NRC Weld Residual Stress Model Validation Program

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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

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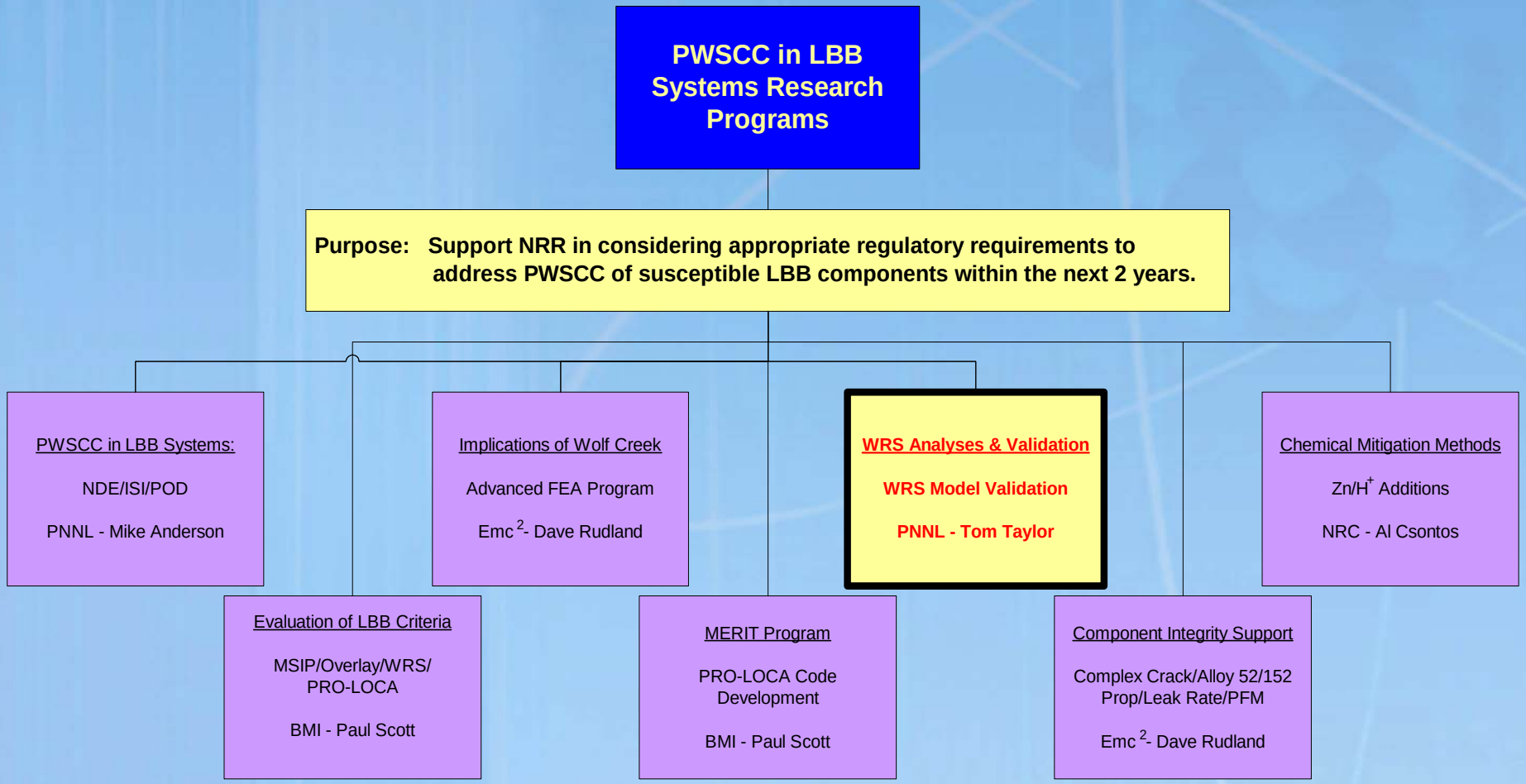
PWSCC in LBB Systems Research Programs



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Residual Stress Validation: PNNL – Tom Taylor

- Background:
  - Component integrity analyses (AFEA) for DMW showed that the results were highly dependent upon WRS profiles.
- Purpose:
  - Assess uncertainties and inform/validate WRS models used in NRC/industry PWSCC flaw evaluation and LBB analyses through a blind study of well controlled fabricated mockups, FEA modeling, and WRS measurements.
- Project Objectives:
  - Develop more accurate WRS models.
  - Blind validation of WRS models to measurements.
  - Determine uncertainties in WRS modeling.

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WRS Model Validation Plan

- Phase I Validation (2007):
  - DEI, BMI, & Emc^2 WRS models validated to the EU Network for Evaluating Structural Components-III (NESC-III) round robin study on 309L DMW integrity.
- Phase II Blind Validation (2008):
  - Validate WRS models to controlled research & ASME Section III (NB) fabricated 82/182 DM mockups.
  - Open to those groups willing to participate in a blind validation of their WRS models.
  - NRC will provide the data packages for each mockup to the program participants.
  - NRC may need some support for multiple WRS measurements.

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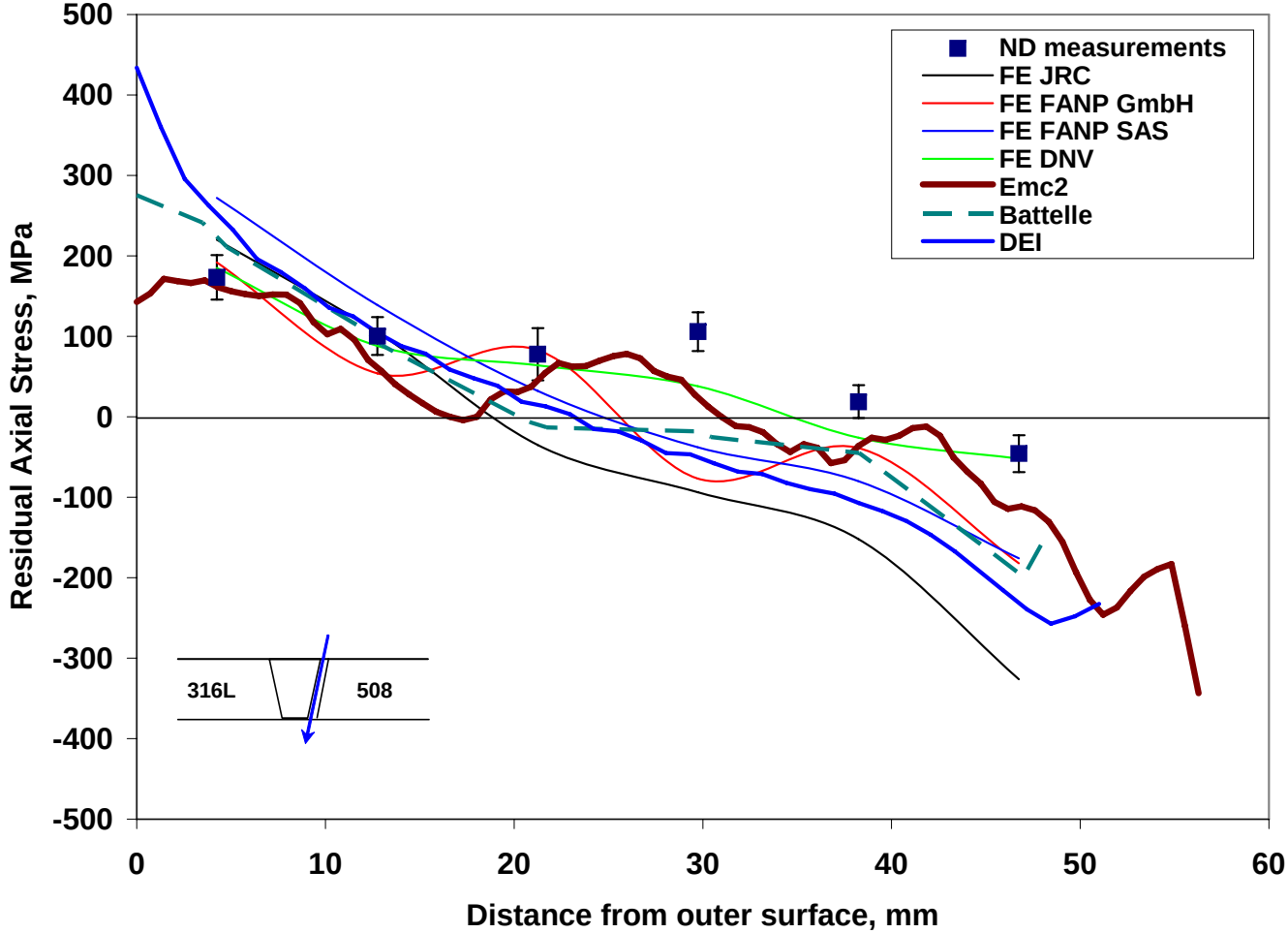
Phase I: Summary of EU NESC III WRS Validation



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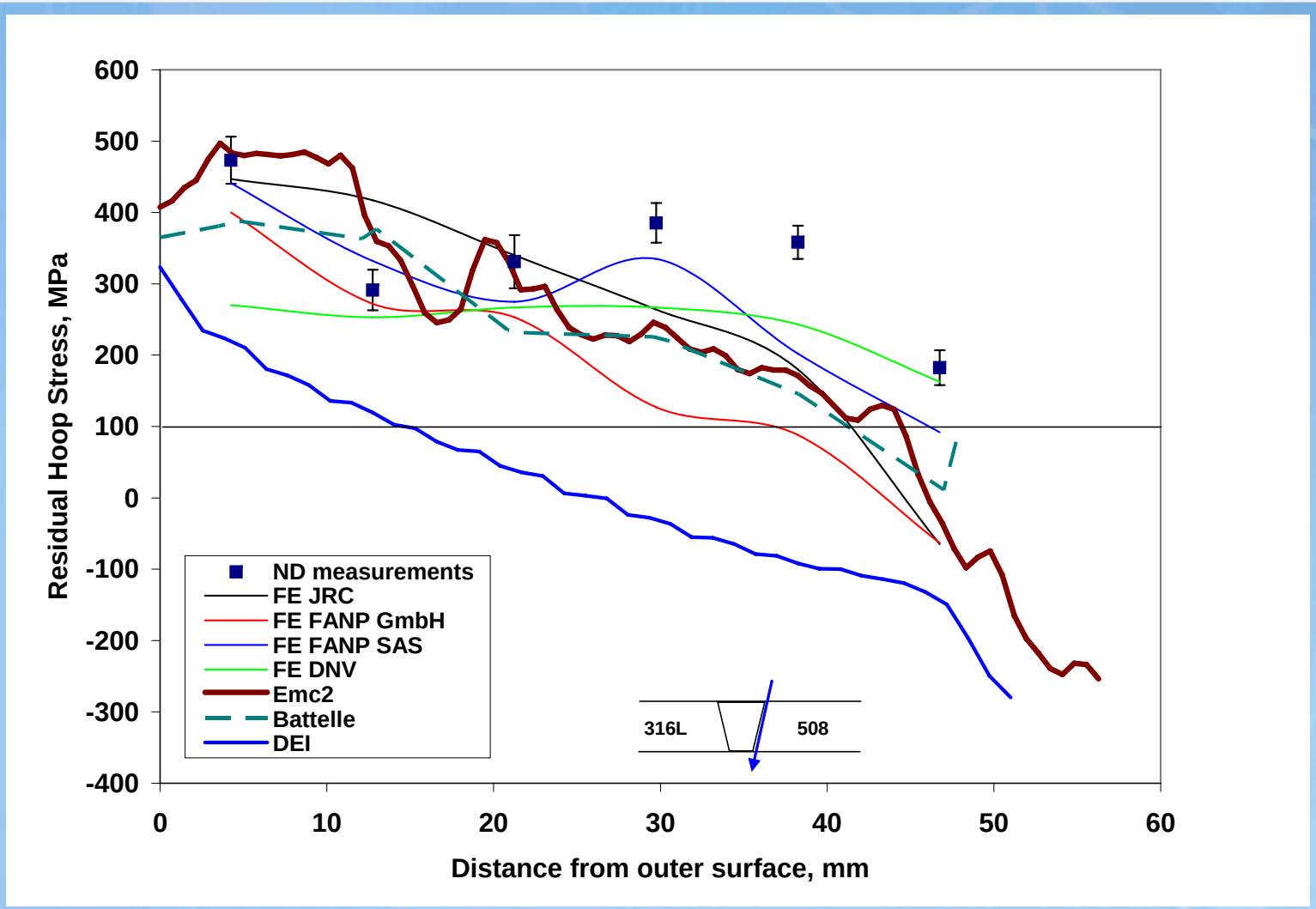
Phase I: Summary of EU NESC III WRS Validation



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Phase II: Blind Validation of Welded Mockups

- Tensile properties will be provided in a data package sent to WRS modelers as a function of temperature in the as-welded and solution-annealed condition.
- Obtaining 2-4 well controlled research & ASME Section III (NB) fabricated 82/182 DM mockups.
- Model validation to evaluate sequentially harder welded mockups to aid model development.

Geometry	Weld	Plate Material	Diameter	Weld Fabrication	Butter	Safe End	PA Repair	360° Last Pass Weld	Overlay	Start/Stop
Plate	82/182	SS - SS	-	Research	No	-	-	-	-	-
Cylinder	82/182	SS - SS	12"	Research	No	No	Yes (1/4)	No	No	All in 1 Quadrant
Cylinder	82/182	Ferritic - SS	12"	Research	Yes	Yes	Yes (1/4)	No	No	All in 1 Quadrant
Full Scale	82/182	Ferritic - SS	12"	ASME NB	Yes	Yes	Yes (1/2)	Yes (1/2)	Yes	

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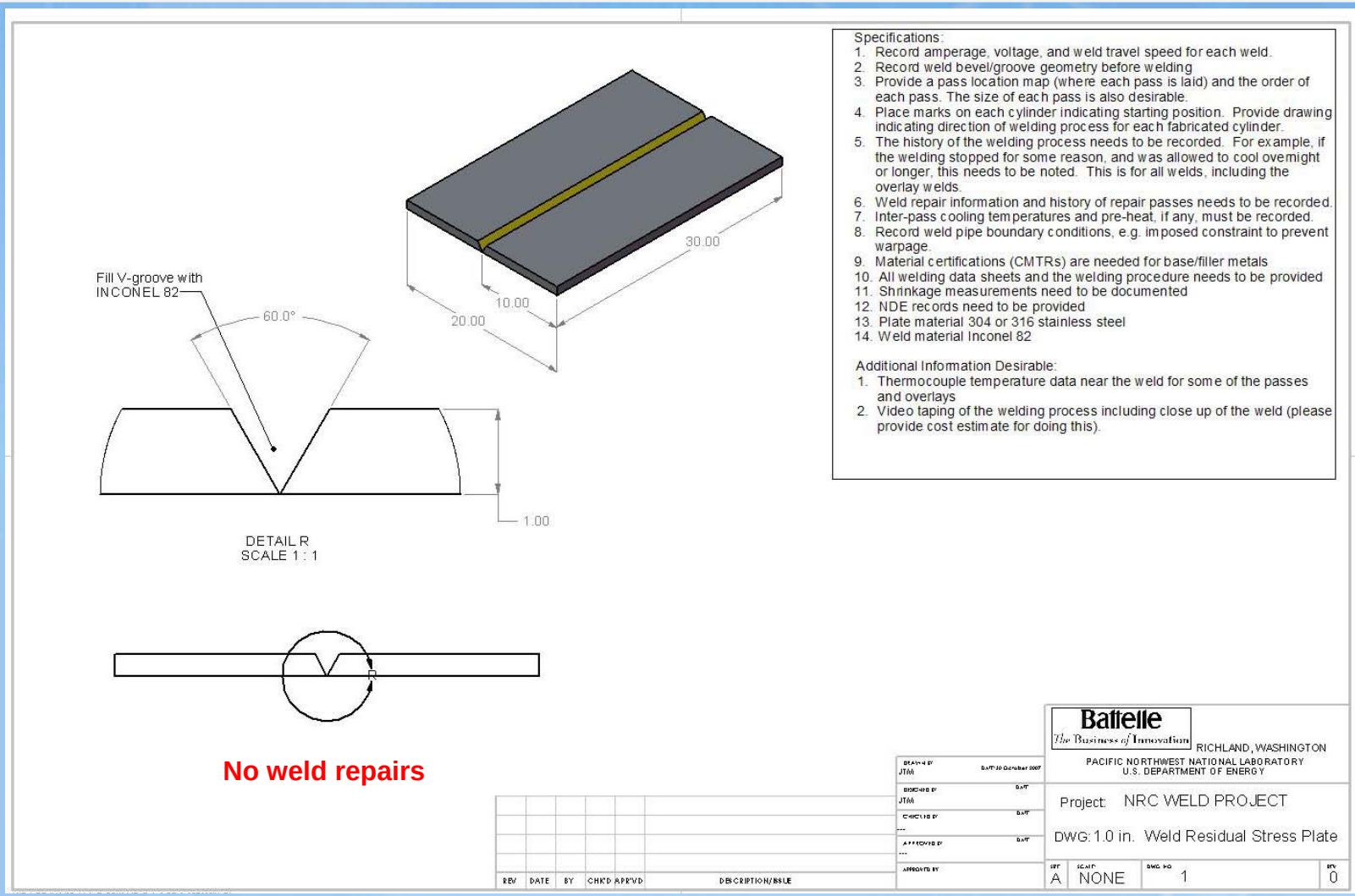
SS-SS Welded Plate 20”(w)x30”(l)x1”(t)



Specifications:
1. Record amperage, voltage, and weld travel speed for each weld.
2. Record weld bevel/groove geometry before welding
3. Provide a pass location map (where each pass is laid) and the order of each pass. The size of each pass is also desirable.
4. Place marks on each cylinder indicating starting position. Provide drawing indicating direction of welding process for each fabricated cylinder.
5. The history of the welding process needs to be recorded. For example, if the welding stopped for some reason, and was allowed to cool overnight or longer, this needs to be noted. This is for all welds, including the overlay welds.
6. Weld repair information and history of repair passes needs to be recorded.
7. Inter-pass cooling temperatures and pre-heat, if any, must be recorded.
8. Record weld pipe boundary conditions, e.g. imposed constraint to prevent warpage.
9. Material certifications (CMTRs) are needed for base/filler metals
10. All welding data sheets and the welding procedure needs to be provided
11. Shrinkage measurements need to be documented
12. NDE records need to be provided
13. Plate material 304 or 316 stainless steel
14. Weld material Inconel 82

Additional Information Desirable:
1. Thermocouple temperature data near the weld for some of the passes and overlays
2. Video taping of the welding process including close up of the weld (please provide cost estimate for doing this).

No weld repairs

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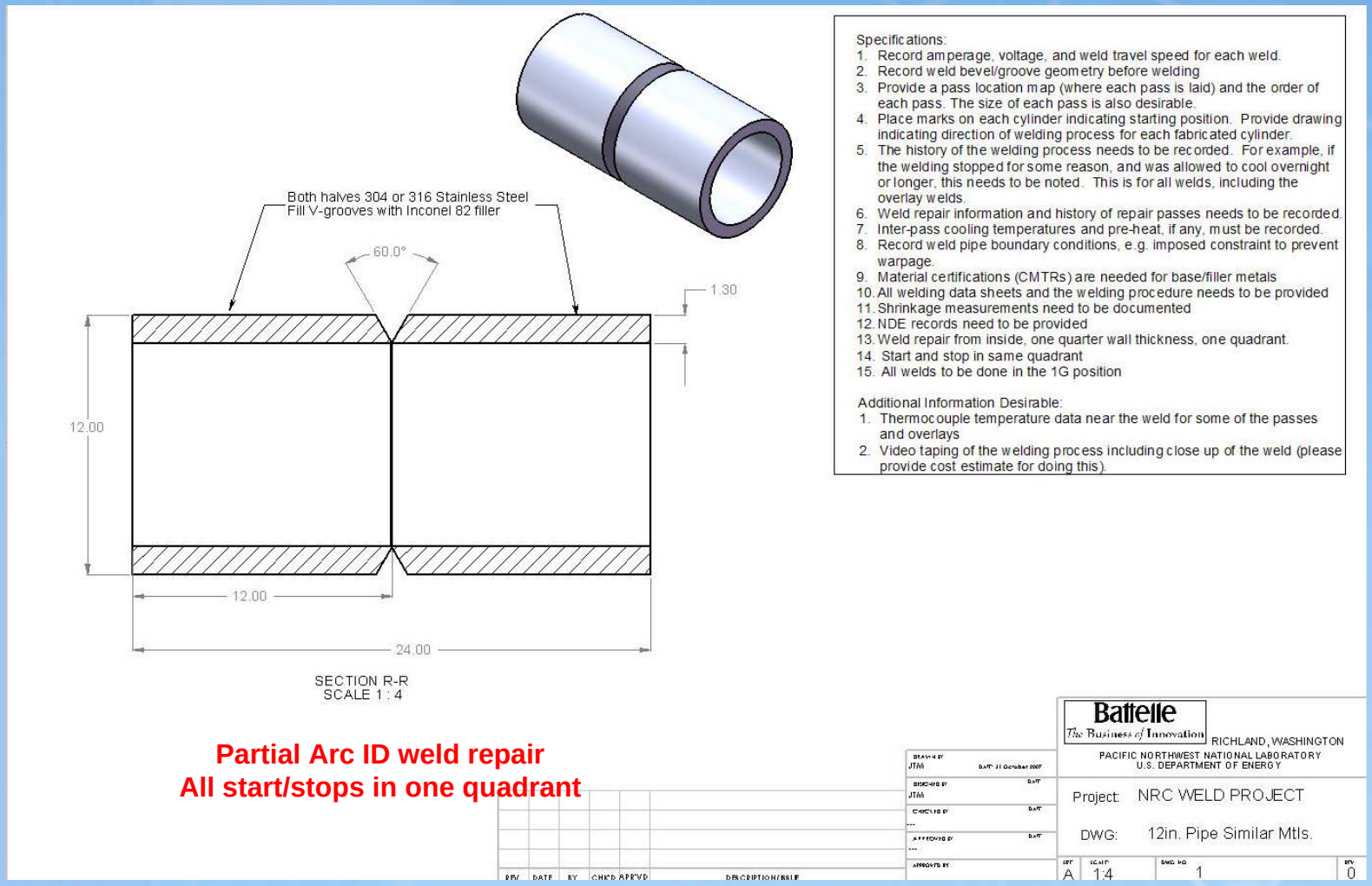
Project: NRC WELD PROJECT

DWG: 1.0 in. Weld Residual Stress Plate

REV	DATE	BY	CHKD	APP'VD	DESCRIPTION/ISSUE

SHT A	SCALE NONE	DWG NO 1	REV 0

SS-SS Welded Cylinder 12”(d)x24”(l)x1.3”(t)



Specifications:
1. Record amperage, voltage, and weld travel speed for each weld.
2. Record weld bevel/groove geometry before welding
3. Provide a pass location map (where each pass is laid) and the order of each pass. The size of each pass is also desirable.
4. Place marks on each cylinder indicating starting position. Provide drawing indicating direction of welding process for each fabricated cylinder.
5. The history of the welding process needs to be recorded. For example, if the welding stopped for some reason, and was allowed to cool overnight or longer, this needs to be noted. This is for all welds, including the overlay welds.
6. Weld repair information and history of repair passes needs to be recorded.
7. Inter-pass cooling temperatures and pre-heat, if any, must be recorded.
8. Record weld pipe boundary conditions, e.g. imposed constraint to prevent warpage.
9. Material certifications (CMTRs) are needed for base/filler metals
10. All welding data sheets and the welding procedure needs to be provided
11. Shrinkage measurements need to be documented
12. NDE records need to be provided
13. Weld repair from inside, one quarter wall thickness, one quadrant.
14. Start and stop in same quadrant
15. All welds to be done in the 1G position

Additional Information Desirable:
1. Thermocouple temperature data near the weld for some of the passes and overlays
2. Video taping of the welding process including close up of the weld (please provide cost estimate for doing this).

Partial Arc ID weld repair
All start/stops in one quadrant

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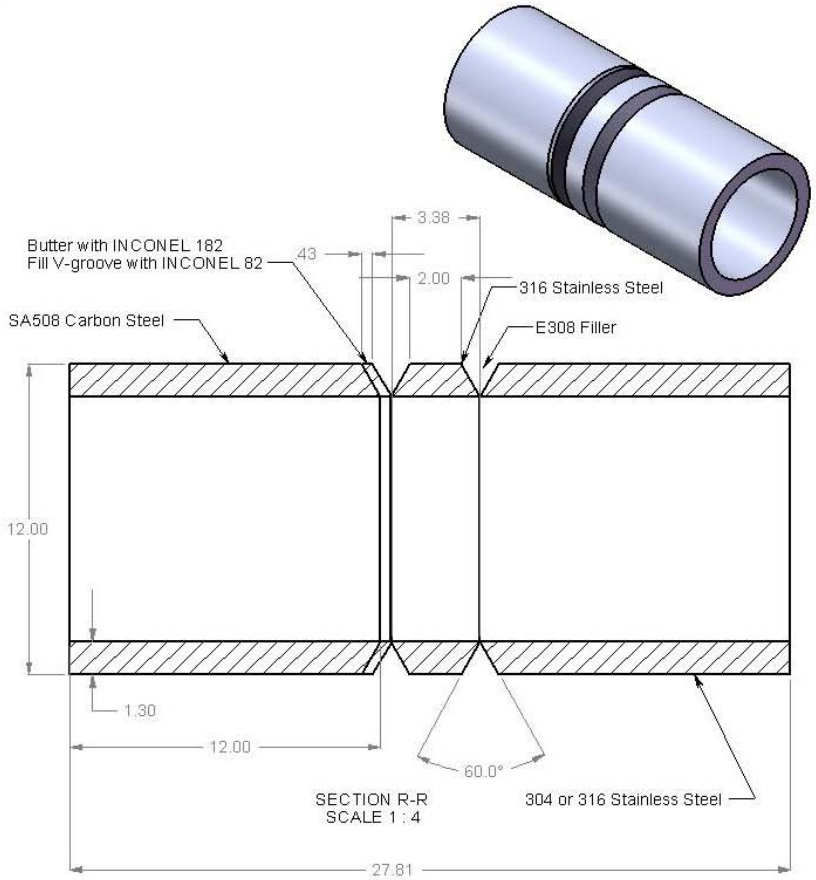
Project: NRC WELD PROJECT
DWG: 12in. Pipe Similar Mtls.

SIZE	SCALE	DWG NO	REV
A	1:4	1	0

DM Weld w/ Safe-End Weld 12”(d)x27.4”(l)x1.3”(t)



Specifications:
1. Record amperage, voltage, and weld travel speed for each weld.
2. Record weld bevel/groove geometry before welding
3. Provide a pass location map (where each pass is laid) and the order of each pass. The size of each pass is also desirable.
4. Place marks on each cylinder indicating starting position. Provide drawing indicating direction of welding process for each fabricated cylinder.
5. The history of the welding process needs to be recorded. For example, if the welding stopped for some reason, and was allowed to cool overnight or longer, this needs to be noted. This is for all welds, including the overlay welds.
6. Weld repair information and history of repair passes needs to be recorded.
7. Inter-pass cooling temperatures and pre-heat, if any, must be recorded.
8. Record weld pipe boundary conditions, e.g. imposed constraint to prevent warpage.
9. Material certifications (CMTRs) are needed for base/filler metals
10. All welding data sheets and the welding procedure needs to be provided
11. Shrinkage measurements need to be documented
12. NDE records need to be provided
13. Weld Repair buttered weld from inside, one quarter wall thickness, one quadrant
14. Start and stop in the same quadrant
15. All welds to be done in the 1G position

Additional Information Desirable:
1. Thermocouple temperature data near the weld for some of the passes and overlays
2. Video taping of the welding process including close up of the weld (please provide cost estimate for doing this).

Partial Arc ID weld repair
All start/stops in one quadrant

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Project: NRC WELD PROJECT

DWG: Buttered 12in. Pipe w/Safe End

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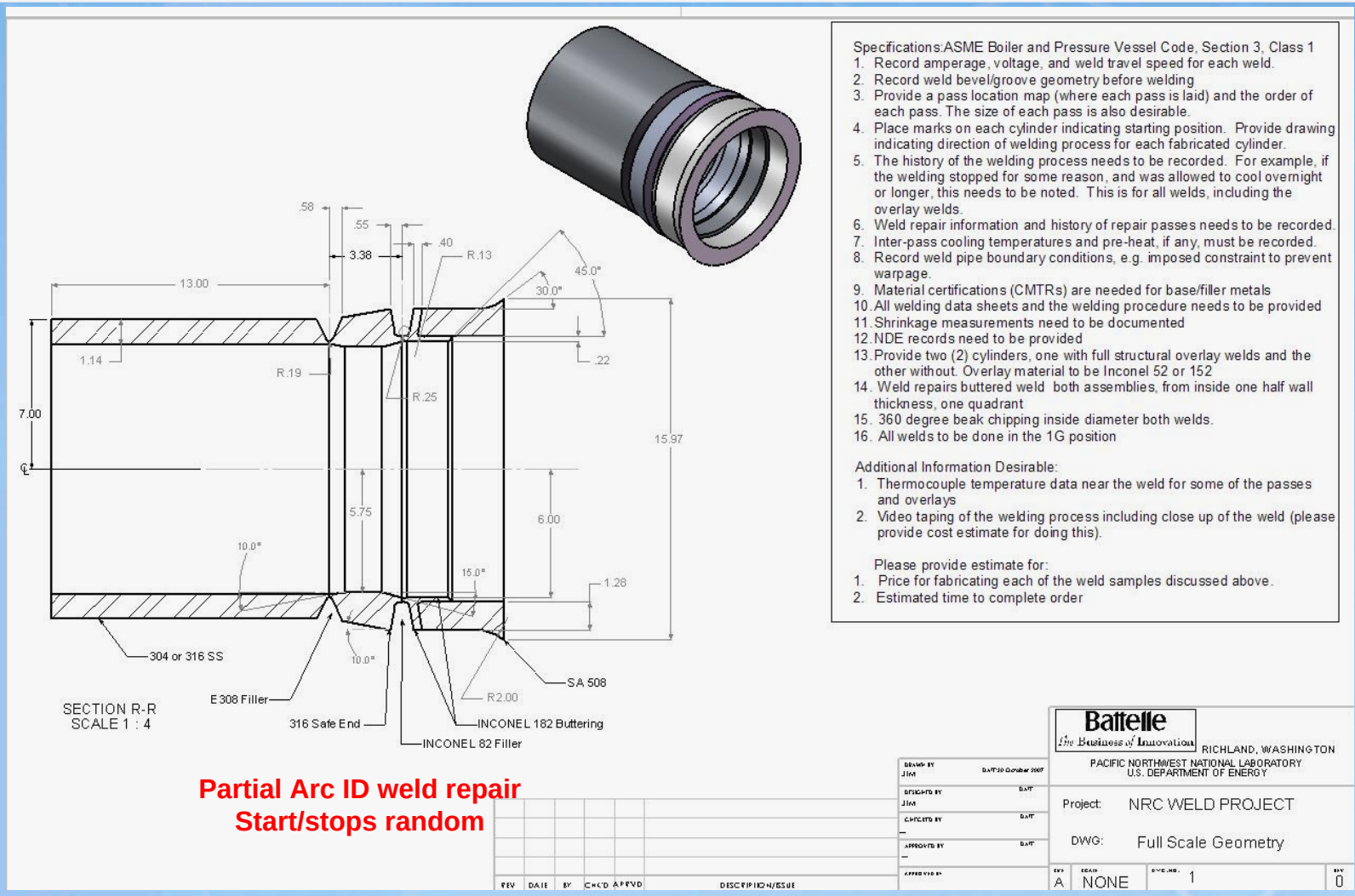
Prototypical Surge DMW 12”(d)x24”(l)x1.3”(t)



Specifications:ASME Boiler and Pressure Vessel Code, Section 3, Class 1

1. Record amperage, voltage, and weld travel speed for each weld.
2. Record weld bevel/groove geometry before welding
3. Provide a pass location map (where each pass is laid) and the order of each pass. The size of each pass is also desirable.
4. Place marks on each cylinder indicating starting position. Provide drawing indicating direction of welding process for each fabricated cylinder.
5. The history of the welding process needs to be recorded. For example, if the welding stopped for some reason, and was allowed to cool overnight or longer, this needs to be noted. This is for all welds, including the overlay welds.
6. Weld repair information and history of repair passes needs to be recorded.
7. Inter-pass cooling temperatures and pre-heat, if any, must be recorded.
8. Record weld pipe boundary conditions, e.g. imposed constraint to prevent warpage.
9. Material certifications (CMTRs) are needed for base/filler metals
10. All welding data sheets and the welding procedure needs to be provided
11. Shrinkage measurements need to be documented
12. NDE records need to be provided
13. Provide two (2) cylinders, one with full structural overlay welds and the other without. Overlay material to be Inconel 52 or 152
14. Weld repairs buttered weld both assemblies, from inside one half wall thickness, one quadrant
15. 360 degree beak chipping inside diameter both welds.
16. All welds to be done in the 1G position

Additional Information Desirable:

1. Thermocouple temperature data near the weld for some of the passes and overlays
2. Video taping of the welding process including close up of the weld (please provide cost estimate for doing this).

Please provide estimate for:

1. Price for fabricating each of the weld samples discussed above.
2. Estimated time to complete order

Partial Arc ID weld repair
Start/stops random

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DRAWN BY JIM — DATE 30 October 2007
DESIGNED BY JIM — DATE
CHECKED BY — DATE
APPROVED BY — DATE

Project: NRC WELD PROJECT
DWG: Full Scale Geometry
REV A | SCALE NONE | SHEET NO. 1 | REV 0

REV | DATE | BY | CHK'D APP'VD | DESCRIPTION/ISSUE

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Specifications for the Welded Mockups

1. Record amperage, voltage, & weld travel speed for each weld.
2. Record weld bevel/groove geometry before welding.
3. Provide a pass location map and the order of each pass.
4. Place marks on each cylinder indicating starting position.
5. The history of the welding process needs to be recorded.
6. Weld repair and history of repair passes needs to be recorded.
7. Inter-pass cooling temps and pre-heat must be recorded.
8. Record weld pipe boundary conditions, e.g. imposed constraint to prevent warpage.
9. Material certs (CMTRs) are needed for base/filler metals
10. All welding data sheets and procedure need to be provided
11. Shrinkage measurements need to be documented.
12. NDE records need to be provided.

* Thermocouple data near the weld & video tape the welding.

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Phase II: Blind Validation of Welded Mockups

- Measurement techniques under consideration:
  - NDE:
    - X-ray diffraction for ID & OD surfaces (Proto)
    - Neutron diffraction (potential free beam time at ORNL)
      - Need a D_o stress free sample to normalize data
  - DE:
    - Deep-hole drilling (http://www.veqter.co.uk/)
    - Hole drilling
    - Strain gauging
    - Contour method
    - Slitting method
- List of techniques to interrogate the DMW will be finalized at a TAG meeting later this year.