PG&E	REPAIR OF PIPELINE DEFECTS		084491 (A-65)
Dept:	Gas System Technical Support	**Section:**	Pipeline
Approved by:	[redacted]	**Date:**	02-24-95
Rev. #00: This document supersedes Engineering Standard 084491 (A-65). For a description of changes see Page 10.			

Purpose and Scope:

1. This document specifies and illustrates the requirements for repair of steel pipelines.

General:

2. The following criteria are established:
   - A. Maximum hoop stress permitted during welding.
   - B. Specifies allowable methods of repair for welded steel pipelines.
   - C. Work procedures and design requirements for allowable repair methods.
   - D. Welding procedure on pipelines under pressure.
   - E. Cathodic protection requirements for leak repairs
   - F. It is not the intent of this document to preclude the use of methods of repair other than welding, such as temporary emergency methods or mechanical clamps, when these other methods are more appropriate (such as anticipated early retirement of the main). However, any alternate action taken must be in compliance with G.O. 112-D.
   - G. This document specifies repairs abased on MAOP's and % SMYS. The pipeline's ability to operate at pressure above the MAOP may be limited by some repairs. Accordingly a repair method qualified for the Future Design Pressure (FDP) should be used when the FDP is greater than the MAOP (making future upgrades or uprating possible) and removal of the repaired section will not be practical or likely.

Maximum Hoop Stress Permitted During Welding:

3. Prior to performing any welding on a pipeline under pressure, an evaluation must be made to determine if the operating pressure needs to be lowered so that the hoop stress will be at or below the level specified by this document.The maximum operating pressure permitted during welding is the least pressure provided in paragraphs 3 A.,B., C.,D., and E. of this document.

   The maximum pressures are also shown on the pipeline survey sheets. Where the condition of the pipe is found to be poor, or where other conditions exist which could cause problems while performing the welding, a lower operating pressure may be necessary. This lower pressure should be determined based on an evaluation of the observed condition of the pipe and good engineering judgement.

   A. For seamless and double submerged arc welded pipe, the maximum pressure permitted during welding shall be determined using the formula given below or the MAOP, or a pressure which will produce a hoop stress of 50% of the specified minimum yield strength, whichever is lowest:

$$P = \frac{2S(t - 0.094 \text{ in.})(0.72)}{D}$$

P = Internal Pressure, psig
S = Specified Minimum Yield Strength, psi
t = Nominal Pipe Wall Thickness, inches
D = Outside Pipe Diameter, inches

For all other pipe, the maximum pressure permitted during welding shall be determined by the formula given above or the MAOP, or a pressure which will produce a hoop stress of 40% of the specified minimum yield strength, whichever is lowest.

B. The maximum hoop stress permitted during welding shall not exceed 20% of the specified minimum yield strength when:

1. Welding within 3" of the longitudinal seam, the circumferential, and any branch weld on any type of pipe except the longitudinal seam of double-submerged arc welded pipe.
2. Welding within 3" of any defect (gouges, corrosion, laminations, etc.) in the pipe which exceeds 1/3 of the nominal wall thickness in depth and/or 1/4 of the nominal pipe diameter in length. Any number of closely spaced adjacent defects shall be treated as one defect of a size and depth encompassing all the defects.
3. More than one weld repair is required in any length equal to five pipe diameters or five feet, whichever is less.

C. When preheating to temperatures less than 450°F, the maximum hoop stress permitted shall not exceed 50% of the specified minimum yield strength for seamless and double submerged arc welded pipe, or 40% of the specified minimum yield strength for all other types of pipe.

D. Preheating above 450°F or high temperature stress relieving is not permitted on pipelines under pressure. The yield point and fracture sensitivity of non-expanded high strength pipe are adversely affected when it is heated above 600°F unless it is heated and cooled under controlled conditions. The yield point of expanded pipe is permanently lowered by approximately 20% when it is heated above this temperature.

Extent of Defects and Methods of Repair:

4. Repairs are required when the extent of defect exceeds that allowed by the appropriate Welding Repair Selection Table 1, Table 3 or Table 6 shown on Pages 4 thru 10. For corrosion, a qualified engineer may determine the MAOP of the pipe and the allowable extent of defects using ASME B31G guidelines or other fitness for purpose methods approved by Gas System Technical Support..
5. Only those methods of repair recommended in this document are approved as permanent repairs to welded steel mains. When a repair cannot be made in conformance with the conditions of this document, the section of defective pipe shall be replaced with a good piece of pipe. The most appropriate method of repair permitted shall be selected from the proper Welding Repair Selection Table 1, Table 3 or Table 6 on Pages 4 thru 10, and the repair completed in conformance with the work procedures established in Paragraphs 2.,4.,5.,and 6.

Work Procedures and Design Requirements:

6. Grinding

   When grinding to eliminate a defect, care must be used to remove the entire defect. Such grinding shall be smoothly contoured to the pipe to eliminate all possible points of stress concentration.

7. Grinding and Fill Welding

   When grinding and fill welding, the repair area must be ground clean. The fill weld metal shall penetrate the base material. The surface of the finished repair weld shall be ground smooth to the contour of the pipe on all lines operating over 100 psi.

8. Patching

   Patches shall be designed installed and tested in accordance with document 284041 (A-64).

9. Sleeving

   Sleeve design and testing shall be in accordance with documents 088312 (A-60) or 083871 (A-61).

10. Mueller Save-A-Valve Nipple

    The Mueller Save-A-Valve nipple may be used to repair an individual corrosion pit (either leaking or non-leaking) where the diameter of the pit at the surface of the pipe is less than the inside diameter of the nipple. The weld shall be visually inspected. Refer to Doc. 282981 (A-62) for installation procedure on high pressure mains. See the Welding Repair Selection Tables for pressure-stress level limitations when using the Mueller Save-A-Valve.

11. Canning

    Gas main repair cans may be used for repairs on pipelines with a design pressure which produces a hoop stress of less than 20% SMYS and not exceeding 400 psi. Can design and testing shall be in accordance with document 083908 (A-63).

12. Replace Segment of Pipe

    Take the segment out of service. Remove the damaged portion of pipe by cutting out cylindrical piece of pipe. Replace it with pipe of equal or greater design strength and equal or greater wall thickness. Testing shall be performed as set forth in documents 087950 (A-34) and 085210 (D-33).

13. Dents (Pipe Distortion)

    A. Distortion or denting may be defined as a depression which produces a gross disturbance in the curvature of the pipe wall (as opposed to a scratch or gouge which reduces the pipe wall thickness). The depth of a dent shall be measured as the gap between the lowest point of the dent and prolongation of the original contour of the pipe in any direction.

        1. All dents which affect the curvature of the pipe at the longitudinal or any circumferential weld shall be removed on mains operating at greater than 100 psi. Dents at welds in mains operating below 100 psi shall be treated the same as a dent which does not affect a weld.

        2. Per cent distortion shall be defined as the ratio of the depth of the dent to the actual diameter of the pipe times 100. Distortion exceeding the limitations in Table 1, Table 3 and Table 6 shall be removed.

Welding Procedure on Pipelines Under Pressure:

14. Arc welding and preheat on pipe while under pressure shall be as specified in Doc. 086432 (D-22). Arc welding is preferred for all repairs. For small lower pressure lines where arc welding is not convenient or the equipment is not readily available, oxyacetylene welding may be used wherever it is allowed under document 283263 (D-20).

    A. When the surface temperature of the pipe is less than 50°the pipeline flow should be made static and the pipe preheated and welded as set forth in document 086432 (D-22).

        1. When the surface temperature of the pipe is less than 50°F, and the pipeline flow cannot be made static, all welding thereon shall be made using low hydrogen electrode in accordance with the procedures set forth in document 086432 (D-22).

        2. Before welding, proper precautions shall be taken to make sure that there are no liquids in the segment of the pipeline to be welded. Install drains per documents 284303 (A-32) or 387173 (A-32.1) and check existing drains for liquids.

15. All welding shall be done in accordance with an approved welding procedure specification. Low hydrogen electrodes or gas metal arc welding shall be used if the line flow cannot be made static. If line flow is made static and welding is to be done using cellulose electrodes, the pipe at the weld location must be preheated in accordance with document 086432 (D-22).

16. Instructions for Field Application

    It is recommended that each division tabulate the maximum operating pressure permitted during the various welding operations for each transmission line or principal distribution main within the division. The tabulations should include a listing of extent of defect, permissible methods of repair and actual dimensions or other limitations on the method of repair. The tabulation should be designed to facilitate routine application of this document under emergency field conditions by repair personnel.

Cathodic Protection Requirements for Leak Repairs:

17. Install one 9-lb. magnesium anode or one 5-lb. zinc anode on each corrosion leak repair unless adequate pipe to soil potential is measured at the leak location.

Repair of Pipeline Defects

Table 1 Welding Repair Selection Table for Mains With A MAOP of 100 PSIG or Less [1]

Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Mechanical Damage: Notches, Scratches, Gouges, Grooves and Dents		
Dent - less than 10% distortion (1/2" for 4-1/2" OD. and smaller)	No Repair Required	No notches, scratches, gouges or grooves in dent
Dent - more than 10% distortion (1/2" for 4-1/2" OD or smaller)	Sleeving or Canning	Dent must not prevent proper fit up
	Replace Segment of Pipe	Entire section affected must be removed
Notch, scratch, gouge, groove - less than 50% of pipe wall thickness	Grinding	Less than 10% distortion or dent (1/2" for 4 1/2" O.D. & smaller). Pipe wall not to be reduced to less than 50% of original nominal wall thickness.
Notch, scratch, gouge, groove - more than 50% of pipe wall thickness	Grinding & Welding	Less than 10% distortion or dent (1/2" for 4 1/2" O.D. & smaller). Repair not to exceed 1/4 circumference of pipe nor 5 square inches. Not more than one repair per foot of pipe length
	Patching	Less than 10% distortion or dent (1/2" for 4 1/2" O.D. or smaller). Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches
	Sleeving or Canning	Dent must not prevent proper fit up
	Replace Segment of Pipe	Entire section affected must be removed
Corrosion Damage		
Depth less than 50% of pipe wall thickness	No Repair Required	Limitations on Methods
Depth over 50% of pipe wall thickness but less than 80% No Leakage (or as determined by a qualified engineer per Paragraph 3.A.)	Grinding & Welding	Repair not to exceed 1/4 circumference of pipe nor 5 square inches. Not more than one repair per foot of pipe length.
	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving or Canning	No Limitations
	Mueller Save-A-Valve Nipple	2" Maximum Size
	Leak Clamps	See document 283851 (B-53)
Depth 80% of pipe wall thickness or more including leaking corrosion pits	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving or Canning	No Limitations
	Mueller Save-A-Valve Nipple	2" Maximum Size
	Leak Clamps	See document 283851 (B-53)
	Replace Segment of Pipe	Entire Section Affected Must Be Removed

[1] See Footnote 1 on Page 5 for repair procedures. Also, FDP may be limited. See Note 2.G., Page 1.

Repair of Pipeline Defects

Table 2 Welding Repair Selection Table for Mains With A MAOP of 100 PSIG or Less (Continued) [1]

Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Leaks in Weld		
All	Patching	Existing Facilities Only – Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving or Canning	Existing Facilities Only
	Mueller Save-A-Valve Nipple	2" Maximum Size – Existing Facilities Only
Non-Leaking Cracks or Defects in Welds		
Any longitudinal weld crack greater than 2" long, a branch or circumferential weld crack that is more than 8% of weld length, or a crack that penetrates either the root or second bead.	Replace Segment of Pipe	Entire Section Affected Must Be Removed. If not feasible to take main out of service, install sleeve
Any longitudinal weld crack less than or equal to 2" long, a branch or circumferential weld crack less than or equal to 8% of weld length, or other defects.	Grinding or Fill Welding	If crack penetrates either the root or second bead, replace pipe segment
	Patching, Sleeving or Canning	Limitations For Patches – Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches
	Replace Segment of Pipe	Entire Section Affected Must Be Removed
Leaks in Body of Fitting or in Clamps		
All	Canning	Existing Facilities Only
	Replace Fitting or Clamp	No Limitations

[1] For repair procedures see Paragraph 4. of this document or the following applicable Gas documents:
088312 (A-60),083871 (A-61) Sleeving
282981 (A-62) Mueller nipple, leak patch
083908 (A-63) Canning
284041 (A-64) Patching
283851 (B-53) Leak repair clamps
086432 (D-22) Arc welding
Also, FDP may be limited, see Note 2.G., Page 1.

Table 3 Welding Repair Selection Table for Mains With A MAOP Greater Than 100 PSIG But Less Than 20% of the SMYS and 500 PSIG [1]

Mechanical Damage: Notches, Scratches, Gouges, Grooves and Dents		
Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Dent - less than 5% distortion (3/8" for 6-5/8" OD. and smaller)	No Repair Required	No notches, scratches, gouges or grooves in dent. No welds affected.
Dent - more than 5% distortion (3/8" for 6-5/8" OD or smaller)	Sleeving or Canning	Dent must not prevent proper fit up. Cans not to be used on main with MAOP over 400 PSIG.
	Replace Segment of Pipe	Entire section affected must be removed.
Notch, scratch, gouge, groove -Depth less than 10% of pipe wall thickness	Grinding	Pipe wall not to be reduced to less than 90% of nominal pipe wall thickness. Dent or distortion less than 5% of O.D.
Notch, scratch, gouge, groove - Depth between 10% and 30% of pipe wall thickness	Grinding & Welding	Dent or distortion less than 5% of O.D. (3/8" for 6-5/8" O.D. & smaller). Repair not to exceed 1/4 of pipe circumference nor 4 square inches. Not more than one repair per 5 pipe diameters of length.
	Patching	Dent or distortion less than 5% of O.D. (3/8" for 6-5/8" O.D. & smaller). Repair not to exceed 1/2 of pipe circumference. Length not over 10 pipe diameters on pipe over 8-5/8" O.D.. A minimum of 3" clearance between patches
	Sleeving or Canning	Dent must not prevent proper fit up. Cans not to be used on mains with MAOP over 400 PSIG.
Notch, scratch, gouge, groove -Depth less than 30% of pipe wall thickness	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving or Canning	Dent must not prevent proper fit up. Cans not to be used on main with MAOP over 400 PSIG.
	Replace Segment of Pipe	Entire section affected must be removed.

[1] See Footnote 1 on Page 8 for repair procedures. Also, FDP may be limited, see Note 2.G., Page 1.

Table 4 Welding Repair Selection Table for Mains With A MAOP Greater Than 100 PSIG But Less Than 20% of the SMYS and 500 PSIG (Continued) [1]

Corrosion Damage		
Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Depth less than 20% of pipe wall thickness	No Repair Required	Limitations on Methods
Depth between 20% and 30% of pipe wall thickness (or as determined by a qualified engineer per Paragraph 3.A.)	Grinding & Welding	Repair not to exceed 1/4 circumference of pipe nor 4 square inches. Not more than one repair per 5 pipe diameters of length.
	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving	No Limitations
Depth over 30% of pipe wall thickness but less than 80% - No Leakage. (or as determined by a qualified engineer per Paragraph 3.A.)	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
Depth over 30% of pipe wall thickness but less than 80% - No Leakage. (or as determined by a qualified engineer per Paragraph 3.A.)	Sleeving	No Limitations
	Mueller Save-A-Valve Nipple	2" Maximum Size
Depth 80% of pipe wall thickness or more (including leaking corrosion pits)	Patching	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving	No Limitations
	Mueller Save-A-Valve Nipple	2" Maximum Size
	Replace Segment of Pipe	Entire Section Affected Must Be Removed
Leaks in Weld		
All	Patching	Existing Facilities Only - Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches.
	Sleeving or Canning	Existing Facilities Only. Cans not to be used on mains with MAOP over 400 PSIG.
	Mueller Save-A-Valve Nipple	2" Maximum Size - Existing Facilities Only

[1] See Footnote 1 on Page 8 for repair procedures. Also, FDP may be limited, see Note 2.G., Page 1.

Table 5 Welding Repair Selection Table for Mains With A MAOP Greater Than 100 PSIG But Less Than 20% of the SMYS and 500 PSIG (Continued) [1]

Non-Leaking Cracks or Defects In Welds		
Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Any longitudinal weld crack greater than 2" long, a branch or circumferential weld crack that is more than 8% of weld length, or a crack that penetrates either the root or second bead	Replace Segment of Pipe	Entire Section Affected Must Be Removed. If not feasible to take main out of service, install sleeve
Any longitudinal weld crack less than or equal to 2" long, a branch or circumferential weld crack less than or equal to 8% of weld length, or other defects	Grinding and Fill Welding	If crack penetrates either the root or second bead, replace pipe segment
	Patching, Sleeving or Canning	Patch not to exceed 1/2 pipe circumference. On pipe over 8-5/8" O.D., length not over 10 pipe diameters. A minimum of 3" clearance between patches. Cans not to be used on mains with MAOP over 400 PSIG.
	Replace Segment of Pipe	Entire Section Affected Must Be Removed
Leaks In Body of Fittings or In Clamps		
All	Canning	Existing Facilities Only. Not to be used on mains with MAOP over 400 PSIG.
	Replace Fitting or Clamp	No Limitations

[1] For repair procedures see Paragraph 4 of this Gas document or the following applicable Gas documents:
088312 (A-60),083871 (A-61) Sleeving
282981 (A-62) Mueller nipple, leak patch
083908 (A-63) Canning
284041 (A-64) Patching
Also, FDP may be limited, see Note 2.G., Page 1.

Table 6 Welding Repair Selection Table for Lines With A MAOP of 20% or More of the SMYS, or 500 PSI or Greater [1]

Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Mechanical Damage; Notches, Scratches, Gouges, Grooves and Dents		
Dent - Less than 2% distortion (1/4" for O.D. less than 12.750")	No Repair Required	No notches, scratches, gouges or grooves in dent. No welds affected by dent.
Dent - More than 2% distortion (1/4" for O.D. less than 12.750")	Sleeving	Dent must not prevent proper fit up. If dent affects a weld, entire section affected must be removed.
	Replace Segment of Pipe	Entire section affected must be removed.
Notch, scratch, gouge, groove - Depth less than 10% of pipe wall thickness and less than 8% of pipe wall thickness for welded pipe 20" O.D. or larger	Grinding	Pipe wall not to be reduced to less than 90% of nominal wall thickness (92% on welded pipe 20" O.D. or larger). Dent or distortion less than 2% of O.D. (1/4" for O.D. less than 12.750").
Notch, scratch, gouge, groove – Depth 10% or more of pipe wall thickness. Design pressure less than 40% SMYS.	Sleeving	Dent or distortion must not prevent proper fit up.
Notch, scratch, gouge, groove – Depth 10% or more of pipe wall thickness. Design pressure 40% SMYS or more. (8% or more for welded pipe 20" or larger).	Replace Segment of Pipe	Entire section affected must be removed. If not feasible to take main out of service, repair with sleeve. Dent must not prevent proper fit up. If dent affects a weld, entire section affected must be removed.
Corrosion Damage		
Depth 10% or less of pipe wall thickness. [2]	No Repair Required	Limitations on Methods
Depth over 10% of pipe wall thickness but less than 80% No Leakage (or as determined by a qualified engineer per Paragraph 3.A)	Patching	Pipe of not more than 40,000 PSI SMYS. Length or width of patch not to exceed 1/2 pipe circumference. A minimum of 3" clearance between patches.
	Sleeving	No Limitations.
	Replace Segment of Pipe	Entire Section Affected Must Be Removed.
Depth 80% of pipe wall thickness or more including leaking corrosion pits.	Patching	Pipe of not more than 40,000 PSI SMYS. Length or width of patch not to exceed 1/2 pipe circumference. A minimum of 3" clearance between patches.
	Sleeving	No Limitations.
	Replace Segment of Pipe	Entire Section Affected Must Be Removed.

[1] See Footnote 1 on Page 10 for repair procedures. Also, FDP may be limited, see Note 2.G., Page 1.

[2] The allowable depth is less for ASTM A-381 material. Contact Gas Engineering & Environmental Services.

Table 7 Welding Repair Selection Table for Lines With A MAOP of 20% or More of the SMYS, or 500 PSI or Greater (Continued) [1]

Extent of Defect	Permissible Methods of Repair	Limitations on Methods
Leaks In Weld		
All	Replace Segment of Pipe	Entire section affected must be removed. If not feasible to take main out of service, repair with sleeve. Dent must not prevent proper fit up. If dent affects a weld, entire section affected must be removed.
Non-Leaking Cracks or Defects In Welds		
Any longitudinal weld crack greater than 2" long, a branch or circumferential weld crack that is more than 8% of weld length, or a crack that penetrates either the root or second bead.	Replace if Feasible to Remove From Service or Sleeve	Entire section affected must be removed. If not feasible to take main out of service, repair with sleeve. Dent must not prevent proper fit up. If dent affects a weld, entire section affected must be removed.
Any longitudinal weld crack less than or equal to 2" long, a branch or circumferential weld crack less than or equal to 8% of weld length, or other defects.	Grinding or Fill Welding	At least 1/8" wall thickness remaining. For maximum hoop stress permitted during welding, see Paragraph 2 of this document. Inspect repair. If defect remains, entire section affected must be removed. If not feasible to take main out of service, repair with sleeve. Dent must not prevent proper fit up. If dent affects a weld, entire section affected must be removed.
	Sleeving	No Limitations.
	Replace Segment of Pipe	Entire Section Affected Must Be Removed.
Leaks In Body of Fittings or In Clamps		
All	Canning	Existing Facilities Only.
	Replace Fitting or Clamp	X-ray tie-in welds of replaced fittings.

[1] For repair procedures see Paragraph 4 of this document or the following applicable documents:
033312 (A-60) Sleeving
282981 (A-62) Mueller nipple, leak patch
083908 (A-63) Canning
284041 (A-64) Patching
086432 (D-22) Arc welding
Also, FDP may be limited, see Note 2.G. Page 1.

Revision 00 has the following changes: Converted Engineering Standard 084491 (A-65) to Interleaf document 084491. Rearranged contents; completely revised text, table and graphics numbering streams; reset Revision number stream to zero.