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REV	DATE	CHANGE	AUTHOR	REVIEWED
00	170305	Initial release	BMW	SCB
01	180319	Update ref to other procedures, title change, burr chemistry added	PPP	KAL
02	180716	Clarified surface maximum allowable surface removal	BMW	KAL
03	190313	Updates and clarifications	SDP	PPP
04	190823	Lap-welded seams accounted for; Estimated testing duration adjusted	PPP	SDP
05	200914	HSD Tester sample testing capabilities added	PPP	SCB

MMTF000 – General Field Testing Procedure

1. MMT's Job Site Requirements

Time to complete material verification of 1 joint: 4-6 hours

Pipeline Preparation: Sandblasted pipe outer diameter to SSPC-SP5 (NACE #1) for 2 foot length and all-around circumference. Site excavation should allow at least 18 inches of clearance below pipeline. Work area should be dry.

Testing Completed: Hardness, Strength, and Ductility (HSD) Testing, longitudinal seam determination, metallographic microstructure grain analysis, chemical analysis through burr samples, thickness mapping for informational purposes only, and magnetic particle analysis for informational purposes only.

2. Requested Information

We ask that the customer provide us with the following information prior to field work:

- **Safety**: PPE and safety training requirements
- **Site**: Address including GPS location and accessibility
- **Asset info**: Pipeline diameter, nominal wall thickness, location, pipe joint naming convention, seam location from ILI tool run (if available), year of installation (if available), and material grade (if available). Additional details required for fittings, Table 1 details the HSD Tester's capabilities for different sample types. Note, the below table only outlines assets verified for testing, smaller assets may be tested but would require pre-testing discussion to determine feasibility.

Table 1: HSD Testing capability ranges for different sample types.

Sample Type	Straight Pipe Joint	Elbows	Tee Joints	Reducers
Geometry Range	3” OD and greater, including flat plates.	8” OD and greater, both 90° and 45° elbows. Drawings or dimensional information preferred beforehand.	3” OD and greater, required minimum of 12” of unobstructed straight pipe. Drawings or dimensional information preferred beforehand.	Capabilities dependent on length and transition from larger diameter to small diameter. More gradual transition will allow for testing.

3. Safety and Personnel Training Requirements

All MMT personnel have completed the following:

- **Safety:** OSHA 10 Hour Construction Safety and Drug and Alcohol Testing
- **Testing:** All personnel are familiar with all MMT Procedures
- **Staff Level:** Personnel are qualified in accordance with proper MMT staff level training

4. MMT Testing Procedures

The overall MMT standard testing procedure is outlined in the steps below. For MMT procedures listed in the following steps, the latest revision of the document at the time the work is performed shall be used.

1. Conduct initial site inspection and pipe documentation in accordance with MMTF007 – Ultrasonic Thickness Measurements Procedure and MMTF008 – Magnetic Particle Testing Procedure. This step includes verifying the nominal wall thickness reported or determining an initial wall thickness if nominal is unknown and locating the seam or verifying that the pipe is seamless using MMTF010 – Longitudinal Seam Location Procedure.
2. Calibrate the HSD equipment in accordance with MMTF009 – HSD Calibration Procedure.
3. Locate two 4 inch by 6 inch test areas with least external corrosion and no pipe wall anomalies. If an electric-resistance-welded (ERW) seam or a lap-welded seam is identified, one of the test areas shall be centered over the seam. If a submerged-arc-welded (SAW) or flash welded seam is identified, both areas should be at least 6-inches circumferentially away from the seam or 90 degrees for pipes with diameters less than 12-inches. If possible, test areas should be located at least 90 degrees from each other in the circumferential direction and at least offset by 6 inches along the length. All test areas must meet initial pre-surface preparation UT wall thickness requirements in accordance with MMTF002 – Surface Preparation Procedure. If requirements are not met, permission is required from the operator or appropriate representative to potentially exceed material removal standards.
4. For each test area, buff away at least 0.005 inches of the surface to remove the decarburization layer and polish the surface to 2000 grit in accordance with MMTF002 – Surface Preparation Procedure.
5. Conduct base metal and weld HSD tests in accordance with the HSD Testing Procedure. For ERW joints, one HSD test is performed over the longitudinal seam (test time ~ 15 min) and three tests are used for the base metal away from the seam (test time ~ 10 min each). For all other pipe joints, two tests are performed in two base metal areas that were prepared for testing, for a total of four base metal tests.

6. Remove HSD grooves that remain on surface by buffing in accordance with MMTF002 – Surface Preparation Procedure. Confirm the total wall thickness removed does not exceed 10% of the pipe nominal wall thickness and does not fall below the minimum wall thickness standards identified in MMTF002 – Surface Preparation Procedure unless prior permission was granted by the operator or appropriate representative.
7. Extract material for chemistry in accordance with MMTF005 – General Procedure to take Metal Burr Samples for Chemistry of Pipelines.
8. Perform metallographic analysis of the base metal microstructure in accordance with MMTF003 – Metallographic Grain Structure Procedure.
9. For ERW pipe joints, image and document the apparent heat-affected-zone surrounding the longitudinal seam in accordance with MMTF006 – OD Seam Etch Procedure.

REV	DATE	CHANGE	AUTHOR	REVIEWED BY
00	170520	Initial release	BMW	PPP
01	171215	Changed tool to PTX	KT	PPP
02	180723	Included additional guidelines on surface removal	PPP	KAL
03	190311	40 and 80 grit steps changed to minimize material removal. Steps to track material removal and MMT minimal wall thickness requirements defined	PPP	SDP/BMW
04	190823	Additional NWT values added to Table 1; Clarification of operator permissions for wall thickness removal	PPP	SDP

MMTF002 – Surface Preparation Procedure

1. Overview

This document details the procedure for surface preparation for Hardness, Strength, and Ductility (HSD) testing on pipeline steel. Proper surface preparation is necessary to achieve reliable and consistent material characterization, and to ensure a safe nondestructive assessment of the pipe joint. Refer to Appendix A for additional guidelines and requirements for material removal during surface preparation, and to Appendix B for surface preparation requirements of plates, cutouts, and testing over areas that have been previously tested with the HSD.

2. Pipeline Material Removal Requirements

It is critical that the amount of material removed is kept to a minimum and never exceeds 10% of the nominal wall thickness (NWT). Please note that while 10% is the maximum established by MMT procedures, some operators may have lower thresholds and wall thickness removal limits must be discussed and established prior to performing the surface preparation procedure. All correspondence shall be received in writing and documented. The amount of material removed from pipeline steel is largely dependent on the extent of surface pitting corrosion which must be removed prior to testing. Material removal is monitored throughout the surface preparation process using an ultrasonic thickness (UT) gauge. Application of this procedure on hundreds of pipe joints has shown that typical material removal ranges from 0.010 to 0.020 inches (0.25 to 0.51 mm). To ensure safe operation of pipelines and consistent material verification, the following requirements must be met.

- **Minimum material removal**: The minimum material removal is 0.005 inches (0.13 mm) to ensure the removal of any decarburized layer of the pipe surface.
- **Maximum material removal**: Total material removal must be limited to 10% of the NWT, unless the pipeline owner/operator has provided additional removal requirements to the MMT Operations Manager prior to mobilization of technicians for testing. All

correspondence shall be received in writing and documented. For pipes with smaller wall thickness or with heavy corrosion, the technician following this procedure must take special care to ensure that excessive material is not removed. Guidelines for ensuring material removal is less than 10% NWT are provided in Appendix A and **MUST** be read and understood prior to the surface preparation procedure. **IMPORTANT: If the maximum allowable material requirements are exceeded during any step of the surface preparation process, the technician must stop surface preparation and prepare a new area away from the initial region. If the total material removal exceeds 10% of the NWT, the technician must notify the MMT Operations Manager.**

- **Removal of HSD grooves after testing**: The HSD Tester creates four superficial grooves on the pipe surface that are less than 0.002 inches (51 μm) deep. These grooves must be removed from the surface after testing to ensure no stress risers remain on the pipe joint.

3. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Face Shield, Hearing Protection, Hand Protection, Steel Toed Boots, FR Clothing
- **Testing:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training

4. Equipment

- PTX sander
- 40, 80, 120, 280, 600, 1200, 2000 grit sanding paper
- Ultrasonic thickness (UT) gauge

5. Procedure

Surface preparation should be completed with the PTX sander using the following sandpaper grits:

- 40, 80, 120, 280, 600, 1200, and 2000 grit

When required, UT wall thickness measurements are used to verify that the remaining pipe wall thickness meets the minimum requirements given in Table 1. If the requirements in Table 1 cannot be met, a new region on the pipe surface should be selected for surface preparation. If no suitable initial location is found, the technician should contact the MMT Operations Manager to discuss appropriate steps. All correspondence shall be received in writing and documented. All UT measurements should be performed in accordance with MMTF007. A summary of the surface preparation procedure is shown in Table 2, and a detailed description is provided in Section 5.1.

Table 1: MMT minimum required wall thickness (in inches) to continue with surface preparation.

Nominal Wall Thickness (inches)		Minimum allowable thickness during prep (inches)				
Fraction	**Decimal**	**Initial Area (pre surface prep)** (3% below NWT)	**After 40 grit** (5% below NWT)	**After 80 grit** (7% below NWT)	**After 120 grit** (8% below NWT)	**Post HSD and after grooves removed**(10% below NWT)
	0.969	0.940	0.921	0.901	0.891	0.872
7/8	**0.875**	0.849	0.831	0.814	0.805	0.788
13/16	**0.813**	0.789	0.772	0.756	0.748	0.732
3/4	**0.750**	0.728	0.713	0.698	0.690	0.675
11/16	**0.688**	0.667	0.654	0.640	0.633	0.619
	0.656	0.636	0.623	0.610	0.604	0.590
5/8	**0.625**	0.606	0.594	0.581	0.575	0.563
	0.594	0.576	0.564	0.552	0.546	0.535
9/16	**0.563**	0.546	0.535	0.524	0.518	0.507
1/2	**0.500**	0.485	0.475	0.465	0.460	0.450
7/16	**0.438**	0.425	0.416	0.407	0.403	0.394
	0.406	0.394	0.386	0.378	0.374	0.365
3/8	**0.375**	0.364	0.356	0.349	0.345	0.338
	0.365	0.354	0.347	0.339	0.336	0.329
	0.325	0.315	0.309	0.302	0.299	0.293
	0.322	0.312	0.306	0.299	0.296	0.290
5/16	**0.313**	0.304	0.297	0.291	0.288	0.282
	0.308	0.299	0.293	0.286	0.283	0.277
	0.275	0.267	0.261	0.256	0.253	0.248
1/4	**0.250**	0.243	0.238	0.233	0.230	0.225
	0.219	0.212	0.208	0.204	0.201	0.197
3/16	**0.188**	0.182	0.179	0.175	0.173	0.169
	0.150	0.146	0.143	0.140	0.138	0.135

Table 2: Summary procedure requirements for each step of surface preparation.

Sandpaper Grit	**Buffing directions**	**Total buffing time (seconds)**	**Periodic UT required**	**Verify WT after step**	**General Comments**
40	1	As needed	Yes	Yes	Remove most surface pits
80	1	As needed	Yes	Yes	Remove almost all surface pits
120	3	As needed	Yes	Yes	All surface pitting removed
280	3	45 s	No	No	
600	3	45 s	No	No	
1200	3	45 s	No	No	Scratches for different directions may no longer be visible
2000	3	45 s	No	No	Scratches for different directions may no longer be visible

- Buffing directions should differ by approximately 20 degrees.
- Total buffing time should be monitored to ensure excessive surface material is not removed. If multiple directions are used, the time for each direction = total buffing time / number of buffing directions.
- Periodic UT means that UT readings are made after every 45 seconds of continuous surface preparation to ensure the wall thickness requirements of Table 1 are satisfied.
- Verifying the wall thickness after the step means that UT readings are made after the completion of that surface preparation step to ensure the wall thickness requirements of Table 1 are satisfied.

5.1 Surface Prep Procedure for Pipelines

1. **Identify Test Location and Determine NWT**: Identify a 4 inch by 6 inch (100 x 150 mm) area that contains the least amount of pitting relative to the surrounding areas. Use a UT gauge to map the thickness of the pipe in accordance with MMTF007. Record UT measurements in the MMT Field Notes Sheet. UT thickness should be compared to the initial allowable wall thickness requirements in Table 1 for the given pipe NWT, and if the requirements are not met a different region on the pipe surface should be selected. Generally, the NWT is provided by the pipeline owner/operator prior to testing. If the NWT is not known, the operator should use the average UT thickness as the NWT and refer to Appendix A for the procedure to calculate the allowable material removal for a measured wall thickness.

2. **Buff with 40 grit**: Use the PTX sander with the 40 grit belt and grind the surface in 1 direction until **MOST, BUT NOT ALL** surface pits and other anomalies are removed (Figure 1a). After the completion of this step, use the UT gauge to verify the remaining wall thickness requirements in Table 1 are met. Record these thickness measurements on the MMT Field Notes under the appropriate section.

   WARNING: The 40, 80, and 120 grit belt can quickly remove significant amounts of material. As a result, UT measurements must be periodically performed after every 45 seconds of continuous grinding to monitor material removal. The minimum wall thickness requirements in Table 1 for the 40, 80, and 120 grit steps must be met throughout this process and recorded in the MMT Field Notes Sheet. If at any time the maximum permissible material removal is exceeded, the technician must stop and prepare a new test area.

3. **Buff with 80 grit**: Use the PTX sander with the 80 grit belt, rotate the PTX tool by approximately 20 degrees with respect to the 40 grit prior grinding direction, and grind the surface until all scratches from the previous step are removed, and pitting is approximately 90% removed (Figure 1b). After the completion of this step, use the UT gauge to verify the remaining wall thickness requirements in Table 1 are met. Record these thickness measurements on the MMT Field Notes under the appropriate section.

4. **Buff with 120 grit**: Use the PTX sander with the 120 grit belt and use the three-direction grinding process summarized below. At the end of this step all pitting should be removed (Figure 1c). After the completion of this step, use the UT gauge to verify the remaining wall thickness requirements in Table 1 are met. Record these thickness measurements on the MMT Field Notes under the appropriate section.
   A. Grind the surface in 1 direction until all scratches are oriented in the new grinding direction and no scratches remain from the previous grinding step.
   B. Change the direction by at least 20 degrees and repeat until all scratches are oriented in the new grinding direction and no scratches remain from Step 4A.

C. Change the direction by at least 20 degrees and repeat until all scratches are oriented in the new grinding direction and no scratches remain from Step 4B.

5. **Buff with 280 through 2000 grit**: Continue to use the PTX sander with the progressively increasing grit belts of 280, 600, 1200, and 2000. For each grit, use the three-direction grinding process summarized below which should be performed for a total duration of 45 seconds (15 seconds per direction). Minimal material will be removed during these steps if the total grind duration is followed. Note that for the 1200 and 2000 grit steps, the scratch marks for different directions may not be visible, so timing can be used to determine when to switch directions.
   A. Grind the surface in 1 direction until all scratches are oriented in the new grinding direction and no scratches remain from the previous grinding step.
   B. Change the direction by at least 20 degrees and repeat until all scratches are oriented in the new grinding direction and no scratches remain from Step 5A.
   C. Change the direction by at least 20 degrees and repeat until all scratches are oriented in the new grinding direction and no scratches remain from Step 5B.

6. **Surface preparation evaluation**: Upon completion of surface preparation to 2000 grit, the surface will exhibit a mirror-like finish and contain no large scratches that remain from the sandpaper grits coarser than 2000 grit. If any scratches from previous grits remain a new area shall be prepared for testing. After this step, the region that has been prepared is ready for HSD tests to be conducted.

7. **Groove Removal After HSD Testing**: Upon completion of HSD testing on a pipe, the residual grooves will be removed by sanding with a 120 grit belt. Sanding should cease immediately after the grooves are removed, which typically takes only 5 seconds. After the completion of this step, use the UT gauge to map the test area wall thickness in accordance with MMTF007, and verify the final wall thickness requirements in Table 1 are met. Record these thickness measurements on the MMT Field Notes.

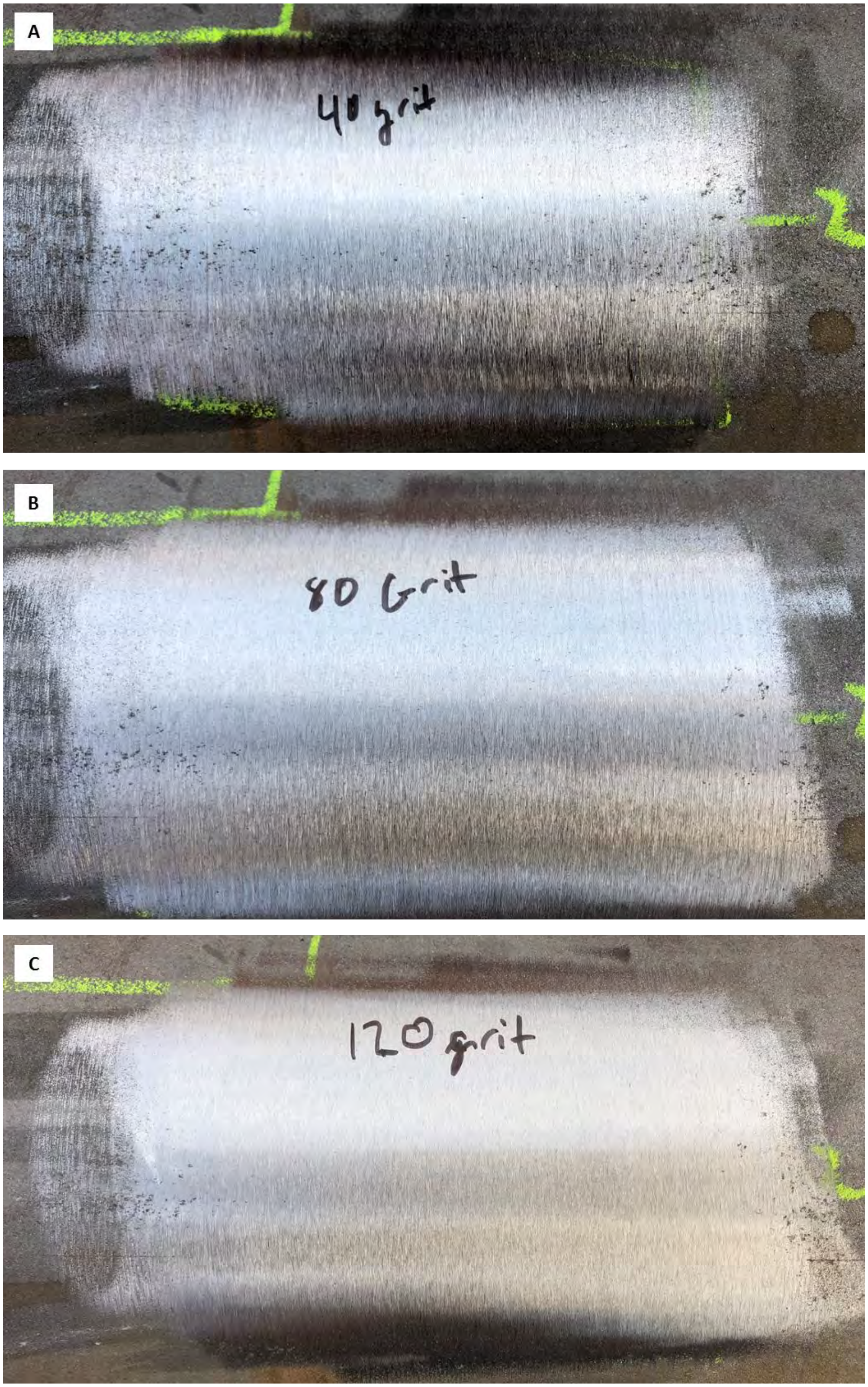

Figure 1: (**A**) Surface appearance after 40 grit stage; (**B**) Surface appearance after 80 grit stage; (**C**) Surface appearance after 120 grit stage

Appendix A – Guidelines for Safe Material Removal

To ensure safe completion of surface preparation it is critical that no more than 10% of the nominal wall thickness (NWT) be removed after the HSD grooves are buffed away. This appendix provides guidelines on ensuring that total material removal is less than 10%, and how to calculate the allowable wall thicknesses at different stages of surface preparation.

Calculating percent material removal

The percent of material removed is calculated using the following equation:

$$percent\ material\ removed = \left(\frac{nominal\ wall\ thickness - current\ wall\ thickness}{nominal\ wall\ thickness}\right) x\ 100$$

Where:
current wall thickness is wall thickness measured with a UT gauge during surface preparation.
nominal wall thickness is determined from the following:

- As indicated by the pipeline owner/operator prior to testing.
- If no NWT was provided, use the average of 5 UT measurements taken on the initial surface preparation area prior to grinding, as described in Section 5.1 of the procedure

Minimum wall thickness to continue surface preparation

Table 1 in this Procedure defines the minimum allowable thickness for pipes of common nominal wall thicknesses before testing, after 40, 80, and 120 grit prep stages, and after HSD testing is complete and grooves are removed. As indicated in Table 1, the following requirements must be verified with UT thickness measurements to ensure safe surface preparation:

- Before buffing, the wall thickness must be no more than 3% below the NWT.
- After buffing with the 40 grit belt is complete, the wall thickness must be no more than 5% below the NWT.
- After buffing with the 80 grit belt is complete, the wall thickness must be no more than 7% below the NWT.
- After buffing with the 120 grit belt is complete, the wall thickness must be no more than 8% below the NWT.
- After HSD testing is complete and the grooves have been removed, the wall thickness must be no more than 10% below the NWT.

If the NWT is not known, the minimum thickness criterion for 40 grit, 80 grit, 120 grit, and after the completion of testing shall be determined using the Initial Wall Thickness (IWT). The IWT is the average of 5 UT measurements taken on the initial surface preparation area prior to grinding. The minimum wall thicknesses to continue surface preparation can then be determined using the formulas below. Table 1 was constructed using these formulas with the NWT, instead of IWT.

$$minimum\ thickess\ after\ 40\ grit = IWT - (IWT\ x\ 0.05)$$
$$minimum\ thickess\ after\ 80\ grit = IWT - (IWT\ x\ 0.07)$$
$$minimum\ thickess\ after\ 120\ grit = IWT - (IWT\ x\ 0.08)$$
$$minimum\ thickess\ after\ HSD\ testing\ and\ grooves\ removed = IWT - (IWT\ x\ 0.10)$$

Examples

Example 1: The pipeline owner/operator indicated a NWT of 0.25 inches. UT measurements from a 4 inch by 6 inch area being considered for surface preparation read 0.264, 0.260, 0.255, 0.265, 0.263 inches, for an average wall thickness value of 0.261 inches. For a 0.25 inch NWT, Table 1 indicates the minimum wall thickness before surface preparation is 0.243 inches, after 40 grit is 0.238 inches, after 80 grit is 0.233 inches, after 120 grit is 0.230 inches, and after HSD grooves are removed is 0.225 inches.

Example 2: The pipeline owner/operator indicated a NWT of 0.25 inches. UT measurements from a 4 inch by 6 inch area being considered for surface preparation read 0.251, 0.247, 0.242, 0.252, 0.250 inches, for an average wall thickness value of 0.248 inches. For a 0.25 inch NWT, Table 1 indicates the minimum wall thickness before surface preparation is 0.243 inches, after 40 grit is 0.238 inches, after 80 grit is 0.233 inches, after 120 grit is 0.230 inches, and after HSD grooves are removed is 0.225 inches. Surface preparation can proceed, but care should be taken because the measured wall thickness is initially less than the given NWT.

Example 3: The pipeline owner/operator indicated a NWT of 0.375 inches. UT measurements from a 4 inch by 6 inch area being considered for surface preparation read 0.364, 0.360, 0.355, 0.365, 0.363 inches, for an average wall thickness value of 0.361 inches. For a 0.375 inch NWT, Table 1 indicates the minimum wall thickness to being surface preparation is 0.364 inches, which is higher than the initial wall thickness required to begin surface preparation. A different region on the pipe surface with a higher initial wall thickness should be found.

Example 4: The pipeline owner/operator has no records for an asset and cannot provide a NWT prior to testing. UT measurements from a 4 inch by 6 inch area being considered for surface preparation read 0.384, 0.380, 0.375, 0.385, 0.383 inches, for an average wall thickness value of 0.381 inches. The minimum allowable wall thicknesses to proceed with testing must be calculated from the average IWT of 0.381 inches because no NWT was provided. Using the formulas above, the minimum wall thickness after 40 grit is 0.362 inches, after 80 grit is 0.355 inches, after 120 grit is 0.351 inches, and after HSD grooves are removed is 0.343 inches.

Appendix B – Guidelines for Surface Preparation on Plates and Cutouts

No Prior HSD Testing: For plates and cutouts with no prior HSD testing, the surface preparation procedure outlined in Section 5.1 should be followed. The only exception to this implementation is there is no need for UT thickness measurements on flat plates.

Prior HSD Testing on the Sample: For samples with prior HSD testing (i.e. cutouts with limited surface area, plates within the MMT database of limited quantity, etc.) adjustments in Step 2 of Section 5.1 of the surface preparation procedure are required. The new procedure for this step should read:

1. **Buff with 40 grit**: Use the PTX sander with the 40 grit belt and grind the surface in 1 direction until **ALL** HSD grooves are removed. After the completion of this step, continue prepping with the 40 grit belt in the same direction for an equivalent amount of time to how long it took to initially remove the grooves. Change directions by 20 degrees and prep for the same time period once again. This step ensures that the test surface will contain no material that has been affected by prior HSD testing.

Continue with the remainder of the original surface preparation procedure as described in Section 5.1.

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REV	DATE	CHANGE	AUTHOR	REVIEWED BY
00	170718	Initial release	PP	BMW
01	180103	PTX tool, Cotton Swab	PP	RP
02	180309	Field Microscope	RP	PP
03	180507	Calibration and Sample Images	PP	SS
04	190318	Etchant and Alcohol Change, addition of Appendix A	SS	PPP
05	190920	Identification of location for grain imaging, over-etch solutions, and revisions to Appendix A	PPP	SDP

MMTF003 – Metallographic Grain Structure Procedure

1. Overview

The following document provides the procedure for imaging the metallographic grain structure of pipeline steel. This procedure shall be performed in the same area prepared for HSD base metal testing. This process requires the use of hazardous chemicals and appropriate PPE is required. Appendix A of this procedure provides a detailed description and background on etching steel microstructures along with guidelines on determining the quality of microstructure images. Personnel must be familiar with Appendix A prior to implementing this procedure.

2. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Rubber Gloves, Steel Toed Boots
- **Testing:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training

3. Equipment

- PTX tool – 2000 grit belt
- Dremel
- Felt Polishing Bobs (2)
- 4µm Diamond Polishing Paste
- 1µm Diamond Polishing Paste
- Ethanol
- Soft Lab Paper Towels
- Cotton Balls

- Nital 2% Etchant
- Distilled Water
- Pipet
- Metkon Mobiscope (50X Objective Lens)
- Magnetic Stage
- AmScope Camera

4. Procedure

1. Polish surface with the PTX tool to 2000 grit in accordance with MMTF002 - Surface Prep Procedure. Ensure that at least 0.005 inches of pipe wall thickness have been removed to ensure there is no decarburized surface layer remaining.

2. Use the rotary tool (Dremel) with felt polishing bob to continue surface preparation according to the steps below.

    a) Apply small amount (pea-sized) of 4 μm diamond paste to pipe surface. You only need enough paste to keep the surface lubricated with a thin film during polishing

    b) Using the Dremel with felt polishing bob, polish an area roughly 1 inch by 1 inch.

    c) During the polishing process, if it appears that there is no paste left, add more.

    d) When all 2000 grit scratches are gone (approx. 2 minutes), clean the surface gently using a cotton swab.

    e) Repeat steps a-c with a new felt polishing bob and 1 μm diamond paste. You must dedicate separate bobs for each paste, and they must never be cross contaminated. Continue polishing until achieving a mirror-like finish (approx. 2 minutes of additional polishing with the 1 μm diamond paste).

3. Put on gloves.

4. Thoroughly clean the surface with ethanol and a clean cotton ball to degrease. Allow ethanol to fully dry before next step. Using anything other than a cotton ball will scratch the surface finish which could lead to bad imaging.

    WARNING: NEVER MIX ETHANOL AND NITRIC/NITAL, THEY CAN EXPLODE.

5. Using a cotton swab apply a small amount of 2% Nital (nitric acid and methanol) to the polished area. Continuously rub the Nital infused cotton ball for approximately 8 to 12 seconds. Observe as the surface finish transitions from a reflective mirror to opaque.

6. Immediately rinse the surface with distilled water to dilute and remove the Nital. Wash the water away with ethanol.

7. Let the surface dry completely. Make sure you don't have any remaining liquid residue or dried liquid stains on the surface. Rinse the surface again with ethanol if any stains remain.

8. Place the Metkon Mobiscope portable microscope over the etched area and confirm the quality of the etch using the 50X objective lens (500X total magnification). An acceptable etched microstructure is shown in Fig. 1.

a) If the surface under the microscope appears over-etched like the microstructure in Fig. 2, this indicates that the Nital applied during Step 5 was left on the surface for too long prior to rinsing with distilled water. To remedy an over-etched surface, the technician should first attempt to re-etch the surface for an additional 5 seconds which may remove the layer of over-etched material and reveal a suitably etched surface beneath it. If no improvements are observed under the microscope, the surface must be re-polished, cleaned, etched and rinsed by repeating the steps described above and starting at Step 2 with the 4 μm diamond paste. The 4 μm diamond paste polish should be performed for twice as long as typically needed to ensure that all over-etched surface material is removed. The Nital should be applied to the surface for less time prior to rinsing with distilled water.

b) If the surface under the microscope appear under-etched like the microstructure in Fig. 3, this indicates that the Nital applied during Step 5 was rinsed away with distilled water to quickly and before the microstructure could be properly etched. Briefly re-apply Nital according to Step 5 for five more seconds before rinsing with distilled water and ethanol. Re-examine the dried surface with the portable microscope and confirm that the surface is properly etched.

c) Repeated steps (a) or (b) as required until an acceptable etch is achieved. Refer to Appendix A for additional references on proper etching procedures.

9. Replace the observation scope on the microscope with an AmScope camera and connect to the field laptop. Open the ToupView program and using the microscope camera snap at least 10 images of the etched area that meet the image quality requirements in Appendix A of this procedure. Use the knobs on the magnetic base to move the microscope to a completely new region between images. There should be no overlap of the microstructure on any of the recorded images.

10. Batch save the images using the format ([SAMPLE NAME] - 50X) and save them in their appropriate folder location for the sample being examined. This will save all images taken in ToupView in sequential order.

11. After imaging has been completed, disengage the microscope, disassemble, and pack away.

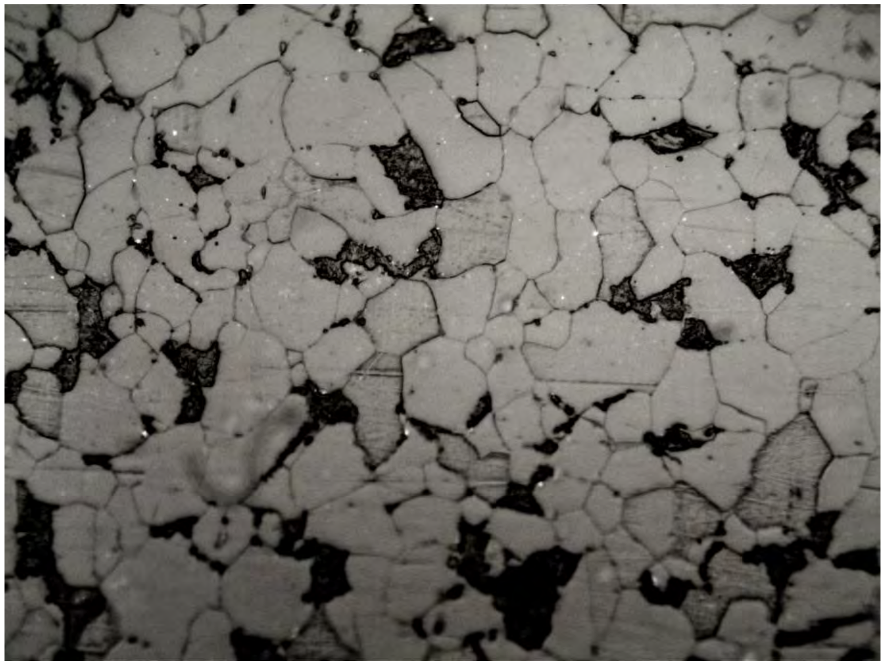

Fig. 1: Properly etched and imaged microstructure, with clear grain boundaries and minimal scratches

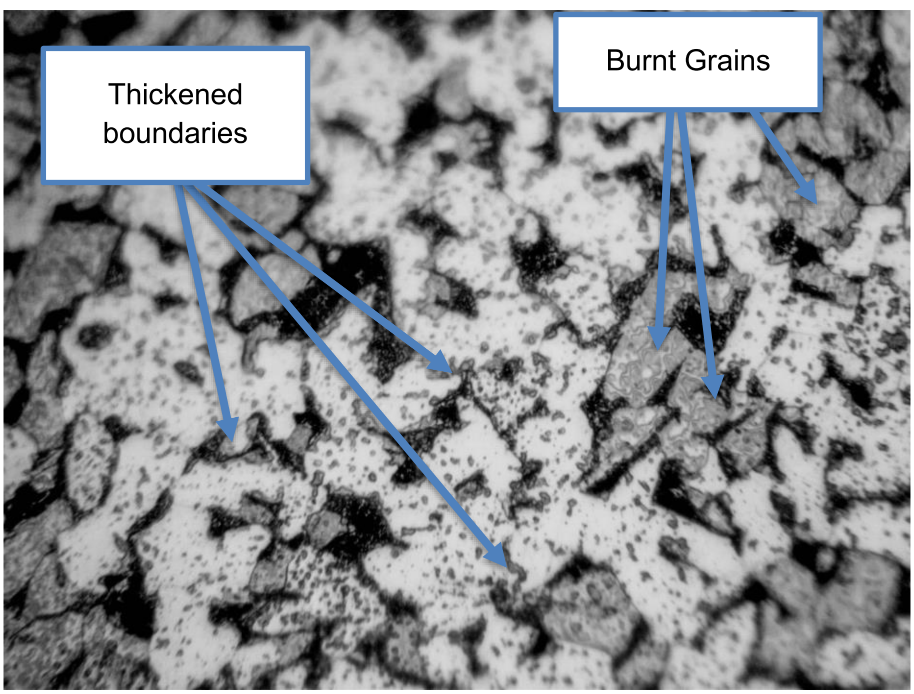

Fig. 2: Over-etched surface where grain boundaries appear thicker and grains are “burnt” because of too much exposure to the Nital solution. The surface should be re-polished starting at the 1 μm diamond paste, and the Nital should be applied for less time before diluting with distilled water

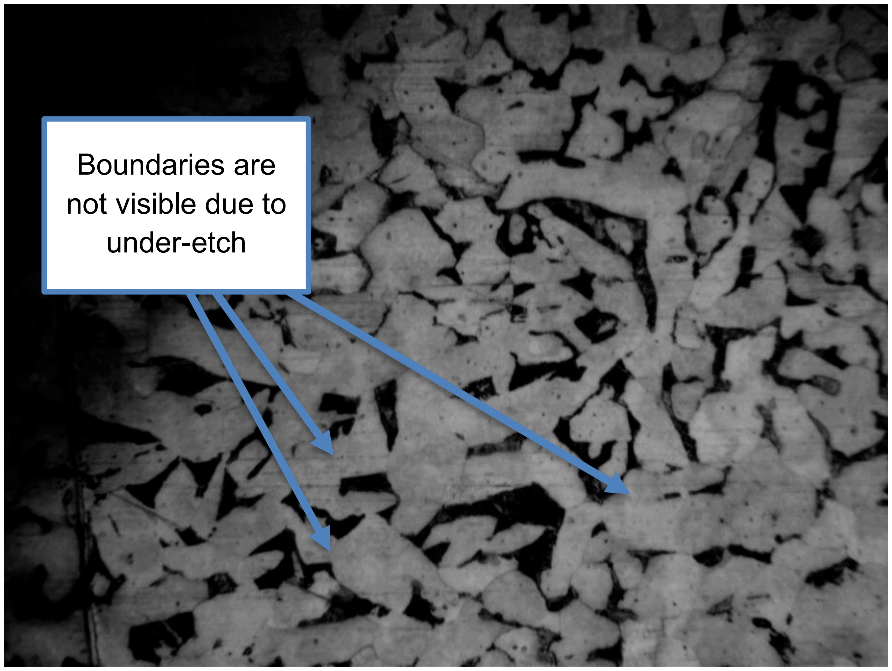

Fig. 3: Under-etched surface where grain boundaries are not visible because the Nital solution was diluted too quickly. The surface should be re-etched by briefly re-applying the Nital solution.

Appendix A – Supplemental materials

The following section details the essentials in doing in-situ steel metallography and how to properly diagnose and address them.

1. Focus

It is essential to make sure you have the best focus possible while snapping an image. Figure A1 shows a poorly focused image that does not meet acceptable image standards.

- **Pipe curvature**: Since pipes are not flat surfaces, it is difficult to create a corner-to-corner focused image and it is expected that the peripheral areas may be out of focus, especially with pipes of small diameter. However, there are ways to maximize the in-focus area:
    a. Set the microscope to be at the center of the holder magnet.
    b. Only move along the pipe (longitudinally) for taking different images rather than circumferentially (especially for low diameter pipes).
    c. Make sure the microscope stage is set on a prepped area. Uneven and rough rust layers under the stage can tilt the view angle and make focusing difficult.
- **Frame rate**: The feed from the microscope movement, to the camera, and to the laptop display can be delayed and experience lag. This can make imaging difficult and reduce the precision in providing optimal focus. In order to solve this problem:
    a. Close all other programs or restart the laptop to give the software a larger portion of graphic processors.
    b. Use the “Frame Rate” tab within the ToupView program to increase the rate for fast computers and decrease it for slow computers.

    NOTE: Refrain from having any of MMTControl, LabVIEW, and PipeWhisperer operating while taking microscope images to increase performance.
- **Loosing focus after tuning**: Since the imaging is done at a microscopic level of 500X, minimal changes in lens distance to the surface will greatly affect the focus. Often, after tuning to a fine focus, the visual will become blurry once the technician releases the pressure applied by their hand during the focusing process. In order to maintain focus, the microscope should be pushed down with a constant force and an image should be snapped simultaneously.
- **Losing your focus when you switch from eyepiece to camera**: While zoom levels are in theory the same between the eye piece and the camera, the reality is that focus will fluctuate when changing between the two components. As a result, minor re-focusing is necessary after switching between the eyepiece and camera.

Fig A1: Example of poorly focused image

2. Light Balance

One of the most important parameters that must be tuned for each image is the light balance. This can be controlled by both hardware and software inputs. Images need proper lighting to visibly display the grains and boundaries. However, it is easy to have excessive lighting/exposure that makes the grain boundaries difficult to see and identify. This is demonstrated in Figs. A2 and A3 where the grain boundaries are concealed due to excessive light. In order to control the lighting for images, technicians must adjust the following:

- **Inputs**: Directly increase or decrease the light intensity using the microscope. Also, you can tune the extent of exposure via ToupView software.
- **Auto exposure**: Use of auto exposure is **not** recommended because it tends to result in over exposed images. Disable this feature within the ToupView window.
- **Frame rate**: A higher exposure time will reduce your frame rate. If this is causing frame rate problems, increase the light intensity input by the microscope and decrease exposure time in the software.
- If lighting remains an issue**, a darker image is better than a brighter image.**

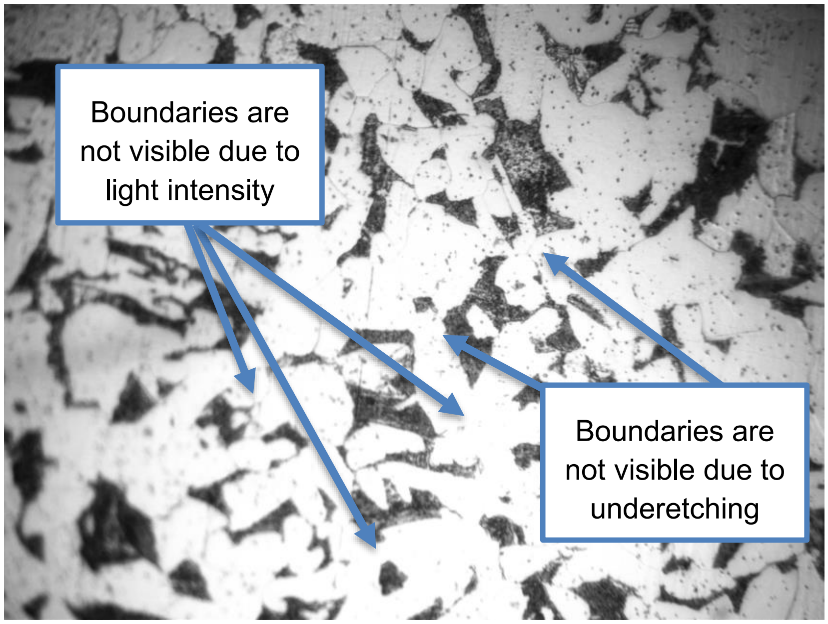

Fig A2: Excessive light intensity is making grain boundaries disappear and the surface is slightly under-etched

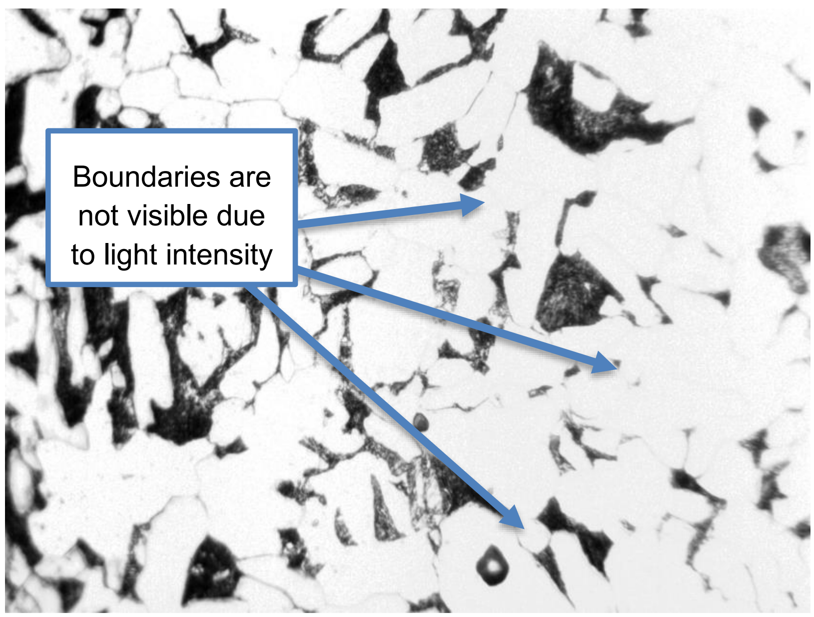

Fig. A3: Excessive light intensity is making grain boundaries disappear and the focus is not centered. The etch appears to be good.

3. <u>Etching</u>

The most important and sensitive step during metallography is the application of the etchant solution. Small deviation from the ideal conditions could result in an over-etched or under-etched microstructure that could provide misleading outcomes in grain size calculations. Optimal etching conditions can vary with different pipe materials, cleanliness, surface preparation, exposure time, and environmental conditions. The following steps should be taken to ensure a properly etched microstructure:

- **Prep**: Proper preparation and polishing is critical. The last sanding grit applied should remove all scratches made by previous grits and the diamond paste polishing should provide a mirror quality surface. Any remaining scratches will appear as grain boundaries during subsequent image processing and analysis, so it is imperative to get rid of all scratches during surface preparation.
- **Clean surface**: It is important to wash the prepped surface and ensure that any paste and other surface contaminants are removed.
- **Etching**: Make sure your cotton swab is thoroughly soaked in Nital etchant solution, and your test location is consistently and evenly etched throughout the recommended etching period. The actual etching time for each material will vary, and adjustments may be required after observation of the quality of the etched microstructure. After applying the etchant, it is important that you **immediately** wash the solution away from the surface with **ONLY distilled water**, and then wash the water away using **Ethanol** or another non-reactive alcohol. Water droplets that remain dried on the surface will significantly reduce the image quality and increase blurry areas.
- **Timing**: A high quality etched surface does not last forever and should be imaged promptly to ensure acceptable images. The air is constantly reacting with the metal surface and creating a thin layer of oxide on the surface that can lead to blurry images that conceal the grain boundaries.
- **Under-etching**: If insufficient etchant is applied the surface will be under-etched. This means that the surface corrosion required to dissolve the high energy areas (such as grain boundaries) was not surpassed. Under-etching is detected by seeing grains connected with no visible boundaries between them or a lack of distinguishable features in the microstructure. Examples of under-etched microstructures are shown in Figs. A4 through A6. Under-etching can be remedied by re-applying the etchant solution, and no additional prep is needed before re-application. To avoid under-etching, take the following steps:
    1. **Increase etching time**: Technicians must accurately monitor the time that is spent etching the surface before applying distilled water to stop the etching process. If some microstructure features are visible, but grain boundaries are not, the area should be etched for an additional 3 - 5 seconds. If no microstructure features are visible, the area should be etched for at least an additional 5 - 7 seconds. Always wash off etchant with distilled water after etching the surface, and then use ethanol to remove the water from the surface.
    2. **Ensure enough etching solution is applied**: Technicians should ensure that the cotton swab is sufficiently soaked with Nital solution and that the etchant is being dispersed correctly over the entire surface with uniform pressure.

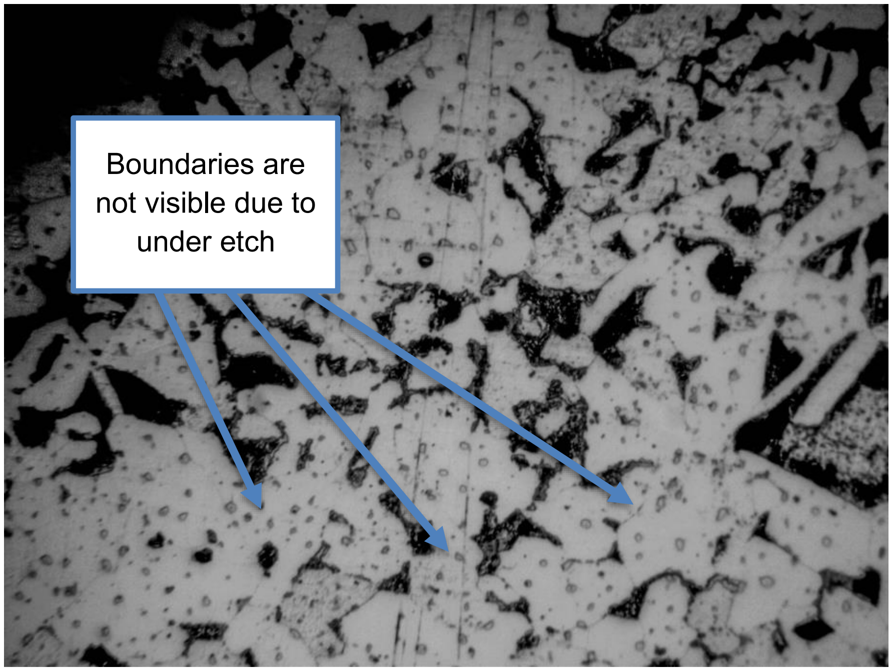

Fig. A4: Slightly under-etched image. Boundaries are not clear and scratches on the surface. Surface should be re-etched for an additional 3 – 5 seconds.

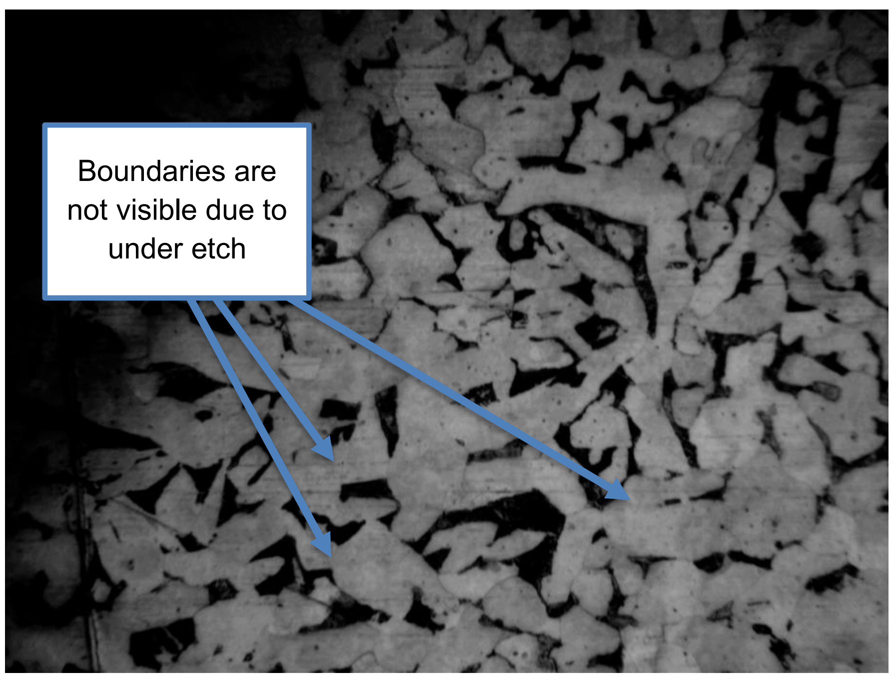

Fig. A5: Very under-etched image. Boundaries are not visible at all. Surface should be re-etched for at least an additional 5 – 7 seconds.

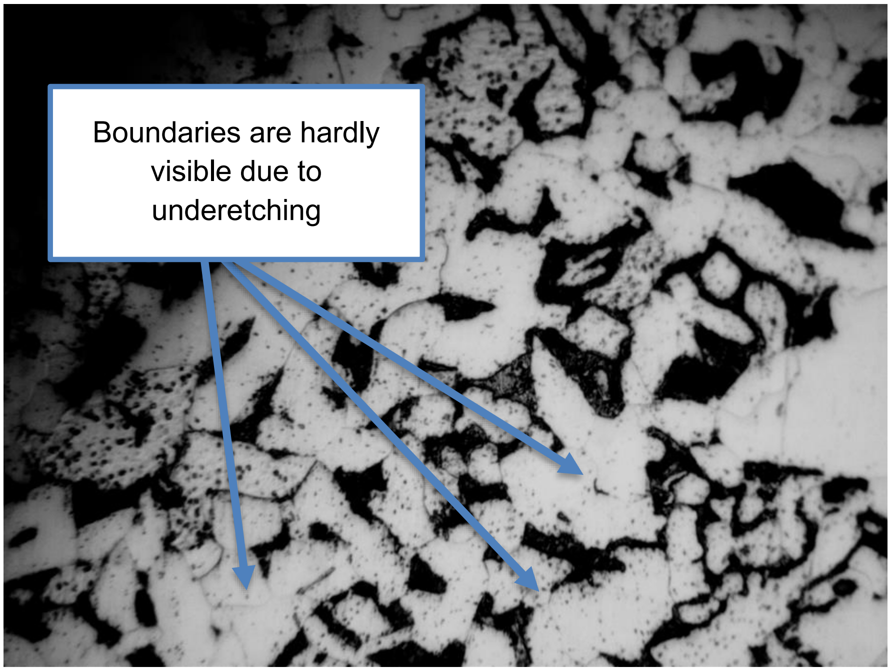

Fig A6: Slightly under-etched image. Surface should be re-etched for an additional 3 – 5 seconds.

- **Over-etching**: Over-etching occurs when the surface is exposed to etchant for too long. An over-etched surface will result in very thick grain boundaries and many indistinguishable areas. Grains are often pitted and carbon saturated areas will look burnt. Examples of an over-etched microstructure are shown in Figs. A7 and A8. To remedy an over-etched surface, the technician should first attempt to etch the surface for an additional 5 seconds which may remove a layer of over-etched material and reveal a suitably etched surface beneath it. If no improvements are observed, technicians will need to re-polish and etch the surface as described in the main procedure. To avoid over-etching, take the following steps:

    1. **Reduce etching time**: If etchant is left on the surface for too long the surface will be over-etched. The default time is 8 – 12 seconds of actively applying the etchant with the soaked cotton swab, however, adjustments in time may be required based on observation of the initial results. After re-polishing an over-etched surface, the etchant should be administered for 3 – 5 seconds less than the initial application.

    2. **Proper surface cleaning**: An improper cleaning of the surface after application of the etchant solution can cause over-etching. Water must be used to completely dilute all remaining acid on the surface. Ethanol is then used to neutralize the remaining acid and eliminate the water from the surface.

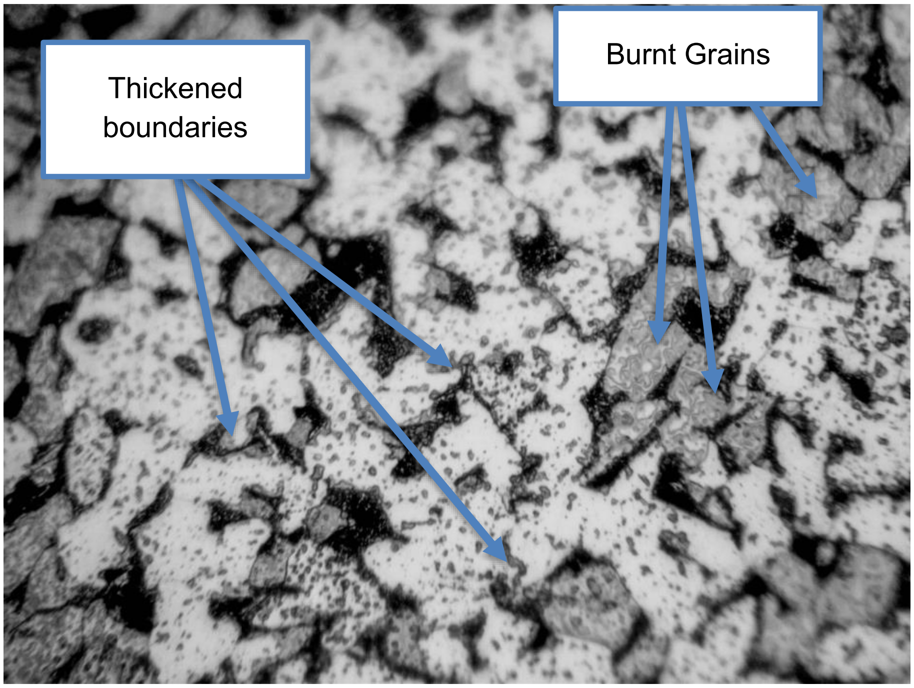

Fig. A7: Over-etched image. Thick boundaries and burnt grains are visible. Etching time should be decreased by 5-7 seconds.

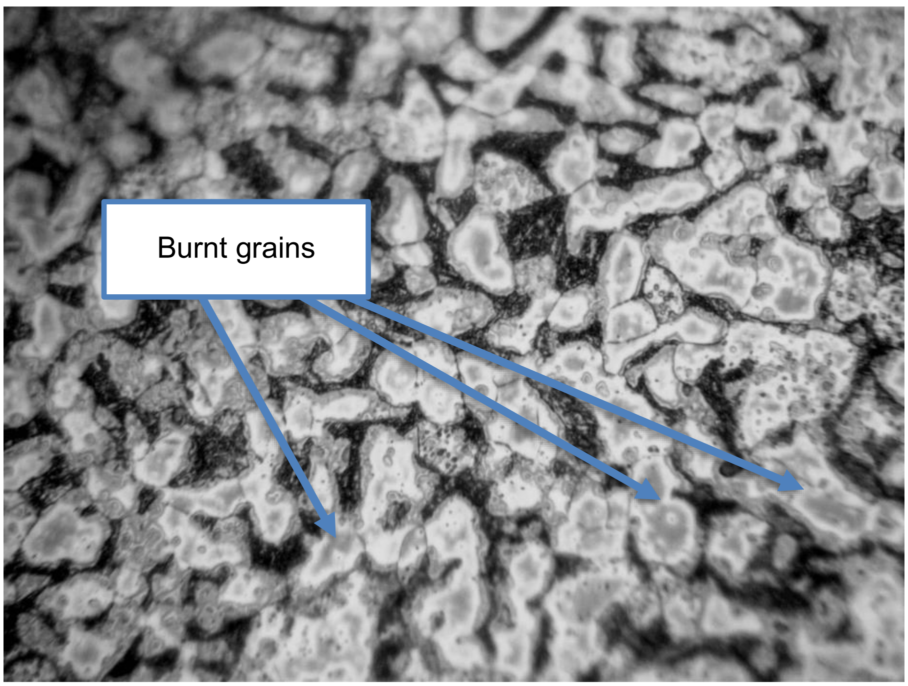

Fig. A8: Over-etched image. Thick boundaries and burnt grains are visible. Etching time should be decreased by 5-7 seconds.

4. Etched Microstructure Images That Meet MMT Standards

Figures A9 through A11 provide examples of microstructure images that meet MMT standards for focus, lighting, surface preparation, and etching.

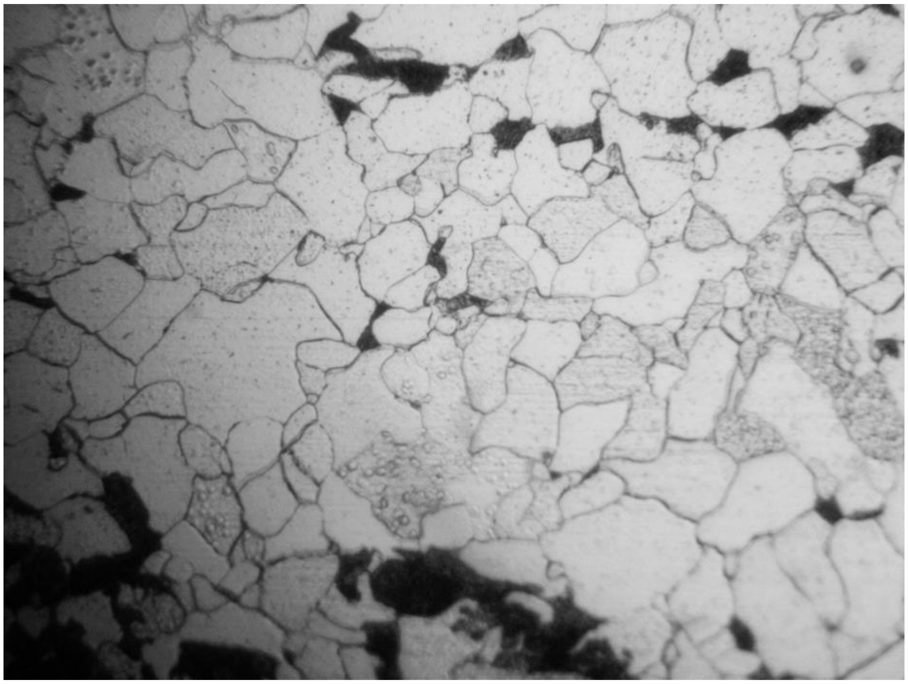

Fig. A9: Good image, grains are clearly visible

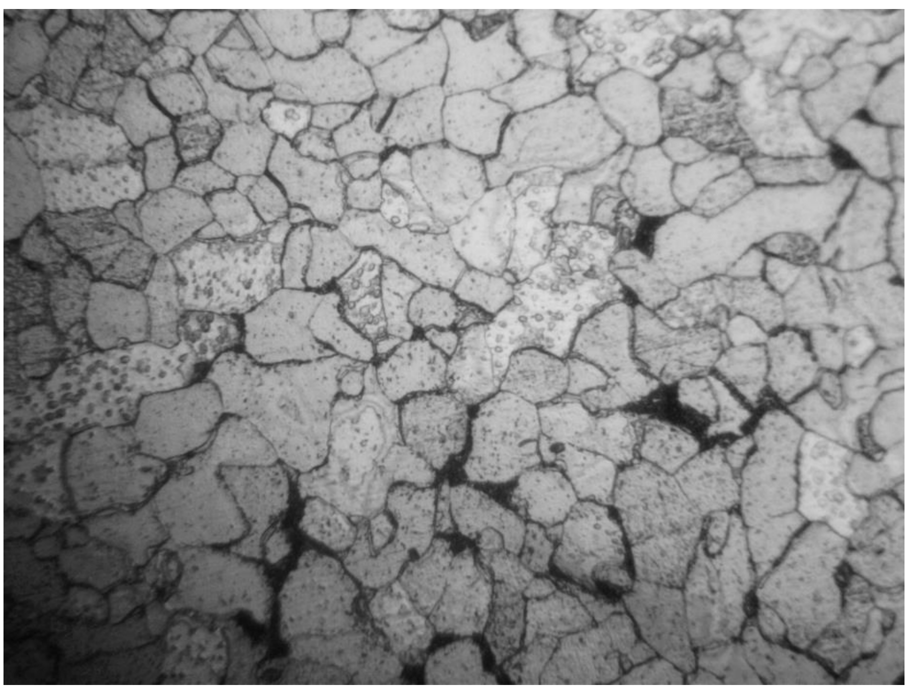

Fig. A10: Good image, grains are clearly visible

Fig. A11: Good image, grains are clearly visible

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00	180322	Initial release	CJM	PPP
01	180725	UT Thickness Mapping and Sample Request Form	PPP	BMW
02	190313	Clarification of material removal	SDP	PPP
03	190627	Request for new deburring tips; Larger area for collection	PPP	SDP

MMTF005 – Metal Burr Collection for Chemical Analysis of Pipes Procedure

1. Overview

This document provides the procedure for collecting metal burr samples for chemical analysis. This procedure includes surface preparation instructions, proper sample collection instructions, and instructions on sending samples to a lab for analysis. The total material removal shall never exceed 10% of the pipe nominal wall thickness. The minimum material removal prior to sample collection is 0.005 inches to ensure that material in the decarburized layer is not collected.

2. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Face Shield, Hearing Protection, Hand Protection, Steel Toed Boots, FR Clothing
- **Training:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training
- **Wall Thickness:** Ultrasonic inspection before sampling will confirm an area ≥ the nominal wall thickness. Additional mag particle analysis will confirm the absence of laminations and internal corrosion.

3. Equipment Needed

- PTX sander
- 40, 80, and 120 grit sanding rings
- Die grinder
- Diamond shaped carbide deburring tool
- Methyl alcohol (methanol)
- Turn magnet
- Sample bag
- Scale
- UT gauge

4. Procedure

1. Select a 6 inch by 6 inch area near the Hardness, Strength, and Ductility (HSD) testing area for sample collection. Only one sample area is needed per pipe joint. The area furthest from the weld should be chosen.
2. Using a UT gauge in accordance with MMTF007 – Ultrasonic Thickness Measurements Procedure, inspect the selected area for adequate wall thickness, internal corrosion, and laminations. If the selected area is suitable, proceed to step 3. If wall thickness does not meet the specified requirements in MMTF002 – Surface Preparation Procedure, or if other defects are detected, select a new area.
3. Completely clean the couplant used for UT measurements from the surface using a paper towel and acetone if required.
4. Using the PTX tool, prepare the selected 6 inch by 6 inch sample area in accordance with MMTF002 – Surface Preparation Procedure using only the 40 and 80 grit sand paper. Use the UT gauge to record the reduced wall thickness and ensure that at least 0.005 inches of pipe wall thickness have been removed so that no decarburized layer remains.
5. Using the PTX tool, sand the area in one direction for 15 seconds using the 120 grit sanding paper. This step is to ensure that all contaminates are completely removed from the surface. **DO NOT apply any foreign substance on the surface after this step, and DO NOT touch the surface with gloves or bare hands.**
6. Clean the carbide deburring tool by rinsing it with methanol. **DO NOT USE water, oil, or other lubricants to clean the deburring tool, as these will contaminate the sample**.

When requested by the customer or pipeline operator, a new carbide deburring tip will be required for each sample being tested. This will be reflected on MMT Field Notes.

7. Turn the sample bag inside out and insert the magnet.
8. Activate the magnet and place it on the pipe so that it is just below where the deburring will occur.
9. Using the die grinder with the deburring tip attached, gently pass the tool circumferentially across the prepped area carefully trying to direct the removed burr samples towards the magnet (Figure 1). Use gentle pressure to avoid gouging the surface. Use the entire test area to ensure you collect enough sample material. Use the field scale to ensure a minimum of 3 grams of sample has been collected. This procedure should remove approximately 0.005 inches of additional material from the pipe wall thickness.
10. Gently remove the sample bag and unroll it so it is back to normal. Deactivate the magnet.
11. Seal and label the sample bag. The label should include the date, sample ID, and MMT project ID. Sample ID and MMT project ID should be consistent with what is used for HSD testing.
12. When sampling is complete, use the PTX tool with 120 grit sandpaper to create a uniform surface finish.
13. Measure the wall thickness of the sample area to ensure that no more than 10% of the pipe nominal wall thickness has been removed.
14. Package and send samples to a commercial laboratory that does chemical analysis. The laboratory will report the sample ID, MMT project ID, and results of the chemical analysis. Refer to the “MMT Burr Sample Test Request Form” for proper element demands.

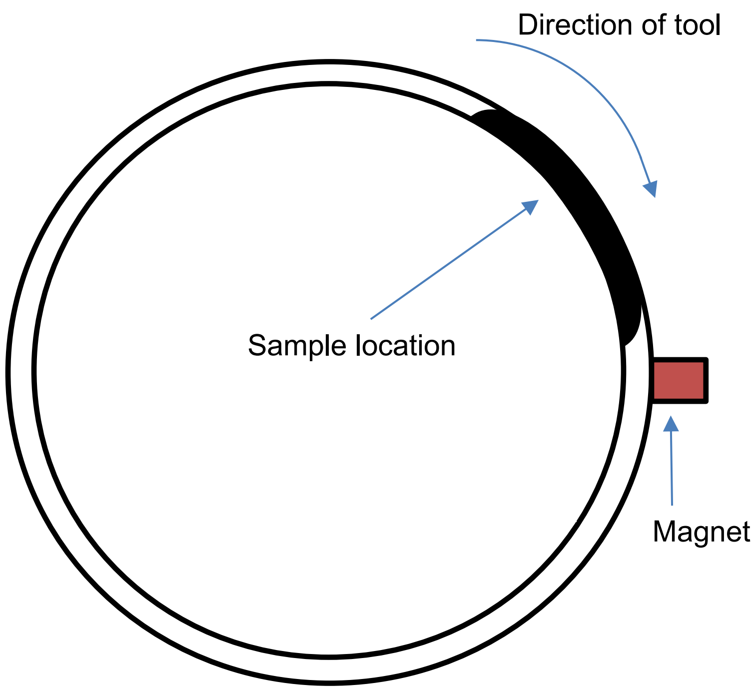

Fig. 1: Burr test procedure diagram

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00	180417	Initial release	PPP	SS, SDP
01	190313	Methodology updates	SDP	PPP
02	190920	Updated figures and imaging method	PPP	SDP

MMTF006 – OD Seam Etch Procedure

1. Overview

This document provides the procedures for etching the outer diameter at the longitudinal seam on electric-resistance-welded (ERW) pipelines. The size of the apparent heat-affected-zone (HAZ) on the pipe surface can be used to classify ERW welds as low frequency (LF), high frequency (HF), or high frequency normalized (HFN). The OD seam etch should be performed before and after the completion of a successful Hardness, Strength, and Ductility (HSD) test across the welded seam which will help to confirm the size and location of heat-affected regions. This procedure requires the use of several hazardous chemicals and careful documentation of results. Refer to the relevant MSDS for additional safety information.

2. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Rubber Gloves
- **Testing:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training

3. Equipment

- Nital 5% Etchant
- Fry's Reagent
- Distilled Water
- Cotton Balls
- Pipets
- Squirt Bottle
- Camera
- Transparent Ruler for Scale
- Seam Encapsulating Optical Luminosity Filter (SEOLF)

4. Procedure

1. SAFETY: Wear safety glasses and rubber gloves throughout this procedure.
2. Prepare a 4 inch by 6 inch area on the outer diameter of the pipe at the longitudinal seam to a 2000 grit finish in accordance with MMTF002 – Surface Preparation Procedure.
3. Using a pipet, load a clean cotton ball with Nital 5% etchant solution.
4. Rub the Nital on the prepped surface, travelling circumferentially back and forth over the seam. Etch an area approximately 2 inches long and 1 inch wide in the circumferential direction on either side of the seam (total area is 2 inches by 2 inches centered on seam). The etched area should be directly adjacent to a HSD weld test.
5. Continue to etch for approximately 15-20 passes of the cotton ball over the seam. Etch until the bond line and heat affected zones become visible. Be careful to not over-etch the surface. You should be rubbing the surface in a continuous back and forth motion for approximately 15-20 seconds. While etching, note changes in the steel appearance.
6. Rinse the surface with distilled water to stop the etching process.
7. Dry the surface with a clean paper towel or compressed air. **The surface must be dry before moving to the next step, otherwise the area will rust**. If a well characterized and contrasted seam is visible, skip steps 8-10.
8. Using a pipet, load a new cotton ball with Fry's Reagent.
9. Rub Fry's Reagent on the etched area for approximately 10 seconds, or until additional contrast is seen within the etched region.
10. Allow the surface to dry or wipe down with a paper towel.
11. Using a sharpie, mark a small dot at the location of the bond line, edges of the inner heat affected zone (if applicable), edges of the outer heat affected zone (if applicable), and/or edges of any contact points (if applicable). Refer to Section 5 as a reference for the appearance of these regions.
12. Using the SEOLF, place the 3 inch mark at the center of the bond line to allow for subsequent measurements of the size of the heat-affected regions.
13. Use the camera to take overview images of the etched region. Select lighting and angles that emphasize features of the etched surface such as heat-affected-zones, the bond line, and contact points. Additionally, ensure that the ruler and seam are visible in every image. Take at least 3 images of the etched seam with different zoom, one from standard, one zoomed in on the seam, and one that captures the seam and HSD weld test (See Section 5). If the seam and HSD weld test do not fit within the SEOLF, take a fourth image without the SEOLF but be sure to include a ruler for scale in the image. This will be used to determine the distance from the start of the HSD weld test to the bondline of the seam.
14. Record the measured width of the HAZ on the MMT Field Notes, along with the distance from the start of the HSD test across the weld and the center of the bondline.

5. Sample Images

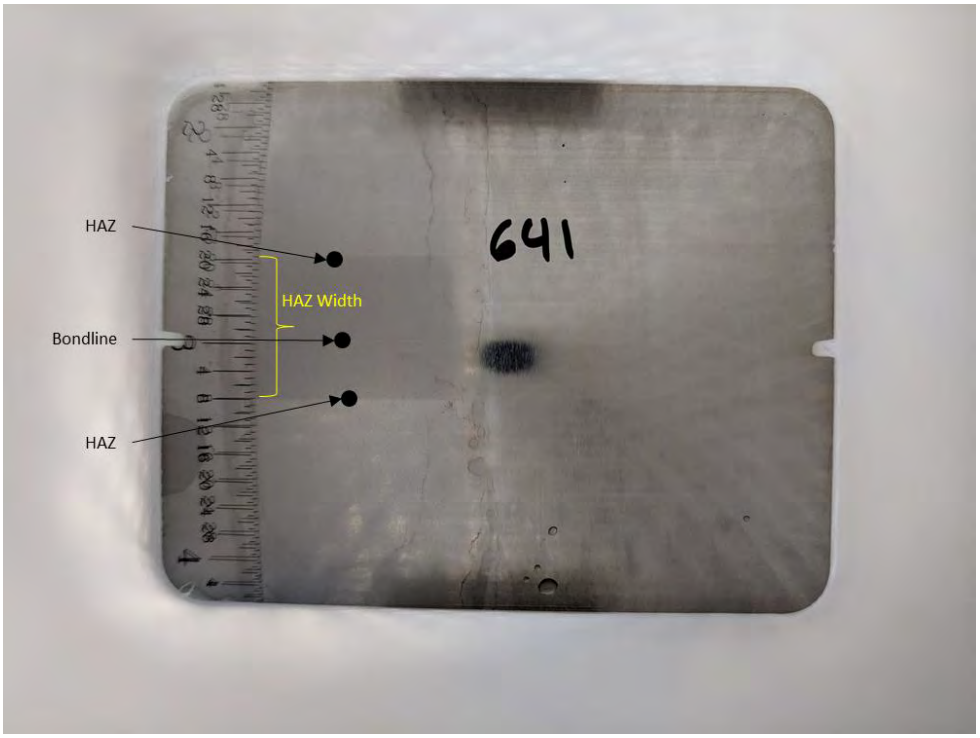

Fig. 1: Sample of marking and imaging of HFN-ERW OD Seam Etch (Normal Zoom)

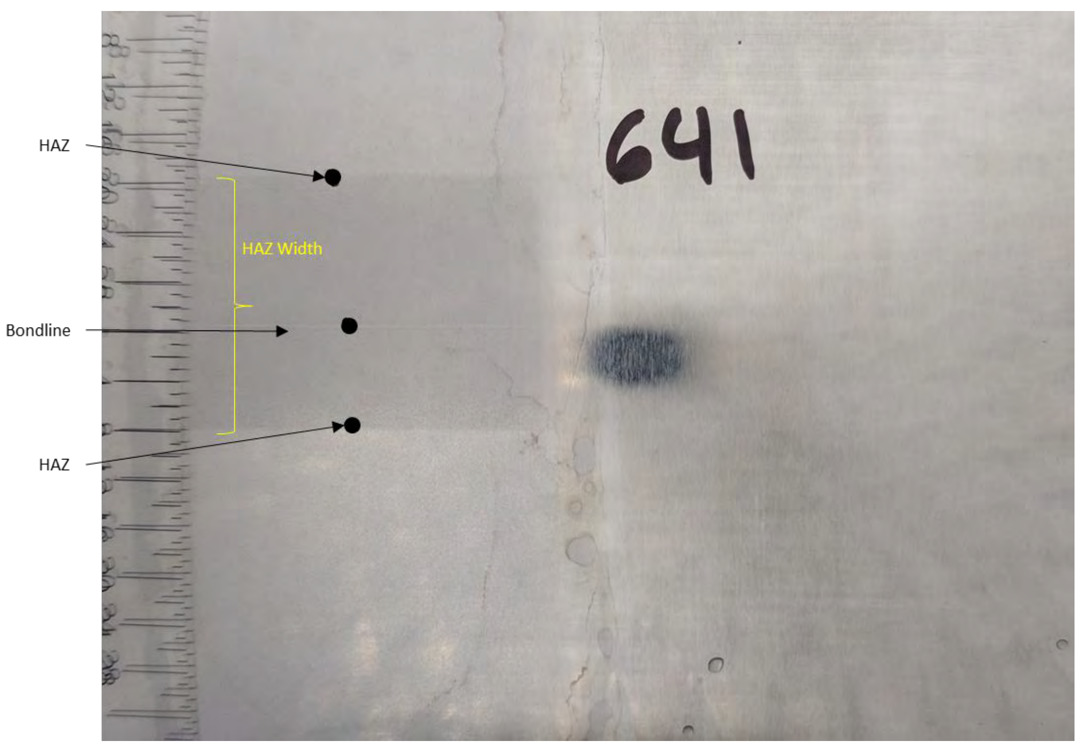

Fig. 2: Sample of marking and imaging of HFN-ERW OD Seam Etch (Zoomed In)

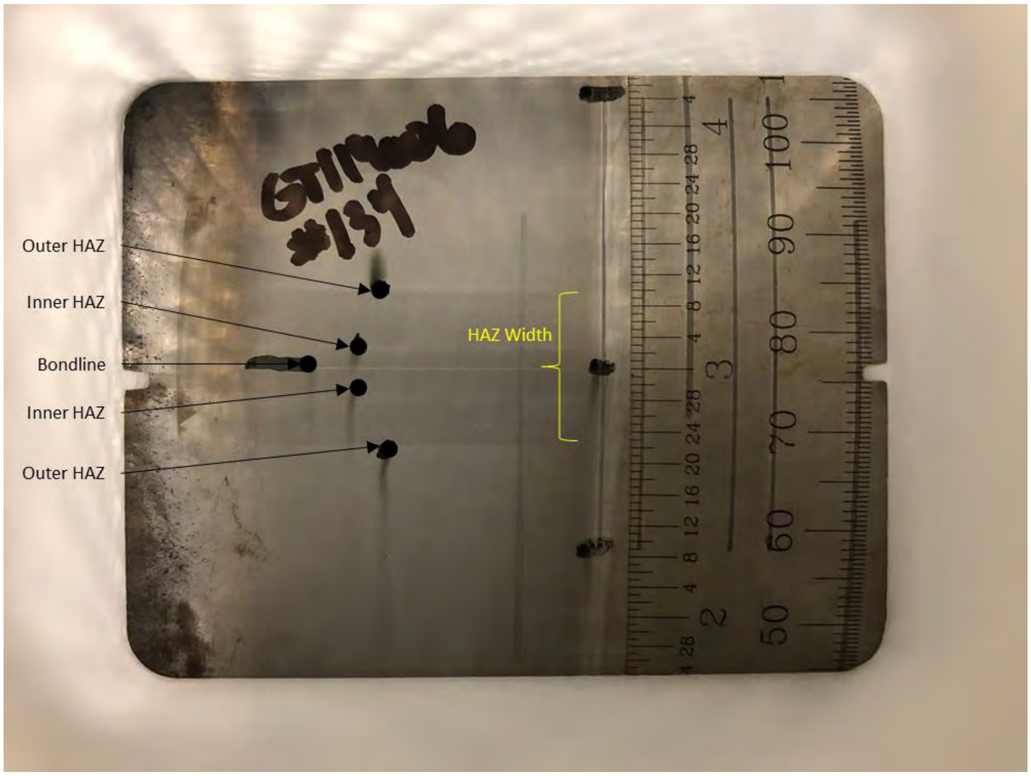

Fig. 3: Sample of marking and imaging of HFN-ERW OD Seam Etch with HSD Test in SEOLF

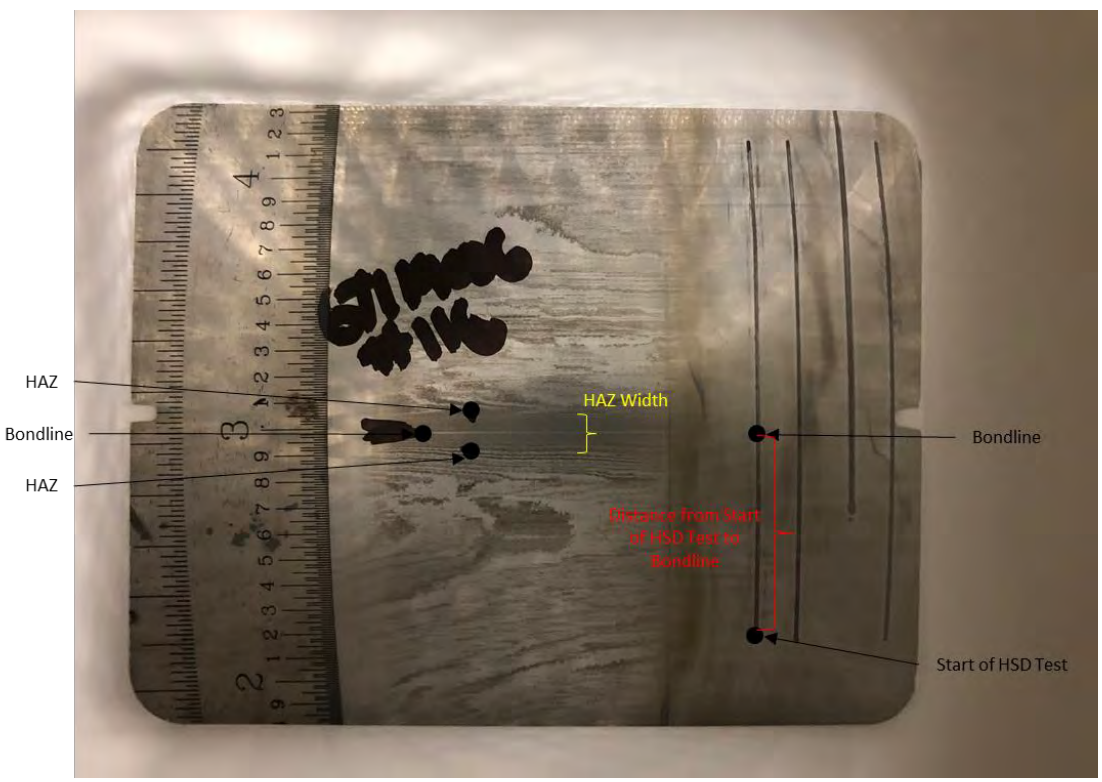

Fig 4: Sample of marking and imaging of HF-ERW OD Seam Etch with HSD Test in SEOLF

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00	180417	Initial release	KAL	PPP
01	180829	4.2 Surface Conditions/Scanning	KAL	BMW
02	190318	Updates to terminology and references	SDP	PPP
03	190627	Added Section 4.5 on Circumferential Thickness Mapping	PPP	SDP

MMTF007 – Ultrasonic Thickness Measurements Procedure

1. Overview

This document provides the procedures and general requirements for ultrasonic testing (thickness measurements) of pipelines and plates using digital ultrasonic testing (UT) gauges. All UT thickness tests shall be performed using dual-element or single element piezo electric transducers that convert electrical energy into mechanical energy (straight beam testing, longitudinal wave). Dual element transducers should be used for material under 0.375 inches in thickness.

2. Purpose

The purpose of this testing is for locating the longitudinal seam (MMTF010) and for verification of the amount of material removal during surface preparation (MMTF002) or burr sample collection (MMTF005). UT thickness measurements provide a practical, safe, and accurate solution to determining material removal and ensuring that no more than 10% of pipe nominal wall thickness (NWT) is removed. Massachusetts Materials Technologies (MMT) is not a certified provider of ultrasonic thickness inspection, and these measurements are for MMT internal use only.

3. Personnel Qualifications

All MMT staff have completed the following training:

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Face Shield, Hearing Protection, Hand Protection, Steel Toed Boots, FR Clothing
- **Training:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training. Personnel performing digital thickness measurements are not required to meet the requirements of SNT-TC-1A

4. Procedure

4.1 Calibration

1. Thickness testing instruments shall be calibrated on a reference block made of the same material type as the samples being tested.
2. Calibration blocks shall be flat and smooth and free of gouges or defects.
3. The UT gauge must read within ±0.005 inches of actual thickness of the reference block.

4.2 Surface Conditions/Scanning

1. The surface temperature shall be no less than 40°F and no more than 150°F. Surfaces shall be free of rust, scale, loose paint, or any other contaminants that could interfere with readings or scanning over the test surface. Excessive surface roughness may affect the reliability or accuracy of readings.
2. Scanning for small mid-wall or concentrated internal pitting should be done at +12dB over reference for detection purposes. Adjust gain as needed for characterization purposes.
3. For most accurate results, the backwall signal should be placed at 80% full screen height during calibration and wall thickness measurements.

4.3 Couplant

All measurements shall be made using a couplant. The couplant is placed between the sensor and the material to be measured. The calibration and test measurements should be performed using the same couplant.

4.4 Reporting

Thickness readings taken by MMT personnel are for locating HSD test locations only and are to meet the MMT pretest requirements. Pre and Post HSD Test UT thickness readings are for informational purposes only.

4.5 Circumferential Thickness Mapping

Using the UT gauge, thickness mapping should be conducted around the circumference of the pipe joint in accordance with Fig. 1 below. Circumferential thickness mapping is required for all joints regardless of presence of weld reinforcement or known seam types. The thickness mapping will be used to locate optimal testing areas, confirm the nominal wall thickness (if provided), establish the initial thickness for MMTF002 – Surface Preparation Procedure, and determine if a pipe without a visual weld reinforcement is a seamless or seamed pipe as detailed in MMTF010 – Longitudinal Seam Location and Identification Procedure.

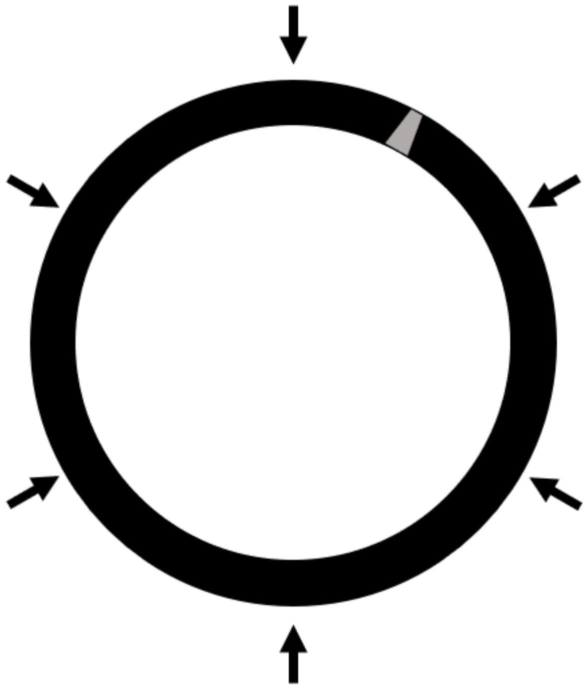

Fig. 1: UT thickness measurements should be taken circumferentially around the pipe OD at 6 evenly spaced clock positions.

4.6 Area Thickness Mapping

Area thickness mapping is used to examine the average and variation of UT thickness readings within a rectangular area. Figure 2 below illustrates the 5 points that should be recorded. Area mapping is used when required by MMTF002 – Surface Preparation Procedure and MMTF005 – Metal Burr Collection for Chemical Analysis of Pipes Procedure.

Fig. 2: Diagram of UT Measurement Mapping

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00	180417	Initial release	KAL	PPP
01	190920	Removed acceptance criteria because MMT is not a provider of inspection services for flaw detection and sizing	SDP	PPP

MMTF008 – Magnetic Particle Testing Procedure

1. Overview

This document provides the procedures and general requirements for the Visible Wet Contrast (black on white) magnetic particle examination technique. The magnetic particle examination process described in this procedure is applicable to in-process, final, and maintenance (in-service) examination of pipeline steel. This process is applicable for the detection of discontinuities such as lack of fusion, cracks, laps, laminations, cold shuts, and porosity, that are open, or connected to, the surface of the component under examination of ferromagnetic materials and welds.

2. Purpose

The purpose of this procedure is for additional verification that the pipe area is safe to test. MMT is not a provider of inspection services for flaw detection and sizing but MMT takes this additional precaution to ensure safety.

3. Personnel Qualifications

All MMT staff have completed the following training:

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses, Face Shield, Hand Protection, Steel Toed Boots
- **Training:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training

4. Equipment

- AC Yoke
- Alternating Current

- Black magnetic particles, suspended
- Bath applicator
- White contrast spray paint

5. Procedure

5.1 Surface Preparation

The surface of the area being examined should be clean, dry, and free from all contaminants such as water, oil, dirt, grease, loose rust, sand or scale, thick paint, weld flux, weld splatter, or any other matter that could interfere with the examination results.

5.2 Examination

- The yoke method of longitudinal magnetizing shall be employed to detect discontinuities at or near the surface.
- A thin film of the white contrast spray will be applied to the surface to be examined so that a background contrast is provided without masking defects.
- The pipe will be examined with the aid of a sufficiently illuminated white light, as necessary, to ensure adequate lighting at the surface of the part.
- The magnetizing force will be continuous and activated before the particles are applied. Acceptance will be terminated after the excess media has been removed and the examination has been completed.
- The yoke spacing will be as required for optimum examination coverage.

5.3 Repairs

When a defect is detected, no repair will be attempted. The test area will be moved to a location determined acceptable by MMT personnel, and/or as discussed with the client.

5.4 Records

The results of the examination will be considered informational for the use of MMT.

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REV	DATE	CHANGE	PREPARED	REVIEWED BY
00	180711	Initial release	PPP	BMW
01	190314	Significant revision	SDP	PPP
02	190920	Updates to acceptance criterion	SDP	PPP

MMTF009 – HSD Calibration Procedure

1. Overview

This document provides the procedure for calibrating the HSD Tester and the criteria for evaluation and verification. The HSD unit must be calibrated at the start of every day of testing with a calibration sample prepared in accordance with MMTS001 – Calibration Plate Certification. A successful calibration confirms that the HSD unit is performing suitably for testing on unknown samples. A failed calibration alerts the user of a potential issue with the unit. This procedure describes how to determine a successful calibration.

2. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses minimum
- **Testing:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training

3. Calibration Test Frequency

A calibration must always be performed prior to testing on unknown materials. Calibrations are also required after any maintenance, disassembly, or shipping of the unit which could impact the performance of the overall assembly. Typical situations that require calibration of the HSD are listed below.

- Prior to performing HSD tests for any testing service project
- After replacing contact styluses
- After replacing profilometer styluses
- After calibrating HSD sensors such as load cells or profilometers
- After shipping the unit through freight
- After traveling with the unit as checked luggage during air travel

4. Calibration Test Parameters

Calibration tests require the use of a calibration frame for mounting the HSD to test on a flat sample. The unit should be centered over the calibration sample before securing the tester to the calibration frame and applying stylus loads. HSD test parameters for the core motor travel and scans per raster for a calibration test are shown in Table 1. These values are automatically assigned when selecting the “CAL” test type on MMT HSD Controls software.

Table 1: Calibration Testing Parameters

Parameter	Groove Scan Motor	Core Motor
Travel (in)	0.27	1.0
End Speed (in/min)	2.16	0.1332
Start Speed (in/min)	2.16	0.1332
Scans per Raster	30	

5. Calibration Samples

Calibration samples are materials with homogeneous properties that are well established through prior testing with two or more calibrated HSD units, and a surface that is prepared through a standardized process using laboratory equipment. Calibration samples must be prepared in accordance with MMTS001 – Calibration Sample Certification, to ensure they meet these requirements. A certified calibration sample will have a Calibration Certification Label (CCL) that describes the expected mechanical property ranges and calibration sample ID. An example CCL is shown in Fig. 1. The yield strength (YS), ultimate tensile strength (UTS), and stylus hardness (H1, H2, H3 and H4) values are used to evaluate the calibration test results, as described in Section 6.

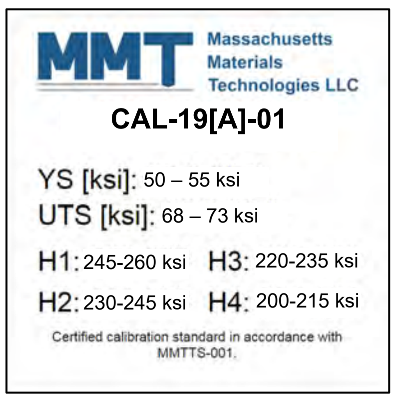

Fig. 1: Example of a Calibration Certificate Label (CCL) for sample CAL-19[A]-01 with allowable ranges for stylus hardness (H1,H2,H3,H4), and ranges of the yield strength (YS) and ultimate tensile strength (UTS) for reference.

6. Calibration Pass/Fail Requirements

After the test is completed, process the results using MMT data processing software and open the Surface Test Report file that is automatically generated. The report contains test results like the average measured stylus hardness that is used to evaluate the outcome of a calibration test as shown in Fig. 2. The stylus average hardness values from this report should be recorded in the MMT Field Notes to document the calibration test results. A passing calibration test must meet all of the requirements in Table

2. If the calibration sample does not meet all of the criterion in Table 2, Section 7 provides additional steps for investigating the performance of the unit.

Table 2: Calibration Test Result Pass/Fail Criterion Parameters

Test Result on Surface Report	Passing Criterion Compared to Calibration Certificate Label
Average Stylus-1 Hardness	Within H1 range
Average Stylus-2 Hardness	Within H2 range
Average Stylus-3 Hardness	Within H3 range
Average Stylus-4 Hardness	Within H4 range

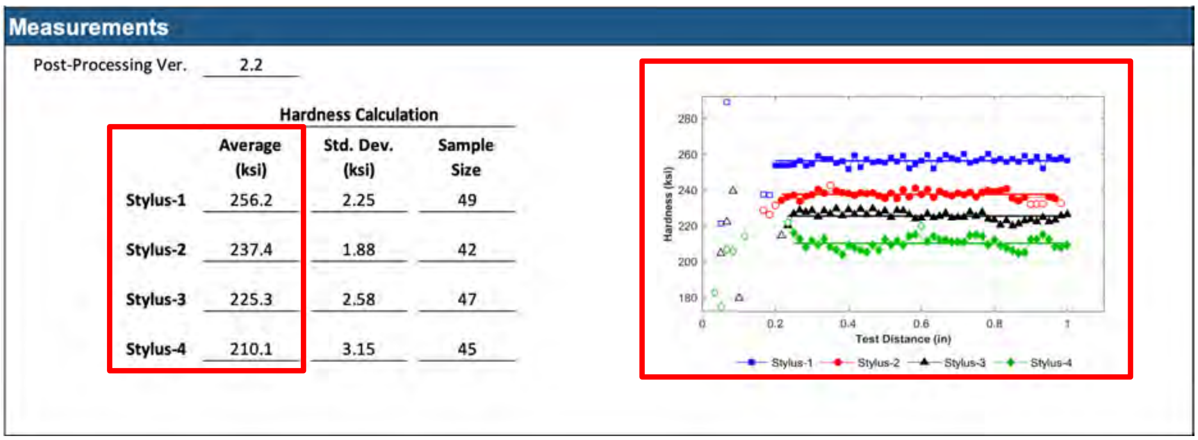

Fig. 2: Stylus hardness values from a calibration test report. The average stylus hardness should fall within the expected range given on the Calibration Certificate Label. The stylus hardness plot should be flat and exhibit no trends like the results shown here.

7. <u>Failed Calibration Tests</u>

A failed calibration test can indicate a potential problem with the HSD unit. The operator should examine additional details of the test results and instrument. After completing the instrument evaluation, an additional calibration test should be performed to see if changes lead to a passing calibration test based on the requirements in Table 2. The additional calibration test results should be recorded in the MMT Field Notes. If subsequent tests do not pass calibration, contact a member of the MMT Reporting Group for guidance on how to proceed.

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REV	DATE	CHANGE	AUTHOR	REVIEWED BY
00	190319	Initial release	PPP	SDP
01	190920	Updated for lap-welded seams & circumferential thickness mapping	PPP	SDP

MMTF010 – Longitudinal Seam Location and Identification Procedure

1. Overview

This document provides the procedure for conducting a visual inspection and an ultrasonic thickness survey around the circumference of a pipe joint to determine if a pipe joint is seamless or seam welded. For seam welded pipe joints, this document also outlines the procedure for locating the longitudinal seam and classifying it as submerged-arc-welded (SAW), flash welded, electric-resistance-welded (ERW) or lap-welded. Once this determination has been made, the appropriate testing procedure detailed in MMT F001a – General Field Testing Procedure should be followed.

2. Safety and Personnel Training Requirements

- **Safety:** OSHA 10 Hour Construction Safety, Drug and Alcohol Testing, JSA Covering Tasks to be Performed
- **PPE:** Safety Glasses
- **Testing:** All personnel shall be familiar with all MMT Procedures
- **Staff Level:** Personnel performing this procedure must be qualified in accordance with proper MMT staff level training. Personnel performing digital thickness measurements are not required to meet the requirements of SNT-TC-1A

3. Equipment

- Digital Ultrasonic Testing Gauge
- Dual-Element Piezo Electric Transducer
- Couplant
- PTX
- 40, 80, 120, 280, 600 Grit Belts
- Nital 5%

4. Procedure

4.1 Visual Inspection for External Indications of Seam Weld

Once the pipe joint is fully exposed and all coating is removed, an initial visual inspection around the circumference of the joint should be performed to identify and locate any weld reinforcements. Weld reinforcements include all caps of various shapes formed during manufacturing of a seam welded pipe joint. If a weld reinforcement is located, the technician should record its shape and clock position on the MMT field notes. Figure 1 provides an overview of reinforcement that can be observed on different seam-welded pipe joints. The rounded cap seen in Fig. 1(A) is indicative of a SAW pipe, while the square cap in Fig. 1(B) is indicative of a flash welded pipe. Some ERW pipes will have excess material that was not completely trimmed during manufacturing like the pipe in Fig. 1(C), but this will be much smaller and less prevalent than the flash welded or SAW reinforcement. Figure 1(D) shows a lap-welded pipe joint exhibiting a knurled or spellerized waffle-like pattern that is embossed on the surface along with a visible bondline. If the pipe seam is located based on visual inspection of external features, at least two pictures at different angles should be taken to document these features for reporting, and the seam type should be indicated in the MMT Field Notes .

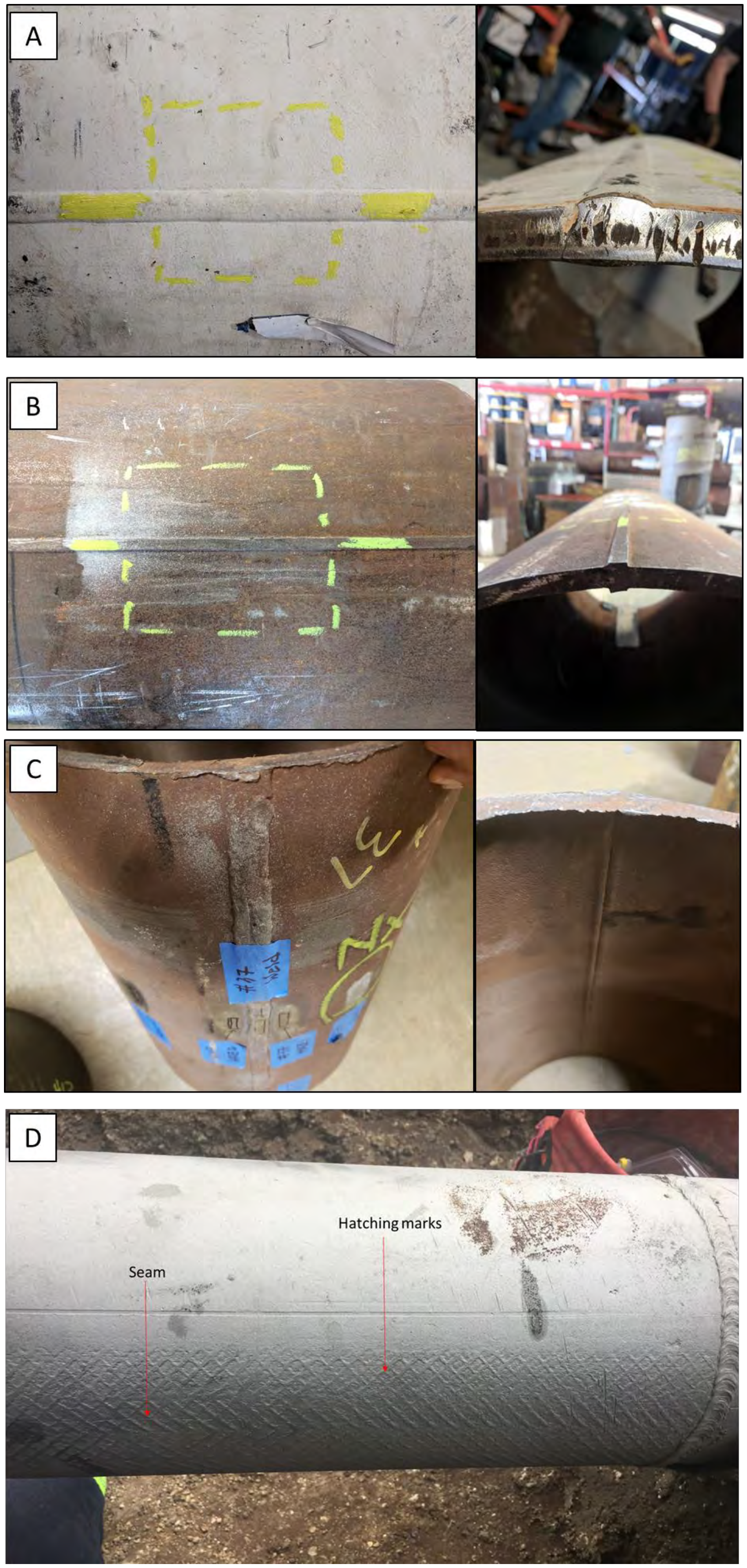

Fig 1: (A) Rounded weld reinforcement cap on SAW pipe; **(B)** Square weld reinforcement cap on flash pipe; **(C)** Excess material not trimmed off during manufacturing of ERW seam pipe; **(D)** Spellerized hatch mark pattern on lap-welded pipe.

4.2 Additional Steps for Pipes with No External Seam Weld Features

The following steps are required if visual inspection could not determine the manufacturing method for the pipe joint. These steps are required for seamless and ERW pipe joints that do not typically exhibit characteristic external features that would be identified during visual inspection.

4.2.1 Circumferential Thickness Mapping

Circumferential thickness mapping should be performed in accordance with MMTF007 – Ultrasonic Thickness Measurements Procedure to determine whether a pipe without visual external weld features is seamless. A seamless pipe will exhibit a wall thickness that varies continuously around the circumference of the pipe. This is demonstrated schematically in Fig. 2, where the thinnest and thickest regions of the pipe are approximately 180 degrees apart as a result of the seamless pipe manufacturing process. These maximum and minimum thickness locations can have a wall thickness variation of 0.01 inches or greater. This determination should be confirmed with the operator/site representative to ensure that thickness variation is not due to other sources such as internal corrosion. If the maximum wall thickness variation is less than 0.01 inches, or the wall thickness did not vary continuously around the pipe circumference, the joint is likely a seam welded ERW pipe, and additional steps are required to locate the seam as described below.

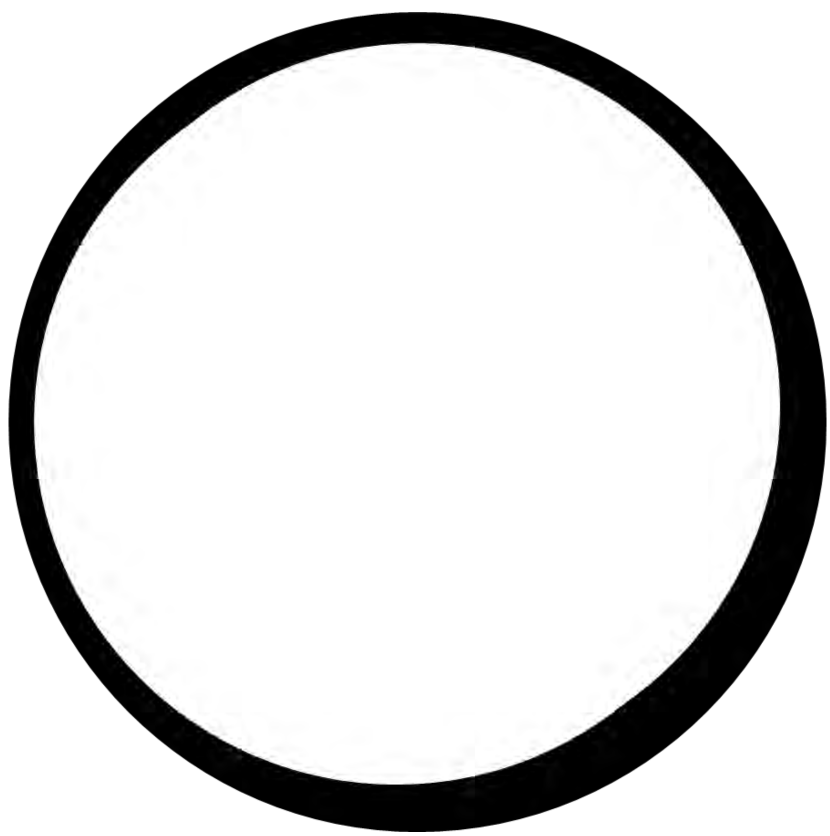

Fig. 2: Schematic of circumferential wall thickness variation in seamless pipe.

4.2.2 Locating an ERW Seam

If the circumferential thickness mapping indicates that the pipe is ERW, the seam will need to be located using the UT gauge. A noticeable change in thickness upwards of 0.015 inches will be observed in the vicinity of the seam as a result of material build-up or occasionally excessive weld flash trimming that occurs during manufacturing of ERW pipes. Technicians should begin by performing a detailed UT examination near the 2, 3, 6, 9, 10, and 12 o'clock positions as these are common seam locations during pipe installation.

4.2.3 Seam Confirmation of ERW pipes

Once an assumed ERW seam is located, and the technician has executed MMTF007 – Ultrasonic Thickness Measurements Procedure and MMTF008 – Magnetic Particle Testing Procedure, the MMTF002 – Surface Preparation Procedure should be followed to prepare a test region centered on the assumed seam. After the 600-grit step, the technician should stop and etch the surface with a 5% Nital solution. The technician should continue to etch the surface until the bondline becomes visible and the seam location is confirmed. The remainder of the surface preparation procedure should be completed with the now confirmed bondline centered in the testing area. This area will later be examined according to MMTF006 – OD Seam Etch Procedure to fully characterize the heat-affected-zones surrounding the seam.