Regulatory Analysis Input - SGRRA

Revised CC N-638 to Initiate the 48 hour hold after layer 3 completion for Section XI Ambient Temperature Temper Bead Welding activities

Action Item Number

RRA 05-08
ISI
BC

Action Item Explanation: Revise Code Case N-638-3 to permit initiation of the 48 hour mandatory waiting period immediately after completion of the third weld layer. This action revises Code Case N-638 to incorporate this change.

OMB Analysis (Hours/year)

Reduce/increase Reporting requirements: There is no anticipated change to the reporting requirements as a result of this change. It is anticipated that this Code Case would be approved by the NRC and therefore, would not require submittal of a Relief Request to the NRC.

Reduce/increase Record Keeping requirements: There is no increase or decrease in the record keeping requirements since this Code Case would have the same requirements for record keeping as current Section XI temper bead qualifications.

Regulatory Analysis (Quantify dollars, time, dose): This action will not affect or change the regulatory analysis associated with ambient temperature temperbead repair activities. It is anticipated that the revised Code Case will be submitted to NRC for review, which is typical of nuclear Code Cases.

Reduce/increase safety: This action will improve/increase plant safety by enabling ambient temperature repair activities to retain the mandatory 48 hour delay between welding and final NDE, which will result in no change in safety. The initiation of the 48 hour delay is changed from current requirements (i.e., initiated after completion of the entire weld) to after completion of the third weld layer. Since welding of the 4^{th} and subsequent layers will not introduce additional hydrogen into the original weld HAZ, this change in 48 hour initiation time has no effect on safety.

Reduce/increase cost: This action will enable substantial cost reductions by reducing the schedule impacts of ambient temperature temperbead welding. The 48 hour delay as currently mandated is has a direct and significant effect on costs and on outage scheduling. Critical path cost estimates very among nuclear stations, but can approach $1M per day. As repair welding activities are streamlined, this need to moderate the impact of this requirement has become increasingly important.

Reduce/increase requirements: This action does not change the current requirement for a mandatory 48 hour hold. It modifies this requirement, however, so that the 48 hour time period is initiated earlier in the welding process. The result is a decrease in the impact that this requirement has on costs and scheduling.

Reduce/increase complexity of plant operation: This action reduces the complexity of plant operation, specifically with regard to plant operation during outage periods. By reducing scheduling constraints associated with the 48 hour NDE hold, plant operational flexibility during outages is improved, thereby decreasing the complexity of plant operation.

Reduce/increase facility down time: This action has the potential to directly reduce facility down time. The impact of this reduction is significant, since this 48 hour hold has a direct effect on scheduling, and this reduction will have a correspondingly direct effect on facility down time.

Reduce/increase radiation exposure: This action has the potential to reduce radiation exposure. Current operations involve preliminary NDE examinations during the 48 hour hold time, then final NDE examinations upon expiration of the 48 hour window. This change will minimize or eliminate the need for preliminary NDE, which will directly reduce radiation exposure.

RRA 05-08 Technical Basis Paper
N-638-x, Ambient Temperature Temperbead Welding: Begin 48 Hour Hold After 3rd Layer Completion

Background:

Ambient temperature temperbead welding eliminates elevated-temperature preheat and post-soak when conventional temperbead welding is impractical. Extensive nuclear industry experience continues to demonstrate its viability, safety, and effectiveness.

Historically, temperbead welding rules impose a 48 hour delay between welding completion and final NDE. The 48 hour delay serves solely to provide time for delayed hydrogen cracking before final NDE is performed. Early temperbead welding employed welding processes that were primarily flux-based and were, therefore, known to be susceptible to hydrogen pick-up. The 48 hour delay provided an effective measure of weld safety; necessary because of the moisture inherent in welding fluxes.

N-638 retains the conventional 48 hour NDE delay. N-638, however, excludes flux-based processes; it relies solely on the GTAW machine welding process. This process has been proven, through extensive laboratory testing, to consistently deliver low-hydrogen weld deposits. Testing includes welds deposited in fog chambers ($\approx$95% humidity) using high-moisture argon shield gas, wherein deposits consistently meet "very low" hydrogen criteria (i.e., <1.0 ml/100g H_2). These 'worst case' conditions are far more severe than will be encountered in field applications. Still, test samples demonstrated that the most severe environments achievable yielded hydrogen levels too low to support delayed hydrogen cracking (Ref. EPRI Report GC-111050). Filler wire is another potential hydrogen source; however, the solid bare wire used for GTAW is not considered susceptible to moisture absorption. Test results prove, therefore, that the GTAW environment is essentially impervious to hydrogen from both internal and external sources. The inherently low hydrogen contents of GTAW machine weld deposits, coupled with extensive crack-free industry experience in their application, enables limited relaxation of the mandatory 48 hour NDE delay period.

Description of Change:

This action retains the 48 hour NDE hold, but revises the time at which the 48 hour hold time is initiated. Current rules require hold initiation after weld completion, and after the weldment has cooled to ambient temperature. The proposed change revises hold initiation time such that the 48 hour hold begins immediately after completion of the third weld layer.

Justification for Change:

Industry experts generally accept the inherent low-hydrogen characteristics of GTAW machine welding. These inherently low hydrogen characteristics enable consistently low-hydrogen deposits even when external sources of hydrogen are present during welding. Still, external contaminants may be present during welding, and laboratory conditions cannot effectively simulate every potential hydrogen source. The 48 hour NDE hold is a conservative means of hydrogen assessment, since it evaluates hydrogen's effects, rather than its presence. In so doing, the 48 hour NDE hold evaluates hydrogen introduced through any number of sources, including surface oxides, residues, and other base metal contaminants.

While the potential for external contaminants during temperbead welding cannot be completely ruled out, the extent of these contaminants can be minimized. Regarding surface cleanliness prior to welding, N-638 requires a liquid penetrant examination before weld initiation. As a result, the weld area and adjacent base materials are cleaned to bright, shiny metal. This cleaning removes potential hydrogen sources, and demonstrates substrate soundness, which ensures that external sources of hydrogen are effectively minimized. N-638 further minimizes HAZ exposure to external contaminants by stipulating that only the first weld layer contact the base material(s). The initial weld layer, therefore, constitutes the only weld layer in which unknown surface contaminants may be encountered. All subsequent layers contact only clean, newly deposited weld material. Since the initial weld layer constitutes the primary opportunity for hydrogen ingress to the crack-susceptible coarse-grained heat affected zone, it is reasonable to tie initiation of the 48 hour hold to completion of this layer, instead of to overall weld completion.

Contaminant exposure is one concern; another is welding's proximity to the HAZ. Only welding performed in contact with, or in close proximity to the HAZ has the potential to introduce hydrogen into the hardened HAZ. In temperbead welding, each successive layer provides a progressively decreasing opportunity for HAZ hydrogen introduction, because of each successive layers' decreasing proximity to the HAZ. Only the first weld layer contacts base material, and the second and third layers extend along the full length of this first layer. When these three layers are installed, the HAZ is considered to be effectively tempered. Existing N-638 methodology, therefore, identifies these three layers as an effective, protective barrier between subsequent weld layers and the HAZ. This protective barrier not only insulates the HAZ from additional tempering, but also effectively protects the HAZ from additional hydrogen introduction.

Test data clearly demonstrates that GTAW machine welds installed using N-638 methodology are likely to free of damaging levels of hydrogen be completely free of hydrogen. Nevertheless, let us assume that some external contaminant was not removed from the base metal surface and serves as a hydrogen source. Further, let us assume that the GTAW processes' inherent propensity to protect the weld pool from free hydrogen somehow fails, and hydrogen is introduced into the weld deposit. In this situation, HAZ hydrogen exposure would occur during installation of the first weld layer. This layer, because it is the only layer in direct contact with the base metal contaminants and since it is the only layer that directly contacts the HAZ, is considered to have the greatest potential contribution to hydrogen cracking. For the second and third (tempering) weld layers, the likelihood of additional hydrogen introduction is negligible. For the fourth through final weld layers, the likelihood of introducing additional HAZ hydrogen is virtually nonexistent. Because the proposed change to N-638 is limited to austenitic filler materials, and because austenitic filler materials have a much greater affinity for hydrogen than carbon steel base metals, hydrogen can be assumed to move rapidly away from the HAZ through the austenitic material matrix, further reducing chances of HAZ cracking.

Weldment Temperatures During Ambient Temperature Temperbead Welding:

When conventional GTAW temperbead welding is employed, HAZ hydrogen is mitigated either by imposing a 48 hour NDE delay, or by performing a 450°F to 550 °F post-soak for two hours. Ambient temperature temperbead welding effectively simulates these alternatives during installation of the fourth and subsequent weld layers, as follows:

Water Backed Applications: Ambient temperature temperbead welding is often performed with water backing, wherein the base metal acts as an infinite heat sink during welding. This heat sink contributes to a moderate HAZ temperature, particularly as the fourth and subsequent weld layers are installed. This reduced HAZ temperature effectively enables 'time at ambient temperature' to occur while the fourth and subsequent weld layers are installed. The proposed change enables credit to be taken for this 'time at ambient temperature', even though it occurs while welding is in process.

Non-Water Backed Applications: As ambient temperature temperbead methodology has matured, changes in conventional temperbead welding have occurred. These changes recognize that an elevated temperature post-soak (typically 450°F to 550 °F for 2 hours) accelerates hydrogen dissipation. Current Code rules recognize, therefore, that an elevated temperature post-soak is an effective alternative to the 48 hour NDE delay period (Ref. IWA-4624, 2004 Edition). Ambient temperature temperbead welding may, in some instances, be performed without water backing. In these instances, the 350°F interpass temperature imposed by N-638, combined with the effective heat sink provided by the vessel or nozzle to be welded, typically contributes to low HAZ temperatures during welding. In some instances, however, smaller weldments may experience temperature increases. In these applications, moderate HAZ temperature increases serve to accelerate hydrogen dissipation, reducing the risk of delayed hydrogen cracking. Since hydrogen sources are essentially nonexistent for the second and subsequent layers, this accelerated dissipation effectively mitigates the risk of hydrogen cracking. Hydrogen dissipation is improved when austenitic filler materials are used, as is the case for all welding within the scope of this proposed Action. Hydrogen dissipates much more easily through the austenitic matrix of these filler materials, further reducing the propensity for high hydrogen levels in the hardened carbon steel HAZ.

Both with and without water backing, therefore, ambient temperature temperbead welding contains process controls that effectively moderate adverse hydrogen effects during weld installation. These factors, when considered in light of the inherent low-hydrogen characteristics of GTAW machine weld deposits, help to explain why not a single instance of delayed hydrogen cracking has been identified in any ambient temperature temperbead repair performed to date.

<u>*Summary:*</u>

This action recognizes that welding occurs in a variety of locations, and that sources of external contamination cannot always be completely quantified and/or eliminated. Acknowledging these variables, this action retains the existing 48 hour NDE hold, but enables it to start immediately upon completion of the third weld layer. The proposed change thereby provides an effective method that delays final NDE sufficiently to detect any delayed hydrogen cracking. Concurrently, this action acknowledges the inherently low susceptibility of GTAW ambient temperature temperbead welding to delayed hydrogen cracking. The result is an effective compromise that maintains safety, yet enables application of recognized science to reduce unwarranted costs and schedule delays associated with the existing 48 hour requirement.