



Nuclear Energy Standards Coordination Collaborative

Topical Report: Welding Codes and Standards for Nuclear Power Plants

Recommendations for Improvements

Nuclear Energy Standards Coordination Collaborative (NESCC)

Topical Report of the Welding Task Group
**Welding Codes and Standards for Nuclear Power Plants: Recommendations
for Improvements**

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Contact:

Tom Siewert, Task Group Chairman
National Institute of Standards and Technology
Email: siewertt@gmail.com

Edited by:

Casandra Robinson, NESCC Federal Co-chair
National Institute of Standards and Technology
Email: casandra.robinson@nist.gov

Preparation of This Report

This report was prepared by the Nuclear Energy Standards Coordination Collaborative (NESCC) Welding Task Group. Membership on the task group was open to all interested nuclear power plant stakeholders, and members and their organizations are listed in Table 1. The task group was chaired by Tom Siewert of the National Institute of Standards and Technology (NIST), Boulder CO (USA).

Table 1. Membership of the Welding Task Group

Name	Organization
Annette Alonso	America Welding Society (AWS)
Mike Bernasek	C-SPEC
Tom Boyce	U.S. Nuclear Regulatory Commission (NRC)
Denis Clark	Idaho National Laboratory (Ret.)/AWS volunteer
Dana Couch	Electric Power Research Institute (EPRI)
Kurt Cozens	NRC
Andrew Davis	AWS
David Failla	NRC
James Fekete	National Institute of Standards and Technology (NIST)
Shane Findlan	CBI
Phil Flenner	Flenner Engr. Services, LLC (ASME Volunteer) (supported by EPRI)
Jeffery Fluckiger	Battle Energy Alliance, Idaho National Laboratory (INL)
Greg Fredrick	EPRI
Mike Gase	John E. Green Company
John Gayler	AWS
Heather Gilmer	Tampa Tank Inc./ Florida Structural Steel (TTI-FSS)
Stan Gingrich	URS Corporation
Harold Gray	NRC
Ross Hancock	AWS
Ed Herderick	Edison Welding Institute (EWI)
Blake Hobson	Image Industries, Inc.
Richard Holdren	Arc Specialties, Inc.
Mark Holland	PV Steel Industries
Jeff Hufsey	AWS
Ted Hutton	Arkema
Dale Ison	Tampa Tank Inc./ Florida Structural Steel (TTI-FSS)

Name	Organization
Steven Jones	Rolls-Royce
Dan Kaufman	American Institute of Steel Construction (AISC)
Steve Knostman	Hobart Brothers Company
J Lawmon	AEMI
Steve Levesque	EWI
Stephen Liu	Colorado School of Mines
Paul May	National Fire Protection Association (NFPA)
Bob MeierHoff	Bendtec Inc.
Jim Merrill	AMEC
Michael Moles	Olympus NDT
Clyde Morell	NRC
Jeff Noruk	Servo Robot Corp.
Alan Patterson	TWI Ltd.
Sayee Raghunathan	TWI
Casandra Robinson	NIST
Jim Sekely	Consultant, Welding Services Inc.
Abhijit Sengupta	NRC
Eric Sjerne	IRISNDT
Tom Siewert	NIST (Ret.)/ AWS Volunteer
Michael Sloan	International Training Institute for the Sheet Metal and Air Conditioning Industry
Jeff Sowards	NIST
Walt Sperko	Sperko Engineering Services
Phillip Temple	eNergy Wise Consulting, LLC (DTE Energy Retired; AWS Volunteer)
Ambler Thompson	NIST
Julio Tolaiai	Alstom
Chuck Violand	Scott Process
Paul Woollin	TWI

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1. Background

The goal of the Welding Task Group was to develop a list of welding codes and standards for nuclear construction and repair that merit attention, together with specific examples of what aspects should be addressed. This included identifying changes that should occur in current codes and standards to make them more streamlined (i.e., easier to read and follow, reduced construction times) and safer (i.e., more precise control of key parameters) as well as pointing out technical advances that have occurred since their last major revision and should be addressed within the standards. The list of needs was based on data collected from users of the standards, specifically those who construct nuclear plants or will be the eventual owners with responsibility for repairs. Then, the technology specialists on the committee were able to identify the organizations that could respond to these needs.

The inaugural meeting of the Welding Task Group was held in November 2011, and 15 meetings were held to develop this report. The task group began with 10 members but soon grew to over 50 as specialists were added to address emerging topics. Minutes of the meetings and other task group documents are available in the NESCC document library within the Welding Task Group folder, which may be found at:

<http://publicaa.ansi.org/sites/apdl/NESCCDocs/Forms/welding.aspx>

Welding is central to nuclear construction and repair activities, and the considerable volume of code language devoted to welding indicates how crucial it can be in terms of inspection, fitness for service, and the response of materials to design and out-of-design loads and environments. While welds may comprise only about 1% of the structure on a volume basis, the labor and technology necessary to produce them comprises at least 10% of the cost of the final structure. Welding costs can be such a large component of plant construction and maintenance that they drive the development of innovative processes and techniques to increase effective deposition rates, increase weld quality, and decrease weld time. Also, just as a chain is only as strong as its weakest link, the integrity of a structure depends equally on the properties of the base material, the weld, and the heat affected zone. Thus, substantial effort must be given to understanding the properties of the weld and the interaction between the weld and the base material within the heat affected zone.

This topical report lists key issues and recommendations identified by the task group. Further details and the basis for this report may be found in the aforementioned Welding Task Group folder.

2. Key Issues

The task group identified five key issues that need to be addressed:

2.1. **Need to eliminate inconsistencies between codes and standards in procedure and welder qualifications.**

Frequently asked questions include: “Why do we need to repeatedly requalify to prove what we already know? Why must we substantially repeat a test to meet the minor nuances of different codes?” Such repetition could be greatly reduced through harmonizing the approaches taken within the various codes used for nuclear plant construction and repair, such as those used by American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section IX and the

American Welding Society (AWS) B2.1 and D1 committees and various subcommittees. Following harmonization of approaches, new standard welding procedures could be developed that contain certain key property categories not covered in existing standard welding procedures. Addressing these two issues would facilitate harmonization of welder qualification.

2.2. Need for personnel certification of Welding Engineers.

There is a drive toward better documentation of the certification and training of personnel (such as what has happened within International Organization for Standardization (ISO) requirements), yet serious gaps remain within the United States (U.S.) system. In fact, the Professional Engineering (PE) registration in welding was discontinued in the past few years due to low participation by the states. Should this registration be reinstated? Does AWS's Certified Welding Engineer (CWEng) program meet this need, or should it be modified? If a PE in a discipline other than welding signs off on an entire structure during the design phase, how can those with welding expertise who advise the lead PE be identified, and what certification is necessary to demonstrate their competence?

2.3. Need for qualification of Welding Supervisors or Welding Coordinators.

Many individuals whose companies have given them the title of Welding Supervisor or Welding Coordinator do not have a welding background and would have difficulty in achieving PE or CWEng registration. Yet, they need a training and certification route that would allow them to establish and then prove their competence. During the late 1980s and 1990s, the industry experienced a reduction in the number of people entering construction in general and welding in particular. As a result, there exists a shortage of craftspeople in the 35 to 55 age range. Selection of those to be moved into welding supervisory positions should be tied to achieving some qualification level and recognition of this qualification by the welding codes.

2.4. Need to make better use of the inspection capabilities of phased array technology.

The dominant standards development organization in phased array codes is ASME, in association with other standards bodies (e.g., ASTM International, American Petroleum Institute (API)). ASME recently published a full series of mandatory automated ultrasonic testing (AUT) and phased array appendices in Section V (NDE). These now cover most aspects of AUT (including time-of-flight-diffraction [TOFD]) and are specifically aimed at boiler and piping weld inspections. The three new AUT appendices essentially replace ASME Code Case 2235 but are significantly easier to read and understand; however, they do not include acceptance criteria as these will be developed in other ASME reference sections.

Some feel that AWS has been slower in the inclusion of AUT and needs to expand its use, although changes are currently being balloted in AWS D1.1 and D1.5. Presently, the D1.1 inspection code mentions phased array as an example of "advanced ultrasonic systems," but the section is vague and does not specify manual or S-scan. Phased array could reasonably be assumed to be covered by Annex S (although the code doesn't explicitly say so), and that annex does rely on manual methods. It would be beneficial if the treatment and requirements in D1.1 are made very similar to those in the BPVC, so users do not have to follow different procedures.

2.5. **Need to make repair decisions based on fitness-for-service assessments.**

Currently, many repair decisions are made on workmanship standards, where accept/reject decisions are based on appearance by visual testing and nondestructive examination (NDE) results, primarily radiographic testing (RT) but sometimes UT. However, unnecessary repairs often introduce additional damage that can be the source for later failures during service. Switching to repair decisions based on quantitative engineering calculations (such as fracture mechanics) rather than workmanship standards (based on appearance) would result in only necessary repairs being made and provide a quantitative measure of expected performance, rather than just accept/reject.

While some of the technical issues are already under code committee consideration in ASME BPVC Section III, API 579, AWS D1.1, and AWS D1.5, more can be added, and the approaches should be consistent with each other. This is applicable both to construction of new plants and repair of existing plants.

3. **Recommendations**

The task group is providing five recommendations to address the previously noted key issues:

3.1. **Harmonize procedures and welder qualifications.**

3.1.1. *Develop a strong liaison between the AWS B2 committee (which is well aligned with ASME Section IX) and the AWS D1 committee so their welding procedure philosophies and requirements could be as similar as possible or, ideally, be identical.*

Repetition in procedure development can be greatly reduced through harmonizing the approaches taken within the various codes used for nuclear plant construction and repair. An innovative approach toward harmonization has already occurred within certain ISO welding standards using an approach titled “cohabitation”, where two or more well-established regional procedures have both been incorporated within a single ISO standard, without having to select from among the competing approaches.

The path to effective and successful harmonization of ASME BPVC Section IX/AWS B2 and AWS D1 qualification requirements is achievable provided more than one committee volunteer¹ participates in the shaping of all three standards. At least one volunteer from a utility (preferably the owner of both nuclear and non-nuclear facilities), one from the architect/engineer/construction industry, and one from the general user category representing a cross-section of the entire industrial spectrum of qualification code users should be encouraged to proactively attend all ASME BPVC Section IX/AWS B2 and AWS D1.1 meetings and work toward harmonization².

3.1.2. *Develop new standardized welding procedures and expand the scope of existing procedures so that individual companies do not need to develop their own procedures.*

¹ The committee volunteer is currently Mike Bernasek of C-SPEC.

² Mike Bernasek of C-SPEC is an example of an individual that fits this profile.

This might be funded by having the AWS B2 and D1 committees develop a joint proposal to the ASME Foundation³. While existing standardized welding procedures have saved companies millions of dollars over the past 20 or so years, additional welding procedures need to be developed that contain property categories, such as toughness requirements for welds in carbon and low alloy steels and delta ferrite (FN) requirements (RG 1.31) and sensitization limits (RG 1.44) for welds in austenitic stainless steels. While there is some disagreement within the Welding Task Group of how many additional standard procedures are needed and how many companies would use them, there is enough interest to propose some forum where this topic can be discussed among a much larger number of potential users.

- 3.1.3. *Develop uniform (maybe even standardized) procedures for welder qualification, so that one approach works for both ASME and AWS codes.*

This issue of welder qualification is closely related to the two issues mentioned previously and should be harmonized as well. In fact, many of the same people work on all three of these issues in the committees, and it has been recommended that these issues be addressed in the sequence listed here.

- 3.2. **Expand the options for welding engineer certification within the U.S.**

This would allow engineers of different backgrounds to demonstrate an appropriate level of competence for various applications. Perhaps the most difficult certification to achieve has been the welding PE license. The welding PE test given through the Ohio State University was dropped a few years ago because too few states were participating to meet the requirements of the national board (NCEES). However, there is a drive within AWS to find a way to reinstitute it. For most welding engineers, signing design documents as the responsible engineer is not going to occur. Therefore, consideration should be given to the role of the welding engineer as a required input into designs but not as the engineer who will affix their PE stamp as the responsible design engineer. An alternate approach to certification is to modify the AWS CWEng certification to bring it more in line with international requirements. A third approach is to develop a practical welding engineering certificate for those who have been assigned to serve as the active welding engineer for their organization but do not have a traditional welding engineering background. All three of these approaches should be followed as they really address different aspects of the demand.

Also, welding needs to be considered during the design phase. Many organizations only consider welding when it is time to qualify procedures and welders, and this has created many issues within manufacturing and construction where proper input has not been provided to avoid problems. Raising the awareness of organizations to the importance of welding and the professionalism of welding engineers is vitally important. AWS B5.16, “Specification for the Qualification of Welding Engineers” is a start, but this should be driven by an industry need to increase acceptance and engineers’ pursuit of this qualification. One industry that has adopted a standard is nuclear power. The Institute of Nuclear Power Operations (INPO) published EPG-17, “Engineering Program Guide – Welding Program.” This is a good practice that all operating nuclear power plants are

³ The ASME Foundation funds research to make the application of ASME codes more efficient.

expected by INPO to adopt. The guide "...identifies the essential elements or features of an integrated welding program for nuclear power plants." The main focus is on the overall programmatic aspects of welding in a nuclear plant, but it does address the other essential areas of staff experience and expertise, qualification, and training. For a welding engineer, the initial qualification requirements for college and years of experience exceed those of the AWS standard and then add to those requirements other areas of knowledge, such as codes and standards, NRC requirements, NDE, metallurgy, etc. The good practice then returns to what a program should encompass. This, like every other standard, does not address the fact that welding begins with designing structures, systems, and components (SSC) for weldability and metallurgical issues, factors that can exert a large influence on the service life of SSCs.

3.3. Expand the personnel certification of welding supervisors.

Training opportunities should be increased for welding supervisory positions, especially for new supervisors who do not have a welding background, and recognition of the qualification of welding supervisors should be inserted into the welding codes. Much of the work already exists in documents, such as AWS B5.9, "Specification for the Qualification of Welding Supervisors" and ISO 14731, "Welding Coordination – Tasks and Responsibilities." Both of these standards contain criteria for experience and knowledge about welding processes, consumables, base materials, equipment, safety, welding instructions, procedures and practices, qualification, inspection, report preparation, and related codes and standards. The AWS Welding Supervisor program can be found at <http://www.aws.org/certification/CWS/>. Also, INPO EPG-17 should be referenced for information that addresses supporting welding staff members, such as qualification test supervisor and planners.

3.4. Expand the allowed application of phased array ultrasonic testing (PAUT) inspection within codes.

The capabilities of PAUT inspection continue to expand, and fabricators and repair contractors should be able to take advantage of them so the advanced inspection capabilities and economies of automated inspection can be applied to a wider range of welds in nuclear applications. The latest PAUT equipment can more precisely discriminate the characteristics of buried indications and in a range of orientations. Not only does this technology promise improved quality of inspection, but it allows more rapid inspection as well, reducing downtime of emergency repairs. The success of PAUT is dependent on the quality of the equipment and systems set up. When applied correctly, the interpretation of the data can be very straightforward. PA applications may produce either non-encoded or encoded data, where the indication is coordinated with its location.

3.5. Make more repair decisions based on fitness-for-service assessments.

Currently many repair decisions are made on workmanship standards; cosmetic repairs (those having no effect on the service life or performance) often introduce additional damage that can be the source for later failures during service. Switching to repair decisions based on quantitative engineering calculations, such as fracture mechanics, would result in only necessary repairs being made.

4. Responsible Parties

The first three recommendations (on the topic of procedure and welder qualification) fall within the domain of ASME BPVC Section IX and AWS B2.1 and D1 committees. The first step is to develop better liaison between the groups and then search for ways to bring the requirements into closer alignment.

The recommendations to expand Welding Engineering and Welding Supervisor certification fall mostly within AWS. Changes to the CWEng program are apparently being addressed within the AWS Technical Activities Committee. A Special Committee established by the AWS Board is considering how to expand training for the welding engineers assigned that responsibility but lacking a welding background. Likely this responsibility will be assigned to the AWS Education Committee. The activity to reinstate the PE certificate in welding⁴ may or may not be steered through an AWS committee. The need to include a broader consideration of welding, starting in the design phase, is an issue that should be addressed in the higher-level requirements, probably within the ASME code or the NRC regulations.

The recommendation to expand the allowed application of PAUT inspection falls mostly within the AWS D1 committees and the Electric Power Research Institute (EPRI), with input from the phased array equipment developers and suppliers.

The recommendation to make more repair decisions based on fitness-for-service assessments is more applicable to AWS codes, but ASME should continue to monitor new advances in this technology and expand applications as appropriate.

5. References

API 579-1, *Fitness-for-Service*, American Petroleum Institute, 2007.

ASME Boiler & Pressure Vessel Code, 2010 Edition, Section III, *Rules for Construction of Nuclear Facility Components*, American Society of Mechanical Engineers, 2010.

ASME Boiler & Pressure Vessel Code, 2010 Edition, Section V, *Nondestructive Examination*, American Society of Mechanical Engineers, 2010.

ASME Boiler & Pressure Vessel Code, 2010 Edition, Section IX, *Welding and Brazing Qualifications*, American Society of Mechanical Engineers, 2010.

ASME Code Case 2235-9, ASME Boiler & Pressure Vessel Code, Sections I, VIII and XII, *Use of Ultrasonic Examination in Lieu of Radiography*, American Society of Mechanical Engineers, 2005.

AWS B2.1, *Base Metal Grouping for Welding Procedure and Performance Qualification*, American Welding Society, 2009.

⁴ The effort to reinstate the PE welding certificate program is being led by Richard Holdren of Arc Specialties, Inc.

AWS B5.9, *Specification for the Qualification of Welding Supervisors*, American Welding Society, 2006.

AWS B5.16, *Specification for the Qualification of Welding Engineers*, American Welding Society, 2006.

AWS D1.1, *Structural Welding Code*, American Welding Society, 2010.

AWS D1.5, *Bridge Welding Code*, American Welding Society, 2002.

EPG-17, *Engineering Program Guide – Welding Program*, Institute of Nuclear Power Operators, 2009.

ISO 14731, *Welding Coordination – Tasks and Responsibilities*, International Organization for Standardization, 2006.

Regulatory Guide 1.31, *Control of Ferrite Content in Stainless Steel Weld Metal*, Nuclear Regulatory Commission, 2013.

Regulatory Guide 1.44, *Control of the Processing and Use of Stainless Steel*, Nuclear Regulatory Commission, 2011.