Sense & Nonsense of Welding Procedure Qualification

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Experience

- ‘73 graduate of TOSU
- Employment experience
  - 35+ years at three different consulting companies in Columbus, Ohio including 11 years at EWI
  - Currently Senior Welding Engineer of ARC Specialties Engineering & Consulting Services
- Joined first AWS committee in 1978
  - Member: Education, A2, B1, D1, D14, and TAC
  - Currently Chair of A2b (Terms & Definitions) and TAC

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AWS technical committees

- Technical Activities Committee (TAC)
  - Guides development and maintenance of all AWS technical standards
  - Consists of the Chairs of all AWS technical committees plus 6 at-large members
  - Assures that the AWS standards comply with ANSI standards
    - Developed by a “balanced” committee membership
    - Reviewed and either revised or reinstated in compliance with the ANSI 5-year renewal rule

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Introduction

- Most of this presentation was originally presented at AWS Codes & Standards Conference in Orlando in July
- Original plan was to discuss the Technical Activities Committee's efforts over the past 10+ years to standardize the manner in which welding procedures are qualified
  - And to bring attention to AWS B2.1, *Standard for Welding Procedure and Performance Qualification*

Introduction

- What has evolved however is a more global look at the qualification activity we are all engaged in at one time or another
- For this presentation, I have provided a local flavor by discussing the Houston way of qualifying procedures for corrosion-resistant overlays (CROs)

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TAC initiatives

- More than 10 years ago, upon the urgings of Walt Sperko, TAC sought to minimize the differences among AWS fabrication standards with regard to welding procedure qualification
  - More than a dozen standards addressed procedure qualification
  - All the same but different
- Standards committees urged to embrace AWS B2.1

AWS B2.1

- AWS's version of ASME Section IX
- Desirable features
  - M-number groupings (comparable to P-numbers)
  - Position <u>not</u> an essential variable
  - Means of qualifying fillet welds for both strength and soundness in a single testpiece
  - Simplified, standardized testing requirements
- A concentration on essential variables affecting metallurgical characteristics of a welding procedure

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B2.1 and SWPSs

- One of the most powerful extensions of AWS B2.1 is the Standard Welding Procedure Specification (SWPS)
  - Based on multiple previously qualified procedure qualification records (PQRs)
  - SWPS limitations are the most stringent of all those PQRs
  - The Navy is developing a series of SWPSs for use by contractors and their suppliers
  - This same approach has been suggested for future nuclear construction

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D14 – Leading the charge

- D14 standards provide fabrication requirements for a variety of equipment, including: cranes, presses, construction & agriculture equipment, and rotating elements of equipment
  - In D14.3, the base metal groupings portion of the document was bigger than the rest of the document
  - The 2005 edition of D14.3 specified B2.1 as the qualification standard and allowed the use of Standard Welding Procedure Specifications (SWPSs)
  - B2.1-BMG published as separate document and is available as a free down-load on AWS website

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Status of this harmonization effort

- Those accepting procedures qualified per B2.1
  - D14.1 through D14.8
  - D1.1 and D1.3 (with Engineer's approval)
  - D1.6 (if conflicts exist, D1.6 requirements prevail)
  - D9.1
- Those specifying B2.1 for qualification
  - D14.3
  - D17.1
- Success???

Lessons learned

- Too busy looking for differences to see the common aspects
- Legacy is powerful
- Often people expect more than a welding procedure can provide
  – The manner in which a procedure is qualified becomes insignificant if it isn't followed

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What is a welding procedure?

- It's a "recipe" for a the creation of an acceptable weld
  - It specifies the "ingredients" and instructions how they are combined
- The essential variables for a welding procedures should be those factors that can affect the metallurgical result of the welding process
  - We are trying to establish weldability

Excessive essential variables

- Specifying essential variables that have no effect on the metallurgical properties of the weld just add cost
  - Examples include:
    - Position of welding
    - Base metal specivity
    - Industry/application specivity
- AWS B2.1 levels the playing field and, like ASME Section IX, pays attention to the variables that matter
  - Provides a means of addressing production constraints that could reduce the potential for success of a procedure
  - Provides a means of qualification that is not application-specific

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Practical benefits of AWS B2.1

- Procedures recognized by multiple AWS standards, as well as ASME
- Flat position qualifies all positions
- Plate qualifies pipe without diameter limitation
- Base metal groupings (consistent with ASME Section IX)
- ¾ in weld thickness with 1½ in test coupon qualifies up to 8 in thick

Overcoming the roadblocks

- D1.1 is the elephant in the room
  - It's all about what's different
  - Don't want to require their customers to buy another book
  - Major stumbling blocks
    - Position ⇨ essential variable for toughness applications
    - Material grouping ⇨ use B2.1-BMG
    - Essential variables ⇨ use existing Table 4.5

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Invest wisely

- Too much emphasis on qualification, but too little attention given to the control and performance of a WPS
  - Deficiencies in the control and verification of production welding is what can easily lead to weld rejects
  - Monitoring the performance of a qualified WPS in the production environment is critical to assure that the process can be operated successfully

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Invest wisely

- Rather than requalifying a procedure, perform auxiliary testing to enhance the procedure
  - Verify the specified ranges of an existing procedure
    - Like D1.5 min-max heat input rate (HIR)
  - Verify the ability of a qualified procedure under production conditions
    - Use mock-ups to simulate specific joint configurations and/or inaccessibility
    - Recommended as alternate qualification approach by B2.1, D14.3 and D17.1

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B2.1 Summary

- Let's take advantage of the flexibility offered by procedures qualified in accordance with B2.1
- Let's quit wasting our money retesting the same procedures over and over again
- Requalification of a procedure does not guarantee success as much as careful monitoring of existing procedures

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Local qualification issues

- Since entering the Houston market, have been re-educated regarding qualification
- ARC E&C works with its customers to develop and qualify welding procedures for use on their equipment
  – Both overlay and "strength" welds

Qualification requirements

- Must satisfy ASME, API, and NACE requirements
  - Plus the variations and interpretations of the OEMs
  - To develop an effective qualification program, must consider of all of these requirements
  - Finding materials, especially welding filler materials, to meet these requirements is a challenge

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Qualification issues

- Use of *boutique* test materials
  - Pretested materials can be purchased for qualification
  - Heat-treated to withstand long PWHT times
  - No concern for Carbon Equivalent (CE)
  - More importantly, no limitation for CE of production materials
- *CE should be included on PQRs and become a limitation of WPS*

Carbon equivalent

- Chemical composition determines how a steel will react to heat treatment and preheat
  - CE = %C + (%Mn+%Si)/6 + (%Cr+%Mo+%V)/5 + (%Ni+%Cu)/15
  - Higher the CE ⇨ higher preheat temperature

	4130 Min Spec	4130 MaxSspec	Pipe 4130 Ht K2884	Pipe 4130 Ht 18993	Pipe 4130 Ht 13006	Pipe 4130 Ht 22087	Plate 4130 Ht E53839	Plate 4130 Ht 54434	Plate 4130 Ht D5608L	Plate 4130 Ht 55069	4130 Ht 50124	Pipe 4130 Ht 207S636	Pipe 4130 Ht 56289	Pipe 4130 Ht 207L367	Pipe 4130 Ht N0364	Plate 4130 Ht N5479	Block F-22 Ht Y0336	Pipe F-22 Ht 237K032	Pipe 8630 Ht 207J048
Carbon	0.28	0.33	0.31	0.30	0.31	0.31	0.31	0.29	0.30	0.30	0.31	0.33	0.30	0.32	0.31	0.30	0.15	0.12	0.32
Manganese	0.40	0.60	0.58	0.54	0.55	0.59	0.49	0.50	0.54	0.54	0.55	0.57	0.51	0.57	0.58	0.58	0.53	0.44	0.84
Silicon	0.15	0.35	0.25	0.25	0.23	0.29	0.35	0.25	0.32	0.30		0.30	0.23	0.28	0.32		0.33	0.25	0.27
Mn + Si/6	0.092	0.158	0.138	0.132	0.131	0.147	0.140	0.125	0.143	0.140	0.092	0.145	0.123	0.142	0.150	0.097	0.143	0.115	0.185
Chromium	0.80	1.10	0.83	1.03	1.00	0.98	0.97	0.93	0.97	0.97	1.00	1.06	0.99	1.03	1.06	1.07	2.22	2.17	0.89
Molybendum	0.15	0.25	0.20	0.21	0.22	0.16	0.20	0.20	0.21	0.18	0.22	0.24	0.21	0.23	0.22	0.22	1.01	0.96	0.38
Vanadium				0.030	0.002		0.003	0.008	0.006	0.005	0.002	0.026	0.002	0.026	0.027	0.280	0.006	0.001	0.011
Cr+Mo+V	0.95	1.35	1.03	1.27	1.22	1.14	1.17	1.14	1.19	1.16	1.22	1.33	1.20	1.29	1.31	1.57	3.24	3.13	1.28
Cr+Mo+V/5	0.19	0.27	0.21	0.25	0.24	0.23	0.23	0.23	0.24	0.23	0.24	0.27	0.24	0.26	0.26	0.31	0.65	0.63	0.26
Nickel			0.12	0.15	0.16	0.11	0.25	0.19	0.09	0.20	0.16	0.00	0.01	0.17	0.00	0.11	0.16	0.08	0.82
Copper			0.24	0.13	0.28	0.18	0.26	0.20	0.24	0.25	0.28	0.00	0.00	0.21	0.00	0.17	0.19	0.00	0.14
Ni+Cu	0.00	0.00	0.36	0.28	0.44	0.29	0.51	0.39	0.33	0.45	0.44	0.00	0.01	0.38	0.00	0.28	0.35	0.08	0.96
Ni+Cu/15	0.00	0.00	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.00	0.00	0.03	0.00	0.02	0.02	0.01	0.06
Carbon Equivalent	**0.562**	**0.758**	**0.678**	**0.705**	**0.710**	**0.704**	**0.719**	**0.669**	**0.703**	**0.701**	**0.676**	**0.740**	**0.664**	**0.744**	**0.721**	**0.729**	**0.964**	**0.867**	**0.825**

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Hardness testing

- NACE MR0175 requires hardness testing
  - Max HAZ hardness = 250 HV_{10}
    - "As close to fusion line [weld interface] but no more than 1mm away"
  - Some cases allow the use of HR_C
    - 22 HR_C maximum
    - No more than 2mm away from fusion line
    - 22 HR_C is too close to the point where the HR_C scale is no longer accurate (20 HR_C)
      - Recommend using Rockwell A-scale

PQR vs WPS

- ASME allows WPS preheat temperature to be up to 100° F less than PQR temperature
- For CROs, WPS heat input rate (HIR) permitted to be 10% higher than PQR
  - Permissible to list amps, volts and travel speeds that would result in a higher HIR if the maximum amps & volts and minimum travel speed used
- Use of 32h PWHT for PQR allows for up to 40h WPS limit

Summary and recommendations

- Develop a consensus qualification standard with consistent, and realistic, requirements
  - Eliminate the “moving target” for suppliers
  - Get input from the ultimate users
- Make CE an essential variable
- Develop a hardness testing requirement that allows for consistency
- Put the emphasis on control of production welding --- not procedure qualification!

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