The reason for the observed differences in observed pH between the steel and lead experiments at higher CO_2 concentrations is not known at this time.

Table 4-9 Measured Final Brine pH of 12 Month Experiments

0 ppm CO_2		350 ppm CO_2		1500 ppm CO_2		3500 ppm CO_2	
Test Matrix	pH_{meas}	Test Matrix	pH_{meas}	Test Matrix	pH_{meas}	Test Matrix	pH_{meas}
Fe-G-0000-12-f	7.578	Fe-G-0350-12-f	7.525	Fe-G-1500-12-f	7.488	Fe-G-3500-12-f	7.209
Fe-G-0000-12-p	7.590	Fe-G-0350-12-p	7.533	Fe-G-1500-12-p	7.368	Fe-G-3500-12-p	7.224
Fe-Go-0000-12-f	7.558	Fe-Go-0350-12-f	7.517	Fe-Go-1500-12-f	7.338	Fe-Go-3500-12-f	7.213
Fe-Go-0000-12-p	7.573	Fe-Go-0350-12-p	7.523	Fe-Go-1500-12-p	7.240	Fe-Go-3500-12-p	7.226
Fe-E-0000-12-f	7.999	Fe-E-0350-12-f	7.834	Fe-E-1500-12-f	7.593	Fe-E-3500-12-f	7.132
Fe-E-0000-12-p	7.982	Fe-E-0350-12-p	7.790	Fe-E-1500-12-p	7.371	Fe-E-3500-12-p	7.107
Fe-Eo-0000-12-f	7.925	Fe-Eo-0350-12-f	7.791	Fe-Eo-1500-12-f	7.577	Fe-Eo-3500-12-f	7.247
Fe-Eo-0000-12-p	7.872	Fe-Eo-0350-12-p	7.773	Fe-Eo-1500-12-p	7.278	Fe-Eo-3500-12-p	7.225
Pb-G-0000-12-f	7.614	Pb-G-0350-12-f	7.524	Pb-G-1500-12-f	7.432	Pb-G-3500-12-f	7.297
Pb-G-0000-12-p	7.639	Pb-G-0350-12-p	7.527	Pb-G-1500-12-p	7.459	Pb-G-3500-12-p	7.313
Pb-Go-0000-12-f	7.614	Pb-Go-0350-12-f	7.519	Pb-Go-1500-12-f	7.439	Pb-Go-3500-12-f	7.37
Pb-Go-0000-12-p	7.599	Pb-Go-0350-12-p	7.466	Pb-Go-1500-12-p	7.475	Pb-Go-3500-12-p	7.391
Pb-E-0000-12-f	7.971	Pb-E-0350-12-f	7.739	Pb-E-1500-12-f	7.337	Pb-E-3500-12-f	7.226
Pb-E-0000-12-p	8.040	Pb-E-0350-12-p	7.732	Pb-E-1500-12-p	7.490	Pb-E-3500-12-p	7.507
Pb-Eo-0000-12-f	7.912	Pb-Eo-0350-12-f	7.799	Pb-Eo-1500-12-f	7.569	Pb-Eo-3500-12-f	7.452
Pb-Eo-0000-12-p	7.971	Pb-Eo-0350-12-p	7.815	Pb-Eo-1500-12-p	7.567	Pb-Eo-3500-12-p	7.365

Sources: WIPP-FePb-4 p. 33, 35, 39, 40, 43, 44, 45, 49, 50 (ERMS 546084)

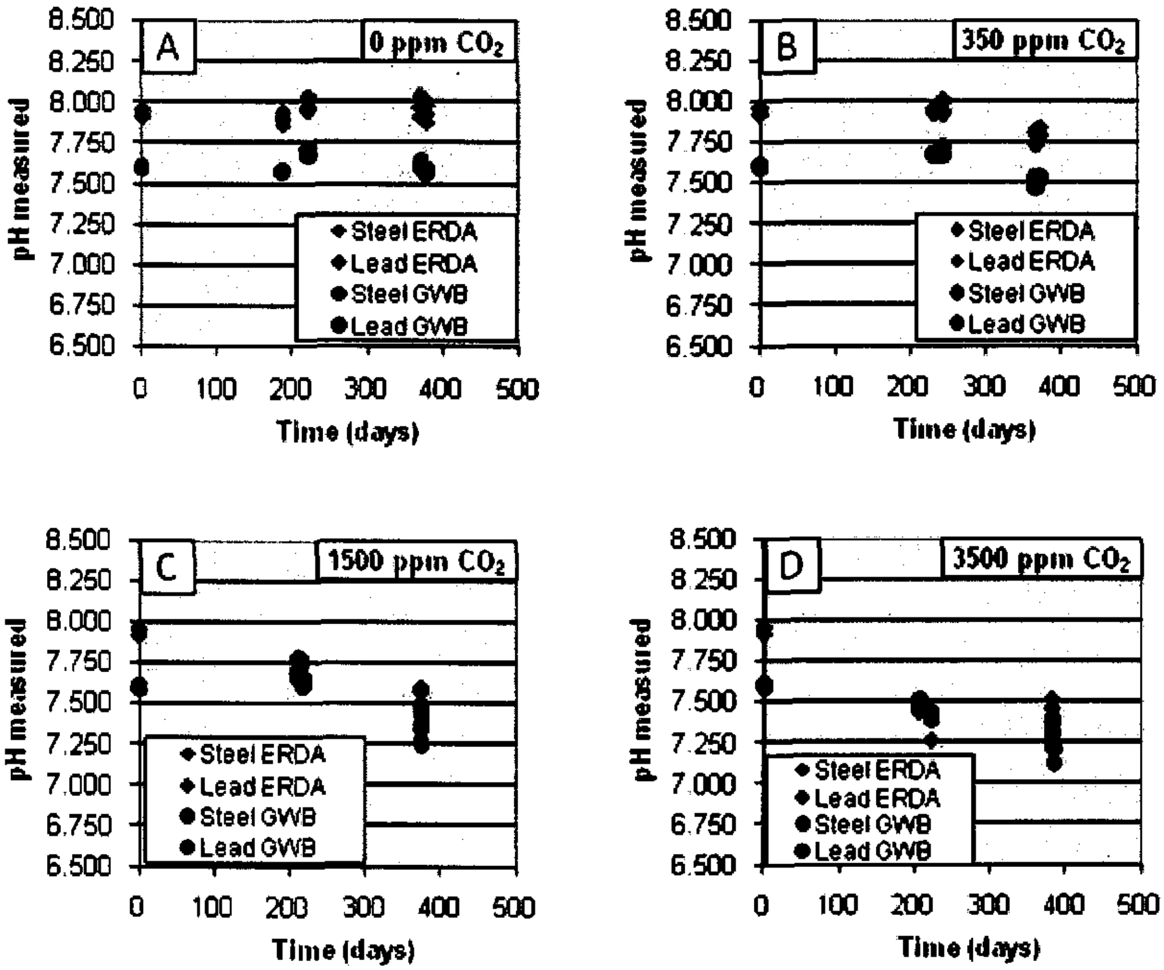


Figure 4-19 Measured pH plotted as a function of experiment duration for different carbon dioxide concentrations: (A) 0 ppm CO_2; (B) 350 ppm CO_2; (C) 1500 ppm CO_2; (D) 3500 ppm CO_2. Data for six month experiments taken from Roselle (2009).

5 CONCLUSIONS

This report describes the 12 month results of a two-year study on the corrosion of steel and lead under WIPP-relevant conditions. Analysis of the results from this set of experiments allows the following conclusions to be drawn. It should be noted, however, that the results of future experiments conducted for longer times may require modification to these conclusions.

- ASTM A1008 low-carbon steel coupons show clear evidence of corrosion after 12 months immersion in brines. Partially submerged coupons develop a band of green corrosion product at the brine atmosphere interface. Fully immersed coupons exhibit a hazy luster with isolated spots of green corrosion products. Humid samples show no visible evidence of corrosion.

- SEM and EDS analysis of the steel coupons from the lower CO_2 atmospheres (<1500 ppm) show that the green corrosion product is likely an iron/magnesium-chlori-hydroxide. A second minor phase can be identified by its different habit and appears also to be an iron-chlori-hydroxide (with little or no Mg). At higher CO_2 concentrations the predominant corrosion product is an iron/calcium carbonate. Although the green corrosion product is seen as well. Carbonate formation seems to be favored by the ERDA-6 brines.

- The corrosion rate of ASTM A1008 low-carbon steel immersed in brine appears to be a function of the CO_2 concentration for all brine types. ERDA-6 brines (with and without organics) appear to be more corrosive than the GWB brines by a factor of nearly 3 at higher CO_2 concentrations. The addition of organic ligands to the ERDA-6 brine results in significantly less corrosion than the organic free ERDA-6. Corrosion rates for GWB appear to be independent of the presence or absence of organic ligands.

- Chemical Pb coupons show little visible evidence of corrosion after 12 months immersion in brines. Partially submerged and humid coupons develop discoloration on the surfaces exposed to the atmosphere. Those portions of fully immersed and partially submerged coupons exposed to brine exhibit no macroscopic evidence of corrosion. In addition, no evidence of corrosion is visible at the brine/atmosphere interface in partially submerged experiments.

- SEM and EDS analysis of the Pb coupons shows a very limited amount of corrosion product formation. In atmospheres of 1500 ppm CO_2 and above the formation of a calcium/lead carbonate phase is seen on coupons immersed in ERDA-6 brines (although it is also seen in one sample at 350 ppm CO_2). No carbonate phases are observed in coupons exposed to GWB with the exception of one experiment conducted at 1500 ppm CO_2. No corrosion product formation is seen in any of the discolored areas of coupons exposed to humid conditions.

- The corrosion rate of chemical Pb may show a slight dependence of corrosion rates on the CO_2 concentration. However, given the relatively large standard deviation in the averages it is difficult to determine if there is an actual dependence on CO_2 concentration. There does not appear to be any significant difference in the corrosion rates between the two brine types (ERDA-6 and GWB). However, brines containing organics appear to be more corrosive than those without organics regardless of the brine type.

- Steel samples subjected only to humid conditions show no corrosion regardless of the CO_2 concentration. Whereas, humid Pb samples show measureable mass loss regardless of the CO_2 concentration. However, the magnitude of the mass loss may be within the measurement uncertainty of the graphical analysis method.

- The corrosion rates calculated for both steel and lead coupons from the 12 month experiments appear to be 20 to 50% lower than the results from the six month experiments. This may be due to the passivation of the coupon surfaces but the rates are still within the standard deviation of each other. More data from the longer term experiments will be needed in order to determine if passivation is occurring.

6 ACKNOWLEDGEMENTS

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APPENDIX A – COUPON DIMENSIONS

Table A-1 lists the length, width and thickness measurements for each steel coupon, as well as, the average value of these measurements used to calculate the surface area. The equivalent data for the lead coupons is given in Table A-2. Additionally, for each of the coupons that were partially submerged the length of the portion of the coupon that was submerged is also given. In this case two measurements are made because the coupon may not have been submerged exactly parallel to the water surface.

For coupons that were fully submerged or exposed only to the atmosphere the following formula is used to calculate surface area:

$$SA = 2(L_{avg} \times W_{avg}) + 2(L_{avg} \times T_{avg}) + 2(W_{avg} \times T_{avg}) - 2\pi R^2 + 2\pi R \times T_{avg} \quad \text{(A1)}$$

where L_{avg} is the average measured length, W_{avg} the average width, T_{avg} the average thickness and R the radius of the hole, which is assumed constant for each coupon at 0.235 cm for steel coupons and 0.296 cm for lead coupons. The surface area for coupons that were partially submerged is calculated as follows:

$$SA = 2(L_1 \times W_{avg}) + (L_1 \times T_{avg}) + (L_2 \times T_{avg}) + (W_{avg} \times T_{avg}) + (W_{avg} \times (L_2 - L_1)) \quad \text{(A2)}$$

where L_1 is the smallest measured partial submersion length, L_2 the largest measured length and all other symbols are the same as for equation A1.

Table A-1 Measured Steel Coupon Dimensions and Calculated Surface Areas

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
060	Length	51.14	51.44	51.29	51.29	5.129	N/A	N/A	41.666
	Width	38.31	38.55	38.62	38.49	3.849			
	Thickness	1.34	1.31	1.25	1.30	0.130			
061	Length	51.31	51.21	51.22	51.25	5.125	N/A	N/A	41.763
	Width	38.39	38.51	38.42	38.44	3.844			
	Thickness	1.39	1.42	1.38	1.40	0.140			
063	Length	51.11	51.22	51.28	51.20	5.120	2.858	2.913	23.495
	Width	38.36	38.50	38.45	38.44	3.844			
	Thickness	1.36	1.39	1.35	1.37	0.137			
064	Length	51.05	51.30	51.34	51.23	5.123	2.832	2.870	23.320
	Width	38.36	38.69	38.78	38.61	3.861			
	Thickness	1.35	1.37	1.37	1.36	0.136			
066	Length	51.04	51.25	51.33	51.21	5.121	N/A	N/A	41.589
	Width	38.37	38.39	38.34	38.37	3.837			
	Thickness	1.41	1.36	1.32	1.36	0.136			
067	Length	51.13	51.25	51.25	51.21	5.121	N/A	N/A	41.678
	Width	38.45	38.54	38.41	38.47	3.847			
	Thickness	1.38	1.35	1.33	1.35	0.135			
069	Length	51.15	51.26	51.24	51.22	5.122	3.399	3.414	27.610
	Width	38.33	38.44	38.50	38.42	3.842			
	Thickness	1.40	1.33	1.31	1.35	0.135			
070	Length	51.28	51.30	51.15	51.24	5.124	3.101	3.218	25.698
	Width	38.41	38.53	38.49	38.48	3.848			
	Thickness	1.38	1.36	1.34	1.36	0.136			
072	Length	51.28	51.26	51.02	51.19	5.119	N/A	N/A	41.656
	Width	38.39	38.53	38.60	38.51	3.851			
	Thickness	1.35	1.32	1.32	1.33	0.133			
073	Length	51.08	51.18	51.26	51.17	5.117	N/A	N/A	41.516
	Width	38.42	38.40	38.35	38.39	3.839			
	Thickness	1.38	1.31	1.29	1.33	0.133			
075	Length	51.09	51.32	51.31	51.24	5.124	2.959	3.033	24.408
	Width	38.44	38.54	38.51	38.50	3.850			
	Thickness	1.35	1.32	1.42	1.36	0.136			
076	Length	51.34	51.33	51.04	51.24	5.124	2.985	3.038	24.385
	Width	38.46	38.55	38.35	38.45	3.845			
	Thickness	1.27	1.25	1.21	1.24	0.124			
078	Length	51.14	51.27	51.25	51.22	5.122	N/A	N/A	41.580
	Width	38.37	38.63	38.58	38.53	3.853			
	Thickness	1.21	1.29	1.30	1.27	0.127			
079	Length	51.19	51.12	50.92	51.08	5.108	N/A	N/A	41.453
	Width	38.51	38.49	38.43	38.48	3.848			
	Thickness	1.25	1.29	1.32	1.29	0.129			

Table A-1 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
081	Length	51.07	51.36	51.03	51.15	5.115	2.858	3.040	24.021
	Width	38.55	38.38	38.32	38.42	3.842			
	Thickness	1.39	1.41	1.40	1.40	0.140			
082	Length	51.11	51.27	51.04	51.14	5.114	3.018	3.081	24.833
	Width	38.47	38.50	38.39	38.45	3.845			
	Thickness	1.40	1.39	1.38	1.39	0.139			
084	Length	51.13	51.19	51.55	51.29	5.129	N/A	N/A	41.748
	Width	38.41	38.48	38.40	38.43	3.843			
	Thickness	1.39	1.38	1.36	1.38	0.138			
085	Length	51.15	51.31	51.51	51.32	5.132	N/A	N/A	41.827
	Width	38.47	38.55	38.42	38.48	3.848			
	Thickness	1.39	1.38	1.36	1.38	0.138			
190	Length	51.11	51.21	51.05	51.12	5.112	N/A	N/A	41.452
	Width	38.40	38.41	38.29	38.37	3.837			
	Thickness	1.34	1.32	1.32	1.33	0.133			
191	Length	51.14	51.23	51.10	51.16	5.116	N/A	N/A	41.453
	Width	38.33	38.50	38.40	38.41	3.841			
	Thickness	1.29	1.30	1.28	1.29	0.129			
192	Length	51.04	51.31	51.20	51.18	5.118	2.593	2.941	22.433
	Width	38.34	38.40	38.29	38.34	3.834			
	Thickness	1.32	1.29	1.27	1.29	0.129			
202	Length	51.01	51.10	51.08	51.06	5.106	2.827	2.913	23.307
	Width	38.34	38.45	38.39	38.39	3.839			
	Thickness	1.33	1.34	1.30	1.32	0.132			
205	Length	51.06	51.40	51.26	51.24	5.124	N/A	N/A	41.706
	Width	38.31	38.86	38.41	38.53	3.853			
	Thickness	1.30	1.33	1.34	1.32	0.132			
206	Length	51.15	51.29	51.05	51.16	5.116	N/A	N/A	41.568
	Width	38.27	38.46	38.50	38.41	3.841			
	Thickness	1.36	1.35	1.33	1.35	0.135			
207	Length	51.07	51.30	51.38	51.25	5.125	3.086	3.178	25.466
	Width	38.25	38.46	38.58	38.43	3.843			
	Thickness	1.42	1.37	1.35	1.38	0.138			
208	Length	50.97	51.06	51.20	51.17	5.117	2.979	3.137	24.809
	Width	38.29	38.30	38.52	38.37	3.837			
	Thickness	1.35	1.34	1.35	1.35	0.135			
210	Length	51.23	51.52	51.14	51.30	5.130	N/A	N/A	41.537
	Width	38.18	38.33		38.26	3.826			
	Thickness	1.34	1.37	1.37	1.36	0.136			
212	Length	50.99	51.19	51.20	51.13	5.113	N/A	N/A	41.561
	Width	38.29	38.52	38.39	38.40	3.840			
	Thickness	1.42	1.34	1.33	1.36	0.136			
213	Length	51.06	51.27	51.26	51.20	5.120	3.180	3.190	25.757
	Width	38.10	38.47	38.34	38.30	3.830			
	Thickness	1.34	1.33	1.32	1.33	0.133			

Table A-1 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
214	Length	51.07	51.18	51.62	51.29	5.129	3.086	3.109	25.133
	Width	38.26	38.54	38.38	38.39	3.839			
	Thickness	1.35	1.35	1.33	1.34	0.134			
217	Length	51.12	51.29	51.03	51.15	5.115	N/A	N/A	41.595
	Width	38.38	38.81	38.47	38.55	3.855			
	Thickness	1.31	1.27	1.29	1.29	0.129			
218	Length	51.19	51.24	51.14	51.19	5.119	N/A	N/A	41.579
	Width	38.28	38.45	38.49	38.41	3.841			
	Thickness	1.32	1.34	1.37	1.34	0.134			
220	Length	51.06	51.17	51.02	51.08	5.108	2.934	3.134	24.663
	Width	38.33	38.47	38.42	38.41	3.841			
	Thickness	1.36	1.36	1.39	1.37	0.137			
221	Length	51.24	51.35	50.99	51.19	5.119	3.025	3.142	25.007
	Width	38.38	38.67	38.65	38.57	3.857			
	Thickness	1.25	1.22	1.19	1.22	0.122			
222	Length	51.08	51.19	51.21	51.16	5.116	N/A	N/A	41.291
	Width	38.28	38.40	38.30	38.33	3.833			
	Thickness	1.29	1.25	1.21	1.25	0.125			
223	Length	51.15	51.19	51.07	51.14	5.114	N/A	N/A	41.427
	Width	38.35	38.63	38.37	38.45	3.845			
	Thickness	1.28	1.27	1.24	1.26	0.126			
280	Length	51.13	51.23	51.07	51.14	5.114	N/A	N/A	41.592
	Width	38.50	38.42	38.48	38.47	3.847			
	Thickness	1.39	1.31	1.31	1.34	0.134			
281	Length	51.19	51.20	51.03	51.14	5.114	N/A	N/A	41.534
	Width	38.35	38.45	38.33	38.38	3.838			
	Thickness	1.35	1.35	1.37	1.36	0.136			
283	Length	51.15	51.15		51.15	5.115	2.728	3.045	23.525
	Width	38.40	38.63	38.38	38.47	3.847			
	Thickness	1.36	1.36	1.38	1.37	0.137			
284	Length	51.17	51.32	51.21	51.23	5.123	2.817	3.051	23.885
	Width	38.36	38.52	38.44	38.44	3.844			
	Thickness	1.36	1.39	1.36	1.37	0.137			
286	Length	51.14	51.28	51.25	51.22	5.122	N/A	N/A	41.620
	Width	38.27	38.61	38.49	38.46	3.846			
	Thickness	1.34	1.31	1.32	1.32	0.132			
287	Length	51.05	51.20	51.26	51.17	5.117	N/A	N/A	41.505
	Width	38.35	38.42	38.34	38.37	3.837			
	Thickness	1.34	1.35	1.31	1.33	0.133			
289	Length	51.10	51.27	51.26	51.21	5.121	2.720	2.751	22.377
	Width	38.49	38.63	38.67	38.60	3.860			
	Thickness	1.37	1.34	1.34	1.35	0.135			
290	Length	51.15	51.30	51.22	51.22	5.122	2.645	2.751	22.094
	Width	38.41	38.77	38.52	38.57	3.857			
	Thickness	1.38	1.39	1.40	1.39	0.139			

Table A-1 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
292	Length	51.23	51.24	51.21	51.23	5.123	N/A	N/A	41.565
	Width	38.34	38.58	38.38	38.43	3.843			
	Thickness	1.29	1.31	1.32	1.31	0.131			
293	Length	51.25	51.40	51.38	51.34	5.134	N/A	N/A	42.073
	Width	38.85	38.92	38.60	38.79	3.879			
	Thickness	1.36	1.33	1.29	1.33	0.133			
295	Length	51.20	51.28	51.27	51.25	5.125	2.873	3.236	24.876
	Width	38.39	38.62	38.52	38.51	3.851			
	Thickness	1.34	1.38	1.35	1.36	0.136			
296	Length	51.07	51.21	51.10	51.13	5.113	2.873	3.373	25.442
	Width	38.57	38.66	38.85	38.69	3.869			
	Thickness	1.26	1.30	1.22	1.26	0.126			
298	Length	51.10	51.34	51.31	51.25	5.125	N/A	N/A	41.791
	Width	38.48	38.79	38.75	38.67	3.867			
	Thickness	1.29	1.30	1.26	1.28	0.128			
299	Length	51.18	51.48	51.21	51.29	5.129	N/A	N/A	41.571
	Width	38.27	38.48	38.44	38.40	3.840			
	Thickness	1.32	1.28	1.31	1.30	0.130			
301	Length	51.07	51.27	51.29	51.21	5.121	2.982	3.147	24.901
	Width	38.39	38.52	38.40	38.44	3.844			
	Thickness	1.34	1.34	1.36	1.35	0.135			
302	Length	51.13	51.25	51.29	51.22	5.122	3.033	3.043	24.639
	Width	38.33	38.45	38.32	38.37	3.837			
	Thickness	1.34	1.34	1.34	1.34	0.134			
304	Length	51.13	51.26	51.23	51.21	5.121	N/A	N/A	41.650
	Width	38.43	38.57	38.44	38.48	3.848			
	Thickness	1.31	1.35	1.34	1.33	0.133			
305	Length	51.06	51.20	51.18	51.15	5.115	N/A	N/A	41.694
	Width	38.68	38.68	38.38	38.58	3.858			
	Thickness	1.30	1.32	1.36	1.33	0.133			
388	Length	51.11	51.25	51.30	51.22	5.122	N/A	N/A	41.679
	Width	38.45	38.62	38.31	38.46	3.846			
	Thickness	1.39	1.34	1.33	1.35	0.135			
389	Length	51.03	51.32	51.24	51.20	5.120	N/A	N/A	41.613
	Width	38.35	38.50	38.36	38.40	3.840			
	Thickness	1.37	1.35	1.36	1.36	0.136			
391	Length	51.10	51.28	51.14	51.17	5.117	2.460	2.604	20.603
	Width	38.29	38.55	38.36	38.40	3.840			
	Thickness	1.33	1.29	1.28	1.30	0.130			
392	Length	51.06	51.21	51.15	51.14	5.114	2.594	2.862	22.200
	Width	38.37	38.55	38.43	38.45	3.845			
	Thickness	1.32	1.32	1.30	1.31	0.131			
394	Length	51.15	51.43	51.17	51.25	5.125	N/A	N/A	41.626
	Width	38.33	38.51	38.36	38.40	3.840			
	Thickness	1.35	1.35	1.34	1.35	0.135			

Table A-1 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
395	Length	51.17	51.26	51.24	51.22	5.122	N/A	N/A	41.664
	Width	38.37	38.56	38.40	38.44	3.844			
	Thickness	1.37	1.35	1.34	1.35	0.135			
397	Length	51.11	51.21	51.15	51.16	5.116	2.902	3.035	24.076
	Width	38.37	38.61	38.32	38.43	3.843			
	Thickness	1.31	1.28	1.27	1.29	0.129			
398	Length	51.03	51.23	51.20	51.15	5.115	2.900	2.900	23.481
	Width	38.23	38.40	38.38	38.34	3.834			
	Thickness	1.27	1.34	1.27	1.29	0.129			
400	Length	51.16	51.26	51.21	51.21	5.121	N/A	N/A	41.510
	Width	38.30	38.44	38.31	38.35	3.835			
	Thickness	1.35	1.33	1.31	1.33	0.133			
401	Length	50.99	51.20	51.12	51.10	5.110	N/A	N/A	41.475
	Width	38.25	38.43	38.29	38.32	3.832			
	Thickness	1.36	1.36	1.39	1.37	0.137			
403	Length	51.16	51.22	51.03	51.14	5.114	2.694	2.933	22.850
	Width	38.37	38.53	38.26	38.39	3.839			
	Thickness	1.30	1.33	1.33	1.32	0.132			
404	Length	51.17	51.22	50.99	51.13	5.113	2.690	2.880	22.597
	Width	38.22	38.52	38.38	38.37	3.837			
	Thickness	1.30	1.31	1.29	1.30	0.130			
406	Length	51.06	51.23	51.14	51.14	5.114	N/A	N/A	41.639
	Width	38.29	38.55	38.38	38.41	3.841			
	Thickness	1.42	1.39	1.37	1.39	0.139			
407	Length	51.22	50.98	51.18	51.13	5.113	N/A	N/A	41.466
	Width	38.14	38.41	38.27	38.27	3.827			
	Thickness	1.37	1.37	1.41	1.38	0.138			
409	Length	51.11	51.21	51.10	51.14	5.114	2.873	2.931	23.658
	Width	38.26	38.59	38.63	38.49	3.849			
	Thickness	1.37	1.34	1.38	1.36	0.136			
410	Length	51.04	51.20	51.15	51.13	5.113	2.819	2.819	22.850
	Width	38.19	38.43	38.28	38.30	3.830			
	Thickness	1.35	1.32	1.31	1.33	0.133			
412	Length	51.02	51.20	51.10	51.11	5.111	N/A	N/A	41.505
	Width	38.24	38.46	38.35	38.35	3.835			
	Thickness	1.38	1.36	1.37	1.37	0.137			
413	Length	51.04	51.23	51.15	51.14	5.114	N/A	N/A	41.386
	Width	38.21	38.47	38.25	38.31	3.831			
	Thickness	1.33	1.31	1.31	1.32	0.132			

Source: Individual data sheets for each coupon in *WIPP-FePb-3 Supplemental Binder C (ERMS 546084)*

Table A-2 Measured Lead Coupon Dimensions and Calculated Surface Areas

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
L055	Length	51.49	51.51	51.54	51.51	5.151	N/A	N/A	42.547
	Width	38.51	38.74	38.63	38.63	3.863			
	Thickness	1.65	1.65	1.68	1.66	0.166			
L056	Length	51.61	51.77	51.69	51.69	5.169	N/A	N/A	42.959
	Width	38.78	38.74	38.84	38.79	3.879			
	Thickness	1.65	1.76	1.72	1.71	0.171			
L058	Length	51.42	51.44	51.48	51.45	5.145	2.700	2.797	22.993
	Width	38.81	38.76	38.90	38.82	3.882			
	Thickness	1.72	1.78	1.79	1.76	0.176			
L059	Length	51.60	51.75	51.66	51.67	5.167	2.647	2.875	23.051
	Width	38.91	38.84	38.73	38.83	3.883			
	Thickness	1.69	1.77	1.68	1.71	0.171			
L061	Length	51.63	51.49	51.37	51.50	5.150	N/A	N/A	42.874
	Width	39.07	38.86	38.65	38.86	3.886			
	Thickness	1.63	1.67	1.82	1.71	0.171			
L062	Length	51.45	51.40	51.40	51.42	5.142	N/A	N/A	42.495
	Width	38.74	38.58	38.56	38.63	3.863			
	Thickness	1.72	1.63	1.67	1.67	0.167			
L064	Length	51.36	51.38	51.46	51.40	5.140	2.461	2.626	21.264
	Width	38.57	38.86	38.76	38.73	3.873			
	Thickness	1.79	1.73	1.70	1.74	0.174			
L065	Length	51.33	51.41	51.50	51.41	5.141	2.451	2.583	21.002
	Width	38.65	38.72	38.64	38.67	3.867			
	Thickness	1.74	1.73	1.70	1.72	0.172			
L068	Length	51.53	51.61	51.57	51.57	5.157	N/A	N/A	42.736
	Width	38.68	38.48	38.75	38.64	3.864			
	Thickness	1.73	1.74	1.71	1.73	0.173			
L069	Length	51.49	51.49	51.18	51.39	5.139	N/A	N/A	42.674
	Width	38.63	38.68	38.62	38.64	3.864			
	Thickness	1.79	1.73	1.78	1.77	0.177			
L071	Length	51.25	51.38	51.32	51.32	5.132	3.038	3.063	25.314
	Width	38.71	38.71	38.67	38.70	3.870			
	Thickness	1.62	1.72	1.79	1.71	0.171			
L072	Length	51.49	51.64	51.68	51.60	5.160	2.781	2.791	23.223
	Width	38.63	38.97	38.90	38.83	3.883			
	Thickness	1.61	1.71	1.70	1.67	0.167			
L074	Length	51.65	51.68	51.77	51.70	5.170	N/A	N/A	43.261
	Width	39.15	39.00	38.79	38.98	3.898			
	Thickness	1.71	1.79	1.76	1.75	0.175			
L075	Length	51.51	51.60	51.67	51.59	5.159	N/A	N/A	42.824
	Width	38.82	38.68	38.83	38.78	3.878			
	Thickness	1.72	1.67	1.67	1.69	0.169			

Table A-2 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
L076	Length	51.44	51.43	51.45	51.44	5.144	2.781	2.781	23.096
	Width	38.55	38.48	38.64	38.56	3.856			
	Thickness	1.71	1.76	1.78	1.75	0.175			
L077	Length	51.42	51.69	51.85	51.65	5.165	2.685	2.891	23.368
	Width	39.49	38.77	38.81	39.02	3.902			
	Thickness	1.65	1.70	1.75	1.70	0.170			
L079	Length	51.69	51.82	51.77	51.76	5.176	N/A	N/A	43.180
	Width	39.22	38.92	38.81	38.98	3.898			
	Thickness	1.69	1.68	1.69	1.69	0.169			
L080	Length	51.93	51.89	51.60	51.81	5.181	N/A	N/A	43.252
	Width	38.84	39.11	38.91	38.95	3.895			
	Thickness	1.68	1.76	1.72	1.72	0.172			
L190	Length	51.21	51.16	51.24	51.20	5.120	N/A	N/A	42.232
	Width	38.45	38.45	38.57	38.49	3.849			
	Thickness	1.67	1.72	1.71	1.70	0.170			
L191	Length	51.23	51.29	51.21	51.24	5.124	N/A	N/A	42.177
	Width	38.40	38.45	38.60	38.48	3.848			
	Thickness	1.63	1.71	1.64	1.66	0.166			
L194	Length	51.33	51.33	51.18	51.28	5.128	2.972	2.885	24.084
	Width	38.38	38.41	38.47	38.42	3.842			
	Thickness	1.63	1.60	1.66	1.63	0.163			
L195	Length	51.20	51.07	51.11	51.13	5.113	3.058	2.784	24.066
	Width	38.33	38.47	38.59	38.46	3.846			
	Thickness	1.66	1.64	1.64	1.65	0.165			
L196	Length	51.12	51.28	51.26	51.22	5.122	N/A	N/A	42.130
	Width	38.32	38.56	38.49	38.46	3.846			
	Thickness	1.66	1.66	1.66	1.66	0.166			
L198	Length	51.27	51.12	51.18	51.19	5.119	N/A	N/A	42.078
	Width	38.43	38.41	38.43	38.42	3.842			
	Thickness	1.67	1.64	1.68	1.66	0.166			
L199	Length	51.24	51.19	51.20	51.21	5.121	2.903	3.015	24.401
	Width	38.26	38.35	38.67	38.43	3.843			
	Thickness	1.69	1.70	1.71	1.70	0.170			
L200	Length	51.26	51.25	51.27	51.26	5.126	2.845	2.924	23.795
	Width	38.36	38.46	38.42	38.41	3.841			
	Thickness	1.72	1.71	1.68	1.70	0.170			
L203	Length	51.21	51.23	51.23	51.22	5.122	N/A	N/A	41.989
	Width	38.34	38.36	38.26	38.32	3.832			
	Thickness	1.65	1.69	1.64	1.66	0.166			
L204	Length	51.16	51.07	51.08	51.10	5.110	N/A	N/A	42.056
	Width	38.29	38.55	38.51	38.45	3.845			
	Thickness	1.69	1.66	1.67	1.67	0.167			
L205	Length	51.14	51.14	51.09	51.12	5.112	2.957	3.259	25.602
	Width	38.54	38.64	38.41	38.53	3.853			
	Thickness	1.62	1.61	1.70	1.64	0.164			

Table A-2 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
L207	Length	51.27	51.35	51.31	51.31	5.131	2.997	3.122	25.223
	Width	38.50	38.46	38.43	38.46	3.846			
	Thickness	1.69	1.72	1.67	1.69	0.169			
L209	Length	51.10	51.02	51.08	51.07	5.107	N/A	N/A	42.113
	Width	38.46	38.48	38.30	38.41	3.841			
	Thickness	1.71	1.67	1.83	1.74	0.174			
L210	Length	51.10	51.07	51.24	51.14	5.114	N/A	N/A	42.032
	Width	38.50	38.60	38.20	38.43	3.843			
	Thickness	1.69	1.66	1.62	1.66	0.166			
L211	Length	51.37	51.25	51.20	51.27	5.127	3.645	3.881	30.914
	Width	38.48	38.57	38.44	38.50	3.850			
	Thickness	1.69	1.70	1.73	1.71	0.171			
L212	Length	51.42	51.29	51.27	51.33	5.133	3.733	3.733	30.709
	Width	38.55	38.61	38.62	38.59	3.859			
	Thickness	1.63	1.68	1.71	1.67	0.167			
L214	Length	51.04	51.22	51.27	51.18	5.118	N/A	N/A	42.012
	Width	38.38	38.49	38.30	38.39	3.839			
	Thickness	1.61	1.66	1.69	1.65	0.165			
L215	Length	51.02	51.08	51.21	51.10	5.110	N/A	N/A	41.992
	Width	38.38	38.39	38.38	38.38	3.838			
	Thickness	1.68	1.69	1.66	1.68	0.168			
L272	Length	51.62	51.27	51.54	51.48	5.148	N/A	N/A	42.492
	Width	38.63	38.67	38.77	38.69	3.869			
	Thickness	1.60	1.61	1.63	1.61	0.161			
L273	Length	51.31	51.26	51.39	51.32	5.132	N/A	N/A	42.115
	Width	38.53	38.20	38.37	38.37	3.837			
	Thickness	1.70	1.65	1.63	1.66	0.166			
L275	Length	51.44	51.39	51.20	51.34	5.134	2.790	2.986	23.794
	Width	38.42	38.48	38.60	38.50	3.850			
	Thickness	1.67	1.48	1.70	1.62	0.162			
L276	Length	51.28	51.40	51.44	51.37	5.137	2.792	2.931	23.649
	Width	38.65	38.55	38.50	38.57	3.857			
	Thickness	1.65	1.66	1.63	1.65	0.165			
L277	Length	51.32	51.62	51.42	51.45	5.145	N/A	N/A	42.389
	Width	38.50	38.56	38.38	38.48	3.848			
	Thickness	1.66	1.74	1.65	1.68	0.168			
L278	Length	51.10	51.37	51.27	51.25	5.125	N/A	N/A	42.102
	Width	38.29	38.54	38.53	38.45	3.845			
	Thickness	1.64	1.65	1.62	1.64	0.164			
L280	Length	51.47	51.46	51.33	51.42	5.142	3.249	3.390	27.327
	Width	38.67	38.56	38.49	38.57	3.857			
	Thickness	1.64	1.59	1.68	1.64	0.164			
L281	Length	50.95	51.03	51.08	51.02	5.102	3.118	3.260	26.337
	Width	38.52	38.58	38.44	38.51	3.851			
	Thickness	1.68	1.76	1.76	1.73	0.173			

Table A-2 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
L283	Length	50.43	51.19	51.09	50.90	5.090	N/A	N/A	41.956
	Width	38.58	38.46	38.37	38.47	3.847			
	Thickness	1.73	1.71	1.64	1.69	0.169			
L285	Length	51.26	51.14	51.16	51.19	5.119	N/A	N/A	42.274
	Width	38.52	38.52	38.42	38.49	3.849			
	Thickness	1.71	1.73	1.75	1.73	0.173			
L286	Length	51.42	51.44	51.56	51.47	5.147	2.797	2.937	23.734
	Width	38.54	38.68	38.62	38.61	3.861			
	Thickness	1.65	1.67	1.66	1.66	0.166			
L287	Length	51.27	51.58	51.71	51.52	5.152	3.220	3.220	26.655
	Width	38.77	38.67	38.74	38.73	3.873			
	Thickness	1.59	1.65	1.75	1.66	0.166			
L290	Length	51.24	51.12	51.04	51.13	5.113	N/A	N/A	42.152
	Width	38.54	38.53	38.52	38.53	3.853			
	Thickness	1.55	1.73	1.72	1.67	0.167			
L291	Length	51.40	51.30	51.24	51.31	5.131	N/A	N/A	42.462
	Width	38.59	38.57	38.60	38.59	3.859			
	Thickness	1.73	1.73	1.70	1.72	0.172			
L292	Length	51.33	51.33	51.32	51.33	5.133	2.820	2.961	23.900
	Width	38.59	38.48	38.49	38.52	3.852			
	Thickness	1.68	1.69	1.71	1.69	0.169			
L293	Length	51.35	51.31	51.32	51.33	5.133	2.820	2.820	23.329
	Width	38.46	38.60	38.58	38.55	3.855			
	Thickness	1.73	1.57	1.72	1.67	0.167			
L295	Length	51.32	51.40	51.28	51.33	5.133	N/A	N/A	42.390
	Width	38.54	38.51	38.46	38.50	3.850			
	Thickness	1.70	1.75	1.71	1.72	0.172			
L297	Length	51.43	51.32	51.10	51.28	5.128	N/A	N/A	42.364
	Width	38.64	38.55	38.64	38.61	3.861			
	Thickness	1.68	1.72	1.61	1.67	0.167			
L386	Length	51.60	51.52	51.44	51.52	5.152	N/A	N/A	42.582
	Width	38.66	38.67	38.69	38.67	3.867			
	Thickness	1.63	1.67	1.65	1.65	0.165			
L387	Length	51.42	51.45	51.24	51.37	5.137	N/A	N/A	42.538
	Width	38.60	38.62	38.55	38.59	3.859			
	Thickness	1.75	1.72	1.73	1.73	0.173			
L389	Length	51.11	51.09	51.12	51.11	5.111	2.994	3.204	25.442
	Width	38.44	38.47	38.41	38.44	3.844			
	Thickness	1.62	1.61	1.60	1.61	0.161			
L390	Length	51.11	51.13	51.09	51.11	5.111	2.945	3.009	24.427
	Width	38.32	38.36	38.36	38.35	3.835			
	Thickness	1.62	1.64	1.63	1.63	0.163			
L392	Length	51.07	51.06	51.14	51.09	5.109	N/A	N/A	42.005
	Width	38.30	38.45	38.56	38.44	3.844			
	Thickness	1.65	1.66	1.67	1.66	0.166			

Table A-2 continued.

Coupon		1 (mm)	2 (mm)	3 (mm)	Average (mm)	Average (cm)	L_1 (cm)	L_2 (cm)	SA (cm^2)
L393	Length	51.12	50.89	51.00	51.00	5.100	N/A	N/A	41.714
	Width	38.44	38.35	38.15	38.31	3.831			
	Thickness	1.63	1.60	1.61	1.61	0.161			
L395	Length	51.05	51.01	51.01	51.02	5.102	2.899	2.899	23.862
	Width	38.41	38.41	38.37	38.40	3.840			
	Thickness	1.64	1.63	1.71	1.66	0.166			
L396	Length	51.19	51.08	51.09	51.12	5.112	2.672	2.744	22.224
	Width	38.13	38.40	38.26	38.26	3.826			
	Thickness	1.64	1.61	1.62	1.62	0.162			
L398	Length	51.24	51.09	50.99	51.11	5.111	N/A	N/A	41.904
	Width	38.27	38.47	38.47	38.40	3.840			
	Thickness	1.62	1.61	1.63	1.62	0.162			
L399	Length	51.04	51.13	51.11	51.09	5.109	N/A	N/A	41.947
	Width	38.35	38.42	38.48	38.42	3.842			
	Thickness	1.66	1.63	1.63	1.64	0.164			
L401	Length	51.12	51.06	51.02	51.07	5.107	3.012	3.105	25.079
	Width	38.30	38.43	38.39	38.37	3.837			
	Thickness	1.61	1.62	1.61	1.61	0.161			
L402	Length	51.07	51.03	51.02	51.04	5.104	2.834	2.869	23.415
	Width	38.27	38.40	38.39	38.35	3.835			
	Thickness	1.62	1.64	1.59	1.62	0.162			
L404	Length	51.44	51.36	51.33	51.38	5.138	N/A	N/A	42.373
	Width	38.49	38.69	38.67	38.62	3.862			
	Thickness	1.61	1.65	1.64	1.63	0.163			
L405	Length	51.48	51.48	51.58	51.51	5.151	N/A	N/A	42.513
	Width	38.66	38.75	38.73	38.71	3.871			
	Thickness	1.60	1.61	1.58	1.60	0.160			
L407	Length	51.45	51.45	51.33	51.41	5.141	3.038	3.038	25.065
	Width	38.53	38.65	38.74	38.64	3.864			
	Thickness	1.61	1.57	1.61	1.60	0.160			
L408	Length	51.57	51.42	51.43	51.47	5.147	3.049	3.120	25.497
	Width	38.65	38.68	38.69	38.67	3.867			
	Thickness	1.65	1.62	1.63	1.63	0.163			
L410	Length	51.46	51.41	51.56	51.48	5.148	N/A	N/A	42.421
	Width	38.70	38.62	38.55	38.62	3.862			
	Thickness	1.62	1.61	1.61	1.61	0.161			
L411	Length	51.69	51.52	51.49	51.57	5.157	N/A	N/A	42.601
	Width	38.64	38.71	38.73	38.69	3.869			
	Thickness	1.63	1.64	1.62	1.63	0.163			

Source: Individual data sheets for each coupon in *WIPP-FePb-3 Supplemental Binder C (ERMS 546084)*

APPENDIX B – WEIGHT LOSS DATA

Table B-1 lists the exposure duration, initial weight, final weight, weight loss, surface area and calculated corrosion rate for each steel coupon. The equivalent data for the lead coupons is given in Table B-2. The reported surface areas are taken from Tables A-1 and A-2 for steel and lead, respectively. The final weight is determined from the cleaning cycle data and graphical analysis, which is presented in Appendix C for the steel coupons and Appendix D for the lead coupons (see Section 4.4 for details).

Corrosion rates are calculated according to Equation (3) given in Section 4.4.

Table B-1 Summary of Steel Coupon Corrosion Rate Data

Test ID	Coupon	Duration (days)	Initial Wt (g)	Final Wt (g) (Calculated)	Weight Loss (mg)	Surface Area (cm^2)	Corrosion Rate (µm/yr)
Fe-G-0000-12-1f	060	377	19.3011	19.2959	5.2	41.666	0.153
Fe-G-0000-12-2f	061	377	20.5591	20.5512	7.9	41.763	0.233
Fe-G-0000-12-1p	063	377	20.3449	20.3417	3.2	23.495	0.168
Fe-G-0000-12-2p	064	377	20.3755	20.3719	3.6	23.320	0.190
Fe-Go-0000-12-1f	066	377	20.1063	20.0992	7.1	41.589	0.210
Fe-Go-0000-12-2f	067	377	20.1960	20.1917	4.3	41.678	0.127
Fe-Go-0000-12-1p	069	377	20.0246	20.0198	4.8	27.610	0.214
Fe-Go-0000-12-2p	070	377	20.2859	20.2817	4.2	25.698	0.201
Fe-E-0000-12-1f	072	377	19.5601	19.5513	8.8	41.656	0.260
Fe-E-0000-12-2f	073	377	19.5790	19.5695	9.5	41.516	0.281
Fe-E-0000-12-1p	075	377	19.8687	19.8646	4.1	24.408	0.207
Fe-E-0000-12-2p	076	377	18.4585	18.4537	4.8	24.385	0.242
Fe-Eo-0000-12-1f	078	377	18.6946	18.6899	4.7	41.580	0.139
Fe-Eo-0000-12-2f	079	377	18.8659	18.8609	5.0	41.453	0.148
Fe-Eo-0000-12-1p	081	377	20.5837	20.5817	2.0	24.021	0.102
Fe-Eo-0000-12-2p	082	377	20.4241	20.4218	2.3	24.833	0.114
Fe-Atm-0000-12-1	084	377	20.2808	20.2805	0.3	41.748	0.009
Fe-Atm-0000-12-2	085	377	20.2084	20.2073	1.1	41.827	0.032
Fe-G-0350-12-2f	190	372	20.1010	20.0934	7.6	41.452	0.229
Fe-G-0350-12-3f	191	372	19.6566	19.6502	6.4	41.453	0.192
Fe-G-0350-12-1p	192	372	19.6893	19.6850	4.3	22.433	0.239
Fe-G-0350-12-2p	202	372	20.1691	20.1651	4.0	23.307	0.214
Fe-Go-0350-12-2f	205	372	19.9700	19.9625	7.5	41.706	0.224
Fe-Go-0350-12-3f	206	372	20.4860	20.4784	7.6	41.568	0.228
Fe-Go-0350-12-1p	207	372	20.5629	20.5574	5.5	25.466	0.269
Fe-Go-0350-12-2p	208	372	20.5510	20.5469	4.1	24.809	0.206
Fe-E-0350-12-1f	210	372	20.7959	20.7910	4.9	41.537	0.147
Fe-E-0350-12-3f	212	372	20.4249	20.4192	5.7	41.561	0.171
Fe-E-0350-12-1p	213	372	20.4342	20.4307	3.5	25.757	0.169
Fe-E-0350-12-2p	214	372	20.5784	20.5740	4.4	25.133	0.218
Fe-Eo-0350-12-2f	217	372	19.8691	19.8647	4.4	41.595	0.132
Fe-Eo-0350-12-3f	218	372	19.9675	19.9621	5.4	41.579	0.162
Fe-Eo-0350-12-2p	220	372	20.5543	20.5494	4.9	24.663	0.248
Fe-Eo-0350-12-3p	221	372	18.5283	18.5247	3.6	25.007	0.179
Fe-Atm-0350-12-1	222	372	18.8982	18.8972	1.0	41.291	0.030
Fe-Atm-0350-12-2	223	372	19.0679	19.0655	2.4	41.427	0.072
Fe-G-1500-12-2f	280	377	20.0104	20.0037	6.7	41.592	0.198
Fe-G-1500-12-3f	281	377	20.5189	20.5123	6.6	41.534	0.195

Table B-1 continued.

Test ID	Coupon	Duration (days)	Initial Wt (g)	Final Wt (g) (Calculated)	Weight Loss (mg)	Surface Area (cm^2)	Corrosion Rate (μm/yr)
Fe-G-1500-12-2p	283	377	20.5013	20.4980	3.3	23.525	0.173
Fe-G-1500-12-3p	284	377	20.5887	20.5868	1.9	23.885	0.098
Fe-Go-1500-12-2f	286	377	20.0247	20.0169	7.8	41.620	0.230
Fe-Go-1500-12-3f	287	377	20.1628	20.1548	8.0	41.505	0.237
Fe-Go-1500-12-2p	289	377	20.4700	20.4669	3.1	22.377	0.170
Fe-Go-1500-12-3p	290	377	20.6715	20.6671	4.4	22.094	0.245
Fe-E-1500-12-2f	292	377	19.6078	19.5819	25.9	41.565	0.766
Fe-E-1500-12-3f	293	377	19.8102	19.7953	14.9	42.073	0.436
Fe-E-1500-12-2p	295	377	20.3754	20.3639	11.5	24.876	0.569
Fe-E-1500-12-3p	296	377	18.6232	18.6121	11.1	25.442	0.537
Fe-Eo-1500-12-2f	298	377	19.1280	19.1211	6.9	41.791	0.203
Fe-Eo-1500-12-3f	299	377	19.5338	19.5266	7.2	41.571	0.213
Fe-Eo-1500-12-2p	301	377	20.2896	20.2865	3.1	24.901	0.153
Fe-Eo-1500-12-3p	302	377	20.1619	20.1568	5.1	24.639	0.255
Fe-Atm-1500-12-2	304	377	20.0619	20.0639	-2.0	41.650	-0.059
Fe-Atm-1500-12-3	305	377	19.9653	19.9669	-1.6	41.694	-0.047
Fe-G-3500-12-1f	388	384	20.2823	20.2717	10.6	41.679	0.307
Fe-G-3500-12-2f	389	384	20.4266	20.4162	10.4	41.613	0.302
Fe-G-3500-12-1p	391	384	19.5371	19.5317	5.4	20.603	0.316
Fe-G-3500-12-2p	392	384	19.7584	19.7525	5.9	22.200	0.321
Fe-Go-3500-12-1f	394	384	20.1677	20.1592	8.5	41.626	0.247
Fe-Go-3500-12-2f	395	384	20.3568	20.3479	8.9	41.664	0.258
Fe-Go-3500-12-1p	397	384	19.0914	19.0857	5.7	24.076	0.286
Fe-Go-3500-12-2p	398	384	19.2442	19.2390	5.2	23.481	0.267
Fe-E-3500-12-1f	400	384	19.9873	19.9496	37.7	41.510	1.097
Fe-E-3500-12-2f	401	384	20.5452	20.5217	23.5	41.475	0.684
Fe-E-3500-12-1p	403	384	19.7813	19.7641	17.2	22.850	0.909
Fe-E-3500-12-2p	404	384	19.4440	19.4252	18.8	22.597	1.005
Fe-Eo-3500-12-1f	406	384	20.9043	20.8890	15.3	41.639	0.444
Fe-Eo-3500-12-2f	407	384	20.6746	20.6577	16.9	41.466	0.492
Fe-Eo-3500-12-1p	409	384	20.2286	20.2170	11.6	23.658	0.592
Fe-Eo-3500-12-2p	410	384	20.0146	20.0024	12.2	22.850	0.645
Fe-Atm-3500-12-1	412	383	20.4797	20.4793	0.4	41.505	0.012
Fe-Atm-3500-12-2	413	383	20.1305	20.1305	0.0	41.386	0.000

Source: WIPP-FePb-3 Supplemental Binder C (ERMS 546084)

Table B-2 Summary of Lead Coupon Corrosion Rate Data

Test ID	Coupon	Duration (days)	Initial Wt (g)	Final Wt (g) (Calculated)	Weight Loss (mg)	Surface Area (cm^2)	Corrosion Rate (μm/yr)
Pb-G-0000-12-1f	L055	371	35.3378	35.3270	10.8	42.547	0.220
Pb-G-0000-12-2f	L056	371	34.0622	34.0532	9.0	42.959	0.182
Pb-G-0000-12-1p	L058	371	36.0145	36.0028	11.7	22.993	0.441
Pb-G-0000-12-2p	L059	371	34.7627	34.7490	13.7	23.051	0.516
Pb-Go-0000-12-1f	L061	371	34.1481	34.1307	17.4	42.874	0.352
Pb-Go-0000-12-2f	L062	371	34.1944	34.1858	8.6	42.495	0.176
Pb-Go-0000-12-1p	L064	371	35.8906	35.8766	14.0	21.264	0.571
Pb-Go-0000-12-2p	L065	371	35.3656	35.3524	13.2	21.002	0.545
Pb-E-0000-12-2f	L068	371	36.0855	36.0766	8.9	42.736	0.181
Pb-E-0000-12-3f	L069	371	36.1265	36.1220	4.5	42.674	0.091
Pb-E-0000-12-2p	L071	371	33.9754	33.9621	13.3	25.314	0.456
Pb-E-0000-12-3p	L072	371	33.9791	33.9665	12.6	23.223	0.471
Pb-Eo-0000-12-2f	L074	371	35.3804	35.3757	4.7	43.261	0.094
Pb-Eo-0000-12-3f	L075	371	35.1943	35.1833	11.0	42.824	0.223
Pb-Eo-0000-12-1p	L076	371	35.3162	35.3046	11.6	23.096	0.436
Pb-Eo-0000-12-2p	L077	371	34.6883	34.6731	15.2	23.368	0.564
Pb-Atm-0000-12-1	L079	371	34.5752	34.5705	4.7	43.180	0.094
Pb-Atm-0000-12-2	L080	371	34.9096	34.9033	6.3	43.252	0.126
Pb-G-0350-12-1f	L190	365	35.3755	35.3648	10.7	42.232	0.223
Pb-G-0350-12-2f	L191	365	36.1066	36.0964	10.2	42.177	0.213
Pb-G-0350-12-2p	L194	365	34.6025	34.6029	-0.4	24.084	-0.015
Pb-G-0350-12-3p	L195	365	34.6846	34.6793	5.3	24.066	0.194
Pb-Go-0350-12-1f	L196	365	35.2779	35.2688	9.1	42.130	0.190
Pb-Go-0350-12-3f	L198	365	36.1804	36.1648	15.6	42.078	0.327
Pb-Go-0350-12-1p	L199	365	35.2663	35.2696	-3.3	24.401	-0.119
Pb-Go-0350-12-2p	L200	365	35.9647	35.9593	5.4	23.795	0.200
Pb-E-0350-12-2f	L203	365	35.3566	35.3824	-25.8	41.989	-0.542
Pb-E-0350-12-3f	L204	365	35.3174	35.3161	1.3	42.056	0.027
Pb-E-0350-12-1p	L205	365	34.5903	34.5897	0.6	25.602	0.021
Pb-E-0350-12-3p	L207	365	36.2173	36.2095	7.8	25.223	0.273
Pb-Eo-0350-12-2f	L209	365	35.4896	35.4886	1.0	42.113	0.021
Pb-Eo-0350-12-3f	L210	365	35.1431	35.1329	10.2	42.032	0.214
Pb-Eo-0350-12-1p	L211	365	35.2497	35.2378	11.9	30.914	0.339
Pb-Eo-0350-12-2p	L212	365	35.1299	35.1283	1.6	30.709	0.046
Pb-Atm-0350-12-1	L214	365	35.1582	35.1602	-2.0	42.012	-0.042
Pb-Atm-0350-12-2	L215	365	35.2606	35.2560	4.6	41.992	0.097
Pb-G-1500-12-2f	L272	375	34.5033	34.4886	14.7	42.492	0.297
Pb-G-1500-12-3f	L273	375	34.8008	34.7912	9.6	42.115	0.196

Table B-2 continued.

Test ID	Coupon	Duration (days)	Initial Wt (g)	Final Wt (g) (Calculated)	Weight Loss (mg)	Surface Area (cm^2)	Corrosion Rate (µm/yr)
Pb-G-1500-12-2p	L275	375	35.3713	35.3528	18.5	23.794	0.667
Pb-G-1500-12-3p	L276	375	34.8719	34.8532	18.7	23.649	0.679
Pb-Go-1500-12-1f	L277	375	34.9428	34.9349	7.9	42.389	0.160
Pb-Go-1500-12-2f	L278	375	34.7336	34.7241	9.5	42.102	0.194
Pb-Go-1500-12-1p	L280	375	35.0697	35.0544	15.3	27.327	0.481
Pb-Go-1500-12-2p	L281	375	35.8230	35.8051	17.9	26.337	0.583
Pb-E-1500-12-1f	L283	375	36.0889	36.0817	7.2	41.956	0.147
Pb-E-1500-12-3f	L285	375	36.1523	36.1476	4.7	42.274	0.095
Pb-E-1500-12-1p	L286	375	34.9871	34.9682	18.9	23.734	0.684
Pb-E-1500-12-2p	L287	375	34.7513	34.7326	18.7	26.655	0.602
Pb-Eo-1500-12-2f	L290	375	35.8010	35.7934	7.6	42.152	0.155
Pb-Eo-1500-12-3f	L291	375	35.8531	35.8446	8.5	42.462	0.172
Pb-Eo-1500-12-1p	L292	375	35.8814	35.8667	14.7	23.900	0.528
Pb-Eo-1500-12-2p	L293	375	35.8772	35.8620	15.2	23.329	0.559
Pb-Atm-1500-12-1	L295	375	36.1501	36.1463	3.8	42.390	0.077
Pb-Atm-1500-12-2	L297	375	34.9107	34.9035	7.2	42.364	0.146
Pb-G-3500-12-1f	L386	383	34.9965	34.9893	7.2	42.582	0.142
Pb-G-3500-12-2f	L387	383	36.1403	36.1293	11.0	42.538	0.217
Pb-G-3500-12-1p	L389	383	34.7017	34.6910	10.7	25.442	0.353
Pb-G-3500-12-2p	L390	383	34.6293	34.6156	13.7	24.427	0.471
Pb-Go-3500-12-1f	L392	383	34.9198	34.9082	11.6	42.005	0.232
Pb-Go-3500-12-2f	L393	383	34.3856	34.3793	6.3	41.714	0.127
Pb-Go-3500-12-1p	L395	383	35.0050	35.0004	4.6	23.862	0.162
Pb-Go-3500-12-2p	L396	383	34.1048	34.0989	5.9	22.224	0.223
Pb-E-3500-12-1f	L398	383	34.6465	34.6452	1.3	41.904	0.026
Pb-E-3500-12-2f	L399	383	34.4017	34.4032	-1.5	41.947	-0.030
Pb-E-3500-12-1p	L401	383	34.0783	34.0683	10.0	25.079	0.335
Pb-E-3500-12-2p	L402	383	34.7546	34.7414	13.2	23.415	0.474
Pb-Eo-3500-12-1f	L404	383	34.6299	34.6217	8.2	42.373	0.163
Pb-Eo-3500-12-2f	L405	383	33.8274	33.8195	7.9	42.513	0.156
Pb-Eo-3500-12-1p	L407	383	33.8222	33.8115	10.7	25.065	0.359
Pb-Eo-3500-12-2p	L408	383	35.2047	35.1998	4.9	25.497	0.162
Pb-Atm-3500-12-1	L410	383	34.1198	34.1149	4.9	42.421	0.097
Pb-Atm-3500-12-2	L411	383	34.8854	34.8814	4.0	42.601	0.079

Source: WIPP-FePb-3 Supplemental Binder C (ERMS 546084)

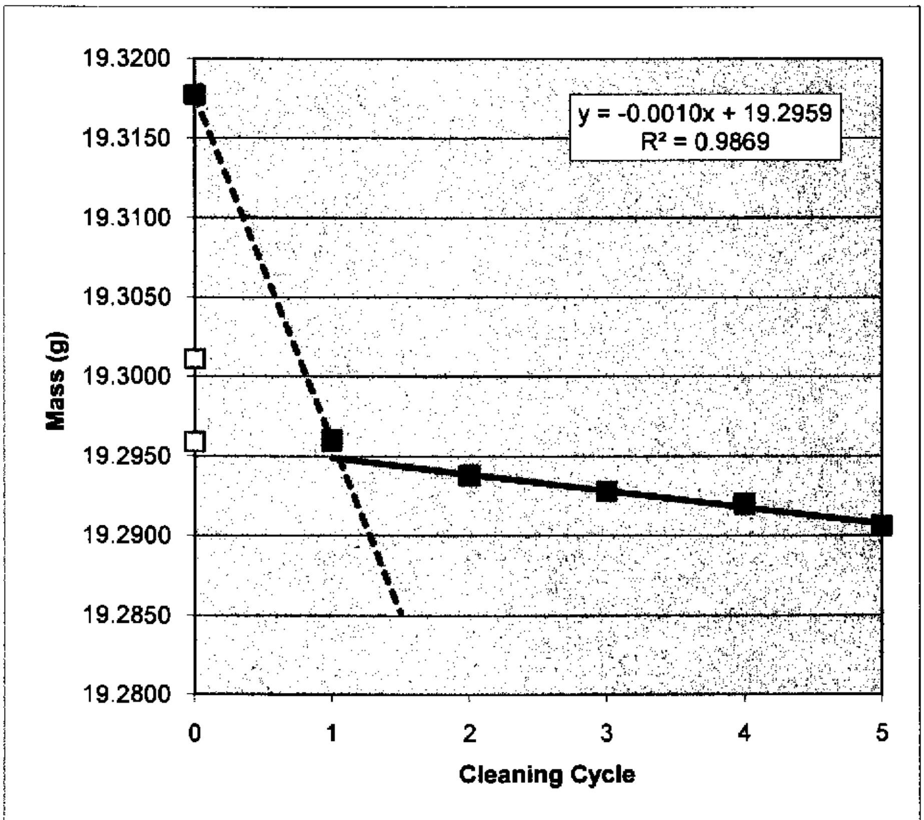
APPENDIX C – STEEL COUPON CLEANING PLOTS

This appendix contains all of the weight loss cleaning cycle data, as well as the results of the graphical analysis of that data for each of the steel coupons (see individual data sheets for each coupon in WIPP-FePb-3 Supplemental Binder C). Each of the following pages lists the initial coupon weight, removal weight, cleaning cycle weights, calculated final weight and the resulting weight loss. The environmental conditions for each coupon can be read from the test matrix label that is given for each coupon. The meaning of the test matrix labels is discussed in Section 2.4.

For each coupon the graphical analysis is shown (see Section 4.4 in Roselle (2009) for details of the process). The blue symbols indicate those parts of the cleaning cycle data used to determine the calculated final weight, which is the y-intercept of the line fit to the blue symbols. The red symbols show the cleaning cycle data not used in the linear regression. Yellow symbols indicate the initial coupon weight (prior to the experiment) and the final calculated weight. The decision as to which cleaning cycle data points (blue symbols) to include in the fit is based on a visual inspection of the plots. Therefore it is somewhat of a subjective decision. However, in all cases at least 3 data points are used in the fit.

Coupon:	060			
Test matrix:	Fe-G-0000-12-1f			
Initial wt (g)	19.3011		**Calculated final wt (g)**	19.2959
Removal wt (g)	19.3177		**Total wt loss (g)**	0.0052
			Total wt loss (mg)	5.2

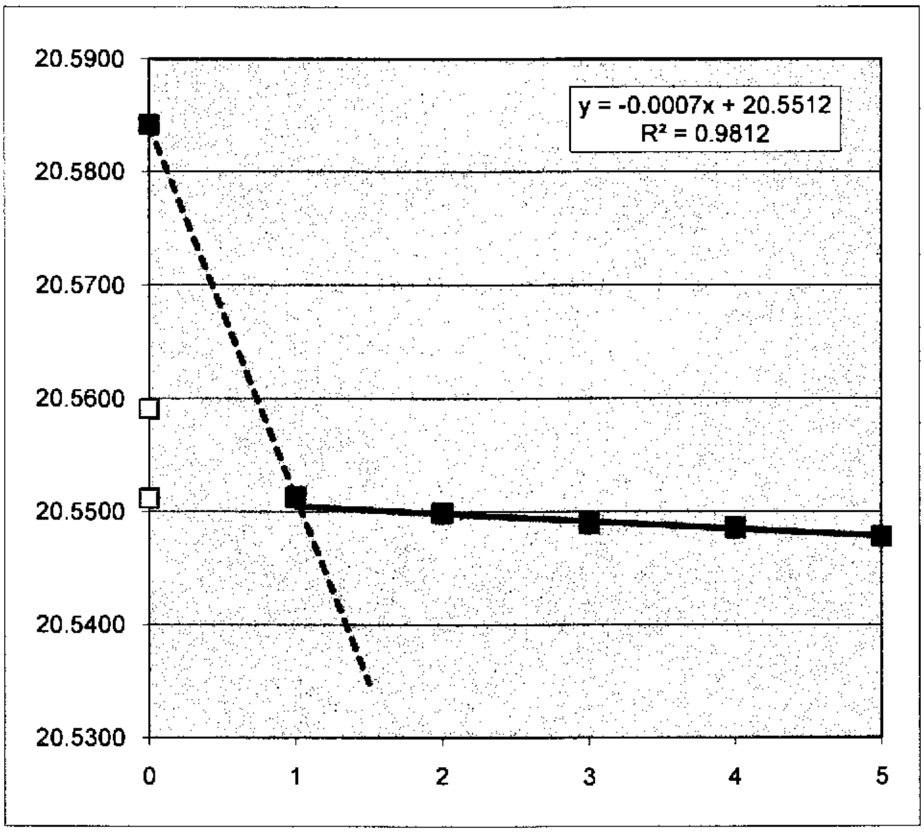
Cleaning Cycle	Wt (g)
0	19.3177
1	19.2960
2	19.2938
3	19.2928
4	19.2920
5	19.2906



Coupon:	061
Test matrix:	Fe-G-0000-12-2f
Initial wt (g)	20.5591
Removal wt (g)	20.5842

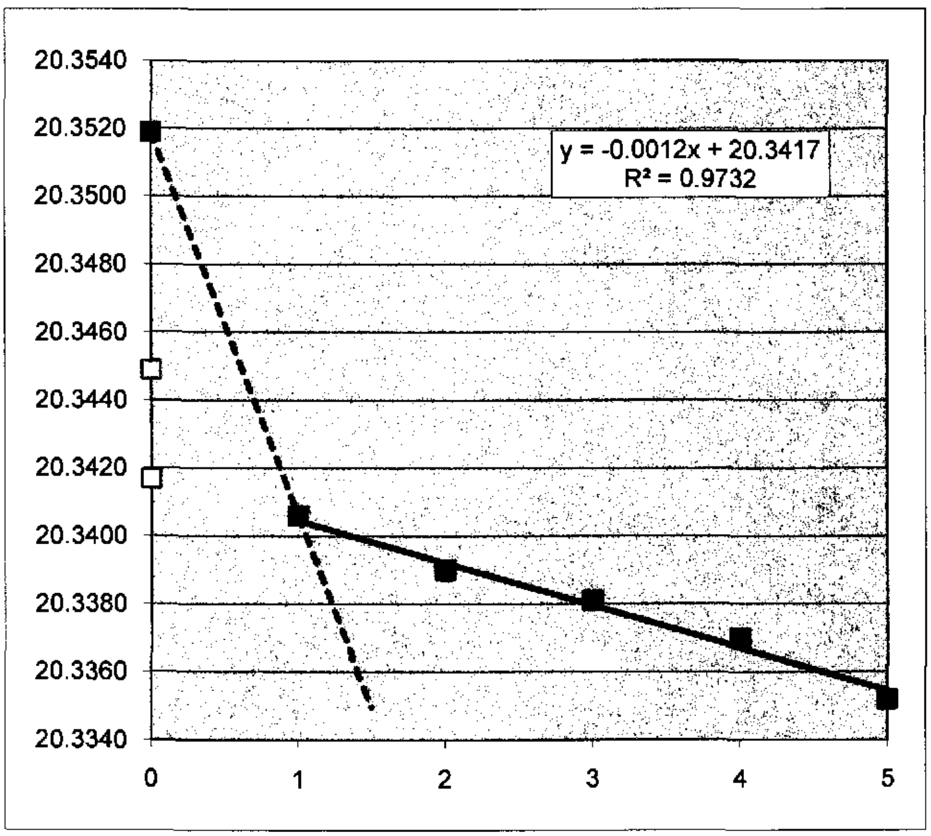
Calculated final wt (g)	20.5512
Total wt loss (g)	0.0079
Total wt loss (mg)	7.9

Cleaning Cycle	Wt (g)
0	20.5842
1	20.5513
2	20.5499
3	20.5490
4	20.5486
5	20.5478



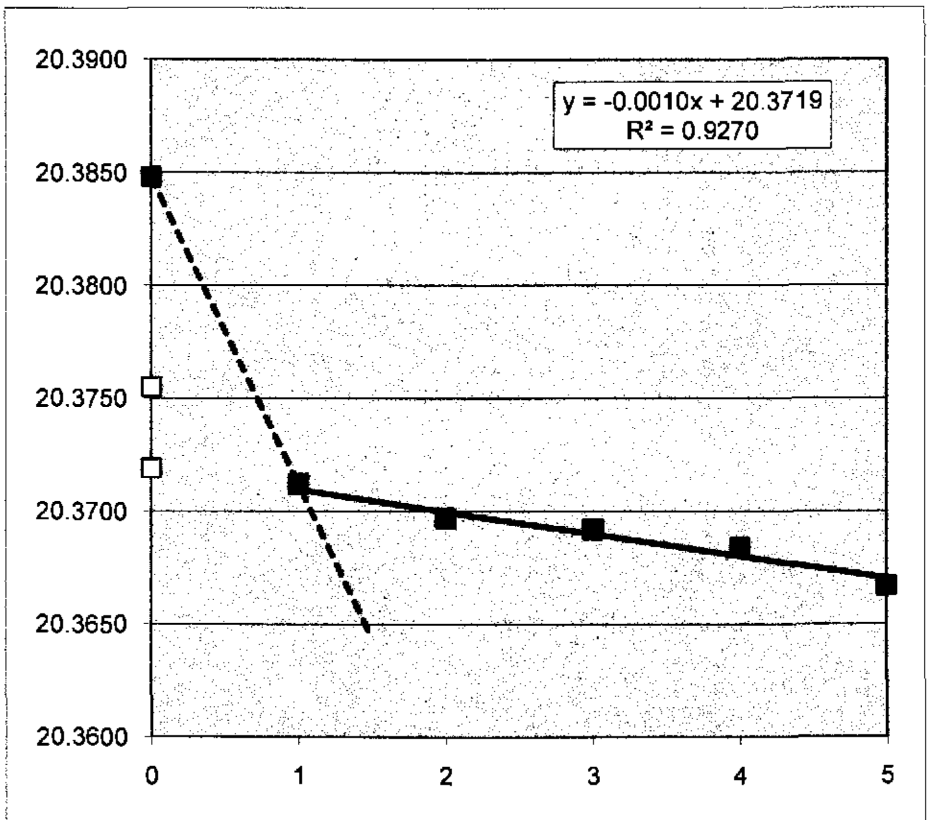
Coupon:	063		
Test matrix:	Fe-G-0000-12-1p		
Initial wt (g)	20.3449	**Calculated final wt (g)**	20.3417
Removal wt (g)	20.3519	**Total wt loss (g)**	0.0032
		Total wt loss (mg)	3.2

Cleaning Cycle	Wt (g)
0	20.3519
1	20.3406
2	20.3390
3	20.3381
4	20.3370
5	20.3352



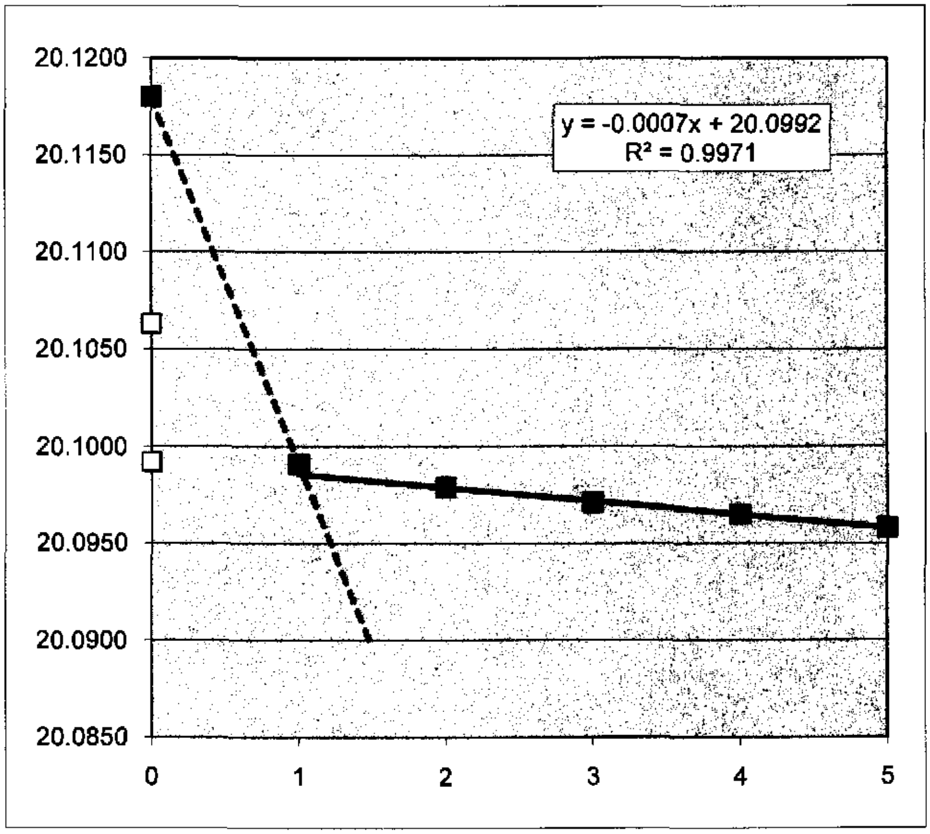
Coupon:	064		
Test matrix:	Fe-G-0000-12-2p		
Initial wt (g)	20.3755	**Calculated final wt (g)**	20.3719
Removal wt (g)	20.3848	**Total wt loss (g)**	0.0036
		Total wt loss (mg)	3.6

Cleaning Cycle	Wt (g)
0	20.3848
1	20.3712
2	20.3697
3	20.3692
4	20.3684
5	20.3667



Coupon:	066		
Test matrix:	Fe-Go-0000-12-1f		
Initial wt (g)	20.1063	**Calculated final wt (g)**	20.0992
Removal wt (g)	20.1180	**Total wt loss (g)**	0.0071
		Total wt loss (mg)	7.1

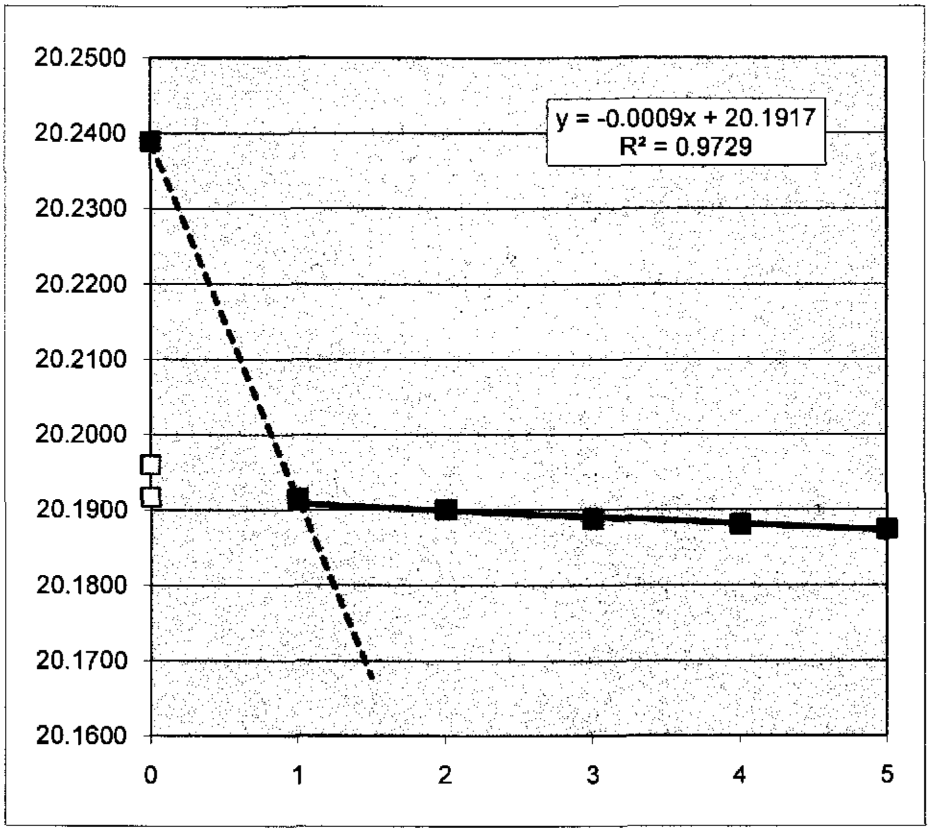
Cleaning Cycle	Wt (g)
0	20.1180
1	20.0991
2	20.0979
3	20.0971
4	20.0965
5	20.0958



Coupon:	067
Test matrix:	Fe-Go-0000-12-2f
Initial wt (g)	20.1960
Removal wt (g)	20.2389

Calculated final wt (g)	20.1917
Total wt loss (g)	0.0043
Total wt loss (mg)	4.3

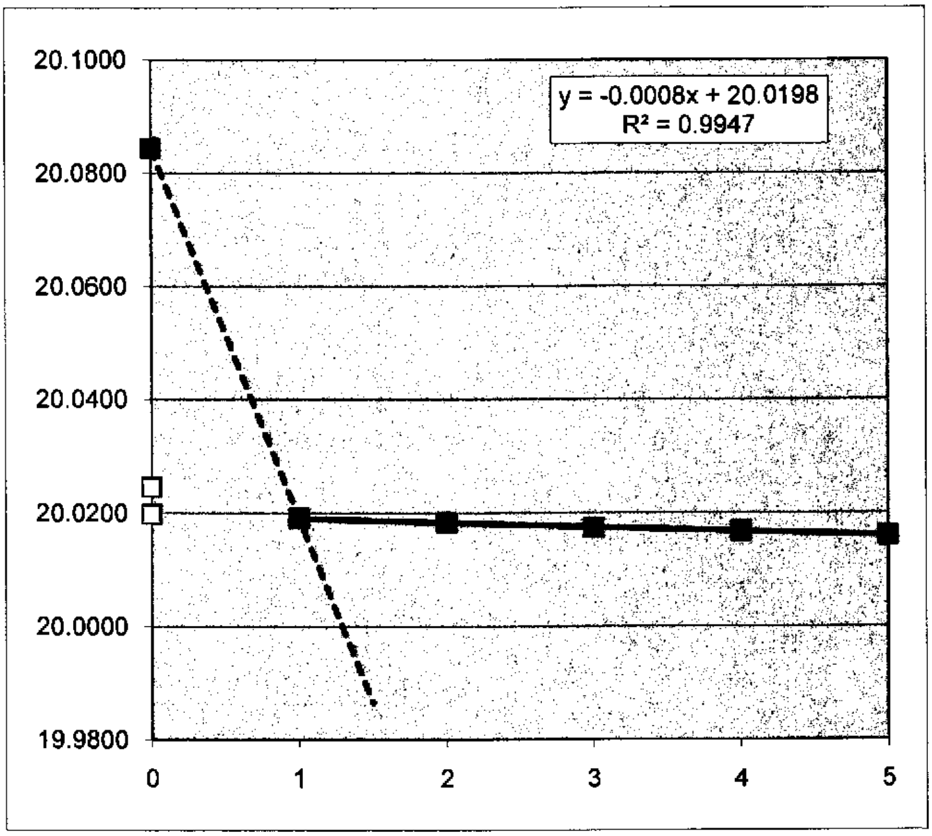
Cleaning Cycle	Wt (g)
0	20.2389
1	20.1915
2	20.1901
3	20.1888
4	20.1881
5	20.1874



Coupon:	069
Test matrix:	Fe-Go-0000-12-1p
Initial wt (g)	20.0246
Removal wt (g)	20.0844

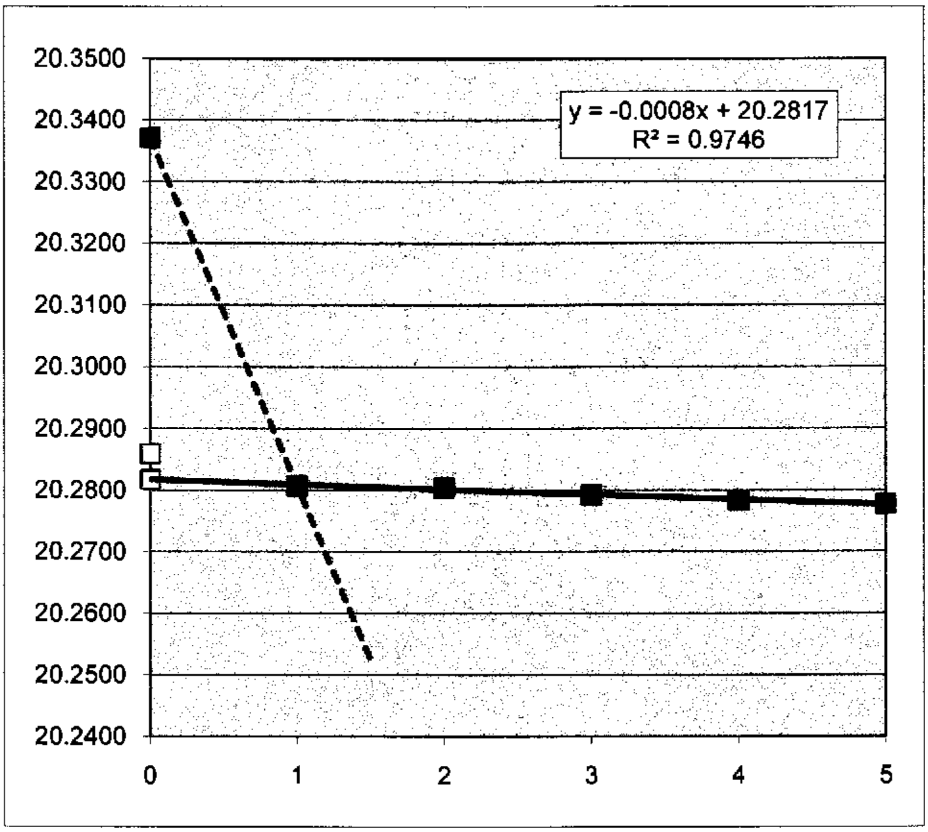
Calculated final wt (g)	20.0198
Total wt loss (g)	0.0048
Total wt loss (mg)	4.8

Cleaning Cycle	Wt (g)
0	20.0844
1	20.0191
2	20.0183
3	20.0174
4	20.0168
5	20.0160



Coupon:	070		
Test matrix:	Fe-Go-0000-12-2p		
Initial wt (g)	20.2859	**Calculated final wt (g)**	20.2817
Removal wt (g)	20.3371	**Total wt loss (g)**	0.0042
		Total wt loss (mg)	4.2

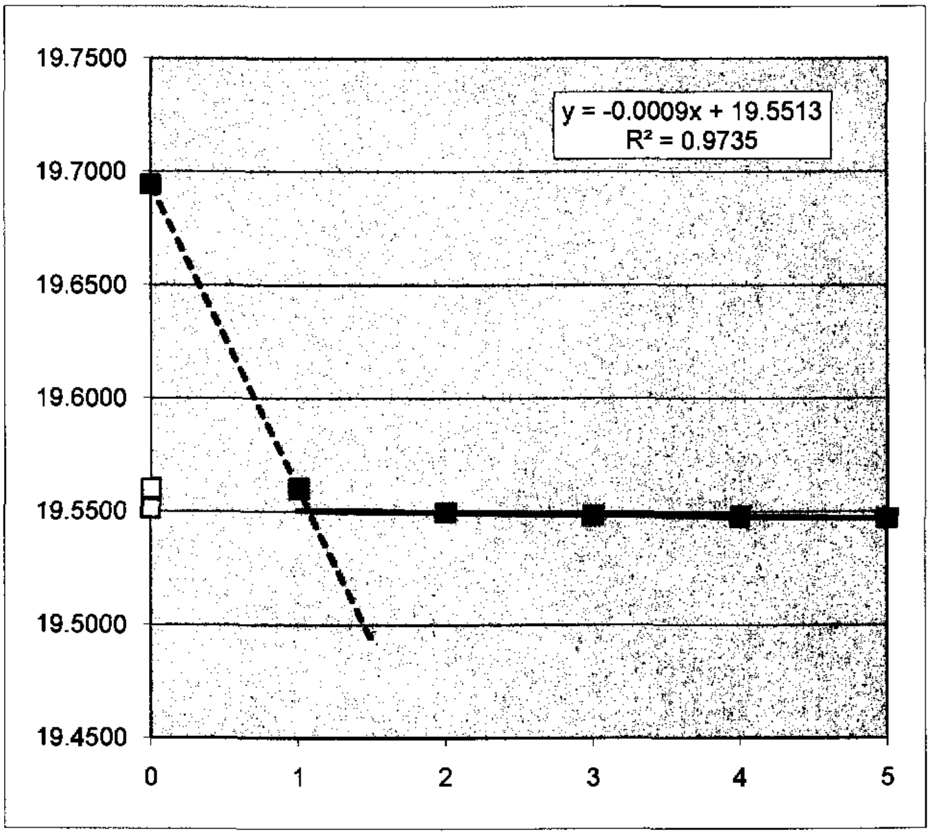
Cleaning Cycle	Wt (g)
0	20.3371
1	20.2807
2	20.2804
3	20.2792
4	20.2783
5	20.2777



Coupon:	072
Test matrix:	Fe-E-0000-12-1f
Initial wt (g)	19.5601
Removal wt (g)	19.6942

Calculated final wt (g)	19.5513
Total wt loss (g)	0.0088
Total wt loss (mg)	8.8

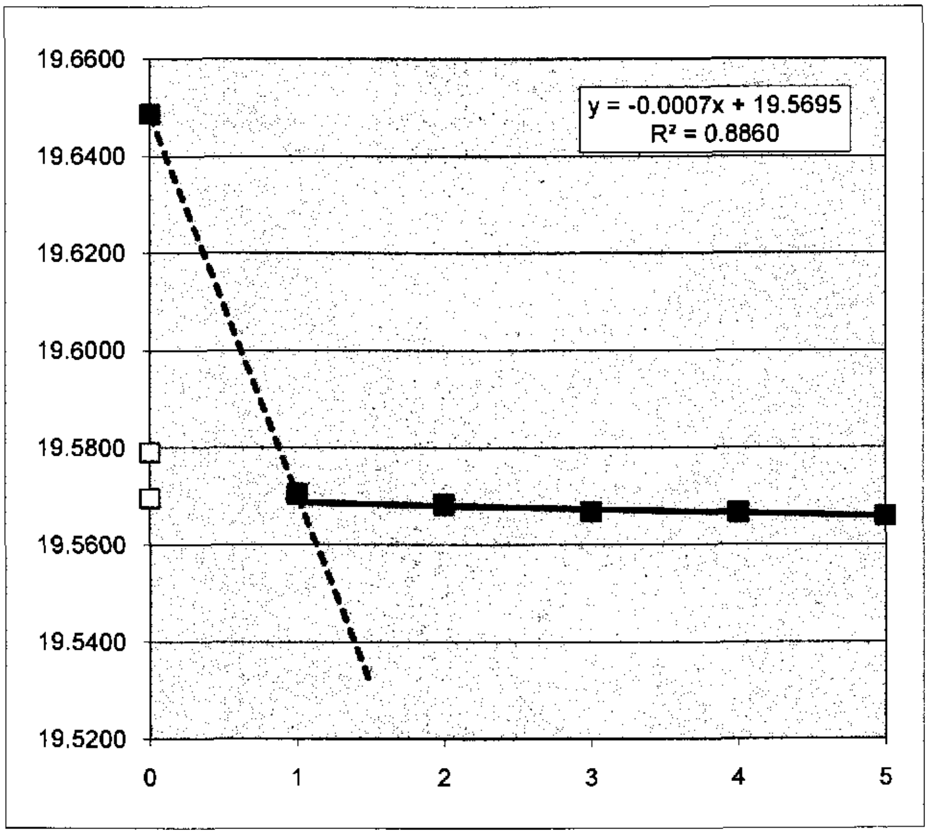
Cleaning Cycle	**Wt (g)**
0	19.6942
1	19.5600
2	19.5497
3	19.5484
4	19.5478
5	19.5470



Coupon:	073
Test matrix:	Fe-E-0000-12-2f
Initial wt (g)	19.5790
Removal wt (g)	19.6487

Calculated final wt (g)	19.5695
Total wt loss (g)	0.0095
Total wt loss (mg)	9.5

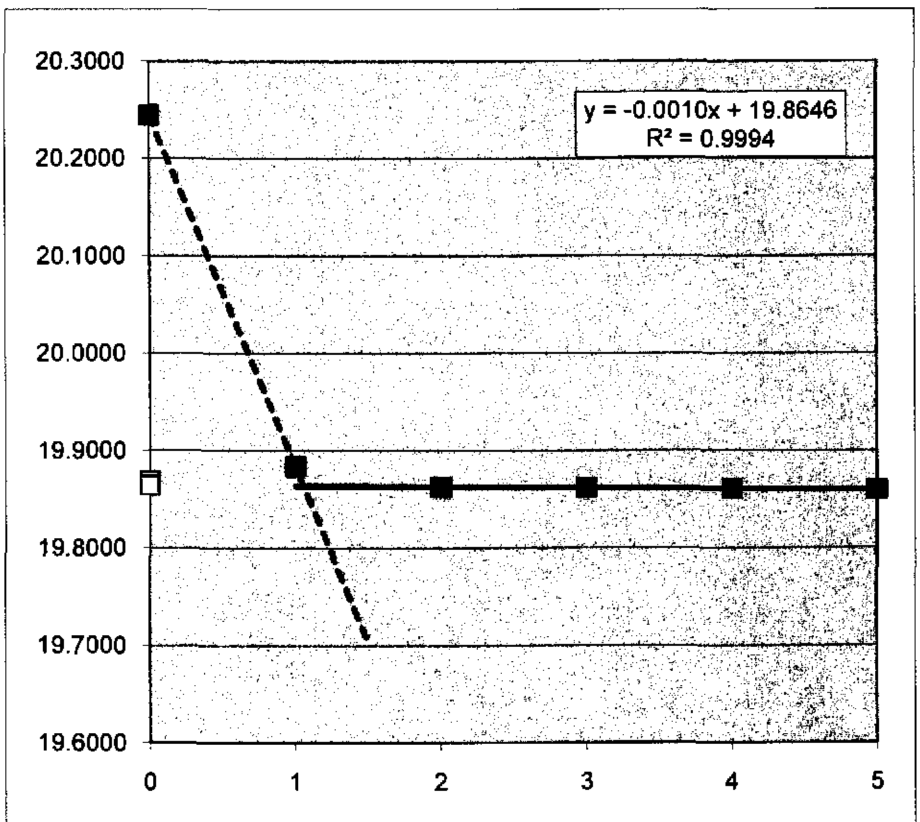
Cleaning Cycle	Wt (g)
0	19.6487
1	19.5704
2	19.5683
3	19.5668
4	19.5667
5	19.5659



Coupon:	075
Test matrix:	Fe-E-0000-12-1p
Initial wt (g)	19.8687
Removal wt (g)	20.2443

Calculated final wt (g)	19.8646
Total wt loss (g)	0.0041
Total wt loss (mg)	4.1

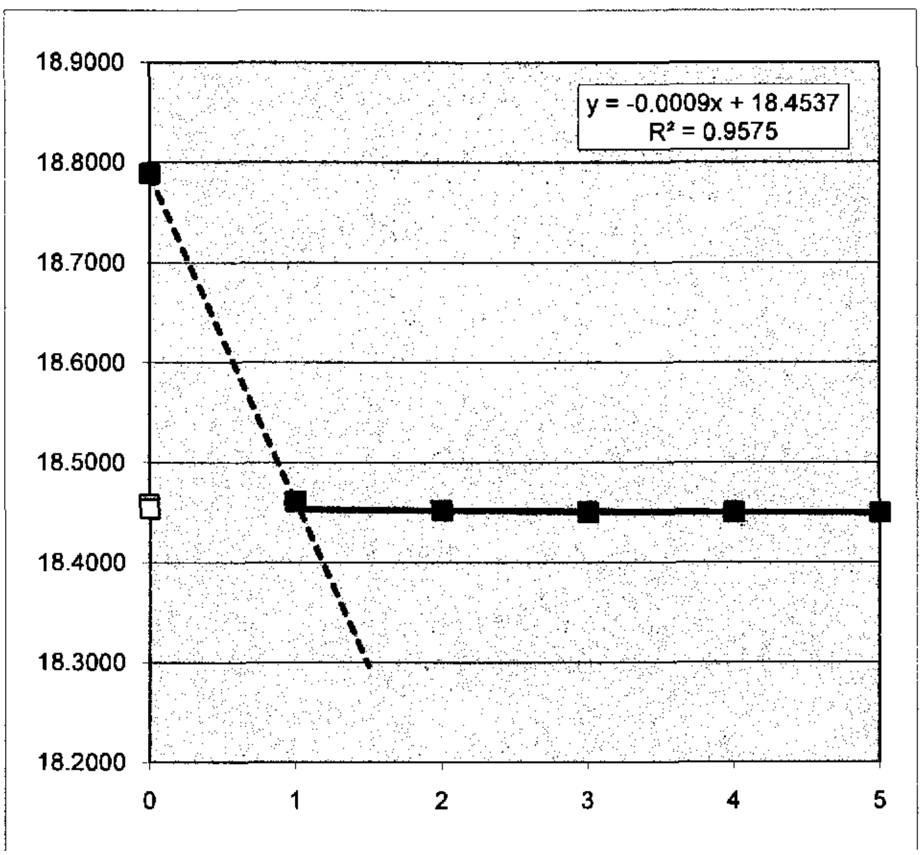
Cleaning Cycle	Wt (g)
0	20.2443
1	19.8839
2	19.8626
3	19.8617
4	19.8607
5	19.8597



Coupon:	076
Test matrix:	Fe-E-0000-12-2p
Initial wt (g)	18.4585
Removal wt (g)	18.7886

Calculated final wt (g)	18.4537
Total wt loss (g)	0.0048
Total wt loss (mg)	4.8

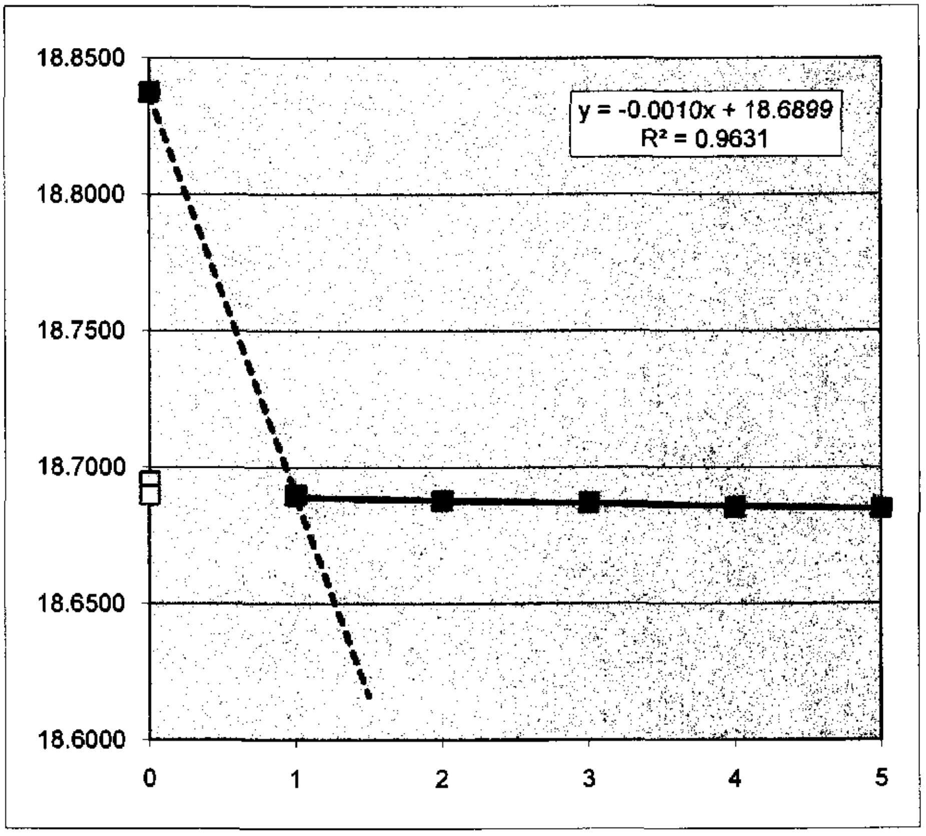
Cleaning Cycle	Wt (g)
0	18.7886
1	18.4605
2	18.4521
3	18.4506
4	18.4501
5	18.4492



Coupon:	078
Test matrix:	Fe-Eo-0000-12-1f
Initial wt (g)	18.6946
Removal wt (g)	18.8374

Calculated final wt (g)	18.6899
Total wt loss (g)	0.0047
Total wt loss (mg)	4.7

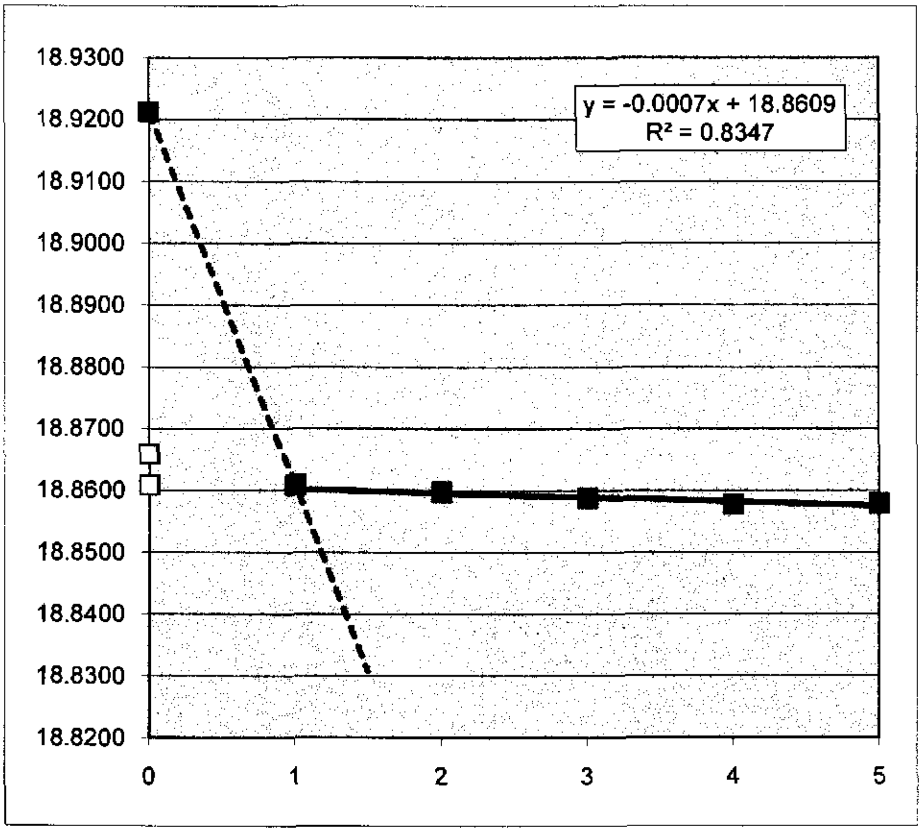
Cleaning Cycle	Wt (g)
0	18.8374
1	18.6899
2	18.6878
3	18.6870
4	18.6854
5	18.6849



Coupon:	079
Test matrix:	Fe-Eo-0000-12-2f
Initial wt (g)	18.8659
Removal wt (g)	18.9212

Calculated final wt (g)	18.8609
Total wt loss (g)	0.005
Total wt loss (mg)	5.0

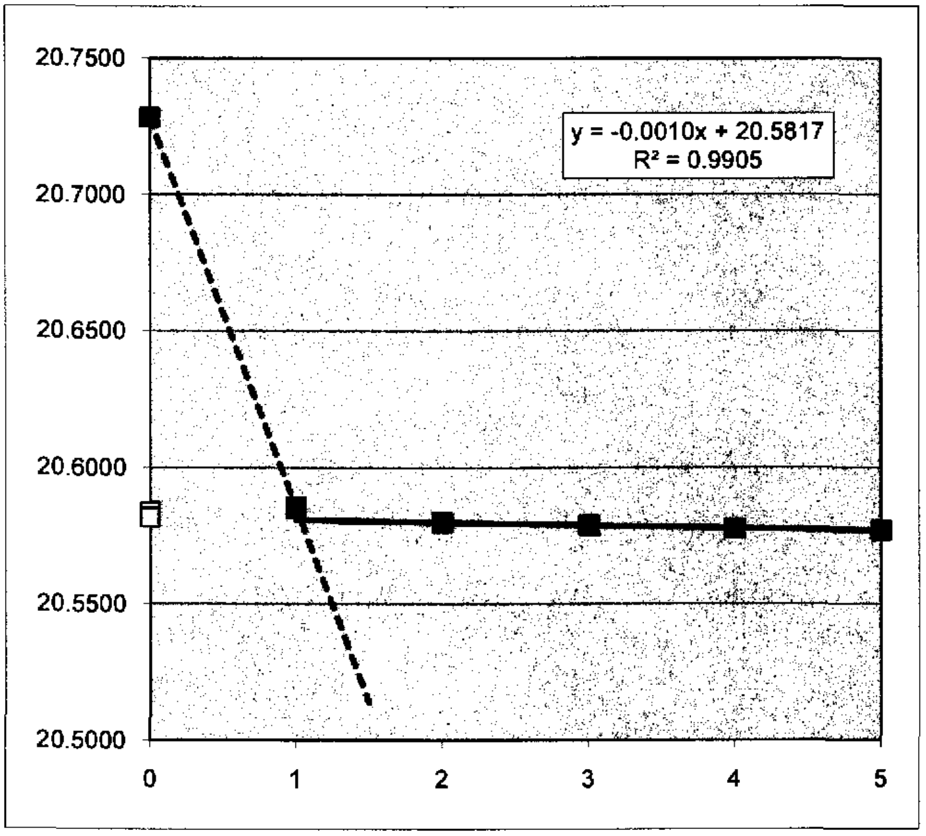
Cleaning Cycle	Wt (g)
0	18.9212
1	18.8609
2	18.8598
3	18.8588
4	18.8577
5	18.8579



Coupon:	081
Test matrix:	Fe-Eo-0000-12-1p
Initial wt (g)	20.5837
Removal wt (g)	20.7283

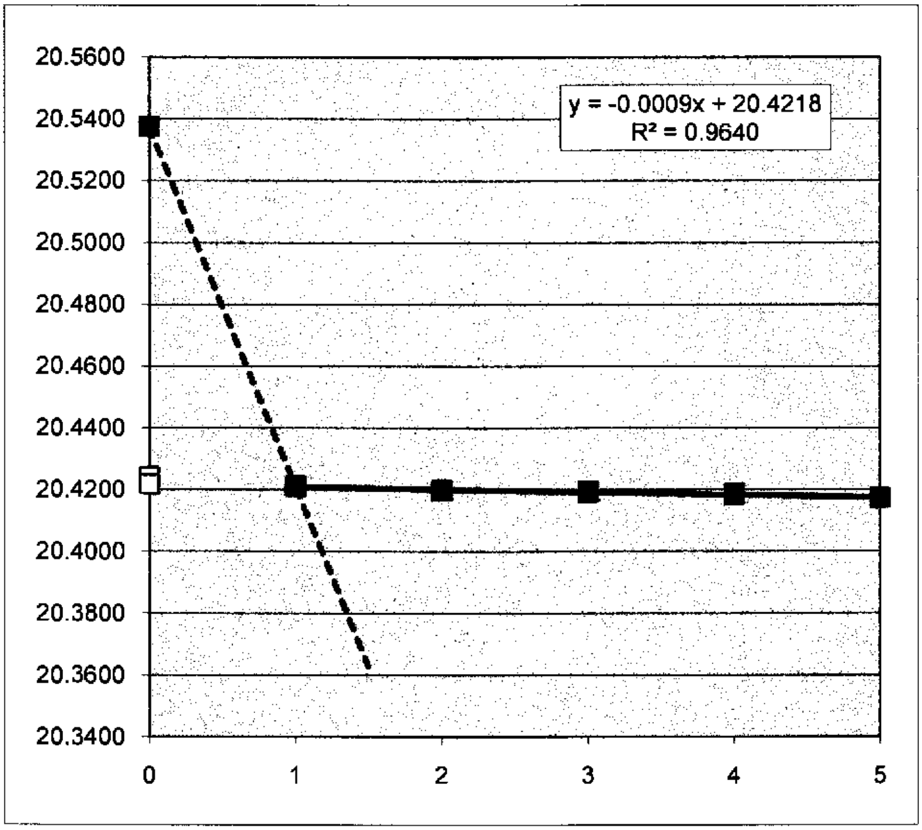
Calculated final wt (g)	20.5817
Total wt loss (g)	0.002
Total wt loss (mg)	2.0

Cleaning Cycle	Wt (g)
0	20.7283
1	20.5853
2	20.5798
3	20.5788
4	20.5776
5	20.5769



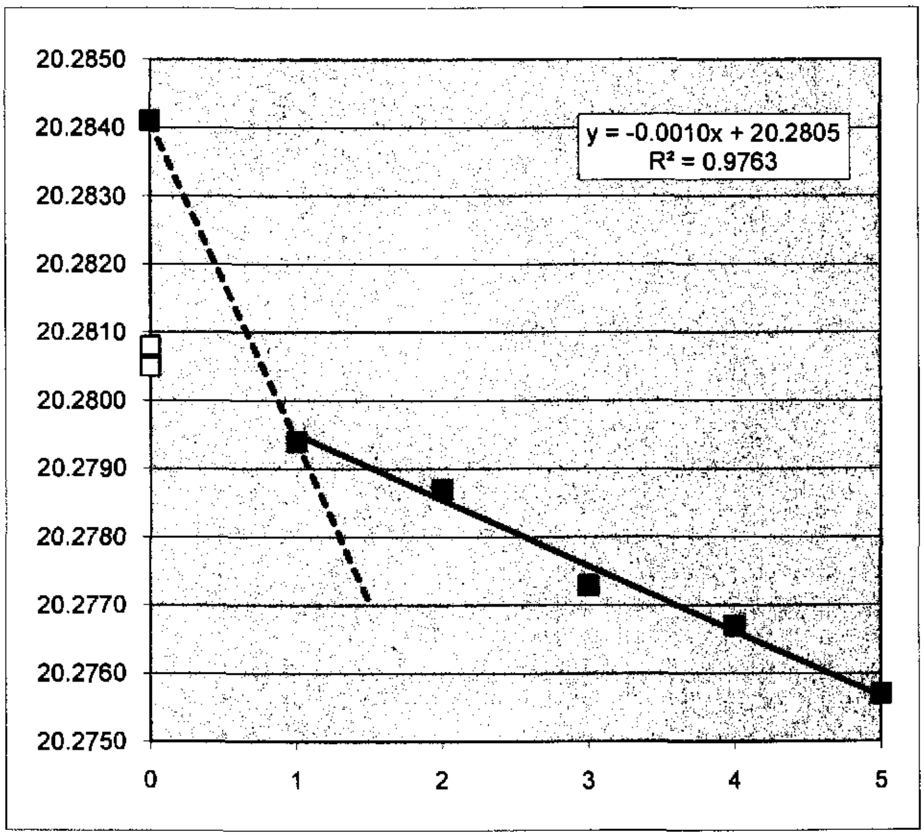
Coupon:	082		
Test matrix:	Fe-Eo-0000-12-2p		
Initial wt (g)	20.4241	**Calculated final wt (g)**	20.4218
Removal wt (g)	20.5376	**Total wt loss (g)**	0.0023
		Total wt loss (mg)	2.3

Cleaning Cycle	Wt (g)
0	20.5376
1	20.4211
2	20.4199
3	20.4193
4	20.4186
5	20.4173



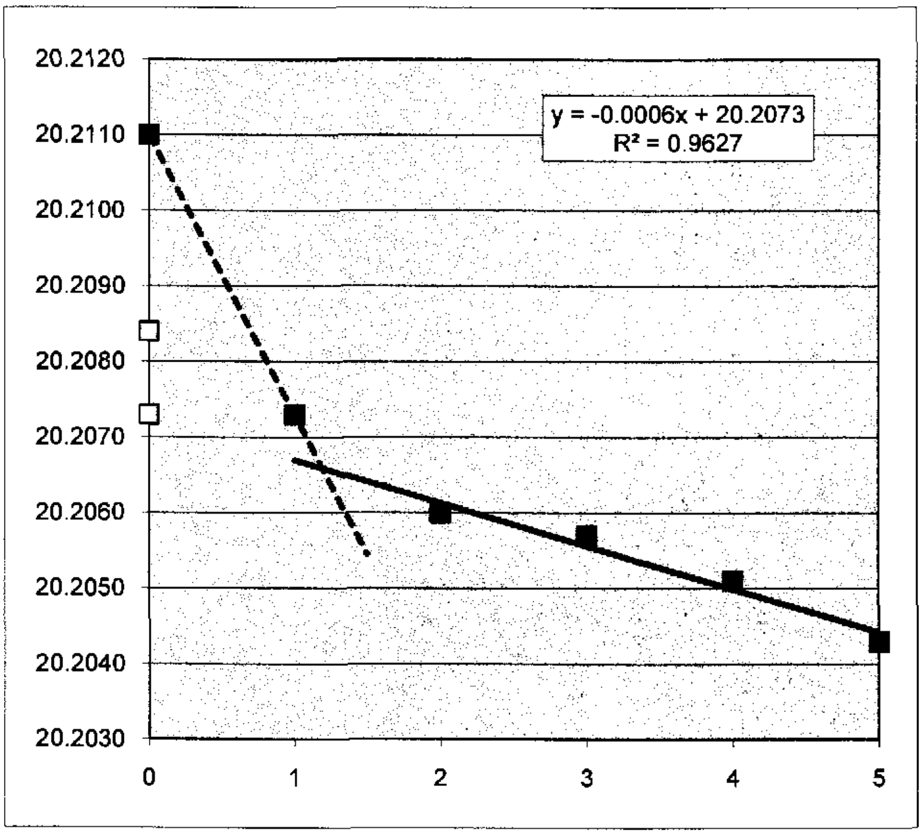
Coupon:	084		
Test matrix:	Fe-Atm-0000-12-1		
Initial wt (g)	20.2808	**Calculated final wt (g)**	20.2805
Removal wt (g)	20.2841	**Total wt loss (g)**	0.0003
		Total wt loss (mg)	0.3

Cleaning Cycle	Wt (g)
0	20.2841
1	20.2794
2	20.2787
3	20.2773
4	20.2767
5	20.2757



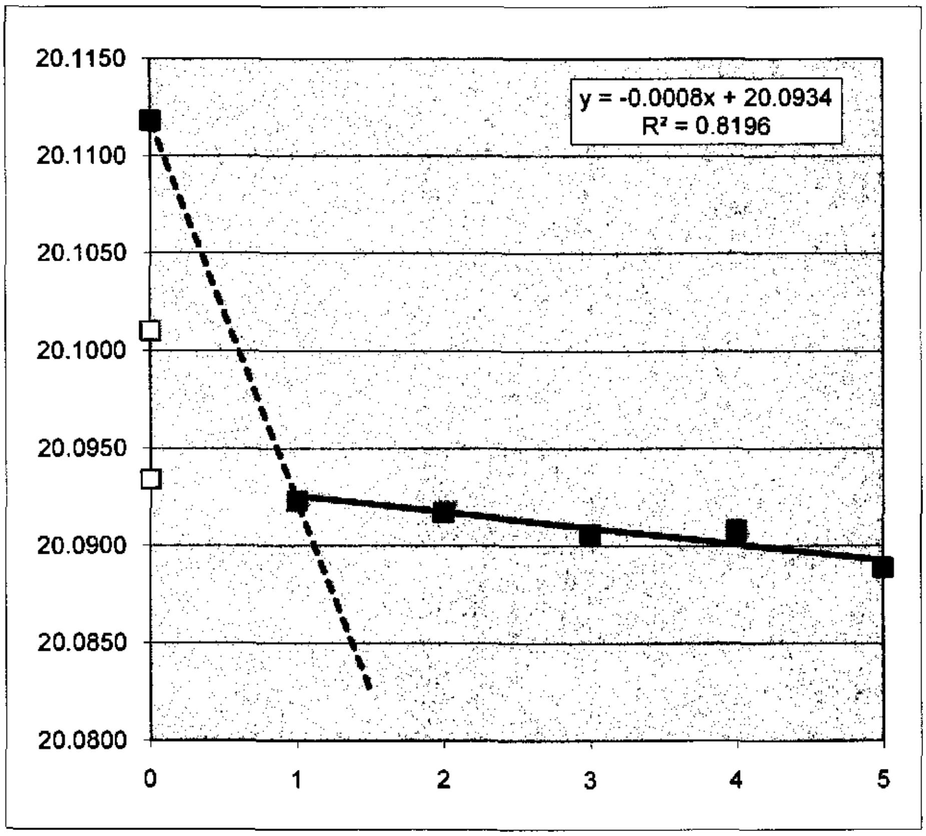
Coupon:	085		
Test matrix:	Fe-Atm-0000-12-2		
Initial wt (g)	20.2084	**Calculated final wt (g)**	20.2073
Removal wt (g)	20.2110	**Total wt loss (g)**	0.0011
		Total wt loss (mg)	1.1

Cleaning Cycle	Wt (g)
0	20.2110
1	20.2073
2	20.2060
3	20.2057
4	20.2051
5	20.2043



Coupon:	*190*			
Test matrix:	Fe-G-0350-12-2f			
Initial wt (g)	20.1010		**Calculated final wt (g)**	20.0934
Removal wt (g)	20.1118		**Total wt loss (g)**	0.0076
			Total wt loss (mg)	7.6

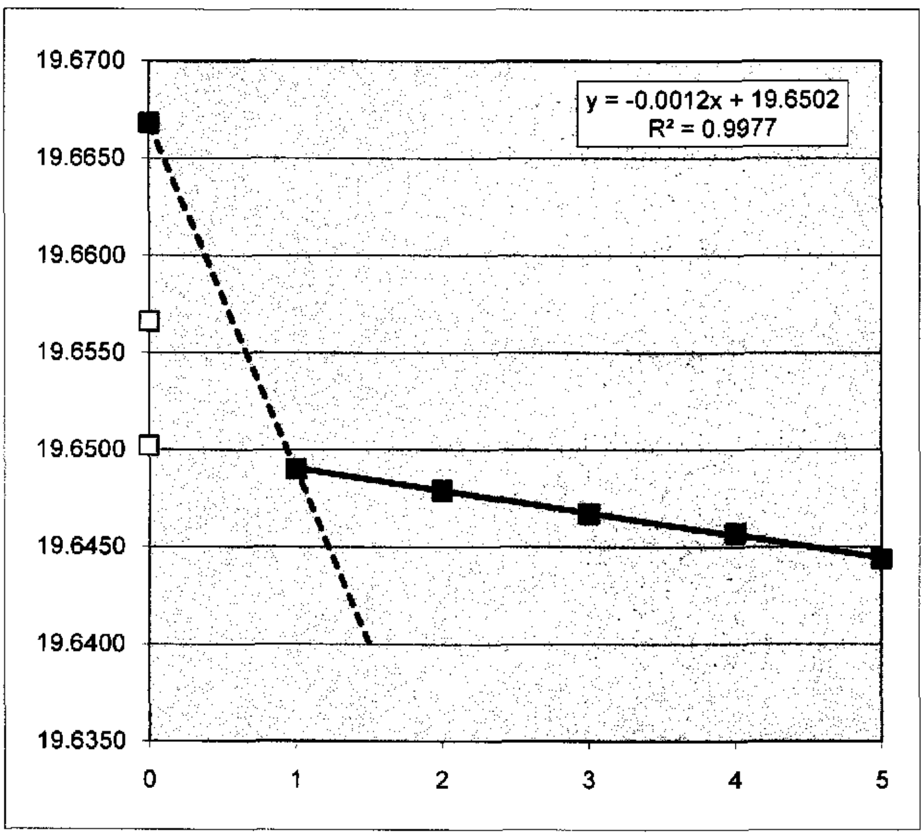
Cleaning Cycle	Wt (g)
0	20.1118
1	20.0923
2	20.0917
3	20.0906
4	20.0908
5	20.0889



Coupon:	191
Test matrix:	Fe-G-0350-12-3f
Initial wt (g)	19.6566
Removal wt (g)	19.6668

Calculated final wt (g)	19.6502
Total wt loss (g)	0.0064
Total wt loss (mg)	6.4

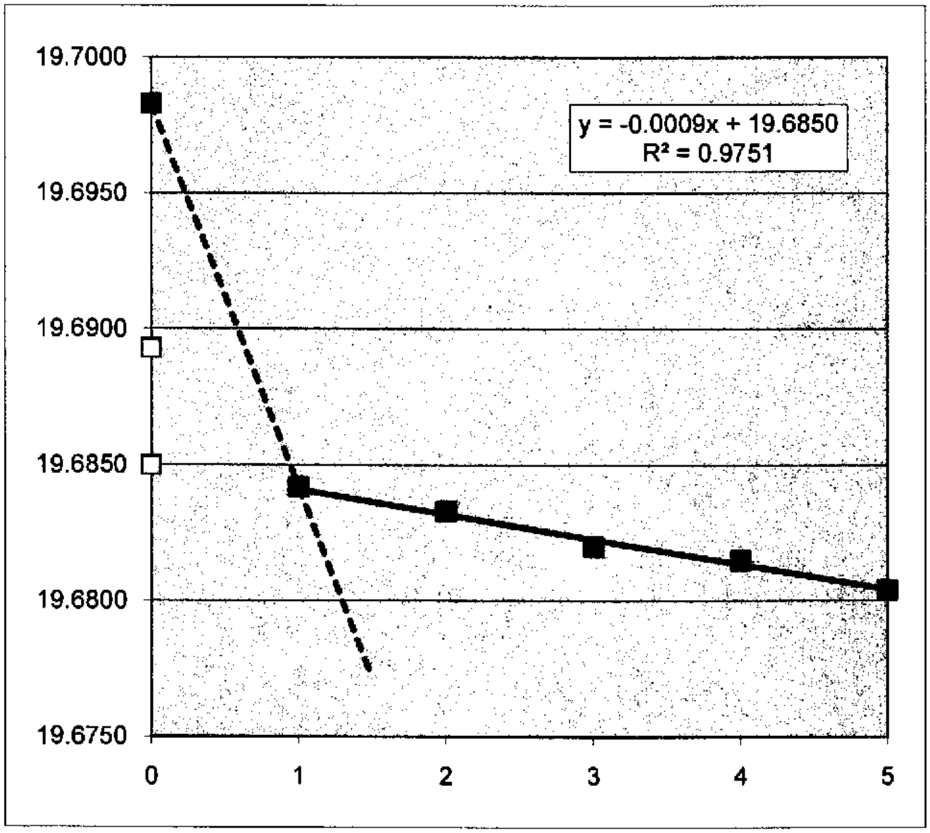
Cleaning Cycle	Wt (g)
0	19.6668
1	19.6490
2	19.6479
3	19.6467
4	19.6457
5	19.6444



Coupon:	192
Test matrix:	Fe-G-0350-12-1p
Initial wt (g)	19.6893
Removal wt (g)	19.6983

Calculated final wt (g)	19.6850
Total wt loss (g)	0.0043
Total wt loss (mg)	4.3

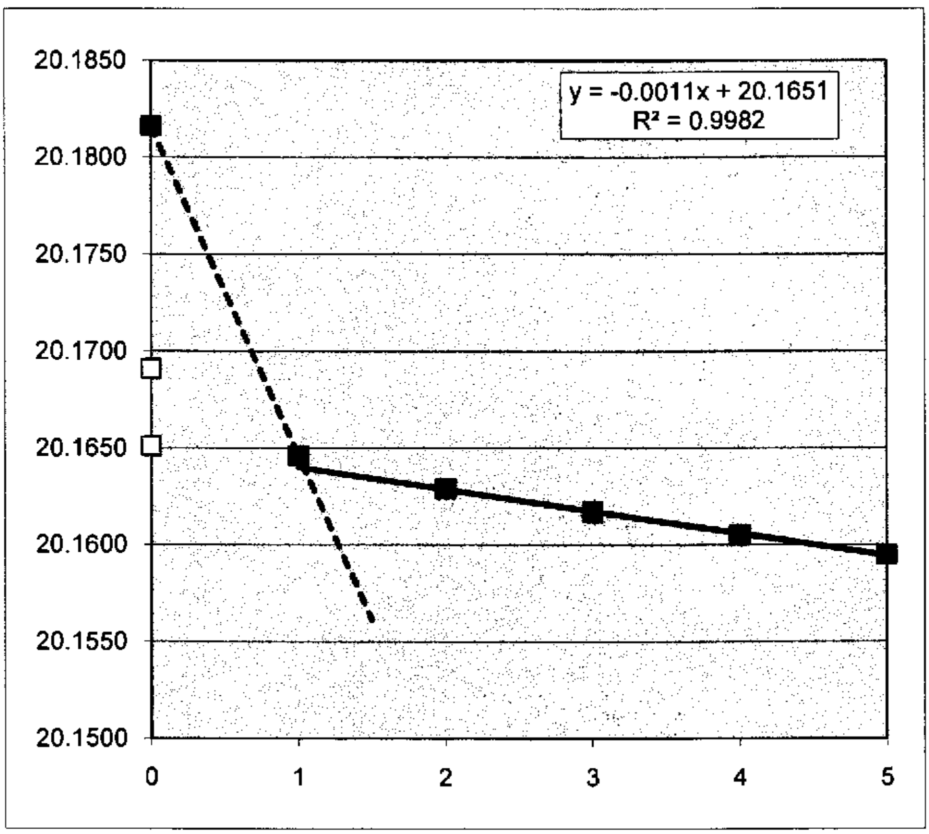
Cleaning Cycle	Wt (g)
0	19.6983
1	19.6842
2	19.6833
3	19.6820
4	19.6815
5	19.6804



Coupon:	202
Test matrix:	Fe-G-0350-12-2p
Initial wt (g)	20.1691
Removal wt (g)	20.1816

Calculated final wt (g)	20.1651
Total wt loss (g)	0.0040
Total wt loss (mg)	4.0

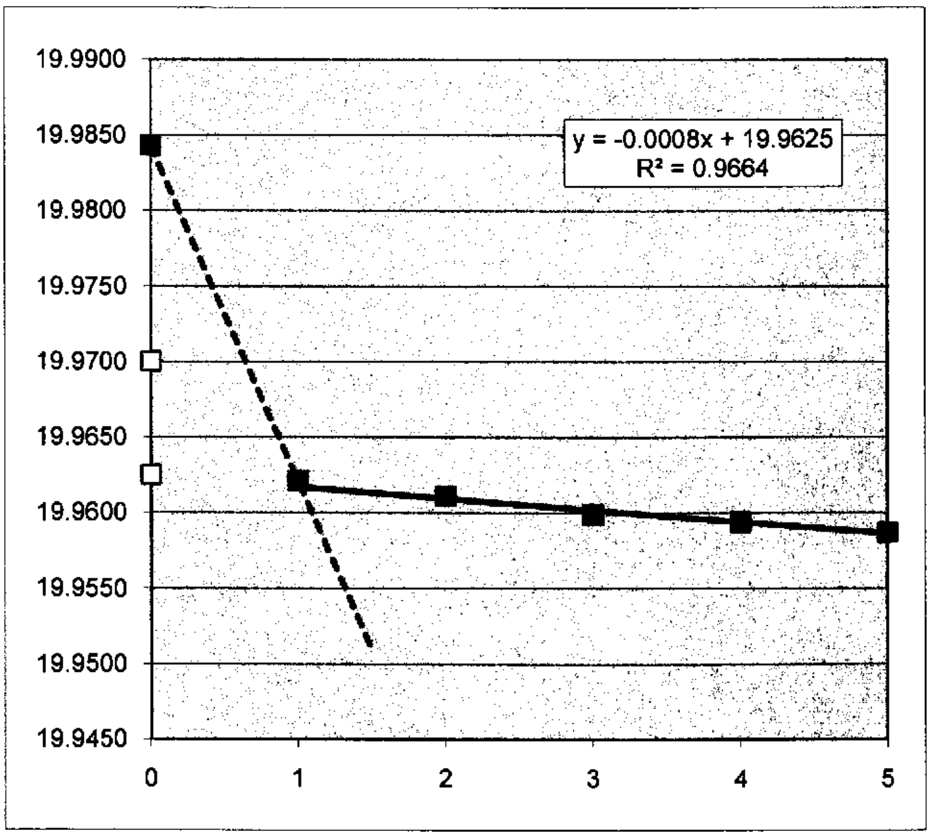
Cleaning Cycle	Wt (g)
0	20.1816
1	20.1646
2	20.1629
3	20.1617
4	20.1605
5	20.1595



Coupon:	205
Test matrix:	Fe-Go-0350-12-2f
Initial wt (g)	19.9700
Removal wt (g)	19.9843

Calculated final wt (g)	19.9625
Total wt loss (g)	0.0075
Total wt loss (mg)	7.5

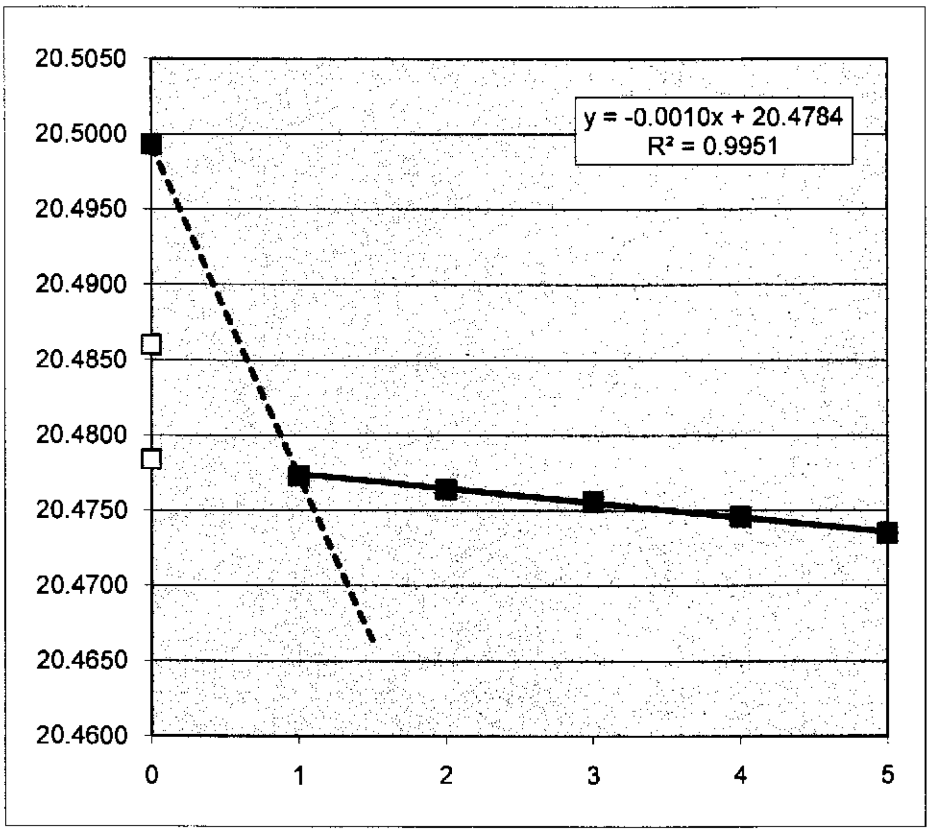
Cleaning Cycle	Wt (g)
0	19.9843
1	19.9621
2	19.9611
3	19.9599
4	19.9594
5	19.9587



Coupon:	206
Test matrix:	Fe-Go-0350-12-3f
Initial wt (g)	20.4860
Removal wt (g)	20.4993

Calculated final wt (g)	20.4784
Total wt loss (g)	0.0076
Total wt loss (mg)	7.6

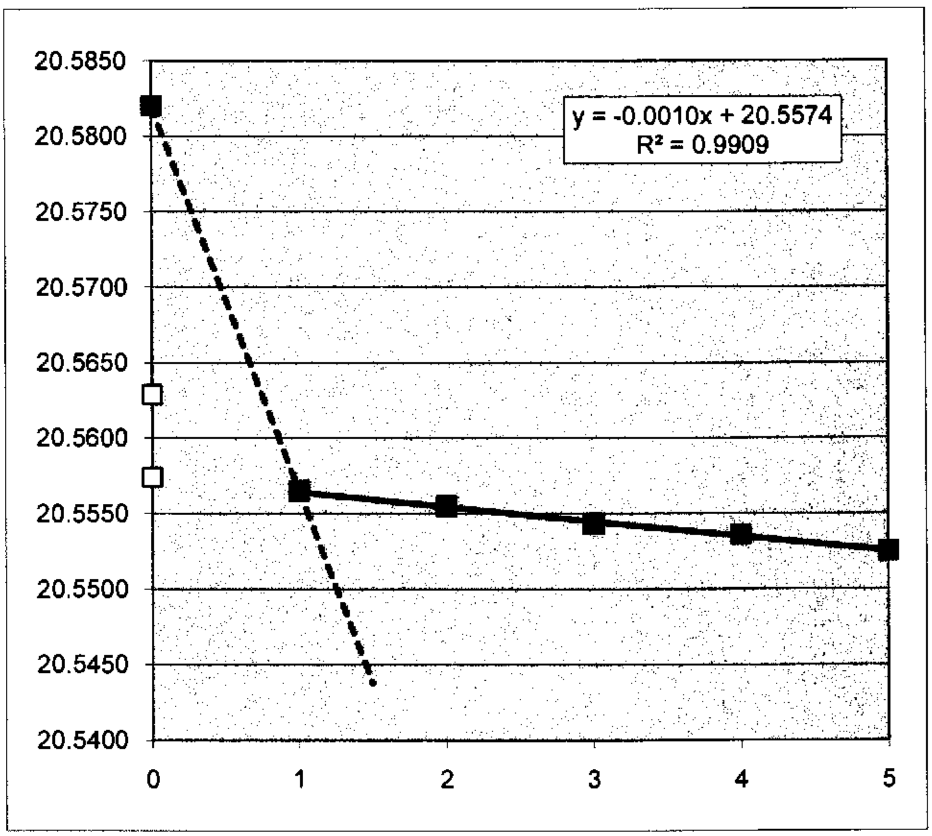
Cleaning Cycle	Wt (g)
0	20.4993
1	20.4773
2	20.4764
3	20.4756
4	20.4746
5	20.4735



Coupon:	207
Test matrix:	Fe-Go-0350-12-1p
Initial wt (g)	20.5629
Removal wt (g)	20.5820

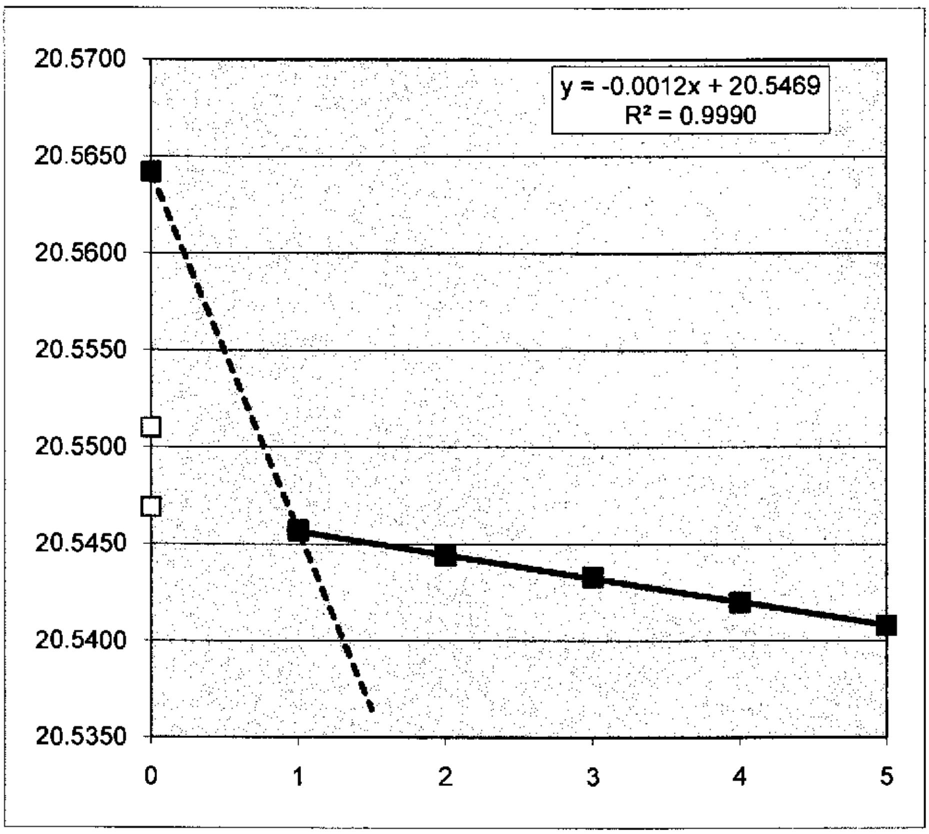
Calculated final wt (g)	20.5574
Total wt loss (g)	0.0055
Total wt loss (mg)	5.5

Cleaning Cycle	Wt (g)
0	20.5820
1	20.5565
2	20.5555
3	20.5543
4	20.5536
5	20.5525



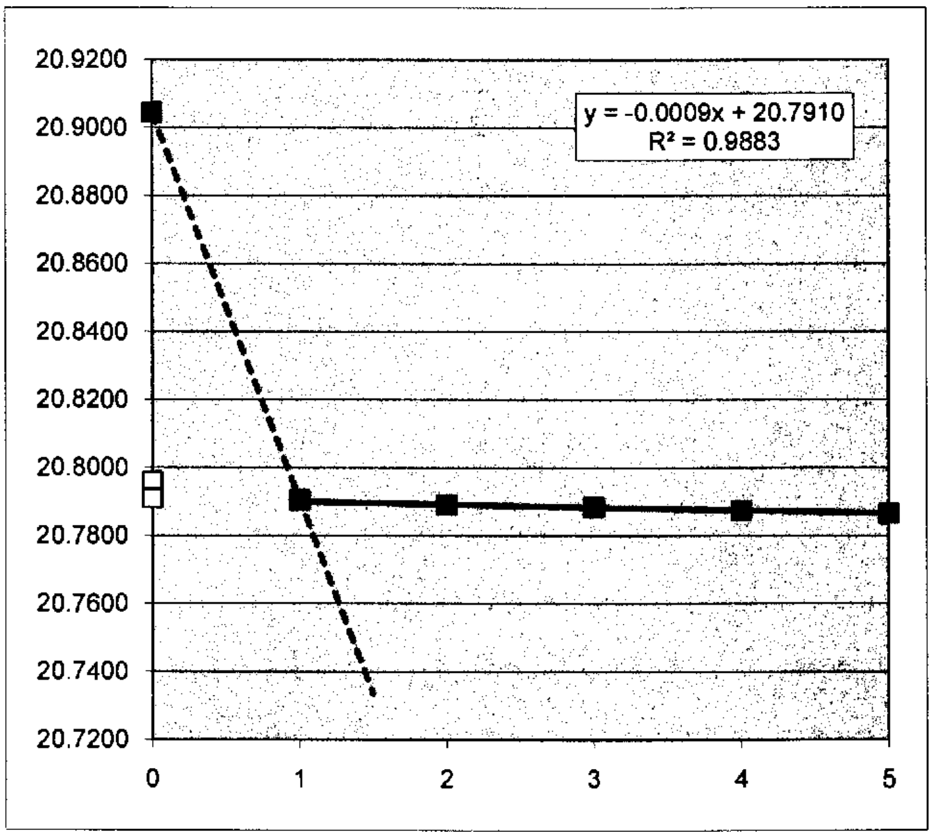
Coupon:	208		
Test matrix:	Fe-Go-0350-12-2p		
Initial wt (g)	20.5510	**Calculated final wt (g)**	20.5469
Removal wt (g)	20.5642	**Total wt loss (g)**	0.0041
		Total wt loss (mg)	4.1

Cleaning Cycle	Wt (g)
0	20.5642
1	20.5457
2	20.5444
3	20.5433
4	20.5420
5	20.5408



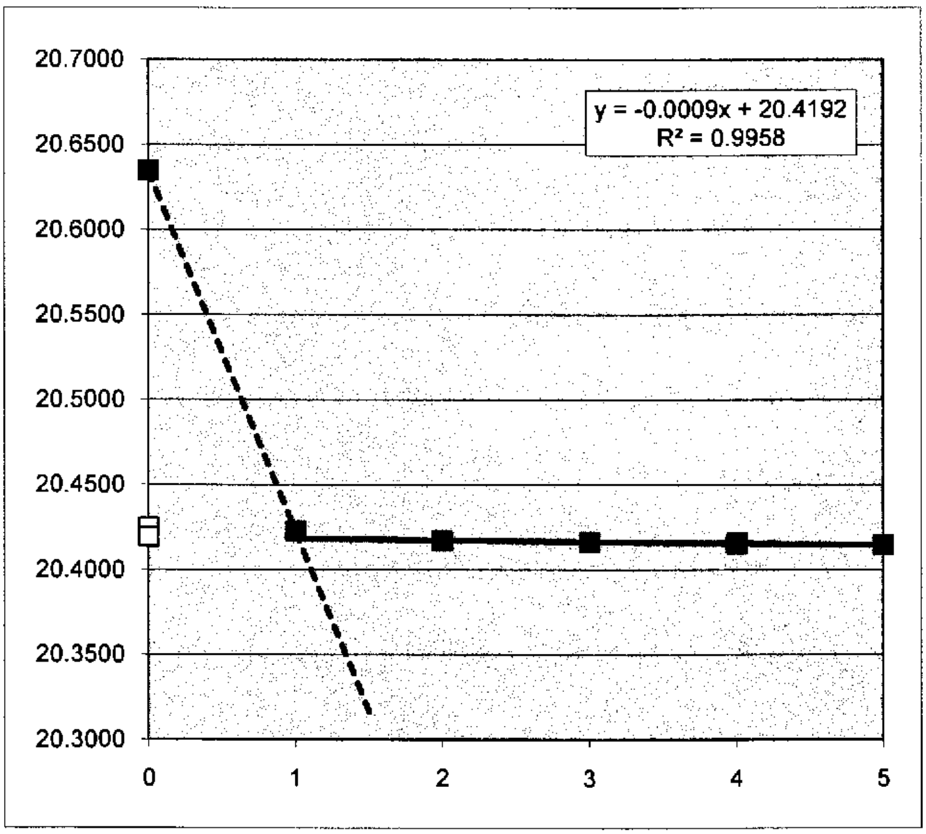
Coupon:	210			
Test matrix:	Fe-E-0350-12-1f			
Initial wt (g)	20.7959		**Calculated final wt (g)**	20.7910
Removal wt (g)	20.9045		**Total wt loss (g)**	0.0049
			Total wt loss (mg)	4.9

Cleaning Cycle	Wt (g)
0	20.9045
1	20.7905
2	20.7891
3	20.7885
4	20.7874
5	20.7865



Coupon:	212		
Test matrix:	Fe-E-0350-12-3f		
Initial wt (g)	20.4249	**Calculated final wt (g)**	20.4192
Removal wt (g)	20.6347	**Total wt loss (g)**	0.0057
		Total wt loss (mg)	5.7

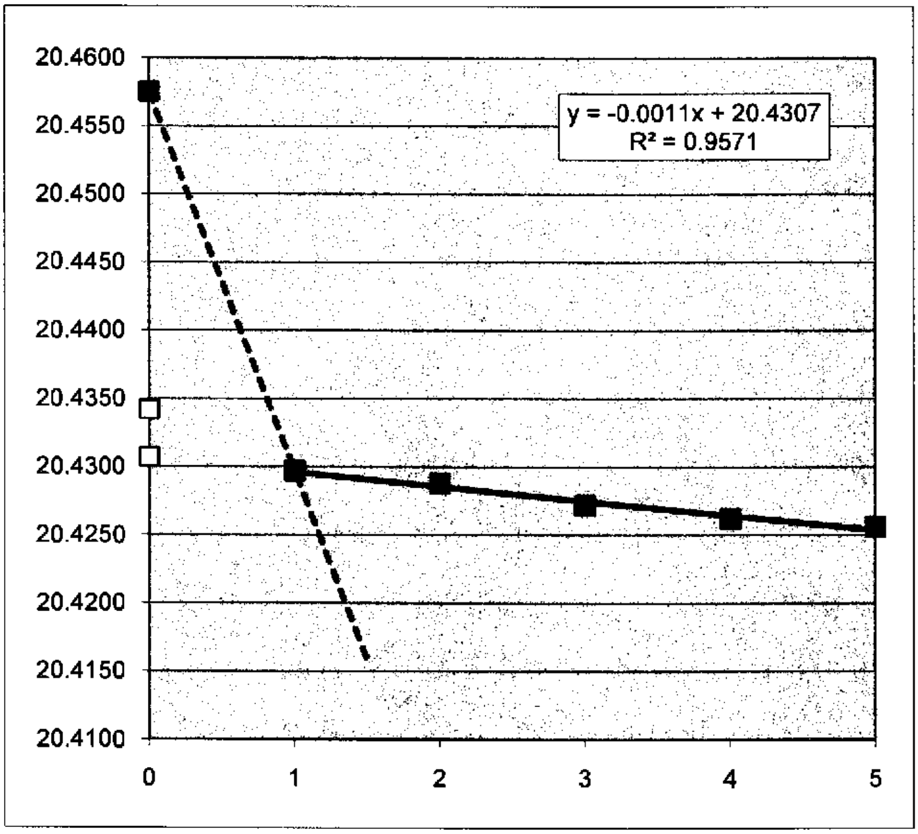
Cleaning Cycle	Wt (g)
0	20.6347
1	20.4228
2	20.4173
3	20.4164
4	20.4156
5	20.4145



Coupon:	213
Test matrix:	Fe-E-0350-12-1p
Initial wt (g)	20.4342
Removal wt (g)	20.4575

Calculated final wt (g)	20.4307
Total wt loss (g)	0.0035
Total wt loss (mg)	3.5

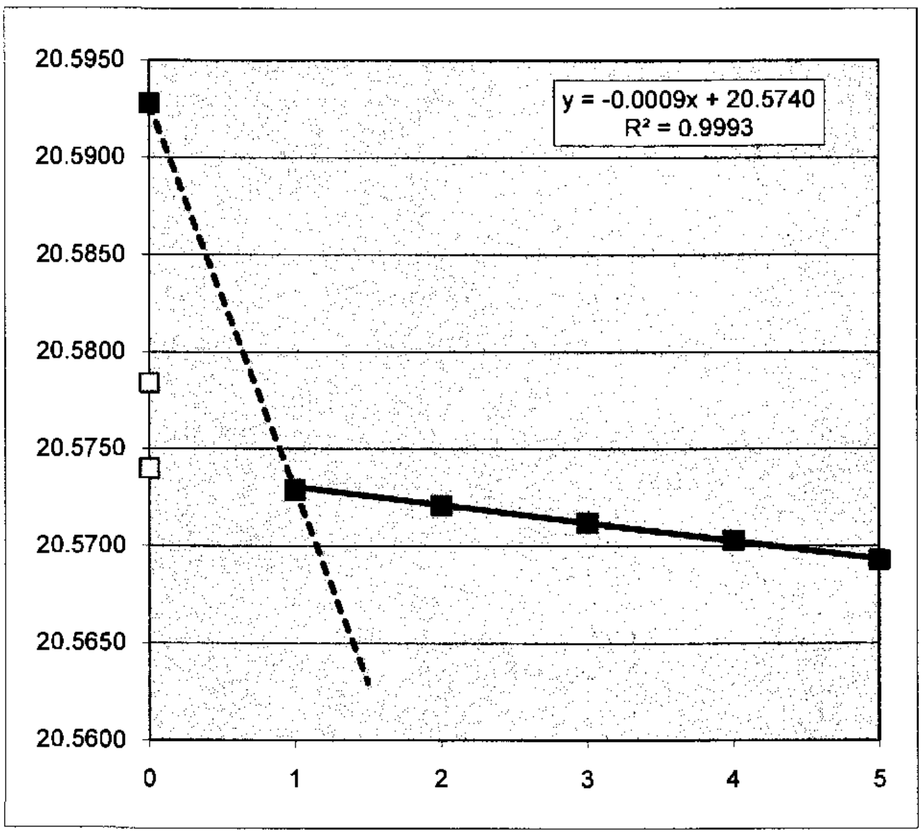
Cleaning Cycle	Wt (g)
0	20.4575
1	20.4297
2	20.4288
3	20.4272
4	20.4262
5	20.4256



Coupon:	214
Test matrix:	Fe-E-0350-12-2p
Initial wt (g)	20.5784
Removal wt (g)	20.5928

Calculated final wt (g)	20.5740
Total wt loss (g)	0.0044
Total wt loss (mg)	4.4

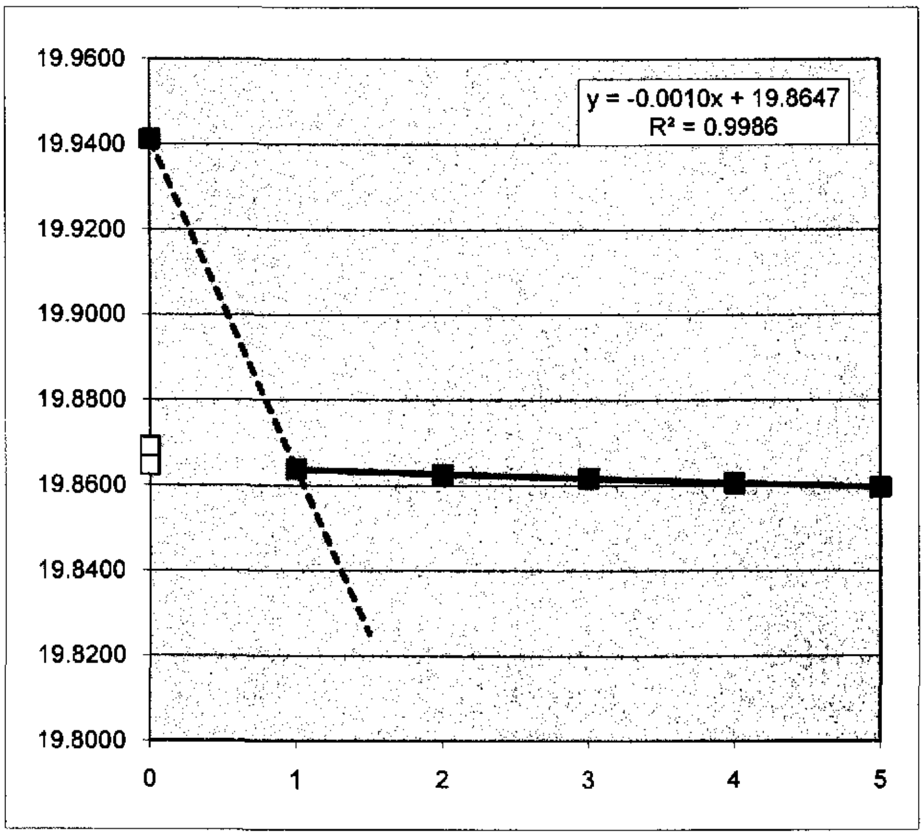
Cleaning Cycle	Wt (g)
0	20.5928
1	20.5729
2	20.5721
3	20.5712
4	20.5703
5	20.5693



Coupon:	217
Test matrix:	Fe-Eo-0350-12-2f
Initial wt (g)	19.8691
Removal wt (g)	19.9412

Calculated final wt (g)	19.8647
Total wt loss (g)	0.0044
Total wt loss (mg)	4.4

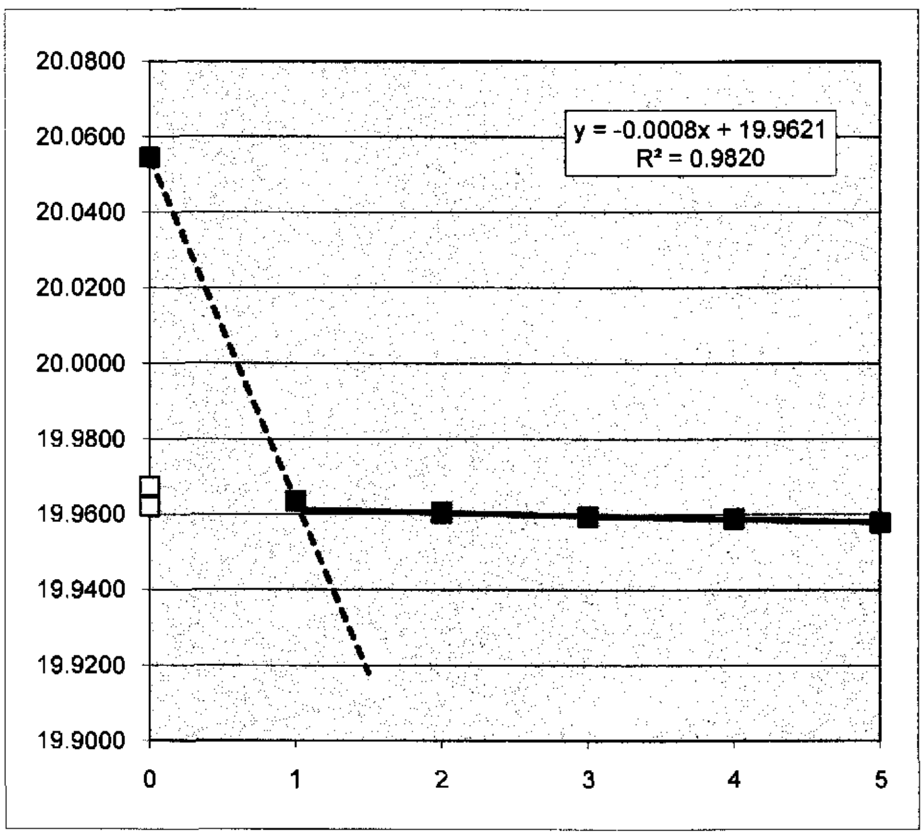
Cleaning Cycle	Wt (g)
0	19.9412
1	19.8638
2	19.8626
3	19.8617
4	19.8606
5	19.8596



Coupon:	218
Test matrix:	Fe-Eo-0350-12-3f
Initial wt (g)	19.9675
Removal wt (g)	20.0546

Calculated final wt (g)	19.9621
Total wt loss (g)	0.0054
Total wt loss (mg)	5.4

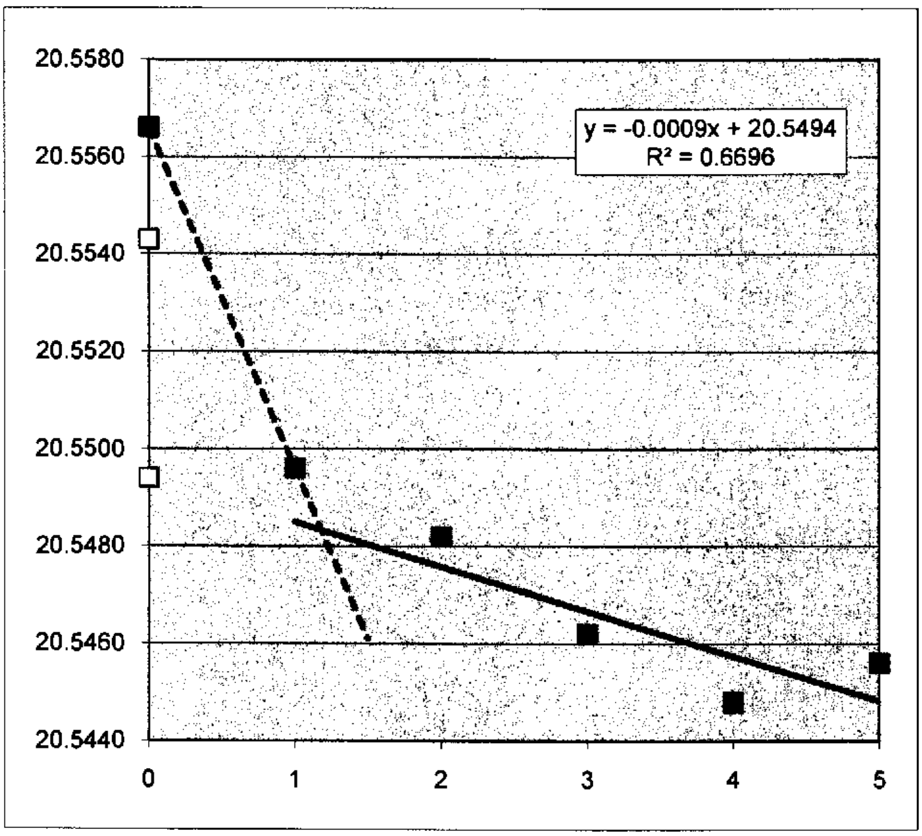
Cleaning Cycle	Wt (g)
0	20.0546
1	19.9635
2	19.9605
3	19.9594
4	19.9589
5	19.9579



Coupon:	220
Test matrix:	Fe-Eo-0350-12-2p
Initial wt (g)	20.5543
Removal wt (g)	20.5566

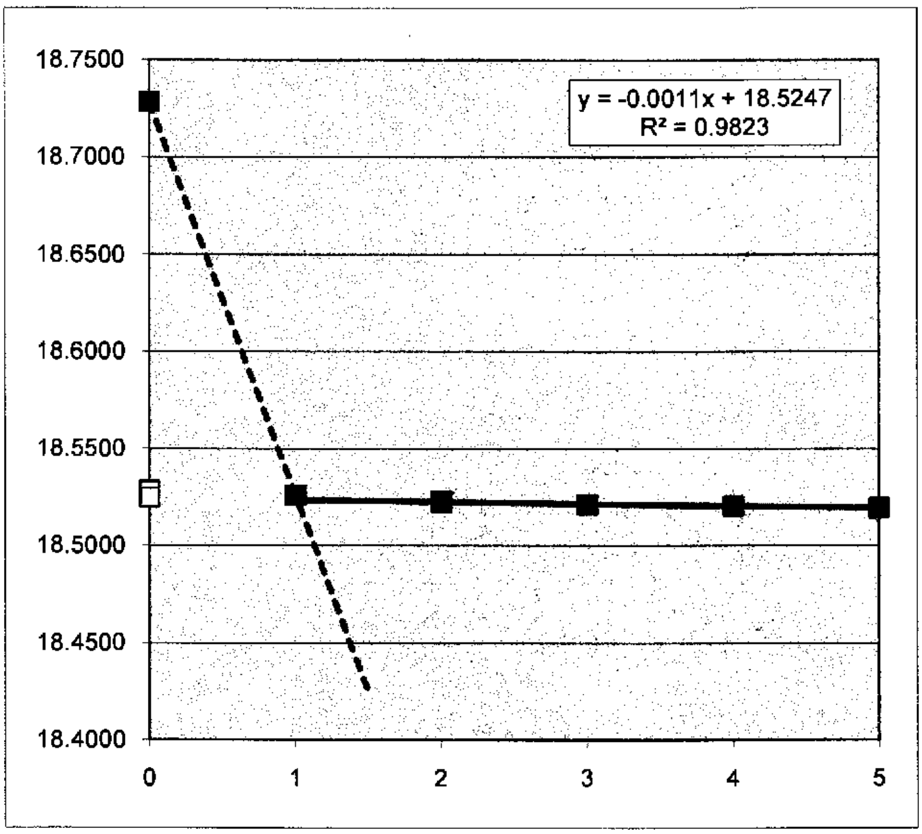
Calculated final wt (g)	20.5494
Total wt loss (g)	0.0049
Total wt loss (mg)	4.9

Cleaning Cycle	Wt (g)
0	20.5566
1	20.5496
2	20.5482
3	20.5462
4	20.5448
5	20.5456



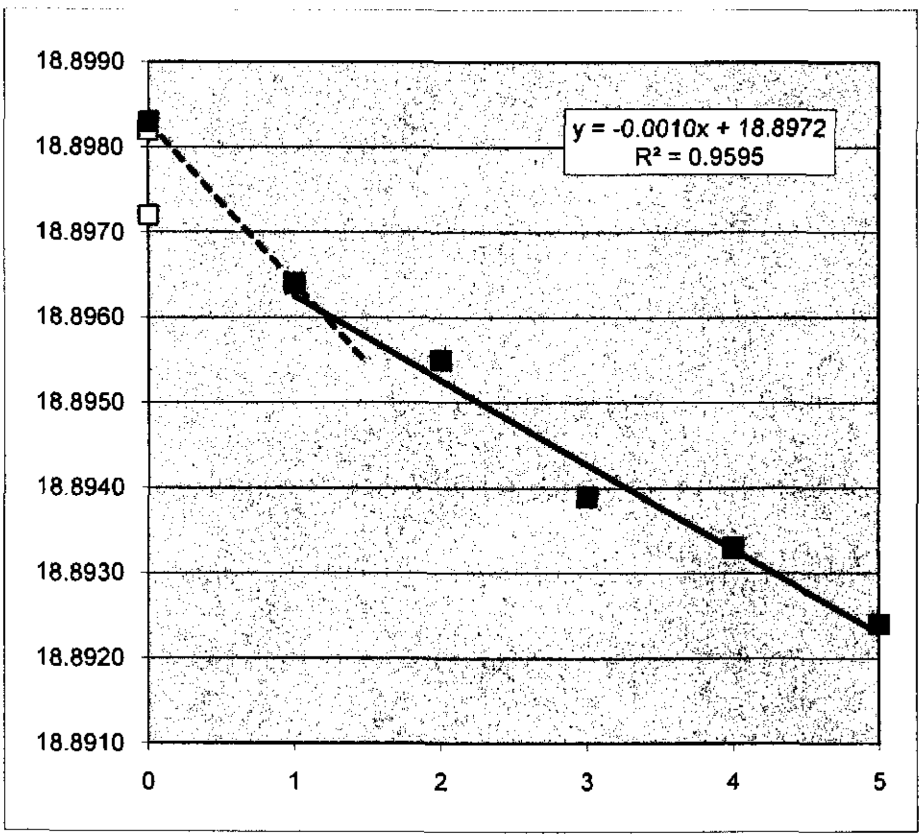
Coupon:	221		
Test matrix:	Fe-Eo-0350-12-3p		
Initial wt (g)	18.5283	**Calculated final wt (g)**	18.5247
Removal wt (g)	18.7283	**Total wt loss (g)**	0.0036
		Total wt loss (mg)	3.6

Cleaning Cycle	**Wt (g)**
0	18.7283
1	18.5259
2	18.5227
3	18.5212
4	18.5204
5	18.5194



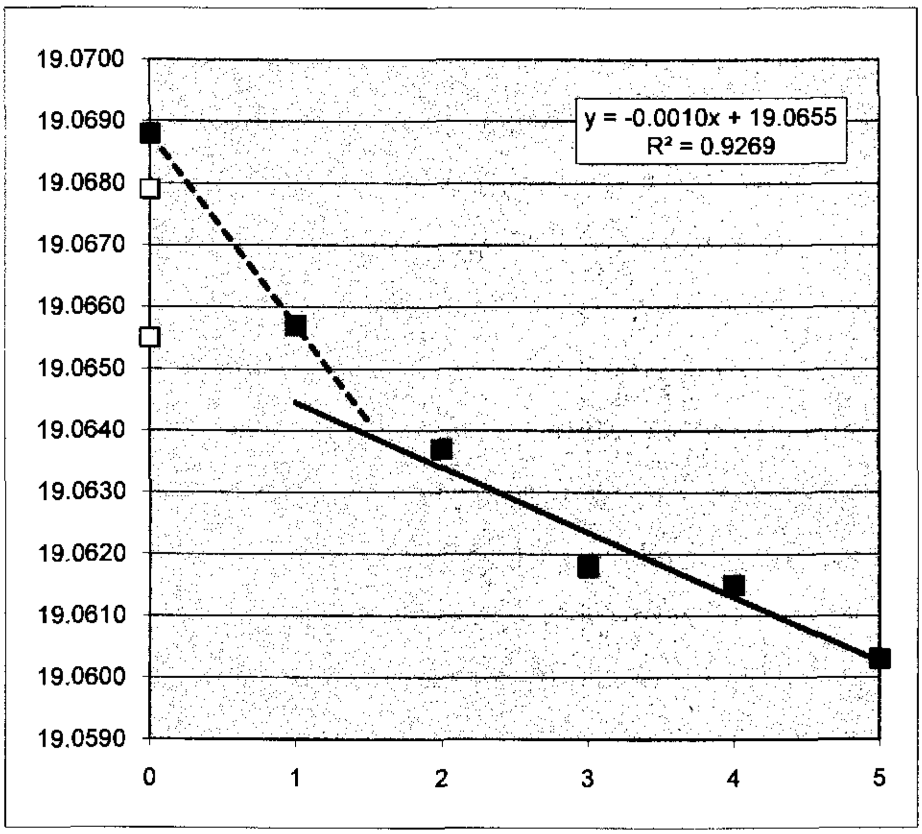
Coupon:	222		
Test matrix:	Fe-Atm-0350-12-1		
Initial wt (g)	18.8982	**Calculated final wt (g)**	18.8972
Removal wt (g)	18.8983	**Total wt loss (g)**	0.0010
		Total wt loss (mg)	1.0

Cleaning Cycle	**Wt (g)**
0	18.8983
1	18.8964
2	18.8955
3	18.8939
4	18.8933
5	18.8924



Coupon:	223		
Test matrix:	Fe-Atm-0350-12-2		
Initial wt (g)	19.0679	**Calculated final wt (g)**	19.0655
Removal wt (g)	19.0688	**Total wt loss (g)**	0.0024
		Total wt loss (mg)	2.4

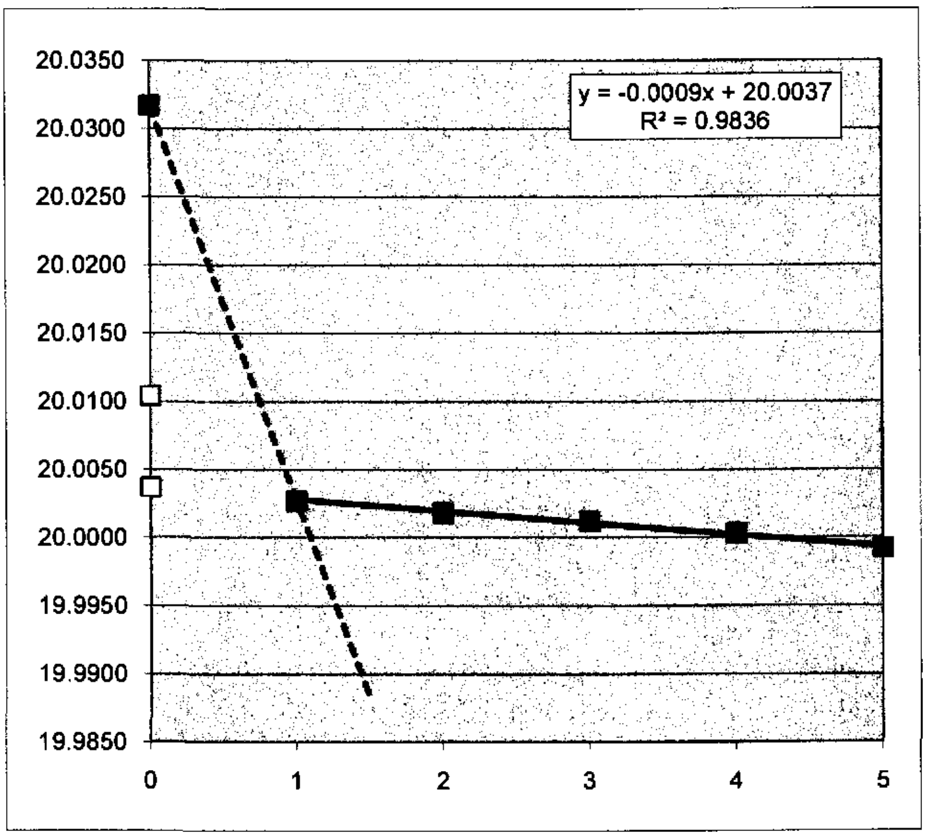
Cleaning Cycle	Wt (g)
0	19.0688
1	19.0657
2	19.0637
3	19.0618
4	19.0615
5	19.0603



Coupon:	280
Test matrix:	Fe-G-1500-12-2f
Initial wt (g)	20.0104
Removal wt (g)	20.0317

Calculated final wt (g)	20.0037
Total wt loss (g)	0.0067
Total wt loss (mg)	6.7

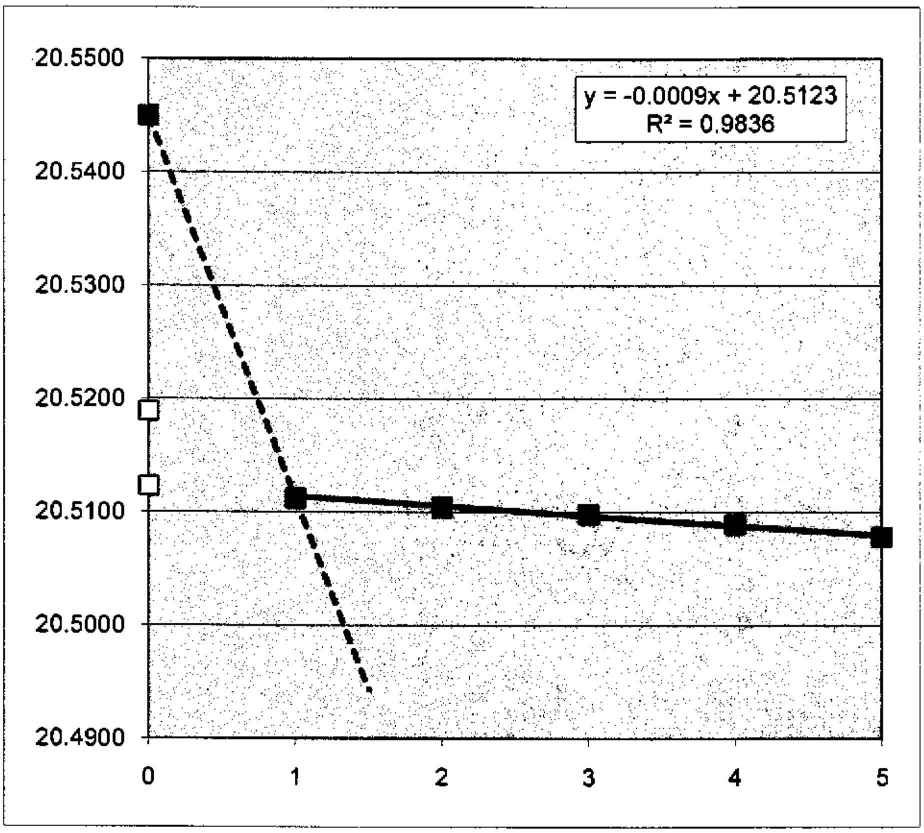
Cleaning Cycle	Wt (g)
0	20.0317
1	20.0027
2	20.0018
3	20.0012
4	20.0003
5	19.9992



Coupon: 281
Test matrix: Fe-G-1500-12-3f
Initial wt (g) 20.5189
Removal wt (g) 20.5450

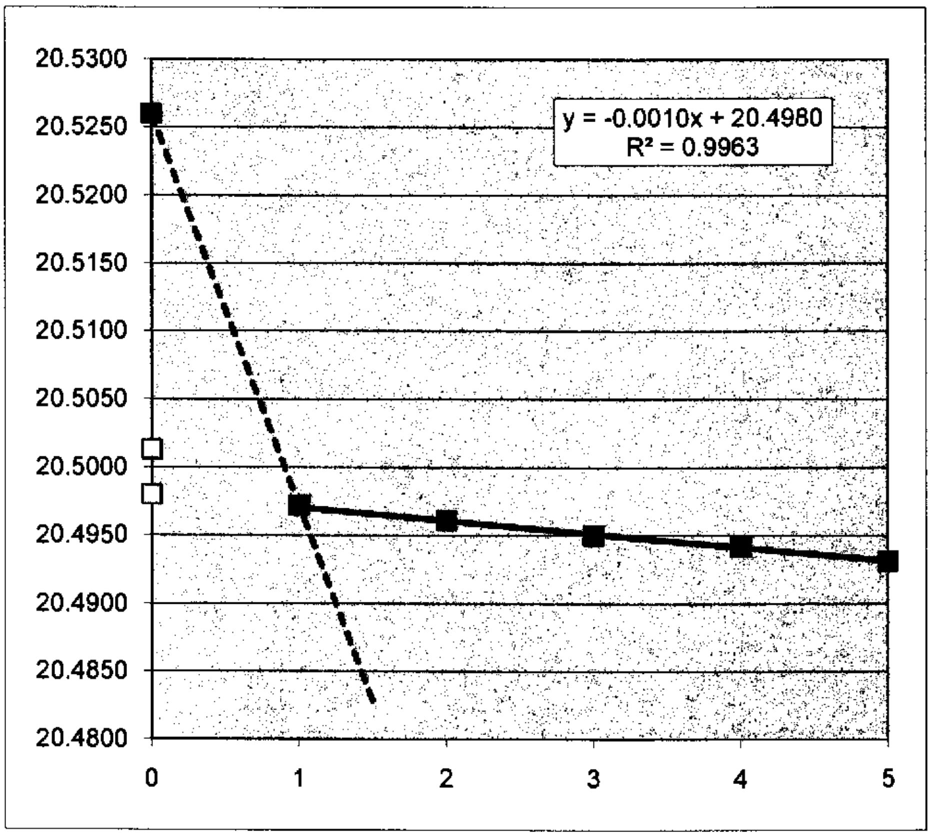
Calculated final wt (g) 20.5123
Total wt loss (g) 0.0066
Total wt loss (mg) 6.6

Cleaning Cycle	Wt (g)
0	20.5450
1	20.5112
2	20.5104
3	20.5098
4	20.5089
5	20.5078



Coupon:	283		
Test matrix:	Fe-G-1500-12-2p		
Initial wt (g)	20.5013	**Calculated final wt (g)**	20.4980
Removal wt (g)	20.5260	**Total wt loss (g)**	0.0033
		Total wt loss (mg)	3.3

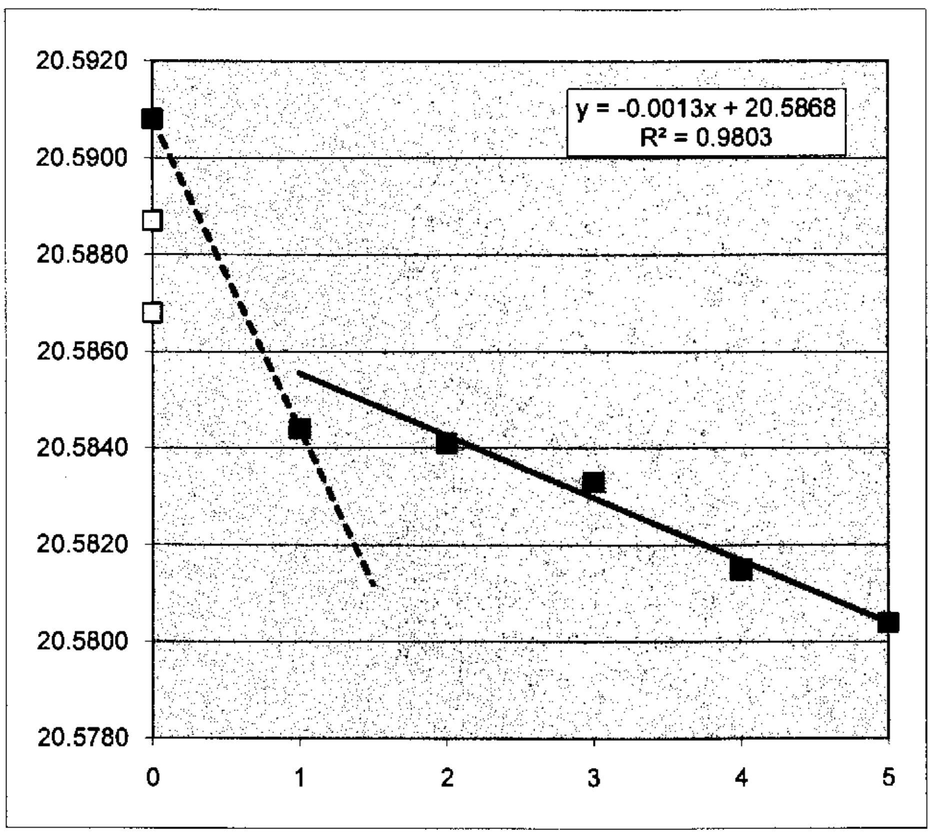
Cleaning Cycle	Wt (g)
0	20.5260
1	20.4972
2	20.4961
3	20.4950
4	20.4942
5	20.4931



Coupon:	284
Test matrix:	Fe-G-1500-12-3p
Initial wt (g)	20.5887
Removal wt (g)	20.5908

Calculated final wt (g)	20.5868
Total wt loss (g)	0.0019
Total wt loss (mg)	1.9

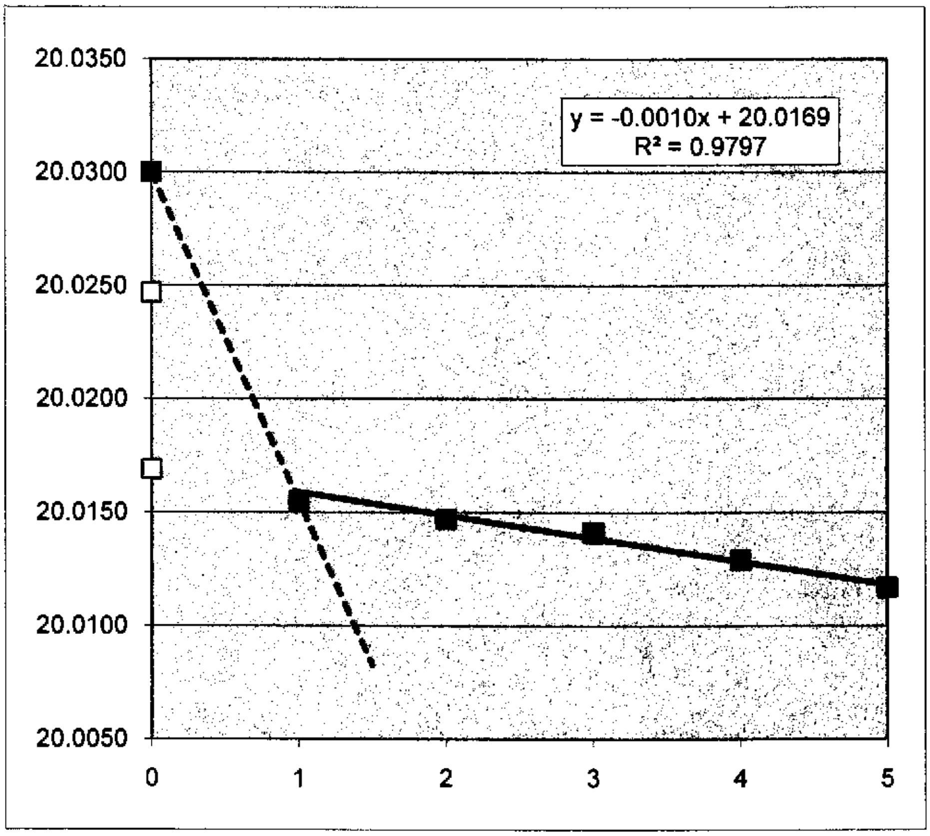
Cleaning Cycle	Wt (g)
0	20.5908
1	20.5844
2	20.5841
3	20.5833
4	20.5815
5	20.5804



Coupon:	286
Test matrix:	Fe-Go-1500-12-2f
Initial wt (g)	20.0247
Removal wt (g)	20.0300

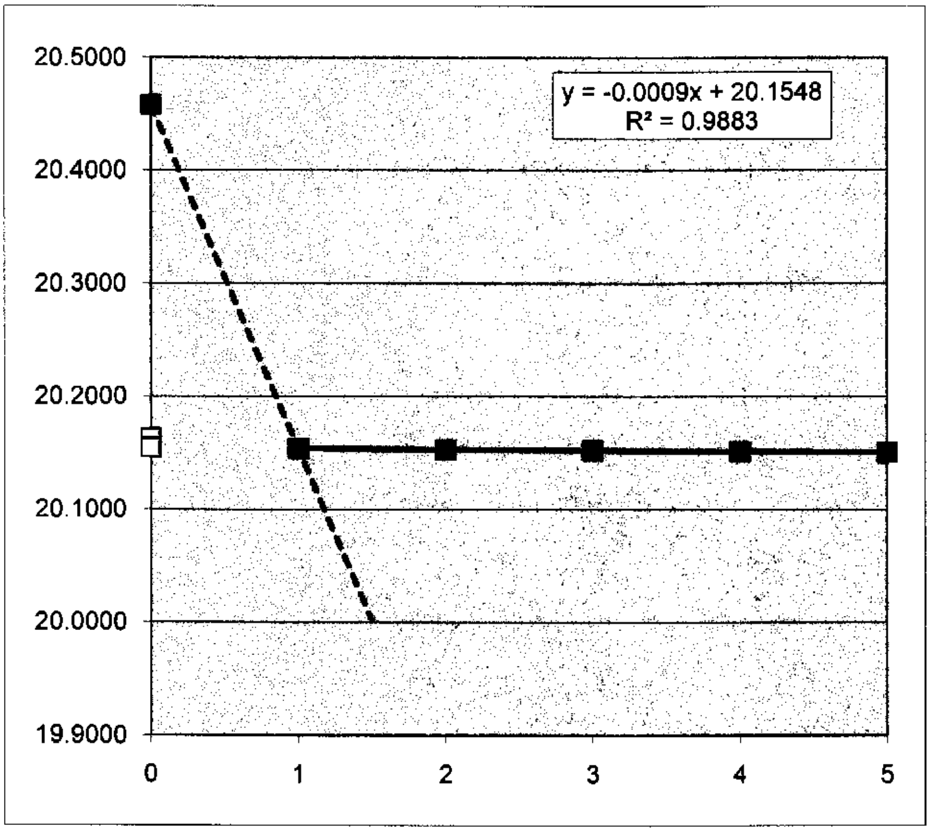
Calculated final wt (g)	20.0169
Total wt loss (g)	0.0078
Total wt loss (mg)	7.8

Cleaning Cycle	Wt (g)
0	20.0300
1	20.0155
2	20.0147
3	20.0141
4	20.0129
5	20.0117



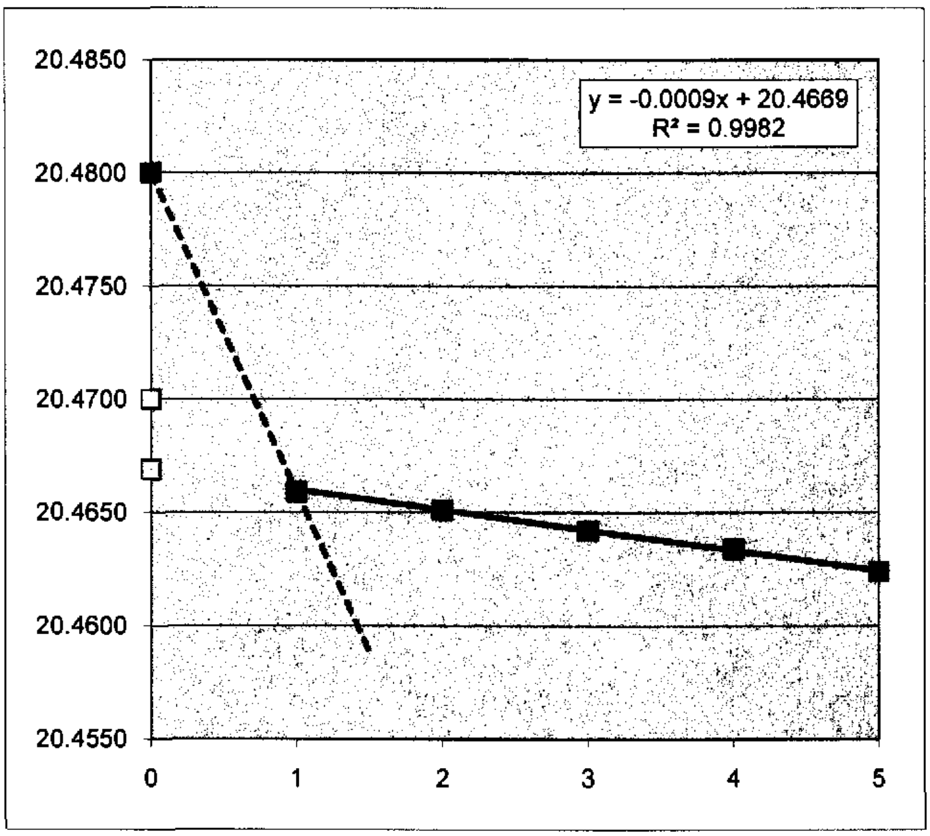
Coupon:	287		
Test matrix:	Fe-Go-1500-12-3f		
Initial wt (g)	20.1628	**Calculated final wt (g)**	20.1548
Removal wt (g)	20.4585	**Total wt loss (g)**	0.0080
		Total wt loss (mg)	8.0

Cleaning Cycle	Wt (g)
0	20.4585
1	20.1537
2	20.1529
3	20.1523
4	20.1512
5	20.1503



Coupon:	289		
Test matrix:	Fe-Go-1500-12-2p		
Initial wt (g)	20.4700	**Calculated final wt (g)**	20.4669
Removal wt (g)	20.4800	**Total wt loss (g)**	0.0031
		Total wt loss (mg)	3.1

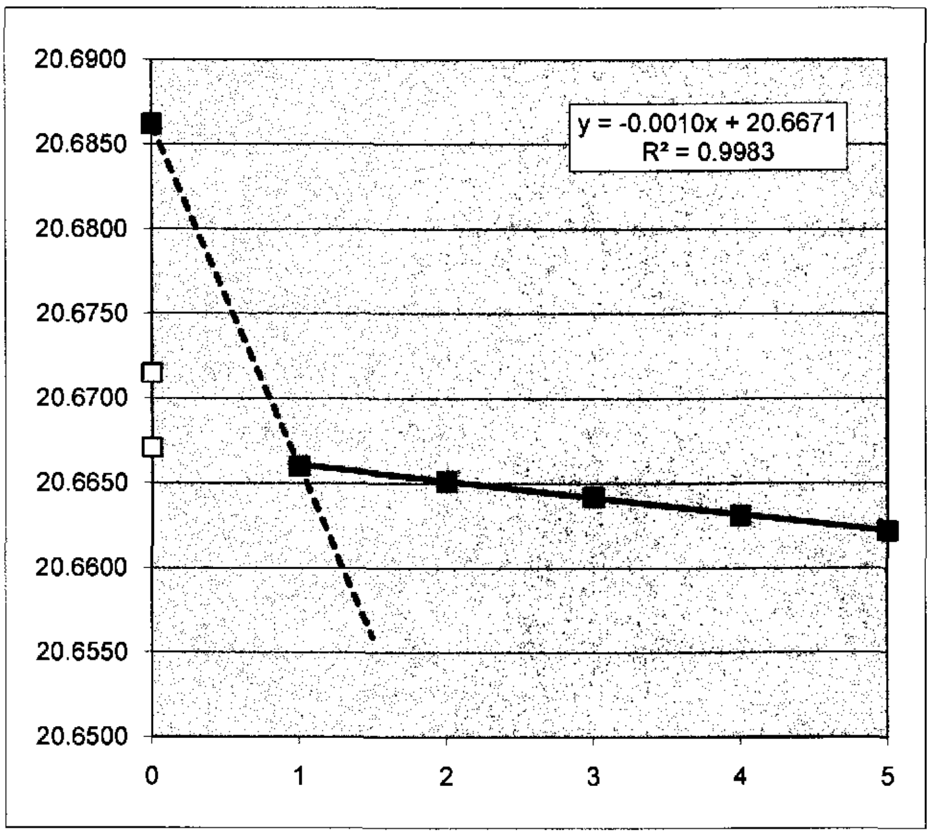
Cleaning Cycle	Wt (g)
0	20.4800
1	20.4659
2	20.4651
3	20.4642
4	20.4634
5	20.4624



Coupon:	290
Test matrix:	Fe-Go-1500-12-3p
Initial wt (g)	20.6715
Removal wt (g)	20.6862

Calculated final wt (g)	20.6671
Total wt loss (g)	0.0044
Total wt loss (mg)	4.4

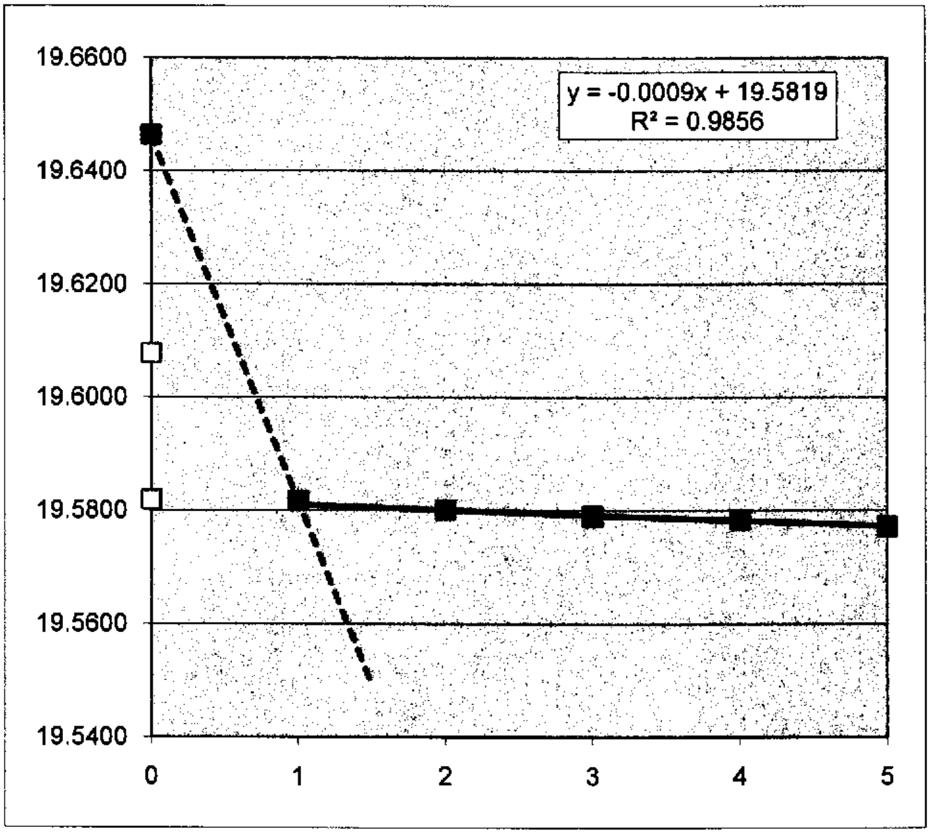
Cleaning Cycle	Wt (g)
0	20.6862
1	20.6660
2	20.6651
3	20.6642
4	20.6631
5	20.6622



Coupon:	292
Test matrix:	Fe-E-1500-12-2f
Initial wt (g)	19.6078
Removal wt (g)	19.6463

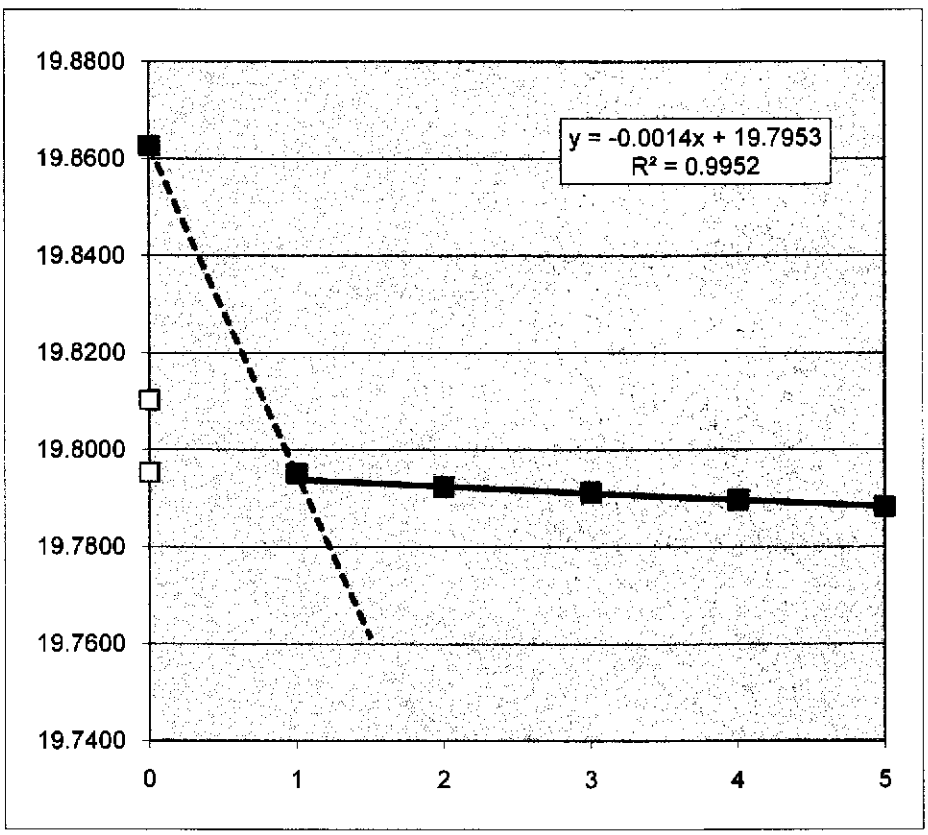
Calculated final wt (g)	19.5819
Total wt loss (g)	0.0259
Total wt loss (mg)	25.9

Cleaning Cycle	Wt (g)
0	19.6463
1	19.5817
2	19.5801
3	19.5790
4	19.5784
5	19.5772



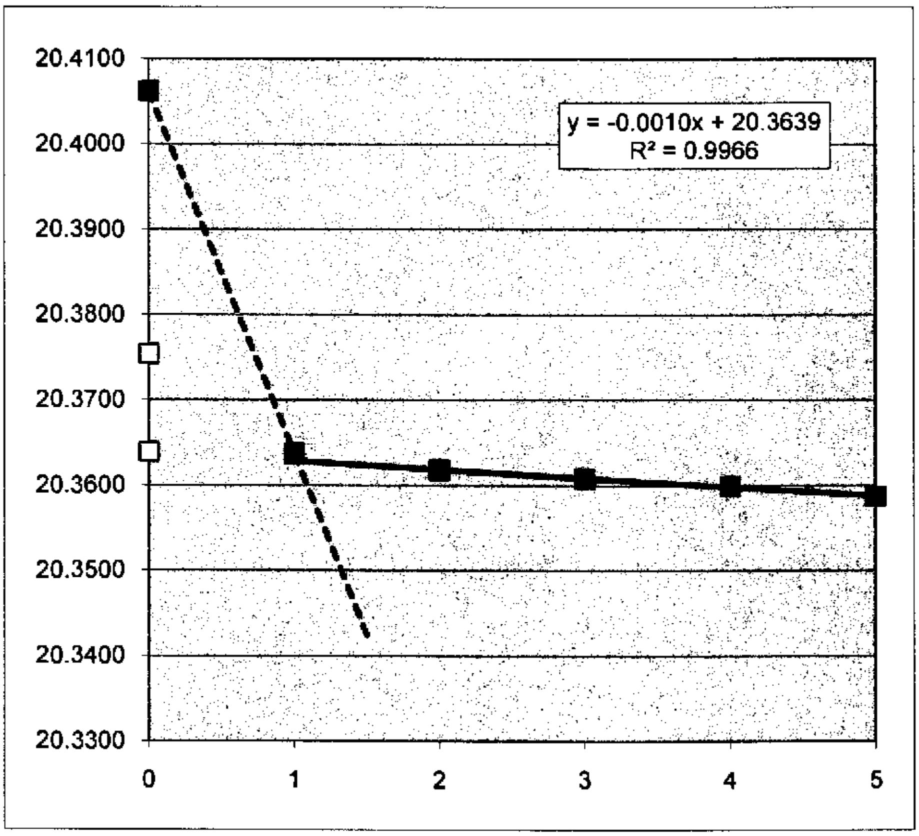
Coupon:	293		
Test matrix:	Fe-E-1500-12-3f		
Initial wt (g)	19.8102	**Calculated final wt (g)**	19.7953
Removal wt (g)	19.8626	**Total wt loss (g)**	0.0149
		Total wt loss (mg)	14.9

Cleaning Cycle	Wt (g)
0	19.8626
1	19.7952
2	19.7924
3	19.7913
4	19.7897
5	19.7883



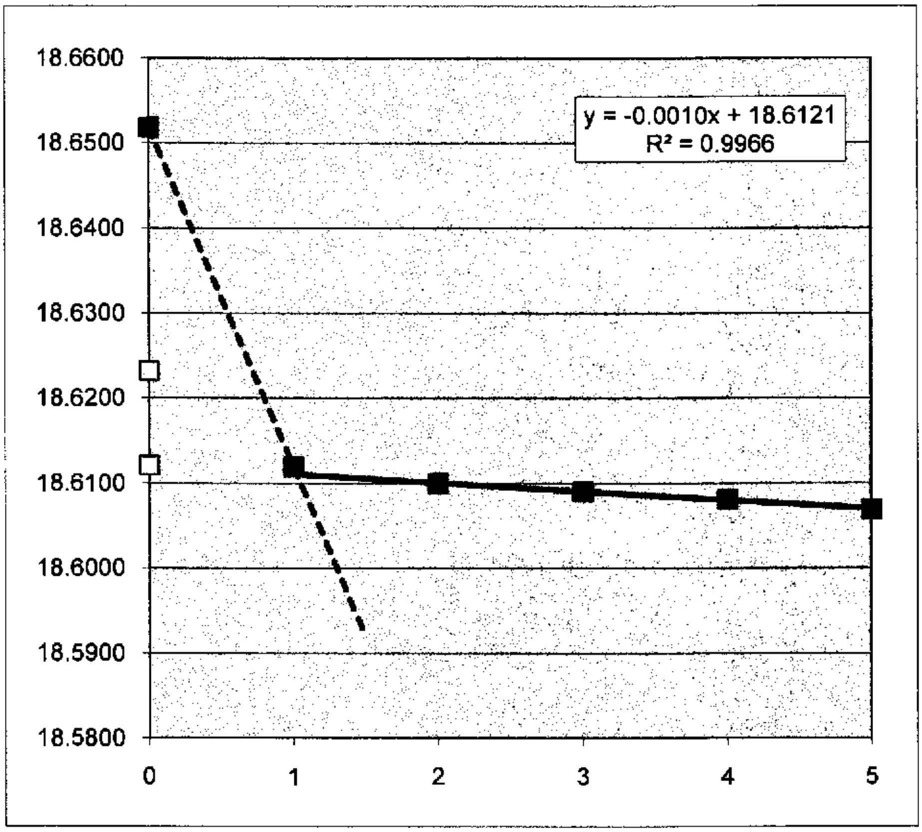
Coupon:	295		
Test matrix:	Fe-E-1500-12-2p		
Initial wt (g)	20.3754	**Calculated final wt (g)**	20.3639
Removal wt (g)	20.4062	**Total wt loss (g)**	0.0115
		Total wt loss (mg)	11.5

Cleaning Cycle	Wt (g)
0	20.4062
1	20.3637
2	20.3618
3	20.3608
4	20.3599
5	20.3587



Coupon:	296			
Test matrix:	Fe-E-1500-12-3p			
Initial wt (g)	18.6232		**Calculated final wt (g)**	18.6121
Removal wt (g)	18.6518		**Total wt loss (g)**	0.0111
			Total wt loss (mg)	11.1

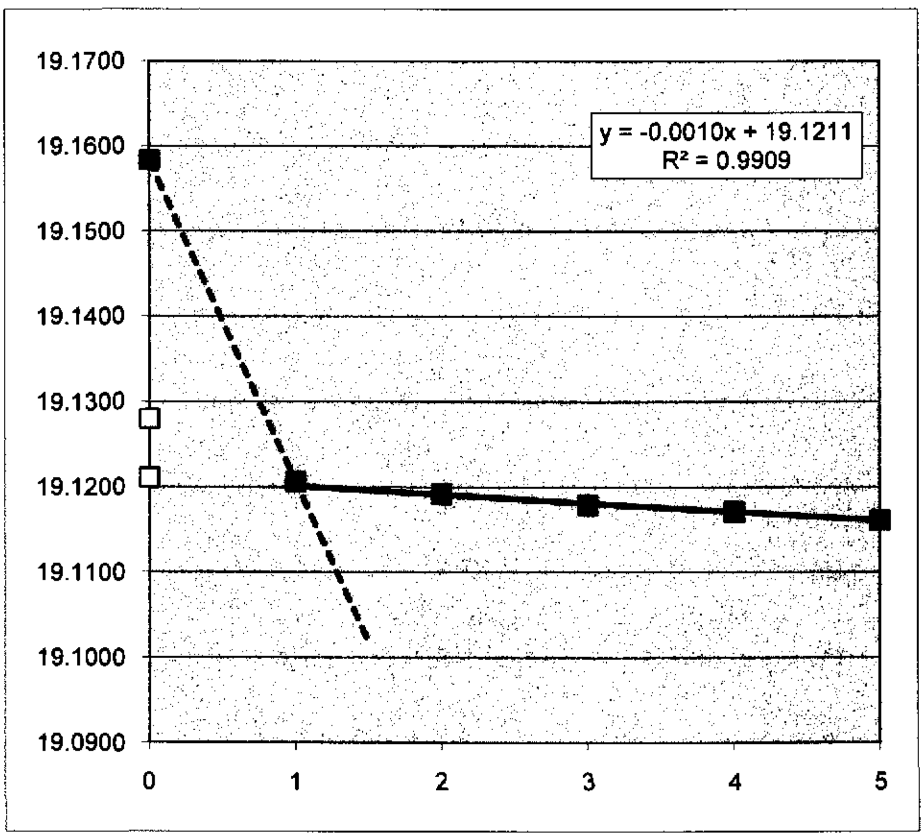
Cleaning Cycle	Wt (g)
0	18.6518
1	18.6119
2	18.6100
3	18.6090
4	18.6081
5	18.6069



Coupon:	298
Test matrix:	Fe-Eo-1500-12-2f
Initial wt (g)	19.1280
Removal wt (g)	19.1583

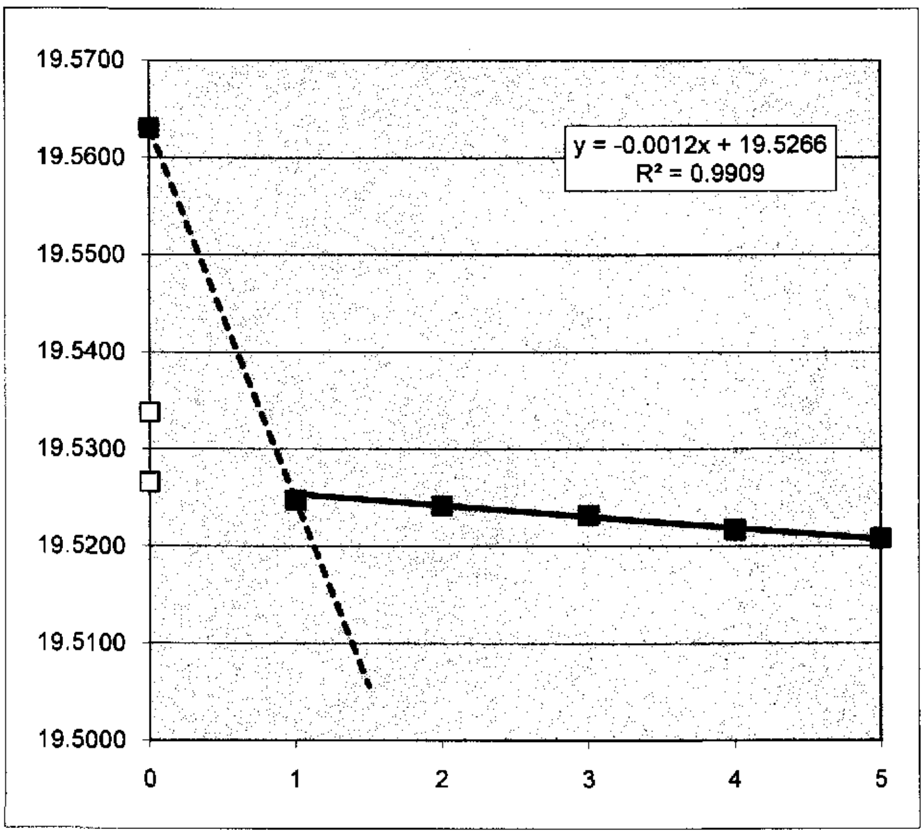
Calculated final wt (g)	19.1211
Total wt loss (g)	0.0069
Total wt loss (mg)	6.9

Cleaning Cycle	Wt (g)
0	19.1583
1	19.1206
2	19.1192
3	19.1179
4	19.1171
5	19.1161



Coupon:	299		
Test matrix:	Fe-Eo-1500-12-3f		
Initial wt (g)	19.5338	**Calculated final wt (g)**	19.5266
Removal wt (g)	19.5631	**Total wt loss (g)**	0.0072
		Total wt loss (mg)	7.2

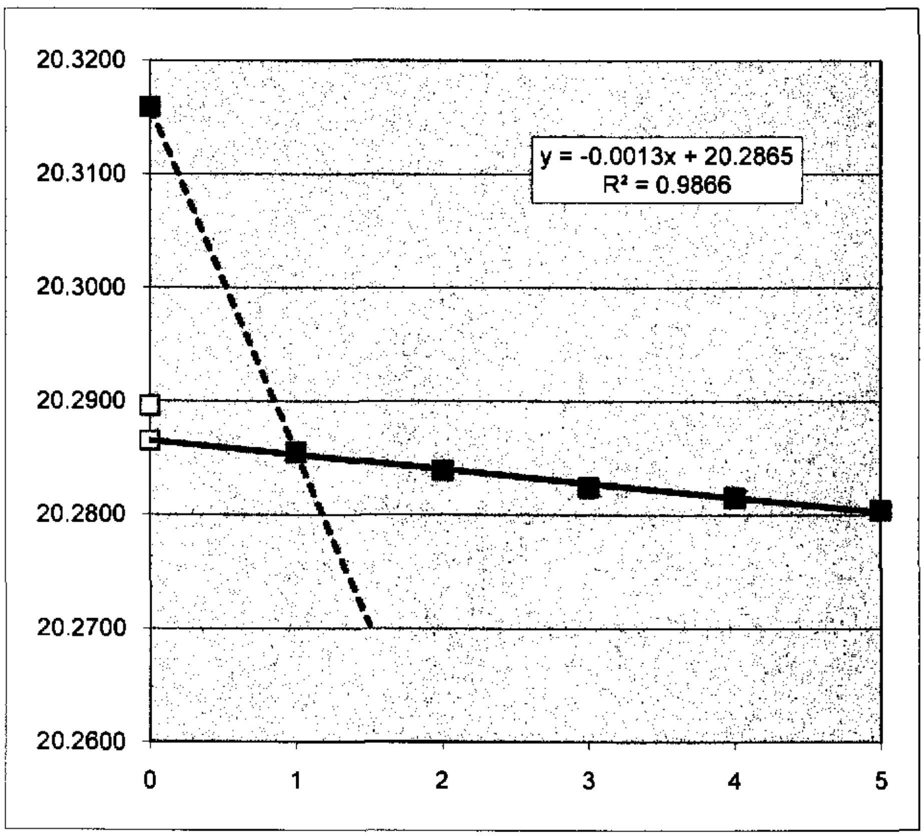
Cleaning Cycle	Wt (g)
0	19.5631
1	19.5248
2	19.5242
3	19.5232
4	19.5217
5	19.5208



Coupon:	301
Test matrix:	Fe-Eo-1500-12-2p
Initial wt (g)	20.2896
Removal wt (g)	20.3159

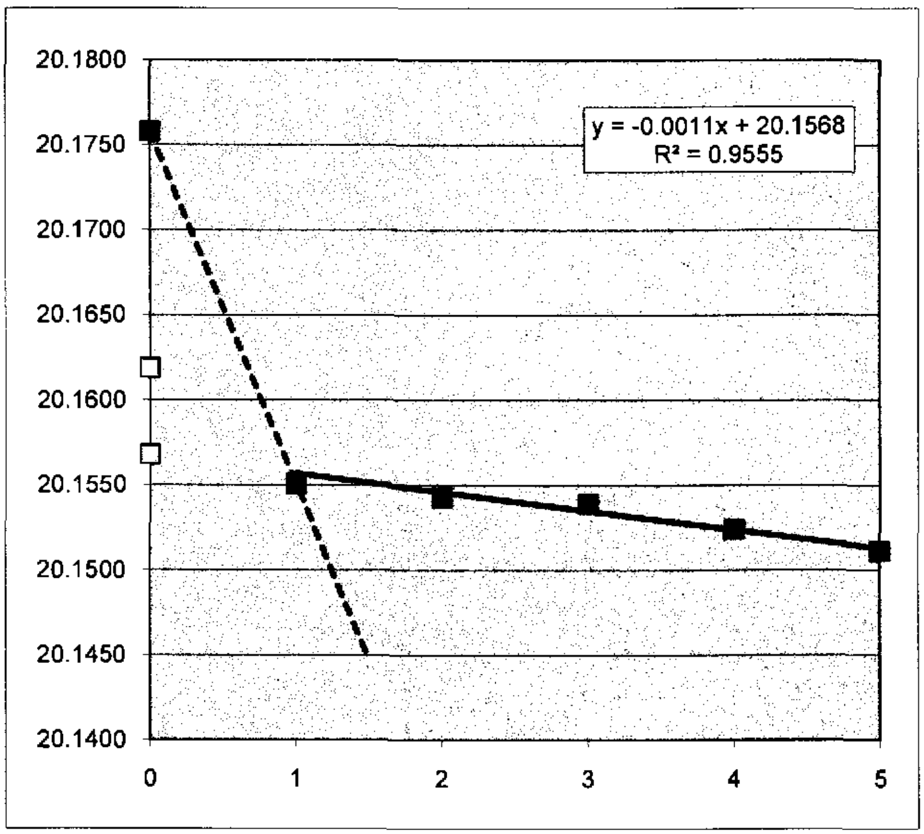
Calculated final wt (g)	20.2865
Total wt loss (g)	0.0031
Total wt loss (mg)	3.1

Cleaning Cycle	Wt (g)
0	20.3159
1	20.2855
2	20.2839
3	20.2824
4	20.2815
5	20.2804



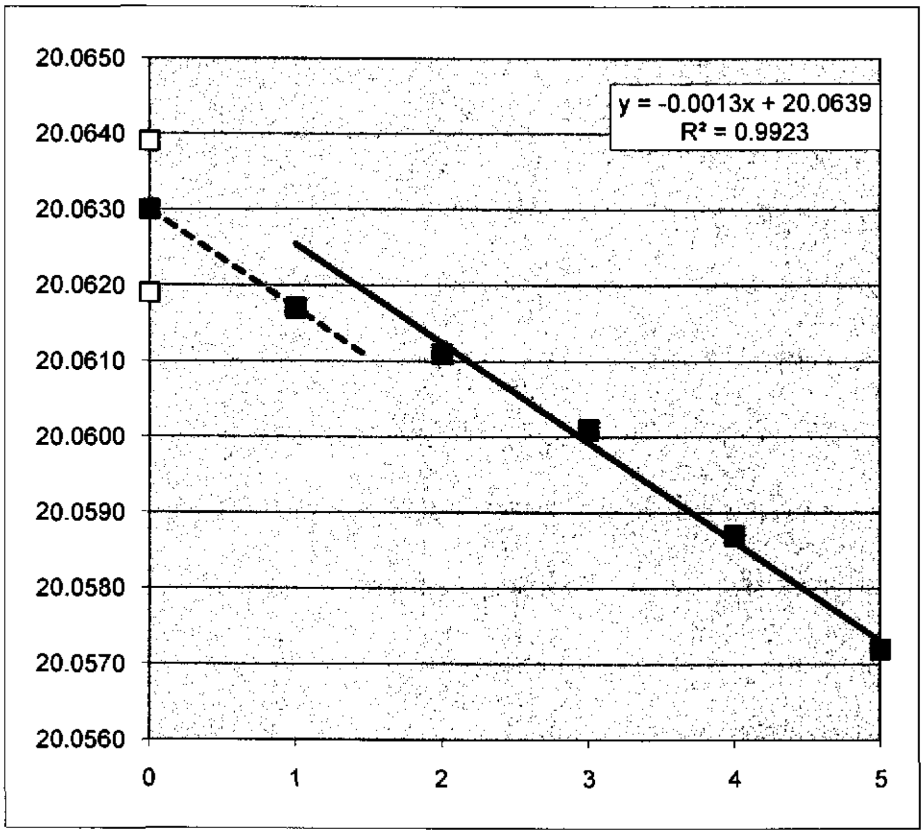
Coupon:	302		
Test matrix:	Fe-Eo-1500-12-3p		
Initial wt (g)	20.1619	**Calculated final wt (g)**	20.1568
Removal wt (g)	20.1758	**Total wt loss (g)**	0.0051
		Total wt loss (mg)	5.1

Cleaning Cycle	Wt (g)
0	20.1758
1	20.1551
2	20.1543
3	20.1539
4	20.1524
5	20.1511



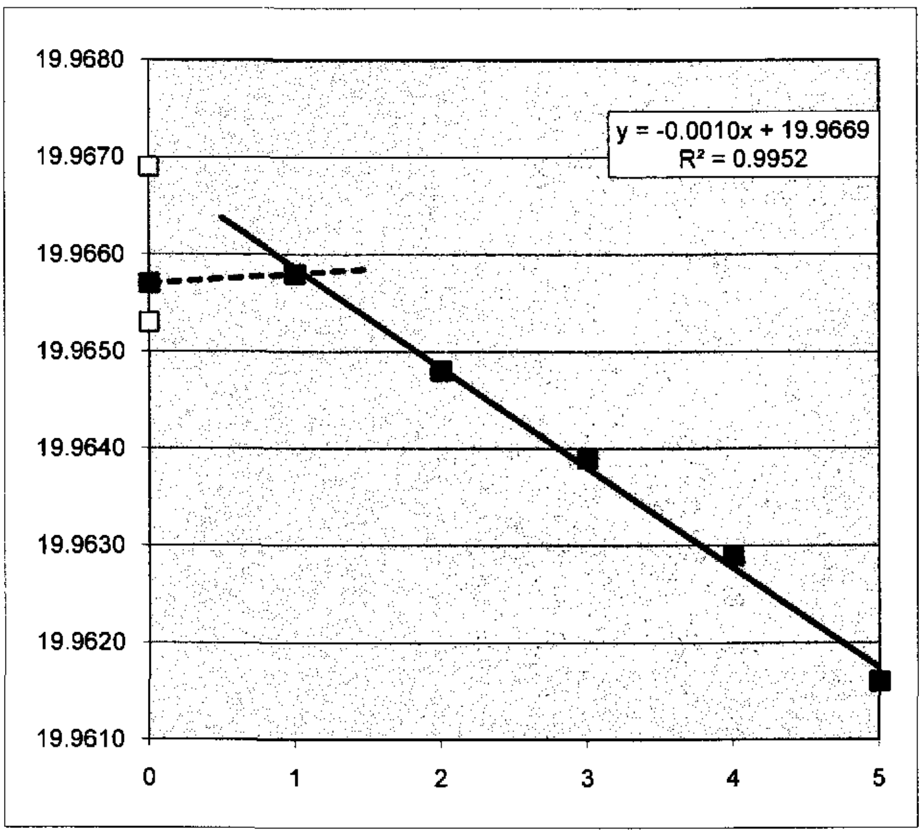
Coupon:	304			
Test matrix:	Fe-Atm-1500-12-2			
Initial wt (g)	20.0619		**Calculated final wt (g)**	20.0639
Removal wt (g)	20.0630		**Total wt loss (g)**	-0.0020
			Total wt loss (mg)	-2.0

Cleaning Cycle	Wt (g)
0	20.0630
1	20.0617
2	20.0611
3	20.0601
4	20.0587
5	20.0572



Coupon:	305			
Test matrix:	Fe-Atm-1500-12-3			
Initial wt (g)	19.9653		**Calculated final wt (g)**	19.9669
Removal wt (g)	19.9657		**Total wt loss (g)**	-0.0016
			Total wt loss (mg)	-1.6

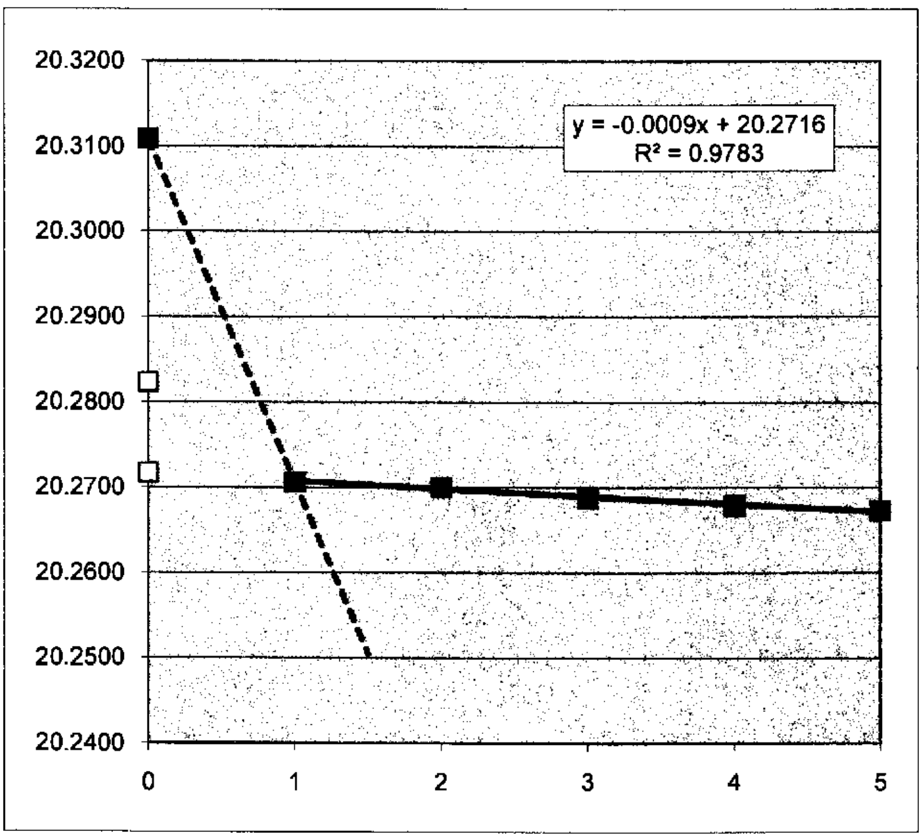
Cleaning Cycle	Wt (g)
0	19.9657
1	19.9658
2	19.9648
3	19.9639
4	19.9629
5	19.9616



Coupon:	388
Test matrix:	Fe-G-3500-12-1f
Initial wt (g)	20.2823
Removal wt (g)	20.3109

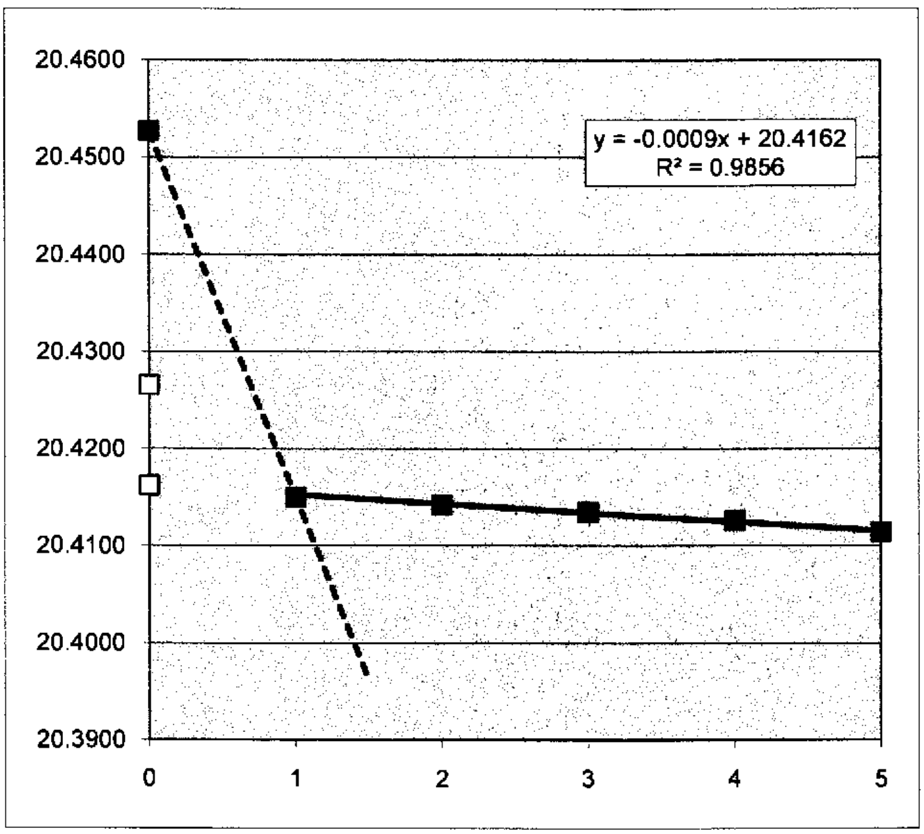
Calculated final wt (g)	20.2717
Total wt loss (g)	0.0106
Total wt loss (mg)	10.6

Cleaning Cycle	Wt (g)
0	20.3109
1	20.2706
2	20.2700
3	20.2688
4	20.2679
5	20.2673



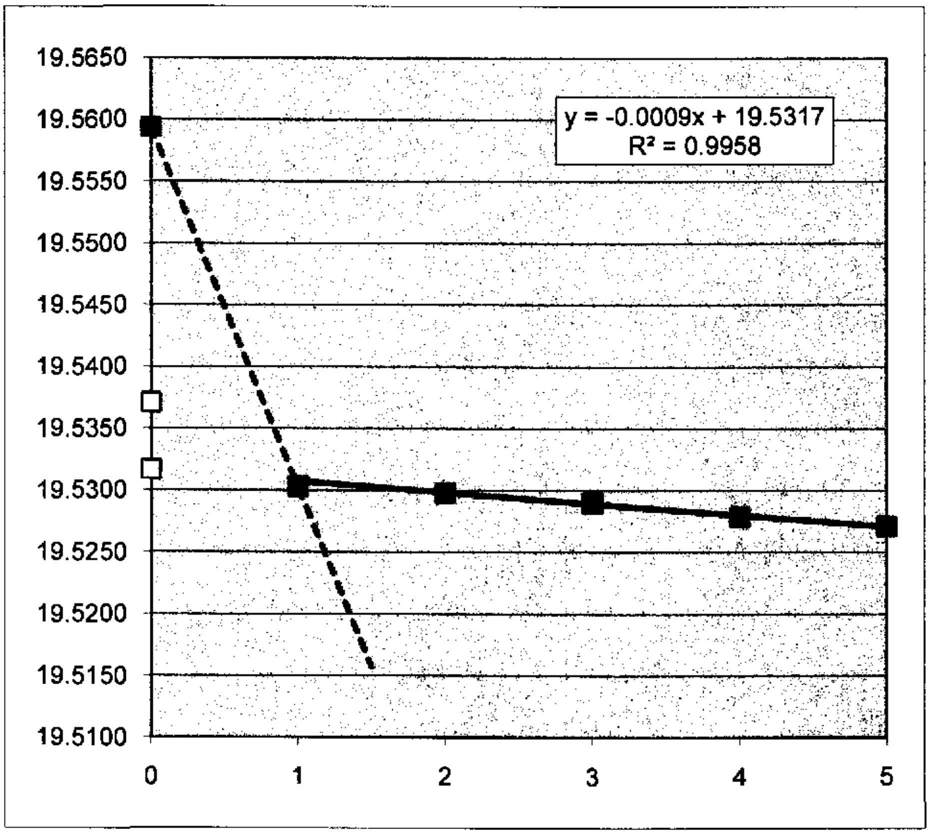
Coupon:	389		
Test matrix:	Fe-G-3500-12-2f		
Initial wt (g)	20.4266	**Calculated final wt (g)**	20.4162
Removal wt (g)	20.4527	**Total wt loss (g)**	0.0104
		Total wt loss (mg)	10.4

Cleaning Cycle	Wt (g)
0	20.4527
1	20.4150
2	20.4142
3	20.4135
4	20.4126
5	20.4114



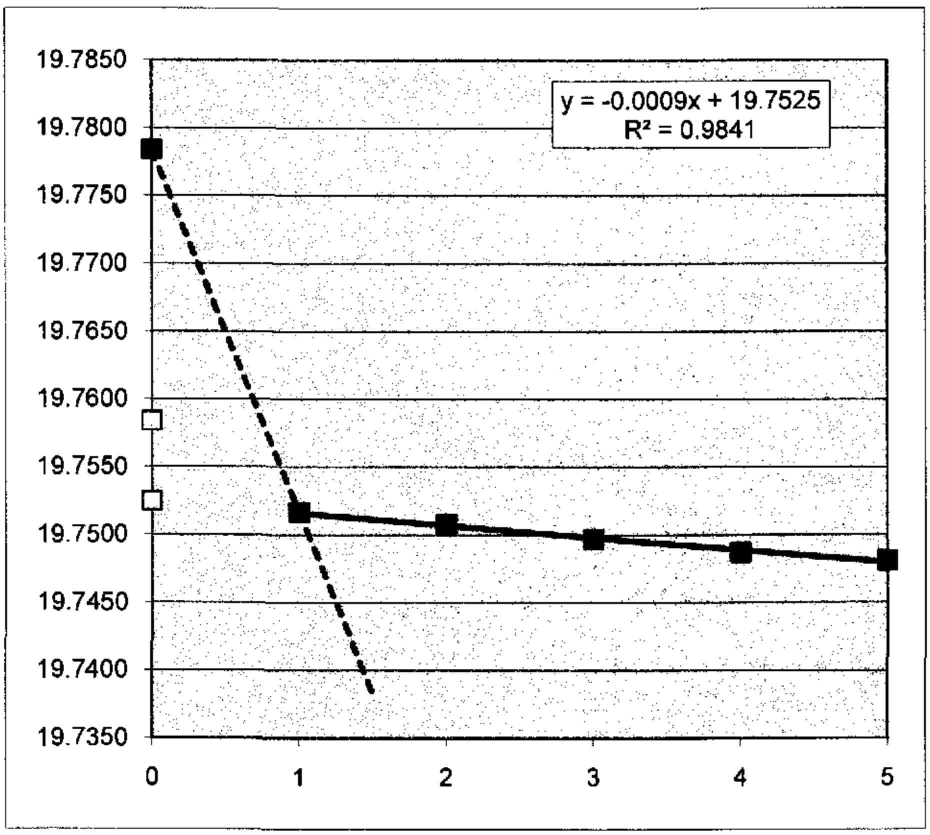
Coupon:	391		
Test matrix:	Fe-G-3500-12-1p		
Initial wt (g)	19.5371	**Calculated final wt (g)**	19.5317
Removal wt (g)	19.5594	**Total wt loss (g)**	0.0054
		Total wt loss (mg)	5.4

Cleaning Cycle	Wt (g)
0	19.5594
1	19.5303
2	19.5298
3	19.5290
4	19.5279
5	19.5271



Coupon:	392		
Test matrix:	Fe-G-3500-12-2p		
Initial wt (g)	19.7584	**Calculated final wt (g)**	19.7525
Removal wt (g)	19.7784	**Total wt loss (g)**	0.0059
		Total wt loss (mg)	5.9

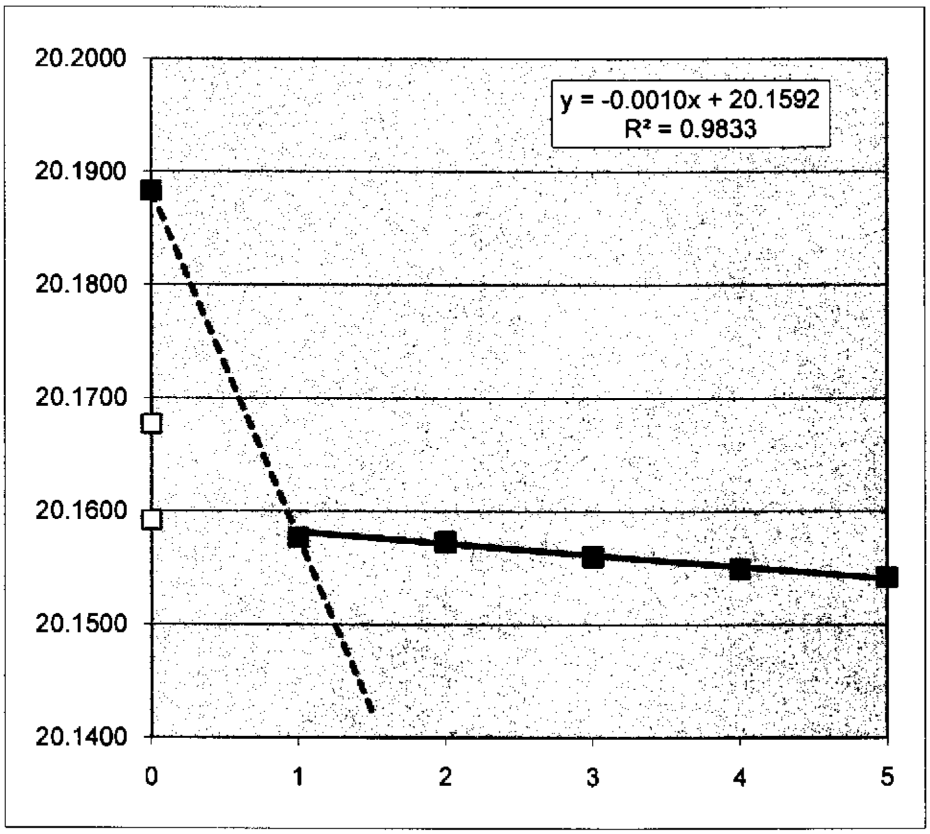
Cleaning Cycle	Wt (g)
0	19.7784
1	19.7517
2	19.7508
3	19.7497
4	19.7487
5	19.7481



Coupon:	394
Test matrix:	Fe-Go-3500-12-1f
Initial wt (g)	20.1677
Removal wt (g)	20.1883

Calculated final wt (g)	20.1592
Total wt loss (g)	0.0085
Total wt loss (mg)	8.5

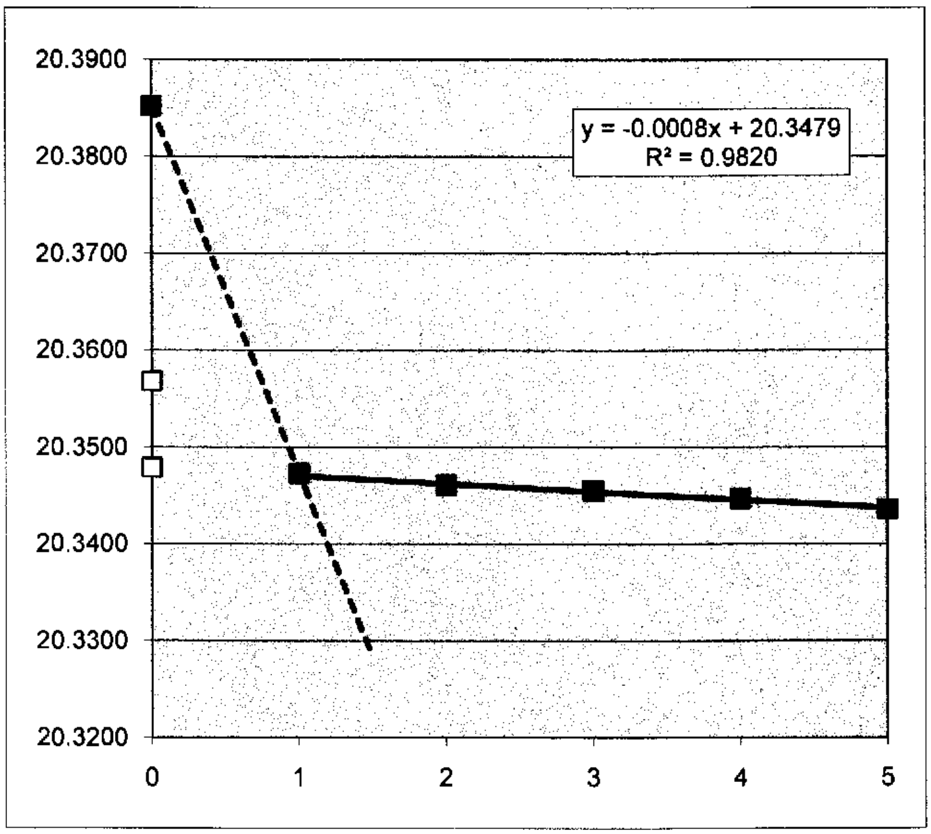
Cleaning Cycle	Wt (g)
0	20.1883
1	20.1577
2	20.1573
3	20.1560
4	20.1549
5	20.1542



Coupon:	395
Test matrix:	Fe-Go-3500-12-2f
Initial wt (g)	20.3568
Removal wt (g)	20.3852

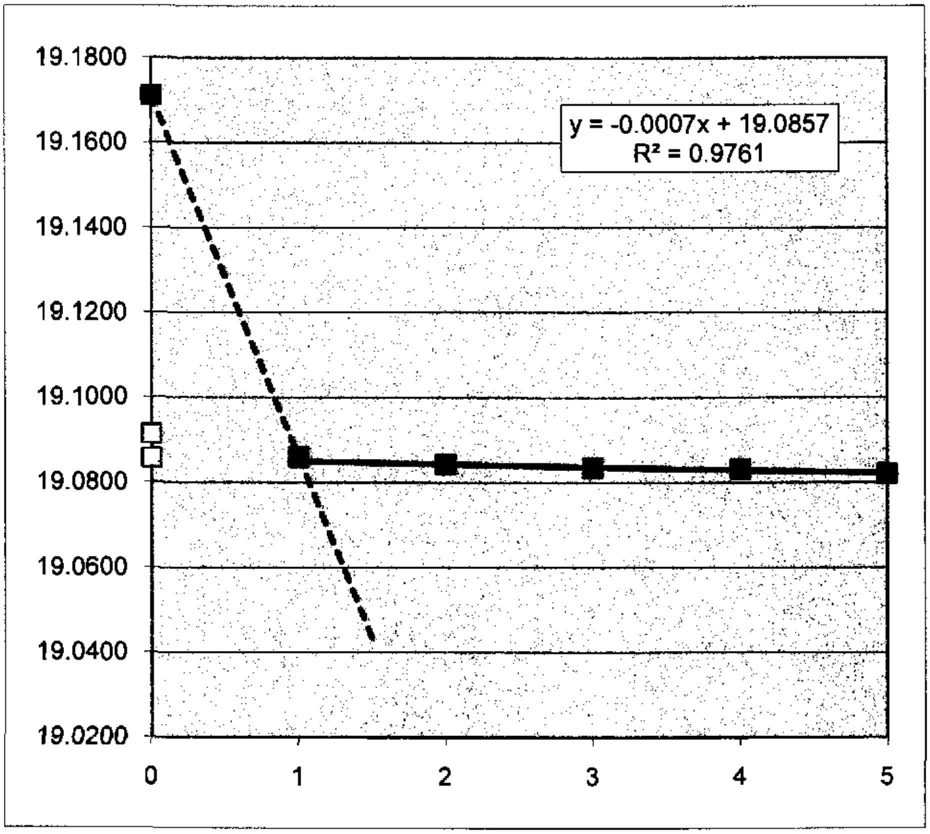
Calculated final wt (g)	20.3479
Total wt loss (g)	0.0089
Total wt loss (mg)	8.9

Cleaning Cycle	Wt (g)
0	20.3852
1	20.3473
2	20.3461
3	20.3455
4	20.3447
5	20.3436



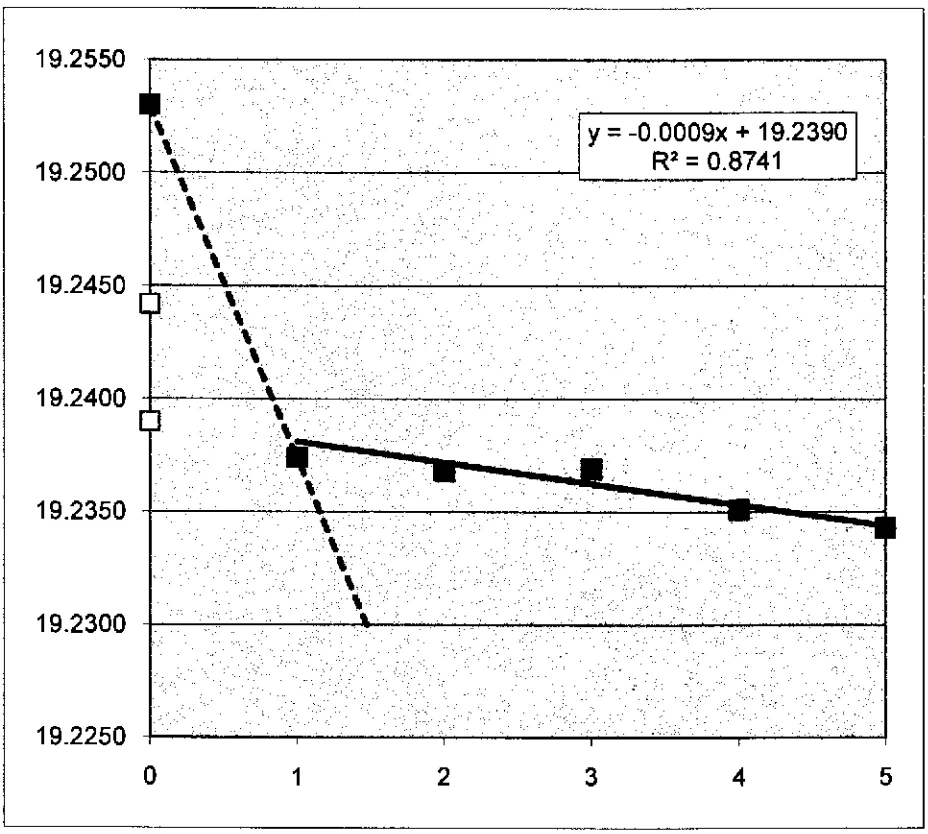
Coupon:	397		
Test matrix:	Fe-Go-3500-12-1p		
Initial wt (g)	19.0914	**Calculated final wt (g)**	19.0857
Removal wt (g)	19.1711	**Total wt loss (g)**	0.0057
		Total wt loss (mg)	5.7

Cleaning Cycle	Wt (g)
0	19.1711
1	19.0860
2	19.0843
3	19.0835
4	19.0831
5	19.0821



Coupon:	398		
Test matrix:	Fe-Go-3500-12-2p		
Initial wt (g)	19.2442	**Calculated final wt (g)**	19.2390
Removal wt (g)	19.2530	**Total wt loss (g)**	0.0052
		Total wt loss (mg)	5.2

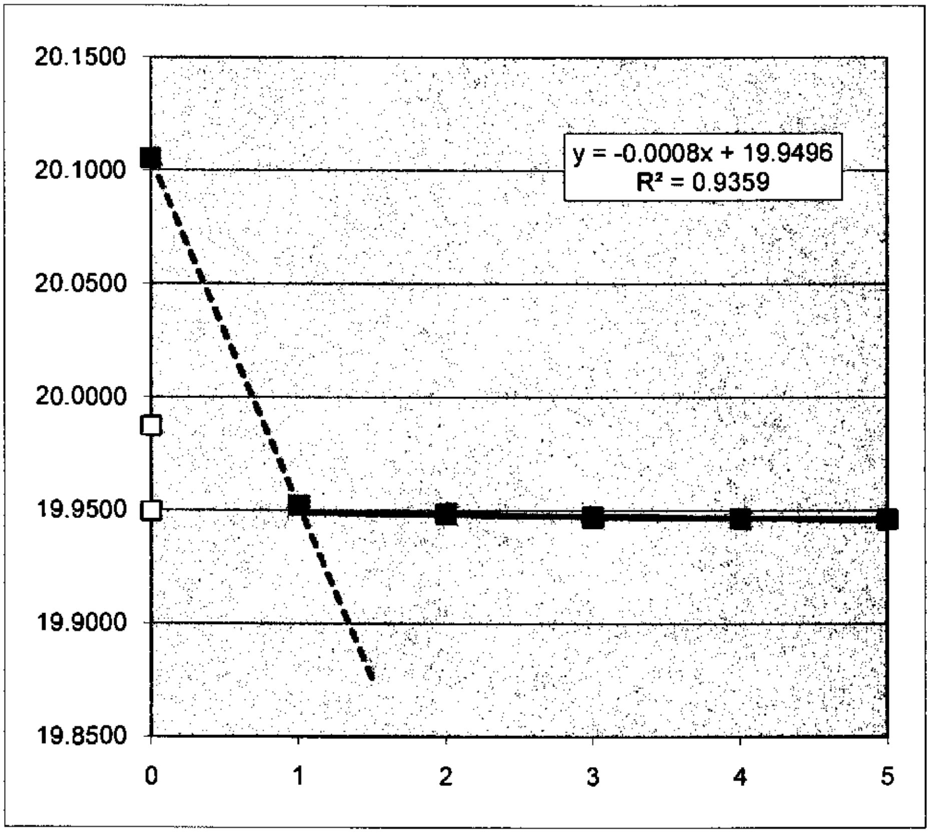
Cleaning Cycle	Wt (g)
0	19.2530
1	19.2374
2	19.2368
3	19.2369
4	19.2351
5	19.2343



Coupon:	400
Test matrix:	Fe-E-3500-12-1f
Initial wt (g)	19.9873
Removal wt (g)	20.1054

Calculated final wt (g)	19.9496
Total wt loss (g)	0.0377
Total wt loss (mg)	37.7

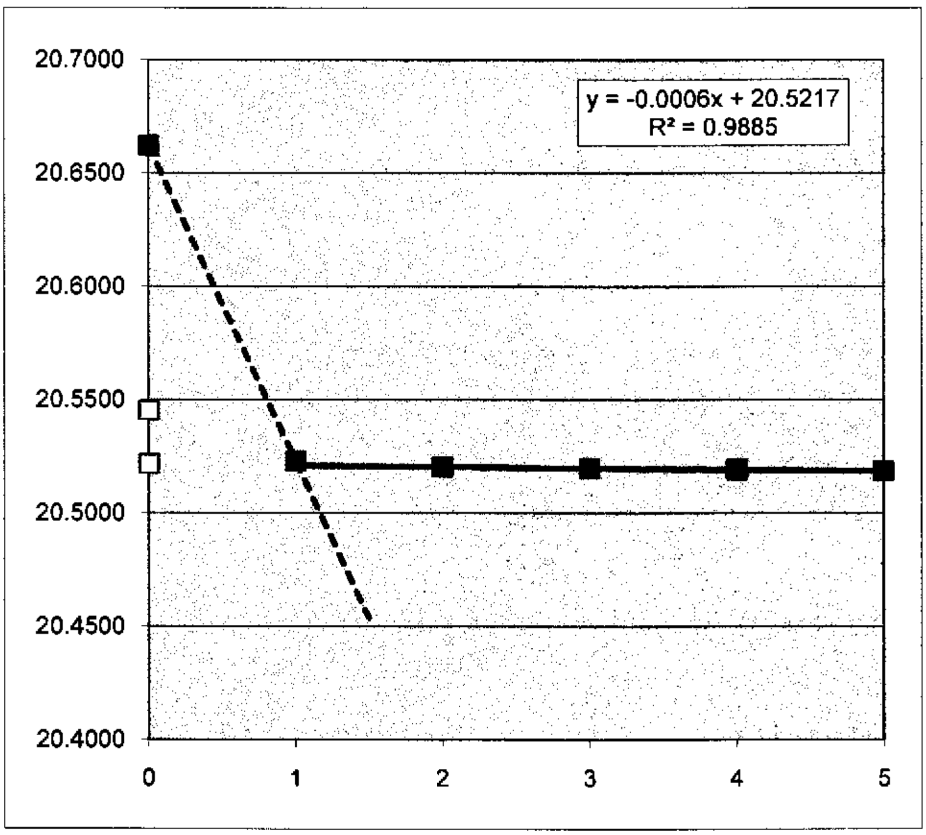
Cleaning Cycle	Wt (g)
0	20.1054
1	19.9522
2	19.9483
3	19.9471
4	19.9463
5	19.9460



Coupon:	401
Test matrix:	Fe-E-3500-12-2f
Initial wt (g)	20.5452
Removal wt (g)	20.6620

Calculated final wt (g)	20.5217
Total wt loss (g)	0.0235
Total wt loss (mg)	23.5

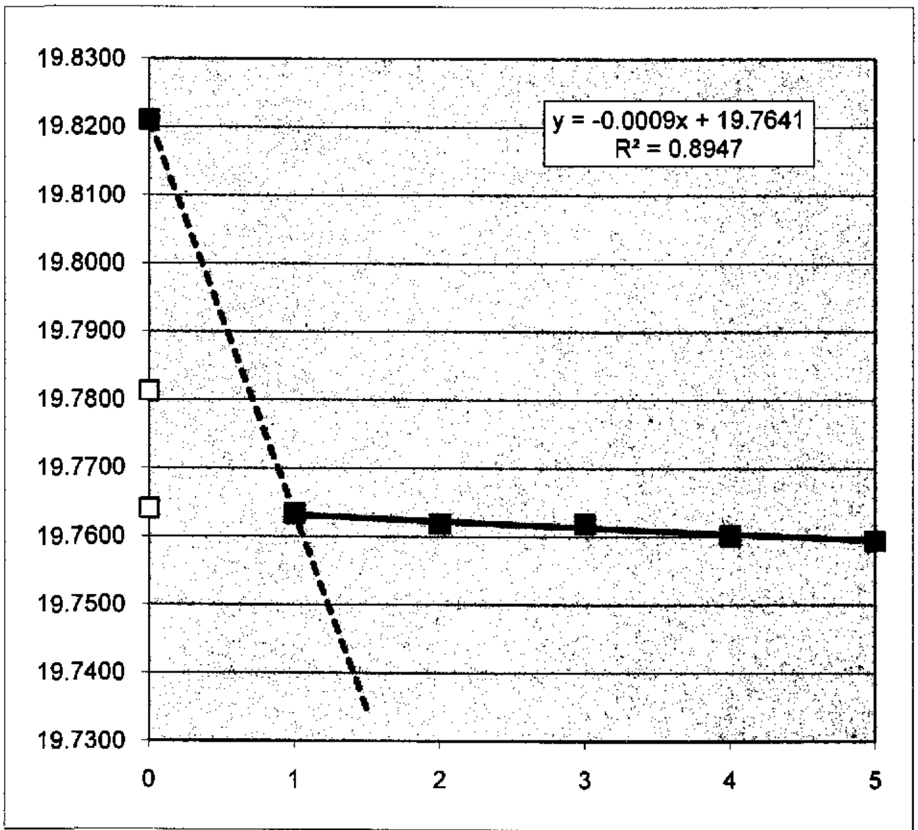
Cleaning Cycle	Wt (g)
0	20.6620
1	20.5231
2	20.5204
3	20.5199
4	20.5193
5	20.5185



Coupon:	403
Test matrix:	Fe-E-3500-12-1p
Initial wt (g)	19.7813
Removal wt (g)	19.8210

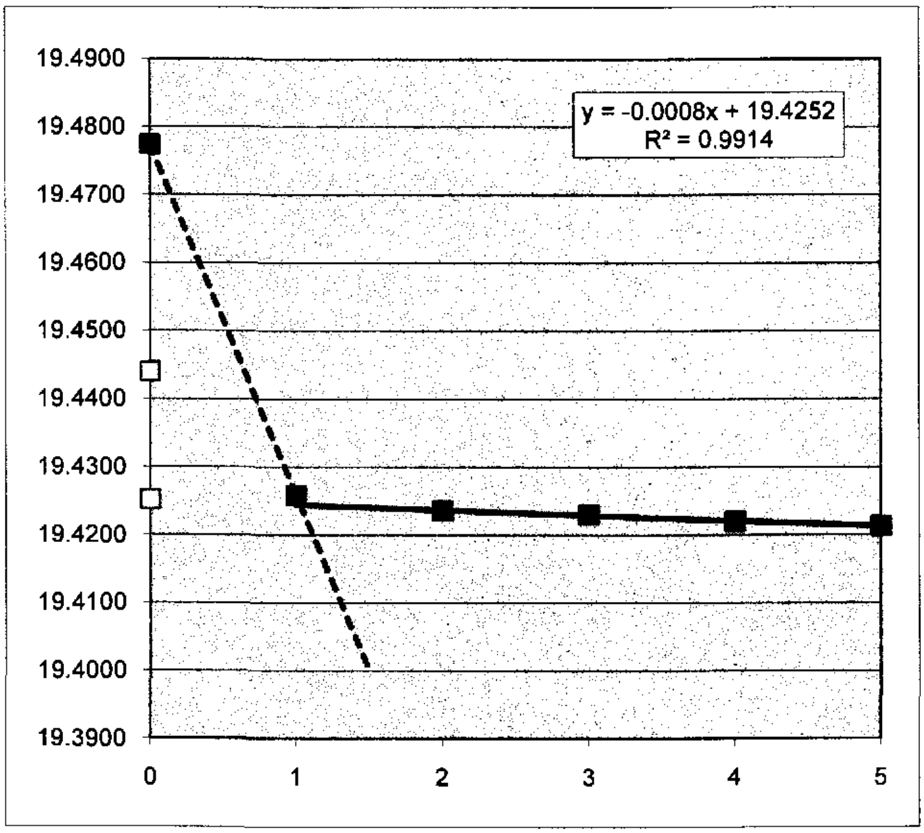
Calculated final wt (g)	19.7641
Total wt loss (g)	0.0172
Total wt loss (mg)	17.2

Cleaning Cycle	Wt (g)
0	19.8210
1	19.7634
2	19.7619
3	19.7619
4	19.7602
5	19.7594



Coupon:	404		
Test matrix:	Fe-E-3500-12-2p		
Initial wt (g)	19.4440	**Calculated final wt (g)**	19.4252
Removal wt (g)	19.4774	**Total wt loss (g)**	0.0188
		Total wt loss (mg)	18.8

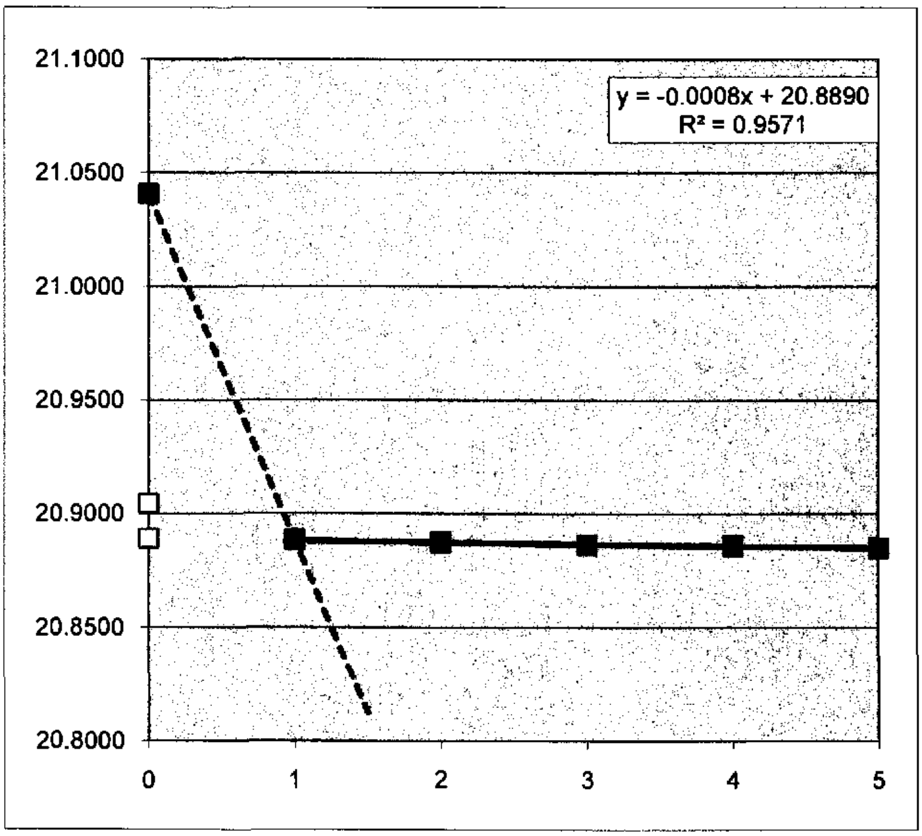
Cleaning Cycle	Wt (g)
0	19.4774
1	19.4258
2	19.4236
3	19.4230
4	19.4220
5	19.4213



Coupon:	406
Test matrix:	Fe-Eo-3500-12-1f
Initial wt (g)	20.9043
Removal wt (g)	21.0407

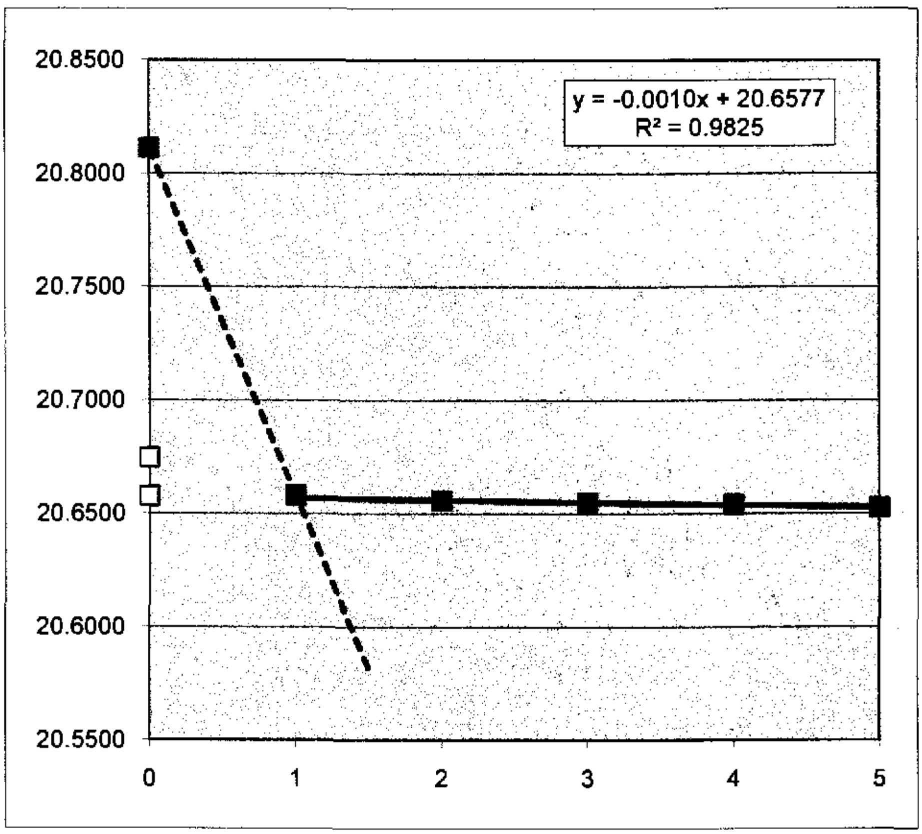
Calculated final wt (g)	20.8890
Total wt loss (g)	0.0153
Total wt loss (mg)	15.3

Cleaning Cycle	Wt (g)
0	21.0407
1	20.8885
2	20.8875
3	20.8863
4	20.8860
5	20.8849



Coupon:	407		
Test matrix:	Fe-Eo-3500-12-2f		
Initial wt (g)	20.6746	**Calculated final wt (g)**	20.6577
Removal wt (g)	20.8112	**Total wt loss (g)**	0.0169
		Total wt loss (mg)	16.9

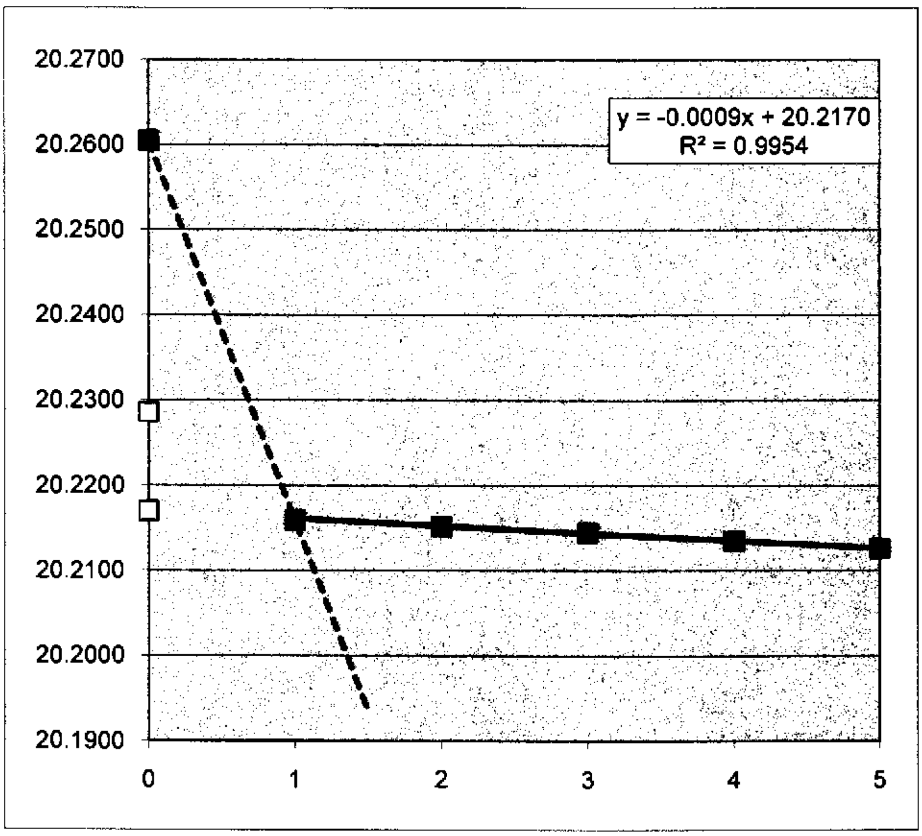
Cleaning Cycle	Wt (g)
0	20.8112
1	20.6580
2	20.6558
3	20.6547
4	20.6541
5	20.6528



Coupon:	409
Test matrix:	Fe-Eo-3500-12-1p
Initial wt (g)	20.2286
Removal wt (g)	20.2605

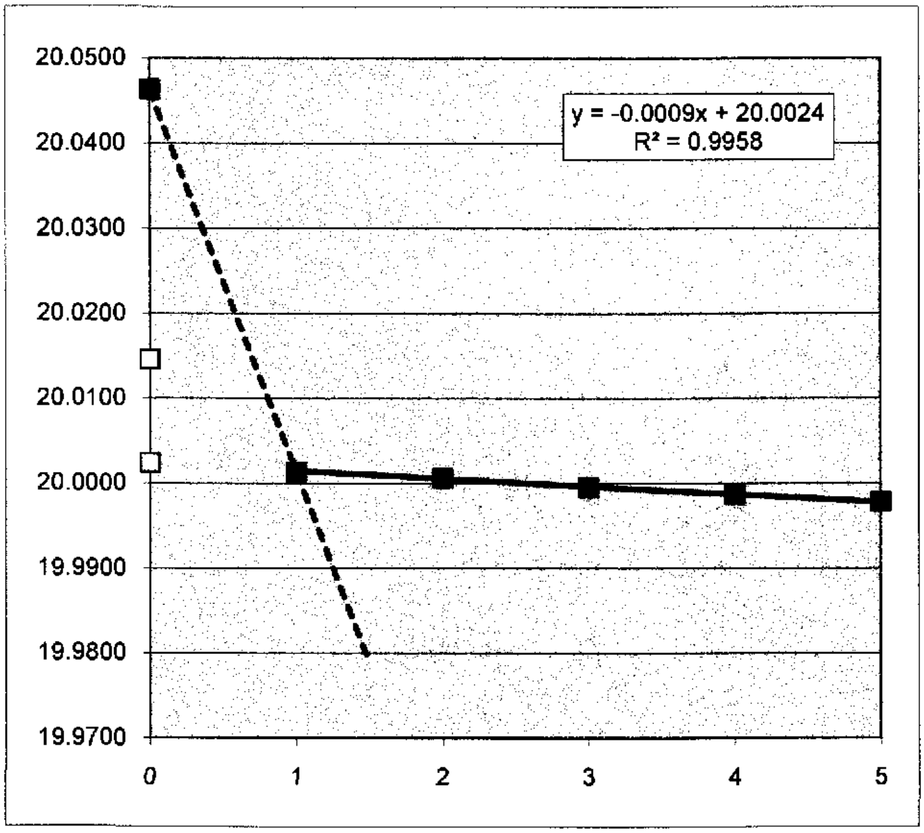
Calculated final wt (g)	20.2170
Total wt loss (g)	0.0116
Total wt loss (mg)	11.6

Cleaning Cycle	Wt (g)
0	20.2605
1	20.2159
2	20.2152
3	20.2145
4	20.2135
5	20.2126



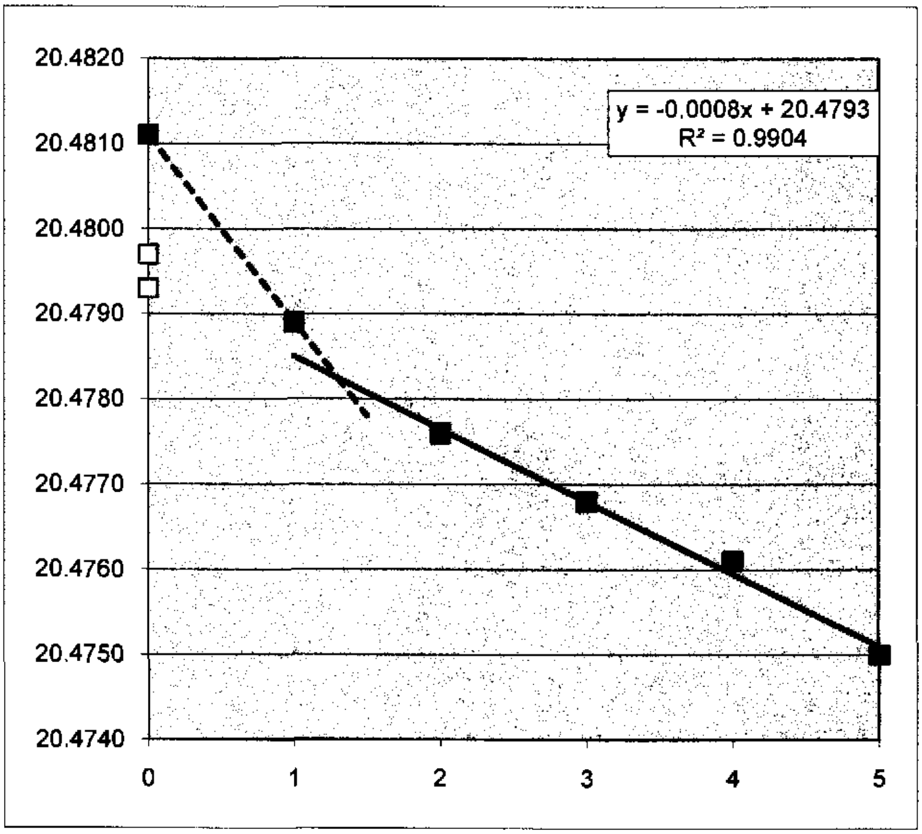
Coupon:	410			
Test matrix:	Fe-Eo-3500-12-2p			
Initial wt (g)	20.0146		**Calculated final wt (g)**	20.0024
Removal wt (g)	20.0463		**Total wt loss (g)**	0.0122
			Total wt loss (mg)	12.2

Cleaning Cycle	Wt (g)
0	20.0463
1	20.0013
2	20.0006
3	19.9995
4	19.9987
5	19.9978



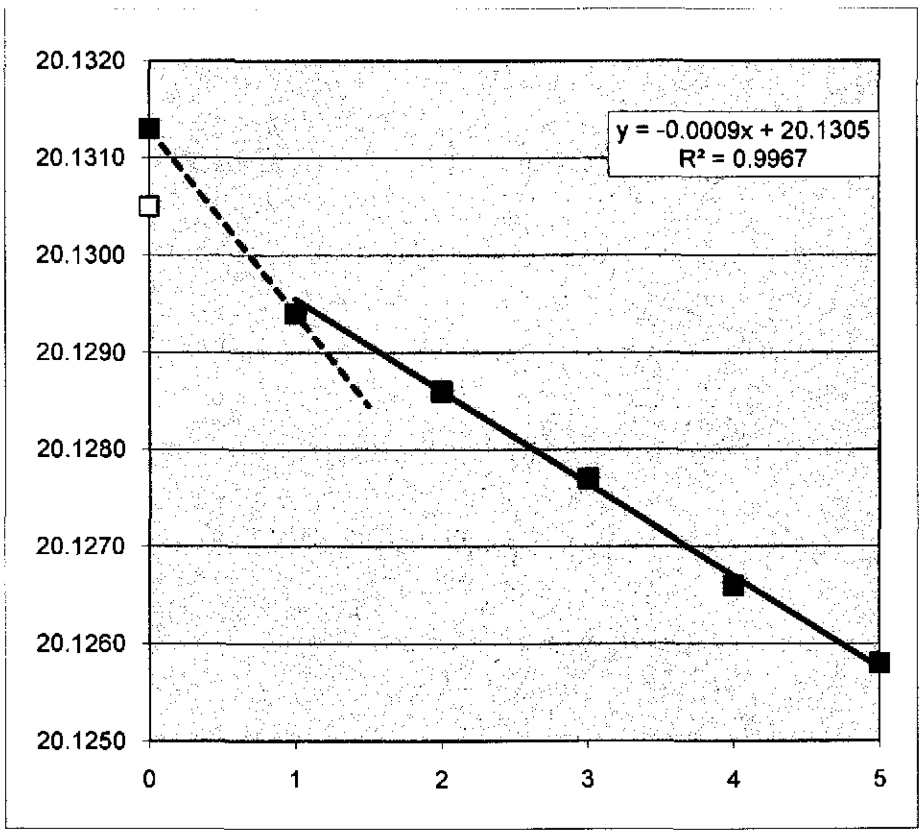
Coupon:	412			
Test matrix:	Fe-Atm-3500-12-1			
Initial wt (g)	20.4797		**Calculated final wt (g)**	20.4793
Removal wt (g)	20.4811		**Total wt loss (g)**	0.0004
			Total wt loss (mg)	0.4

Cleaning Cycle	Wt (g)
0	20.4811
1	20.4789
2	20.4776
3	20.4768
4	20.4761
5	20.4750



Coupon:	413		
Test matrix:	Fe-Atm-3500-12-2		
Initial wt (g)	20.1305	**Calculated final wt (g)**	20.1305
Removal wt (g)	20.1313	**Total wt loss (g)**	0.0000
		Total wt loss (mg)	0.0

Cleaning Cycle	**Wt (g)**
0	20.1313
1	20.1294
2	20.1286
3	20.1277
4	20.1266
5	20.1258



APPENDIX D – LEAD COUPON CLEANING PLOTS

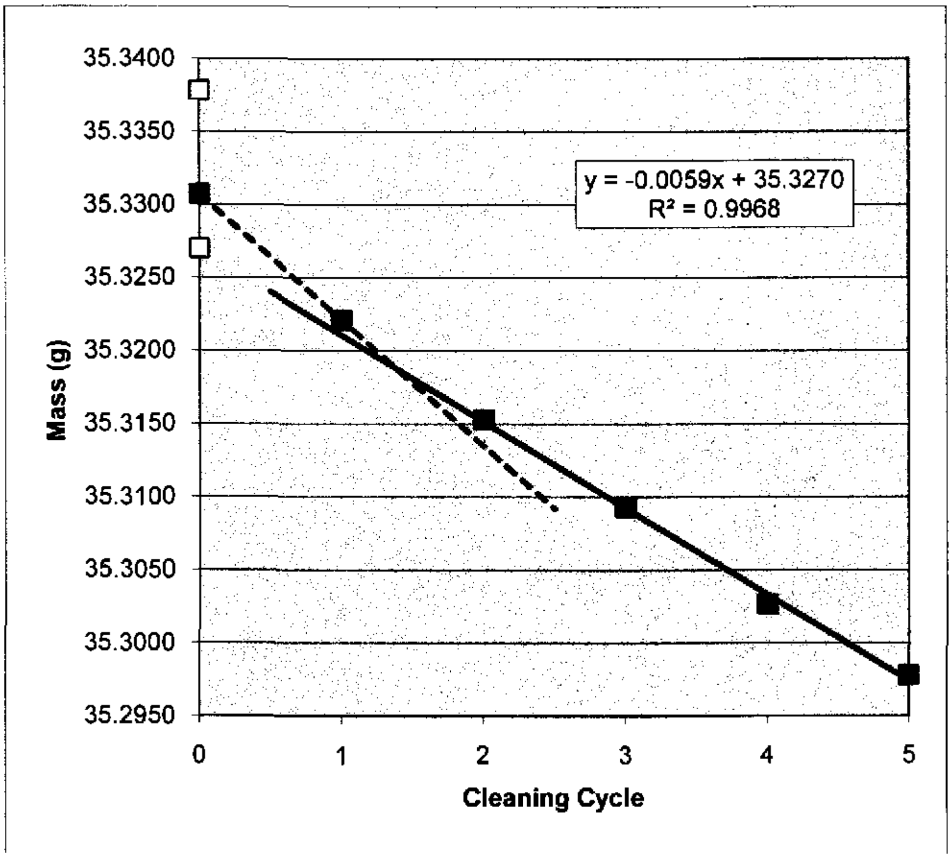
This appendix contains all of the weight loss cleaning cycle data, as well as the results of the graphical analysis of that data for each of the lead coupons (see individual data sheets for each coupon in WIPP-FePb-3 Supplemental Binder C). Each of the following pages lists the initial coupon weight, removal weight, cleaning cycle weights, calculated final weight and the resulting weight loss. The environmental conditions for each coupon can be read from the test matrix label that is given for each coupon. The meaning of the test matrix labels is discussed in Section 2.4.

For each coupon the graphical analysis is shown (see Section 4.4 in Roselle (2009) for details of the process). The blue symbols indicate those parts of the cleaning cycle data used to determine the calculated final weight, which is the y-intercept of the line fit to the blue symbols. The red symbols show the cleaning cycle data not used in the linear regression. Yellow symbols indicate the initial coupon weight (prior to the experiment) and the final calculated weight. The decision as to which cleaning cycle data points (blue symbols) to include in the fit is based on a visual inspection of the plots. Therefore it is somewhat of a subjective decision. However, in all cases at least 3 data points are used in the fit.

Note that in samples L395 and L410 the final weight is taken as the 0^{th} cleaning cycle value. This is a judgment call made by the investigator based on the appearance of the weight loss plots.

Coupon:	L055			
Test Matrix:	Pb-G-0000-12-1f			
Initial wt (g)	35.3378		**Calculated final wt (g)**	35.3270
Removal wt (g)	35.3307		**Total wt loss (g)**	0.0108
			Total wt loss (mg)	10.8

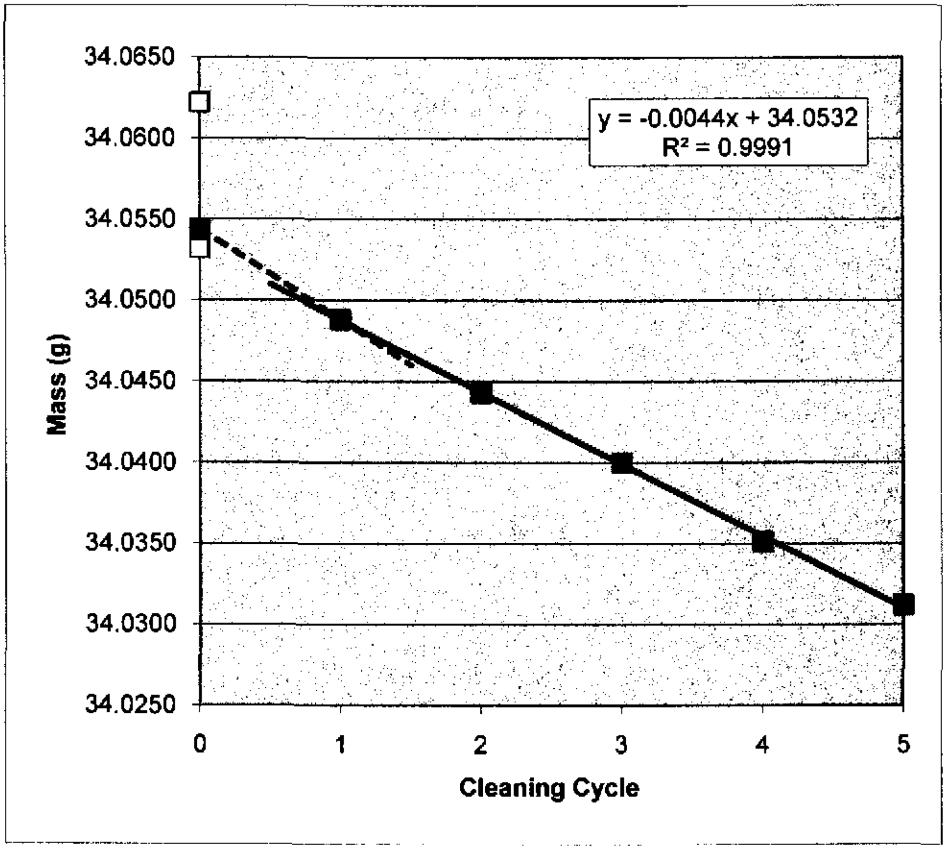
Cleaning Cycle	Wt (g)
0	35.3307
1	35.3221
2	35.3153
3	35.3093
4	35.3027
5	35.2978



Coupon:	L056
Test Matrix:	Pb-G-0000-12-2f
Initial wt (g)	34.0622
Removal wt (g)	34.0544

Calculated final wt (g)	34.0532
Total wt loss (g)	0.0090
Total wt loss (mg)	9.0

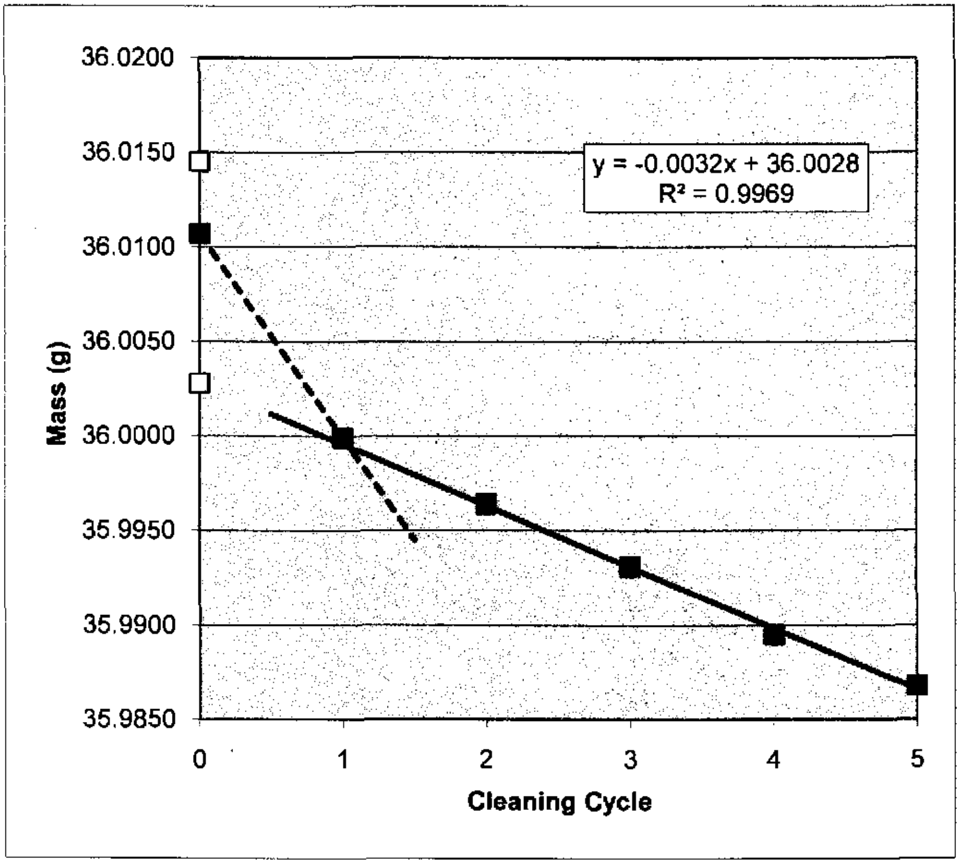
Cleaning Cycle	Wt (g)
0	34.0544
1	34.0488
2	34.0443
3	34.0400
4	34.0351
5	34.0312



Coupon:	L058
Test Matrix:	Pb-G-0000-12-1p
Initial wt (g)	36.0145
Removal wt (g)	36.0107

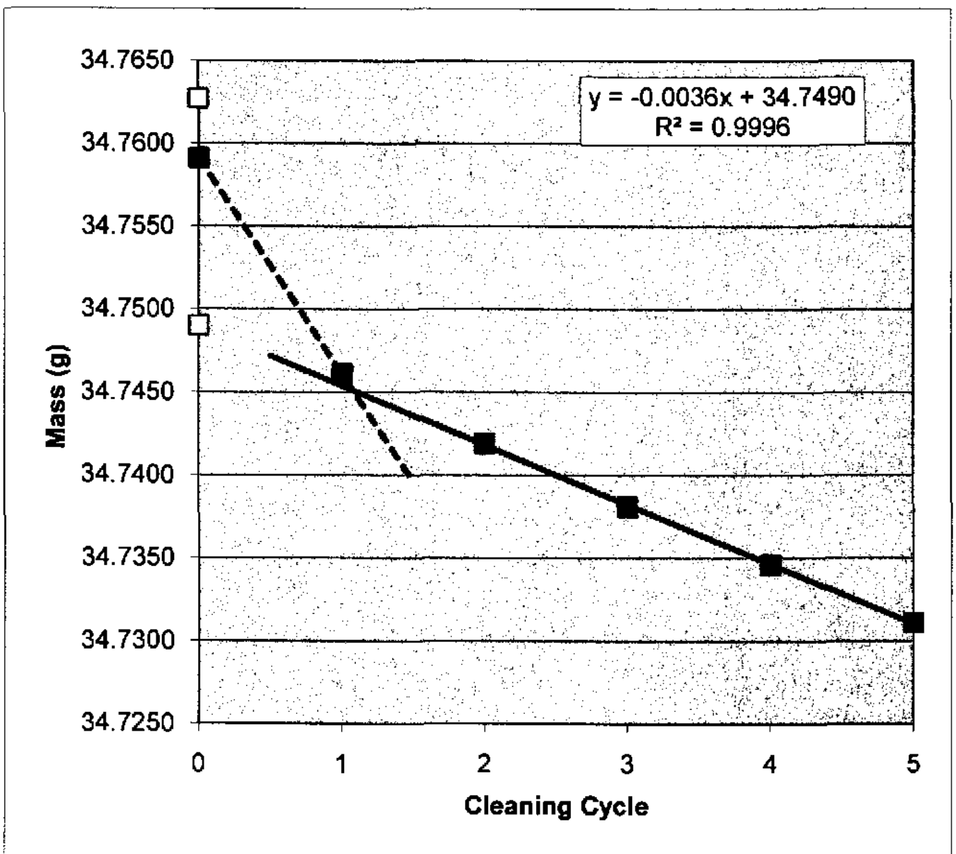
Calculated final wt (g)	36.0028
Total wt loss (g)	0.0117
Total wt loss (mg)	11.7

Cleaning Cycle	Wt (g)
0	36.0107
1	35.9999
2	35.9964
3	35.9931
4	35.9895
5	35.9868



Coupon:	L059		
Test Matrix:	Pb-G-0000-12-2p		
Initial wt (g)	34.7627	**Calculated final wt (g)**	34.7490
Removal wt (g)	34.7591	**Total wt loss (g)**	0.0137
		Total wt loss (mg)	13.7

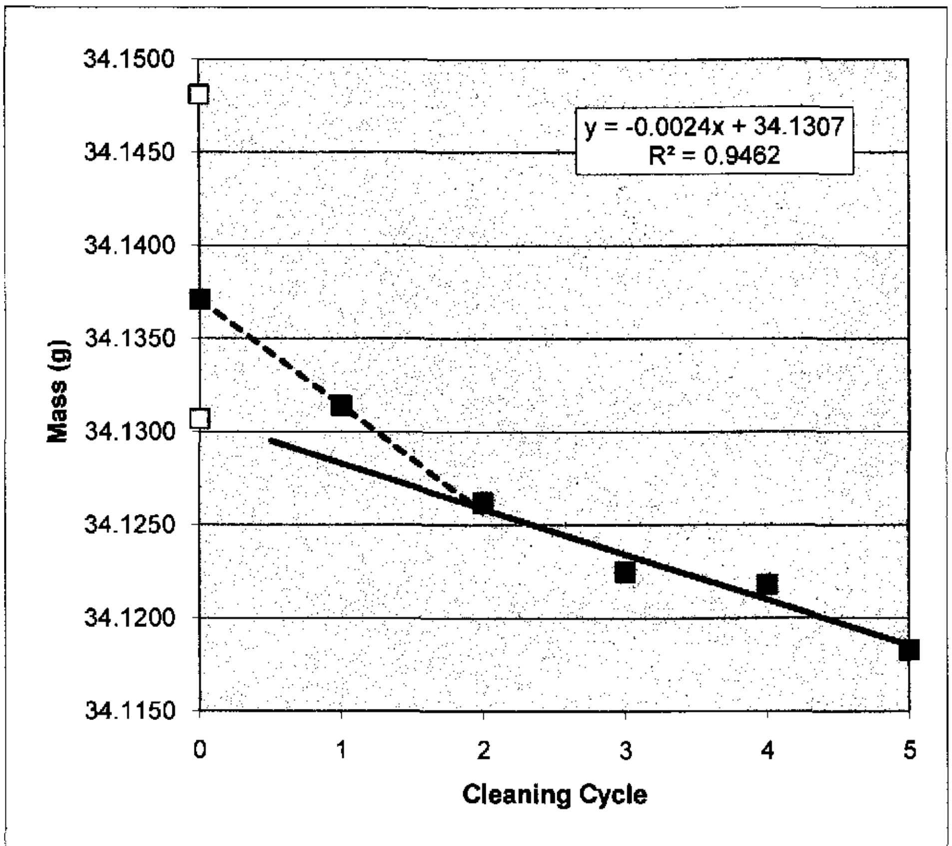
Cleaning Cycle	Wt (g)
0	34.7591
1	34.7461
2	34.7419
3	34.7381
4	34.7346
5	34.7311



Coupon: L061
Test Matrix: Pb-Go-0000-12-1f
Initial wt (g) 34.1481
Removal wt (g) 34.1371

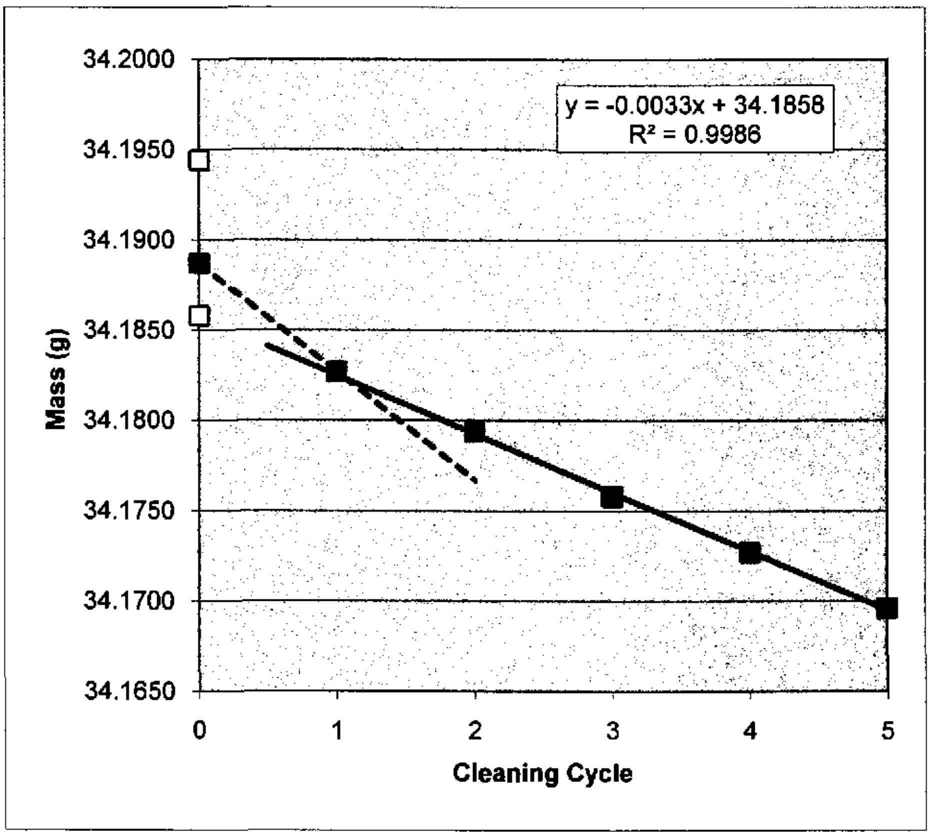
Calculated final wt (g) 34.1307
Total wt loss (g) 0.0174
Total wt loss (mg) 17.4

Cleaning Cycle	Wt (g)
0	34.1371
1	34.1314
2	34.1262
3	34.1225
4	34.1218
5	34.1183



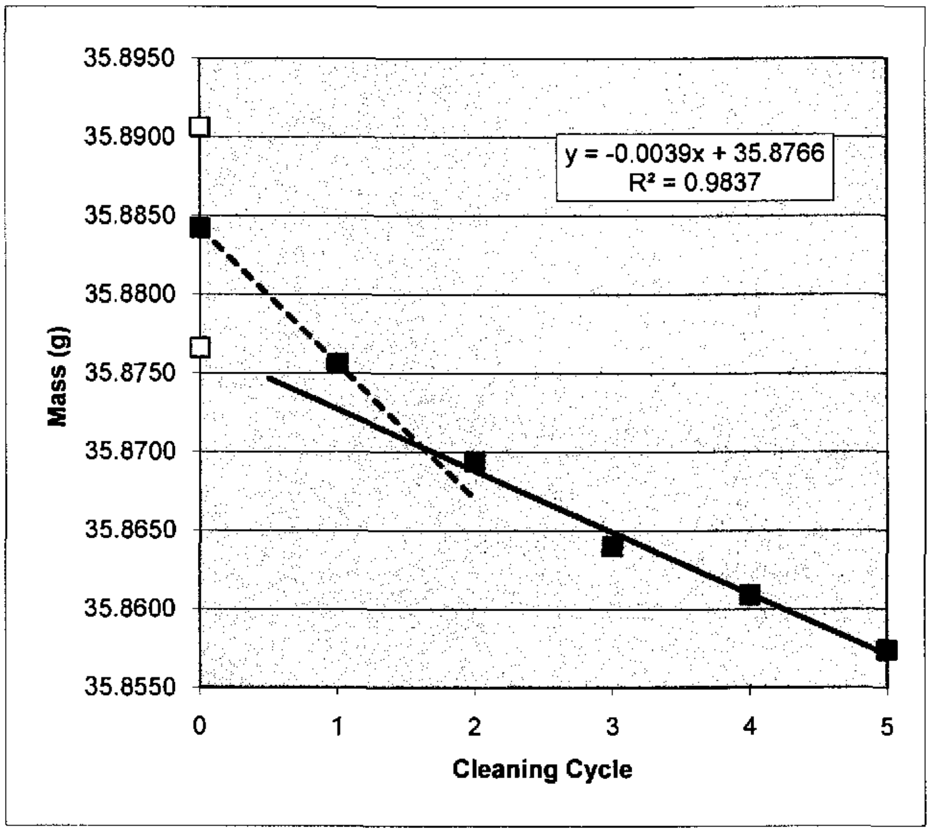
Coupon:	L062		
Test Matrix:	Pb-Go-0000-12-2f		
Initial wt (g)	34.1944	**Calculated final wt (g)**	34.1858
Removal wt (g)	34.1887	**Total wt loss (g)**	0.0086
		Total wt loss (mg)	8.6

Cleaning Cycle	Wt (g)
0	34.1887
1	34.1827
2	34.1794
3	34.1758
4	34.1727
5	34.1696



Coupon:	L064		
Test Matrix:	Pb-Go-0000-12-1p		
Initial wt (g)	35.8906	**Calculated final wt (g)**	35.8766
Removal wt (g)	35.8842	**Total wt loss (g)**	0.0140
		Total wt loss (mg)	14.0

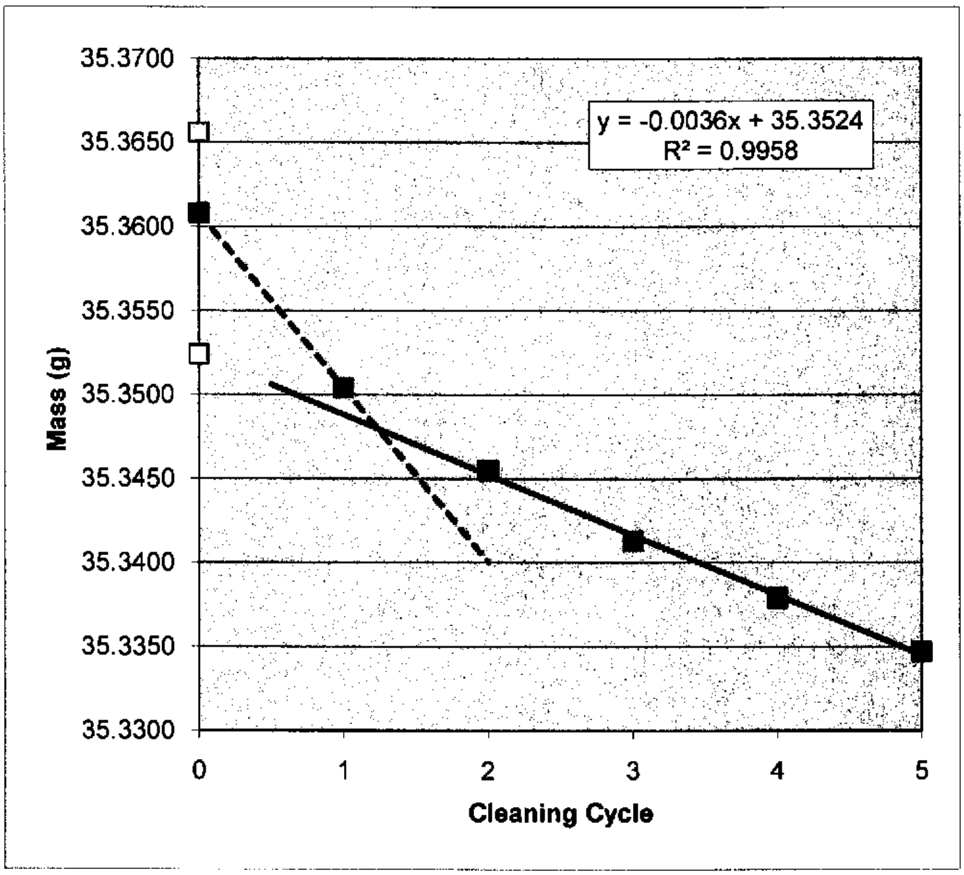
Cleaning Cycle	Wt (g)
0	35.8842
1	35.8756
2	35.8694
3	35.8640
4	35.8609
5	35.8574



Coupon:	L065
Test Matrix:	Pb-Go-0000-12-2p
Initial wt (g)	35.3656
Removal wt (g)	35.3608

Calculated final wt (g)	35.3524
Total wt loss (g)	0.0132
Total wt loss (mg)	13.2

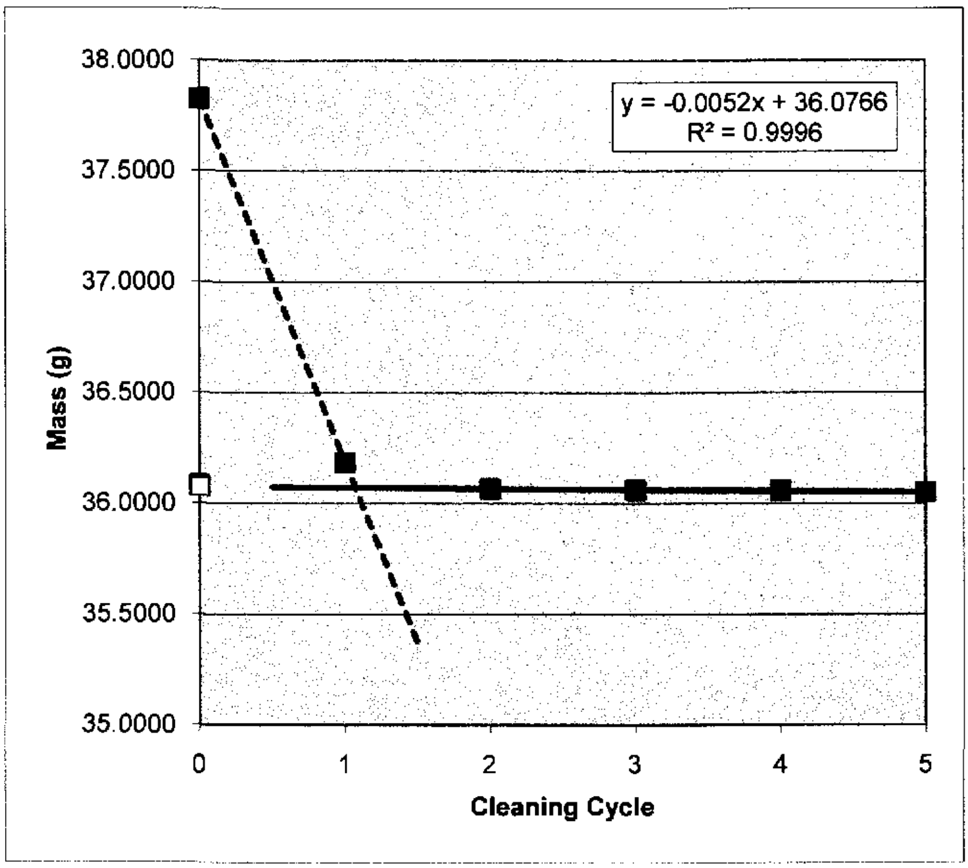
Cleaning Cycle	Wt (g)
0	35.3608
1	35.3504
2	35.3455
3	35.3413
4	35.3379
5	35.3347



Coupon:	L068
Test Matrix:	Pb-E-0000-12-2f
Initial wt (g)	36.0855
Removal wt (g)	37.8252

Calculated final wt (g)	36.0766
Total wt loss (g)	0.0089
Total wt loss (mg)	8.9

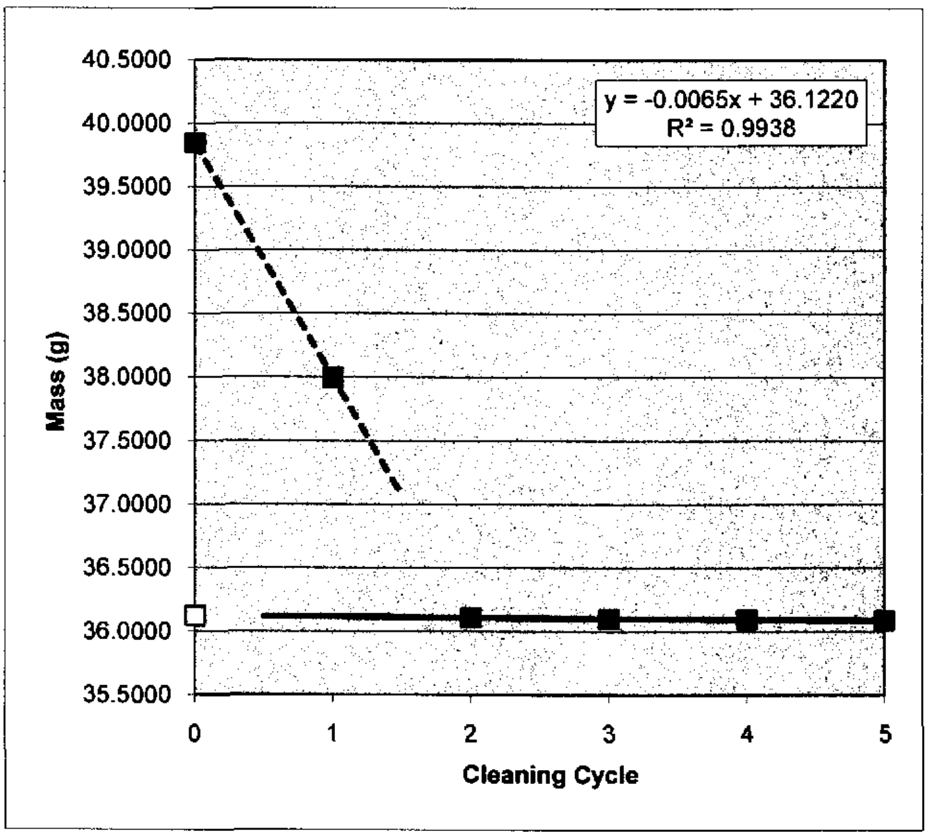
Cleaning Cycle	Wt (g)
0	37.8252
1	36.1842
2	36.0662
3	36.0608
4	36.0559
5	36.0505



Coupon:	L069
Test Matrix:	Pb-E-0000-12-3f
Initial wt (g)	36.1265
Removal wt (g)	39.8443

Calculated final wt (g)	36.1220
Total wt loss (g)	0.0045
Total wt loss (mg)	4.5

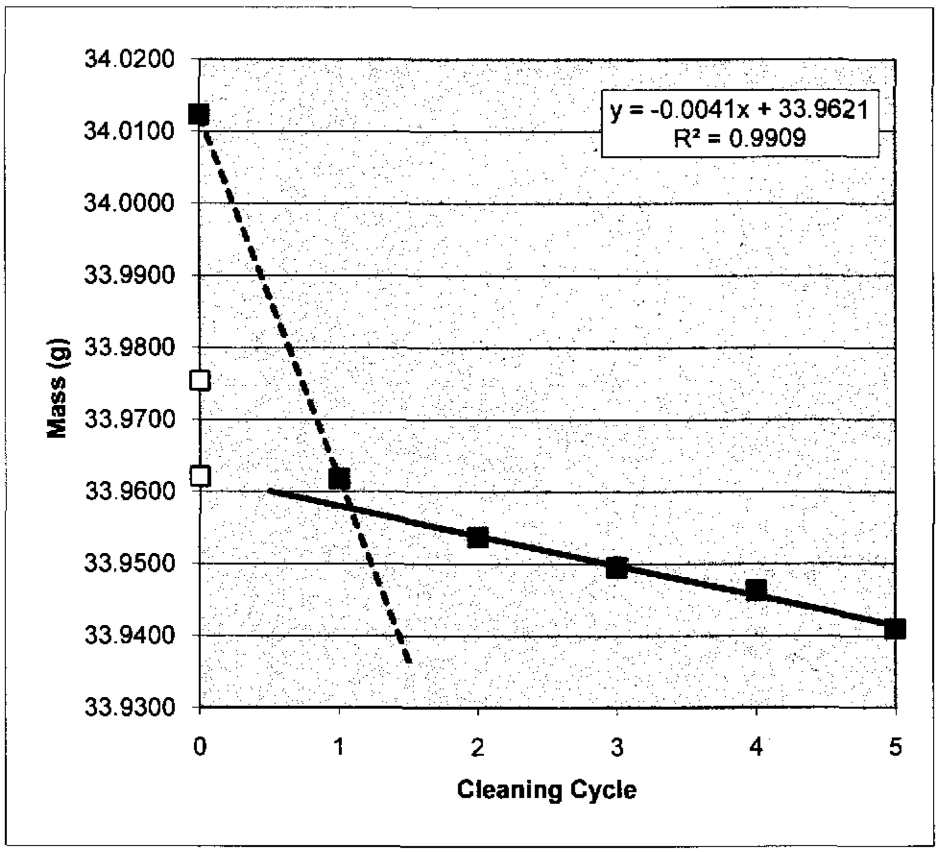
Cleaning Cycle	Wt (g)
0	39.8443
1	37.9960
2	36.1096
3	36.1016
4	36.0957
5	36.0898



Coupon:	L071
Test Matrix:	Pb-E-0000-12-2p
Initial wt (g)	33.9754
Removal wt (g)	34.0123

Calculated final wt (g)	33.9621
Total wt loss (g)	0.0133
Total wt loss (mg)	13.3

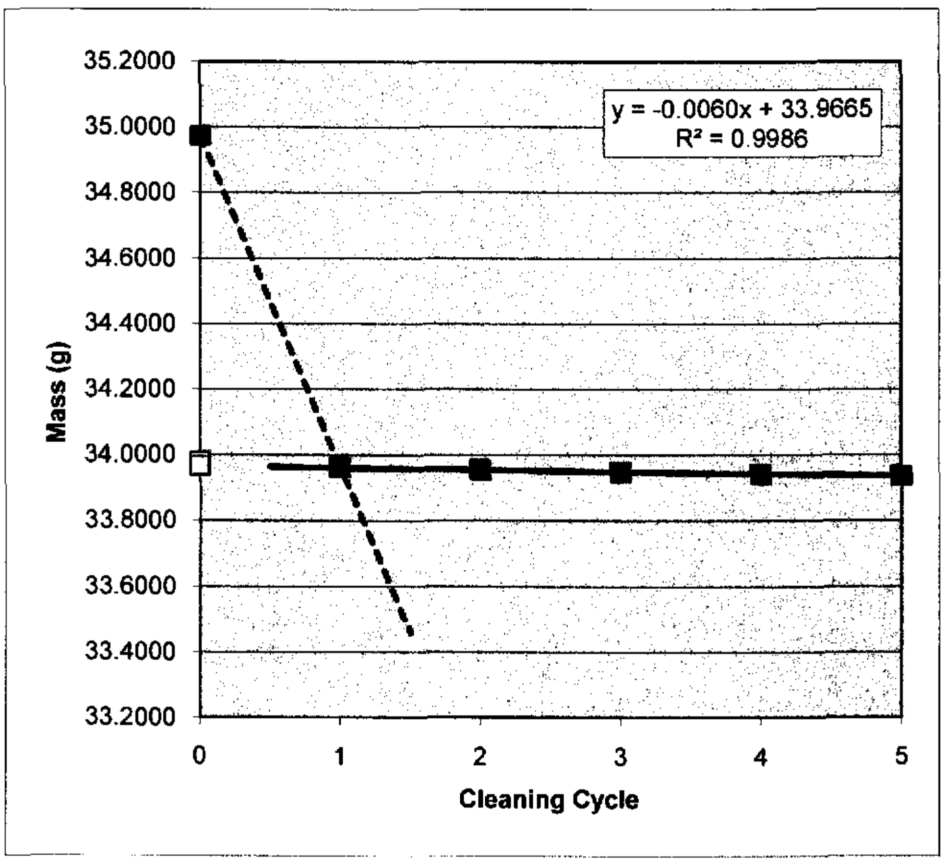
Cleaning Cycle	Wt (g)
0	34.0123
1	33.9618
2	33.9537
3	33.9495
4	33.9463
5	33.9410



Coupon:	L072
Test Matrix:	Pb-E-0000-12-3p
Initial wt (g)	33.9791
Removal wt (g)	34.9733

Calculated final wt (g)	33.9665
Total wt loss (g)	0.0126
Total wt loss (mg)	12.6

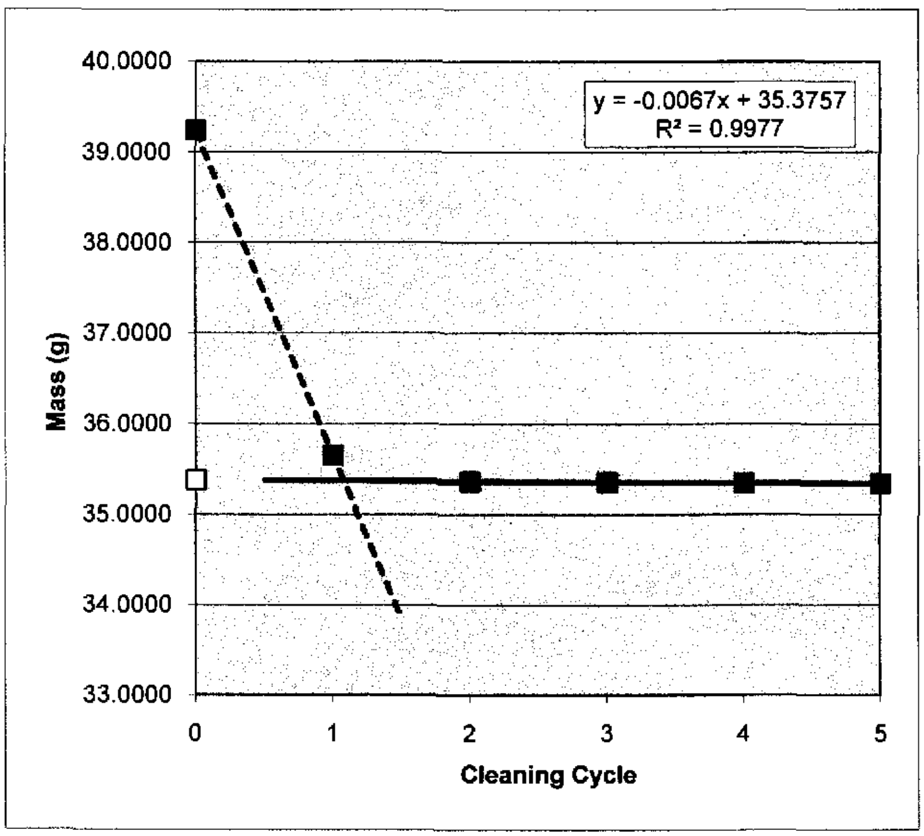
Cleaning Cycle	Wt (g)
0	34.9733
1	33.9629
2	33.9548
3	33.9484
4	33.9423
5	33.9369



Coupon:	L074
Test Matrix:	Pb-Eo-0000-12-2f
Initial wt (g)	35.3804
Removal wt (g)	39.2420

Calculated final wt (g)	35.3757
Total wt loss (g)	0.0047
Total wt loss (mg)	4.7

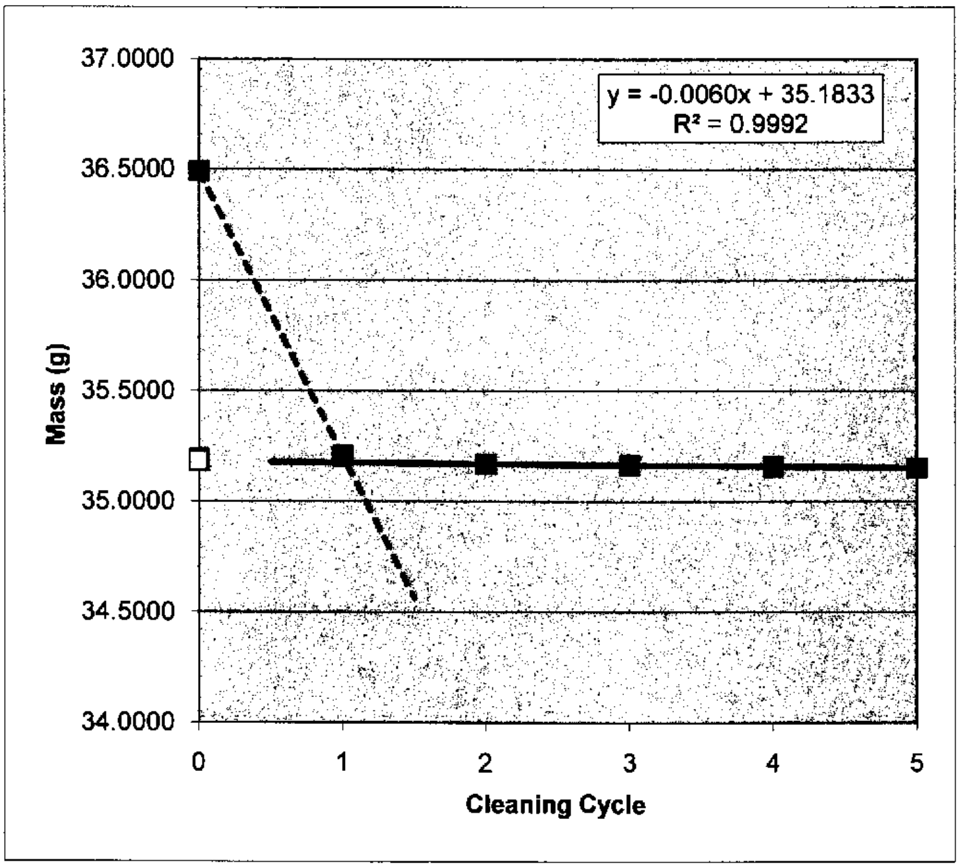
Cleaning Cycle	Wt (g)
0	39.2420
1	35.6538
2	35.3626
3	35.3557
4	35.3485
5	35.3428



Coupon:	L075
Test Matrix:	Pb-Eo-0000-12-3f
Initial wt (g)	35.1943
Removal wt (g)	36.4904

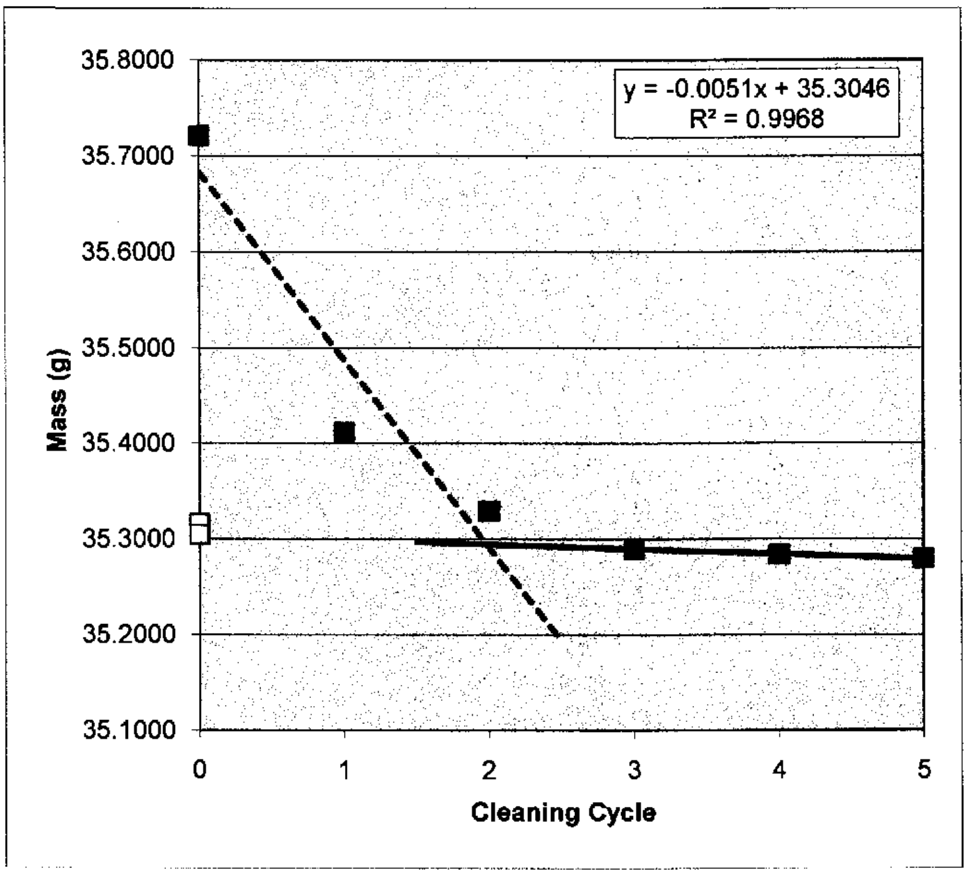
Calculated final wt (g)	35.1833
Total wt loss (g)	0.0110
Total wt loss (mg)	11.0

Cleaning Cycle	Wt (g)
0	36.4904
1	35.2068
2	35.1712
3	35.1651
4	35.1595
5	35.1530



Coupon:	L076		
Test Matrix:	Pb-Eo-0000-12-1p		
Initial wt (g)	35.3162	**Calculated final wt (g)**	35.3046
Removal wt (g)	35.7210	**Total wt loss (g)**	0.0116
		Total wt loss (mg)	11.6

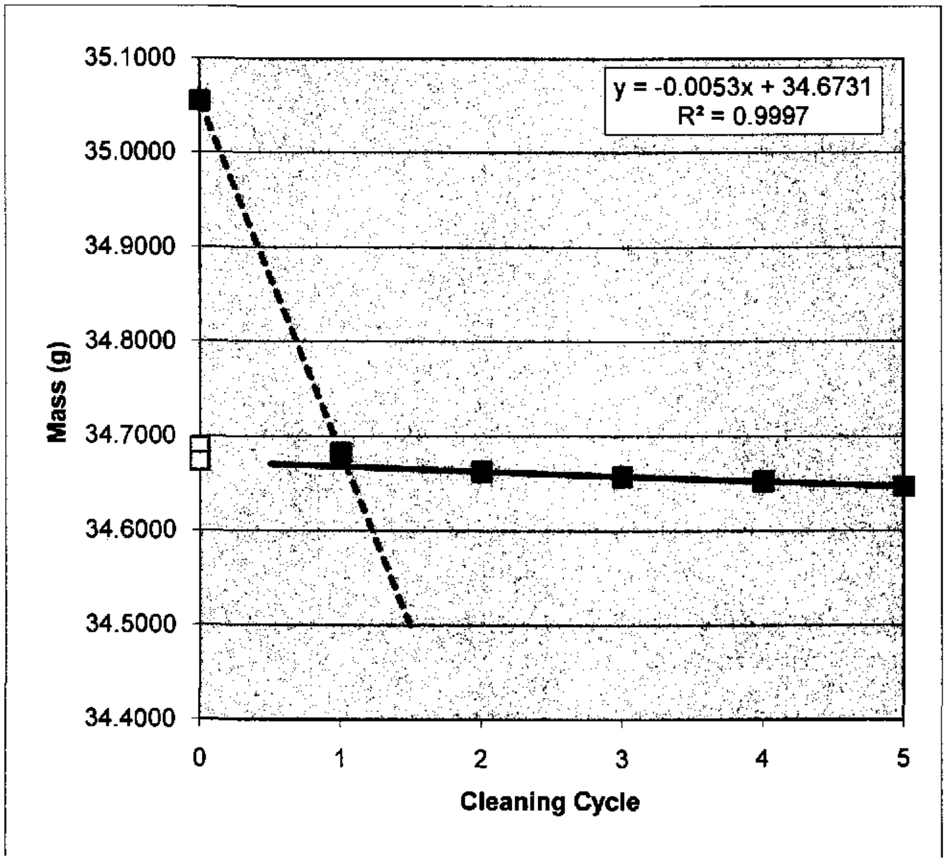
Cleaning Cycle	Wt (g)
0	35.7210
1	35.4117
2	35.3288
3	35.2895
4	35.2839
5	35.2793



Coupon:	L077
Test Matrix:	Pb-Eo-0000-12-2p
Initial wt (g)	34.6883
Removal wt (g)	35.0543

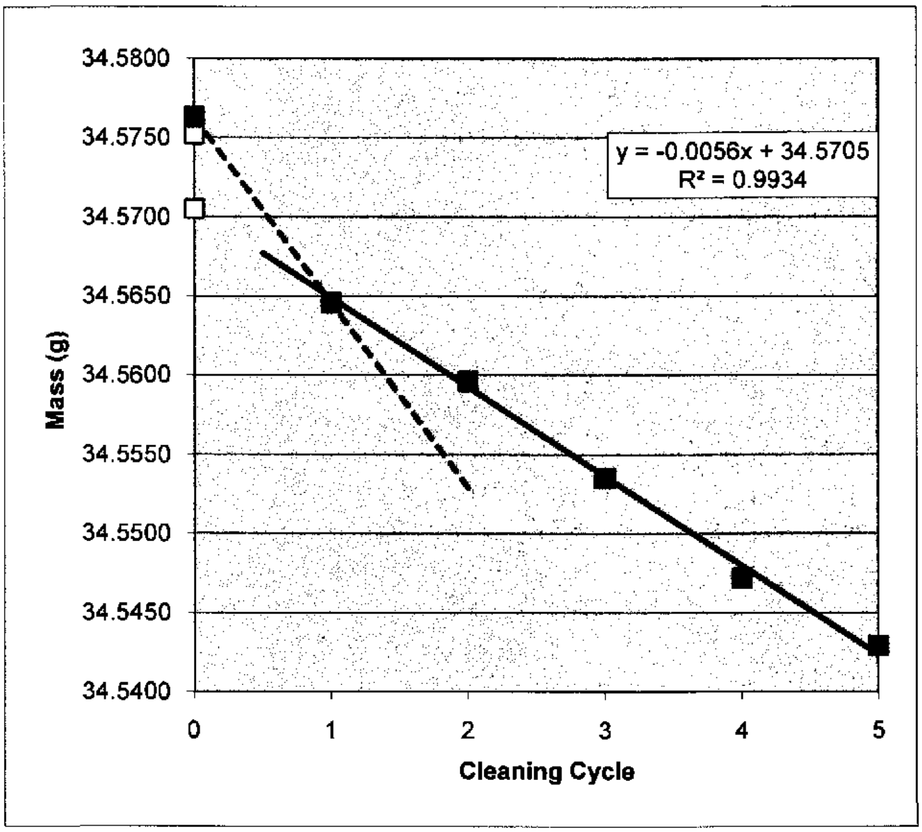
Calculated final wt (g)	34.6731
Total wt loss (g)	0.0152
Total wt loss (mg)	15.2

Cleaning Cycle	Wt (g)
0	35.0543
1	34.6824
2	34.6627
3	34.6572
4	34.6520
5	34.6469



Coupon:	L079			
Test Matrix:	Pb-Atm-0000-12-1			
Initial wt (g)	34.5752		**Calculated final wt (g)**	34.5705
Removal wt (g)	34.5763		**Total wt loss (g)**	0.0047
			Total wt loss (mg)	4.7

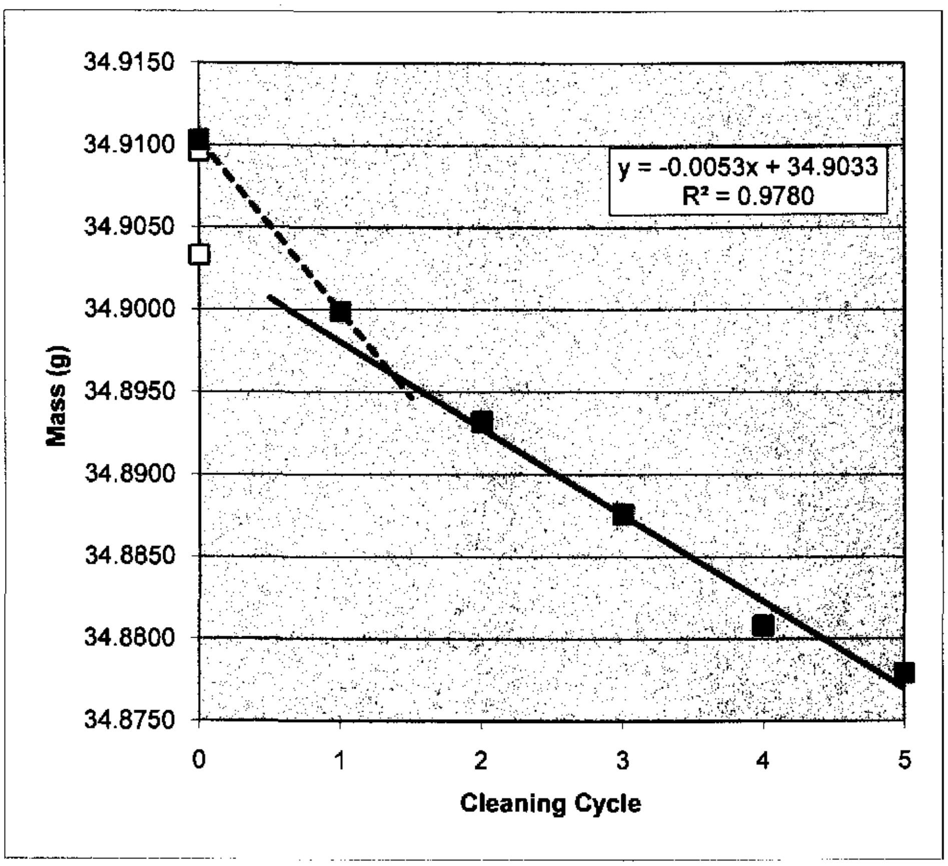
Cleaning Cycle	Wt (g)
0	34.5763
1	34.5646
2	34.5596
3	34.5535
4	34.5472
5	34.5429



Coupon:	L080
Test Matrix:	Pb-Atm-0000-12-2
Initial wt (g)	34.9096
Removal wt (g)	34.9103

Calculated final wt (g)	34.9033
Total wt loss (g)	0.0063
Total wt loss (mg)	6.3

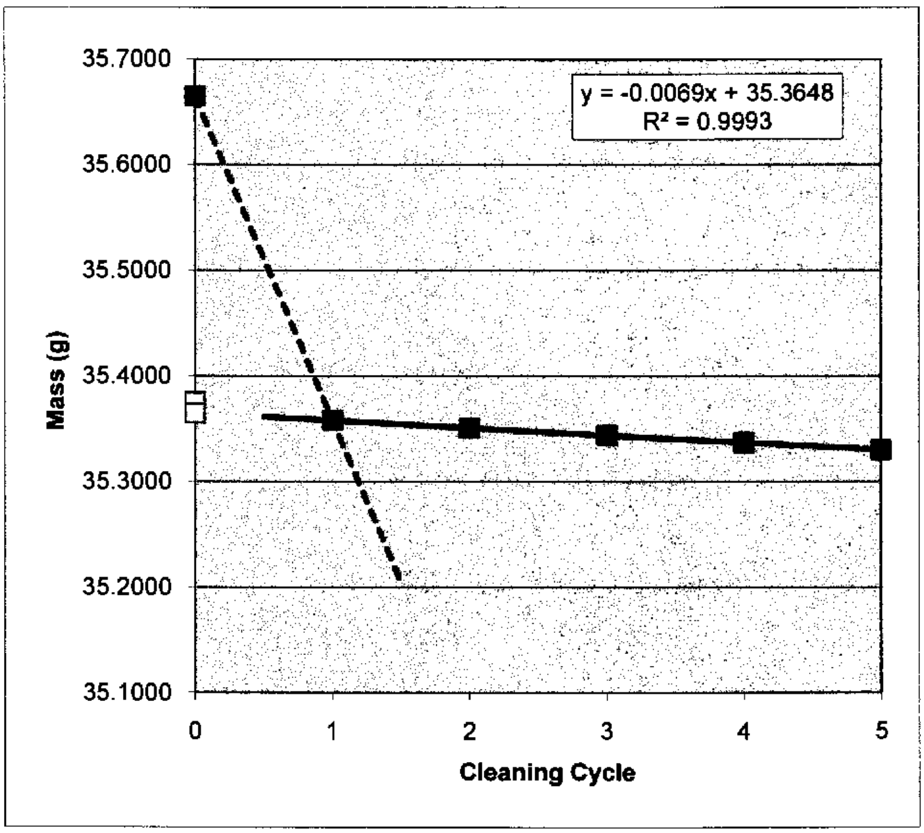
Cleaning Cycle	Wt (g)
0	34.9103
1	34.8999
2	34.8932
3	34.8876
4	34.8808
5	34.8779



Coupon:	L190
Test Matrix:	Pb-G-0350-12-1f
Initial wt (g)	35.3755
Removal wt (g)	35.6646

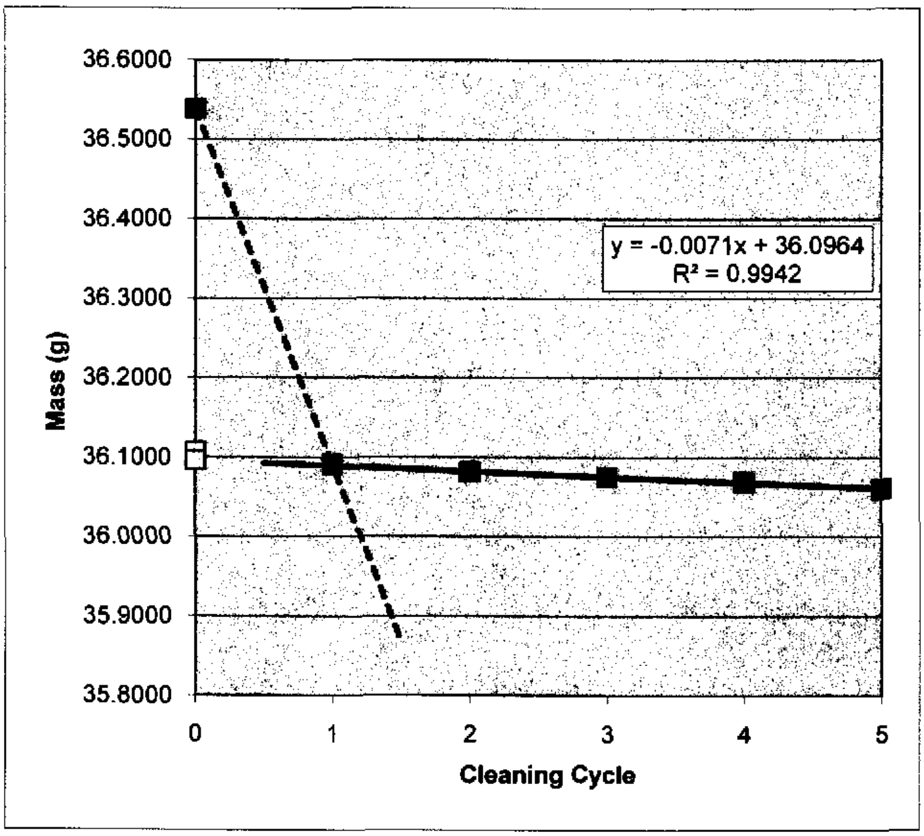
Calculated final wt (g)	35.3648
Total wt loss (g)	0.0107
Total wt loss (mg)	10.7

Cleaning Cycle	Wt (g)
0	35.6646
1	35.3582
2	35.3507
3	35.3443
4	35.3371
5	35.3300



Coupon:	L191			
Test Matrix:	Pb-G-0350-12-2f			
Initial wt (g)	36.1066		**Calculated final wt (g)**	36.0964
Removal wt (g)	36.5388		**Total wt loss (g)**	0.0102
			Total wt loss (mg)	10.2

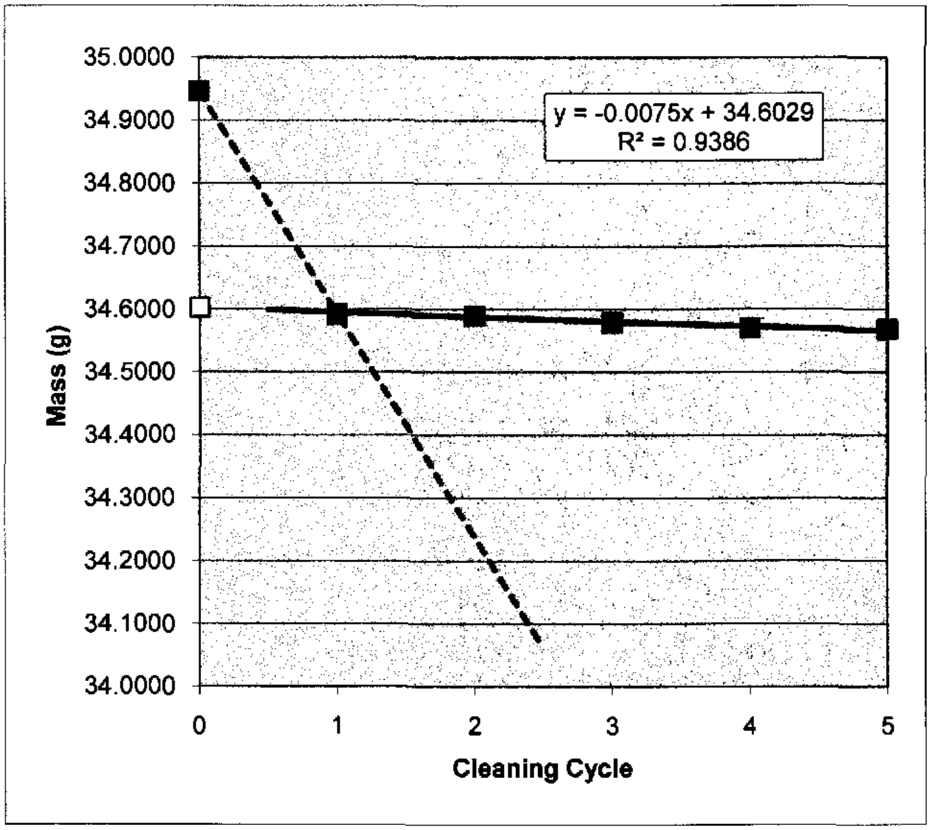
Cleaning Cycle	Wt (g)
0	36.5388
1	36.0910
2	36.0817
3	36.0754
4	36.0688
5	36.0602



Coupon: L194
Test Matrix: Pb-G-0350-12-2p
Initial wt (g) 34.6025
Removal wt (g) 34.9466

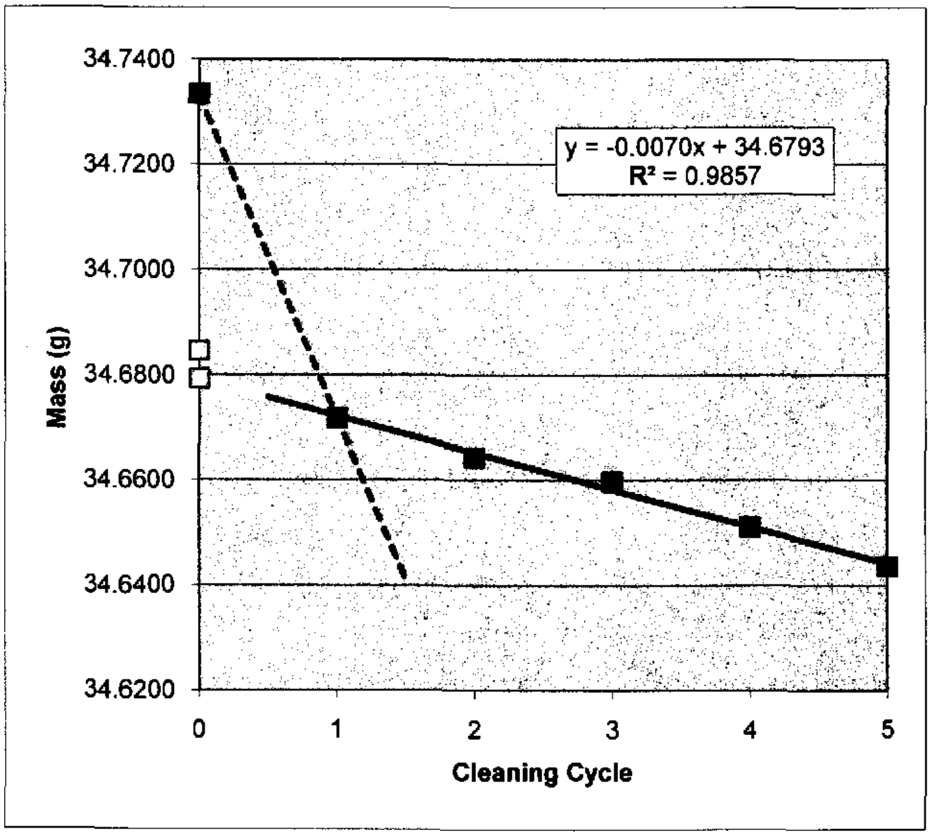
Calculated final wt (g) 34.6029
Total wt loss (g) -0.0004
Total wt loss (mg) -0.4

Cleaning Cycle	Wt (g)
0	34.9466
1	34.5923
2	34.5897
3	34.5794
4	34.5701
5	34.5679



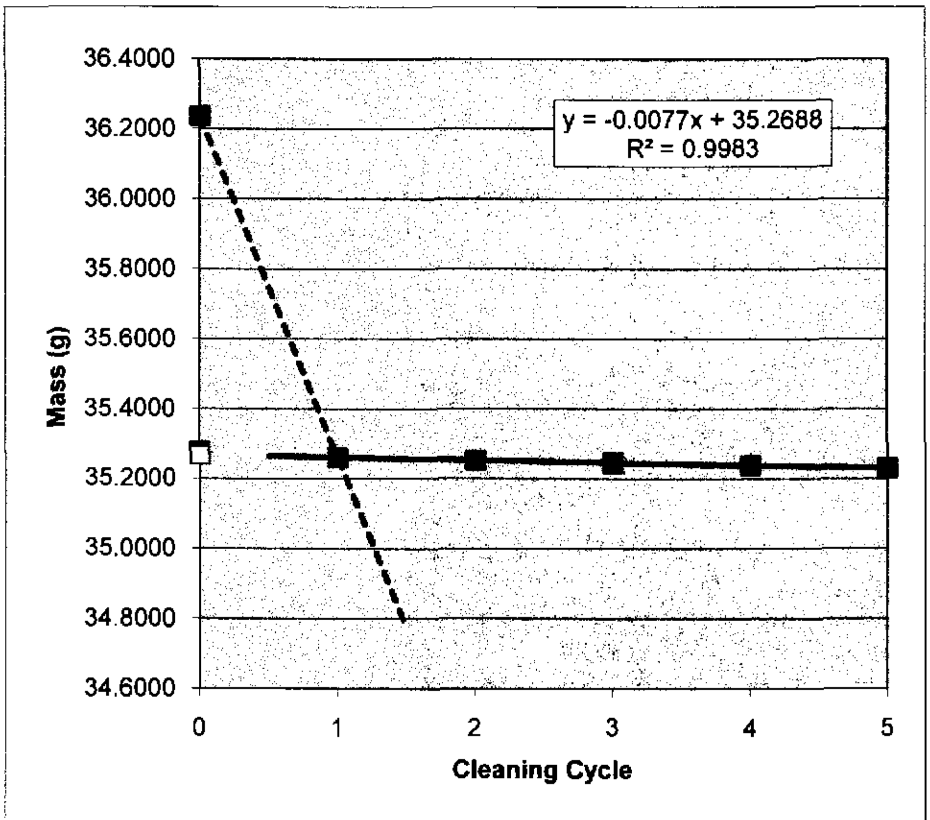
Coupon:	L195		
Test Matrix:	Pb-G-0350-12-3p		
Initial wt (g)	34.6846	**Calculated final wt (g)**	34.6793
Removal wt (g)	34.7334	**Total wt loss (g)**	0.0053
		Total wt loss (mg)	5.3

Cleaning Cycle	Wt (g)
0	34.7334
1	34.6718
2	34.6642
3	34.6597
4	34.6511
5	34.6436



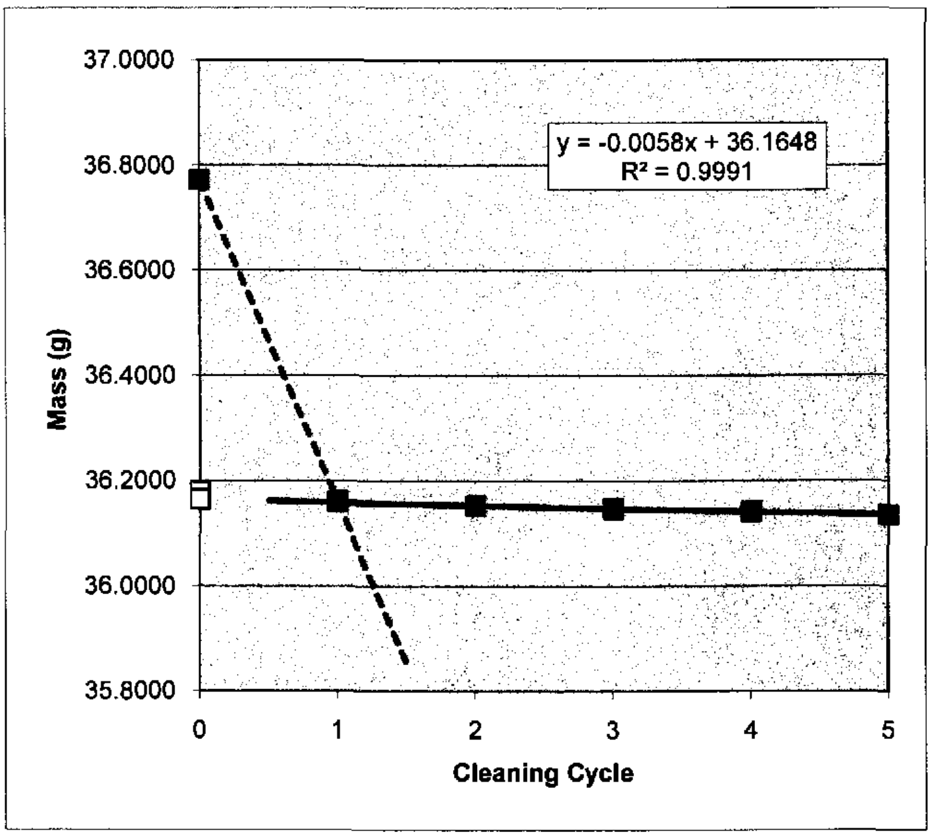
Coupon:	L196		
Test Matrix:	Pb-Go-0350-12-1f		
Initial wt (g)	35.2779	**Calculated final wt (g)**	35.2688
Removal wt (g)	36.2364	**Total wt loss (g)**	0.0091
		Total wt loss (mg)	9.1

Cleaning Cycle	Wt (g)
0	36.2364
1	35.2606
2	35.2532
3	35.2458
4	35.2386
5	35.2300



Coupon:	L198		
Test Matrix:	Pb-Go-0350-12-3f		
Initial wt (g)	36.1804	**Calculated final wt (g)**	36.1648
Removal wt (g)	36.7718	**Total wt loss (g)**	0.0156
		Total wt loss (mg)	15.6

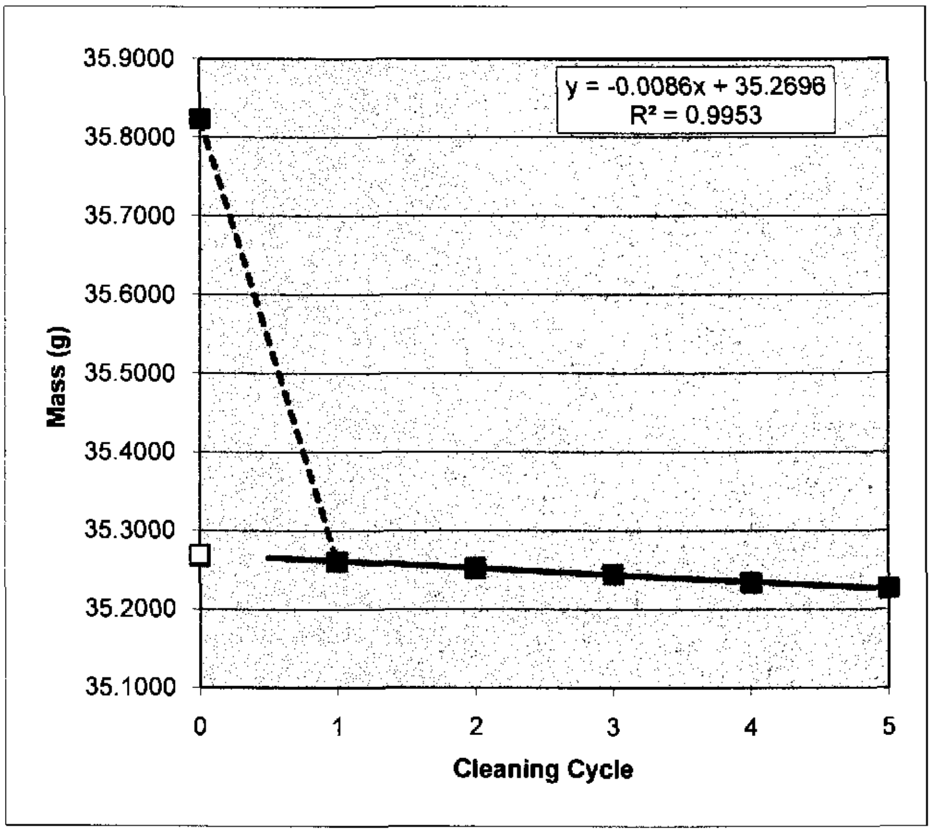
Cleaning Cycle	Wt (g)
0	36.7718
1	36.1607
2	36.1532
3	36.1470
4	36.1417
5	36.1355



Coupon:	L199
Test Matrix:	Pb-Go-0350-12-1p
Initial wt (g)	35.2663
Removal wt (g)	35.8238

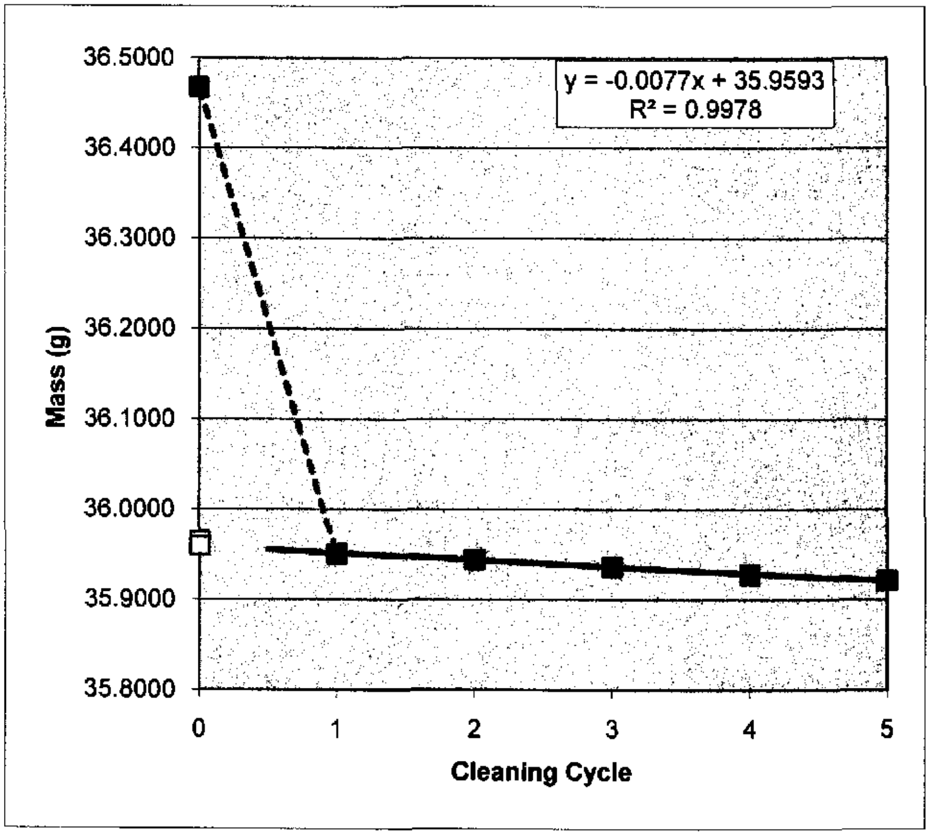
Calculated final wt (g)	35.2696
Total wt loss (g)	-0.0033
Total wt loss (mg)	-3.3

Cleaning Cycle	Wt (g)
0	35.8238
1	35.2601
2	35.2523
3	35.2445
4	35.2342
5	35.2271



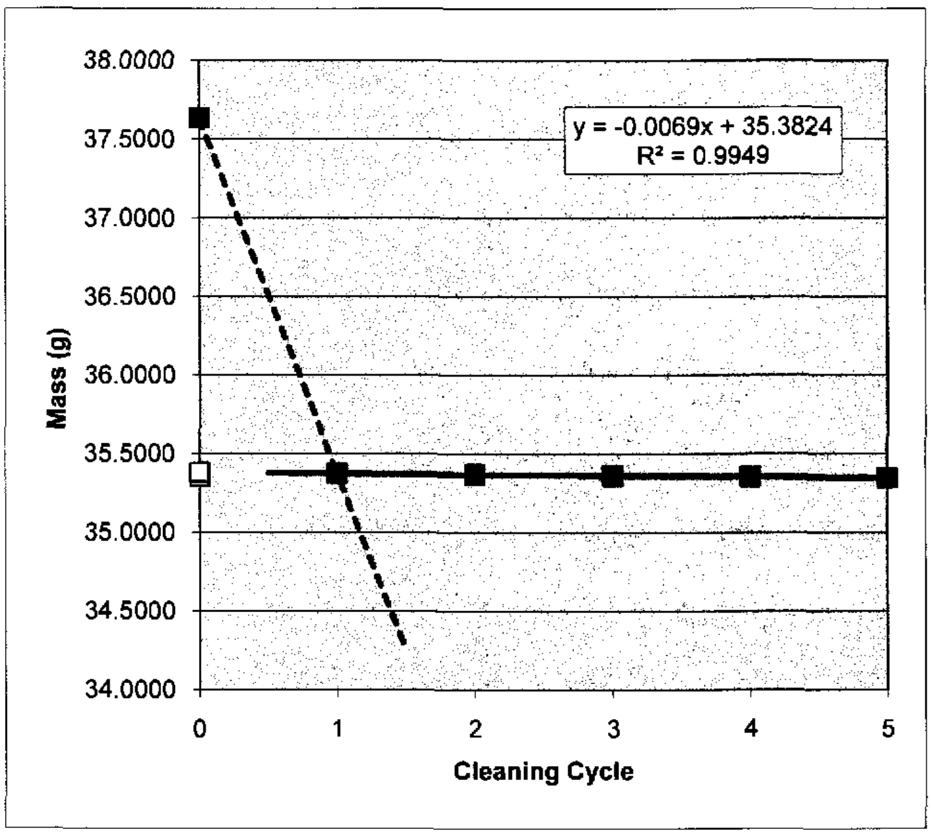
Coupon:	L200		
Test Matrix:	Pb-Go-0350-12-2p		
Initial wt (g)	35.9647	**Calculated final wt (g)**	35.9593
Removal wt (g)	36.4675	**Total wt loss (g)**	0.0054
		Total wt loss (mg)	5.4

Cleaning Cycle	Wt (g)
0	36.4675
1	35.9506
2	35.9441
3	35.9363
4	35.9279
5	35.9213



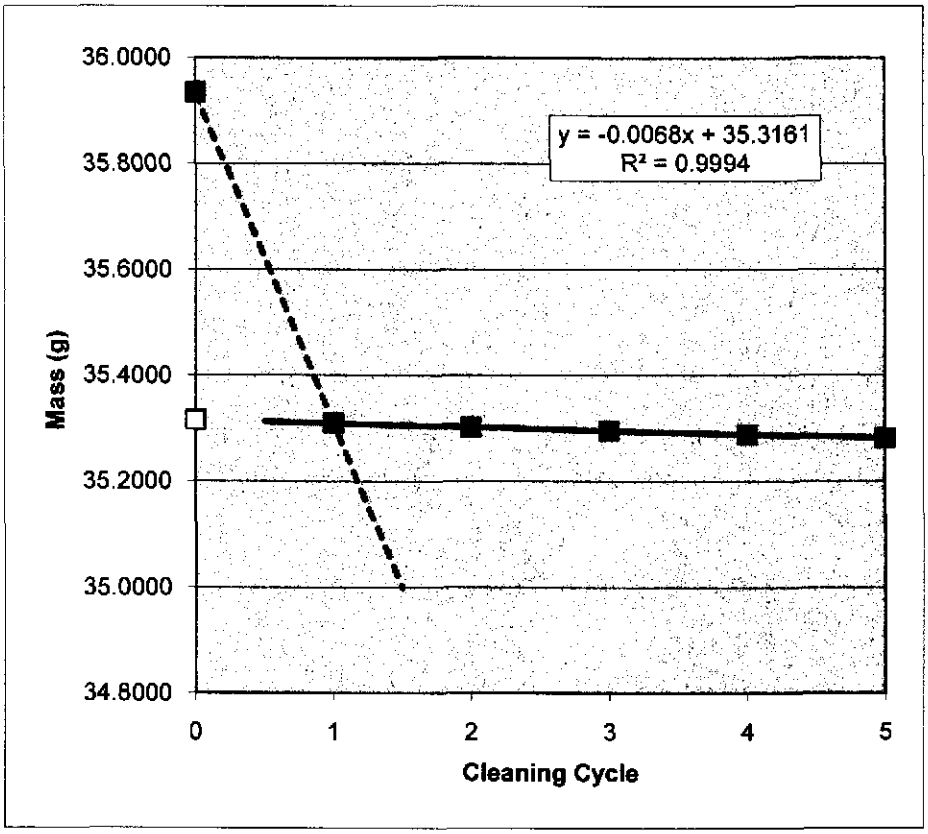
Coupon:	L203		
Test Matrix:	Pb-E-0350-12-2f		
Initial wt (g)	35.3566	**Calculated final wt (g)**	35.3824
Removal wt (g)	37.6349	**Total wt loss (g)**	-0.0258
		Total wt loss (mg)	-25.8

Cleaning Cycle	Wt (g)
0	37.6349
1	35.3763
2	35.3691
3	35.3611
4	35.3542
5	35.3484



Coupon:	L204			
Test Matrix:	Pb-E-0350-12-3f			
Initial wt (g)	35.3174		**Calculated final wt (g)**	35.3161
Removal wt (g)	35.9349		**Total wt loss (g)**	0.0013
			Total wt loss (mg)	1.3

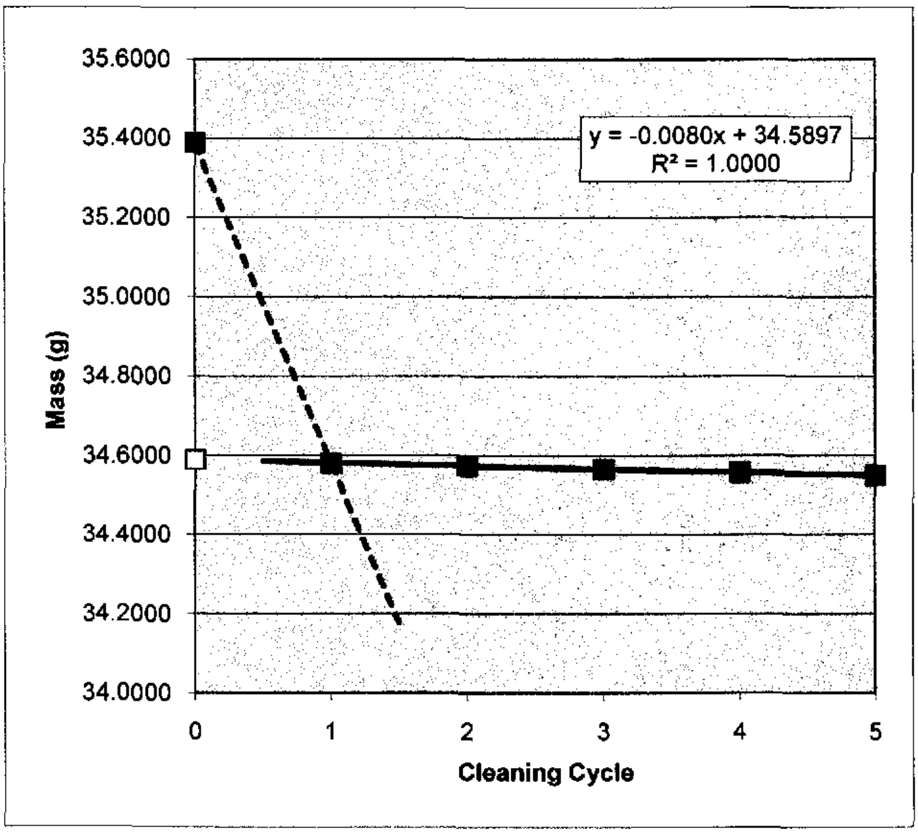
Cleaning Cycle	Wt (g)
0	35.9349
1	35.3105
2	35.3024
3	35.2961
4	35.2889
5	35.2822



Coupon:	L205
Test Matrix:	Pb-E-0350-12-1p
Initial wt (g)	34.5903
Removal wt (g)	35.3881

Calculated final wt (g)	34.5897
Total wt loss (g)	0.0006
Total wt loss (mg)	0.6

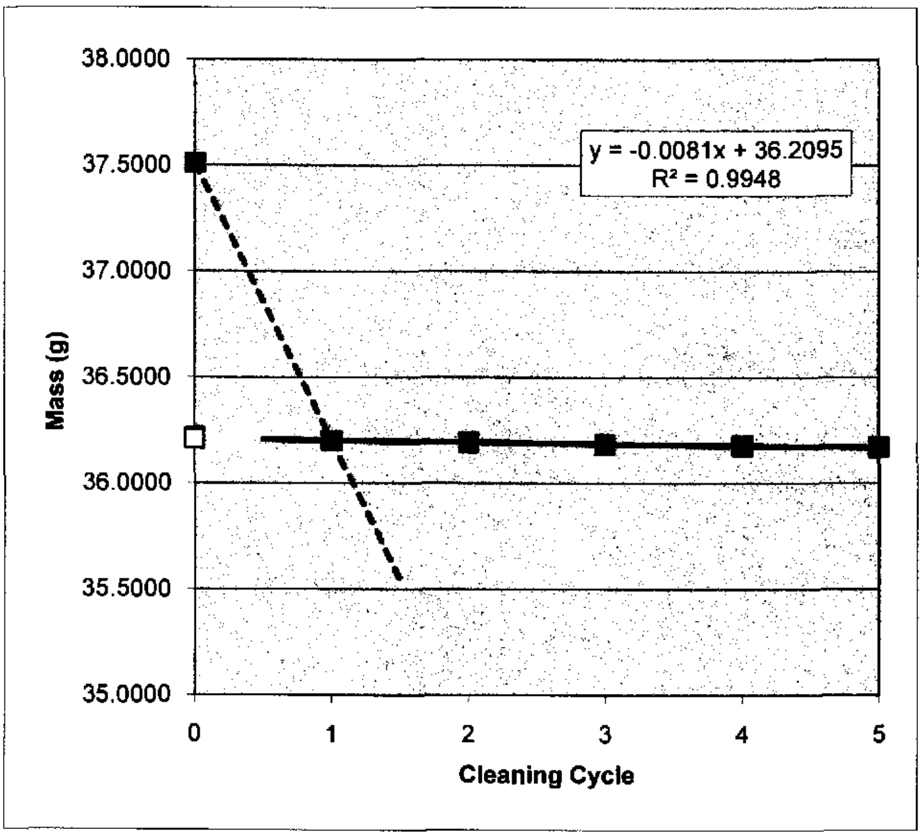
Cleaning Cycle	Wt (g)
0	35.3881
1	34.5802
2	34.5737
3	34.5656
4	34.5575
5	34.5496



Coupon:	L207
Test Matrix:	Pb-E-0350-12-3p
Initial wt (g)	36.2173
Removal wt (g)	37.5112

Calculated final wt (g)	36.2095
Total wt loss (g)	0.0078
Total wt loss (mg)	7.8

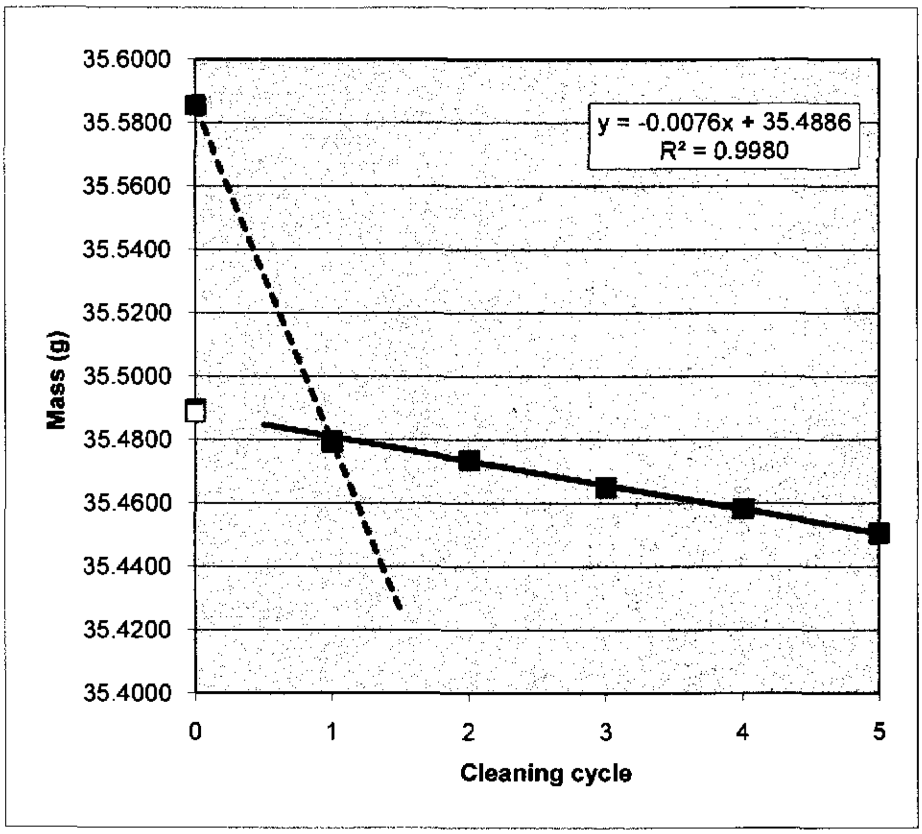
Cleaning Cycle	Wt (g)
0	37.5112
1	36.2004
2	36.1940
3	36.1842
4	36.1774
5	36.1694



Coupon:	209
Test Matrix:	Pb-Eo-0350-12-2f
Initial wt (g)	35.4896
Removal wt (g)	35.5855

Calculated final wt (g)	35.4886
Total wt loss (g)	0.0010
Total wt loss (mg)	1.0

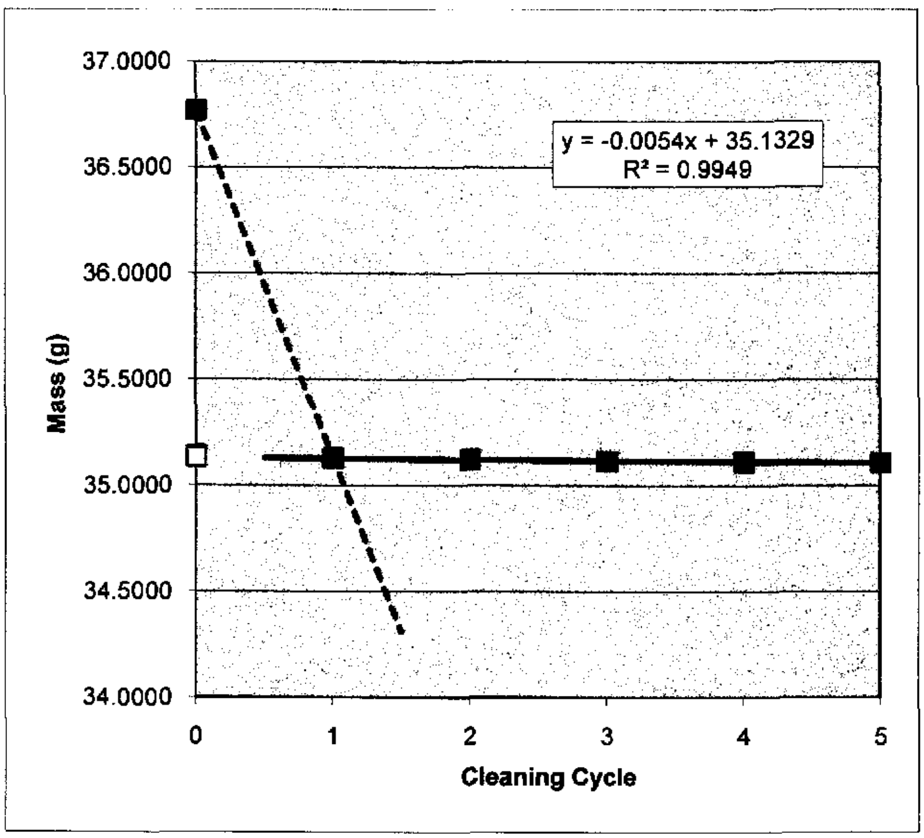
Cleaning Cycle	Wt (g)
0	35.5855
1	35.4794
2	35.4737
3	35.4651
4	35.4583
5	35.4506



Coupon:	L210
Test Matrix:	Pb-Eo-0350-12-3f
Initial wt (g)	35.1431
Removal wt (g)	36.7687

Calculated final wt (g)	35.1329
Total wt loss (g)	0.0102
Total wt loss (mg)	10.2

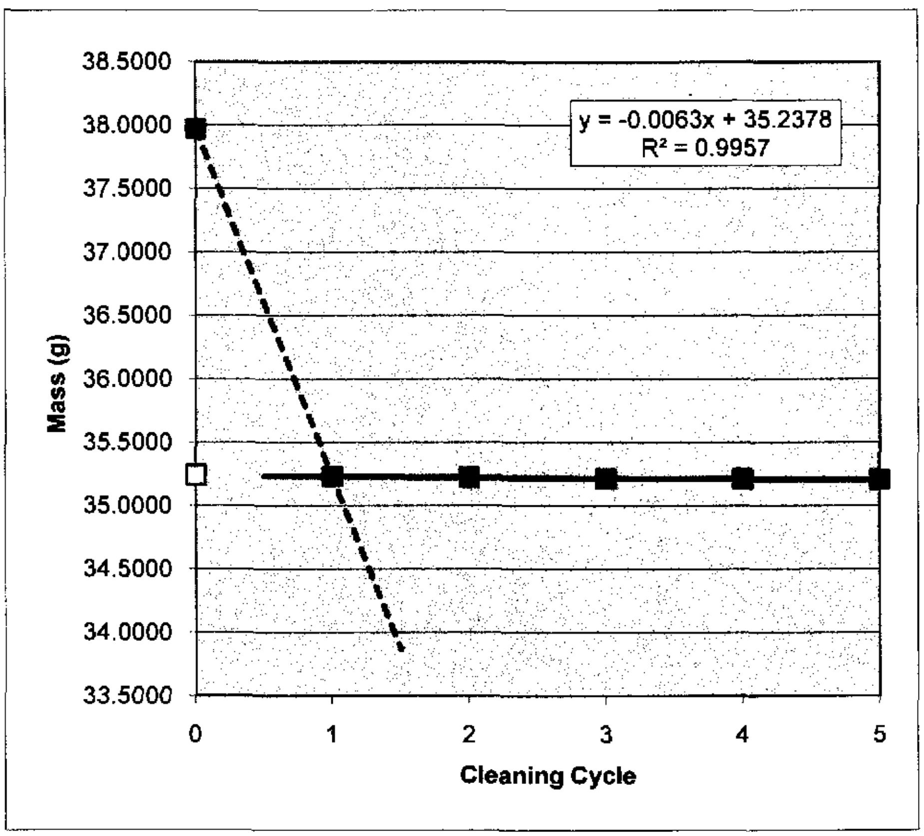
Cleaning Cycle	Wt (g)
0	36.7687
1	35.1292
2	35.1226
3	35.1161
4	35.1114
5	35.1063



Coupon:	L211
Test Matrix:	Pb-Eo-0350-12-1p
Initial wt (g)	35.2497
Removal wt (g)	37.9677

Calculated final wt (g)	35.2378
Total wt loss (g)	0.0119
Total wt loss (mg)	11.9

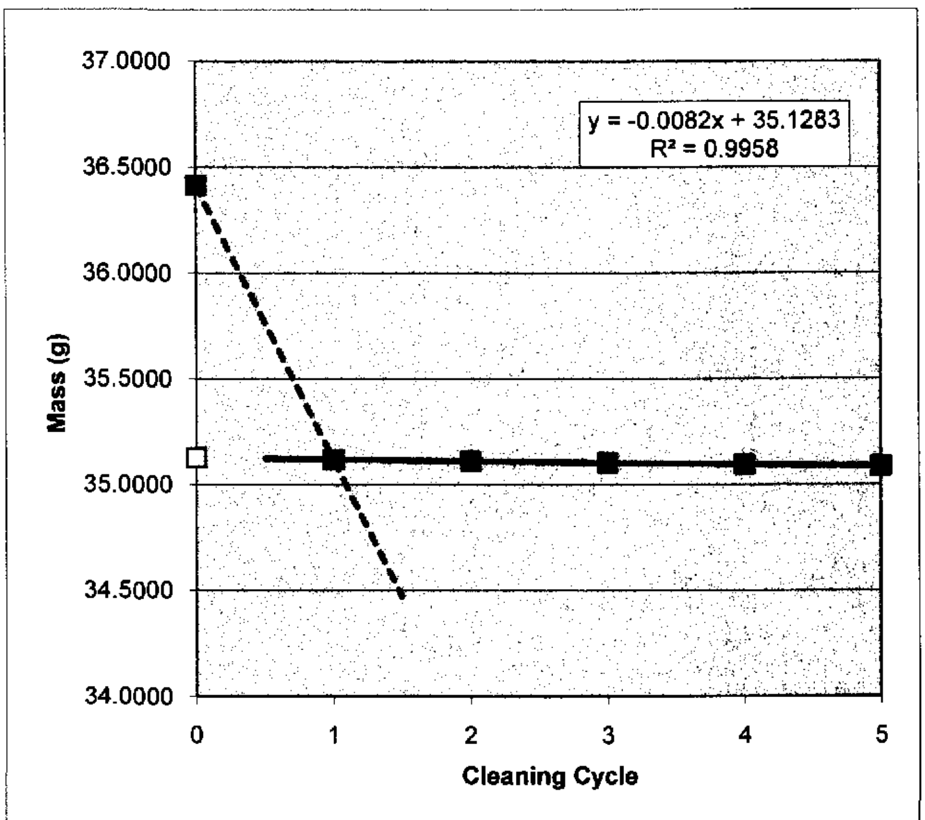
Cleaning Cycle	Wt (g)
0	37.9677
1	35.2324
2	35.2258
3	35.2184
4	35.2126
5	35.2069



Coupon:	L212
Test Matrix:	Pb-Eo-0350-12-2p
Initial wt (g)	35.1299
Removal wt (g)	36.4140

Calculated final wt (g)	35.1283
Total wt loss (g)	0.0016
Total wt loss (mg)	1.6

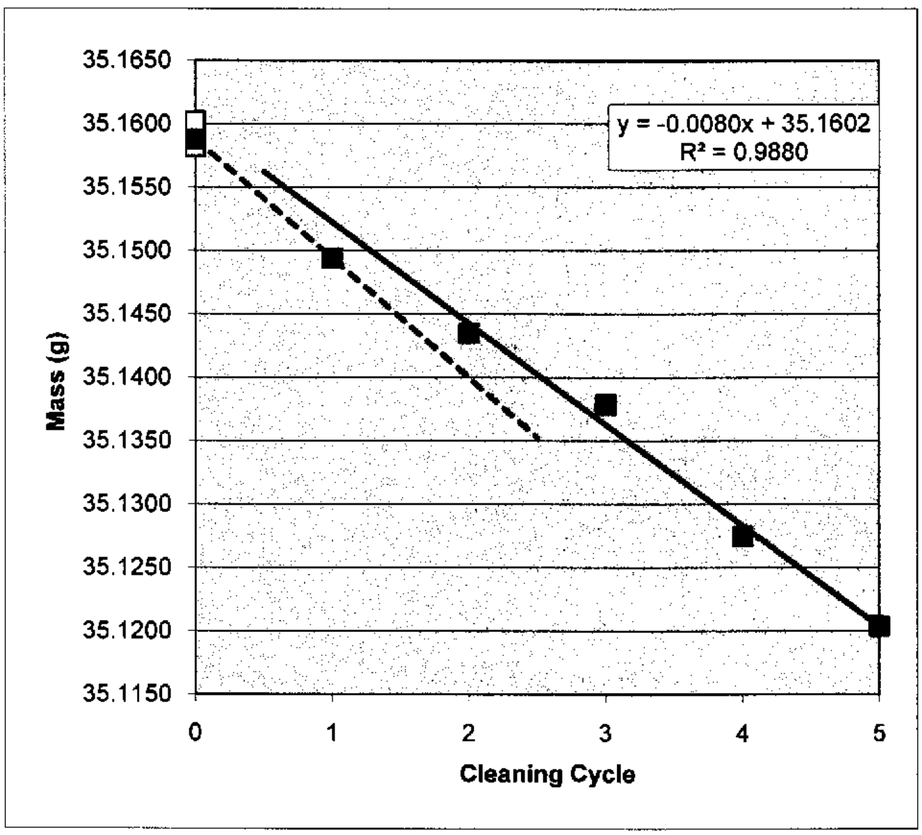
Cleaning Cycle	Wt (g)
0	36.4140
1	35.1188
2	35.1119
3	35.1040
4	35.0944
5	35.0877



Coupon:	L214
Test Matrix:	Pb-Atm-0350-12-1
Initial wt (g)	35.1582
Removal wt (g)	35.1588

Calculated final wt (g)	35.1602
Total wt loss (g)	-0.0020
Total wt loss (mg)	-2.0

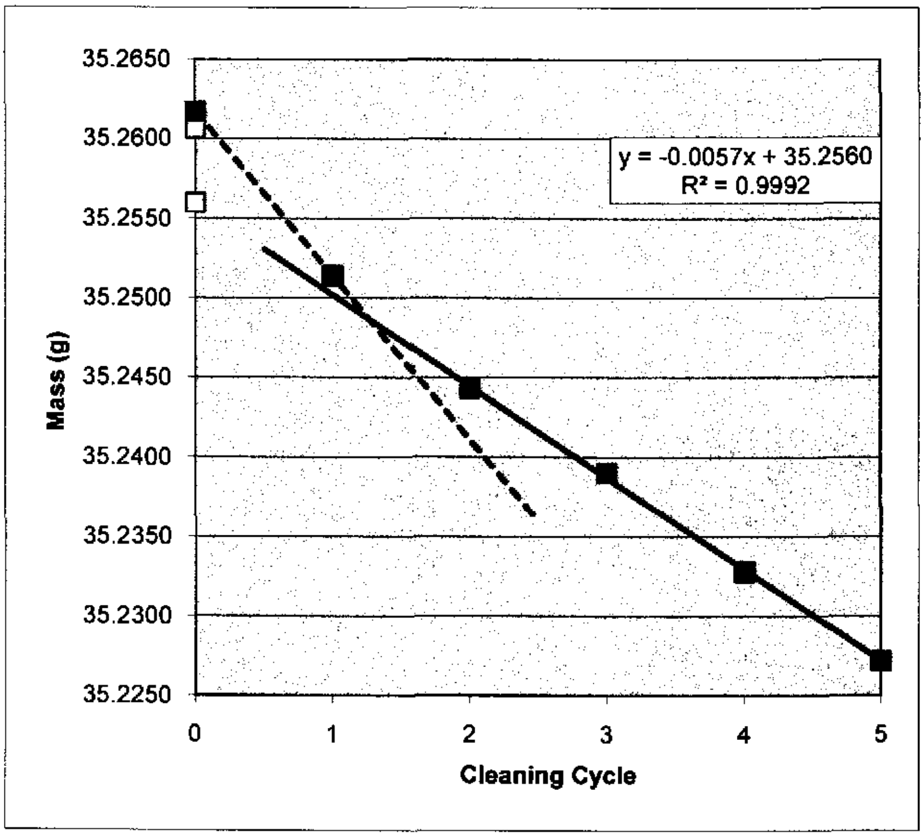
Cleaning Cycle	**Wt (g)**
0	35.1588
1	35.1494
2	35.1435
3	35.1379
4	35.1275
5	35.1204



Coupon: L215
Test Matrix: Pb-Atm-0350-12-2
Initial wt (g) 35.2606
Removal wt (g) 35.2617

Calculated final wt (g) 35.2560
Total wt loss (g) 0.0046
Total wt loss (mg) 4.6

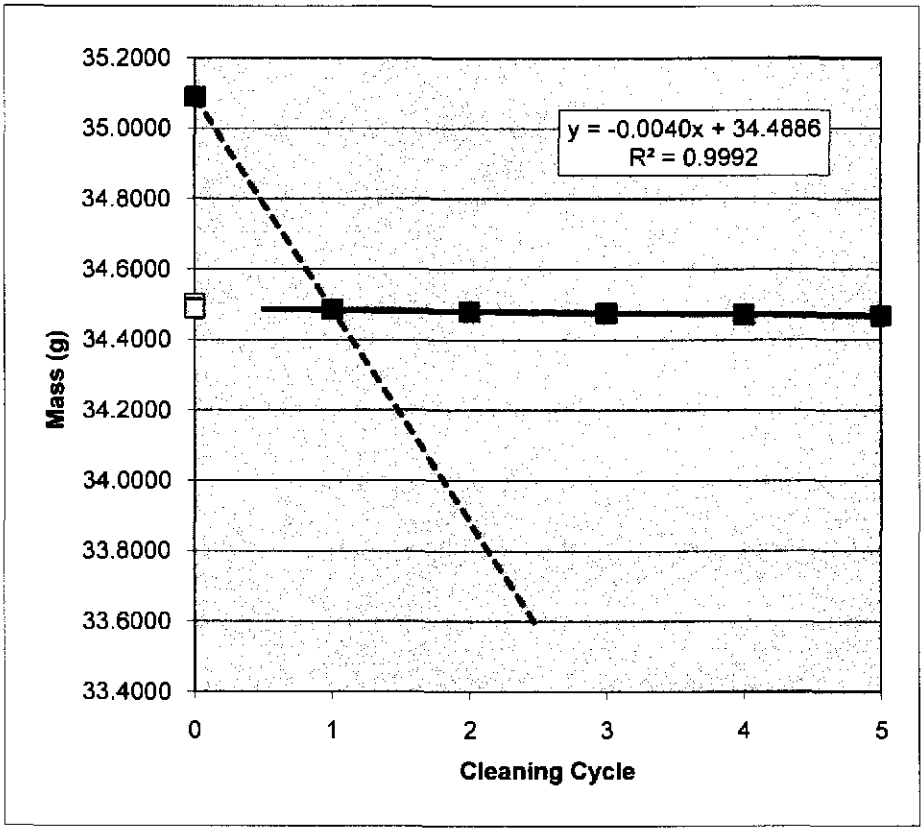
Cleaning Cycle	Wt (g)
0	35.2617
1	35.2514
2	35.2443
3	35.2390
4	35.2328
5	35.2272



Coupon:	L272
Test Matrix:	Pb-G-1500-12-2f
Initial wt (g)	34.5033
Removal wt (g)	35.0895

Calculated final wt (g)	34.4886
Total wt loss (g)	0.0147
Total wt loss (mg)	14.7

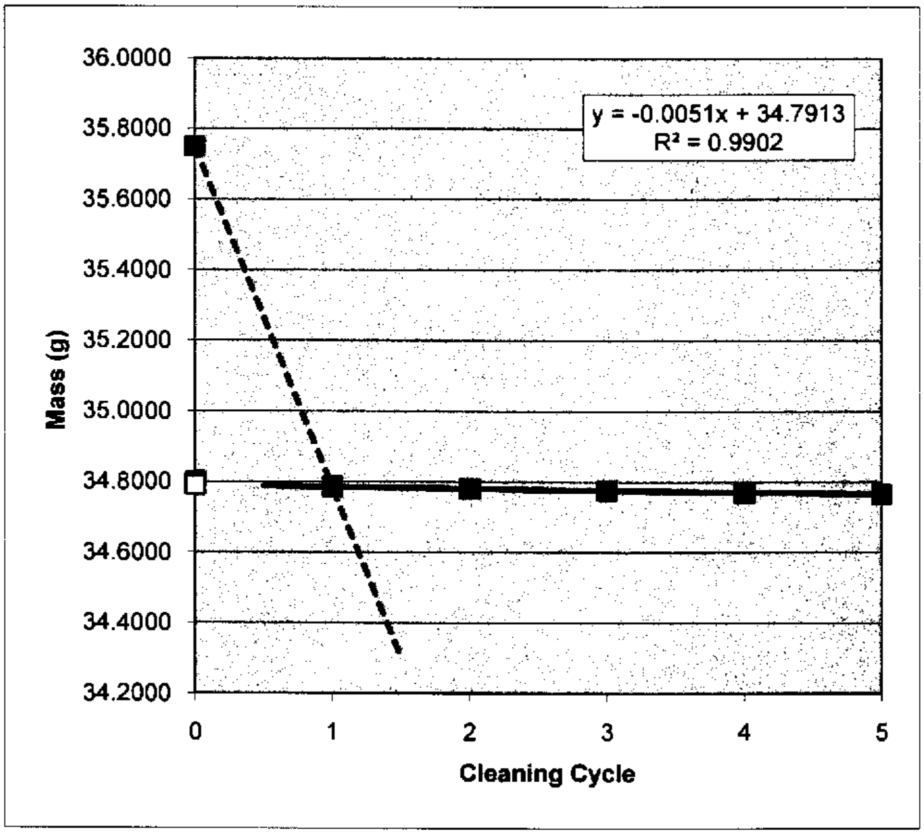
Cleaning Cycle	Wt (g)
0	35.0895
1	34.4867
2	34.4804
3	34.4767
4	34.4724
5	34.4684



Coupon:	L273
Test Matrix:	Pb-G-1500-12-3f
Initial wt (g)	34.8008
Removal wt (g)	35.7497

Calculated final wt (g)	34.7913
Total wt loss (g)	0.0096
Total wt loss (mg)	9.6

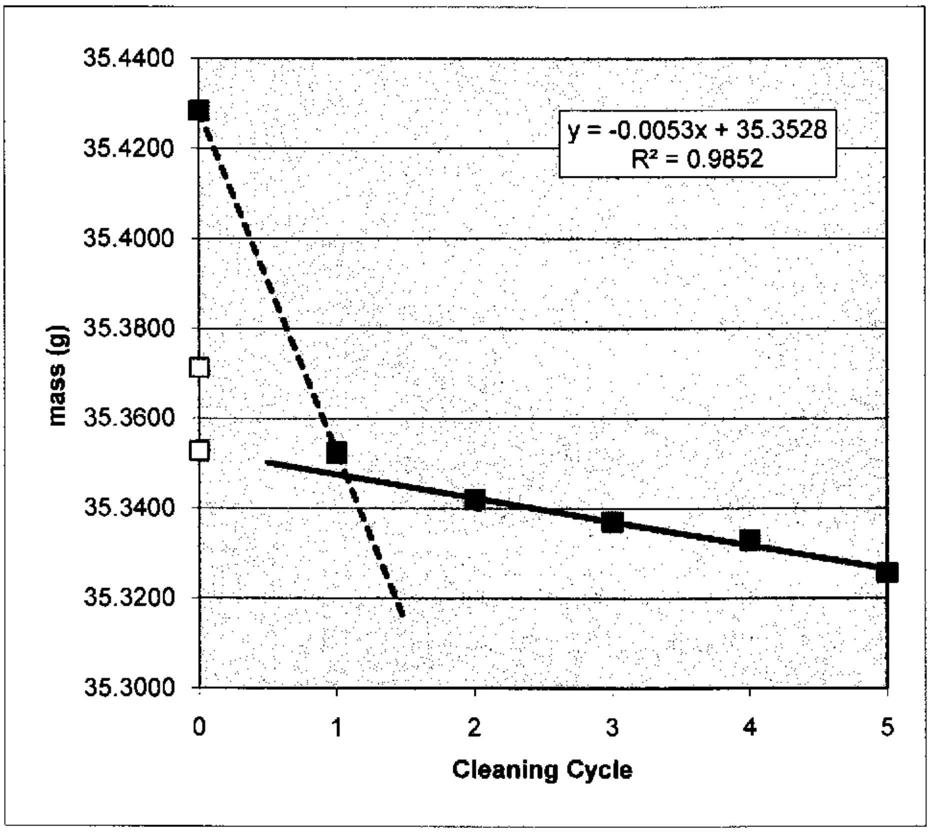
Cleaning Cycle	Wt (g)
0	35.7497
1	34.7862
2	34.7810
3	34.7762
4	34.7697
5	34.7660



Coupon:	L275
Test Matrix:	Pb-G-1500-12-2p
Initial wt (g)	35.3713
Removal wt (g)	35.4284

Calculated final wt (g)	35.3528
Total wt loss (g)	0.0185
Total wt loss (mg)	18.5

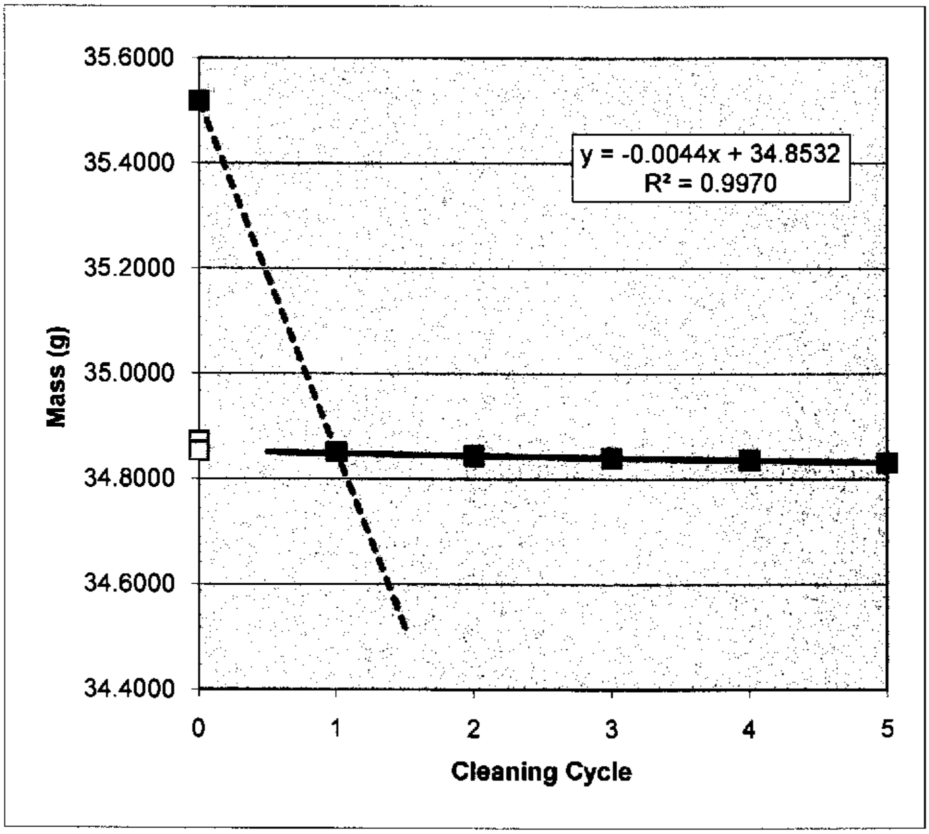
Cleaning Cycle	Wt (g)
0	35.4284
1	35.3524
2	35.3419
3	35.3370
4	35.3329
5	35.3257



Coupon:	L276
Test Matrix:	Pb-G-1500-12-3p
Initial wt (g)	34.8719
Removal wt (g)	35.5183

Calculated final wt (g)	34.8532
Total wt loss (g)	0.0187
Total wt loss (mg)	18.7

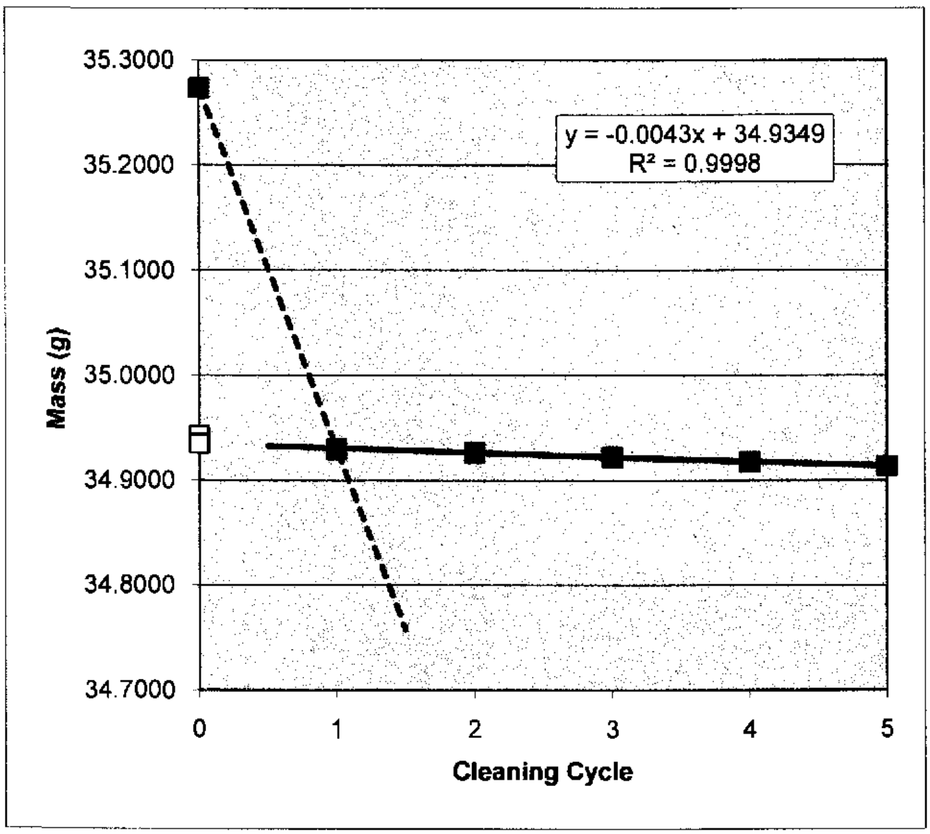
Cleaning Cycle	Wt (g)
0	35.5183
1	34.8520
2	34.8444
3	34.8396
4	34.8359
5	34.8309



Coupon:	L277
Test Matrix:	Pb-Go-1500-12-1f
Initial wt (g)	34.9428
Removal wt (g)	35.2735

Calculated final wt (g)	34.9349
Total wt loss (g)	0.0079
Total wt loss (mg)	7.9

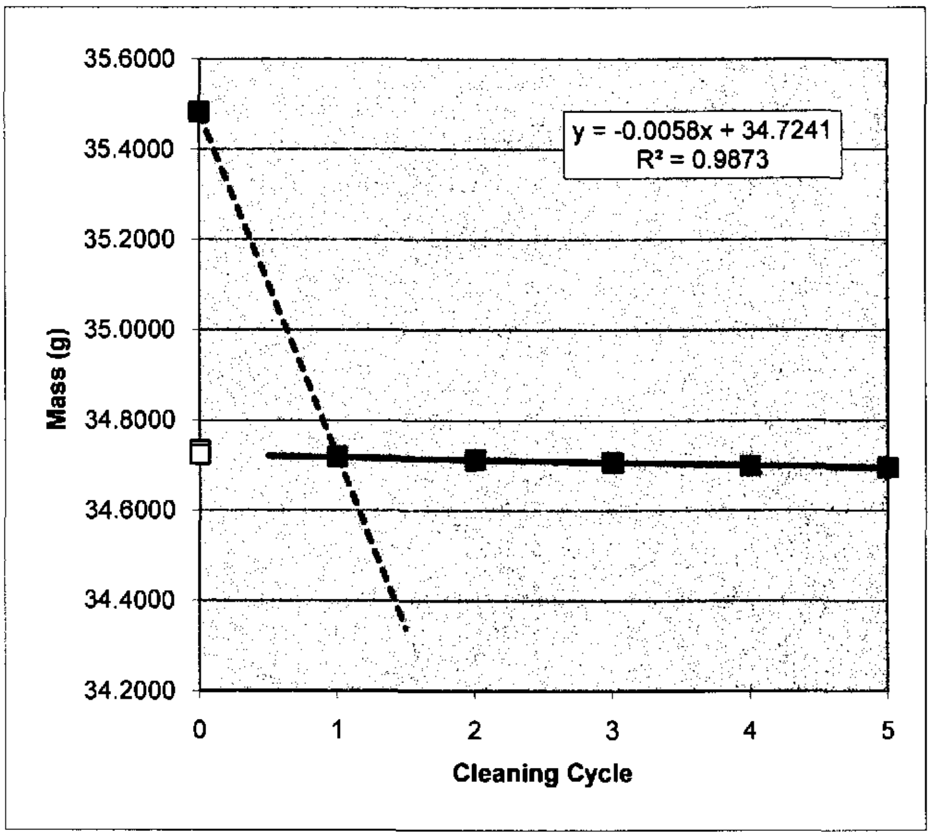
Cleaning Cycle	Wt (g)
0	35.2735
1	34.9295
2	34.9264
3	34.9222
4	34.9178
5	34.9137



Coupon:	L278
Test Matrix:	Pb-Go-1500-12-2f
Initial wt (g)	34.7336
Removal wt (g)	35.4825

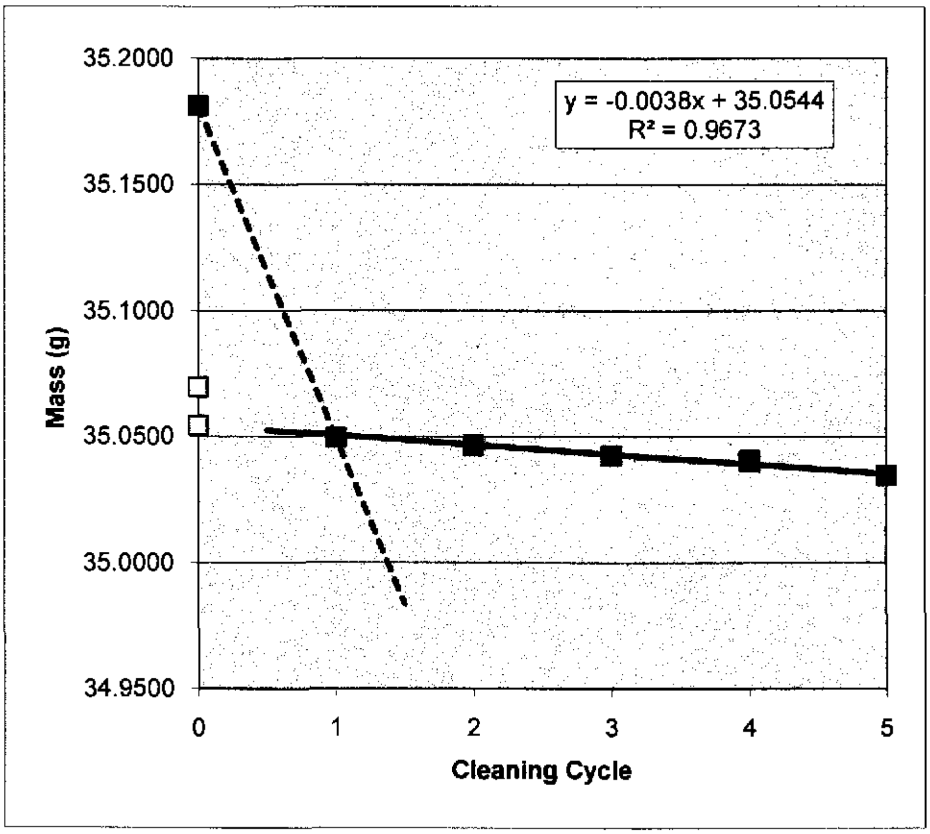
Calculated final wt (g)	34.7241
Total wt loss (g)	0.0095
Total wt loss (mg)	9.5

Cleaning Cycle	Wt (g)
0	35.4825
1	34.7196
2	34.7129
3	34.7064
4	34.6996
5	34.6957



Coupon:	L280		
Test Matrix:	Pb-Go-1500-12-1p		
Initial wt (g)	35.0697	**Calculated final wt (g)**	35.0544
Removal wt (g)	35.1811	**Total wt loss (g)**	0.0153
		Total wt loss (mg)	15.3

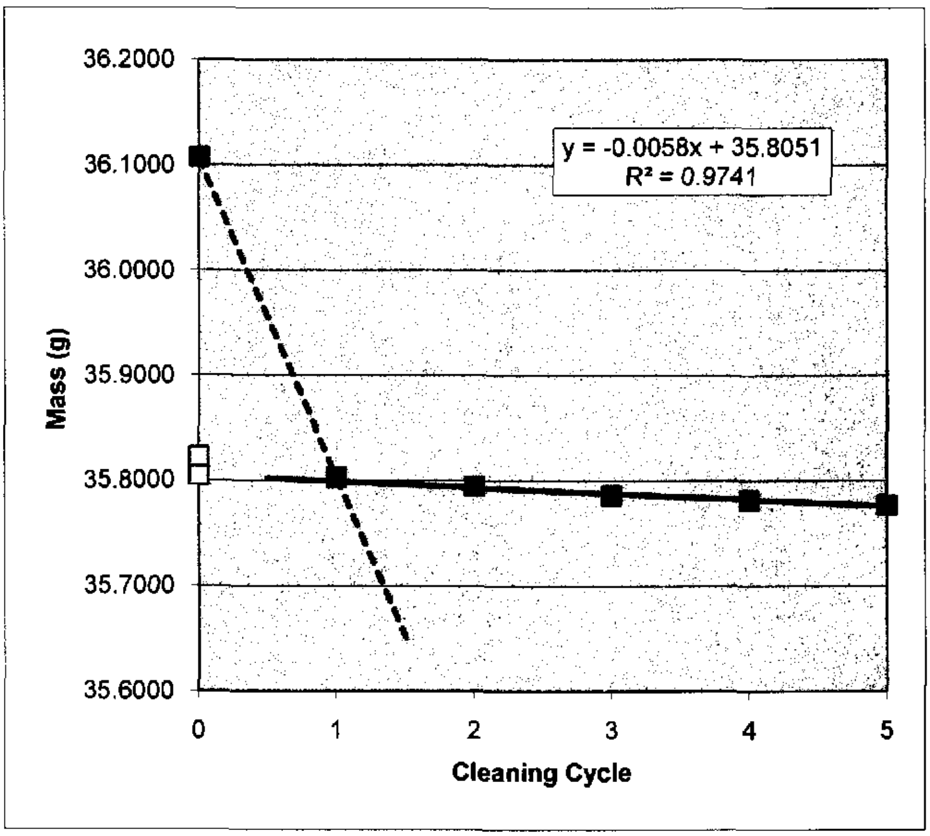
Cleaning Cycle	Wt (g)
0	35.1811
1	35.0496
2	35.0466
3	35.0425
4	35.0404
5	35.0345



Coupon: L281
Test Matrix: Pb-Go-1500-12-2p
Initial wt (g) 35.8230
Removal wt (g) 36.1072

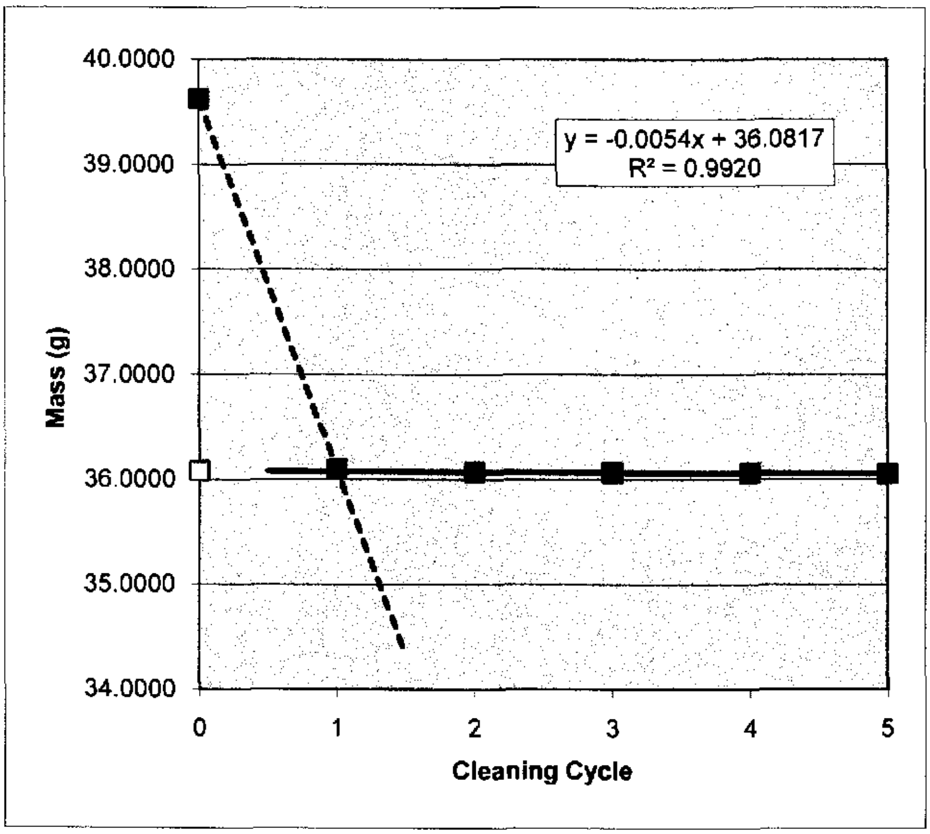
Calculated final wt (g) 35.8051
Total wt loss (g) 0.0179
Total wt loss (mg) 17.9

Cleaning Cycle	Wt (g)
0	36.1072
1	35.8030
2	35.7946
3	35.7861
4	35.7814
5	35.7768



Coupon:	L283			
Test Matrix:	Pb-E-1500-12-1f			
Initial wt (g)	36.0889		**Calculated final wt (g)**	36.0817
Removal wt (g)	39.6229		**Total wt loss (g)**	0.0072
			Total wt loss (mg)	7.2

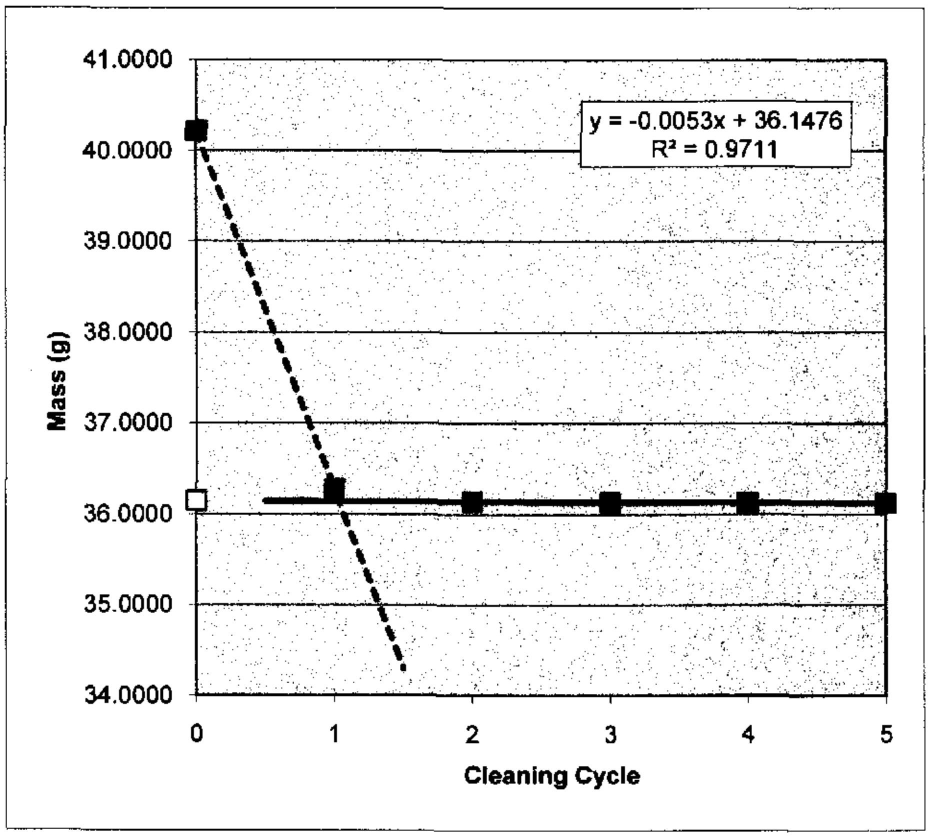
Cleaning Cycle	Wt (g)
0	39.6229
1	36.0993
2	36.0703
3	36.0662
4	36.0604
5	36.0542



Coupon:	L285
Test Matrix:	Pb-E-1500-12-3f
Initial wt (g)	36.1523
Removal wt (g)	40.2186

Calculated final wt (g)	36.1476
Total wt loss (g)	0.0047
Total wt loss (mg)	4.7

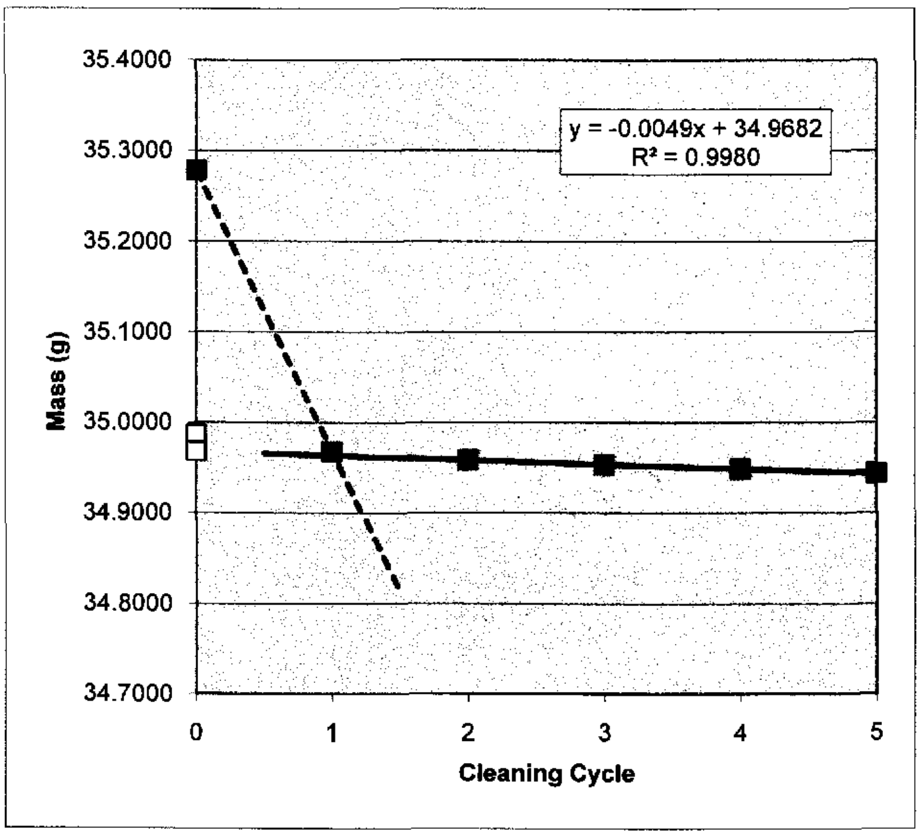
Cleaning Cycle	Wt (g)
0	40.2186
1	36.2709
2	36.1382
3	36.1303
4	36.1263
5	36.1220



Coupon:	L286
Test Matrix:	Pb-E-1500-12-1p
Initial wt (g)	34.9871
Removal wt (g)	35.2785

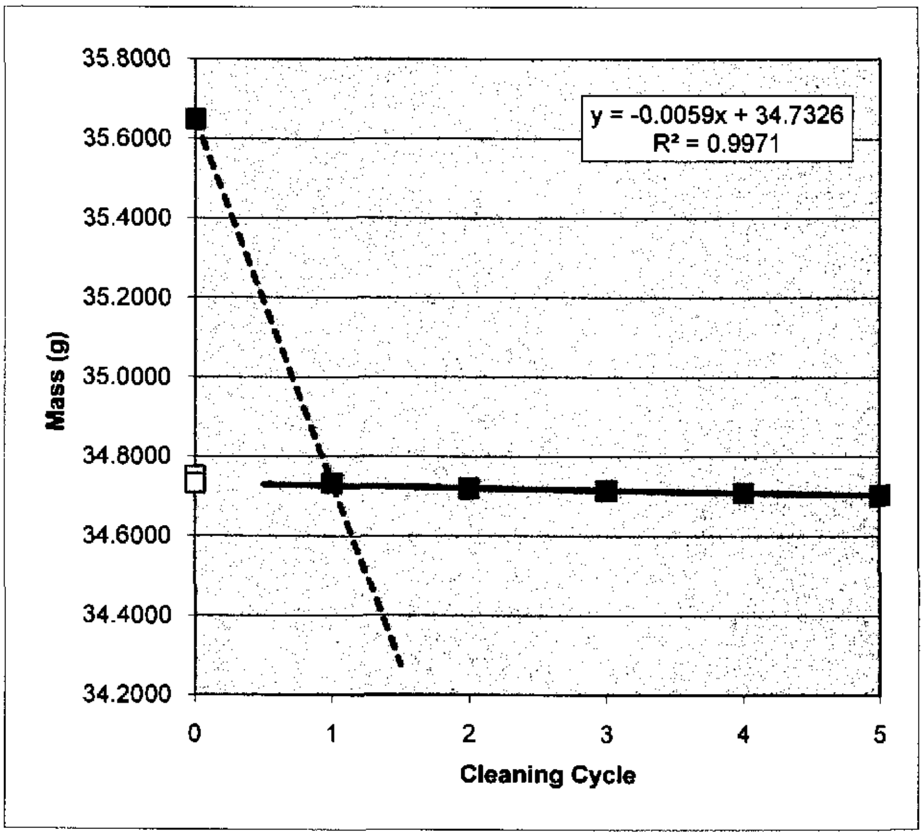
Calculated final wt (g)	34.9682
Total wt loss (g)	0.0189
Total wt loss (mg)	18.9

Cleaning Cycle	Wt (g)
0	35.2785
1	34.9678
2	34.9587
3	34.9532
4	34.9488
5	34.9440



Coupon:	L287			
Test Matrix:	Pb-E-1500-12-2p			
Initial wt (g)	34.7513		**Calculated final wt (g)**	34.7326
Removal wt (g)	35.6483		**Total wt loss (g)**	0.0187
			Total wt loss (mg)	18.7

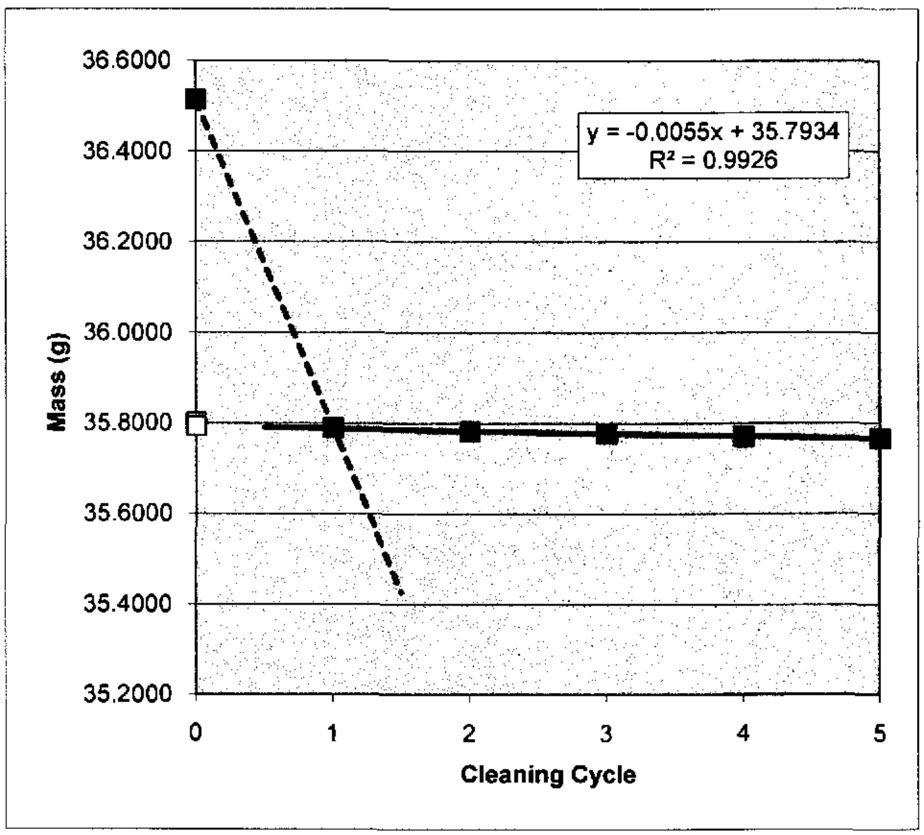
Cleaning Cycle	Wt (g)
0	35.6483
1	34.7330
2	34.7204
3	34.7153
4	34.7092
5	34.7027



Coupon:	L290
Test Matrix:	Pb-Eo-1500-12-2f
Initial wt (g)	35.8010
Removal wt (g)	36.5142

Calculated final wt (g)	35.7934
Total wt loss (g)	0.0076
Total wt loss (mg)	7.6

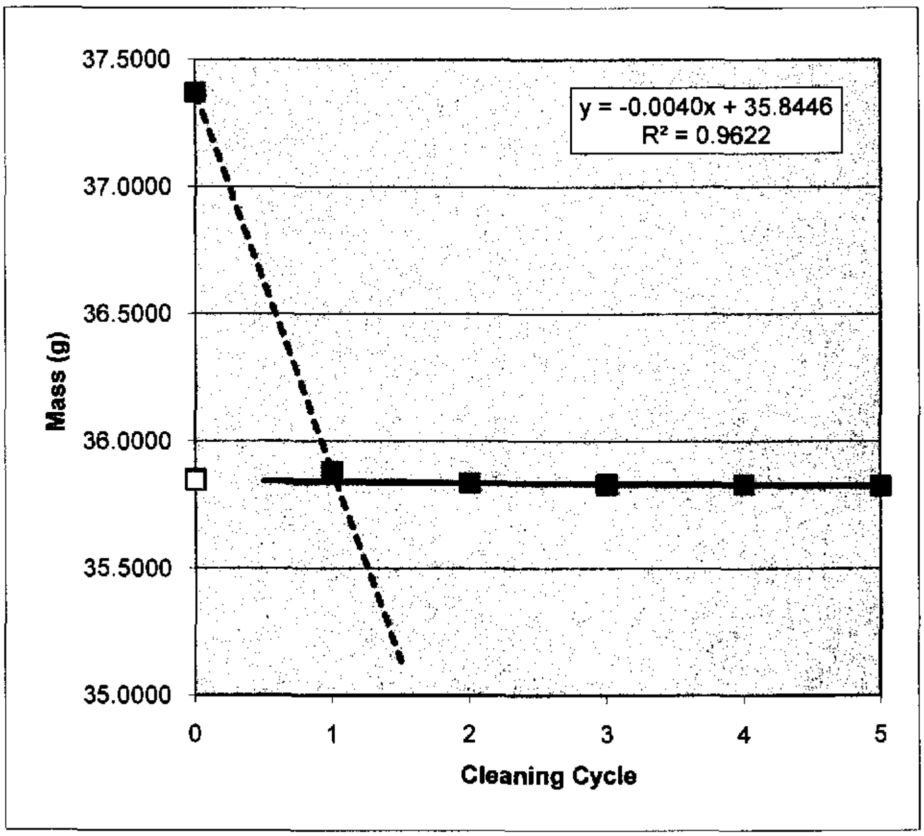
Cleaning Cycle	Wt (g)
0	36.5142
1	35.7892
2	35.7824
3	35.7773
4	35.7705
5	35.7663



Coupon:	L291
Test Matrix:	Pb-Eo-1500-12-3f
Initial wt (g)	35.8531
Removal wt (g)	37.3703

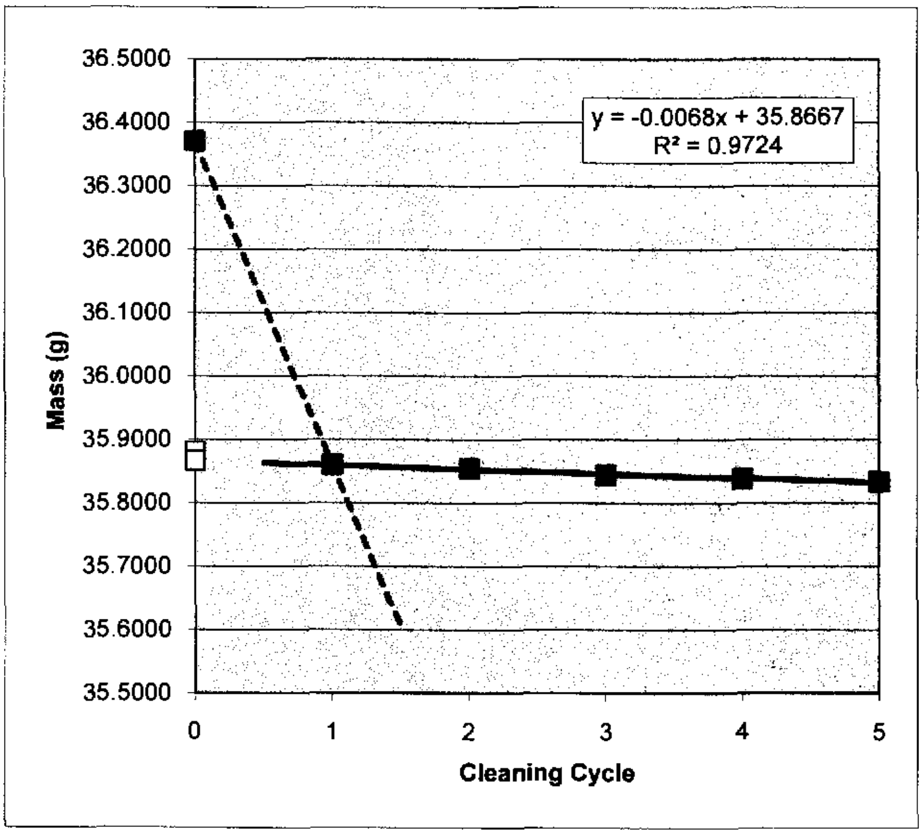
Calculated final wt (g)	35.8446
Total wt loss (g)	0.0085
Total wt loss (mg)	8.5

Cleaning Cycle	Wt (g)
0	37.3703
1	35.8818
2	35.8367
3	35.8315
4	35.8298
5	35.8238



Coupon:	L292		
Test Matrix:	Pb-Eo-1500-12-1p		
Initial wt (g)	35.8814	**Calculated final wt (g)**	35.8667
Removal wt (g)	36.3703	**Total wt loss (g)**	0.0147
		Total wt loss (mg)	14.7

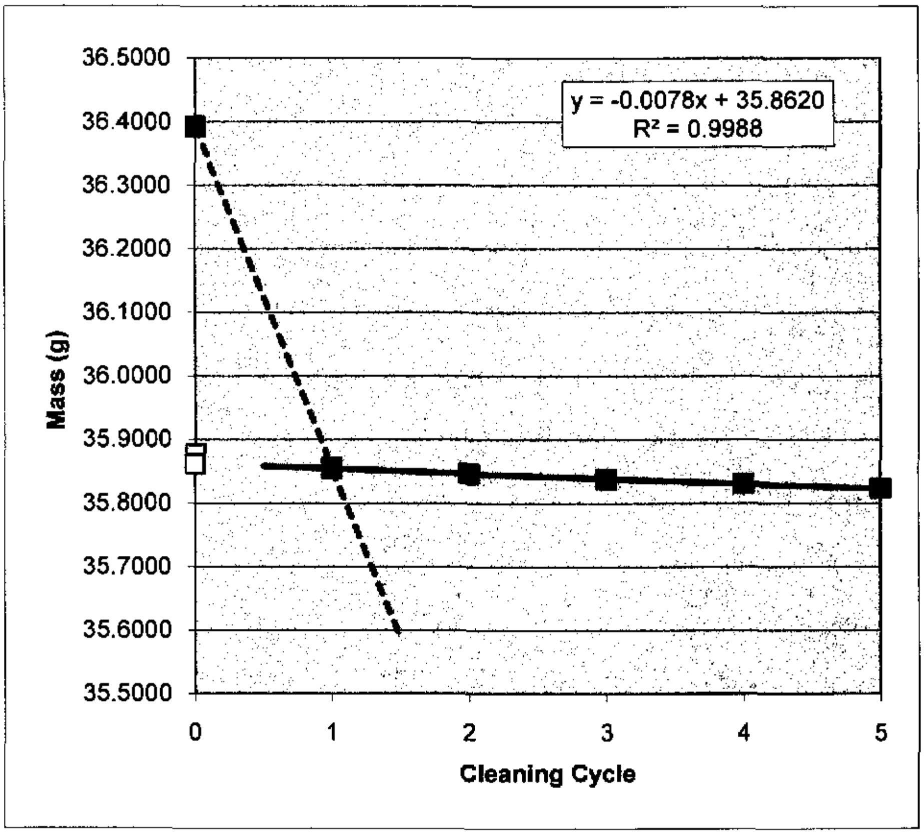
Cleaning Cycle	Wt (g)
0	36.3703
1	35.8606
2	35.8545
3	35.8446
4	35.8388
5	35.8338



Coupon:	L293
Test Matrix:	Pb-Eo-1500-12-2p
Initial wt (g)	35.8772
Removal wt (g)	36.3929

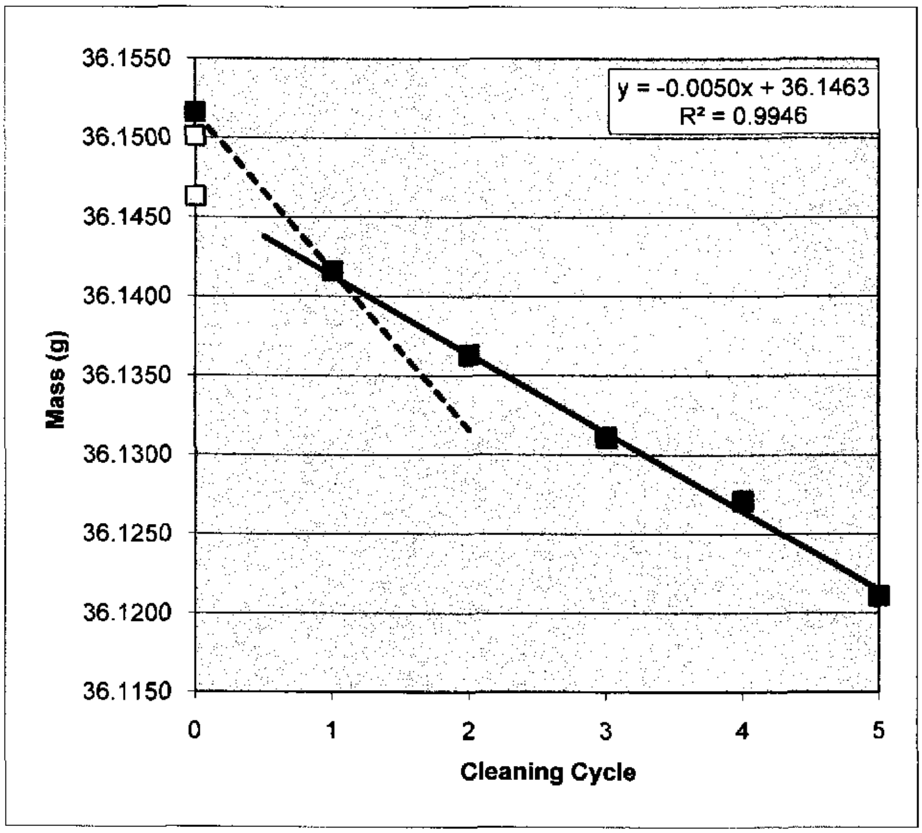
Calculated final wt (g)	35.8620
Total wt loss (g)	0.0152
Total wt loss (mg)	15.2

Cleaning Cycle	Wt (g)
0	36.3929
1	35.8550
2	35.8468
3	35.8382
4	35.8309
5	35.8233



Coupon:	L295		
Test Matrix:	Pb-Atm-1500-12-1		
Initial wt (g)	36.1501	**Calculated final wt (g)**	36.1463
Removal wt (g)	36.1516	**Total wt loss (g)**	0.0038
		Total wt loss (mg)	3.8

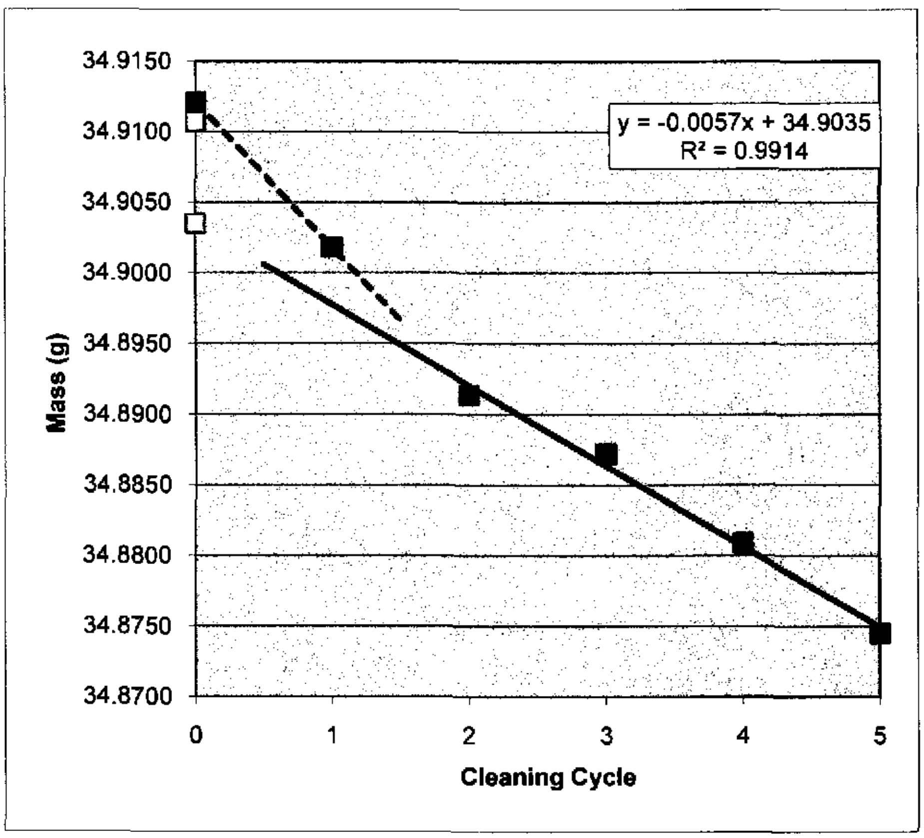
Cleaning Cycle	Wt (g)
0	36.1516
1	36.1416
2	36.1363
3	36.1311
4	36.1271
5	36.1211



Coupon:	L297
Test Matrix:	*Pb-Atm-1500-12-2*
Initial wt (g)	34.9107
Removal wt (g)	34.9121

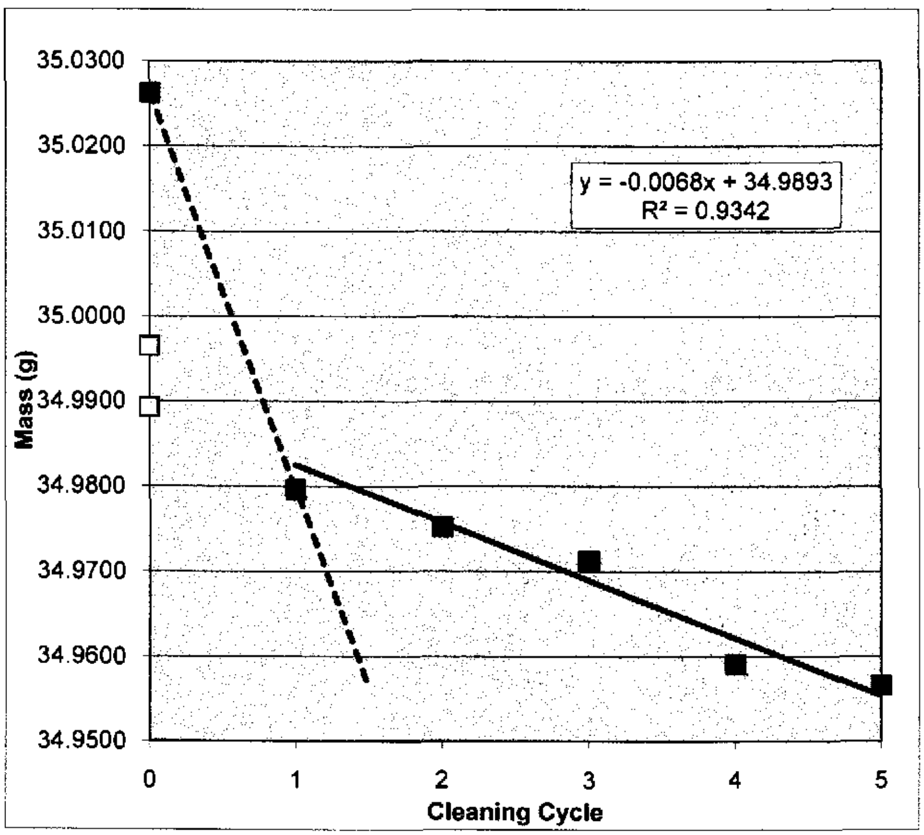
Calculated final wt (g)	34.9035
Total wt loss (g)	0.0072
Total wt loss (mg)	7.2

Cleaning Cycle	Wt (g)
0	34.9121
1	34.9018
2	34.8914
3	34.8872
4	34.8809
5	34.8745



Coupon:	L386		
Test Matrix:	Pb-G-3500-12-1f		
Initial wt (g)	34.9965	**Calculated final wt (g)**	34.9893
Removal wt (g)	35.0262	**Total wt loss (g)**	0.0072
		Total wt loss (mg)	7.2

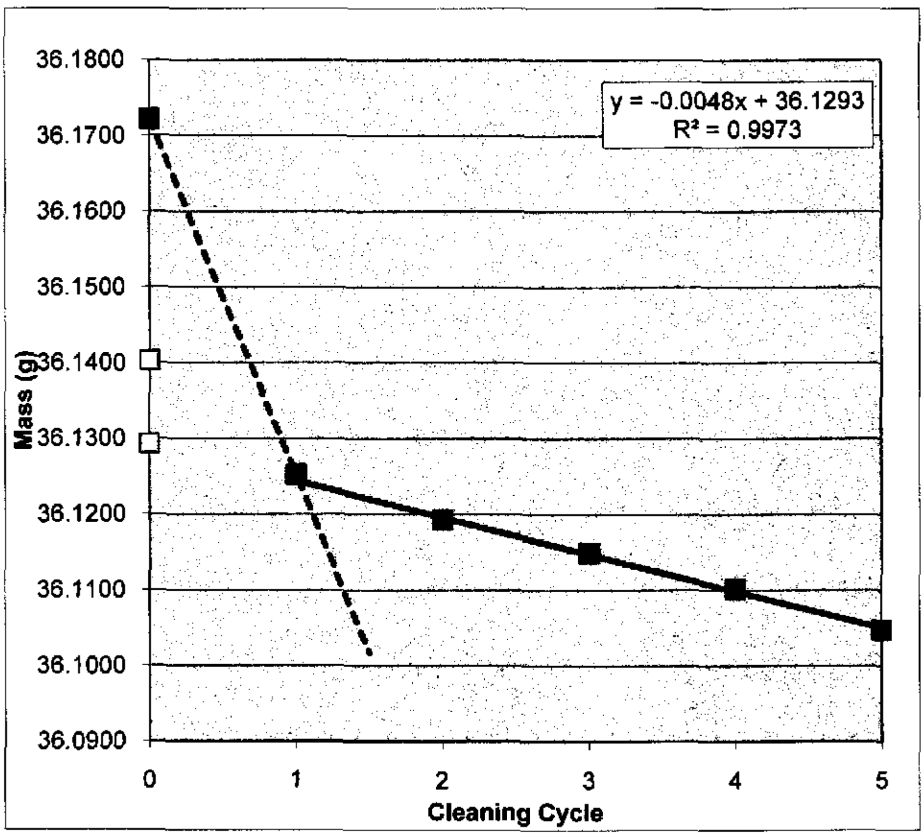
Cleaning Cycle	Wt (g)
0	35.0262
1	34.9796
2	34.9752
3	34.9712
4	34.9591
5	34.9566



Coupon:	L387
Test Matrix:	Pb-G-3500-12-2f
Initial wt (g)	36.1403
Removal wt (g)	36.1722

Calculated final wt (g)	36.1293
Total wt loss (g)	0.0110
Total wt loss (mg)	11.0

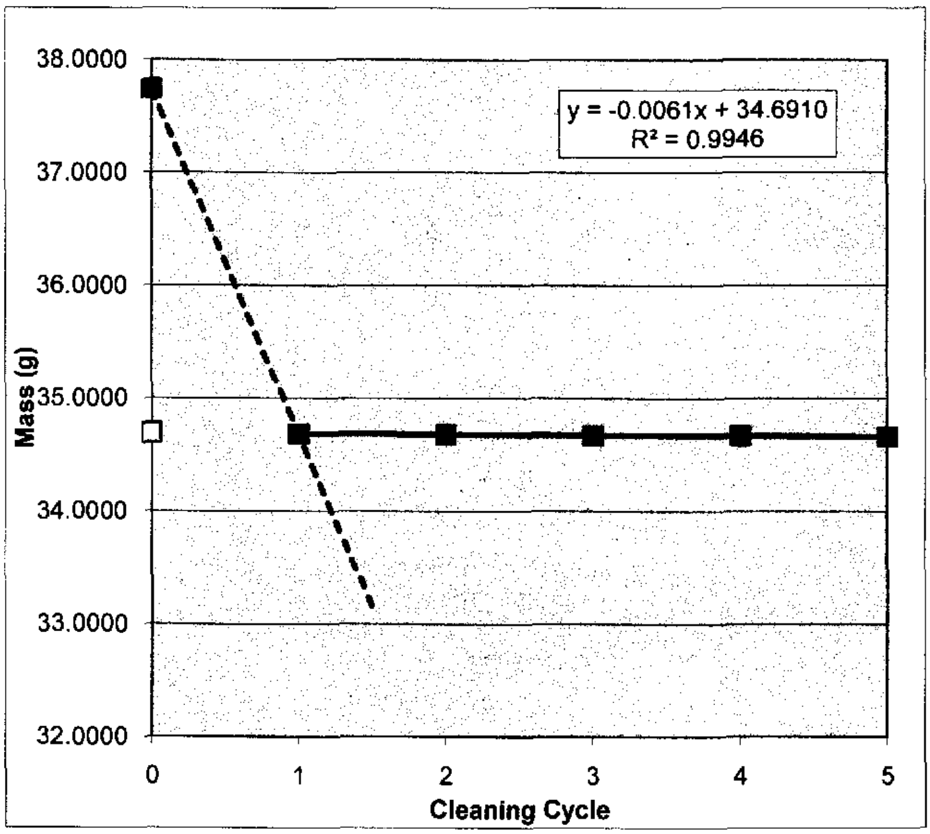
Cleaning Cycle	Wt (g)
0	36.1722
1	36.1252
2	36.1193
3	36.1149
4	36.1102
5	36.1047



Coupon:	L389
Test Matrix:	Pb-G-3500-12-1p
Initial wt (g)	34.7017
Removal wt (g)	37.7440

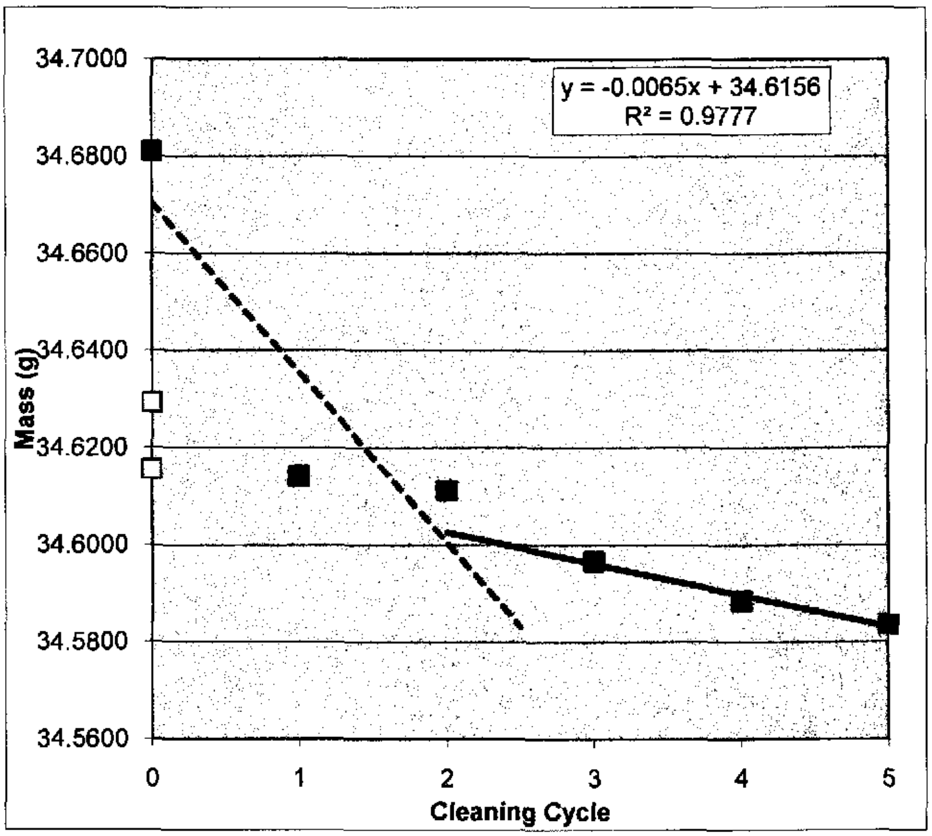
Calculated final wt (g)	34.6910
Total wt loss (g)	0.0107
Total wt loss (mg)	10.7

Cleaning Cycle	Wt (g)
0	37.7440
1	34.6860
2	34.6785
3	34.6726
4	34.6673
5	34.6598



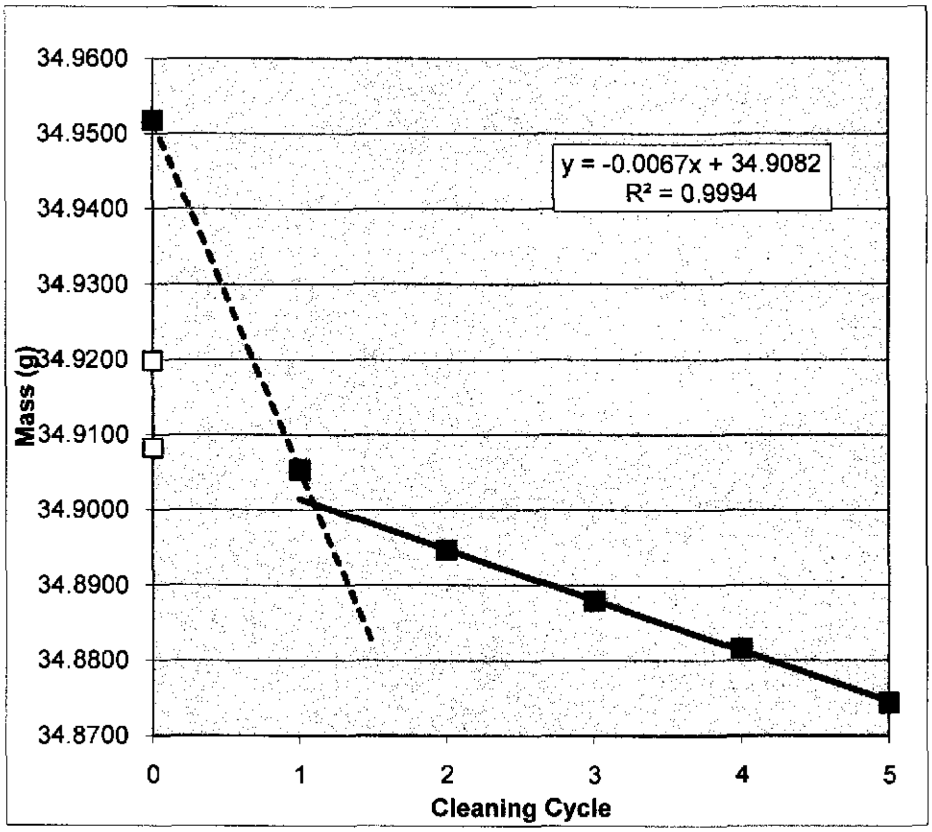
Coupon:	L390			
Test Matrix:	Pb-G-3500-12-2p			
Initial wt (g)	34.6293		**Calculated final wt (g)**	34.6156
Removal wt (g)	34.6811		**Total wt loss (g)**	0.0137
			Total wt loss (mg)	13.7

Cleaning Cycle	Wt (g)
0	34.6811
1	34.6141
2	34.6112
3	34.5967
4	34.5885
5	34.5837



Coupon:	L392		
Test Matrix:	Pb-Go-3500-12-1f		
Initial wt (g)	34.9198	**Calculated final wt (g)**	34.9082
Removal wt (g)	34.9518	**Total wt loss (g)**	0.0116
		Total wt loss (mg)	11.6

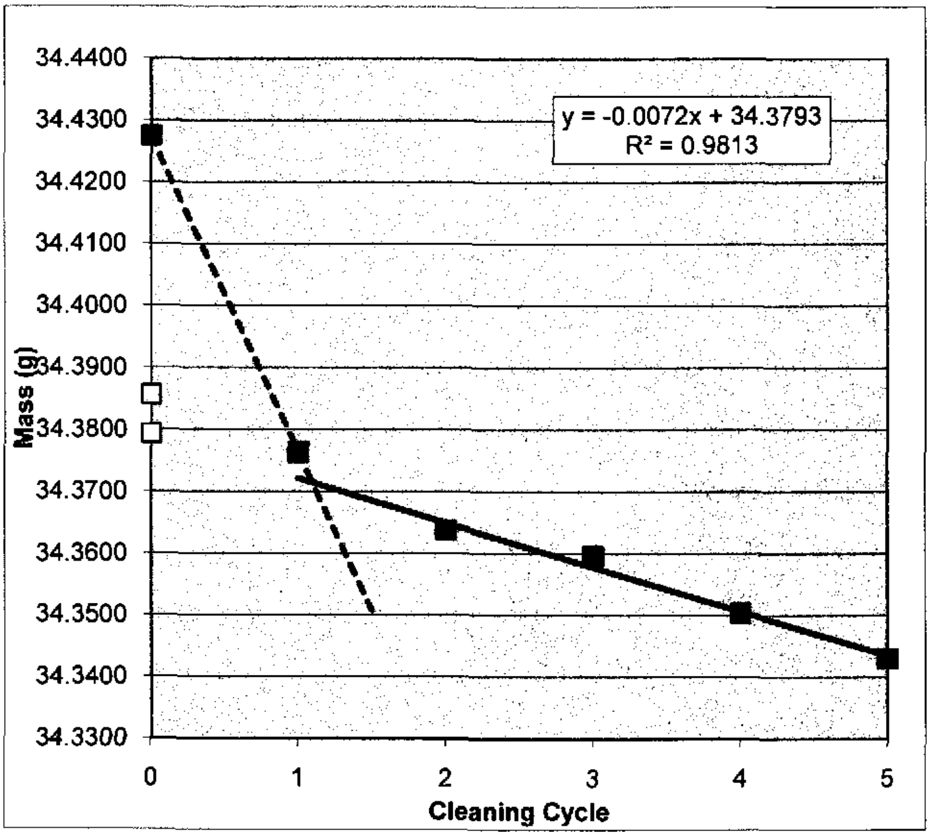
Cleaning Cycle	Wt (g)
0	34.9518
1	34.9053
2	34.8947
3	34.8879
4	34.8816
5	34.8744



Coupon:	L393
Test Matrix:	Pb-Go-3500-12-2f
Initial wt (g)	34.3856
Removal wt (g)	34.4275

Calculated final wt (g)	34.3793
Total wt loss (g)	0.0063
Total wt loss (mg)	6.3

Cleaning Cycle	Wt (g)
0	34.4275
1	34.3763
2	34.3638
3	34.3596
4	34.3504
5	34.3430

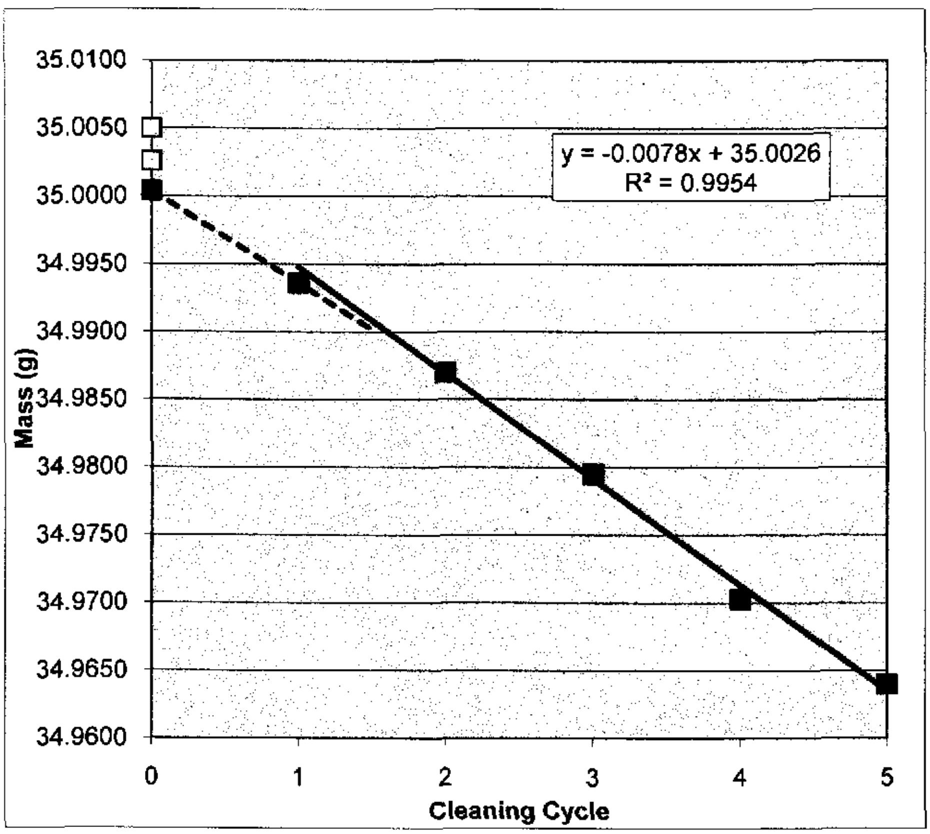


Coupon:	L395
Test Matrix:	Pb-Go-3500-12-1p
Initial wt (g)	35.0050
Removal wt (g)	35.0004

Calculated final wt (g)	*35.0004
Total wt loss (g)	0.0046
Total wt loss (mg)	4.6

Cleaning Cycle	Wt (g)
0	35.0004
1	34.9936
2	34.9870
3	34.9795
4	34.9703
5	34.9640

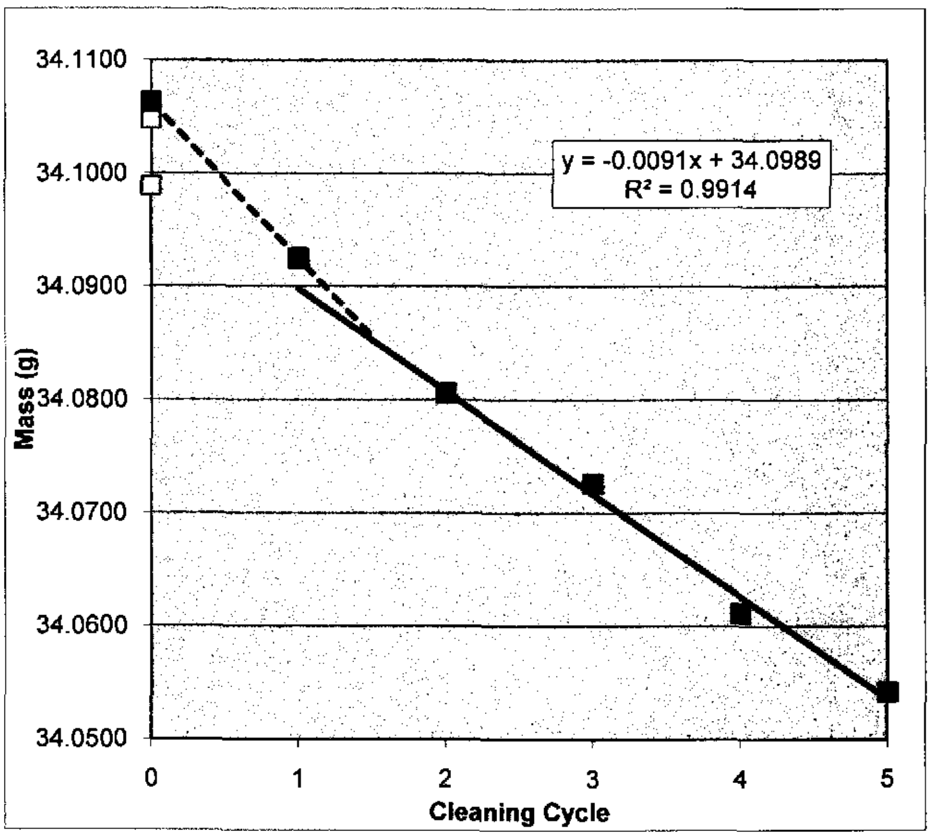
*Note: Removal weight used to calculate the corrosion rate



Coupon:	L396
Test Matrix:	Pb-Go-3500-12-2p
Initial wt (g)	34.1048
Removal wt (g)	34.1063

Calculated final wt (g)	34.0989
Total wt loss (g)	0.0059
Total wt loss (mg)	5.9

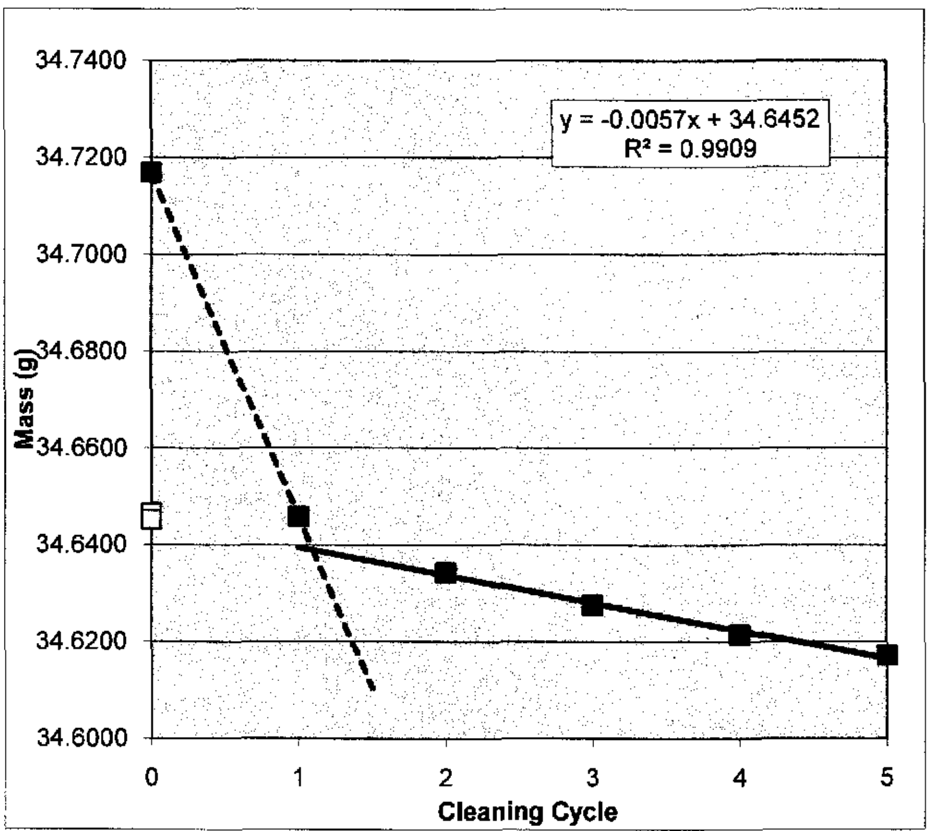
Cleaning Cycle	Wt (g)
0	34.1063
1	34.0925
2	34.0806
3	34.0726
4	34.0611
5	34.0542



Coupon:	L398
Test Matrix:	Pb-E-3500-12-1f
Initial wt (g)	34.6465
Removal wt (g)	34.7169

Calculated final wt (g)	34.6452
Total wt loss (g)	0.0013
Total wt loss (mg)	1.3

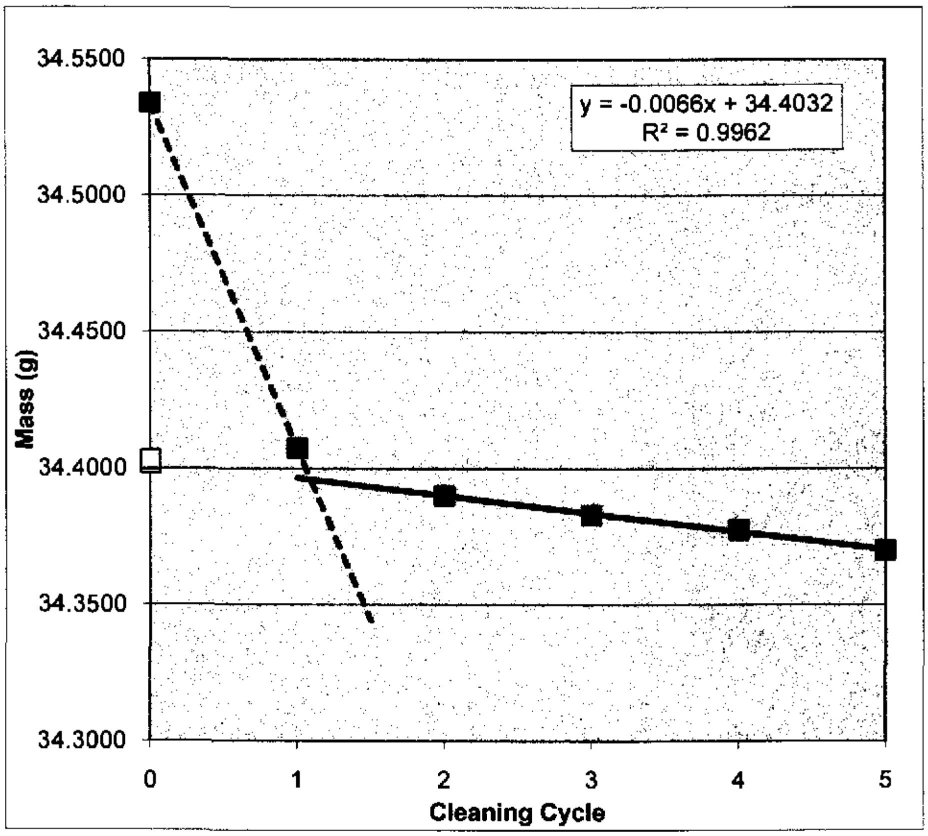
Cleaning Cycle	Wt (g)
0	34.7169
1	34.6459
2	34.6343
3	34.6276
4	34.6215
5	34.6172



Coupon:	399
Test Matrix:	Pb-E-3500-12-2f
Initial wt (g)	34.4017
Removal wt (g)	34.5339

Calculated final wt (g)	34.4032
Total wt loss (g)	-0.0015
Total wt loss (mg)	-1.5

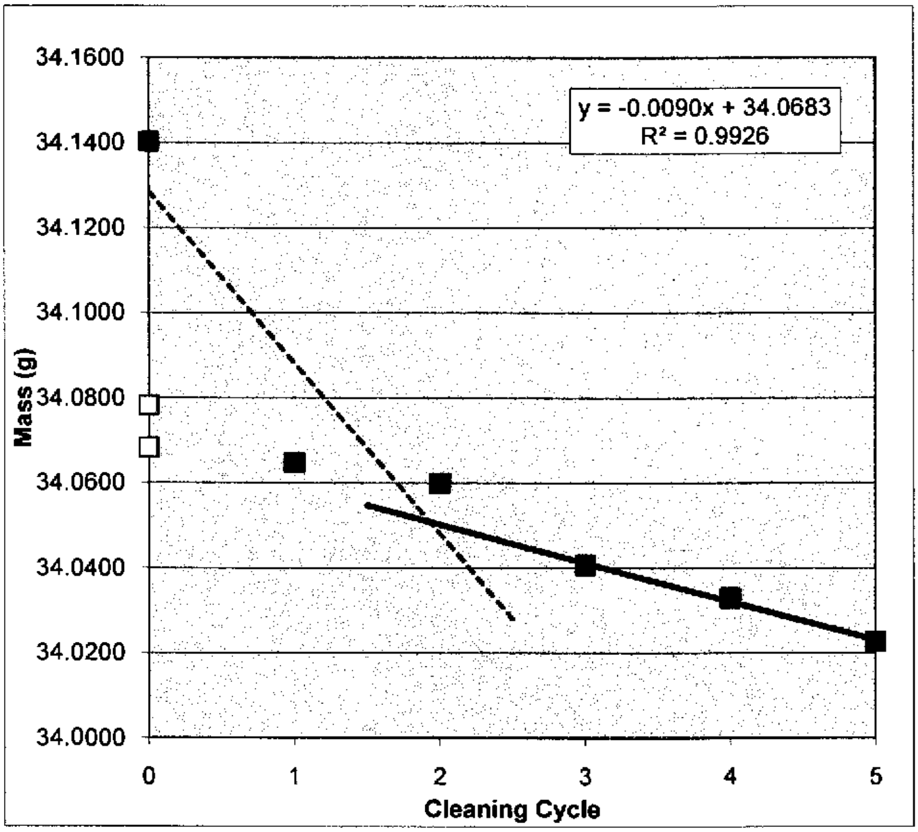
Cleaning Cycle	Wt (g)
0	34.5339
1	34.4075
2	34.3901
3	34.3829
4	34.3775
5	34.3699



Coupon:	L401
Test Matrix:	Pb-E-3500-12-1p
Initial wt (g)	34.0783
Removal wt (g)	34.1403

Calculated final wt (g)	34.0683
Total wt loss (g)	0.0100
Total wt loss (mg)	10.0

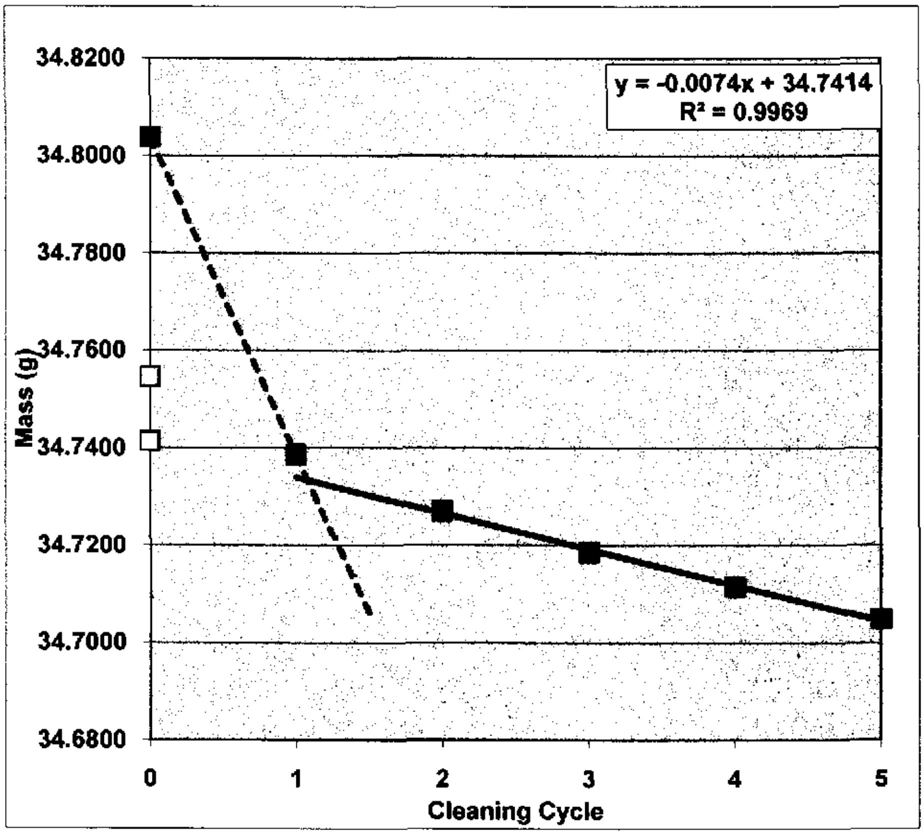
Cleaning Cycle	Wt (g)
0	34.1403
1	34.0648
2	34.0599
3	34.0407
4	34.0330
5	34.0226



Coupon:	L402
Test Matrix:	Pb-E-3500-12-2p
Initial wt (g)	34.7546
Removal wt (g)	34.8038

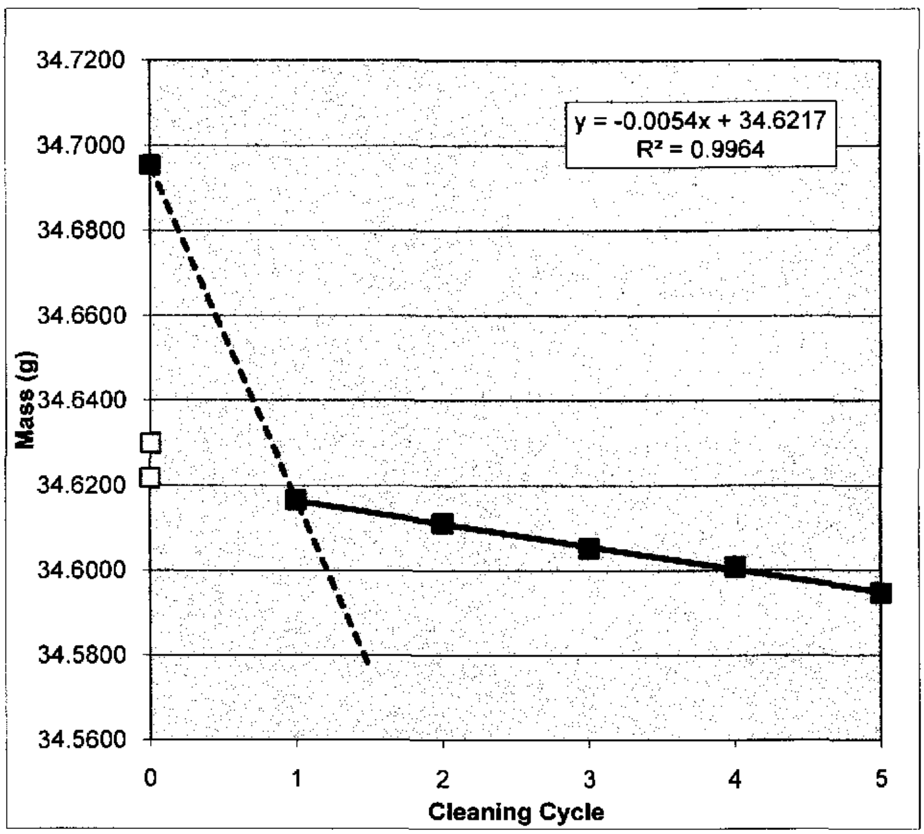
Calculated final wt (g)	34.7414
Total wt loss (g)	0.0132
Total wt loss (mg)	13.2

Cleaning Cycle	Wt (g)
0	34.8038
1	34.7386
2	34.7271
3	34.7186
4	34.7115
5	34.7048



Coupon:	L404		
Test Matrix:	Pb-Eo-3500-12-1f		
Initial wt (g)	34.6299	**Calculated final wt (g)**	34.6217
Removal wt (g)	34.6954	**Total wt loss (g)**	0.0082
		Total wt loss (mg)	8.2

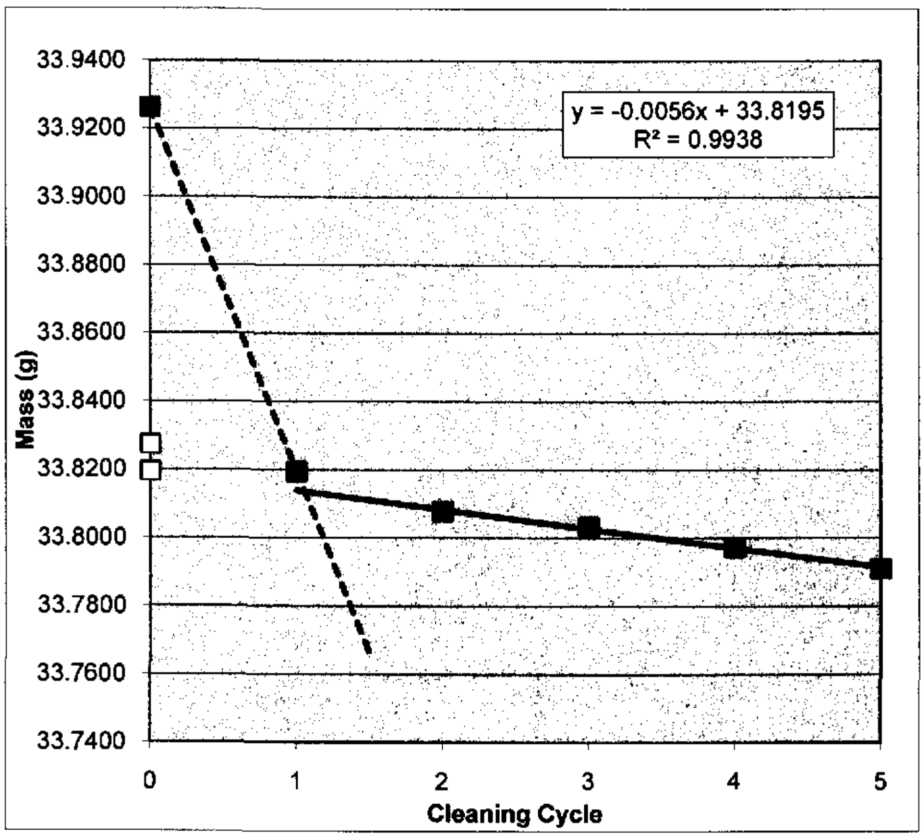
Cleaning Cycle	Wt (g)
0	34.6954
1	34.6166
2	34.6111
3	34.6052
4	34.6008
5	34.5947



Coupon:	L405
Test Matrix:	Pb-Eo-3500-12-2f
Initial wt (g)	33.8274
Removal wt (g)	33.9262

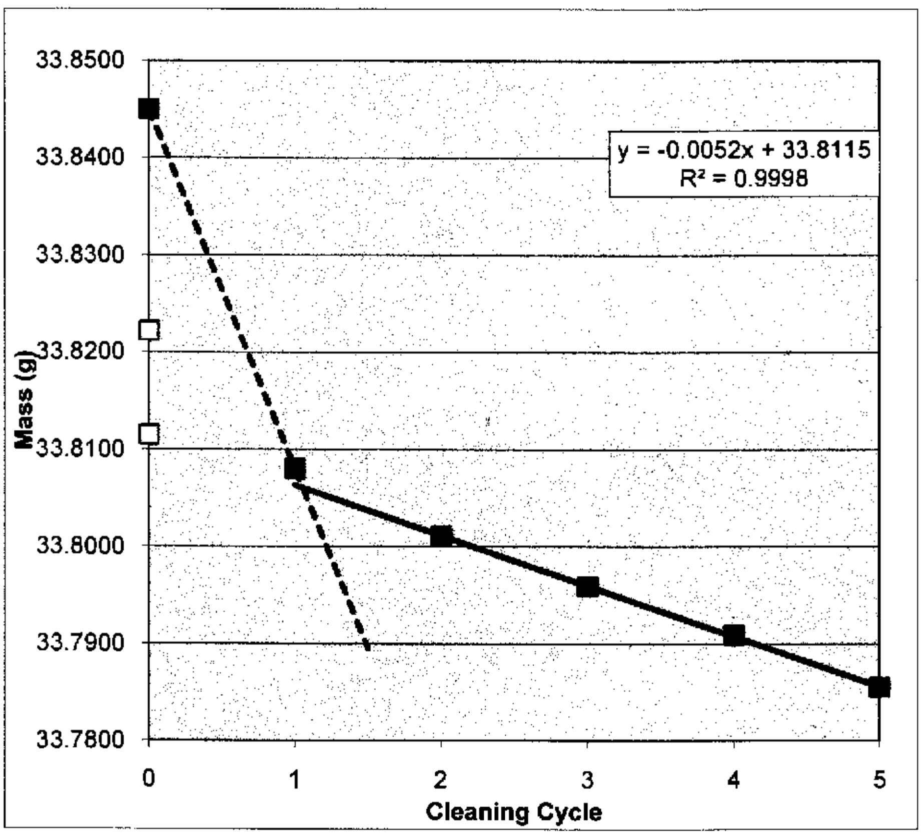
Calculated final wt (g)	33.8195
Total wt loss (g)	0.0079
Total wt loss (mg)	7.9

Cleaning Cycle	Wt (g)
0	33.9262
1	33.8194
2	33.8077
3	33.8033
4	33.7973
5	33.7910



Coupon:	L407			
Test Matrix:	Pb-Eo-3500-12-1p			
Initial wt (g)	33.8222		**Calculated final wt (g)**	33.8115
Removal wt (g)	33.8450		**Total wt loss (g)**	0.0107
			Total wt loss (mg)	10.7

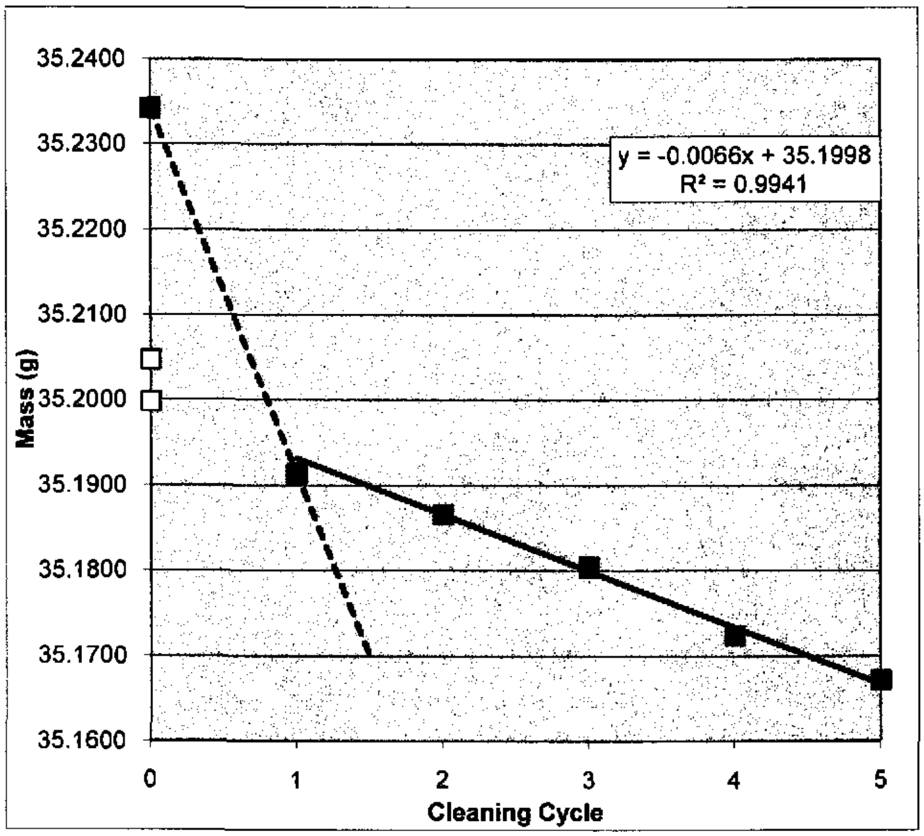
Cleaning Cycle	Wt (g)
0	33.8450
1	33.8080
2	33.8011
3	33.7959
4	33.7909
5	33.7855



Coupon:	L408
Test Matrix:	Pb-Eo-3500-12-2p
Initial wt (g)	35.2047
Removal wt (g)	35.2342

Calculated final wt (g)	35.1998
Total wt loss (g)	0.0049
Total wt loss (mg)	4.9

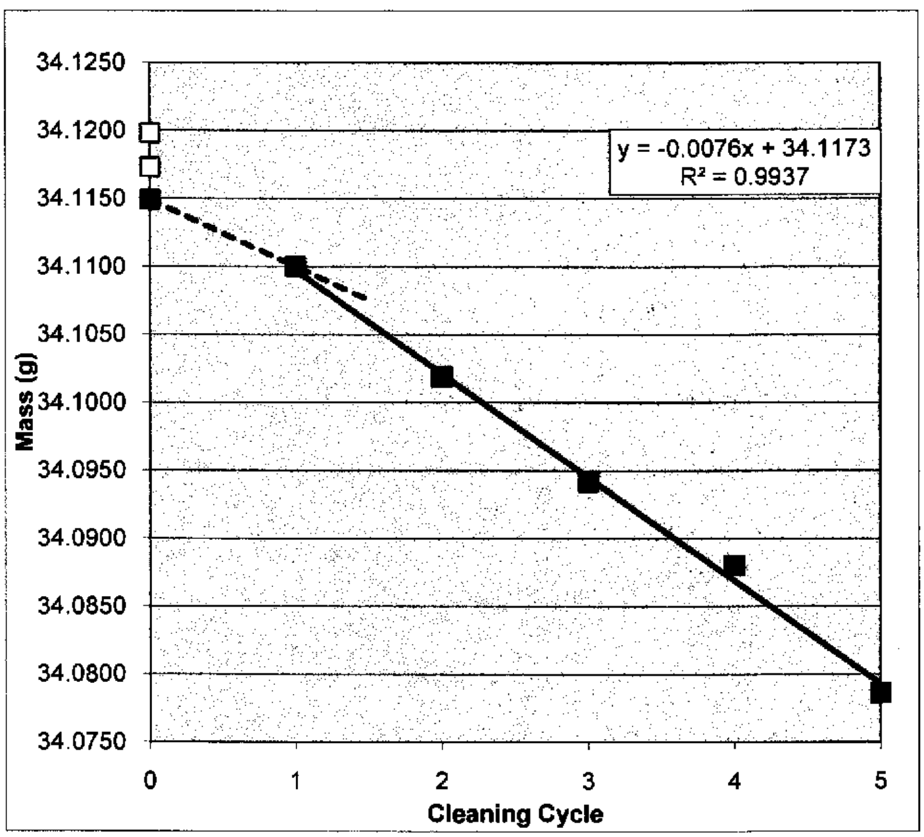
Cleaning Cycle	Wt (g)
0	35.2342
1	35.1914
2	35.1866
3	35.1804
4	35.1724
5	35.1672



Coupon:	L410		
Test Matrix:	Pb-Atm-3500-12-1		
Initial wt (g)	34.1198	**Calculated final wt (g)**	*34.1149
Removal wt (g)	34.1149	**Total wt loss (g)**	0.0049
		Total wt loss (mg)	4.9

Cleaning Cycle	Wt (g)
0	34.1149
1	34.1100
2	34.1019
3	34.0942
4	34.0880
5	34.0786

*Note: Removal weight used to calculate the corrosion rate



Coupon:	L411		
Test Matrix:	Pb-Atm-3500-12-2		
Initial wt (g)	34.8854	**Calculated final wt (g)**	34.8814
Removal wt (g)	34.8816	**Total wt loss (g)**	0.0040
		Total wt loss (mg)	4.0

Cleaning Cycle	Wt (g)
0	34.8816
1	34.8770
2	34.8700
3	34.8650
4	34.8599
5	34.8533