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Graphite Process Equipment Repair • Quality Assurance • Graphite Process Equipment Reliability

I have been directly involved in all aspects of Graphite Process Equipment repairs and maintenance for over 27 years in positions including Graphite Technician, Project Manager, Quality Assurance Manager, President, and General Manager. Over this time I have worked closely with all of the major graphite CPE manufacturers, many chemical producers, and other professionals to repair, maintain, and increase the reliability of a wide range of graphite chemical process equipment. I currently participate in all of the activities listed below.

PROFESSIONAL EXPERIENCE

GRAPHITE MAINTENANCE, INC, Mulberry, FL

President 2006-Present

- Assume Quality Control Manager duties for daily operations.
- Obtained and maintain authorization for use of the "R" stamp for graphite repairs from the NBIC. GMI is the only independent (non-OEM) "R" stamp holder for Graphite repairs.
- Coordinate Shop and Field operations to provide the highest level of comprehensive graphite heat exchanger maintenance and repair available.
- Evaluate failed graphite heat exchangers to determine possible and likely cause of failure and available material and design changes for increased productivity and reliability.

Vice President 1997-2006

- Managed and operated full capacity graphite heat exchanger repair facilities in Florida and Louisiana.
- Developed a robust preventative maintenance program for Phosphoric Acid Evaporators.
- Developed a robust standard for rebuilding Phosphoric Acid Evaporators.
- Implemented preventative maintenance programs and rebuild standards for the Phosphate Industry that resulted in a 420% plus increase in heat exchanger reliability and over 30% increase in productivity.
- Track failure modes, repairs, parts, and other historical data for customers equipment.

Project Manager 1995-1997

- Managed all aspects of rebuilds of graphite heat exchangers.
- Developed a Quality Control Program for graphite repairs.
- Worked with multiple graphite OEM's in designing and/or assembling new graphite heat exchangers.
- Provided evaluations and worked with customers to develop job scopes based on available options and customer requirements.
- Worked closely with major Graphite CPE Manufacturers, Chemical Manufacturers, and industry professionals to develop the highest rebuild standards and practices in the industry.

Continued…

- Began working with various committees established by end users of graphite heat exchangers to identify and resolve reliability and production problems with their equipment.

Graphite Technician 1988-1995

- Performed all tasks involved in repairing graphite heat exchangers.
- Participated in complete disassembly, inspection, and reassembly of various types of graphite heat exchangers including cylindrical block, cubic block, and tube and shell.
- Lead field service crews in a wide variety of chemical plants. Field service included inspections, troubleshooting, repairs and rebuilds of all types of graphite CPE.
- Participated in developing rebuild standards and best practices for TexasGulf's Aurora, NC operation.

GULF COAST GRAPHITE SERVICES, LLC. PORT ALLEN, LA

General Manager May 2016-Present

- Obtain tooling, equipments, and property necessary to operate a full service graphite repair shop.
- Develop job scopes, plan, and estimate repairs.
- Develop and implement repair procedures.
- Develop a Quality Control program for graphite repairs.

Education

84 hours, Agriculture
SANTA FE COLLEGE – Gainesville, Florida

S3.5.5 PLUGGING OF LEAKING OR DAMAGED TUBES

a) The material used for plugging tubes shall comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

b) The point(s) of leakage shall be verified, and the corresponding leak site(s) shall be marked/labeled on the tubesheet, and recorded.

c) A minimum of two (2) graphite plugs, each with a minimum length of 1 in. (25 mm), shall be used to plug each end of the tube(s) in question. This represents a minimum total of four (4) plugs per tube.

d) The tube(s) shall be prepared for plugging by enlarging the inside of the tube(s) with a suitable drill bit or reamer.

   1) To ensure a sound cement joint between the tube sidewall and the plug, a slightly smaller diameter plug shall be selected. The maximum clearance between the tube inside diameter and the outside diameter of the plug shall not exceed 3/32 in. (2.4 mm).

   2) As an alternative to d)1) a mandrel with an abrasive, such as sandpaper, may be used, as long as the maximum tube I.D. to plug O.D. clearance of 3/32 in. (2.4 mm) is not exceeded.

   3) The minimum plug insertion depth of the prepared hole(s) shall meet the minimum combined plug length requirements of “c”. When the minimum plug length of “c” is exceeded, the total insertion depth of the plugs may exceed the combined length of the plugs; however, the longer plugs shall not project outside the face of the tube(s) being plugged.

e) Plugging of leaking or damaged tubes shall be performed by certified cementing technicians, using qualified cementing procedures, in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

f) The cement shall be prepared per the cement manufacturer’s instructions.

g) When cementing the plugs, 100% of individual plugs, as well as the inside diameter of the tube opening(s), shall be coated with cement. The plugs shall then be inserted one by one, against each other, into each end of the tube(s) being plugged.

h) Once the plugging is completed, and before the cement cures, the endplugs may need to be held in place, as newly cemented plugs may exhibit a tendency to dislodge from the plugged tube(s) prior to final curing of the cement.

i) Curing time is dependent upon the cement manufacturer’s instructions, and is considered complete when the cement is hardened to the point that it cannot be indented with pressure from a flat screwdriver or other similar instrument.

j) After the cement is completely cured, the plugged, cemented area(s) on the tubesheet face may be dressed with sandpaper or other suitable abrasive.

k) Repaired tubes shall be tested in accordance with this code, using a method acceptable to the Inspector, with a written procedure as approved by the manufacturer’s internal quality system, to ensure leaks have been repaired.

l) The scope of the work completed shall be described and reported on a Form R-1.

S3.5.6 TUBE REPLACEMENT (15)

Tube replacement should be performed with the unit preferably in the horizontal position. Avoid replacing adjacent tubes simultaneously because the replacement areas may overlap or reduce the ligament between

holes and possibly damage the tubesheet. The general steps used in horizontal tube replacement follow below.

a) The material used for tube replacement shall comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

b) Tube replacement shall be performed by qualified cementing technicians, using qualified cementing procedures, in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG-79~~(b), (c),~~ and UIG-80~~(b)~~.

c) Determine the thickness of each tubesheet and inside distance between the tubesheets to obtain tube and sleeve length.

d) Access each tubesheet face, clearly identify and mark each tube hole on each tubesheet of the tubes to be replaced.

e) Prepare/clean the existing tube hole in preparation for extracting the damaged tube. Some holes may contain plugs which require removal. A boring tool slightly larger than the outside diameter of the tube being replaced is required.

f) Drill/bore out the tube hole in each tubesheet to release the tube from the tubesheet. Exercise caution when centering and align cutting to the common axis of the tube.

g) The damaged tube should disengage and become loose. Using guides, remove the damaged tube. Ensure that no debris is trapped in the space where the tube was removed (Fig. S3.5.6-a).

h) Replacement tube shall have sleeves at the ends cemented in the bored holes to replace the material in the tubesheet that was bored out to access the damaged tube (Fig. S3.5.6-b and S3.5.6-c).

   1) Dry-fit a new tube and sleeve.

   2) The sleeve length may vary.

   3) Prior to applying cement, prepare and clean all surfaces to be cemented.

i) Cement the ID of the prepared bore in the floating tubesheet and the tube end OD at the fixed tubesheet. (Fig. S3.5.6-b).

j) Insert the tube through the fixed tubesheet and through the floating tubesheet cemented bore so that it protrudes. Cement the ID of the fixed tubesheet bore as shown in (Fig. S3.5.6-c). The use of alignment dowels can assist/guide in tube handling.

k) Cement the OD of the tube end protruding from the floating tubesheet. Cement the ID of the mating sleeve end, fit it to the cemented tube end and push the assembly part-way into the floating tubesheet. Cement the remainder of the OD of the floating tube end sleeve. Push this cemented assembly the rest of the way into the floating tubesheet (Fig S3.5.6-c).

l) Cement the ID and OD of the sleeve for the fixed tubesheet and insert it until it mates with the tube end inside. Push together cemented tube/sleeve assemblies. (Fig S3.5.6-d). Clean/wipe away any excess cement.

m) Apply slight pressure on the sleeves to seat the joints. Remove excess cement.

n) Maintain pressure and cure both ends of the cemented assembly according to the cement manufacturer's instructions.

o) Sleeves may be trimmed after curing.

SUPPLEMENT 3
INSPECTION OF GRAPHITE PRESSURE EQUIPMENT

S3.1 SCOPE

a) The purpose of this supplement is to provide requirements for inservice inspection of pressure equipment manufactured from impervious graphite materials.

b) The impervious graphite (carbon, graphite, or graphite compound) used for the construction of graphite pressure vessels is a composite material, consisting of “raw” carbon or graphite that is impregnated with a resin using a tightly controlled pressure/heat cycle(s). The interaction between the raw material and the resin is the determining factor when considering the design characteristics of the material. The design characteristics include the strengths (flexural, compressive, and tensile), permeability, co-efficient of thermal expansion, thermal conductivity, and ultimately, the safe operating life of the vessel.

c) The process used in the manufacturing of the raw material is well documented. The expertise developed in this field allows for many different grades to be manufactured to meet the specific needs of various industries, including corrosive chemical-processing pressure vessels. In the chemical processing industry the properties of the raw material are dictated by the manufacturer of the impregnated material, based on the pressure/temperature cycle and the type of resin used for impregnation. The raw material requirements are defined and communicated to the manufacturer of the raw material. The cycle and resin type may vary from manufacturer to manufacturer, and also for each “grade” of impregnated material a manufacturer produces.

d) After over a century of experience with graphite pressure equipment, the essential variables of the process have been defined and apply universally to all manufacturers of impervious graphite equipment. Therefore, by requiring the essential variables of the resin impregnation cycle to be identified and verified, it is possible to assign a “lot” number to all certified materials at completion of the resin impregnation process. This can be done with the assurance of meaningful and consistent test results.

S3.2 APPLICATION

Due to inherent resistance to chemical attack, graphite pressure equipment is often used in corrosive applications, which may include lethal service.

S3.3 OPERATIONS

The owner should maintain controlled conditions for use of graphite pressure equipment, including the use of temperature and pressure recorders and/or operating logs. The owner should maintain operating procedures, and ensure that pressure and temperature are controlled. A thermal or pressure spike may damage the graphite or metal components.

S3.4 INSERVICE INSPECTION

a) The guidelines provided in NBIC Part 2, Section 1 shall apply to graphite pressure equipment, except as modified herein.

b) Graphite pressure vessels, pressure parts, and vessel components should receive an external visual examination biennially. All accessible surfaces should be chemically cleaned. Cleaning fluids containing strong oxidants should not be used.

c) Typical indicators that should necessitate graphite pressure equipment inspection, evaluation, and repair include:

1) Cross-contamination of either process or service fluids;

2) Obeservation of external leaking;

3) Observation of reduced rate or excessive pressure drop; and

4) Reduction of heat-transfer performance.

d) Cracks, bulges, blisters, delaminations, spalling conditions, and excessive erosion are cause for repair or replacement. Any surface discoloration should be recleaned and examined more closely to determine if a delamination or spalling condition exists.

e) Other typical discontinuities include chipping, erosion, baffle cutting due to vibration, and cement deterioration. All passageways are susceptible to fouling.

SUPPLEMENT 3
REPAIR AND ALTERATION OF GRAPHITE PRESSURE EQUIPMENT

S3.1 SCOPE

Repairs to graphite pressure equipment require the use of certified impregnated graphite and cement. The determining factor in establishing the desired material properties is the resin impregnation cycle. If the resin impregnation cycle is not controlled, it is not possible to meet the minimum design values.

S3.2 REPAIRS

The requirements provided in this supplement shall apply, insofar as they are applicable to graphite pressure equipment. Graphite specific requirements include:

a) Organizations performing repairs shall be accredited as described in NBIC Part 3, 1.6 as appropriate for the scope of work to be performed.

b) When the standard governing the original construction is not the ASME Code, repairs or alterations shall conform to the edition of the original construction standard or specification most applicable to the work. Where the original code of construction is unknown, the edition and addenda of the ASME Code most appropriate for the work shall be used, provided the "R" Certificate Holder has the concurrence of the Inspector and the Jurisdiction where the pressure-retaining item is installed.

c) The materials used in making repairs or alterations shall conform to the requirements of the original code of construction except as provided in NBIC Part 3, S3.2 j). The "R" Certificate Holder is responsible for verifying identification of existing materials from original data, drawings, or unit records and identification of the materials to be installed.

d) When ASME is the original code of construction, replacement parts subject to internal or external pressure, which require shop inspection by an Authorized Inspector, shall be fabricated by an organization having an appropriate ASME *Certificate of Authorization*. The item shall be inspected and stamped as required by the applicable section of the ASME Code. A completed ASME *Manufacturer's Partial Data Report* shall be supplied by the manufacturer. Further, all impregnated graphite material subject to internal or external pressure shall be fabricated by an organization having the appropriate ASME *Certificate of Authorization*. The impregnated graphite material shall be inspected and stamped as required by the applicable section of the ASME Code. A completed ASME *Manufacturer's Partial Data Report* with supplementary U1B shall be supplied by the impregnated graphite material manufacturer.

e) When the original code of construction is other than ASME, replacement parts subject to internal or external pressure shall be manufactured by an organization certified as required by the original code of construction. The item shall be inspected and stamped as required by the original code of construction. Certification to the original code of construction as required by the original code of construction or equivalent shall be supplied with the item. When this is not possible or practicable, the organization fabricating the part may have a National Board *Certificate of Authorization*; replacement parts shall be documented on Form R-3 and the "R" Symbol Stamp applied as described in NBIC Part 3, Section 5.

f) Organizations performing repairs under an "R" stamp program shall register such repairs with the National Board.

g) Before signing the appropriate NBIC Form, the Inspector shall review the drawings, witness any required pressure test, ensure that the required nondestructive examinations have been performed satisfactorily, and that the other functions necessary to ensure compliance with the requirement of this code have been performed.

h) Pressure-retaining items repaired in accordance with the NBIC shall be marked as required by NBIC Part 3, Section 5. The letter "G" shall be applied to the nameplate under the "R" stamp when graphite repairs are made. The alternate procedure defined in NBIC Part 3, 5.10 may be used in lieu of the stamping and nameplate attachment requirements of NBIC Part 3, Section 5.

i) Legible copies of the completed Form R-1, together with attachments, shall be distributed to the owner or user, the Inspector, the Jurisdiction if required, and the Authorized Inspection Agency responsible for inservice inspection. Form R-1 shall be registered with the National Board. Distribution of Form R-1 and attachments shall be the responsibility of the organization performing the repair.

j) Graphite parts that have previously been in service in one pressure vessel should not be used in a second vessel without prior approval of the owner. Consideration should be given to the service condition of the previous process and possible contamination of the subsequent process.

k) Blind cracks and delaminations may not be repaired by cement injection only.

l) Cracks and porosity in tubes may not be repaired. Cracked and porous sections may be removed so that the remainder of the tube may be used. Individual tube sections shall not be less than 24 in. (610 mm) in length, and the number of segments in a tube shall not exceed the quantity listed in NBIC Part 3, Table S3.2.

TABLE S3.2

PERMITTED QUANTITY OF TUBE SEGMENTS

Total Tube Length, ft. (m)	Number of Tube Segments	Number of Joints
6 (1.8)	1	0
9 (2.7)	2	1
12 (3.7)	3	2
14 (4.3)	3	2
16 (4.9)	4	3
18 (5.5)	4	3
20 (6.1)	4	3
22 (6.7)	4	3
24 (7.3)	5	4
27 (8.2)	5	4

m) Cementing procedure specifications shall be qualified by the repair organization. The specifications shall be qualified as required by the code of construction. Cementing procedure qualification shall be verified by the Inspector.

n) Cementing technicians shall be qualified by the repair organization. The technicians shall be qualified as required by the code of construction. A cementing technician is any individual who is responsible for proper joint preparation, cleaning parts to be joined, mixing cement, applying cement, securing the joint during the curing process, and controlling the curing process.

o) All records shall be made available to the Inspector.

p) Completed repairs shall be subjected to a pressure test. The test pressure shall not be less than the maximum allowable working pressure or twice the operating pressure, whichever is lower. The test pressure shall be maintained for 30 minutes.

q) Reimpregnation may be used to reduce porosity in an existing graphite component, which will improve the existing graphite component's performance and expected life. Reimpregnation of graphite shall not be considered a means to restore original strength, nor shall it be considered a means to restore the original depth of impregnation.

S3.3 REPAIRS OF A ROUTINE NATURE

a) The following repairs shall be considered routine, and shall comply with NBIC Part 3, 3.3.2.

1) Machining — routine repair shall not include the machining of pressure-retaining parts with the exception of minor machining for cleaning and joint preparation not to exceed 1/32 in. (0.8 mm) of material thickness.

2) Repair of Gasket Surfaces — re-machining of gasket surfaces, re-serrating, or flattening is permitted if the design thickness is maintained.

3) Replacing Individual Tubes — drilling out and replacing tubes with new tubes or repaired tubes. Only certified materials shall be used for this repair.

4) Nozzle Replacement — replacement of nozzles by removing the old nozzle and cementing a new nozzle in place. This is applicable for nozzles with inside diameters not exceeding 18 in. (460 mm).

5) Plugging Tubes — plugging individual tubes using accepted procedures.

6) Surface Repair — surface repair by installation of plugs or inlay material shall not exceed 1 cu. in. (16 cu. cm) of total volume.

7) Replacement or Addition of Non-Load Bearing Attachments to Pressure-Retaining Item — For attachment of non-load bearing attachments to pressure-retaining items, the cementing procedure specification need only be qualified for the pressure part and cement to be used.

b) Complete records of these routine repairs shall be kept for review by the Inspector. The records shall include the number of tubes replaced or plugged and their location within the tube bundle.

S3.4 ALTERATIONS

a) The requirements provided in this section shall apply, insofar as they are applicable to the materials discussed herein. Completed alterations shall be subjected to a pressure test not less than that required by the code of construction. The test pressure shall be maintained for a minimum of 30 minutes. The pressure shall be reduced to MAWP and maintained for inspection.

b) The nameplate shall be applied in accordance with Section 5 of this part. The letter "G" shall be applied to the nameplate under the "R" stamp when graphite alterations are made. The alternate procedure defined in 5.10 may be used in lieu of the stamping and nameplate attachment requirements of NBIC Part 3, Section 5 .

c) Organizations performing alterations under an "R" stamp program shall register such alterations with the National Board.

S3.5 REPAIR GUIDE FOR IMPERVIOUS GRAPHITE

S3.5.1 INTRODUCTION

a) This section is intended to provide suggested process and technique details for repairs. This section should be used as a guide by the repair organization in developing specific repair procedures.

b) Damage to domes (heads), tubesheets, or nozzles is invariably a sign of improper installation, operation, or maintenance. Because such damage is random in nature, each case must be analyzed separately to determine the appropriate repair procedure, and the economics of repair versus replacement.

c) Impervious graphite is a machinable material. Parts can be modified or repaired in the field, or in a repair shop.

d) Machining operations may be handled with high-speed steel tools. Extensive machining requires tungsten carbide or diamond tooling. No cooling or flushing fluid is required, nor should either be used.

e) Cleanliness is important. Dusty, dirty, and chemically contaminated surfaces prevent proper cement adhesion. Poor cement adhesion will result in a low strength joint or a joint which leaks. All surfaces should be neutralized to a pH of 7. Graphite parts should be cleaned and washed with acetone to remove all moisture.

f) All damage should be examined and evaluated to determine the cause. Identification and elimination of the cause is essential in helping to prevent a recurrence.

g) A hydrophilic solvent wash on the surface of the damaged part is useful in identifying the full extent of the cracks. The hydrophilic solvent will quickly evaporate from the surface, leaving the cracks damp and clearly visible.

FIGURE S3.5.1-a
TYPICAL TUBE-TUBESHEET JOINTS

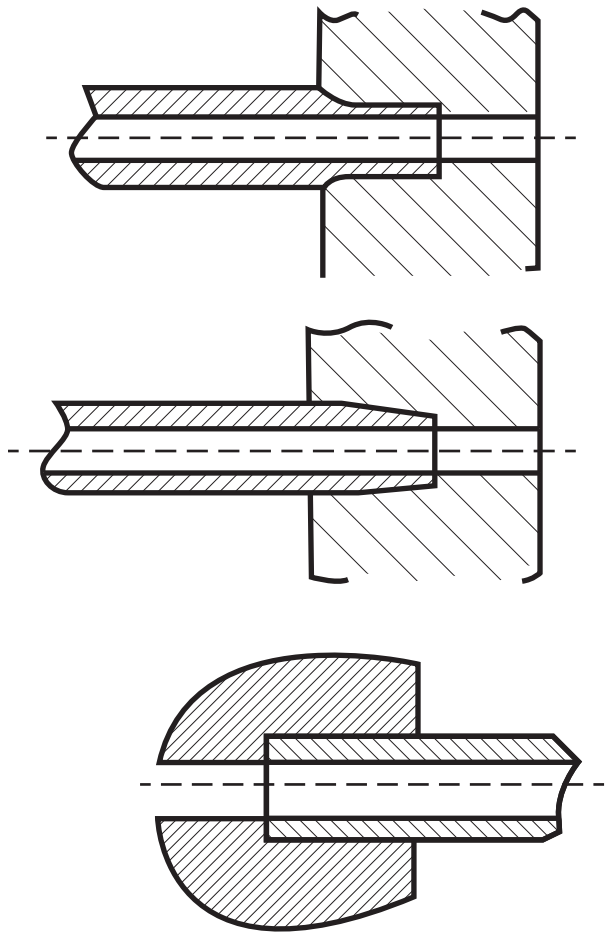


FIGURE S3.5.1-b

TYPICAL TUBE REPLACEMENT USING SLEEVE AND INSERT AT TUBESHEET JOINT

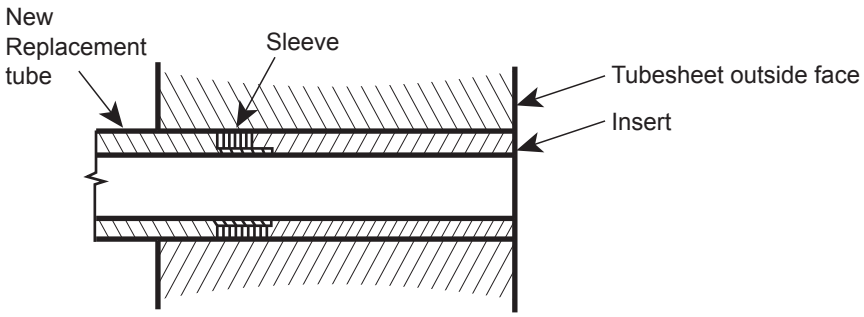


FIGURE S3.5.1-c

TYPICAL TUBE REPLACEMENT USING SLEEVE AT TUBESHEET JOINT

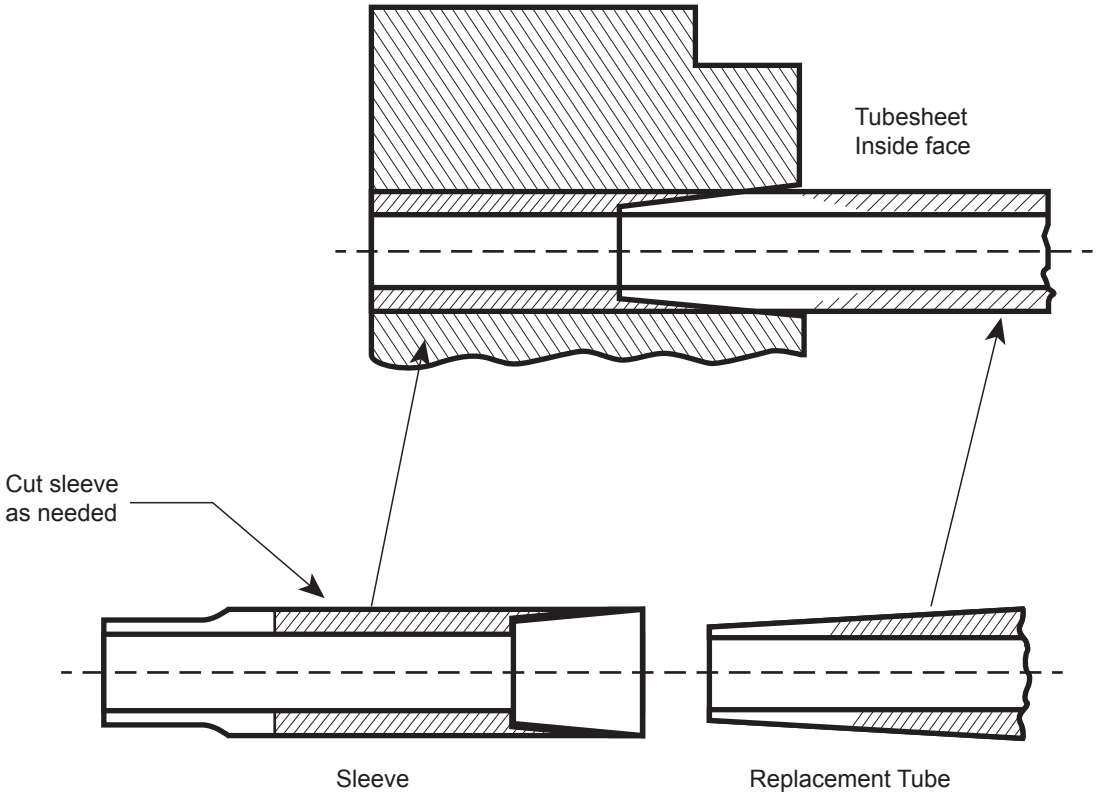


FIGURE S3.5.1-d
TYPICAL TUBE-TUBE JOINT

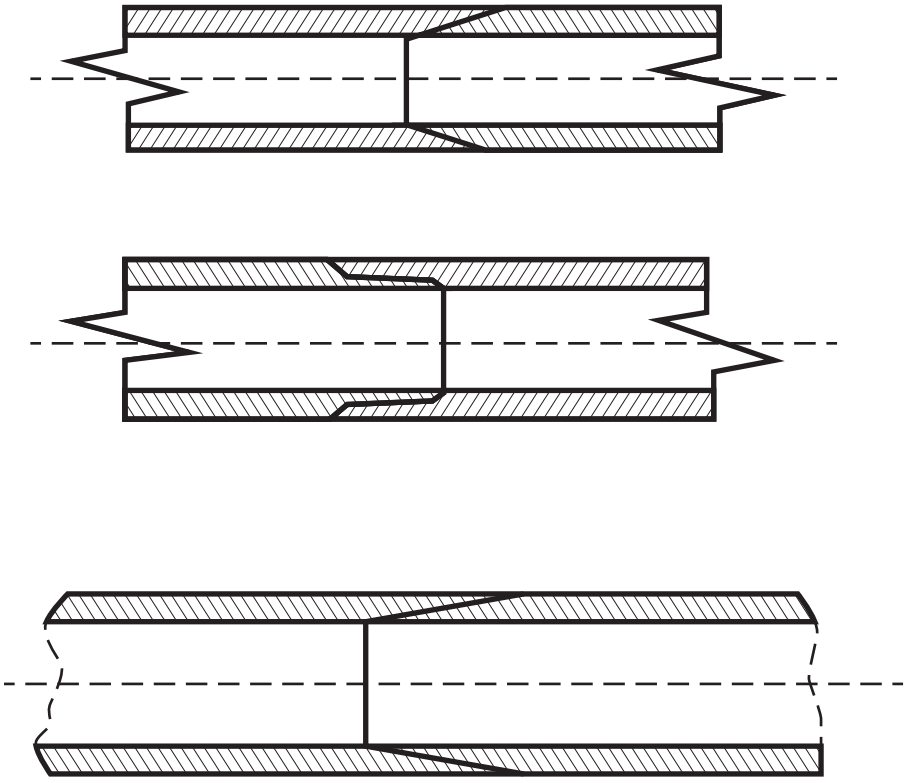


FIGURE S3.5.1-e
TYPICAL EDGE REPAIR MATERIAL INLAY

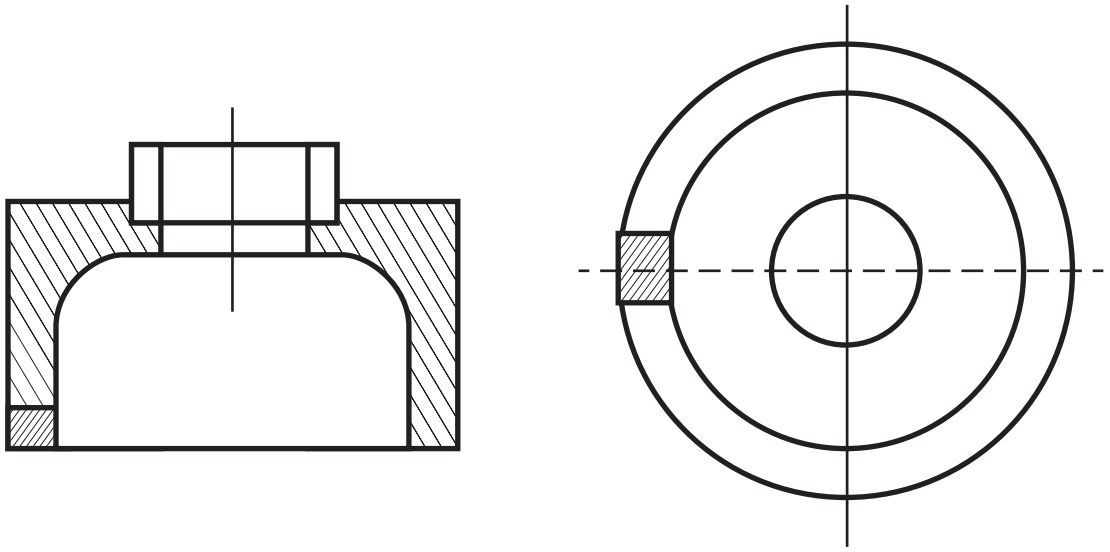
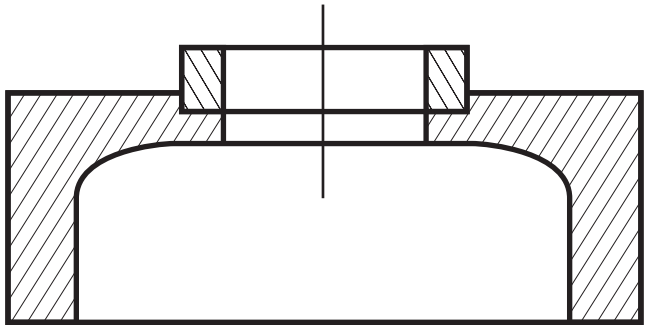


FIGURE S3.5.1-f
TYPICAL NOZZLE CONNECTION

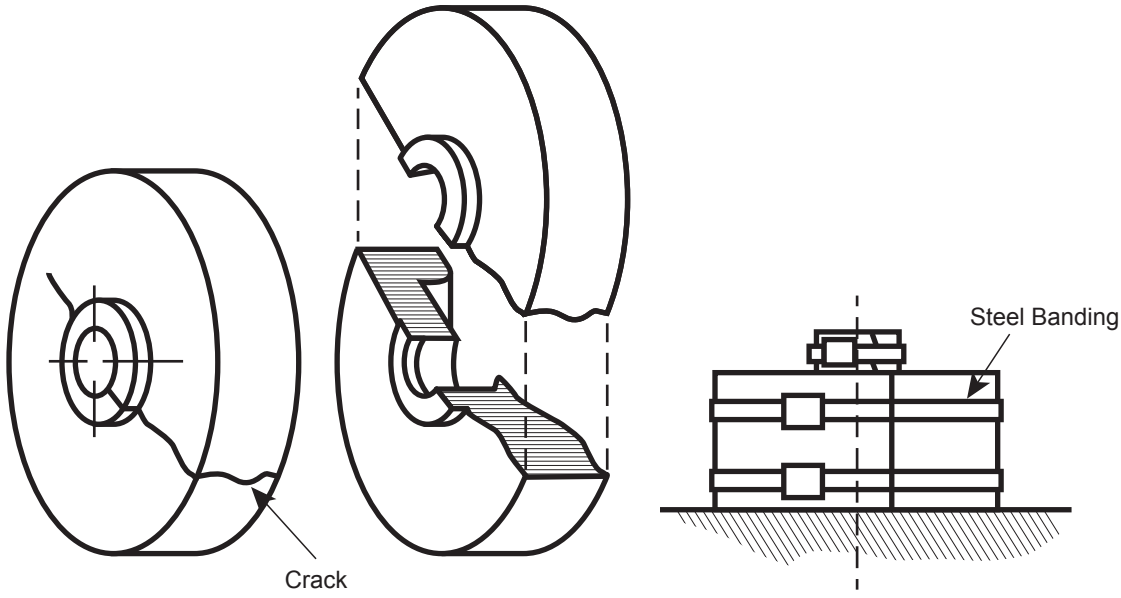


S3.5.2 TYPICAL GRAPHITE FRACTURES

S3.5.2.1 MAJOR FRACTURE

An extensive fracture, such as shown in NBIC Part 3, Figure S3.5.2.1, is best repaired by completing the break and re-cementing the two pieces. Temporary steel banding around the circumference is a method of clamping the repair until the cement is cured.

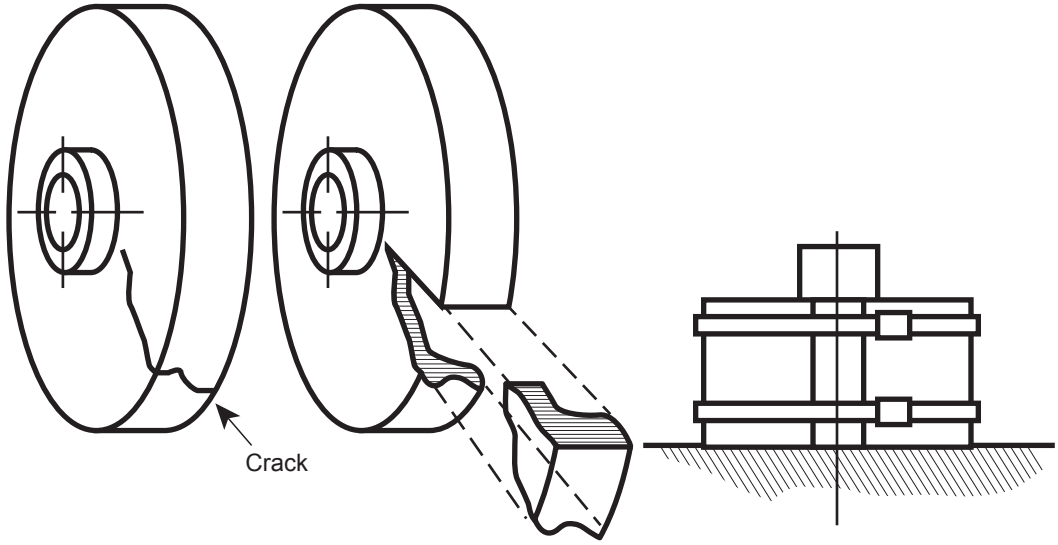
FIGURE S3.5.2.1
EXAMPLE OF EXTENSIVE FRACTURE REPAIR



S3.5.2.2 INTERMEDIATE FRACTURE

If the break is too minor to warrant completing the fracture, a pie-shaped cut may be made and the segment re-cemented in place. (See NBIC Part 3, Figure S3.5.2.2).

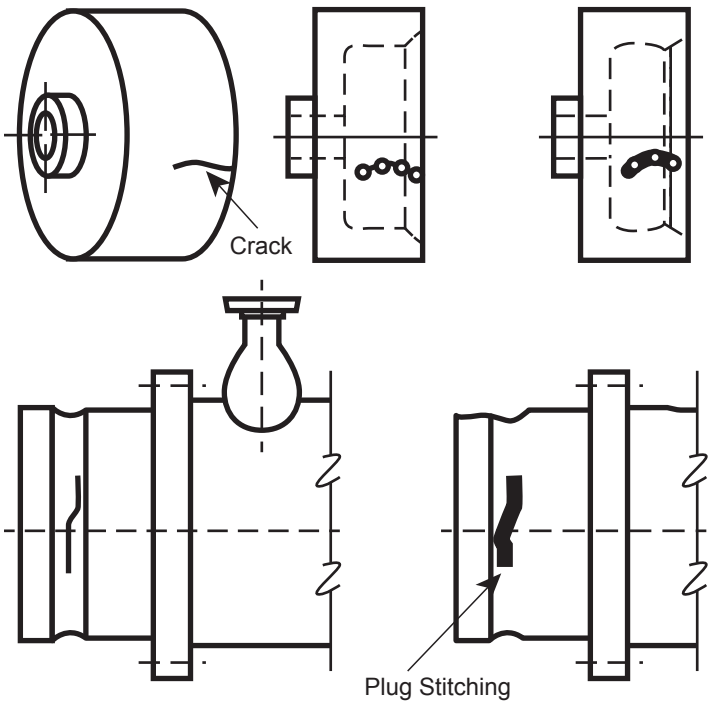
FIGURE S3.5.2.2
EXAMPLE OF INTERMEDIATE FRACTURE REPAIR



S3.5.2.3 MINOR FRACTURE

For minor fractures, such as those shown in NBIC Part 3, Figure S3.5.2.3, plug stitching can be used. The crack is removed by drilling and plugging a continuous chain of overlapping holes along the length and depth of fracture.

FIGURE S3.5.2.3
EXAMPLES OF MINOR FRACTURE REPAIR



S3.5.2.4 FINISHING THE REPAIR

(15)

a) The parts should be held in place to prevent movement while curing the cemented joint to achieve a proper repair. The repair firm should take care to ensure that the cement joint thickness is within the range recommended by the cement manufacturer. Care spent in precisely aligning the parts while clamping will avoid many finishing and machining operations later. Particular attention should be given to gasket and other bearing surfaces.

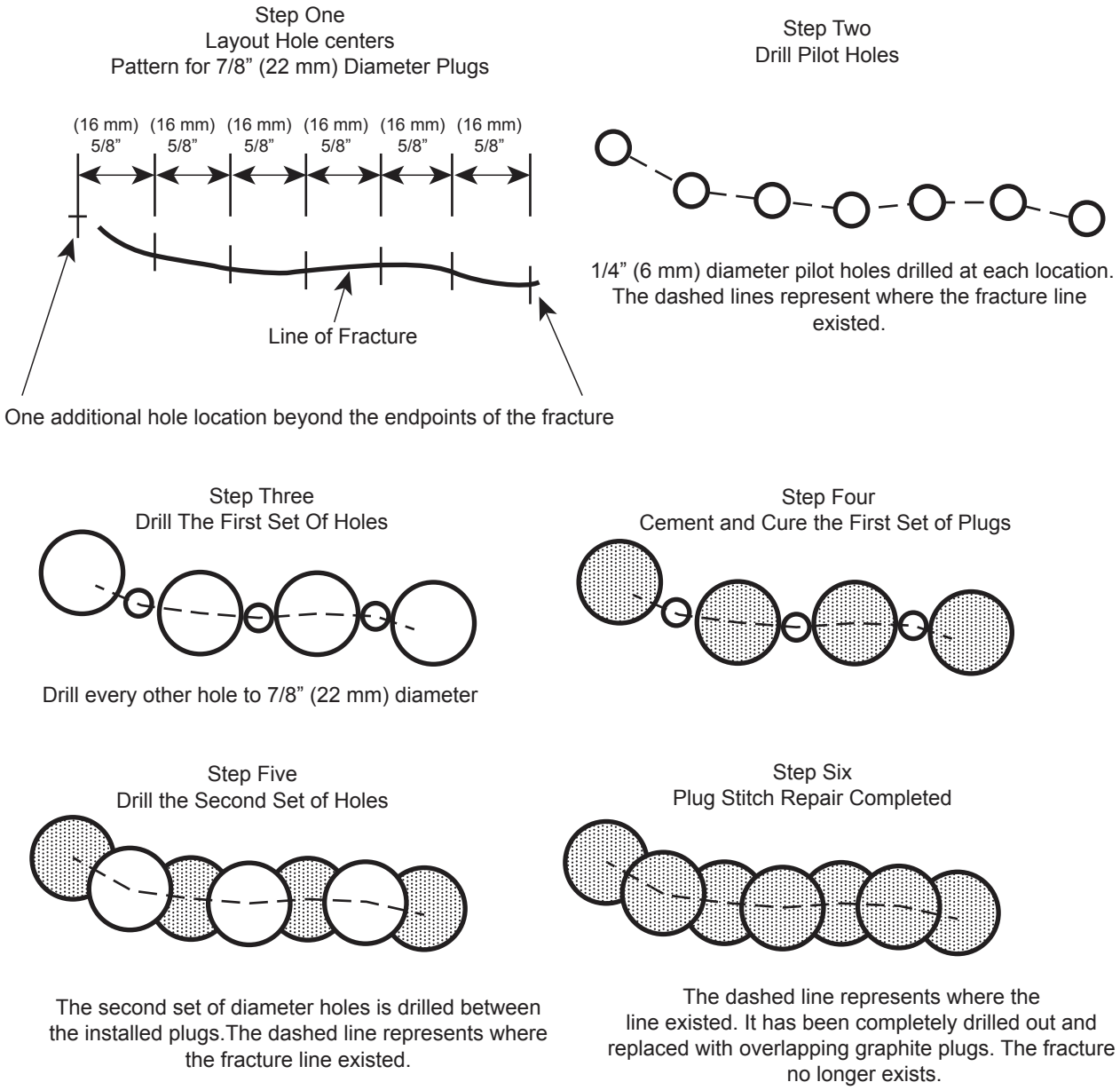
b) Gasket and bearing surfaces may have to be machined, filed, or sanded before the job is completed. Gasket serrations must be clean and continuous. Serrations can be easily re-cut into graphite and any repair plugs that cross the gasket surface.

S3.5.3 GRAPHITE REPAIR BY PLUG STITCHING

a) Plug stitching is a form of repair by material inlaying. In this case, the inlays are small cylindrical impervious graphite plugs. The crack or fracture is removed by drilling and plugging a continuous series of overlapping holes along its length and depth.

b) Most plug stitching is done with 7/8 in. (22 mm) diameter plugs. The plugs are laid out along the fracture line on a pitch of 5/8 in. (16 mm) centers. The overlap of plug material is 1/4 in. (6 mm) along the fracture line. A number of plug sizes are available and are used in repair, and the amount of overlapping is proportional to their diameters.

FIGURE S3.5.3



S3.5.3.1 PLUG STITCHING PROCEDURE (SEE NBIC PART 3, FIGURE S3.5.3)

The following procedure is defined for 7/8 in. (22 mm) diameter plugs (an undersized plug will allow the use of common size tooling). Dimensions for other size plugs shall be adjusted proportionally to the diameter.

a) Trace the line of fracture with a hydrophilic solvent and mark its length and direction.

b) Beyond the end points of the fracture (crack), one additional plug shall be installed.

c) Starting 5/8 in. (16 mm) beyond the end point of the crack, mark drilling centers every 5/8 in. (16 mm) along its length. Make sure there is a plug to be installed outside both end points of the line of fracture.

d) Drill a 1/4 in. (6 mm) pilot hole at each location.

e) Redrill a 7/8 in. (22 mm) hole at every other pilot hole. Holes must be drilled the full depth of the crack. The depth and direction of the crack can be checked with hydrophilic solvent.

f) A 7/8 in. (22 mm) diameter reamer may be used to true the drilled holes.

g) Dry fit a plug into the holes. There should be 0.005 in. to 0.010 in. (0.13 mm to 0.25 mm) clearance for the cement joint. At no time should there be a force fit of plugs into any drilled hole. Provisions shall be provided for venting trapped air.

h) Sand the outside surface of the plugs. Thoroughly clean all the surfaces of the repair, plugs, and drilled holes with hydrophilic solvent.

i) Apply graphite cement to both plugs and holes. All surfaces of plugs and holes to be joined are to be wetted with cement.

j) Insert the cemented plugs into the holes allowing 1/16 in. (1.5 mm) of the plug to extend beyond the surface of the graphite part.

k) Cure the graphite cement according to the cement manufacturer's instruction.

l) At this point, half of the plug stitch repair is completed. A row of plugs has been installed with 1/4 in. (6 mm) pilot holes between them.

m) Redrill the remaining pilot holes to 7/8 in. (22 mm) diameter. The drill will remove part of the plugs that were installed. It is important to have the plugs replace all of the fracture. If the new holes do not cut into the installed plugs, it will be necessary to repeat the procedure between these holes and plug locations to ensure that all of the crack has been repaired. The line of fracture is completely removed by the overlapping effect of the graphite plugs.

n) After the second set of holes have been drilled, repeat the plug cementing procedures.

o) Contour the plugs to provide a smooth transition into the adjoining surface area. The finished repair may be coated with a wash coat for appearance.

S3.5.3.2 FIGURES — TYPICAL PLUG STITCHING PROCEDURE

a) Step one: Layout hole centers.

b) Step two: Drilling pilot holes.

c) Step three: Drilling the first set of holes.

d) Step four: Cementing and curing the first set of plugs.

e) Step five: Drilling the second set of holes.

f) Step six: Plug stitching repair completed.

S3.5.4 REIMPREGNATION OF GRAPHITE PARTS (TUBESHEETS, HEADS, AND BLOCKS)

a) As a function of time, temperature, and chemical exposure, the resin used to impregnate graphite may shrink and/or degrade. As such, it is possible for voids to develop in impregnated graphite that has been in chemical service for a period of time. The resin loss can vary from slight to almost complete loss of impregnation. There is no practical way to determine the amount of resin remaining in the pores. However, a pressure test will determine if the graphite has continuous porosity.

b) Reimpregnation of a graphite component may be used to reduce porosity in an existing graphite component, which in turn will improve the performance and expected life of the existing graphite components. A written re-impregnation procedure acceptable to the Inspector is required. The reimpregnation procedure shall include as a minimum:

1) Decontamination and drying of the graphite component

2) Subjecting the component to a vacuum

3) Introducing resin under pressure

4) Curing the resin at a specified temperature and time

5) Leak test

S3.5.4.1 CONTROL OF IMPREGNATION MATERIAL

a) Impregnation material shall be the same as that specified in the Reimpregnation Procedure. Each impregnation material shall be traceable by the name of its manufacturer and the trade name or number of that manufacturer.

b) The impregnation material manufacturer shall supply the Certificate Holder a *Certificate of Analysis* for each material. It shall include the following:

1) Impregnation material identification

2) Batch number(s)

3) Date of manufacture

4) Shelf life

5) Viscosity per ASTM D 2393

6) Specific gravity

c) Prior to reimpregnation, and at subsequent intervals not to exceed 14 days, the Certificate Holder shall test each batch of impregnation material to assure that the characteristics of the material have not changed from values specified in the Reimpregnation Procedure. The values obtained for viscosity and specific gravity for the impregnation material shall be within the limits specified by the manufacturer and as listed in the Reimpregnation Procedure. The test values shall be made available to the Inspector.

S3.5.4.2 FINISHING THE REPAIR

a) The parts should be held in place to prevent movement while curing the cemented joint to achieve a proper repair. The repair firm should take care to ensure that the cement joint thickness is within the range recommended by the cement manufacturer. Care spent in precisely aligning the parts while clamping will avoid many finishing and machining operations later. Particular attention should be given to gasket and other bearing surfaces.

b) Gasket and bearing surfaces may have to be machined, filed, or sanded before the job is completed. Gasket serrations must be clean and continuous. Serrations can be easily re-cut into graphite and any repair plugs that cross the gasket surface.

S3.5.5 PLUGGING OF LEAKING OR DAMAGED TUBES

a) The material used for plugging tubes shall comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

b) The point(s) of leakage shall be verified, and the corresponding leak site(s) shall be marked/labeled on the tubesheet, and recorded.

c) A minimum of two (2) graphite plugs, each with a minimum length of 1 in. (25 mm), shall be used to plug each end of the tube(s) in question. This represents a minimum total of four (4) plugs per tube.

d) The tube(s) shall be prepared for plugging by enlarging the inside of the tube(s) with a suitable drill bit or reamer.

   1) To ensure a sound cement joint between the tube sidewall and the plug, a slightly smaller diameter plug shall be selected. The maximum clearance between the tube inside diameter and the outside diameter of the plug shall not exceed 3/32 in. (2.4 mm).

   2) As an alternative to d)1) a mandrel with an abrasive, such as sandpaper, may be used, as long as the maximum tube I.D. to plug O.D. clearance of 3/32 in. (2.4 mm) is not exceeded.

   3) The minimum plug insertion depth of the prepared hole(s) shall meet the minimum combined plug length requirements of “c”. When the minimum plug length of “c” is exceeded, the total insertion depth of the plugs may exceed the combined length of the plugs; however, the longer plugs shall not project outside the face of the tube(s) being plugged.

e) Plugging of leaking or damaged tubes shall be performed by certified cementing technicians, using qualified cementing procedures, in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

f) The cement shall be prepared per the cement manufacturer’s instructions.

g) When cementing the plugs, 100% of individual plugs, as well as the inside diameter of the tube opening(s), shall be coated with cement. The plugs shall then be inserted one by one, against each other, into each end of the tube(s) being plugged.

h) Once the plugging is completed, and before the cement cures, the endplugs may need to be held in place, as newly cemented plugs may exhibit a tendency to dislodge from the plugged tube(s) prior to final curing of the cement.

i) Curing time is dependent upon the cement manufacturer’s instructions, and is considered complete when the cement is hardened to the point that it cannot be indented with pressure from a flat screwdriver or other similar instrument.

j) After the cement is completely cured, the plugged, cemented area(s) on the tubesheet face may be dressed with sandpaper or other suitable abrasive.

k) Repaired tubes shall be tested in accordance with this code, using a method acceptable to the Inspector, with a written procedure as approved by the manufacturer’s internal quality system, to ensure leaks have been repaired.

l) The scope of the work completed shall be described and reported on a Form R-1.

S3.5.6 TUBE REPLACEMENT (15)

Tube replacement should be performed with the unit preferably in the horizontal position. Avoid replacing adjacent tubes simultaneously because the replacement areas may overlap or reduce the ligament between

holes and possibly damage the tubesheet. The general steps used in horizontal tube replacement follow below.

a) The material used for tube replacement shall comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG.

b) Tube replacement shall be performed by qualified cementing technicians, using qualified cementing procedures, in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UIG-79(b), (e), and UIG-80(b).

c) Determine the thickness of each tubesheet and inside distance between the tubesheets to obtain tube and sleeve length.

d) Access each tubesheet face, clearly identify and mark each tube hole on each tubesheet of the tubes to be replaced.

e) Prepare/clean the existing tube hole in preparation for extracting the damaged tube. Some holes may contain plugs which require removal. A boring tool slightly larger than the outside diameter of the tube being replaced is required.

f) Drill/bore out the tube hole in each tubesheet to release the tube from the tubesheet. Exercise caution when centering and align cutting to the common axis of the tube.

g) The damaged tube should disengage and become loose. Using guides, remove the damaged tube. Ensure that no debris is trapped in the space where the tube was removed (Fig. S3.5.6-a).

h) Replacement tube shall have sleeves at the ends cemented in the bored holes to replace the material in the tubesheet that was bored out to access the damaged tube (Fig. S3.5.6-b and S3.5.6-c).

   1) Dry-fit a new tube and sleeve.

   2) The sleeve length may vary.

   3) Prior to applying cement, prepare and clean all surfaces to be cemented.

i) Cement the ID of the prepared bore in the floating tubesheet and the tube end OD at the fixed tubesheet. (Fig. S3.5.6-b).

j) Insert the tube through the fixed tubesheet and through the floating tubesheet cemented bore so that it protrudes. Cement the ID of the fixed tubesheet bore as shown in (Fig. S3.5.6-c). The use of alignment dowels can assist/guide in tube handling.

k) Cement the OD of the tube end protruding from the floating tubesheet. Cement the ID of the mating sleeve end, fit it to the cemented tube end and push the assembly part-way into the floating tubesheet. Cement the remainder of the OD of the floating tube end sleeve. Push this cemented assembly the rest of the way into the floating tubesheet (Fig S3.5.6-c).

l) Cement the ID and OD of the sleeve for the fixed tubesheet and insert it until it mates with the tube end inside. Push together cemented tube/sleeve assemblies. (Fig S3.5.6-d). Clean/wipe away any excess cement.

m) Apply slight pressure on the sleeves to seat the joints. Remove excess cement.

n) Maintain pressure and cure both ends of the cemented assembly according to the cement manufacturer's instructions.

o) Sleeves may be trimmed after curing.

p) Replaced tubes shall be tested in accordance with this code per a written procedure acceptable to the Inspector.

q) The scope of work completed shall be described and reported on a Form R-1.

FIGURE S3.5.6-a (15)

CLEANED AND PREPARED TUBESHEETS

FIGURE S3.5.6-b (15)

STARTING TUBE REPLACEMENT

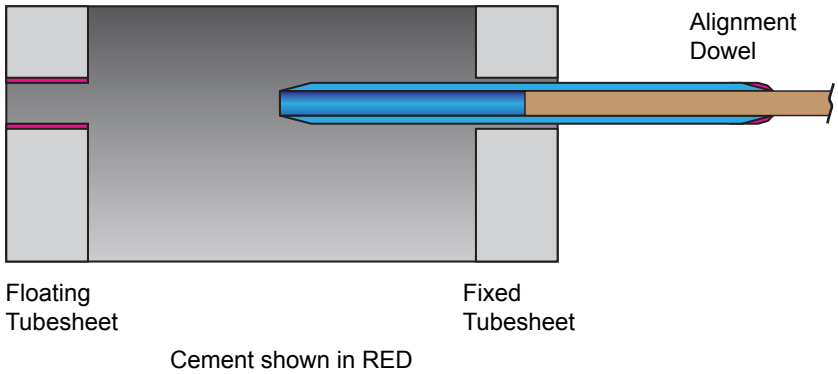
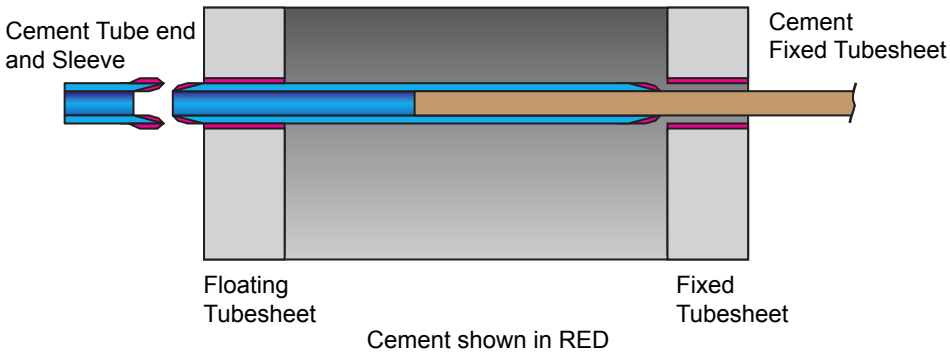


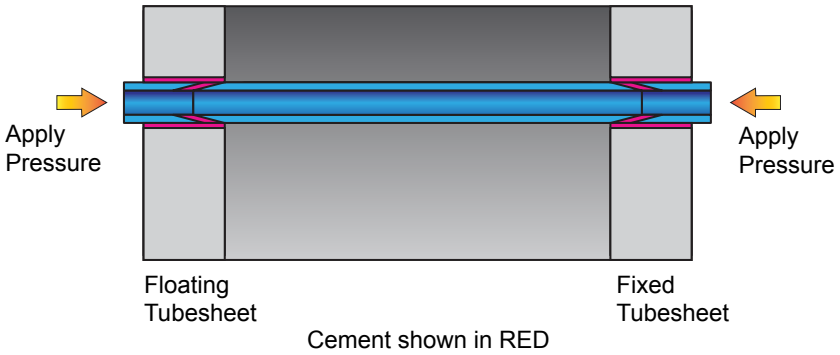
FIGURE S3.5.6-c (15)

SLEEVE CEMENTING



(15) **FIGURE S3.5.6-d**

COMPLETED TUBE REPLACEMENT



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Part 3, S3.5.5 c)

~~c) A minimum of two (2) graphite plugs, each with a minimum length of 1 in. (25 mm), shall be used to plug each end of the tube(s) in question. This represents a minimum total of four (4) plugs per tube.~~

c) A plug shall be used to plug each end of the tube(s) in question and each plug shall have a minimum length of 1 in. (25 mm). Multiple plugs may be used.

To be added to S3.5.5 Plugging of leaking or damaged tubes

m) As an alternative to e) any R Certificate Holder may install graphite tube plugs utilizing a tube plugging kit provided by an ASME Certificate Holder authorized to use the G designator. The kit shall include certified graphite plugs and certified cement ingredients, both accompanied by the appropriate documentation. The kit shall also include the qualified cementing procedure of the ASME Certificate Holder authorized to use the G designator and a step-by-step procedural checklist that shall be followed explicitly. Finally, the kit shall include additional materials that would allow the individual performing the installation to demonstrate the ability to follow the procedure. This demonstration repair, in conjunction with the procedural checklist, shall serve as a cement technician certification valid for a single repair operation. The procedure shall address the entire tube plugging process including plug configuration, tube hole cleaning and preparation, mixing and applying of the cement, application of the plugs, securing the plugs during the curing process, controlling the curing process, and leak testing. The R Certificate Holder shall review the material certifications including verification that the shelf life of the cement has not been exceeded. The Inspector shall review and accept the procedure as well as the completed checklist.

See background information document for additional info.

Background information on impregnated graphite tube plugging:

Cementing tube plugs is a proven field reliable and simple operation that has been effectively used by graphite equipment users for over half a century. With the introduction of the G mark and part UIG in the Code in 2010, and the subsequent inclusion of graphite pressure equipment repair procedures to the NBIC books, the option for end users to use the procedure was obsoleted for vessels marked with the 'G' mark indicator.

It is the opinion of this group that cementing plugs for tube plugging should be given some special consideration in regards to required certifications as detailed in part UIG.

Some key points:

- Cementing tube plugs is a very simple and effective operation.
- All tube plugging will be performed by an "R" Certificate Holder
- A cemented tube plugging operation can be performed successfully in as little as a day or two.
- While there are alternative tube plugging options, cementing is far and away the most effective and longest lasting option.
- There is little to no chance of doing further damage to the part as a result of a failed tube plugging operation. If the plug doesn't hold, or isn't properly installed, the resulting action is simply back to remove the plug and install a new one in its place
- In some jurisdictions, outside contractors are not allowed to perform code repairs on pressure vessels without obtaining a state license. In actual cases like these, a user would be forced to pull a vessel out and ship it to a repair organization certified for graphite to get the repair completed. This can result in weeks of downtime, rather than days, for such a simple operation.
- There are very few repair organizations that have graphite repair included in their scope nationwide.
- While commonly viewed as the graphite version of welding, cementing is a much less complex operation. There is no "fusing" of material as there is in welding, where the weld filler and base materials mix in the welded zone. A poorly cemented plug can be removed and the surrounding material is not affected. Proper combination of ingredients to produce adequate cement, applying enough cement to cover the joining surface, and properly curing the joint are the key factors in a good joint. All of which will be covered in the procedure specification.
- The nature of tube plugging is to simply seal a hole. This sets tube plugging apart from most other cementing operations which can be critical to vessel fit, form, and function.
- All of the design work is included in the kit. The proper bore diameter, and surface preparation steps are detailed, the plug is pre-made and ready to use, the cement mixing recipe is included, and the curing procedure is also part of the given procedure.

It is our belief that tube plugging operations do need to be controlled, but think limiting them to only repair organizations certified for graphite is unnecessary. We think that this proposal covers all the important bases by maintaining that an ASME certificate holder authorized to use the G designator provides the kit, a certified repair organization does the work, providing certified graphite materials with all the proper documentation, providing a qualified cementing procedure, and by requiring that the Inspector representing the repair organization get involved, similar to any other routine repair. All the

material is as required by the Code, and the joining methodology remains controlled by the use of the qualified procedure.

S3.1 SCOPE

a) Repairs to graphite pressure equipment require the use of certified impregnated graphite and cement. The determining factor in establishing the desired material properties is the resin impregnation cycle. If the resin impregnation cycle is not controlled, it is not possible to meet the minimum design values.

~~a)~~b) The letter “G” shall be included on the “R” *Certificate of Authorization* for those organizations authorized to perform repairs/alterations of graphite pressure equipment.