LABORATORY PROCEDURE
LF-5.1, UNIFORM CORROSION TESTING

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References:

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NWST-01313, FINAL REPORT An Investigation of Fire Retardant caused Corrosion (Ocean City. Gehring, 1974)
STP 5.2 Intergranular Corrosion
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Attachments:

(a) Appendix A: Uniform Corrosion Coupon Specification
(b) Appendix B: Sample Corrosion Results letter

1. Abstract

1.1. This procedure outlines the entire uniform corrosion process. All instruction is for WFCS laboratory personnel and is based upon Standard Test Procedure (STP) 5.1, Uniform Corrosion.

2. Overview

2.1. Wildland Fire Chemical Systems performs uniform corrosion testing on all product types (Retardant, Foam, or Water Enhancers). The acceptance limits of this procedure are outlined in each of the applicable Forest Service Specifications.

2.2. Four different alloys are used for this testing. These alloys were determined by Ocean City Research and are provided by the recommendations of the FINAL REPORT (Gehring, 1974). The current corrosion test is run for 90 days and each alloy is subjected to total and partial immersion. Table 1 shows the testing matrix. Each uniform corrosion condition is observed in triplicate.

Table 1- Uniform Corrosion Test Matrix

	Total immersion 70°F	Partial immersion 70°F	Total immersion 120°F	Partial immersion 120°F
Aluminum	3	3	3	3
Steel	3	3	3	3
Brass	none	none	none	3
Magnesium	3	3	3	3

2.3. Following the 90-day immersion, the coupons are acid cleaned and weighed. This is done alongside a control coupon to evaluate and capture weight loss during the acid cleaning. The uniform corrosion test evaluates total weight loss of a coupon with respect to its dimensions. The density of each coupon is then used with the weight loss to calculate the thickness loss per year in mils/year (mpy) which is equal to one thousandth of an inch.

2.4. The results are collected and an average calculated of each triplicate measurement. The average mpy is compared to Table 4 of the applicable Forest Service Specification. A letter is then sent to the company informing them of how their product performed.

2.5. Uniform corrosion testing is performed on fresh products as well as 1-year stability aged products to determine longevity of the product.

2.6. Uniform corrosion testing is considered complete once each letter is sent to the company. Intergranular (IGA) corrosion is then performed as follow up in accordance with STP-5.2.

3. Procedure

This procedure is outlined chronologically for each task performed. Some sections may be performed in an alternative order for preparation efficiency. It is NOT recommended to start uniform corrosion on more than two batches in one day. The analyst shall refer to the calendar to determine if 90 days following immersion, that laboratory personnel will be present to remove the samples (i.e. holidays, weekends). The general rules are:

- No uniform corrosion started on Mondays
- Check calendar for future holidays to avoid overlap with coupon removal

Sections 3.4 and 3.5 MUST be completed on the same day.

BE SURE to wear all appropriate Personal Protection Equipment as deemed necessary by the task being performed (i.e. gloves, goggles, ear protection, etc.).

3.1. COUPON PREPARATION

Coupons are currently ordered from Corrosion Test Supply using the specifications outlined in Appendix A. Alternative suppliers may be a future capability but require validation first.

3.1.1. Use the active copy of Lab Form (LF) LF-5.1.1 to record each batch of coupons.

3.1.2. Fill in product name, FID, mix ratio and any other needed identifiers.

3.1.3. Then fill in the serialized numbers for each set of coupons. The alloy designations are as follows:

- A – Aluminum

- G – Steel
- C – Brass
- L – Magnesium

3.1.4. Use the vibrating etcher to record unique coupon identification to match the numbers recorded on LF-5.1.1. It is acceptable to start a batch with full identification (i.e. A12122) and proceed with subsequent coupons in a batch to only include the alloy designation and final three digits (i.e. A123, A124, etc.).

3.1.5. Alternatively, the coupons can be pre-stamped with a serial identifier and these numbers are then recorded on LF-5.1.1.

3.2. COUPON MEASUREMENT

3.2.1. After coupons are marked with a unique identifier, they are measured to determine the area dimensions.

NOTE: Each corrosion coupon batch is segregated for data transcription purposes. For example all coupons to be dunked in product Y at a 2.0% concentration are measured in a batch of coupons (Aluminum, Steel, Brass, Magnesium) followed by the next batch of coupons for the next product or dilution.

3.2.2. Log on to the corrosion laptop and load the LabVIEW program titled *Caliper.vi* which is located on the desktop. There are instructions listed in the program on how to proceed, but they are also listed below.

3.2.3. Once the VI is opened, assure the BLACK BOX ABC SWITCH is set to the “B” or “Caliper” setting. Also assure the flash drive is connected to save the results. These results auto-fill into a spreadsheet that can be imported into Excel.

3.2.4. Before taking any measurements, fill in each of the fields. Standard practice is to measure in the order outlined in section 3.1.3. Also be sure to zero the caliper by pressing the “set button.”

3.2.5. Press the “check mark” button when the *number of coupons*, *alloy designation*, and *number of first coupon* fields are filled in and then press the “⇨” to run the program.

3.2.6. The *Coupon being measured* field should now read the first coupon’s number.

3.2.7. Each measurement is recorded in duplicate (triplicate for height) and an average is calculated in the software. Measurement begins with Length (shown in Figure 1 as the 10.2cm dimension) followed by width and height. Each replicate measurement should be taken at different spacing across the coupon to assess a true average.

3.2.8. Each measurement should be recorded with the caliper snugly adjusted to the coupon, holding it in place.

3.2.9. To record a measurement, press the “set” button on the caliper. When all replicates have been measured, the next coupon will illuminate for that dimensional measurement.

3.2.10. All lengths are recorded, followed by width and height of the selected alloy.

3.2.11. Width is the 2.5 cm dimension, and height is the 0.3 cm dimension in Figure 1.

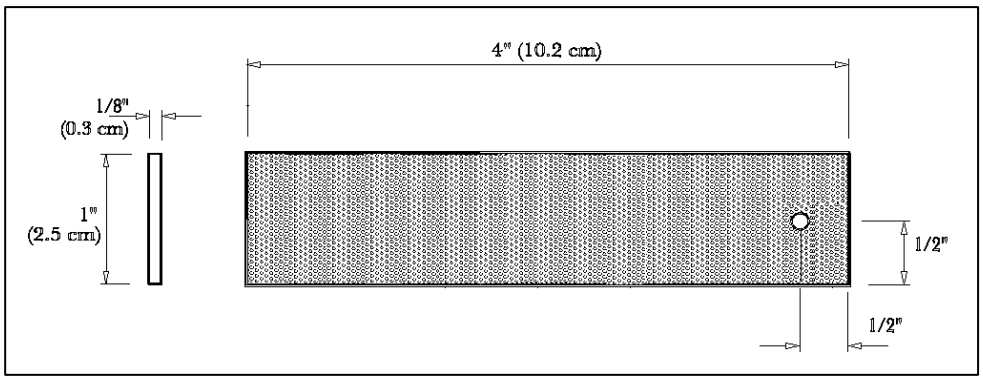


Figure 1- Coupon Dimensions

3.2.12. When each of the replicate measurements have been completed for a coupon, the next coupon number will populate the *Coupon being measured* field for the same (length, width, or height) dimension. Continue through the program measuring duplicate (or triplicate for H) measurements for each dimension of each coupon.

3.2.13. When all coupons of an alloy have been measured, the program will terminate and automatically export the results to two locations, the desktop and the flash drive.

NOTE: It is good practice to assure your first series of measurements is recorded to reduce the need for rework.

3.2.14. Repeat starting at section 3.2.4 for each separate alloy in a batch. Any number of measurement batches can be recorded in a given day, but it works best to always keep them in order (Aluminum, Steel, Brass, Magnesium).

3.2.15. When measurement of a batch has been completed, record this on LF-5.1.1 by checking the measurement check box and entering the date.

3.2.16. Upon completion, each batch of coupons are then ready to be used for analysis.

3.3. PRODUCT MIXING AND LABELING

3.3.1. Use the proper LF mix sheet to calculate correct volumes or weights for mixing. Follow the instructions on the applicable LF for mixing each product type. It is standard to mix around 95,000mL to assure enough product for annual, 14-day stability tests, and uniform corrosion. Sometimes more or less is needed depending on the product type, age, and dilution. Each LF template should provide this estimated volume.

3.3.2. Refer to STP 3.1 and associated mixing instructions for specific laboratory operation and safety considerations.

3.3.3. After completion of mixing, the volume is allocated into the sample jars and carboys as instructed on the LF.

3.3.4. 40 jars are used; 19 filled with 800 mL (total) and 21 filled with 400 mL (partial). Each jar is then capped with a lid. One “total” or full jar is set aside for measurement (pH, viscosity, etc.) and the remaining 39 are sorted on the benchtop as follows:

L	total	total	partial	partial	total	total	partial	partial	total	total	partial	partial
C	partial	partial	partial									
G	total	total	partial	partial	total	total	partial	partial	total	total	partial	partial
A	total	total	partial	partial	total	total	partial	partial	total	total	partial	partial

----------Edge of benchtop----------

3.3.5. Labels are then printed with all of the traceable information. Using Microsoft Word mail merge is an easy way to complete this task with LF-5.1.2 Corrosion Label Merge Template. A finalized sample label should be printed in the design given in Figure 2.

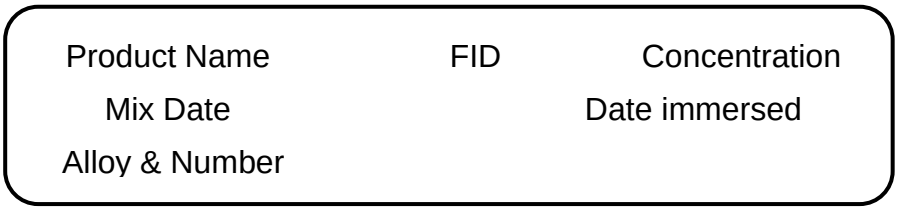


Figure 2- Sample Label

3.3.6. These individual labels are then applied to each of the jars in a numerical order to help reduce error. The grid outlined in 3.3.4 is a useful way to maintain consistency throughout.

EXAMPLE: In a set of 12 Aluminum coupons the organization is as follows:

Immersion	Coupon #
Total 70°F	A21210
Total 120°F	A21211
Partial 70°F	A21212
Partial 120°F	A21213
Total 70°F	A21214
Total 120°F	A21215

Partial 70°F	A21216
Partial 120°F	A21217
Total 70°F	A21218
Total 120°F	A21219
Partial 70°F	A21220
Partial 120°F	A21221

Comparing this example to the grid in 3.3.4, the analyst is able to apply the labels left to right (facing the benchtop). This helps to maintain consistency and reduce error. Note from the example that all EVEN coupons are placed in the 70°F incubator and all ODD coupons are placed in the 120°F chamber.

3.3.7. Once labeled, proceed to section 3.4.

3.3.8. Mixing and labeling may be performed as much as a week in advance of beginning the corrosion test, but standard practice is to start uniform corrosion as timely as possible to reduce unnecessary delays in reporting.

3.4. COUPON CLEANING AND WEIGHING

NOTE 1: This section is to be performed on the same day as immersing the corrosion coupons (section 3.5). Before cleaning assure that your product is properly mixed and poured into the sample jars (section 3.3).

NOTE 2: The analyst shall refer to the calendar to determine if 90 days following immersion, that laboratory personnel will be present to remove the samples (i.e. holidays, weekends). The general rules are:

- No uniform corrosion started on Mondays
- Check calendar for future holidays to avoid overlap with coupon removal

3.4.1. Once all previous sections have been completed for the corrosion coupons, this section can be started.

3.4.2. Check LF-5.1.1 to assure the coupons you have selected have been measured (section 3.2).

3.4.3. Check volumes of cleaning acids to assure enough is on hand for the cleaning procedure. Logbook 5 includes LFs with reagent preparation as needed for full batch cleaning.

3.4.4. Overview of the cleaning of new coupons is:

- Clean with surfactant
- Acid Soak
- Clean with De-ionized (DI) water

3.4.5. Start by filling out LF-5.1.3 for the reagents used for each batch cleaning. Reagent LOGBOOK 5 retains all current LFs for cleaning reagents in use.

- LF-5.1.4 Nitric Acid (Aluminum)
- LF-5.1.5 Stannous Chloride (Steel)
- LF-5.1.6 ½ strength Hydrochloric Acid (1:1) (Brass)
- LF-5.1.7 Chromic Acid (Magnesium)
- LF-5.1.8 Surfactant Log

3.4.6. Before using ScotchBrite green scrubbers on new coupons cut to approximate dimensions (1.5” x 3”) and pre-scrub using the dummy coupons to help remove coarse fibers from each pad. Only use on dummy alloy for the applicable new coupon(s). DO NOT use ScotchBrite green scrubbers on different alloy types.

3.4.7. SURFACTANT CLEANING – use cleaning solution, 409 Formula Antibacterial All Purpose Cleaner (LF-5.1.8) for all initial cleaning prior to acid cleaning. Use the conditioned green scrubber on the same alloy used to condition.

3.4.7.1. Spray the scrubber with enough surfactant to coat scrubber.

3.4.7.2. Use light force when cleaning. Scrub across each dimensional surface 10 times.

3.4.7.3. Rinse with tap water, and set aside. Repeat surfactant cleaning on all coupons to degrease or remove any packaging residue.

3.4.8. ACID CLEANING – use appropriate acid reagent for each alloy type. Section 3.4.5 outlines the lab forms and reagents to use on the different types.

3.4.8.1. Each acid is poured (fresh) into their containers. Nitric acid, Stannous Chloride, and 1:1 hydrochloric acid are put into 800 mL plastic beakers (filled to approximately 750 mL). The Chromic acid is poured into individual 125 mL test tubes (with approximately 75mL of acid).

3.4.8.2. Place the stannous chloride beaker into an ice bath and allow to cool to within the temperature range outlined in section 3.4.8.4. Place each of the test tubes containing chromic acid into the water bath beaker, arranging them upright sitting in the glass beads.

3.4.8.3. Turn on the electric hot plate and allow the water bath to just reach boiling.

3.4.8.4. Acid cleaning is performed by an acid soak as outlined below:

(1) Aluminum, 5 minutes at room temperature (70°F $\pm$ 5°F)
(2) Steel, 6 minute soak at 32°F $\pm$ 5°F
(3) Brass, 5 minutes at room temperature (70°F $\pm$ 5°F)
(4) Magnesium, 15 minute soak at 212°F $\pm$ 5°F

3.4.8.5. Once each of the acid solutions are in the proper temperature range, begin the acid soak times. (1), (2), and (3) Coupons should be cleaned in sets of 6 (this assures enough room in each container so they are not touching during the acid soak). Acid soaks for (4) are done individually and can all be performed all during the same time interval.

3.4.8.6. Use digital timers with the preset times to assure consistency. It is acceptable to perform acid soaks concurrently with other alloy types just assure they are removed at the designated intervals.

3.4.8.7. When each soak has been completed, move the coupons to an 800 mL beaker of water to await final scrub cleaning.

3.4.8.8. Grab a new clean scrubber, condition as in section 3.4.6, but do not add surfactant.

3.4.8.9. Scrub each coupon under running tap water. 10 scrubs on each dimensional side.

3.4.8.10. When finished, rinse the coupon with tap water and place in a third 800 mL beaker filled with deionized water.

3.4.8.11. Repeat sections 3.4.8.9 and 3.4.8.10 with all coupons of an alloy type.

3.4.8.12. Once an entire alloy is finished, start at section 3.4.8.8 with the next alloy and a new 800 mL beaker of fresh DI water. Again, be sure to only use scrubbers conditioned with the same alloy they are used to clean.

3.4.8.13. When all coupons of all alloy types are in DI water move to the coupon drying section.

3.4.9. COUPON DRYING – **Wearing gloves**, one alloy at a time, dump out the DI water and individually wipe each coupon with a chemwipe (or no-lint tissue equivalent) and hang on the wire hooks in the industrial oven.

3.4.9.1. Repeat with all alloy types until all cleaned coupons are suspended in the oven.

3.4.9.2. Set the oven temperature to 150^{o}F and close the oven doors. Wait 1 hour or until the coupons are visibly dry, then turn off the oven and allow coupons to cool.

3.4.9.3. Coupon cooling can be accelerated by opening the oven doors or removing them from the oven hooks and placing in open air.

NOTE: Be sure to always wear gloves when handling coupons after cleaning.

3.4.9.4. After the coupons have cooled to room temperature, move to the Initial Coupon Weighing section.

3.4.10. INITIAL COUPON WEIGHING – LabVIEW is used to record the initial weights of the coupons

3.4.10.1. From the desktop of the corrosion computer select the LabVIEW VI labeled “initialweight.vi”

3.4.10.2. Once the VI is opened, assure the BLACK BOX ABC SWITCH is set to the “A” or “Balance” setting. Also assure the attached Sartorius balance is powered “on”. Make sure the flash drive is connected to save the results. These results auto-fill into a spreadsheet that can be imported into Excel.

3.4.10.3. Coupons are weighed in batches by alloy type. Starting with the aluminum coupons (followed in order by steel, brass, and magnesium), select the alloy designation, how many coupons, and the number of first coupon in the available fields.

3.4.10.4. Press the “check mark” button when the *number of coupons*, *alloy designation*, and *number of first coupon* fields are filled in and then press the “⇨” to run the program. Follow the program prompts, which starts with taring and recording the tare weight before handling any coupons.

3.4.10.5. Figure 3 shows the “tare” (left and right of digital display) and “record” buttons (circled in red).

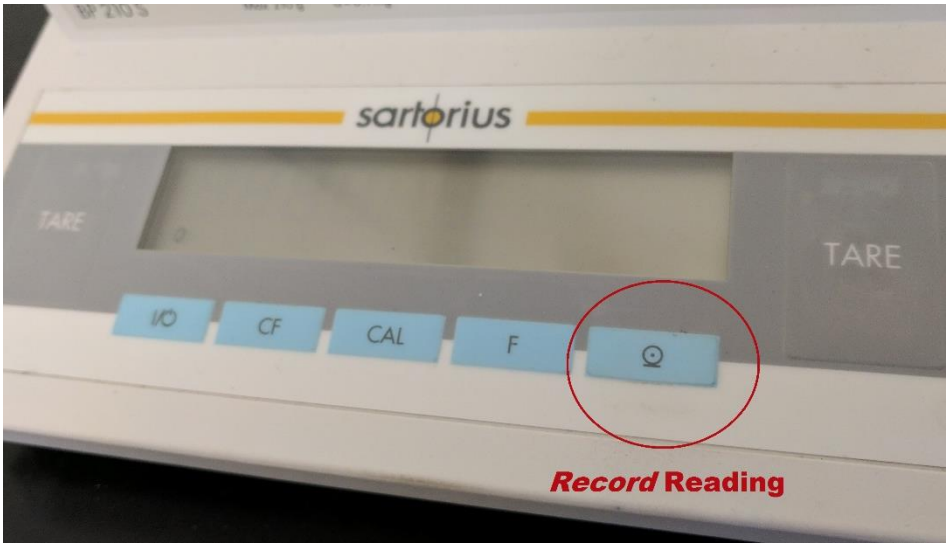


Figure 3-Sartorius Balance

3.4.10.6. Remember to ALWAYS **wear gloves** when handling coupons at this stage.

3.4.10.7. When all coupons of an alloy type have been recorded the program will prompt another recording of the empty balance weight. This finalizes the LabVIEW VI for that alloy.

3.4.10.8. Repeat starting with section 3.4.10.4 for the next alloy type.

3.4.10.9. When all cleaned coupons have been recorded, navigate to the desktop. Select the link labeled *Shortcut to SIMPTECH (E:)*.

3.4.10.10. Open the file named *coupons_initial_weights_hp.xls* and scroll to the bottom of the spreadsheet to make sure the coupons just weighed have been properly recorded.

3.4.10.11. If nothing appears, troubleshoot and re-weigh the coupons before moving to section 3.5.

3.4.10.11.1. Troubleshooting is not commonly required. It can include but is not limited to restarting the computer, LabVIEW program, or reattaching the flash drive.

3.4.10.12. If all coupons have been recorded successfully move to section 3.5 for immersion. REMINDER coupons MUST be dunked the same day they are cleaned.

3.4.11. DO NOT proceed to the next step until it is confirmed that the initial weights and measurements results exist.

3.5. COUPON IMMERSION (Dunking)

When all previous steps have been completed, the coupons are ready to be immersed in the fire chemical product(s). All coupons require attachment of green fishing line, and the partially immersed coupons will require a small 2” dash to use as a sightline when dunking. Remember to ALWAYS **use gloves** when handling coupons at this stage.

3.5.1. MARKING – Align all coupons as shown in figure 4 and (with a wax pen) mark the partial immersed coupons 2” from the bottom with a small dash. Minimize the mark’s length as much as possible while remaining visible to reduce interference with the testing.

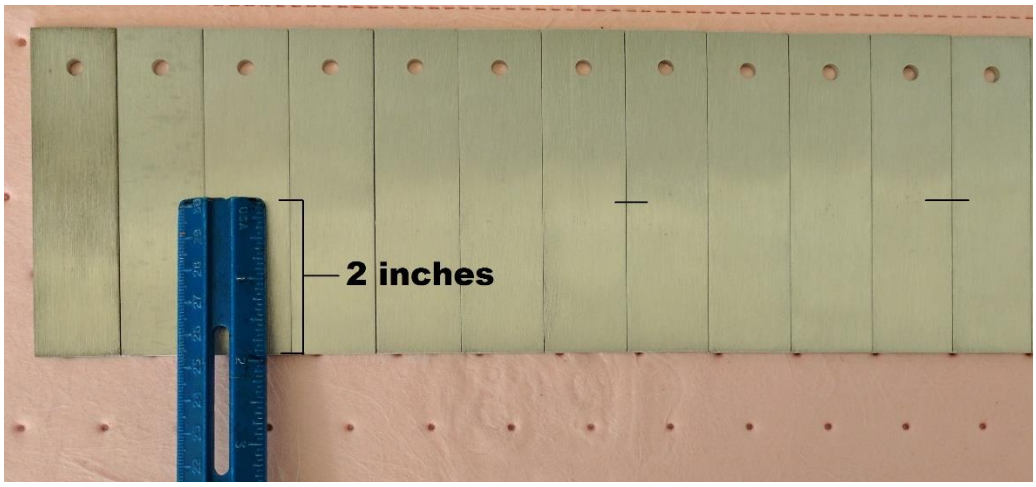


Figure 4- Marking partial immersion coupons

3.5.2. Next wrap and cut the green fishing line using the apparatus shown in figure 5. If more line needs to be ordered, see appendix C.

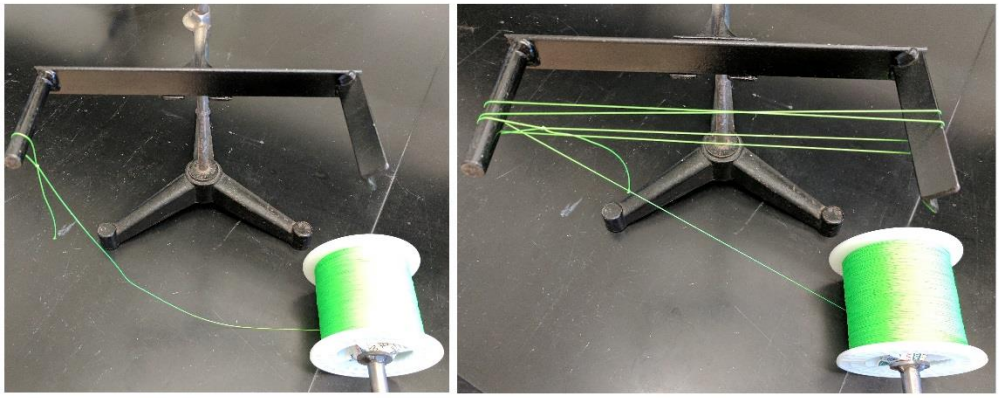


Figure 5- Wrap fishing line around, and use scissor guide (on right) to cut for uniform line length.

3.5.3. Use the scissor guide to cut all of the lines to the same length.

3.5.4. Attaching coupon. One at a time, fold a cut length in half and guide through coupon hole. Loop and finish as shown in figure 6 making ends meet.

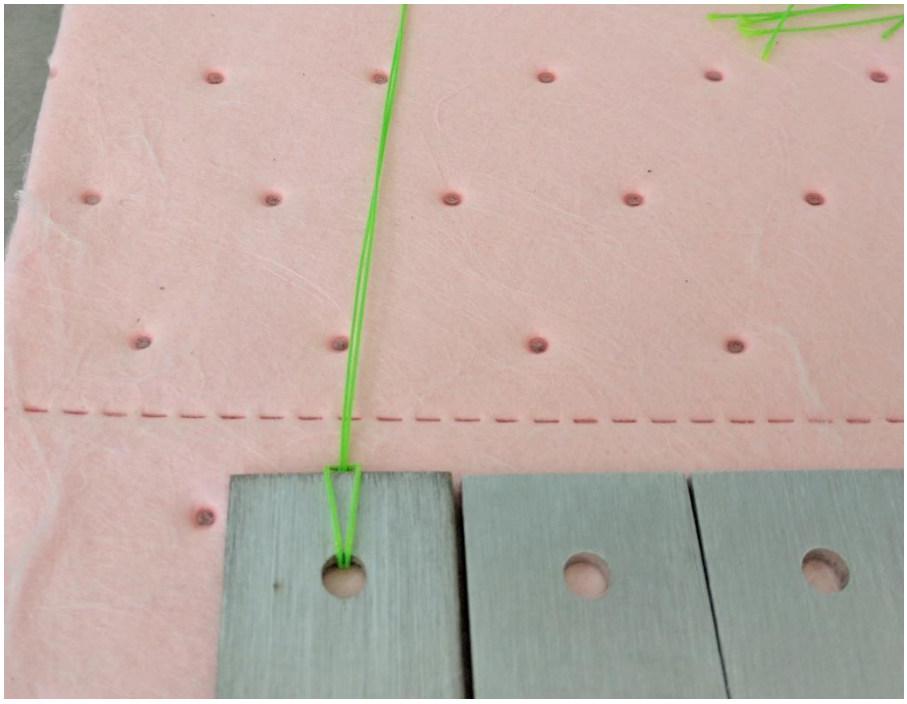


Figure 6

3.5.5. Once all coupons are marked and tied, prepare the sample containers.

3.5.6. CONTAINER PREPARATION – Each jar should be labeled as in section 3.3.6. Next tape over top of each jar and pinch tape together as shown in figure 7.

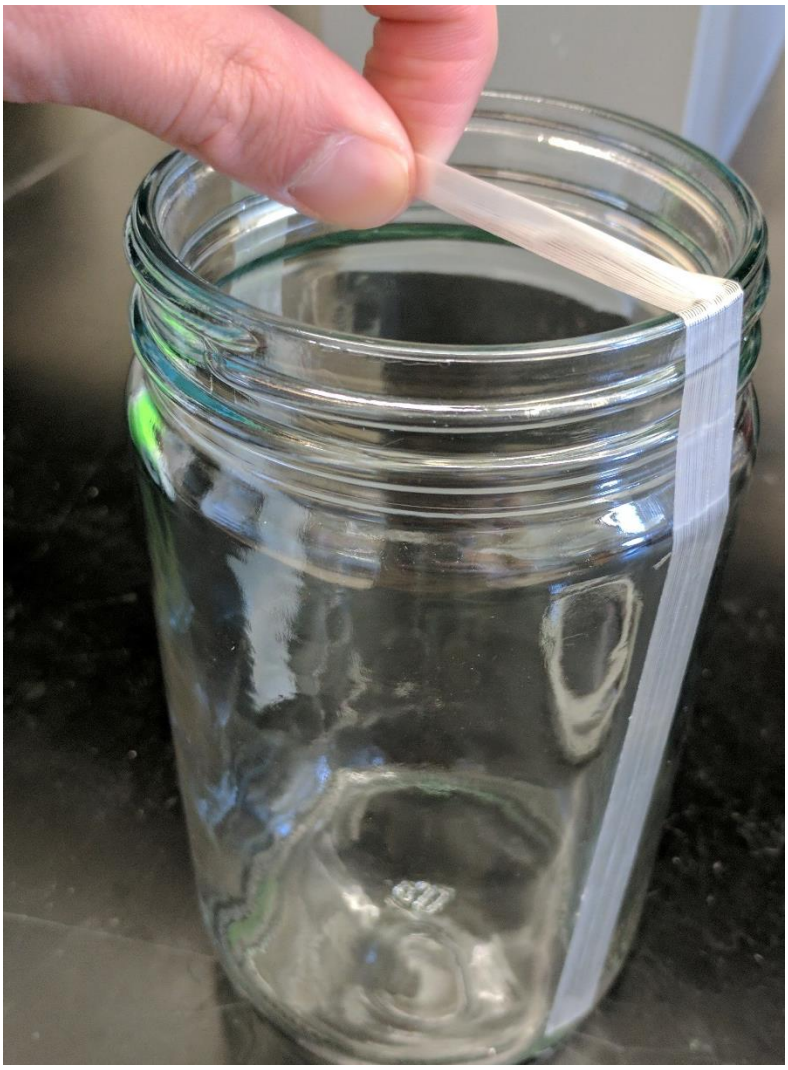


Figure 7-Taped container

3.5.7. Lastly, each coupon is now immersed to the proper depth and the fishing line wrapped once around the pinched tape, and the excess run to the outside of the container.

3.5.8. Tape the rest of the line to the outside of the container in a way to hold the coupon just above its desired depth. When the lid is attached, the coupon will lower slightly; this is more critical for the partially immersed coupons.

3.5.9. Tightly attach each lid (except for magnesium). It is common for the magnesium coupon samples to evolve gas during the initial immersion; these lids are attached loosely to reduce pressure build up.

3.5.10. When all gas evolution has subsided, tighten remaining lids and place each sample container in its appropriate incubator. EVEN numbered coupons into 70°F and ODD coupon numbers into 120°F incubators.

3.5.11. Order jars logically in the incubators with sample labels facing outward to help with identification and sample management.

3.5.12. Lastly, mark the group calendar with the day that each set should be removed. The initial steps of section 3.9 may be started with the results (initial weights and measurements) collected at this time to reduce the time required at the conclusion of the 90-day test.

3.6. COUPON REMOVAL AND CLEANING

3.6.1. After the 90 days have elapsed, remove all necessary containers from the incubators and allow to cool for 0-2 hours.

3.6.2. Once cooled and wearing gloves, clean each coupon under tap water to clean off the bulk fire chemical product. Use of a non-abrasive, plastic spatula can help to remove the tough or hardened material. Be sure not to scrape the coupons in any way as this can lead to requiring a re-test of the samples.

3.6.3. Remove the attached fishing line, wipe dry, and place on a drying rack. Repeat for all coupons. All coupons removed from the incubators must be cleaned on the same day.

3.6.4. When all coupons have been cleaned, move to section 3.7 the final coupon acid cleaning stage.

3.7. FINAL COUPON ACID CLEANING

3.7.1. The final coupon cleaning is performed just as in section 3.4.8 with one change; a control coupon is used with each acid cleaning batch. Follow the instruction given in section 3.4.8 with the slight modifications outlined below.

3.7.2. NO SURFACTANT cleaning is used for the final cleaning ONLY ACIDS.

3.7.3. Section 3.4.8.5 outlines the acid cleaning batches. For this section *final coupon acid cleaning* each batch of 6 (or 12 for magnesium) uses a control coupon of the matching alloy. This coupon is acid cleaned in parallel to account for weight loss due to the cleaning procedure.

3.7.4. The control coupon can be identified from LF-5.1.10, they are numbered (i.e. A1, A2, etc. for each of the aluminum coupons) according to the alloy letter designation of section 3.1.3.

3.7.5. Locate the control coupon most recently used and select the ***next*** numerical control coupon for this final cleaning procedure.

NOTE: For a full batch of 39 samples you will need 2 control coupons for all alloys except magnesium (only requires 1). For consistency, always select control coupons in sequence (i.e. A1 and A2 or G6 and G7) with the lowest number reflecting the first acid soak batch, and the next coupon number for the second batch. This helps with organization and control coupon management.

3.7.6. Record all reagent traceability and control coupons used on LF-5.1.3.

3.7.7. Treat the control coupon just as you would any other coupon with regards to soaking, scrubbing, and drying.

3.7.8. When all coupons have gone through the cleaning and are in DI water awaiting drying proceed as in section 3.4.9 (excluding the direction of 3.4.9.4. DO NOT proceed to the *Initial weighing* section- continue with section 3.8, *final weighing*; the LabVIEW programs operate differently and cannot be used interchangeably.

3.8. FINAL WEIGHING

3.8.1. Once all coupons (including controls) have been dried and cooled it is time for the final weighing.

3.8.2. From the desktop, open the *finalweight.vi* LabVIEW program. The process is very similar to the initial weighing section (3.4.10) with the addition of the control coupons. There is on-screen instruction that helps describe the process flow.

3.8.3. Fill in all the fields and be sure to add the numbers of the control coupons for this batch of samples. As performed in the initial weighing section, group coupons by alloy type.

3.8.4. When the program fields are updated to reflect the batch of coupons to be weighed, click the check mark button followed by the "⇨" to run the program.

3.8.5. Tare the balance and record the tared weight as the on-screen prompts instruct.

3.8.6. Before taking the first coupon weight, weigh the first control sample. This is done by selecting the *Weigh Control?* Button on the right side of the screen as shown in figure 8.

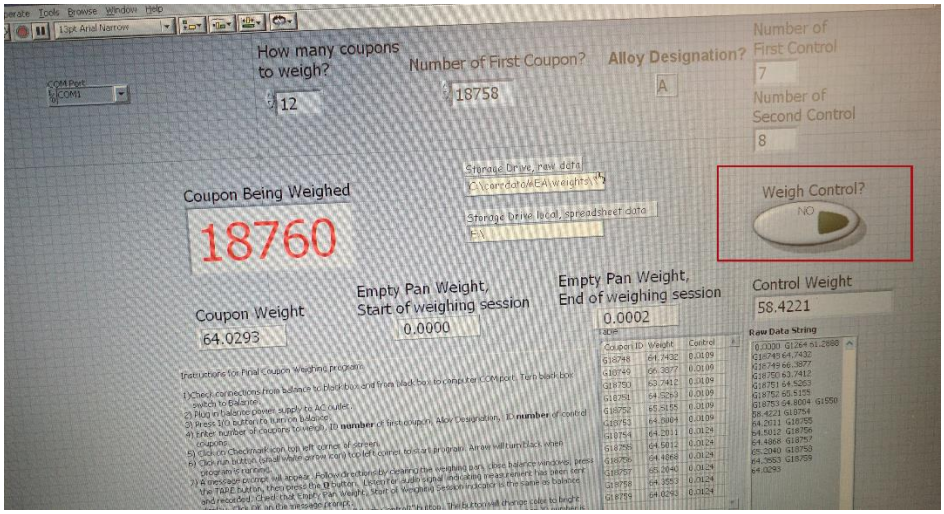
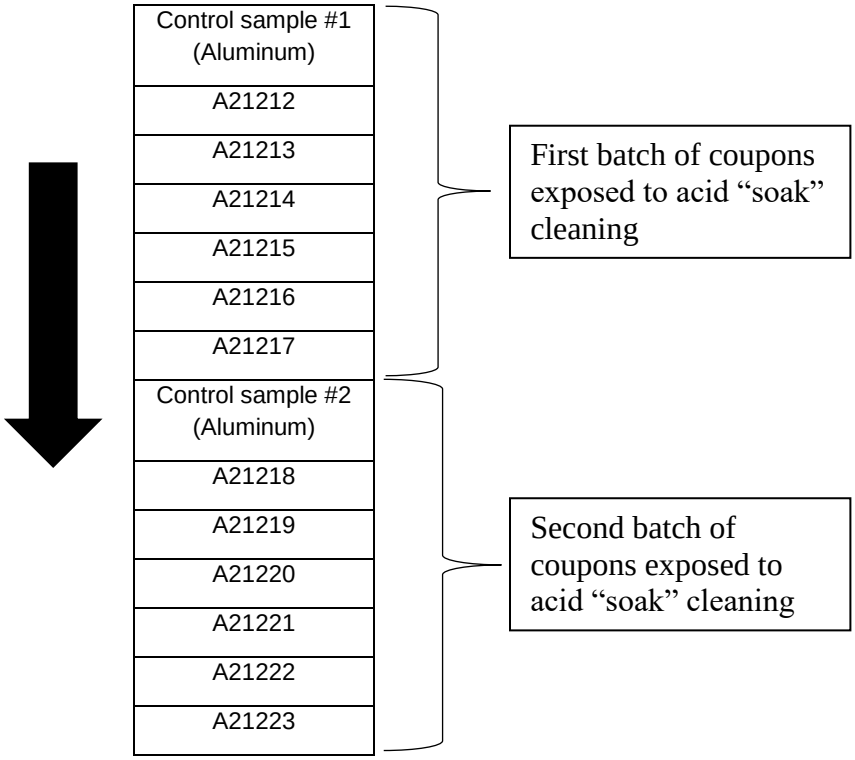


Figure 8-FinalWeights.VI

3.8.7. When the button is illuminated, record the mass of the control coupon (same button as in figure 3), wait to hear the audible “beep” indicating the data was collected, and then press the *Weigh Control?* button once more to deactivate the function.

3.8.8. Proceed as normal until you reach the next control coupon and repeat the steps above. The standard practice is to weigh the control coupon just before weighing the coupons it was acid cleaned with.

EXAMPLE: The ordered coupon weights would follow the diagram below starting at the top and moving down:



3.8.9. When all coupons have been weighed, follow the on-screen prompts to take a final balance weight to complete the data collection.

3.8.10. Repeat starting at section 3.8.3 with each alloy type until the entire corrosion batch has been completed.

3.8.10.1. Confirm the data was recorded by selecting the link labeled *Shortcut to SIMPTECH (E:)* on the desktop.

3.8.10.2. Open the file named *coupons_final_weights.xls* and scroll to the bottom of the spreadsheet to make sure the coupons just weighed have been properly recorded.

3.9. RESULTS AND SPREADSHEET INPUT

3.9.1. Locate LF-5.1.9, *90-day corrosion template* and update all labels on the template to reflect the new batch of samples. Additional tabs may be

duplicated for subsequent dilutions of a product type. Save in an appropriate desktop location as well as on the corrosion flash drive.

3.9.2. Input the start date of each batch and calculate the end date. Add this end date to the group calendar if this has not already been performed. Also make sure these dates are included on the appropriate mix sheet LF (i.e. LF-3.1.1).

3.9.3. Use the LabVIEW data files to copy and paste the measurements and weights into LF-5.1.9.

3.9.4. When LF-5.1.9 is completed, check for transcription error and consistency in measurement and calculations. All spreadsheet calculations are described in section 5.

3.9.5. Use the results of LF-5.1.9 to draft a letter to the company describing the outcome of the testing.

3.10. ISSUING REPORTS TO COMPANIES

3.10.1. Once LF-5.1.9 is completed a report (or letter) is issued to the company. Included in the report are all results from the 90-day corrosion and a narrative explaining whether or not the results meet the acceptance limits of the applicable specification.

3.10.2. The letter also includes the formulation ID# of the product tested and the current specification it was tested under (with any revision or amendment iterations included).

3.10.3. All relevant tables are included within the letter with results

3.10.4. Refer to Appendix A for an example of the drafted letter format.

3.10.5. The final paragraph always includes a question asking the company if they would like to proceed with intergranular corrosion on the applicable alloys (either aluminum or magnesium, or both). Standard practice is to only submit coupons for analysis for products that *pass* the uniform corrosion testing limits. This is all outlined in LF-5.2.

4. Intergranular Analysis Instruction

4.1. This instruction is described in LF-5.2 *Intergranular Corrosion Process (LOP)* and on LF-5.2.1, *IGA Procedure* with use of the Sample Analysis Request (SAR), attachment (c).

5. Calculations

Calculations used in LF-5.1.9 are explained in this section. Simple arithmetic equations and conversions are not included (i.e. Days are calculated from the “In” and “Out” dates).

5.1. COUPON AREA

5.1.1. $Area\ of\ a\ coupon\ (sq.in.) = (2\big((L \times W) + (L \times H) + (H \times W)\big) \div 2.54^2$

5.2. WEIGHT LOSS

5.2.1. Measurement in grams; Result in milligrams:

(Coupon weight$_{initial}$ – Coupon weight$_{final}$ – Control Coupon$_{wtloss}$) x1000mg/g

5.3. CORROSION RATE

5.3.1. Corrosion rate is reported as mpy or mils per year. 1 mil = 0.001inch. The values that are known and calculated are given as:

D = density of alloy (grams/cm^3, section 5.4)

A = area of coupon (in^2, section 5.1)

T = time (in hours)

W_{loss}= weight loss (in mg, section 5.2)

C = 534, Constant. Dimensional analysis correction (hrs·in^3)/(cm^3·yr)

$$Corrosion\ rate\ (mpy) = (C \times W) \div (D \times A \times T)$$

5.4. DENSITY

5.4.1. Density for each alloy is defined as:

2024 grade Aluminum = 2.77 g/cm^3

4130 grade Steel = 7.86 g/cm^3

C260 Yellow Brass = 8.47 g/cm^3

AZ-31-B grade Magnesium = 1.77 g/cm^3

5.5. AVERAGE

5.5.1. Each average from LF-5.1.9 is calculated from the three replicate measurements of each immersion condition. The equation is given as:

$$Average\ Corrosion\ rate, mpy = (CorRate1 + CorRate2 + CorRate3) \div n, (where\ n = 3)$$

6. Training

6.1. Training is provided by a qualified analyst. Uniform Corrosion qualification is achieved through completion of Qualification Plan (QP) 5.1.

UNIFORM CORROSION COUPON SPECIFICATIONS

1. There are 4 different alloys used for uniform corrosion. These coupons and their details are outlined in the Table A1.
2. Location and hole dimensions are discussed in the diagram in section 3.2.11 (figure 1).

Table A 1

Alloy	Specification	Finish	Dimensions	Notes
Aluminum	2024-T3 Aluminum	150-grit	0.125 x 1 x 4”	
Steel[1]	AISI 4130 Steel AMS 6351	150-grit	0.125 x 1 x 4”	Annealed Steel
Brass 36-Y	UNS C26000	150-grit	0.125 x 1 x 4”	
Magnesium	Az31B AMS 4377	150-grit	0.125 x 1 x 4”	

1 This Steel designation was determined from the 1974 Ocean City Research report, pages 19-20, should have Rockwell B hardness around 99-95. NWST-01313

File Code: 5162
Date: April 26, 2016

COMPANY CONTACT
INFORMATION

Dear POC,

The initial uniform corrosion tests have been completed on Product A (formulation identification # AB1234) in accordance with Forest Service Specification 5100-307a.

Table 1 summarizes the results of the uniform corrosion tests on the fresh concentrate of the product. The corrosion rates for aluminum, mild steel, yellow brass, and magnesium exposed under all test conditions are acceptable.

Tables 2 and 3 summarize the results of the uniform corrosion tests on the product mixed at 0.1% and 1.0%. The corrosion rates for aluminum, mild steel, yellow brass, and magnesium exposed under all test conditions are acceptable.

If you wish to proceed with intergranular corrosion testing, please provide me with a note of authorization to have the testing performed and a purchase order to cover the costs of testing 8 aluminum coupons and 8 magnesium coupons.

If you have any questions related to this work, please contact me at 406-829-6741, or email at gjmcbride@fs.fed.us.

Sincerely,

Greg McBride

GREG MCBRIDE
Physical Scientist
Wildland Fire Chemical Systems

CC: S. Zylstra
C. Johnson

Table 1

Uniform corrosion by 90-day Weight Loss Test
of
Product A
AB1234
Fresh concentrate

	Total Immersion		Partial Immersion	
	70° F	**120° F**	**70° F**	**120° F**
	- - - - - - - - - - - - - - mils-per-year - - - - - - - - - - - -			
2024 - T3 Aluminum	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1
Average	<0.1	<0.1	<0.1	<0.1
4130 Steel	0.1	0.8	0.6	2.3
	0.1	0.9	0.5	1.9
	0.1	0.9	0.5	2.0
Average	0.1	0.9	0.5	2.1
Yellow Brass	-	-	-	0.2
	-	-	-	0.2
	-	-	-	0.2
Average	-	-	-	0.2
Az31B Magnesium	4.4	3.6	3.0	7.3
	5.0	3.2	2.7	1.5
	4.6	2.9	2.6	6.2
Average	4.7	3.2	2.8	5.0

Table 2

Uniform corrosion by 90-day Weight Loss Test
of
Product A
AB1234
0.1% mixed from fresh concentrate

	Total Immersion		Partial Immersion	
	70° F	**120° F**	**70° F**	**120° F**
	- - - - - - - - - - - - - - - mils-per-year - - - - - - - - - - - -			
2024 - T3 Aluminum	0.1	<0.1	<0.1	<0.1
	0.1	<0.1	0.1	<0.1
	<0.1	<0.1	<0.1	<0.1
Average	0.1	<0.1	<0.1	<0.1
4130 Steel	1.1	1.5	0.7	2.3
	0.9	1.6	0.6	2.6
	0.6	1.5	0.7	2.4
Average	0.9	1.5	0.7	2.4
Yellow Brass	-	-	-	<0.1
	-	-	-	<0.1
	-	-	-	<0.1
Average	-	-	-	<0.1
Az31B Magnesium	1.4	4.0	1.0	1.8
	1.4	2.2	1.1	1.7
	1.3	1.9	1.2	1.6
Average	1.4	2.7	1.1	1.7

Table 3

Uniform corrosion by 90-day Weight Loss Test
of
Product A
AB1234
1.0% mixed from fresh concentrate

	Total Immersion		Partial Immersion	
	70° F	**120° F**	**70° F**	**120° F**
	- - - - - - - - - - - - - mils-per-year - - - - - - - - - - -			
2024 - T3 Aluminum	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1
	<0.1			
Average		<0.1	<0.1	<0.1
4130 Steel	0.9	1.6	0.7	3.0
	0.5	1.5	0.7	3.7
	0.5	1.4	0.6	3.6
Average	0.6	1.5	0.7	3.4
Yellow Brass	-	-	-	0.1
	-	-	-	0.1
	-	-	-	0.1
Average	-	-	-	0.1
Az31B Magnesium	0.9	3.1	1.2	3.6
	1.0	3.0	1.0	3.2
	0.9	5.4	0.8	2.0
Average	0.9	3.8	1.0	2.9

Appendix C

Details of Procurement Request

Other alternatives may be suitable, but have not undergone a validation study to compare impacts to results.

PROCUREMENT REQUEST INSTRUCTIONS: Agencies must provide entries in unshaded areas. See reverse.		TO: *(Procurement Office)*						1. REQUESTING OFFICE WFCS
2 RECEIVING OFFICE NO.	3 CONTRACT NUMBER *(If Applicable)*	4 ORDER DATE	5	6 UNIT CODE	7 FUND CODE	8 PURCHASE/DELIVERY ORDER NUMBER	9 SUB.	1A. PROCUREMENT REQUEST NO.
				13	TX			1B. DATE 10/01/2014

CHECK ONE ☒ Purchase Order ☐ Delivery Order	10. TO: *(Seller)* Bob Ward's	11. SHIP TO: *(Consignee and Destination)* Greg McBride WFCS/MTDC 5785 Highway 10 West Missoula, MT 59808 ☐ INSIDE DELIVERY REQUESTED

12 LINE ITEM	13 ACT. CODE	14 DESCRIPTION	15 BUDGET OBJECT	16 ACC. LINE	17 QUANTITY	18 UNIT ISSUE	19 UNIT PRICE	20 AMOUNT
1		fly reel backing line (for coupon dunking) Brand: woodstock line company 20 pound test style number: FL250020 Price: 0.25 for 10 yards Quantity: 2500 yards			1	ea	$62.50	$62.50