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NRC INSPECTION MANUAL

PART 9900: TECHNICAL GUIDANCE

SGTUBE.TG

MECHANICAL - STEAM GENERATOR PLUGS AND SLEEVING REPAIRS

A. PURPOSE

To provide inspection guidance to NRC resident inspectors, field inspectors or auditors who are assigned the responsibility of reviewing licensee activities on plugging or sleeving repairs of defective steam generator tubing. The review should include a review of measures to control the repair process and licensee's quality assurance activities to ensure that a quality repair is achieved.

B. DEFINITIONS

Steam Generator Plugging Repair - a repair method of defective steam generator tubes that involves a plugging of both ends of the defective tube with Inconel 600 or Inconel 690 metallic plugs. Plugging repairs may involve manual, automatic or kinetic welded techniques which bond the plug to the tube, or mechanical techniques that permanently deform the plug metal to maintain the plugs in position. Plugs may be either leak limiting or leak tight by design.

Steam Generator Sleeving Repair - a repair method of defective steam generator tubes that involves insertion of an Inconel 600 or 690 sleeve into the steam generator tube such that the sleeve covers the defect area. Sleeving repairs may involve welded or brazed techniques which bond the sleeve to the tube inner diameter (ID), or mechanical techniques that result in plastic deformation of the sleeve to maintain the sleeve in position. Sleeves may be either leak limiting or leak tight by design.

C. BACKGROUND

On August 22, 1993, the Duke Power Company shut down the McGuire Unit 1 reactor due to a 185 gpd primary to secondary leak in the "C" steam generator (SG). A subsequent investigation revealed a circumferential crack in a sleeved tube located in the SG hot leg. Further examinations of the sister SGs indicated that there were a number of other weeping sleeves in the SG hot legs of the "A", "B", and "D" SGs.

On January 10, 1994, the Duke Power Company discovered eight plugs inside of the Oconee Unit 3 reactor internals. A visual examination of the Oconee Unit 3 "B" SG indicated that 14 plugs were missing from the SG tubes in which they were installed. An additional 14 plugs in the "B" SG were determined to have a significant amount of boric acid deposits on their surfaces.

D. DISCUSSION

Plant specific Technical Specifications on steam generators typically require, as a minimum, that licensees plug defective SG tubes. These plant specific Technical Specifications, however, normally **DO NOT** address the quality and process control aspects of plugging repairs. However, some editions of the ASME Code, Section XI, do contain requirements for repairs of defective tubes by the welded plugging techniques. The 1980 Edition of Section XI was the first edition to address these techniques and provided criteria for quality control of the welding and plugging activities employed in these techniques. Some of the sub-articles that address these welded plugging processes are delineated in Table 1.

Licensees are allowed to use sleeving as a method of repairing defective tubes after the plant Technical Specifications have been amended to include sleeving as an acceptable method of tube repair. Licensees should submit an amendment request to NRR which refers to the NSSS vendor's Topical Report on the sleeving method. These Topical Reports, however, do not address quality and process control aspects of sleeving repairs. Process controls of sleeving repair methods were first addressed by ASME in the 1989 Addenda to the 1989 Edition of Section XI, and eventually in the 1992 Edition of Section XI.

IWA-4420 is the appropriate subsubarticle which addresses sleeving in the 1992 Edition of Section XI. Table 1 gives the ASME Section XI subsubarticles or paragraphs which specifically address the requirements for sleeving repairs of tubes.

Attachments 1-10 provide some insight on important repair process activities or aspects that need to be controlled in accordance with the Criteria of Appendix B to 10 CFR Part 50 and, if applicable, with provisions in the ASME Code, Section XI. **It is important to note the following concerning Section XI:**

1. **Only editions of Section XI through the 1989 Edition and addenda through the 1988 Addenda have been endorsed by the NRC. The 1989 and 1990 Addenda to the 1989 Edition of Section XI, and the 1992 Edition of Section XI have not been endorsed by the NRC.**

2. **Not all Section XI editions address plugging or sleeving repair methods. The 1980 Edition was the first edition to address repairs of SG tubing by plugging processes. The 1989 and 1990 Addenda to the 1989 Edition (not endorsed) and the 1992 Edition (not endorsed) were the first Editions of Section XI to address repairs of SG tubing by sleeving processes. Furthermore, Section XI is silent with respect to addressing repairs by mechanical plugging processes.**

3. **The ASME rules listed should not necessarily be interpreted as NRC requirements. The ASME rules constitute NRC requirements <u>only if</u> the specific repair process is addressed by one of the editions of Section XI, <u>or if</u> the licensee has committed to use that specific "ENDORSED" edition of Section XI or has applied one of the later "ENDORSED" editions of Section XI which specifically addresses the repair technique.**

Attachment 1 discusses the relevant 10 CFR 50 Appendix B criteria to repairs of steam generator tubing. Attachments 2 - 4 address the ASME Code, Section XI rules considered important when defective SG tubes are to be repaired using welded plugging techniques. Attachments 5 - 9 provide the applicable ASME Code,

Section XI considers as important requirements when sleeving processes are used to repair defective SG tubing.

Attachment 10 addresses process activities that need to be controlled, as required by 10 CFR 50 Appendix B, when repairs to SG tubing are accomplished by mechanical, hydraulic or rolled plugging techniques. It should be noted that Attachment 10 does not list any ASME Code rules, since the ASME Code, Section XI is silent in regard to repairs of SG tubing by mechanical, hydraulic or rolled plugging applications.

E. REFERENCES

1. Attachment 1, Quality Assurance Control

2. Attachment 2, Code Rules for tube Plugging by Manual Welding

3. Attachment 3, Tube Plugging by Explosive Welding

4. Attachment 4, Tube or Tubesheet Hole Plugging by Fusion Welding

5. Attachment 5, Repairs of Defective Steam Generator Tubing by Sleeving, General Sleeving Requirements

6. Attachment 6, Repairs of Defective Steam Generator Tubing by Sleeving, Tube Sleeving by Explosive Welding

7. Attachment 7, Repairs of Defective Steam Generator Tubing by Sleeving, Tube Sleeving by Fusion Welding

8. Attachment 8, Repairs of Defective Steam Generator Tubing by Sleeving, Tube Sleeving by Brazing

9. Attachment 9, Repairs of Defective Steam Generator Tubing by Sleeving, Tube Sleeving by Expansion

10. Attachment 10, Repair of Defective SG Tubing by Mechanical Plugging Techniques

END

TABLE 1

Plugging and Sleeving Techniques Addressed in ASME Section XI.

	1980 Edition	1983 Edition	1986 Edition	1989 Edition	1992 Edition
Plug. Using [1] Manual Welding	IWB-4440	IWB-4440	IWB-4440	IWB-4240 [2]	IWA-4413 [3]
Plug. Using Explosive Weld.	IWB-4450	IWB-4420	IWB-4420	IWB-4220	IWA-4411 [3]
Plug. Using Fusion Welding	---	---	IWB-4430 [4] IWB-4230 [5]	IWB-4230	IWA-4412 [3]
General Sleeving Requirements	---	---	---	IWB-4310 [2]	IWA-4421 [3]
Tube Sleeving by Explosive Welding	---	---	---	IWB-4320 [2]	IWA-4422 [3]
Tube Sleeving by Fusion Welding	---	---	---	IWB-4330 [2]	IWA-4423 [3]
Tube Sleeving by Brazing	---	---	---	IWB-4340 [2]	IWA-4424 [3]
Tube Sleeving by Expansion	---	---	---	IWB-4350 [2]	IWA-4425 [3]

(1) Applicable only to manual welding techniques of plugs welded to tubes of P-Nos. 8, 41, 42, 43, 44, & 45 material classifications, without post-weld heat treatment.
(2) Only covered by the Addenda to the 1989 Edition of Section XI, not the 1989 Edition itself (the 1989 and the 1990 Addenda to the 1989 Edition of Section XI have not been endorsed).
(3) The 1992 Edition of Section XI has not been endorsed by the NRC.
(4) Addressed by Subsubarticle IWB-4430 in the 1986 Addenda to the 1986 Edition of Section XI
(5) Addressed by Subsubarticle IWB-4230 in the 1988 Addenda to the 1986 Edition of Section XI

QUALITY ASSURANCE/CONTROL

The quality assurance requirements of 10 CFR 50, Appendix B shall be applied to all types of repairs to steam generator tubes, because they are repairs to the reactor coolant pressure boundary. The following paragraphs give some insight to some of the Criteria in 10 CFR 50, Appendix B applicable to activities being performed during plugging or sleeving repairs:

1. **Criterion III. DESIGN CONTROL:** Requires that licensees provide measures which ensure that applicable regulatory requirements and design bases, as defined in 50.2 and specified in the license application, for safety-related systems, structures and components (SS&C) are correctly translated into specifications, drawings, instructions, and/or procedures. This criterion requires that the following be done to assure that proper design control is taken into account when plugging or sleeving repairs are performed on defective steam generator tubing:

   a. For repairs to SG tubing which involve sleeving or welded plugging repairs, verify that the design of the sleeves or plugs is consistent with the steam generator design as specified in the FSAR.

   b. For repairs of SG tubing which involve mechanical plugging processes (including rolled plugging techniques), verify that the plugging design exists and is delineated in a controlled, approved document.

   c. Verify that the following important design considerations are included in the plugging design:

      1) Plug (or sleeve), tube and tubesheet materials are compatible with one another, and that for welded repair processes that filler metal materials used in the process are compatible for the process involved.
      2) Proper dimensional consideration is taken in account with respect to the design of plugs or sleeves.
      3) For kinetically welded plugging or sleeving processes, that the process will create sufficient bonding between the plug or sleeve and the tube or tubesheet it is welded to.
      4) For mechanical or rolled plugging or sleeving processes that sufficient strain exists between the plug or sleeve and the tube or tubesheet wall, so that the plug or sleeve will remain in place, as intended, during normal operational, transient and accident conditions.

2. **Criterion V. INSTRUCTION, PROCEDURES AND DRAWINGS:** Requires that activities affecting quality be prescribed by documented instructions, procedures or drawings of a type appropriate to the circumstances of the activity involved, and that performance of these activities be performed in accordance with these instructions, procedures or drawings. **NOTE: The instructions, procedures or drawings shall include appropriate quantitative or qualitative acceptance criteria for determining that repair activities falling under the scope of this Appendix are satisfactorily accomplished.**

3. **Criterion VII. CONTROL OF PURCHASED MATERIAL, EQUIPMENT AND SERVICES:** Requires that measures be established to assure that purchased material, equipment and services conform with criteria in approved procurement

documents. The scope of this Criterion includes requirements for evaluating and selecting sources of vendor products or services, ensuring that objective evidence of quality is furnished by the vendor, inspecting vendor products or services at the vendor source, and examining vendor provided products or services at delivery.

NOTE: It is a requirement that, should SG tube repairs be contracted out to an outside organization, the licensee be responsible for providing adequate QA oversight of the contractors activities, including any QA activities which may be delegated over to the contractor by the licensee.

4. **Criterion IX. CONTROL OF SPECIAL PROCESSES:** Requires that measures be established to assure that special processes, such as welding, heat treatment, or non-destructive testing, are controlled and accomplished by qualified personnel using qualified procedures which incorporate the requirements from applicable codes, standards, specifications, criteria or other special requirements. Inspectors or auditors should take the following things into account when reviewing activities which relate to special processes involved in the plugging or sleeving repairs:

   a. Weld preheats, post-weld heat treatments, stress relief heat treatments, or other heat treatments are sufficiently controlled to ensure that they are appropriate for the materials involved in the process, and applicable over the entire range of yield strengths, tensile strengths or other materials properties which may be allowed to vary (for the material in question) by material specification.

      As an example of improper control of heat treatments, the NRC determined that stress relief heat treatments used in qualifying a Babcock and Wilcox rolled sleeving process did not sufficiently bound the range of yield strengths which varied among the SG tube materials (Inconel 600) when this process was applied at the McGuire Nuclear Station.

   b. Personnel using these processes are adequately trained and qualified in these processes to perform them. This includes qualification and training of rolling operators who employ mechanical (rolled) plugging or sleeving techniques, and qualification of explosive welders who employ kinetic explosion techniques to bond plugs or sleeves to tube or tubesheet surfaces.

   c. Repair procedures which cover these processes (including special mechanical or welded plugging or sleeving processes) are qualified to achieve the repair product desired. These procedures should include a listing of all essential variables and non-essential variables used in these processes, and acceptance criteria for qualification of procedures and personnel using these processes.

   d. Qualification of personnel and procedures involved in welded or mechanical plugging or sleeving processes are qualified on suitable mock-up test assemblies, to the extent practical, which simulate the conditions that will be experienced in the field, and that personnel performing these procedures perform a sufficient number of acceptable test plugs or sleeves.

   e. Acceptance Criteria for qualification of repair procedures and personnel performing the repair process should be verified to be included in the repair procedures.

NOTE that other Appendix B criteria apply to plugging or sleeving repairs of defective steam generator tubes; however, the four criteria listed above appear to be the Appendix B Criteria which relate most directly repair methods covered by the Scope of this document.

END

CODE RULES FOR TUBE PLUGGING BY MANUAL WELDING

1. Code rules for Steam Generator Tube Plugging by Manual Welding Techniques apply only when manual welding techniques are used to join plugs to SG tubes of P-Nos. 8, 41, 42, 43, 44 and 45 material classifications with subjecting the weld metal to post-weld heat treatments.

2. IWB-4441.1 in the 1980, 1983 and 1986 Editions of Section XI and IWB-4241 in the 1989 Edition require that materials conform to the requirements of IWA-4200. IWA-4200 requires that materials shall conform to the requirements of either the original design specification or ASME Code Section III requirements.

3. The ASME Codes, Section XI rules <u>are not</u> silent in regard to requirements for cleaning of base metal prior to any weld repairs. IWB-4441.3 in the 1980, 1983 and 1986 Editions, and IWB-4243 in the 1989 Edition of Section XI require removal of the SG tube surface oxide prior to plugging and welding.

4. Welder or Weld operator performance qualification shall be done in accordance with the general requirements of IWA-4300 and the requirements of IWB-4441.2 in the 1980, 1983 and 1986 Editions of Section XI, or IWB-4242 in the 1989 Edition of Section XI. IWA-4300 requires qualification of welders in accordance with the provisions of the ASME Code, Section IX. IWB-4441.2 and IWB-4242 both require that the welder or weld operator be tested (qualified) under simulated conditions whenever physical conditions arise which interfere with the welders ability to deposit a sound weld and restrict the welders access to the production weld to less than 12 inches (300 mm) in any direction from the joint.

   a. Welder requalification is required whenever significantly different accessibility conditions occur, or whenever any of the essential variables stated in Section IX of the ASME Code (specific to the weld process used) are changed.

5. IWB-4441.3 in the 1980, 1983 and 1986 Editions of Section XI, and IWB-4243 in the 1989 Edition require that the tube plugging operation be performed in accordance with an approved procedure(s) which delineates, as a minimum, the following requirements:

   a. tube plug material, dimensions and material certification requirements,
   b. preparation of the tube-to-tubesheet joint to be plugged, including inspection requirements for the joint and a means for removal of surface oxide from the joint,
   c. preparation (sizing) of the tube I.D. prior to installation, including inspection requirements,
   d. requirements for inserting the plug into position prior to welding, including inspection requirements,
   e. the essential variables for the welding process as delineated in Section IX,
   f. requirements for non-destructive examination of the welds following completion of the welds.

6. IWB-4441.3 in the 1980, 1983 and 1986 Editions of Section XI, and IWB-4243 in the 1989 Edition require that the tube plugging procedures and welders shall be qualified on a minimum of five consecutive acceptable welds deposited on the qualification test assembly, and performed in accordance with welding procedures for the specific welding techniques involved.

7. IWB-4441.3 in the 1980, 1983 and 1986 Editions of Section XI, and IWB-4243 in the 1989 Edition require that the qualification mock-up assembly simulate the access provisions and work conditions for the SG tube to be plugged, including simulating the following aspects of the tube involved:

   a. tube size,
   b. tube spacing,
   c. tube extension beyond the tubesheet,
   d. tube proximity to the side walls as specified in IWB-4441.2(b) in the 1980, 1983 & 1986 Editions, and IWB-4243(b) in the 1989 Edition,
   e. the requirement that the tubesheet thickness of the mock-up assembly be as thick as that of the production tubesheet, except that it need not exceed a thickness of 2 inches (51 mm).

8. IWB-4441.3 in the 1980, 1983 and 1986 Editions of Section XI, and IWB-4243 in the 1989 Edition require a visual examination of the plugging operation (VT-1, VT-2, VT-3, or VT-4) in accordance with IWA-2210 or a surface examination (Magnetic Particle Exam or Liquid Penetrant Exam) in accordance with IWA-2220, as applicable.

9. IWB-4441.3 in the 1980, 1983 and 1986 Editions of Section XI, and IWB-4243 in the 1989 Edition require that any repairs of the welds associated with the plugs be done in accordance with the original tube plugging procedure; thermal cutting as a weld repair mechanism is prohibited by these Paragraphs.

10. The Owner's and repair organization responsibilities shall include, among other responsibilities, oversight of procedure and welder qualification aspects, and maintenance of records indicating tube plugging locations and retention aspects or related quality documentation.

TUBE PLUGGING BY EXPLOSIVE WELDING

1. Explosive welding techniques are not specifically addressed in Section IX of the ASME Code.

2. IWB-4451 in the 1980 Edition, IWB-4421 in the 1983 and 1986 Editions, and IWB-4221 in the 1989 Edition of Section XI require that plugs installed by explosive welding processes be manufactured or fabricated in accordance with the following requirements:

   a. materials used in the fabrication of the plugs be produced in compliance with the requirements of an SA or SB Specification of the ASME Code, Section III or any other material specification permitted by Section XI,
   b. plugs be traceable to a mill test report (1980 Editions of XI) or a certified material test report (1983, 1986, & 1989 Editions of XI) which indicates the material properties and chemistry of the material used for the explosive plug fabrication.

3. **There is a slight difference between the Owner responsibility requirements in the 1980 Edition of Section XI and the later 1983, 1986 and 1989 Editions of Section XI.**

   Paragraph IWB-4452 in the 1980 Edition of Section XI requires that the Owner or Contractor performing the explosive weld be responsible for the following aspects of the plugging process:

   a. overseeing all welding performed by the welding operators,
   b. establishing the procedures and conducting the tests which are required by the IWB-4000 in order to qualify both the welding procedures used in the welding process and the performance of the weld operators who apply the explosive welding technique in accordance with these procedures,
   c. maintaining the qualification records of their explosive procedures and their welding operators on a form similar to the recommended Record of Welding Operator Qualification Tests For Tube Welding by Explosives, as shown in Appendix B to Section XI, including the test results of the qualification tests (1980 Edition only).

   IWB-4455 in the 1980 Edition of Section requires the Owners to maintain (as a minimum) the following records:

      a. procedure utilized for the welding process,
      b. welding procedure qualifications,
      c. welding operator performance qualifications,
      d. material certifications,
      e. location of plugged tubes.

   In later Editions of Section XI, Paragraphs IWB-4421 (1983 & 1986 Editions) and IWB-4221 (1989 Edition) require that the Owner be responsible for the following actions:

   a. maintaining the following records:
      1) procedure utilized for the welding process,
      2) welding procedure qualifications,

3) welding operator performance qualifications,
4) material certifications,
5) location of plugged tubes or holes,
6) results of heat exchanger examinations required by Article IWB-4300,
7) specific tubes or holes plugged by each welding operator,

b. that the records for the procedure and welder qualification include the results of all tests required under IWB-4422 (1983 & 1986 Editions) or IWB-4222 (1989 Edition), and that the qualifications be certified by the repair organization,
c. that Procedure Qualification Records include a description of all essential and non-essential variables as delineated in IWB-4422.1(a) & (b) (1983 and 1986 Editions of Section XI) or IWB-4222.1(a) & (b) (1989 Edition of Section XI).

4. IWB-4452 in the 1980 Edition, IWB-4421 in the 1983 and 1986 Editions, and IWB-4221 for the 1989 Edition require the following of welding operators performing the explosive welding technique:

a. qualification in accordance with the appropriate requirements of Article IWB-4000,
b. weld operators apply the identification mark assigned by the Owner or Contractor on the explosive plug or adjacent to the tube being plugged following the plugging repair.

5. IWB-4453 in the 1980 Edition, IWB-4423 in the 1983 and 1986 Editions and IWB-4223 in the 1989 Edition of Section XI require that the explosive welding procedure delineate all the requirements of the repair cycle including the following as a minimum:

a. safety requirements,
b. tube plug material, dimensions, and certification requirements,
c. essential variables of the explosive welding process,
d. preparation of the plug,
e. detonation of the charge plug,
f. nondestructive examinations.

In addition, the 1983, 1986 and 1989 Editions of Section XI require that the welding procedure delineate the method of verifying that both ends of the same tube or tubesheet bore hole are to be plugged.

6. IWB-4453 in the 1980 Edition, IWB-4422 in the 1983 and 1986 Editions, and IWB-4222.1 in the 1989 Edition of Section XI all require that the explosive welding procedure for plugging be qualified as a new procedure, and be requalified whenever any of the following essential variables for the process are changed:

a. change in the P-No. of any of the materials to be joined,
b. a 10% or more decrease in the nominal design tube wall thickness,
c. a change in the tubesheet hole pattern,
d. a decrease in the proximity of two simultaneously detonated parts,
e. any increase in the number of plugs to be simultaneously detonated,
f. a change in the detail controlling explosive densities and charge-to-mass ratios,
g. a change in the type of explosive,
h. a change of 10% or more in the explosive charge mass,
i. a decrease of 15% or more in the ligament of the tubesheet,

j. deletion of cleaning activities for the tube, plug, or hole contact surfaces, or a change in the cleanliness requirements (including removal of surface oxide requirements) prior to explosive detonation,
k. any change in the nominal plug configuration,
l. a change of 10% or more in the nominal or average clearance, (standoff) between the tube or the hole and the plug.

In addition, IWB-4422 in the 1983 and 1986 Editions, and IWB-4222.1 in the 1989 Edition of Section XI list an additional essential variable for the process:

a. a change of whether or not the tubes had been expanded into contact with the tubesheet in the area where bonding occurs.

Changes to the non-essential variables may be made without the necessity for requalification, provided the explosive welding procedure is amended to show these changes. Non-essential variables for the explosive welding process are as follows:

a. a change in the P-No. of tubesheet metal,
b. a change in the cladding metal on the tubesheet (such as from austenitic stainless steel to a nickel-based alloy or visa versa), where the explosive charge is installed within one tube diameter of the cladding metal,
c. a change in the tube-to-tubesheet seal welding procedure where the explosive charge is installed within one tube diameter of the tube-to-tubesheet seal weld.

7. IWB-4453 in the 1980 Edition, IWB-4422 in the 1983 and 1986 Editions, and IWB-4222.1 in the 1989 Edition of Section XI all require the following of Test Assemblies used for qualification of the explosive welding procedure:

a. that the test assembly simulate the conditions to be used in the production with respect to position, tube hole pattern, and the essential variables used in the explosive welding process,
b. that the test assembly tubesheet thickness shall be as thick as the production tubesheet, with the exception that it isn't required to be any more that 1 inch greater than the length of the explosive plug,
c. that the minimum number of explosive welds required for procedure qualification shall be ten welds made consecutively.

In addition, IWB-4422 in the 1983 and 1986 Editions, and IWB-4222.1 in the 1989 Edition of Section XI require that the test assembly shall also contain cladding or tube-to-tubesheet welds, as applicable, whenever the explosive charge is to be placed less than one tube diameter from either cladding or a tube-to-tubesheet weld.

8. IWB-4453 in 1980 Edition, IWB-4422.1 in the 1983 & 1986 Editions, and IWB-4222.1 in the 1989 Edition of Section XI require the following of test assemblies used for qualification acceptance of the explosive welding procedure.

a. When cladding or tube-to-tubesheet welds are required, such cladding and tube-to-tubesheet welds shall be examined by the liquid penetrant method and shall comply with the acceptance standards of ASME Section III, Article NB-5000.
b. Each plug weld and tube-to-tubesheet weld (where applicable) shall be sectioned longitudinally to reveal four cross-sectional faces, 180

degrees apart (i.e. cut the welded tubes in half longitudinally). After polishing and etching the four faces, each explosive weld joint area shall be metallographically examined at X50 or greater magnification for the length of the explosive bond. The bonding is considered acceptable if there is a minimum of five times the nominal tube wall thickness of continuous bond between the plug and tube or tubesheet on each cross-sectional face. Each tube-to-tubesheet weld shall be considered acceptable if it is free from explosively produced cracks, as determined visually using X10 magnification.

c. Suitable mechanical tests may also be used to add further assurance that the bond length is adequate. Details of any mechanical tests performed should also be included in the Procedure Qualification Report.
d. Ligament distortion caused by explosive welding is unacceptable when the adjacent tube I.D. is reduced below the diameter of the tube plug.
e. The explosive welding procedure shall be considered as qualified if all ten of the required, consecutively made explosive welds are found to be acceptable.

9. IWB-4453 in 1980 Edition, IWB-4422.2 in the 1983 & 1986 Editions, and IWB-4222.2 in the 1989 Edition of Section XI all require the following things for performance qualification of the explosive weld operators.

   a. Tube plugging shall be performed by welding operators who have been qualified in accordance with the requirements listed in b., c., and d. directly below.
   b. Welding operator shall prepare (if applicable), install and detonate consecutively a minimum of five plugs in conformance with an explosive plug welding procedure (WPS, Welding Procedure Specification). Acceptance of these plug welds qualifies the weld operator for welding with all other explosive plug welding procedures.
   c. The five plug welds shall be examined in accordance with the examination requirements for examination of the test assemblies. All five welds must meet these acceptance standards for the performance qualification to be accepted.
   d. Renewal of the weld operator's performance qualification is required when the operator has not used the process within a period of six months or longer, or when there is a specific reason to question his ability to make quality welds per the procedure. Renewal of performance qualification shall be identical to the initial qualification, except that only one tube plug explosive weld need be made.

10. Section XI Article 4000 requires that a final non-destructive visual examination be made of the plug in accordance with IWA-2200, looking for proper installation and correct location of the plugs.

TUBE OR TUBESHEET HOLE PLUGGING BY FUSION WELDING

The 1986 Addenda and the 1988 Addenda to the 1986 Edition of Section XI and the 1989 Edition of Section XI were the only endorsed editions to address these techniques. The techniques apply to manual or machine welding by the Gas Tungsten Arc Welding (GTAW or TIG) or Gas Metal Arc Welding (GMAW) processes. For simplicity, the references to Paragraphs or Subparagraphs in provisions below are taken from the 1988 Addenda to the 1986 Edition of Section XI and the 1989 Edition of Section XI. The ASME requirements in the 1986 Addenda to the 1986 Edition are equivalent, with the exception that the governing Subsubarticle starts with IWB-443X.

1. IWB-4231 states that the following material requirements are applicable to materials used in SG tube plugging processes by fusion welding.

   a. Materials shall be in accordance with the requirements of an SA, SB or SFA Specification of the ASME Code, Section III or any other material specification permitted by Section III. Material produced to a weld filler metal chemistry shall meet the filler metal requirements of NB-2000.
   b. Materials shall be traceable to a Certified Material Test Report (CMTR).

2. IWB-4232 states that the Weld Procedure Specifications (WPSs) and welders or welding operators shall be qualified in accordance with the following requirements.

   a. IWB-4232.1 requires the following things for Procedure Qualification.

      1) Welds shall be made using either GTAW or GMAW; short-circuiting arc GMAW is prohibited as being an allowable method of welding.
      2) The WPS shall list the essential variables of Section XI and the additional essential variables of Paragraph IWB-4232.2.
      3) WPS qualification shall follow the requirements of IWB-4232.3.
      4) A separate qualification of the WPS is required for any change in the P-No. or A-No. of the plug, tube, sleeve or cladding. A separate qualification is also required when the material has no P-No. or A-No. If the plug is welded to the cladding, the cladding shall be considered as the base material.
      5) Any change to an essential variable requires re-qualification of the WPS. A WPS may require the support of more than one Procedure Qualification Record (PQR); alternatively one PQR may support a number of WPSs.

   b. IWB-4232.3 requires that the following be listed as additional Essential Variables for Procedure Qualification:

      1) a change of more than 1/16 of an inch in the extension or recess of either:
         a) the tube relative to the tubesheet, or
         b) the plug relative to the material being joined (tube sleeve or tubesheet - See Figure IWB-4232.1),
      2) a 10% change in the plug thickness at the weld location,
      3) a 10% change in the nominal wall thickness of the tube or sleeve, where the plug is welded to the tube or sleeve,

4) a decrease of 10% or more in the specified width of the ligament between the tube holes when the specified width is less than 3/8 of an inch or three times the specified tube wall thickness, whichever is greater.

c. IWB-4232.3 states that the following items apply to the Test Assembly used in the procedure qualification process.

1) Procedure qualification shall be made on a test assembly that simulates the tube hole pattern with the essential variables of Section IX and IWB-4232 (additional variables listed above). The tubesheet in the test assembly shall be at least as thick as the production tubesheet, but need not exceed two inches.
2) Five consecutive welds of the test assembly shall be examined by a liquid penetrant method in accordance with the requirements of IWA-2200 and NB-5350 (ASME Section III). These welds shall be cross sectioned longitudinally through the center of each plug. The thickness of the assembly may be reduced to facilitate sectioning. One section of each plug shall be polished, etched with a suitable etchant, and visually examined at X10 magnification. The weld throat and minimum leakage path shall not be less than required by the Design Specification. The weld shall be free of cracks and lack of fusion. Porosity shall not reduce the weld throat thickness below that required by the minimum leakage path.

d. IWB-4232.4 states that the following items are required for Performance qualification of welders or weld operators.

1) Test assembly shall be the same as that required for procedure qualification except that the essential variable for performance qualification are as follows:
   a) a change from one welding process to any other welding process or combination of welding processes,
   b) for welders, a change in F-No.,
   c) for welders, the addition of other welding positions,
   d) the addition or deletion of preplaced metal inserts.
2) For welders and weld operators, five consecutive acceptable welds shall be made and examined in accordance with the requirements of IWB-4232.3 (listed above). The performance qualification shall be made in accordance with a WPS that has been qualified in accordance with IWB-4232.3.
3) Welders and weld operators shall be tested under conditions that simulate the access conditions of the weld area in the field. Such simulated conditions shall include radiation protection gear.
4) Retest shall be performed in accordance with Section IX QW-320.
5) Renewal of qualification is required when the welder or weld operator has not performed tube plugging using the process for which he is qualified for 3 months or longer, or when there is a specific reason to question his ability to make quality weld per the WPS. Renewal of qualification shall be identical to the initial qualification, except that only one tube weld is required.

3. IWB-4233 requires that all welding shall be performed be performed in accordance with a written procedure that identifies the sequence of operations for the repair. The procedure shall include the following:

a. the WPS in accordance with IWB-4232,

b. the preparation of the heat exchanger tube or tubesheet hole to be plugged,
c. requirements for inserting the tube into position for welding, including applicable inspection or examination requirements.

4. IWB-4234 requires a final VT-1 visual examination of the heat exchanger tube plugs and welds.

5. IWB-4235 requires the Owner maintain the following records:
   a. WPS,
   b. PQR,
   c. performance qualification records,
   d. CMTR,
   e. locations of plugged tubes or tubesheet holes,
   f. results of examinations required by IWB-4320.

6. IWB-4325 requires that the PQR and performance qualification records include all tests required by IWB-4320 and be certified by the Owner or repair organization. The welder or weld operator performance qualification record shall identify the WPS that was used for qualification.

END

REPAIRS OF DEFECTIVE STEAM GENERATOR TUBING BY SLEEVING (IWA-4420)

Repairs of SG tubes by sleeving processes were first addressed by ASME in the 1989 and 1990 Addenda to the 1989 Edition of Section XI. The 1992 Edition of Section XI also addresses sleeving processes. IWA-4420 is the appropriate Subsubarticle which addresses Heat Exchanger Tube Sleeving in the 1992 Edition of Section XI. The corresponding ASME sleeving requirements in the 1989 and 1990 Addenda to Section XI are found in Subarticle IWB-4300.

IWA-4421, as summarized below, is the Paragraph in the 1992 Edition of Section XI which addresses the General ASME Sleeving requirements which are applicable to all sleeving repair methods. **NOTE: Neither the 1989 or 1990 Addenda to the 1989 Edition of Section XI, nor the 1992 Edition of Section XI, have been endorsed by the NRC.**

General Sleeving Requirements (IWA-4421)

1. The General Requirements for steam generator tube sleeving are found in IWA-4421.

2. IWA-4421.1 requires that repairs of SG tubes by sleeving processes meet the general welding requirements of Subarticle IWA-4200, with the exception that the NPS 1 or less pipe size exemption of IWA-4120, as invoked on the IWA-4200 rules, shall not apply in this case.

3. IWA-4421.2 requires that each sleeving operation be performed in accordance with a sleeving procedure specification (SPS) which delineates, as a minimum, the following:

   a. sleeve and tube materials and dimensions,
   b. requirements for preparation of the tube inside surface prior to insertion of the sleeve, including examination requirements and acceptance criteria,
   c. requirements for inserting the sleeve into position, including examination requirements and acceptance criteria,
   d. the essential and non-essential variables of IWA-4421.3 and the welding or brazing process used,
   e. required sleeve attachment dimensions,
   f. requirements for final examination and acceptance criteria,
   g. the sequence of operations.

4. IWA-4421.3.1 requires qualification of the SPS and requalification of the SPS whenever an essential variable for the sleeving process involved is changed. The SPS need not be requalified for any changes to non-essential variables provided the SPS is amended to show the changes. The following essential variables apply to all sleeving processes:

   a. a change in the P-No. classification of any of the materials being joined, including tube, sleeve, tubesheet, and cladding materials. Materials not having a P-No. classification require a separate qualification,
   b. a change of 10% or more in nominal tube or sleeve design wall thickness in the area of the joint,
   c. deletion of tube cleaning prior to sleeve insertion,

d. a change in sleeve attachment location from within the tubesheet to beyond the tubesheet or vice versa,
e. a change in the sleeve attachment location from within the sludge pile to beyond the sludge pile or vice versa,
f. the addition or deletion of postweld or postbraze heat treatment,
g. a change of more than 10% in the nominal tube or sleeve diameter.

Additional essential variables are listed for the specific sleeving processes addressed later in Subparagraphs IWA-4422, IWA-4423, IWA-4424, and IWA-4425 to Paragraph IWA-4420.

A change in the method of tube cleaning prior to sleeve insertion is a common NON-essential variable to all sleeving processes.

5. IWA-4421.3.2 requires that sleeve attachment processes be performed by welders, brazers, or equipment operators qualified to the following requirements.

   a. Performance qualification shall be done with the appropriate provisions of Subarticle IWA-4400.
   b. Manual performance qualification shall be performed under conditions simulating the restricted access of the production joint.
   c. Renewal of performance qualification is required when the welder, brazer, or equipment operator has not used the process for more than 6 months, or when there is any reason to question his ability to make quality attachments in accordance with the SPS. Renewal of qualifications shall be identical to the initial qualification except that only one sleeve attachment shall be made.

6. IWA-4421.4 requires that if a combination of processes is used for sleeve installation, either at opposite ends of a single sleeve or as a sequence of processes in a single attachment, then IWA-4422, IWA-4423, IWA-4424, or IWA-4425, as applicable, apply to each process used. The SPS shall require that the processes used during production sleeving shall be performed in the same sequence as used during qualification.

7. IWA-4421.5 requires the Owners to maintain the following records:

   a. those required by IWA-6000,
   b. those required by IWA-4900,
   c. the SPS,
   d. procedure qualification for the attachment process,
   e. performance qualification for each welder, brazer, and equipment operator,
   f. locations of all sleeved tubes and sleeves,
   g. results of all required sleeve examinations.

REPAIRS OF DEFECTIVE STEAM GENERATOR TUBING BY SLEEVING (IWA-4420)

Repairs of SG tubes by sleeving processes were first addressed by ASME in the 1989 Addenda to the 1989 Edition of Section XI. The 1992 Edition of Section XI also addresses sleeving processes. IWA-4420 is the appropriate Subsubarticle which addresses Heat Exchanger Tube Sleeving in the 1992 Edition of Section XI. The corresponding ASME sleeving requirements in the 1989 and 1990 Addenda to Section XI are found in Subarticle IWB-4300.

IWA-4422, as summarized below, is the Paragraph in the 1992 Edition of Section XI which addresses the requirements for tube sleeving by explosive welding techniques. **NOTE: 1) Neither the 1989 or 1990 Addenda to the 1989 Edition of Section XI, nor the 1992 Edition of Section XI have been endorsed by the NRC. 2) The ASME requirements of IWA-4422 below are in addition to the General Sleeving Requirements of IWA-4421.**

TUBE SLEEVING BY EXPLOSIVE WELDING (IWA-4422)

1. In addition to the general sleeving requirements of IWA-4421, tube sleeving by explosive welding shall be addressed by the provisions of IWA-4422.1 (general requirements for sleeving by explosive welding), IWA-4422.2 (qualification requirements), IWA-4422.3 (requirements for explosive sleeving SPS), IWA-4422.4 (examination requirements).

2. IWA-4422.2.1 states that the following additional essential variables apply when qualifying explosive sleeving procedures:

   a. a decrease in the distance between the two closest simultaneously detonated charges,
   b. a decrease in the distance between the two closest individually detonated charges,
   c. an increase in the number of sleeves to be simultaneously welded,
   d. a change of 10% or more in the explosive density or charge-to-mass ratio,
   e. a change in the type of explosive,
   f. a change of 10% or more in the explosive charge mass,
   g. for sleeve attachment within the tubesheet, a decrease of 15% or more in the tubesheet ligament,
   h. for sleeve attachment within the tubesheet, a change from a tube that is expanded into contact with the tubesheet in the area of the weld to a tube that is not expanded, or vise versa,
   i. any change in the sleeve design configuration,
   j. a change of 10% or more in the nominal or average clearance (stand-off) between the tube and sleeve.

   NOTE: These additional essential variables are in addition to the General Sleeving essential variables of IWA-4421.

   IWA-4422.2.1 states that the following are common non-essential variables which apply to explosive sleeving applications:

   a. a change in the P-No. of the tubesheet material when the sleeve in not joined to the tubesheet,

b. a change in the tubesheet cladding material when the sleeve is not joined to the cladding and the explosive charge is installed not less than one tube diameter from the cladding,
c. a change in the tube-to-tubesheet joint configuration when the explosive charge is installed not less than one tube diameter from the tube-to-tubesheet seal weld.

3. IWA-4422.2.1 requires that the test assembly with the tubesheet to be at least as thick as the production tubesheet, with the exception that the test assembly need not be more than 1 inch greater than the length of the sleeve attachment. IWA-4422.2.1 also requires that the qualification test assembly shall contain cladding or tube-to-tubesheet welds, as applicable, whenever the explosive charge in the heat exchanger is to be placed less than one tube diameter from cladding or a tube-to-tubesheet weld.

4. IWA-4422.2.1 requires examinations of the test assembly be done in accordance with the following criteria.

   a. Whenever cladding or welds are required to be included in the test assembly, such cladding and tube-to-tubesheet welds shall be examined by the liquid penetrant method and shall comply with the acceptance standards of NB-5350.
   b. Each sleeve and tube-to-tubesheet weld, when applicable, shall be sectioned longitudinally. After polishing and etching two faces of a single half-section, each explosive weld joint area shall be examined at 50X or greater magnification to determine the length of the explosive bond. <u>The bond shall be acceptable if the length of continuous bond between the sleeve and tube on each cross-section face is at least five times the nominal tube wall thickness.</u>
   c. Each tube-to-tubesheet weld shall be examined at 10X or greater magnification. The weld shall be acceptable if it is free from explosively produced cracks.
   d. Ligament distortion caused by explosive welding is unacceptable when the adjacent tube I.D. is reduced below the diameter of the tube sleeve or minimum diameter specified in the SPS, whichever is less. Ligament distortion shall not adversely affect the structural integrity of the tubesheet assembly.
   e. The procedure shall be qualified if five consecutive explosive welds are found to be acceptable.

5. IWA-4422.2.2 requires that all explosive welding be performed by welding operators who have been qualified in accordance with the following requirements.

   a. The weld operator shall prepare, install, and weld a minimum of five sleeve attachments in conformance with an SPS. Acceptance of five acceptable sleeve welds qualifies the weld operator for welding using any other qualified SPS.
   b. The five sleeve welds shall be examined in accordance with and meet the acceptance standards of IWA-4422.2.1(e) (examination requirements for the test assembly).

6. IWA-4422.3 requires that the SPS delineate the requirements of the explosive welding process.

7. IWA-4422.4 requires that the all explosively welded sleeve attachments undergo a final examination to confirm that the attachment is in the correct location and that it conforms to the Design Specification.

REPAIRS OF DEFECTIVE STEAM GENERATOR TUBING BY SLEEVING (IWA-4420)

Repairs of SG tubes by sleeving processes were first addressed by ASME in the 1989 Addenda to the 1989 Edition of Section XI. The 1992 Edition of Section XI also addresses sleeving processes. IWA-4420 is the appropriate Paragraph which addresses Heat Exchanger Tube Sleeving in the 1992 Edition of Section XI. The corresponding ASME sleeving requirements in the 1989 and 1990 Addenda to Section XI are found in the Subarticle IWB-4300.

IWA-4423, as summarized below, is the Paragraph in the 1992 Edition of Section XI which addresses the requirements for tube sleeving by fusion welding. **NOTE: 1) Neither the 1989 or 1990 Addenda to the 1989 Edition of Section XI have been endorsed by the NRC. 2) The requirements of IWA-4423 are in addition to the General Sleeving Requirements of IWA-4421.**

TUBE SLEEVING BY FUSION WELDING (IWA-4423)

1. IWA-4423.1 requires that tube sleeving by a fusion welding process be done in accordance with the requirements of IWA-4423.1.1 through IWA-4423.4.

2. IWA-4423.1.1 requires that any fusion welding only be done using either the gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), or laser beam welding (LBW) process.

3. IWA-4423.2 addresses the requirements for fusion welding qualifications of the procedure and welders and/or weld operators.

   a. IWA-4423.2.1 lists the following as essential variables for the fusion process involved:

      1) for tubesheet sleeves, whenever the ligament thickness between holes is 3/8 inch or less, a reduction in ligament thickness of 10% of the ligament thickness or three times the specified wall thickness, whichever is less,
      2) any change in an essential variable listed for the specific welding process in ASME Section IX, QW-250.

   b. IWA-4423.2.1 requires that the procedure be qualified using a test assembly that simulates the conditions that will be encountered in production with respect to the essential variables.

   c. IWA-4423.2.1 requires that the test assembly tubesheet thickness be at least as thick as the production tubesheet, with the exception that the tubesheet thickness need not be more than 1 inch greater than the length of the sleeve attachment.

   d. IWA-4423.2.1 requires that five consecutive welds be examined by a liquid penetrant method in accordance with the requirements of IWA-2200 and that the welds meet the acceptance standards of ASME Section III, NB-5350.

      1) Welds inaccessible for liquid penetrant examination may be sectioned longitudinally through the center of the sleeve prior to performing the liquid penetrant examination.

2) The five consecutive welds shall be sectioned longitudinally through the center of each sleeve. The thickness of the assembly may be reduced to facilitate sectioning.
3) The two faces of each half-section shall be polished and etched with a suitable etchant, and visually examined at 10X magnification. The weld throat and minimum leakage path shall not be less than that required by the Design Specification. The weld shall be free from cracks and lack of fusion. Porosity shall not reduce the weld throat thickness below the required minimum leakage path.

4. IWA-4423.2.2 requires that all production welding by fusion processes be performed by welders and weld operators that have been qualified in accordance with the criteria below.

   a. The test assembly for performance qualification shall be the same as that used for procedure qualification.
   b. For welders, five consecutive acceptable welds shall be made and examined in accordance with IWA-4423.2.1(d) (examination requirements for the test assembly). For weld operators, one acceptable weld shall be made and examined in accordance with IWA-4423.2.1(d). The performance qualification shall be made in accordance with an SPS that has been qualified in accordance with IWA-4423.2.1.
   c. Welders shall be tested under simulated access conditions. The qualification mock-up test assembly shall effectively simulate the conditions that will be encountered in production with respect to the essential variables.
   d. Retest shall be in accordance with ASME Section IX, QW-250.

5. IWA-4423.3 requires that the SPS delineate all of the requirements for the fusion welding process involved, including the essential variables for the process as delineated in ASME Section IX, QW-250.

6. IWA-4423.4 requires that the welded sleeve attachments be given a final examination to confirm that the attachment is in the correct location and conforms to the requirements of the Design Specification.

REPAIRS OF DEFECTIVE STEAM GENERATOR TUBING BY SLEEVING (IWA-4420)

Repairs of SG tubes by sleeving processes were first addressed by ASME in the 1989 Addenda to the 1989 Edition of Section XI. The 1992 Edition of Section XI also addresses sleeving processes. IWA-4420 is the appropriate Subsubarticle which addresses Heat Exchanger Tube Sleeving in the 1992 Edition of Section XI. The corresponding ASME sleeving requirements in the 1989 and 1990 Addenda to the 1989 Edition of Section XI are found in Subarticle IWB-4300.

IWA-4424, as summarized below, is the Paragraph in the 1992 Edition of Section XI which addresses the requirements for tube sleeving by brazing. **NOTE: 1) Neither the 1989 or 1990 Addenda to the 1989 Edition of Section XI, nor the 1992 Edition of Section XI have been endorsed by the NRC. 2) The requirements of IWA-4424 are in addition to the General Sleeving Requirements of IWA-4421.**

TUBE SLEEVING BY BRAZING (IWA-4424)

1. IWA-4424.1 requires that the requirements of IWA-4424.2, IWA-4424.3 and IWA-4424.4 be met when brazing is used for sleeve attachments.

2. IWA-4424.2 addresses the requirements for procedure qualifications and brazer and braze operator qualifications.

   a. IWA-4424.2.1 requires the procedure to be qualified in accordance with the requirements of ASME Section IX, QB-200, with the exception that the following represents an additional essential variable for the process:
      1) a change in the designed sleeve installation from free tubes to tubes that are locked to the tube support plate.
   b. IWA-4424.2.1 requires that the procedure be qualified using a test assembly that simulates the conditions that will be encountered in production with respect to the essential variables.
   c. IWA-4424.2.1 requires that the test assembly tubesheet thickness be at least as thick as the production tubesheet, with the exception that the tubesheet thickness need not be more than 1 inch greater than the length of the sleeve attachment.
   d. IWA-4424.2.1 requires the following of examination of test assemblies:
      1) each test specimen be examined to confirm that the braze bond area conforms to the requirements of the Design Specification,
      2) the minimum number of braze joints required for procedure qualification be five braze joints made consecutively.
   e. IWA-4424.2.2 requires that each brazer and brazing operator be qualified as required by ASME Section IX, QB-300, and each test specimen shall be examined to confirm that the braze bond area conforms to the requirements of the Design Specification.

3. IWA-4424.3 requires that the SPS delineate all of the requirements of the brazing process, including the variables of ASME Section IX, QB-200.

4. IWA 4424.4 requires that the brazed sleeve attachments be given a final examination to confirm that the attachment is in the correct location and conforms to the requirements of the Design Specification.

REPAIRS OF DEFECTIVE STEAM GENERATOR TUBING BY SLEEVING (IWA-4420)

Repairs of SG tubes by sleeving processes were first addressed by ASME in the 1989 Addenda to the 1989 Edition of Section XI. The 1992 Edition of Section XI also addresses sleeving processes. IWA-4420 is the appropriate Subsubarticle which addresses Heat Exchanger Tube Sleeving in the 1992 Edition of Section XI. The corresponding ASME sleeving requirements in the 1989 and 1990 Addenda to the 1989 Edition of Section XI are found in Subarticle IWB-4300.

IWA-4425 is the Paragraph in the 1992 Edition of Section XI which addresses the requirements for tube sleeving by expansion. **NOTE: 1) Neither the 1989 or 1990 Addenda to the 1989 Edition of Section XI, nor the 1992 Edition of Section XI have been endorsed by the NRC. 2) The requirements of IWA-4425 are in addition to the General Sleeving Requirements of IWA-4421.**

TUBE SLEEVING BY EXPANSION (IWA-4425)

1. IWA-4425.1 states that the rules of IWA-4425 apply when sleeves are expanded against a tube by mechanical, hydraulic or explosive processes so that the sleeve is permanently deformed and the attachment of the sleeve depends upon frictional forces or interference forces at the tube-sleeve interface. IWA-4425.1 requires that the rules of IWA-4425.2, IWA-4425.3 and IWA-4425.4 be met for these processes.

2. IWA-4425.2.1 requires qualification of the expansion procedures in accordance with the following requirements.

   a. IWA-4425.2.1 states that the following as essential variables apply when sleeving is accomplished by expansion techniques:

      1) any change in the basic expansion process is an essential variable,
      2) a change of 10% or more in sleeve material yield strength,
      3) a change in the expansion length,
      4) a change that results in an expansion diameter outside the range of sleeve or tube expansion diameters qualified. The range of sleeve or tube expansion diameters qualified shall be the expansion diameters between the minimum and maximum expansion diameters obtained in qualification tests,
      5) for mechanical expansion:
         a) a reduction in the minimum rolling torque,
         b) a change in the expansion roller geometry,
         c) a reduction in the minimum expansion pressure if expansion is controlled by hydraulic pressure only,
      6) for explosive expansion:
         a) a change in the type of explosive,
         b) a change of 10% or more in the explosive charge mass,
         c) a change of 10% or more in the explosive density or charge-to-mass ratio,
      7) for expansion procedures using a combination of processes, a change in any of the essential variables listed in items 5) or 6), as applicable.

b. IWA-4425.2.1 requires that the procedure be qualified using a test assembly that simulates the conditions that will be encountered in production with respect to the essential variables.
c. IWA-4425.2.1 requires that the test assembly tubesheet thickness be at least as thick as the production tubesheet, with the exception that the tubesheet thickness need not be more than 1 inch greater than the length of the sleeve attachment.
d. IWA-4425.2.1 requires that specimens representing the expanded sleeve attachment to a tube be cyclically (fatigue) tested in accordance with the requirements of ASME Section III, Appendix II. This fatigue test shall demonstrate the adequacy of the sleeve attachment to withstand the specified design loadings without exceeding the specified design leakage limit.

3. IWA-4425.2.2 requires that the expansion operator demonstrate ability to expand sleeve attachments in accordance with the SPS.

4. IWA-4425,2.3 requires that the SPS delineate the requirements for mechanical expansion. These requirements shall conform to the Design Specification.

5. IWA-4425.2.4 requires that any installed expanded sleeve attachments be examined to confirm that the attachment is in the correct location and conforms to the requirements of the Design Specification.

END

REPAIR OF DEFECTIVE SG TUBING BY MECHANICAL PLUGGING TECHNIQUES

1. The ASME Code Section XI is silent as to how Mechanical Plugging Techniques should be applied and controlled in regard to using them for repair of defective SG tubes.
2. 10 CFR 50 Appendix B Criteria should be applied to mechanical plugging processes to ensure that plugs do not disengage from the SG tubes or excessively leak following the plugging process. This includes ensuring that licensee or vendor supplied activities involved in the repair are sufficient to ensure the quality of the repair:

   a. design control including tube, tubesheet, and plug dimensional control, and tube and plug material compatibility and control considerations.
   b. tube and tubesheet preparation aspects prior to plugging, including tube cleanliness considerations.
   c. rolling machine calibration aspects to ensure that rolling machines provide adequate torque prior to any commencement of rolled installation of plugs.
   d. ensuring that installation of plugs is performed in accordance with an approved procedure or instruction which delineates how the installation is to be performed, and which includes all aspects which could affect the quality of the plug:
      1) design aspects,
      2) material considerations,
      3) cleaning considerations,
      4) calibration of equipment,
      5) tube, tubesheet, and plug preparation requirements,
      6) installation instructions,
      7) quality assurance aspects to ensure that installation is performed in accordance desired loading or torquing criteria,
   e. final examination requirements of the plugged tube.

3. Quality assurance activities delegated over to contractors or vendors performing the repairs should be reviewed or audited by the licensee's own quality assurance department to ensure their adequacy.

END