

TABLE S2.13.7

MAXIMUM ALLOWABLE WORKING PRESSURES FOR STEEL TUBES OR FLUES FOR
FIRETUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES CONFORMING
TO THE REQUIREMENTS OF SPEC. SA-176, SA-192, SA-209, OR SA 210

Outside diameter of tube, inches D	Minimum gage, Birmingham Wire Gage (BWG), inches									
	13 t = 0.095	12 t = 0.109	11 t = 0.120	10 t = 0.134	9 t = 0.148	8 t = 0.165	7 t = 0.180	6 t = 0.203	5 t = 0.220	4 t = 0.238
1	470	690	—	—	—	—	—	—	—	—
1-1/2	320	460	570	720	860	—	—	—	—	—
1-3/4	270	400	490	620	740	890	—	—	—	—
2	240	350	430	540	650	780	900	—	—	—
2-1/4	210	310	380	480	580	690	800	960	—	—
2-1/2	190	280	350	430	520	620	720	860	970	1,080
3	160	230	290	360	430	520	600	720	810	900
3-1/4	—	210	270	330	400	480	550	660	740	830
3-1/2	—	200	250	310	370	450	510	620	690	770
4	—	180	220	270	330	390	450	540	610	680
4-1/2	—	160	190	240	290	350	400	480	540	600
5	—	—	180	220	260	310	360	430	490	540
5-3/8	—	—	160	200	240	290	340	400	450	500
5-1/2	—	—	—	200	240	290	330	390	440	490
6	—	—	—	180	220	260	300	360	410	450
$P = \{(t-0.65)/D\} \times 15550$ where P = maximum allowable working pressure, pounds per square inch, t = minimum wall thickness, inches, D = outside diameter of tubes, inches.										
For pressures below those given in the table, the gage thickness shall be not less than the minimum given in the table. Calculated values of pressure have been rounded to the next higher unit of 10 psi.										

TABLE S2.13.7M

MAXIMUM ALLOWABLE WORKING PRESSURES FOR STEEL TUBES OR FLUES FOR FIRETUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES TO THE REQUIREMENTS OF SPEC. SA-176, SA-192, OR SA 210

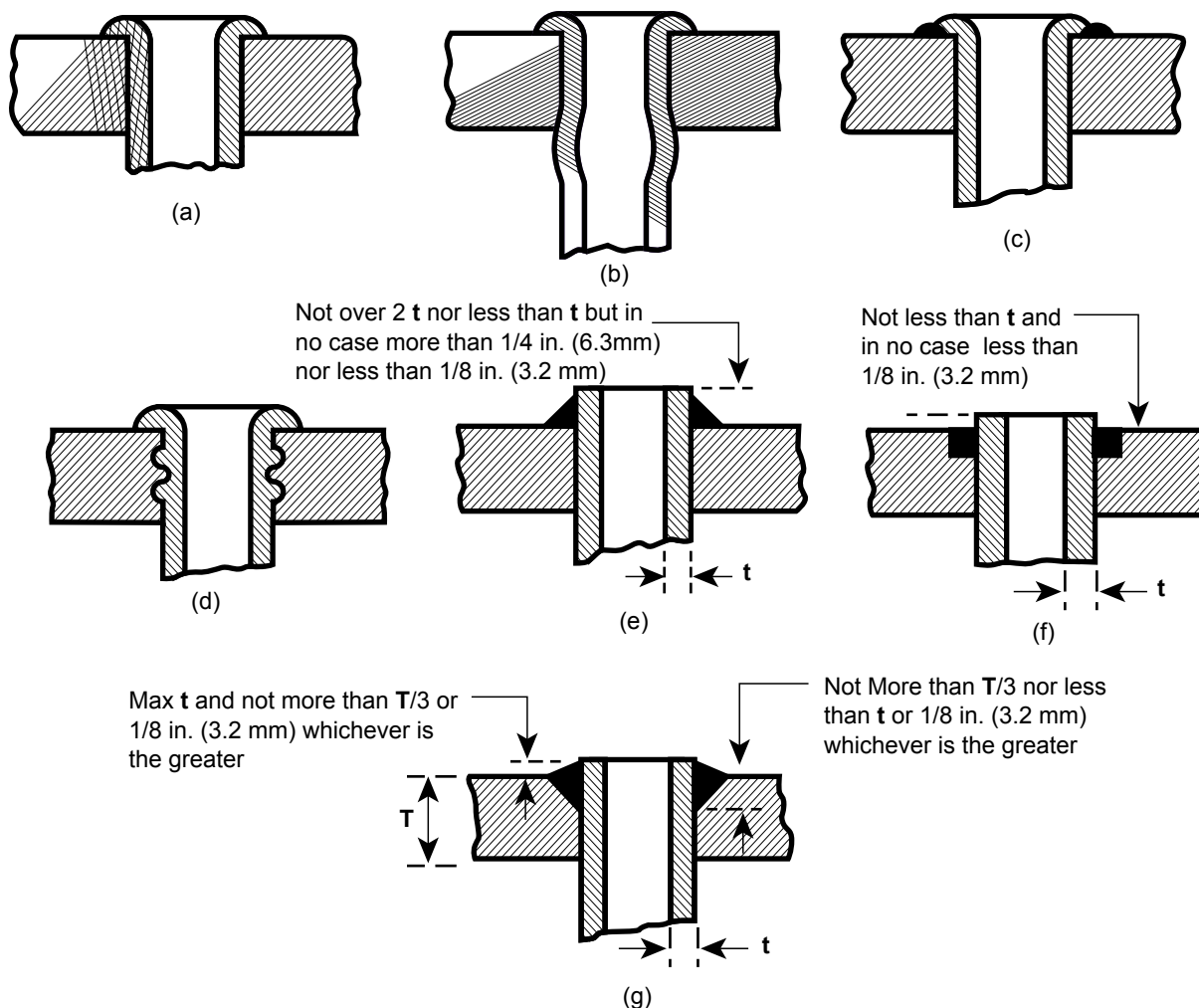
Outside diameter of tube, mm D	Minimum gage, Birmingham Wire Gage (BWG), to mm									
	13 t = 2.4	12 t = 2.8	11 t = 3.0	10 t = 3.4	9 t = 3.8	8 t = 4.2	7 t = 4.6	6 t = 5.2	5 t = 5.6	4 t = 6.0
25	3,250	4,950	—	—	—	—	—	—	—	—
40	2,150	3,250	3,850	4,950	6,100	—	—	—	—	—
45	1,850	2,800	3,300	4,300	5,250	6,250	—	—	—	—
50	1,650	2,450	2,850	3,700	4,550	5,350	6,200	—	—	—
60	1,450	2,200	2,550	3,300	4,050	4,800	5,550	6,700	—	—
65	1,300	1,950	2,300	2,950	3,600	4,300	4,950	5,950	6,650	7,300
75	1,100	1,650	1,950	2,500	3,050	3,600	4,200	5,000	5,600	6,150
85	—	1,500	1,750	2,300	2,800	3,300	3,850	4,600	5,100	5,650
90	—	1,400	1,650	2,150	2,600	3,100	3,550	4,300	4,750	5,250
100	—	1,250	1,450	1,850	2,300	2,700	3,100	3,750	4,150	5,600
115	—	1,100	1,300	1,650	2,050	2,400	2,800	3,300	3,750	4,100
125	—	—	1,150	1,500	1,850	2,200	2,500	3,000	3,350	3,700
135	—	—	1,100	1,400	1,700	2,000	2,350	2,800	3,100	3,400
140	—	—	—	1,350	1,650	2,000	2,300	2,750	3,050	3,350
150	—	—	—	1,250	1,550	1,800	2,100	2,500	2,800	3,100
$P = \{(t-1.65)/D\} \times 107000$ where P = maximum allowable working pressure, kilopascals (kPa), t = minimum wall thickness, mm, D = outside diameter of tubes, mm.										
For pressures below those given in the table, the gage thickness shall be not less than the minimum given in the table. Calculated values of pressure have been rounded to the next higher unit of 50 kPa.										

S2.13.8 FLUE AND TUBE INSTALLATION

- a) When boiler tubes and flues are replaced, the MAWP of the boiler must not exceed the MAWP of the tube or flue per Table S2.13.7.
- b) The boiler shall have the ends of the tubes firmly rolled and beaded, or rolled and welded around the edge of the tube. (See NBIC Part 3, Figure S2.13.8). Tube ends attached by rolling and welding are subject to the following provisions:
 - 1) The tube sheet hole may be beveled or recessed to a depth at least equal to the thickness of the tubes. Where the hole is beveled or recessed, the projection of the tube beyond the tube sheet shall not exceed a distance equal to the tube thickness. The depth of any bevel or recess shall not be less than the tube thickness or 1/8 in. (3 mm), whichever is greater, nor more than one-third of the tube sheet thickness. (See NBIC Part 3, Figure S2.13.8 f) and g))
 - 2) Where no bevel or recess is employed, the tube shall extend beyond the tube sheet not less than a distance equal to the tube thickness, nor more than twice the tube thickness. (See NBIC Part 3, Figure S2.13.8 e))

- 3) On welded attachments, the tubes shall be rolled before welding and again rolled lightly after the welding procedure.
- c) Expanding of tubes by the Prosser method (see NBIC Part 3, Figure S2.13.8 b) in lieu of rolling may be employed in combination with any beaded or welded attachment method.
- d) Seal welding is permissible on any type of beaded attachment. Where seal welding is employed, a single hydrostatic test of the boiler after seal welding shall be performed.
- e) The inner surface of the tube hole in any form of attachment may be grooved or chamfered.
- f) The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

FIGURE S2.13.8
ACCEPTABLE FORMS OF TUBE ATTACHMENTS



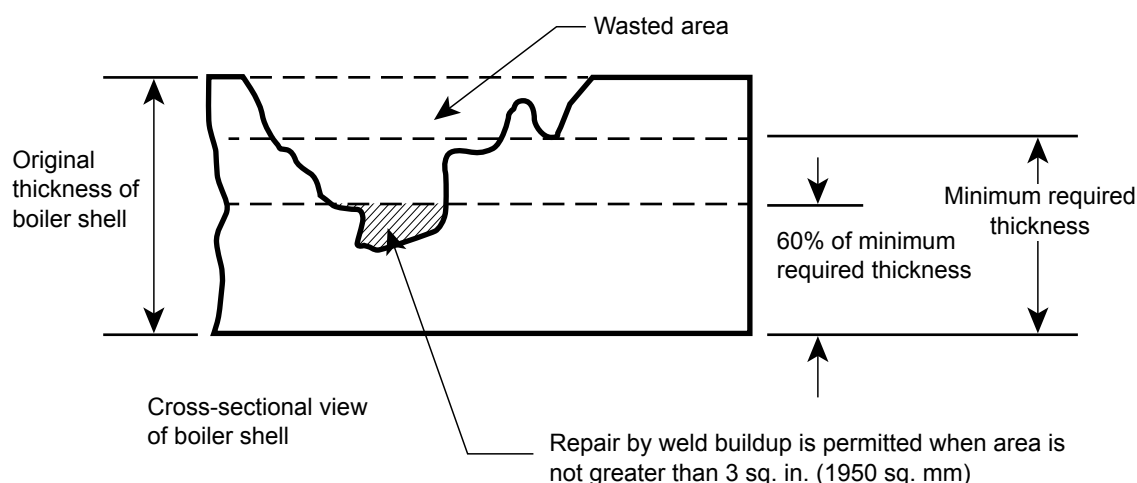
S2.13.9 REPAIRS AND ALTERATIONS TO UNSTAYED AREAS

S2.13.9.1 WELD BUILDUP OF WASTAGE AND GROOVING IN UNSTAYED AREAS

- Weld buildup shall not be used if the affected section of plate has wasted below 60% of the minimum required thickness per NBIC Part 2, Supplement 2 in an area exceeding 3 sq. inches (1,950 sq. mm.). (See NBIC Part 3, Figure S2.13.9.1).
- Wasted sections that have wasted below 60% of the minimum required thickness and have an area exceeding 3 sq. in (1,950 sq. mm) shall be repaired by installing a flush patch using full penetration welds.
- Weld buildup of wasted areas shall not exceed 100 sq. in. (65,000 sq. mm).
- Weld buildup is to replace material that has been lost due to wastage and grooving, and is not to replace thickness on the opposite side of the sheet. Weld buildup must be applied to the side of the sheet that is wasted or grooved.
- Prior to welding, the rivets in the wasted area should be removed.
- Rivets holes should be reamed after welding.
- Welding shall not cover rivet heads.

FIGURE S2.13.9.1

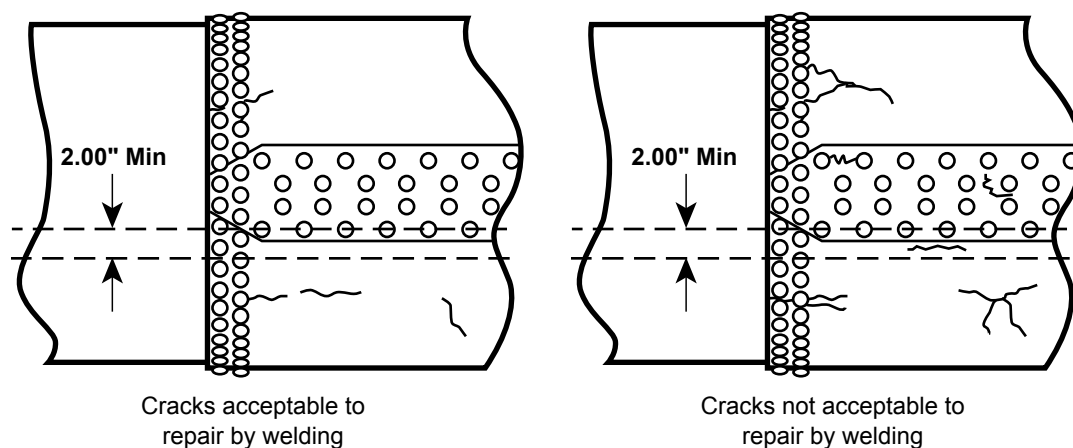
WELD BUILDUP



S2.13.9.2 WELDED REPAIR OF CRACKS IN UNSTAYED AREAS

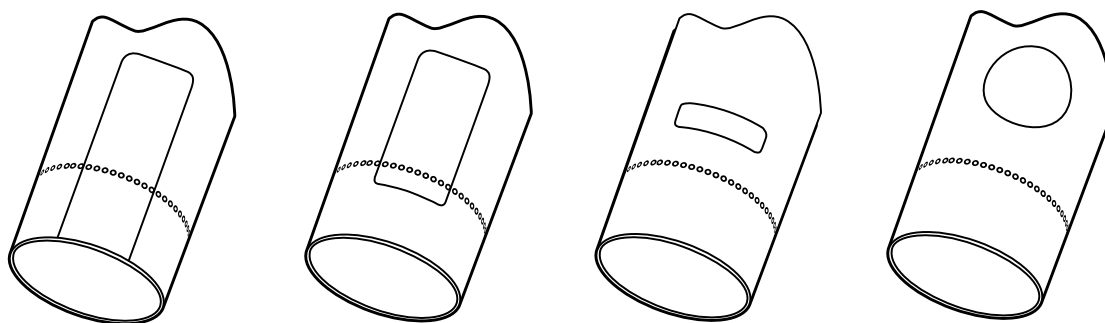
- a) Prior to repairing cracks, the plate shall be NDE examined for other defects. All affected sections shall be repaired.
- b) Cracks in unstayed areas may be repaired by welding. Before cracks are repaired, however, the inner surface of the plate should be examined for possible excessive corrosion or grooving.
- c) Cracks in unstayed areas may be repaired by welding, providing the cracks do not extend between rivet holes in a longitudinal seam or parallel to a longitudinal seam within 2 in. (50 mm) from the center line of the outer most row of rivets. Minimum 175°F (79°C) preheat shall be used. The completed repair shall have volumetric NDE performed and stress relieved. Alternative methods in lieu of postweld heat treatment identified in NBIC Part 3, 2.5.3 may be used. (See NBIC Part 3, Figure S2.13.9.2)
- d) Cracks radiating from a common point (star cracking) shall not be repaired; installation of a flush patch is required. Cracks radiating from a rivet hole in a circumferential seam may be repaired if the plate is not seriously damaged. (See NBIC Part 3, Figure S2.13.9.2)
- e) Prior to welding, the rivets into which cracks extend and the rivets on each side of them shall be removed.
- f) In riveted joints, tack bolts should be placed in alternating holes to hold the plate laps firmly.
- g) Rivets holes should be reamed after welding.
- h) Welding shall not cover rivet heads.

FIGURE S2.13.9.2
UNSTAYED AREA CRACK

**S2.13.9.3 WELDED FLUSH PATCHES IN UNSTAYED AREAS**

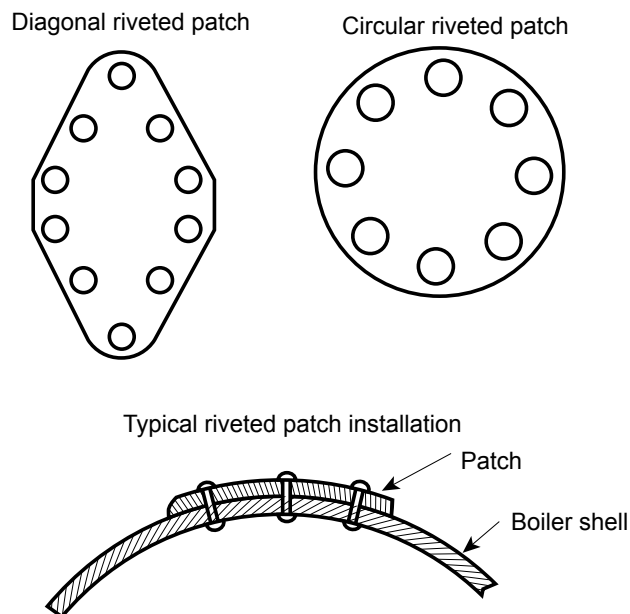
- a) Welded repairs to boiler unstayed areas shall have volumetric NDE performed in accordance with the approved code of construction or ASME Section I, when the size of the repaired area is greater than 3 in. (75 mm) in diameter. The completed repair must be stress relieved. Alternative Methods without Postweld Heat Treatment identified in NBIC Part 3, 2.5.3 may be used.
- b) The weld around a flush patch shall be a full penetration weld and the accessible surfaces shall be ground flush. Examples of flush welded patches are shown in Figure NBIC Part 3, S2.13.9.3.

- c) Before installing a flush patch, the defective material should be removed until sound material is reached.
- d) The patch should be rolled or pressed to the proper shape or curvature. The edges of the patch should align with original material without overlap. Patches shall fit flush on the waterside of the sheet. If the patch includes an existing riveted seam, the patch shall be riveted at that seam. Changing a riveted seam to a welded seam is considered an alteration. Patches may be of any shape or size. If the patch is square or rectangular, an adequate radius, of at least three times the material thickness should be provided at the corners. Square corners shall be avoided.
- e) Material thickness of patches shall be at least equal to, but not greater than, 1/8 in. (3 mm) thicker than original construction thickness.

FIGURE S2.13.9.3**UNSTAYED AREA FLUSH PATCH****S2.13.9.4 REPAIR OF CRACKS, GROOVING, AND WASTAGE USING A RIVETED PATCH IN UNSTAYED AREAS**

- a) If the cracked section of plate is retained and is to be repaired by installation of a riveted patch, the crack may be stopped by drilling stop holes at each end or removed by a method such as grinding, cutting, or machining. Results of stop drilling or crack removal shall be verified by NDE. (See NBIC Part 3, Figure S2.13.9.4)
- b) Riveted patches may be installed on the boiler shell interior or exterior.
- c) Installation of a riveted patch shall be considered an alteration.
- d) Riveted patches may be any shape or size provided the lowest patch efficiency is equal to or greater than the lowest equivalent seam efficiency of the boiler course to which it is applied.
- e) The design margin of all riveted patches shall not be less than four.

FIGURE S2.13.9.4
RIVETED BOILER SHELL PATCH



S2.13.9.5 BARREL REPLACEMENT

An entire course of a barrel may be replaced as a repair provided that:

- a) The replacement material is code-accepted material (see NBIC Part 3, S2.7.1) that has a nominal composition and strength that is equal to or greater than the original, and is suitable for the intended service;
- b) The minimum required thickness shall be at least equal to the original material thickness. The original thickness may be determined from the original Manufacturer's Data Report, original drawings, or by measuring the original material thickness in an area unaffected by corrosion;
- c) The longitudinal joint efficiency of the new barrel course meets or exceeds the original design/construction;
- d) All doubling/reinforcing plates, stays and openings in the original barrel are duplicated or retained on the new barrel and installed in a manner that meets or exceeds the original design/construction;
- e) All attachments and connections with other portions of the boiler are attached in the same manner as the original;
- f) The boiler will not be re-rated at a MAWP greater than the original design MAWP; and
- g) If all of the above requirements are not met, then the replacement will be considered an alteration and must follow the requirements of NBIC Part 3, 3.4 and S2.13.10 repairs and alterations to stayed areas.

S2.13.10 REPAIRS AND ALTERATIONS TO STAYED AREAS

S2.13.10.1 WELD BUILDUP OF WASTAGE AND GROOVING IN STAYED AREAS

Requirements specified in NBIC Part 3, S2.13.9.1 shall apply with the following additional requirements identified below:

- a) Prior to welding, the rivets and or staybolts in the wasted areas should be removed.
- b) Threaded staybolt holes shall be retapped after welding.
- c) Welding shall not cover rivet or staybolt heads.

S2.13.10.2 WELDED REPAIR OF CRACKS IN STAYED AREAS

Requirements specified in NBIC Part 3, S2.13.9.2 shall apply with the following additional requirements identified below:

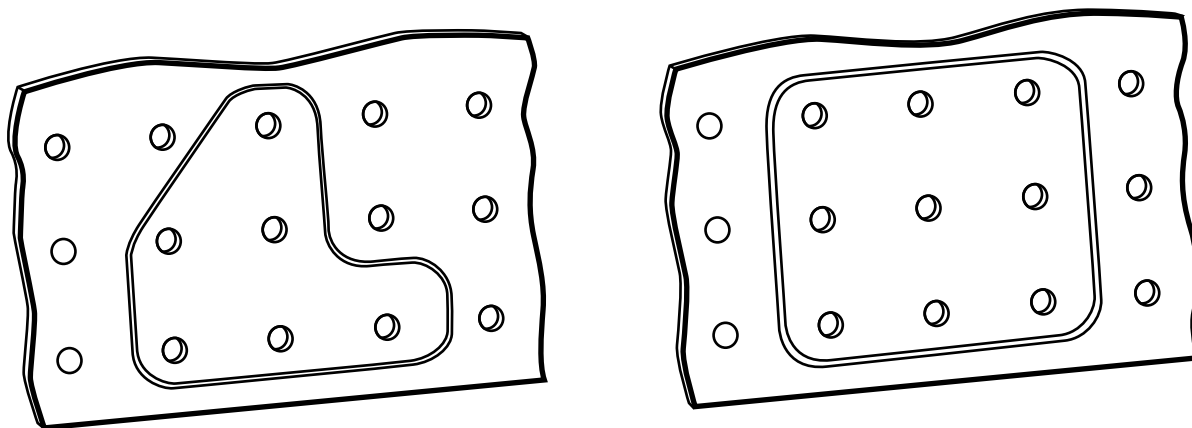
- a) If the crack extends into a staybolt hole, the staybolt shall be removed prior to making the repair.
- b) Threaded staybolts shall be retapped after welding.
- c) If the load on repair area is carried by other forms of construction, such as staybolts, rivets, or tubes, volumetric NDE of the welds is not required.

S2.13.10.3 WELDED FLUSH PATCHES IN STAYED AREAS

The requirements identified in NBIC Part 3, S2.13.9.3 shall apply with the additional requirements specified below:

- a) Patches may be any shape provided they are adequately supported by staybolts, rivets, tubes, or other forms of construction. Patches on stayed surfaces should be designed so weld seams pass between staybolt rows. (See NBIC Part 3, Figure S2.13.10.3-a);
- b) Patches are to be flush type, using full penetration welds. If the load on the patch is carried by other forms of construction, such as staybolts, rivets, or tubes, then volumetric NDE of the welds is not required;
- c) Staybolts and rivets should be installed after welding of patch is completed. Reuse of staybolts and rivets is prohibited; and
- d) For welded flush patches in stayed areas that include a knuckle area, see S2.13.11.3, *Welded Flush Patches in Firebox and Tubesheet Knuckles*.

FIGURE S2.13.10.3-a
STAYED AREA FLUSH PATCH



S2.13.10.4 REPAIR OF STAYED FIREBOX SHEETS GROOVED OR WASTED AT THE MUDRING

- a) Mudgings of the Ogee style (knuckle) shall be repaired in accordance with NBIC Part 3, S2.13.11.
- b) For mudgings of the locomotive style (See NBIC Part 3, Figure S2.13.10.4-a), weld buildup shall not be used if the affected section of plate has wasted below 60% of the minimum required thickness per Part 2, Supplement 2 in an area exceeding 3 sq. in. (1,950 sq. mm). (See NBIC Part 3, Figure S2.13.9.1) Repair by weld buildup cannot be used if the wastage extends below the waterside surface of the mudring or if the strength of the structure will be impaired. If extensive welding is required, the affected area shall be removed and replaced with a flush patch.
- c) Wasted sections that have wasted below 60% of the minimum required thickness, and have an area exceeding 3 sq. in (1950 sq.mm) shall be repaired by installing a flush patch using a full penetration weld.
- d) If wastage and grooving extends below the mudring waterside surface and if the plate thickness remaining has been reduced to less than the minimum required thickness, the affected section shall be removed and replaced with a flush patch. (See NBIC Part 3, Figure S2.13.10.4-a)
- e) Flush patches shall be arranged to include the mudring rivets and at least the first row of staybolts above the mudring. (See NBIC Part 3, Figure S2.13.10.4-b)
- f) For mudgings of the locomotive style, pitted and wasted sections of mudgings may be built up by welding provided the strength of the mudring will not be impaired. Where extensive weld buildup is employed, the Inspector may require an appropriate method of NDE for the repair.
- g) Cracked or broken mudgings may be repaired by welding or installing flush patches using full penetration welds. Patches shall be made from material that is at least equal in strength and thickness to the original material. Patches shall fit flush on waterside surfaces. Where necessary, firebox sheets on both sides of the defect may be removed to provide access for inspection and welding.

FIGURE S2.13.10.4-a
MUDRING WASTAGE REPAIR

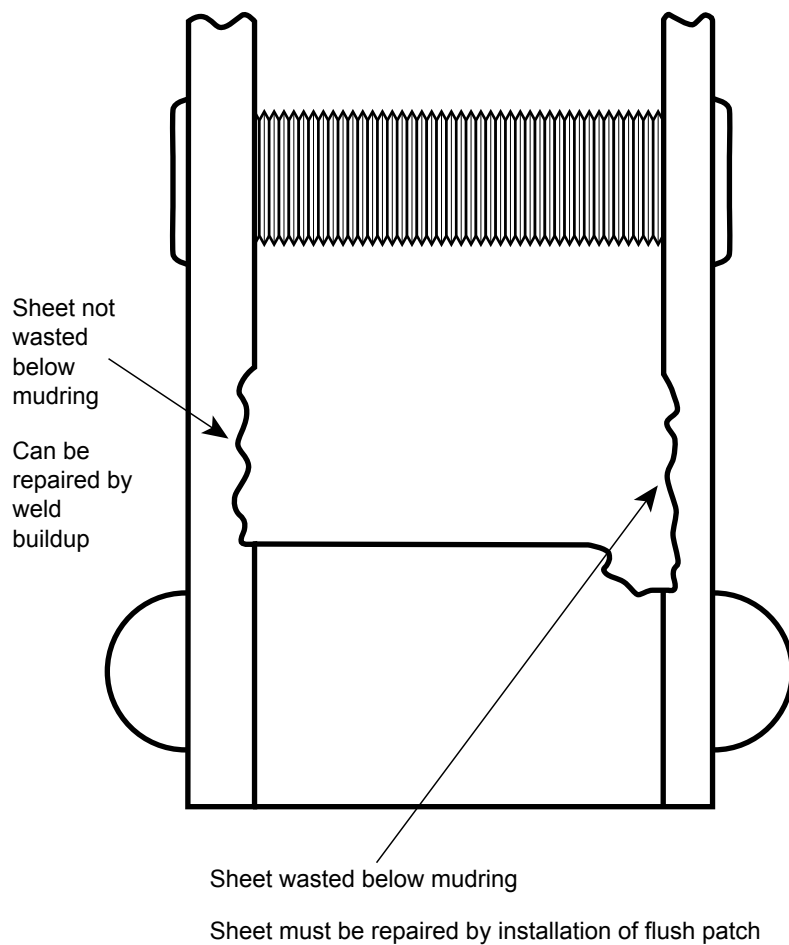
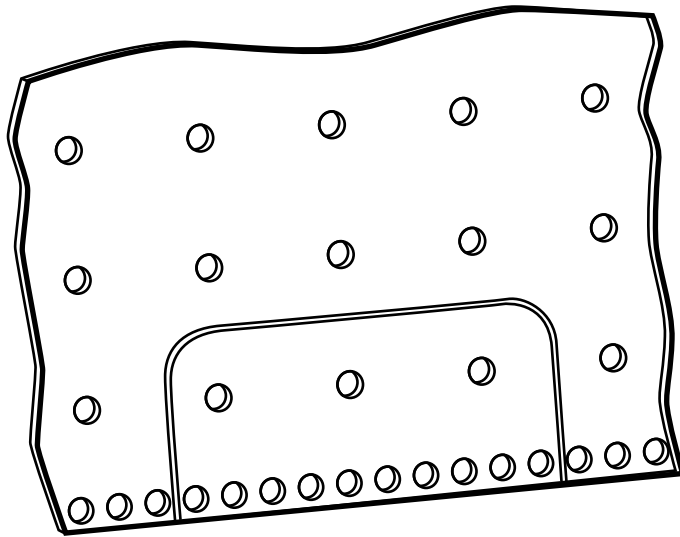


FIGURE S2.13.10.4-b
MUDRING FLUSH PATCH



S2.13.11 REPAIR OF FIREBOX AND TUBESHEET KNUCKLES

S2.13.11.1 WELD BUILDUP OF WASTAGE AND GROOVING IN FIREBOX AND TUBESHEET KNUCKLES

- a) Weld buildup shall not be used if the affected section of plate has wasted below 60% of the minimum required thickness per NBIC Part 2, Supplement 2. (See NBIC Part 3, Figure S2.13.9.1)
- b) Wasted sections that have wasted below 60% of the minimum required thickness shall be repaired by installing a flush patch using full penetration welds.
- c) Weld buildup of wasted areas shall not exceed 100 sq. in. (65,000 sq. mm).
- d) Weld buildup is to replace material that has been lost due to wastage and grooving, and is not to replace thickness on the opposite side of the sheet. Weld buildup must be applied to the side of the sheet that is wasted or grooved.

S2.13.11.2 WELDED REPAIR OF CRACKS IN FIREBOX AND TUBESHEET KNUCKLES

- a) Prior to repairing cracks, the plate shall be NDE examined for other defects. All affected sections shall be repaired.
- b) Welded repair of cracks within the points of tangency of a knuckle are permitted. All welds within the points of tangency of the knuckle shall have volumetric NDE performed.
- c) Cracks radiating from a common point (star cracking) shall not be repaired; installation of a flush patch is required.