Staff Responses to Public Comments on Draft Regulatory Guide DG-1222, "Control of Preheat Temperature for Welding of Low-Alloy Steel" dated June 2009 (Proposed Revision 1 of Regulatory Guide 1.50 dated May 1973)

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Public Comments		NRC Response
NEI-1	The notices requested comments on all of these draft regulatory guides by August 31, 2009. NEI and EPRI are collecting and consolidating industry comments on these draft guides, but it has become apparent that it will not be possible to complete a comprehensive review of all of these documents in the time available, The information contained in these draft guides is important to the industry's work on primary system materials and it is important to carefully evaluate the changes proposed. NEI is therefore requesting a 30-day extension of the public comment period on these draft guides until October 1, 2009, to allow adequate time to complete and document our review.	Extension to October 1, 2009 granted per NRC 7590-01-P dated August 11, 2009 (ML092230530).

Public Comments		NRC Response
NEE-1	Has there been any industry experience of failed welds that would lend to this decision by the NRC to impose a post pre-heat maintenance for a minimum of four hours. There are components may require a 200° preheat but do not require PWHT. Does this rule still apply? The term low-alloy can cover a number of materials. Does the NRC have any specific materials of concern?	Delayed hydrogen-induced cracking in welds is a very well documented phenomenon and is documented in available literature. RG 1.50 recommends that the preheat temperature be maintained until a PWHT has been performed. Over the years, the NRC has received and accepted alternatives, to the above recommendation, to use post weld baking as a means to ensure that cracking does not occur between the completion of welding and PWHT. The staff's intention is to include an alternative to the current recommendation that welds be maintained at the preheat temperature until PWHT is performed. The post weld backing alternative described in DG-1222 is consistent with alternatives approved for various reactor designs reviewed by the NRC. No. RG 1.50 does not apply to those low alloy steel components that are exempt from PWHT by ASME Code. Yes. Please refer to the NRC Response to Comment EPRI-1 below.
W-1	The second sentence of the third paragraph under Procedure Qualification states: "The level of hydrogen in weld filler metal is low enough to preclude adverse effects in the weld, ..." This is not true for all weld filler metals, and further depends on the type of steel being welded. It is suggested this sentence be changed to: "The level of hydrogen in weld filler metal can be low enough to preclude ..... "	The second sentence in the third paragraph under "Procedure Qualification" of Section B, Discussion, of the RG is changed as follows: "The level of hydrogen in weld filler metal may be low enough to preclude adverse effects in the welds…"

Public Comments		NRC Response
W-2	Regulatory Position 2 specifies maintaining preheat until PWHT or a hydrogen bakeout. It is suggested that the remainder of the document be made consistent with this. It is suggested that paragraph 3 of the last sentence under Procedure Qualification be changed to: "Therefore, the minimum preheat temperature should be established to ensure a desirable cooling rate for the weld, and this temperature should be maintained until a post weld heat treatment, or a hydrogen bakeout has been achieved." Also, it is suggested that the last sentence under Production Welds be changed to read: "To ensure that the welds will be acceptable, the metal temperature should be monitored during the welding process and through post weld heat treatment or hydrogen bakeout."	The last sentence in the third paragraph under “Procedure Qualification” of Section B, Discussion, of the RG is changed as follows: “Therefore, the minimum preheat temperature should be established to ensure a desirable cooling rate for the weld, and this temperature should be maintained until a postweld heat treatment or a post weld hydrogen bakeout has been achieved.” The last sentence under “Production Welds” of Section B, Discussion, of the RG is changed as follows: “To ensure that the welds will be acceptable, the metal temperature should be monitored during the welding process and through post weld heat treatment or post weld hydrogen bakeout.”
FPL-1	The concern is with the post-weld preheat maintenance requirement. This is something new and would require a weld program revision at DAEC. Currently this is only applicable to some P#s in B31.1.	The comment has been addressed by a change to Regulatory Position 2 of the RG. Revision 0 of RG 1.50 states the following in Section C, Regulatory Position: “2. For production welds, the preheat temperature should be maintained until a post-weld heat treatment has been performed.” Revision 1 of RG 1.50 allows for a postweld hydrogen bakeout in lieu of maintaining the preheat temperature until final postweld heat treatment. Also, please see the NRC Responses to the DUKE and EPRI comments below.

Public Comments		NRC Response
XEN-1	RG-1.50 should be revised in accordance with the EPRI WRTC (RRAC) efforts and findings in the way of PWHT and pre heat requirements.	Please see the NRC Responses to the EPRI comments below.
DUKE-1	The main change is the inclusion of a post weld hydrogen bakeout and an associated soak time if preheat maintenance is not done. (Assuming a WPS is qualified in accordance with Section IX and Section III as specified by the Reg. Guide) Comments are as follows: Part B, 3rd paragraph) When discussing welding fluxes what welding processes are being discussed?	Any welding process involving a welding flux has the potential to contain moisture in the welding flux. Moisture in the welding flux increases the susceptibility of the weld to hydrogen induced cracking. When discussing welding fluxes, Section B of RG 1.50 applies to any and all welding processes utilizing a welding flux.
DUKE-2	Part B, 3rd paragraph) Are Low hydrogen SMAW electrodes which have been tested to have low levels (H4) of hydrogen and properly controlled before welding included in the description "welding fluxes"?	Yes.

Public Comments		NRC Response
DUKE-3	Part C, item 2.) With proper use of low hydrogen processes and welding filler material, if employed, should negate the need for hydrogen bakeout and soak as the predominant source for hydrogen is controlled to a low level. Please explain why the use of low hydrogen processes and filler materials as one of the main ways to control hydrogen are not discussed as a mitigation technique.	As discussed in Section B, Discussion, of the RG, the level of hydrogen in weld filler metal is low enough to preclude adverse effects in the welds, but greater quantities of hydrogen can be present in the weld region from the dissociation of moisture in hygroscopic welding fluxes or from adsorption on metal surfaces if the welding fluxes and surfaces have not been properly dried before weld deposition. "Using an H8, or even an H4, electrode with controlled diffusible hydrogen alone provides no guarantee of eliminating problems related to hydrogen during or after welding. In addition to the electrode, several other factors can influence the diffusible hydrogen level and the potential for cracking. These should be considered as well: • base metal surface condition (contamination from oils, grease, dirt, moisture, acid, rust and other hydrogen containing materials can increase hydrogen levels); • relative atmospheric humidity (humid conditions generally lead to higher hydrogen levels); • welding shielding gas (higher moisture content results in higher hydrogen levels); • consumable storage conditions (improper or prolonged storage can lead to higher hydrogen levels); • welding procedures (electrical stickout, arc voltage, wire feed speed and other parameters can influence diffusible hydrogen)."[1]

[1] Selecting Filler Metals: Low Hydrogen, Key Concepts in Welding Engineering, R. Scott Funderburk, see http://www.lincolnelectric.com/knowledge/articles/content/fillermetals.asp.

Public Comments		NRC Response
DUKE-4	Part C, item 2.) If PWHT is to be done and low hydrogen processes and/or low hydrogen filler materials used, the associated soak and preheat maintenance should not be required as the small amount of hydrogen will diffuse at the PWHT temperature.	The hydrogen will likely diffuse at the post weld heat treatment (PWHT) temperature. However, the likelihood of hydrogen induced cracking is increased if the minimum preheat temperature is not maintained prior to PWHT.
PGE-1	In Section C2 of the regulatory position, there is only one exception when the preheat temperature doesn't need to be maintained before the final PWHT. That exception is only when a hydrogen bake out is performed. However, in cases where a low hydrogen welding process is used (i.e., GTAW or GMAW with solid wire), there shouldn't be any significant amounts of hydrogen in the weld or HAZ. In these cases, it should be allowed to slowly cool the weld to room temperature prior to the final PWHT. Another example would be in the case where a sufficient weld deposit has been applied (i.e., 3/8" or 25% of the groove is filled) and the weld is allowed to slowly cool to room temperature. In both of the latter cases, if welding has not been completed (due to end of shift), then the welds can be inspected prior to resuming any welding and the required preheat applied.	GTAW and GMAW are generally thought of as producing welds with low levels of diffusible hydrogen. However, factors such as moisture in the shielding gas and contamination of welding surfaces can lead to unacceptable levels of hydrogen in the weld. Also, please see the NRC Responses to the EPRI comments below.
PGE-2	In Section C4, it is not clear whether the weld is acceptable if the soundness is verified by an acceptable examination procedure. This sentence can be reworded for better clarification.	Position 4 of Section C, Regulatory Position, of the RG is changed as follows: "4. If Regulatory Positions 1, 2 and 3 above are not met, the weld is subject to rejection. However, the soundness of the weld may be demonstrated by an acceptable examination procedure meeting the acceptance criteria specified in ASME Code, Section III."

Public Comments		NRC Response
ENT-1	The wording in 2 requires a hydrogen bake out of all CrMo welds for 4 hours.	Regulatory Position 2 states that the preheat temperature should be maintained until final PWHT or a post weld hydrogen bake out has been performed. This does not apply to those low alloy steel components that are exempt from PWHT by ASME Code.
ENT-2	The wording in 4 states if we don't do steps 1-3 we need to an "acceptable" soundness examination. Soundness usually equals volumetric. Since underbead cracking is what is specifically mentioned surface exams are likely out.	Correct.
ENT-3	The real concern is the 4 hour post bake out. We have done a lot of work (EPRI, ASME Code, others) to get unneeded PWHT and post-bake out of our Codes and here it is reintroduced at a lower temperature without any cited value.	Please refer to the NRC Response to Comment NEE-1 above.

Public Comments		NRC Response
EPRI-1	No definition is given for the term "Low-Alloy Steel." The Keys to Metals database defines low alloy steels as follows: "Low-alloy steels constitute a category of ferrous materials that exhibit mechanical properties superior to plain carbon steels as the result of additions of alloying elements such as nickel, chromium, and molybdenum. Total alloy content can range from 2.07% up to levels just below that of stainless steels, which contain a minimum of 10% Cr." For the purpose of ASME Codes therefore, low alloy steels may typically be considered as applying to the materials in P Nos. 3, 4, 5A, 5B, 5C, and 15E. (Note: P No. 15E is a new P No. designation for Grade 91 materials; formerly categorized as P No. 5B, Group 2 prior to the 2009 Addenda to the ASME Codes.) It is suggested that the Draft Regulatory Guide DG-1222 include a definition of low alloy steels as those included in P Nos. 3, 4, 5A, 5B, 5C, and 15E. The P No. 15E is suggested since the 2009 Addenda will likely be issued prior to the issue of Revision 1 to RG 1.50.	Currently operating reactors, approved new reactor designs and new reactor designs currently under review by the NRC use P Nos. 3, 4 and 5A materials in ASME Code Class 1, 2, and 3 components. P Nos. 5B, 5C and 15E materials are not used. The first sentence of Section C, Regulatory Position, of the RG is changed as follows: “Weld fabrication for low-alloy steel (P Nos. 3, 4, and 5A) components should comply with the fabrication requirements specified in Section III and Section IX of the ASME B&PV Code supplemented by the following: …”

Public Comments		NRC Response
EPRI-2	In the 3rd paragraph under "**Procedure Qualifications**" under Section B "**DISCUSSION**", the statement is made that "Prolonged time at the preheating temperature can prevent or interrupt local hardening and assist in reducing the adverse effects of a potential hydrogen gradient." This statement is misleading in that it is technically inaccurate to state that "Prolonged time at the preheating temperature can prevent or interrupt local hardening". Research at EPRI has shown that the local hardening on carbon and low alloy steels can be reduced with the use of the recommended preheat during welding but some hardening will still occur with each welding pass (subsequent welding passes will further reduce the local hardness). The statement however included the information that "Prolonged time at the preheating temperature ... can assist to reduce the adverse effects of a potential hydrogen gradient" which is technically correct. The following revision to the draft proposed sentence is suggested: Section B "**DISCUSSION**", Procedure Qualification, 3rd Paragraph "Prolonged time at the preheating temperature can ~~prevent or interrupt local hardening and~~ assist in reducing the adverse effects of a potential hydrogen gradient. Preheating at the recommended temperatures can also reduce the local hardening by reducing the cooling rate during welding."	The third paragraph under "Procedure Qualification" of Section B, Discussion, of the RG is changed as follows: "… Embrittlement of metal in the weld area as the result of the presence of hydrogen generally occurs at lower temperatures and may be prevented by prolonging the time the weldment is maintained at preheating temperature or by performing a postweld heat treatment. Preheating at the recommended temperatures can reduce the local hardening by reducing the cooling rate during welding. Prolonged time at the preheating temperature can assist in reducing the adverse effects of a potential hydrogen gradient. This gradient would disappear by means of diffusion of the hydrogen before the weldment is returned to room temperature. Therefore, the minimum preheat temperature should be established to ensure a desirable cooling rate for the weld, and this temperature should be maintained until a postweld heat treatment has been achieved."

Public Comments		NRC Response
EPRI-3	The last paragraph under "**Procedure Qualifications**" under Section B "**DISCUSSION**", concerns the specification of an interpass temperature. While it is true that the interpass temperature does potentially affect impact toughness properties, a requirement to apply the specific control of the interpass temperature when toughness is not required to be controlled is often unnecessary and an excessive requirement that will add costs during any welding operation on these materials. The requirements of ASME Section IX, "Welding and Brazing Qualifications" adequately control the interpass temperature by qualification. The rules require the qualified welding procedures thus qualified to be followed when impact toughness is a requirement of the construction code. The following revision to the draft proposed paragraph is suggested: Section B "**DISCUSSION**", Procedure Qualification, Last Paragraph "In addition to the minimum preheat temperature, a maximum interpass temperature must ~~should~~ be specified per the requirements of ASME Section IX if toughness is a requirement of the construction Code or the design. ~~If the weld metal transforms at too high a temperature, the required mechanical properties for the metal may not be met. The maximum interpass temperature varies for different steels, as does the minimum preheat temperature, and~~ For other low alloy steels, a maximum interpass temperature, if required, should be selected on the basis of such influencing factors as the chemical composition of the steel."	The fourth paragraph under "Procedure Qualification" of Section B, Discussion, of the RG is changed as follows: "In addition to the minimum preheat temperature, a maximum interpass temperature must be specified per the requirements of ASME Section IX if toughness is a requirement of the construction Code or the design. For low alloy steel welds not requiring impact testing, a maximum interpass temperature should be selected on the basis of such influencing factors as the chemical composition of the steel."

Public Comments		NRC Response
EPRI-4	Under Section C "**REGULATORY POSITION**", the statement is made in item 1 that "The procedure qualification should require the following:" This is not the purpose of a procedure qualification per the rules of ASME Section IX. The procedure qualification record only provides a documentation of the actual required parameters used during the welding of the qualification coupon and the procedure qualification is an activity rather than a statement of the requirements. To be correct, it is the welding procedure specification (WPS) where the requirements for welding are specified. Under Section C "**REGULATORY POSITION**", the statement is made in 1a that "A minimum preheat and a maximum interpass temperature should be specified." As stated above, a maximum interpass temperature is not always necessary for some low alloy steels. Also, the statement is made in 1b that "The welding procedure should be qualified at the minimum preheat temperature." ASME Section IX, essential variable QW406.1, specifies that the minimum preheat temperature shall be specified in the WPS and that it cannot be decreased more than 55ºC (100ºF) from the preheat temperature qualified. The proposed draft statement could be interpreted as requiring the preheat temperature qualified as the minimum temperature that could be used or specified within the WPS. This could cause increased costs associated with controlling the minor deviations from the target preheat temperature with no appreciable effect on the weld quality. Since this is already covered in ASME Section IX, this statement is not needed.	Please refer to the changes to Position 1 in the response to this comment below. Please refer to the NRC Response to Comment EPRI-3 above. Position 1, Section C, Regulatory Position, of the RG is changed as follows: "1. The Welding Procedure Specification (WPS) should specify a maximum interpass temperature and a minimum preheat temperature that is equal to the minimum preheat temperature and maximum interpass temperature used during procedure qualification

Public Comments		NRC Response
	The following revisions to the draft proposed statements are suggested: <u>Section C “**REGULATORY POSITION**”, Item 1</u> “1. The <u>welding</u> procedure <u>specification (WPS)</u> ~~qualification~~ should <u>specify</u> ~~require the following~~: ~~a.~~ A minimum preheat and a maximum interpass temperature, <u>if required</u> ~~should be specified~~.” ~~b. The welding procedure should be qualified at the minimum preheat temperature.~~”	Please refer to the changes to Position 1 in the response to this comment above.

Public Comments		NRC Response
EPRI-5	Under Section C "**REGULATORY POSITION**", item 2 states: "For production welds, the preheat temperature should be maintained until final postweld heat treatment or a hydrogen bakeout is performed between 200 and 400ºC (400 and 750ºF) for a minimum of four hours after which the component may be slowly cooled to ambient temperature prior to the performance of the final post weld heat treatment. The post weld hydrogen bakeout temperature and soak time should be based on the materials being welded, geometry, and the welding process used." Similarly to the discussion concerning the need for maximum interpass temperature control, there is little need for hydrogen bakeout for many low alloy materials. It is therefore essential that any controls proposed that may require hydrogen bakeout be applied only to those materials which require it in order to reduce the possibility of hydrogen cracking after welding. Applying this rule to materials and welds which do not need it and which maintaining the preheat until the PWHT is performed would be an extraordinary cost due to time and effort with no appreciable benefit. There are many factors which influence the need to perform a hydrogen bakeout at the conclusion of a weld if the preheat is not to be maintained. Included is the hardenability of the material, the thickness, the welding process, the welding technique used (heat input and multiple passes) and the moisture content of the flux (if the process involves a flux). The current Codes provide relatively little restriction based on the imposition of a hydrogen bakeout on low alloy materials. ASME Section III contains nonmandatory preheat rules in Appendix D but there is only a cautionary statement (Para. D-1120) that mentions	Please see the NRC Response to Comment NEE-1 above. In addition, Position 1, Section C, Regulatory Position, of the RG is changed as follows: "2. For production welds, the preheat temperature should be maintained until final postweld heat treatment or a post weld hydrogen bakeout is performed between 200 and 400ºC (400 and 750ºF) for a minimum of four hours after which the component may be slowly cooled to ambient temperature prior to the performance of the final post weld heat treatment. The post weld hydrogen bakeout temperature and soak time should be based on the materials being welded, geometry, and the welding process used."

Public Comments		NRC Response
	the need to consider the effect of reducing the preheat below the stated temperature. More explicit rules exist in ASME B31.1, Para. 131.6.1 where low alloy materials of P Nos. 3, 4, 5A, and 5B are addressed (there are no P No. 5C materials in B31.1 and P No. 15E (now P No. 5B) will not be addressed until the 2009 addenda). The current Para. 131.6 in B31.1 applies to the interruption of welding (preheat) before the welding is completed but the primary concern is the potential for hydrogen cracking once an adequate weld has been deposited for structural purposes. For P Nos. 3, 4, and 5A, the only requirement is that the weld be slowly cooled to room temperature; no intermediate heat treatment is required. For P No. 5B materials, an intermediate heat treatment is required prior to cooling but is not specified other than being adequate. The current B31.1, Para. 131.6.1 is shown as follows: <u>Current B31.1-2007 with 2008 Addenda, Para. 131.6.1:</u> **131.6 Interruption of Welding** **131.6.1** After welding commences, the minimum preheat temperature shall be maintained until any required PWHT is performed on P-Nos. 3, 4, 5A, 5B, and 6, except when all of the following conditions are satisfied. *(A)* A minimum of at least $\frac{3}{8}$ in. thickness of weld is deposited or 25% of the welding groove is filled, whichever is less (the weldment shall be sufficiently supported to prevent overstressing the weld if the weldment is to be moved or otherwise loaded). *(B)* For P-Nos. 3, 4, and 5A (with a chromium content of 3.0% maximum) materials, the weld is allowed to cool slowly to room temperature. *(C)* For P-No. 5B (with a chromium content greater than 3.0%) and P-No. 6 materials, the weld is subjected to an adequate intermediate heat treatment with a controlled rate of cooling. *(D)* After cooling and before welding is resumed, visual examination of the weld shall be performed to assure that no cracks have formed. *(E)* Required preheat shall be applied before welding is resumed.	

Public Comments		NRC Response
	ASME B31.1 has processed a recent change to Para. 131.6.1 that is scheduled for publication in the 2009 addenda to the 2007 edition. The revised Para. 131.6 to be published in the 2009 addenda to ASME B31.1-2007 adds a new Para. 131.6.2 which allows the omission of the intermediate heat treatment for the P No. 5B materials provided the process and electrode moisture content meets certain criteria. The approved change to B31.1, Para. 131.6. is shown as follows: <u>B31.1 Para. 131.6.2 Revision approved for publication in 2009 Addenda.</u> **131.6.2** Intermediate heat treatment for P-5B materials may be omitted entirely when using low-hydrogen electrodes and filler metals classified by the filler metal specification with an optional supplemental diffusible-hydrogen designator of H8 or lower and suitably controlled by maintenance procedures to avoid contamination by hydrogen producing sources. The surface of the base metal prepared for welding shall be free of contaminants. This change reflects the ability to control hydrogen cracking through use of processes that will not introduce excessive levels of diffusible hydrogen into the weld. In Ref. [1], the statement, "The use of a 350 Hv hardness criterion implies a significant tolerance to variations in hydrogen content. Cracking tests show that 350 Hv is a safe level even when using rutile coated electrodes." In Ref. [2], it has been shown that the average maximum hardness in the HAZ of typical multipass welds in P No. 1, 3, 4, and 5A materials is below 350 Hv, even on 1.5 in. thick materials. This discussion reflects the ability to control hydrogen cracking using methods other than the methods that are proposed in the draft regulatory guide, Section C, Item 2. It is therefore suggested that this item be revised as follows:	

Public Comments		NRC Response
	Section C "**REGULATORY POSITION**", Item 2: "For production welds on low alloy materials that are susceptible, the preheat temperature should be maintained until final postweld heat treatment or other process controls should be used to minimize the potential for hydrogen cracking. Controls such as slow cooling, processes with low hydrogen potential, electrodes with low diffusible hydrogen content, welding multiple pass techniques and heat input controls to minimize potential high hardnesses, or a hydrogen bakeout may be used. If needed, the ~~a~~ hydrogen bakeout should be ~~is~~ performed between 200 and 400ºC (400 and 750ºF) for a sufficient time to remove the excess hydrogen, ~~minimum of four hours~~ after which the component may be slowly cooled to ambient temperature prior to the performance of the final post weld heat treatment. The post weld hydrogen bakeout temperature and soak time should be based on the materials being welded, geometry, and the welding process used." REFERENCES [1] Graville, Brian A., *The Principles of Cold Cracking Control in Welds*, p.127, Dominion Bridge Company, Limited, 1975. [2] McGehee, A., Flenner, P., *Investigation of Thickness Limits for Post Weld Heat Treatment (PWHT) Exemption*, Interim Report 1011535, Section 3, Electric Power Research Institute, 2005.	

Public Comments		NRC Response
EXLN-1	Section C, "Regulatory Position" Item 2 states that: "For production welds, the preheat temperature should be maintained until final postweld heat treatment or a hydrogen bakeout is performed between 200 and 400 °C (400 and 750 °F) for a minimum of four hours.... " Exelon considers the minimum "four-hour" period to be excessive for leaner material chemistries, thinner materials, and standard groove weld joint design and high heat input weld processes. Exelon suggests that a graduated scale approach be considered to allow for the variance associated with the factors previously discussed.	Please refer to the NRC Response to Comment EPRI-5 above.