



Engineering Procedure

SAEP-310

25 January 2018

Piping and Pipeline Repair

Document Responsibility: Piping Standards Committee

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1 Scope

- 1.1 This SAEP describes the procedures to be followed for the repair of in-plant piping and onshore pipelines, as covered by ASME B31.4, ASME B31.8, and API RP 570.
- 1.2 The methods and procedures set forth herein are minimum requirements and are not a release from the responsibility for prudent action that circumstances make advisable.
- 1.3 The repair of subsea pipelines is not within the scope of this document. The repair of subsea pipelines shall comply with SAEP-79.

2 Applicable Documents

The requirements contained in the following documents apply to the extent specified in this procedure.

2.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

<u>SAEP-306</u>	<i>Assessment of Pipeline Defects</i>
<u>SAEP-311</u>	<i>Installation of Hot Tapped and Stopple Connections</i>
<u>SAEP-321</u>	<i>Performance Qualification Testing and Certification of Saudi Aramco Welders</i>
<u>SAEP-345</u>	<i>Composite Non-Metallic Repair Systems for Pipelines and Pipework</i>
<u>SAEP-1143</u>	<i>Radiographic Examination</i>

Saudi Aramco Engineering Standards

<u>SAES-A-004</u>	<i>General Requirements for Pressure Testing</i>
<u>SAES-H-002</u>	<i>Internal and External Coating for Steel Pipeline and Piping</i>
<u>SAES-H-002V</u>	<i>Approved Saudi Aramco Data Sheets for Pipeline and Piping Coating</i>
<u>SAES-L-150</u>	<i>Pressure Testing of Plant Piping and Pipelines</i>
<u>SAES-L-310</u>	<i>Design of Plant Piping</i>
<u>SAES-L-350</u>	<i>Construction of Plant Piping</i>
<u>SAES-L-410</u>	<i>Design of Pipelines</i>

<u>SAES-L-450</u>	<i>Construction of On-Land and Near-Shore Pipelines</i>
<u>SAES-W-011</u>	<i>Welding Requirements for On-Plot Piping</i>
<u>SAES-W-012</u>	<i>Welding Requirements for Pipelines</i>
<u>SAES-X-400</u>	<i>Cathodic Protection of Buried Pipelines</i>

Saudi Aramco General Instructions

<u>GI-0002.100</u>	<i>Work Permit System</i>
<u>GI-0002.102</u>	<i>Pressure Testing Safely</i>
<u>GI-0006.012</u>	<i>Isolation, Lockout, and Use of Hold Tags</i>
<u>GI-0006.021</u>	<i>Abrasive Blast Operations</i>
<u>GI-0150.001</u>	<i>Asbestos Hazard Management</i>
<u>GI-1780.001</u>	<i>Atmosphere-Supplying Respirators</i>

Saudi Aramco Standard Drawings

<u>AB-036029</u>	<i>Typical Pipelines Repair Sleeves Installation (Non-Pressure Containing)</i>
<u>AC-036261</u>	<i>Pipeline Corrosion Barrier Patch</i>
<u>AB-036262</u>	<i>Installation of Pipeline Repair Sleeves (Pressure Containing)</i>
<u>AC-036263</u>	<i>Weld Metal Build-Up for the Repair of Pipeline Surface Defects</i>
<u>AE-036265</u>	<i>Pipeline Repair Patch for Minimum Wall Thickness Violations</i>
<u>AC-036279</u>	<i>Corrugated Weld Repair Sleeve Pipe Size 6" Through 48"</i>
<u>AA-036352</u>	<i>Galvanic Anodes for Roads and Camel Pipeline Crossing</i>
<u>AB-036381</u>	<i>Cathodic Protection Cable Connections to Pipelines and Structures</i>
<u>AB-036478</u>	<i>Magnesium Anode Installation at Pipeline Repair Locations, Layout, Sections, and Details</i>
<u>AB-036526</u>	<i>Weld over Sleeve for Repair of Leaking Sleeves on 30" & 31" O.D. Pipe</i>
<u>AC-036655</u>	<i>Tie Rod Arrangement for Weld+Ends Coupling</i>
<u>AC-036660</u>	<i>Road Crossing for Pipelines Sheets 1, 2, 3, 4</i>

AB-036880

Sleeved Crossing for Restrained Pipelines

AE-036833

Detail of Standard Pipe Repair Plug

Saudi Aramco Manuals

Saudi Aramco Construction Safety Manual

Saudi Aramco Crane Safety Handbook

2.2 Industry Codes and Standards

American Society of Mechanical Engineers

ASME B31.3

Process Piping

ASME B31.4

Pipeline Transportation Systems for Liquids and Slurries

ASME B31.8

Gas Transmission and Distribution Piping Systems

ASME B31G

Manual for Determining the Remaining Strength of Corroded Pipelines

ASME PCC-2

Repair of Pressure Equipment and Piping

American Petroleum Institute

API STD 1104

Standard for Welding Pipelines and Related Facilities

API RP 570

Piping Inspection Code: Inspection, Repair, and Re-rating of In Service Piping System

API RP 579

Fitness-for-Service

National Association of Corrosion Engineers

NACE SP0177

Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control System

American Gas Association

Gas Purging Principles and Practices

3 Definition

Anomaly: An indication, detected by nondestructive examination.

Defect: A discontinuity or discontinuities that by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications.

Dent: Permanent concave deformation of the circular cross section of the pipe that produces a decrease in the diameter.

Imperfection: Discontinuity or irregularity which is detected by inspection.

Indication: Finding from a nondestructive testing technique or method that deviates from the expected. It may or not bay be a defect.

Pyrophoric Material: Self igniting material (iron sulfide). In the absence of oxygen, sulfur compounds or hydrogen sulfide in hydrocarbon stream react with steel to form iron sulfide.

4 General Requirements

- 4.1 Any repair methods that are not addressed in this procedure shall be reviewed by the Chairman of the Piping Standards Committee.
- 4.2 Prior to commencing repair activities, defect assessment shall be conducted in accordance with SAEP-306 for pipelines, and in accordance to API RP 570 in-plant piping design to ASME B31.3.
- 4.3 Engineering calculations should be performed to determine the permissible pipe movement and the required support system during any repair.
- 4.4 Prior to commencing any repair work, a written procedure shall be developed. The procedure shall be approved by all parties involved in the repair activities.
 - 4.4.1 The procedure shall comply with GI-0002.100, “Work Permit System,” GI-1780.001, “Atmosphere-Supplying Respirators,” GI-0002.102, “Pressure Testing Safely,” and GI-0006.012, “Isolation, Lockout, and Use of Hold Tags.”
 - 4.4.2 The procedure shall include detailed requirements for safe working conditions. Repair shall be performed under qualified supervision by trained personnel aware of and familiar with hazards to personnel, public and environment. [Appendix B](#), Protection against Electric Shock from Induced Voltage and Underground Cable may be used as minimum requirements.
 - 4.4.3 The procedure shall detail the safety measures associated with all mechanized repair equipment.
 - 4.4.4 The procedure shall include all required data such as pipe diameter, wall thickness, grade, etc.

- 4.4.5 All repairs shall be tracked in accordance with Management of Change (MOC) Procedure of the operating organization.
- 4.5 In case of small leak (weeping), the pipe pressure shall be lowered to 80% of the current operating pressure if the pipe is operating at or greater than 40% SMYS. Once the pressure level has been controlled, the pipe defect shall be examined, and repaired. For other types of leaks, the pipe pressure shall be lowered to zero psig.
- 4.6 Pressure reduction, when the pipeline defects are not acceptable per SAEP-306 or API RP 579 for pipelines and in-plant piping respectively, shall be considered if the pipe is operating at greater than 40% SMYS.

Commentary Note:

Pressure reduction provides a minimum level of assurance that the defect or anomaly will not fail during the course of its examinations and repair.

5 Excavation and Burial (Buried Pipe)

- 5.1 Prior to the start of excavation, the Operation Department shall identify all underground piping and cables crossing in the vicinity of the excavation, and notify the appropriate authorities to assist in the supervision of the excavation.
- 5.2 The buried pipe shall be located by electronic locating devices, manual probing, or test excavations. The pipe locations shall be marked with brightly colored flags. If crawler dozers are used, mark and flag all lines within 60 m (200 ft) of the repair site.

Commentary Note:

Crawler dozers are used to remove sand dune in case of transportation pipelines.

- 5.3 The buried pipe depth shall be identified and marked. Manual excavation is mandatory when the pipelines depth of cover reach 1220 mm (4 ft) or the excavation is 914 mm (3 ft) adjacent to the buried pipe.
- 5.4 The underground sections of pipe requiring repairs shall be uncovered, while under pressure, in sections up to 15.24 m (50 ft) long and separated by buried sections of equal length. There is no limitation on the total length of pipeline that may be uncovered in alternating 15.24 m (50 ft) sections.
- 5.5 The working clearance around the buried pipe shall be adequate for the work being performed.

Commentary Note:

The adequacy of the working clearance around the buried pipe depends on the job to be done at the location.

- 5.6 For excavations over 1,219 mm (4 ft) deep, the sides of the pits and trenches should be sloped back to the natural repose of the soil to avoid a cave-in. Sides which cannot be sloped to natural repose shall be shored according to Saudi Aramco Construction Safety Manual.
- 5.7 Backfilling shall be according to SAES-L-450 for pipelines and SAES-L-350 for in-plant piping.

6 Pipe Defect Removal and Replacement

- 6.1 The repair of cracks, other than their complete removal, shall be reviewed by piping specialist of Consulting Services Department.
- 6.2 The minimum length of any replacement section shall not be less than two times of the pipe diameter but not shorter than 305 mm (12"). The new section shall not be installed closer than 152.5 mm (6") to an existing weld.

Commentary Note:

Minimum length of the new section is required to ensure the proper fit-up and high integrity welds. Full radiographic examination is required in some cases.

- 6.3 Prior to commencing any replacement, pipe isolation and displacing or purging of hydrocarbon procedure shall be developed according to [paragraph 4.4](#). The procedure shall ensure safe, non-combustible atmosphere in the pipe and in the vicinity of the work area. In addition, a Job Safety Analysis (JSA) shall be conducted.
 - 6.3.1 The pipe shall be isolated by blind flanges, blanks, mechanical pipeline isolation plugs or double isolation valves. The use of double isolation valves shall be in accordance with GI-0006.012 requirements. When using isolation valves, verification before and during the work is required to ensure that the valves do not leak. Bleed connection shall be installed between the two isolation valves to ensure no pressure build up. Blanks shall be designed to withstand the differential pressure in accordance with ASME B31.3.
 - 6.3.2 Testing of the atmosphere in the pipe and in the vicinity of the work area shall be conducted before the work is started and at intervals as the work progresses.
- 6.4 Pipe cut should be made with mechanical cutters. Torch cut can be performed on pipe only if the pipe is free from combustible material.

An engineering evaluation of the permissible pipe movement shall be conducted before performing pipe cut according to [paragraph 4.3](#).

- 6.5 Hydrocarbon spillage is not permitted in hot work area. In case of cross country pipelines, oil saturated sand shall be completely removed after the repair activities are done. Pyrophoric material shall be disposed to a designated area approved by Environmental Protection Department.

Pyrophoric material shall be kept wet to prevent auto-ignition. Sludge in pipelines suspected of containing iron sulfide shall be drained to an isolated area at least 32 meters away from any other flammable substance.

- 6.6 The open hydrocarbon pipe shall be isolated, when possible, by a plug prior to conducting any hot work. Vents/drains shall be installed upstream of the plug to prevent pressure build up and drain standing liquid. For the type of plugs see [Appendix C](#).

6.6.1 When installing a plug is not practical in an open hydrocarbon pipe, the isolated section shall not include any combustible atmosphere.

6.6.2 The vent/drains shall be sized to permit draining/venting the line section in one hour with atmospheric pressure. [Table A-2](#) of [Appendix A](#) can be used as a guideline to size the drain line.

- 6.7 The new replacement section shall meet the requirements of [SAES-L-410](#) and [SAES-L-450](#) for pipeline and [SAES-L-310](#) and [SAES-L-350](#) for in-plant piping.

- 6.8 The welding procedure shall be according to [Section 9](#).

- 6.9 The use of repair couplings such as Weld+Ends or equivalent is permitted only for cross country pipeline. They should be used only where it is not practical to perform the girth welds.

6.9.1 The rating of the welded repair couplings shall meet the design condition of the pipeline. The rating of unwelded couplings may be less than the design condition. In such case, pipelines with unwelded repair couplings shall be de-rated in accordance with the coupling manufacturer requirements and specifications.

6.9.2 The tie rod arrangement of repair couplings, when required, shall be installed as per Standard Drawing [AC-036655](#).

6.9.3 The repair couplings shall be installed in accordance with the manufacturer recommendations.

6.9.4 For internally coated or cement line pipe, especially-designed and fabricated couplings shall be used.

7 Repair Methods and Requirements

- 7.1 Grinding is permitted to repair stress concentrating effect such as a gouge, scratch, arch burns or grooves. The grinding contour shall be smooth.
 - 7.1.1 The limit of the metal removal shall be according to [SAEP-306](#) for metal loss criteria. The maximum metal removal shall not exceed 40% of the nominal wall thickness.
 - 7.1.2 The removal of the defect shall be verified by conducting NDE such as dye penetrant or magnetic particle inspection.
 - 7.1.3 Surface cracks can be removed by grinding. The crack shall be mapped to determine the extent of the defect.
 - 7.1.4 Grinding shall produce a smooth contour in the pipe wall. The remaining wall thickness shall be verified after each grinding pass using ultrasonic testing.
 - 7.1.5 The removal of the defect shall be verified by conducting NDE such as dye penetrant or magnetic particle inspection after grinding.
- 7.2 Weld metal build up may be used only for pipeline defects with external metal loss. The metal loss can be caused by external corrosion or gouges, groove and excessive grinding.
 - 7.2.1 Welding on pressurized pipeline shall be according to [paragraph 9.6](#).
 - 7.2.2 The maximum length or width of any individual repair area shall not exceed 102 mm (4"). The repair area shall be separated by at least 102 mm (4") from any other repair area.
 - 7.2.3 Weld metal build up shall be according to Standard Drawing [AC-036263](#).
- 7.3 Patches and half sleeve repair techniques are allowed only on pipe with specified minimum yield strength (SMYS) of 275,800 kPa (40,000 psi) or less.

Commentary Note:

Research and test have shown that the longitudinal fillet weld to pipe is a potential weak point.

 - 7.3.1 The patches shall be according to Standard Drawing [AC-036261](#).
 - 7.3.2 This method shall not be used for internal corrosion defects.
- 7.4 Pipeline Repair Sleeves

- 7.4.1 Pressure Containing Repair Sleeves, ([Figure 1](#), [Appendix A](#)) may be used for leaks or for pipe with internal corrosion defects.
- 7.4.1.1 The design of the repair sleeve shall meet the design pressure of the carrier pipe per the applicable code. It is recommended that the sleeve match the material grade and wall thickness of the carrier pipe.
 - 7.4.1.2 For leaking pipe, a steel plug according to Standard Drawing [AE-036833](#) or wooden plug shall be installed prior installing the repair sleeve. The repair sleeve shall not be welded until the leak is completely stopped and no combustible fumes are present in the annulus.
 - 7.4.1.3 The minimum length of pressure containing sleeve shall not be less than 102 mm (4"). The sleeve shall extend a minimum of 50.8 mm (2") on either side of the defect.
 - 7.4.1.4 Multiple sleeves may be used for extended defects. When the length of the sleeve or sleeves exceeds 4 pipe diameters, formal analysis is required according to paragraph 4.3 to avoid any sagging of the pipe.
 - 7.4.1.5 The repair sleeve shall be cut to provide close fit-up dimensions and installation of the sleeve shall be according to Standard Drawing [AB-036262](#).
 - 7.4.1.6 The welding of the sleeves shall be according to paragraph 9.
- 7.4.2 Butt Strap Non-Pressure Containing Repair Sleeves ([Figure 2](#), [Appendix A](#)) shall be used as corrosion barriers or to provide added reinforcement to the pipe metal loss due to external corrosion or excessive grinding. It also can be used for dents violating the applicable code.

Commentary Note:

Non-pressure containing repair sleeve shall not be used to contain internal pressure because the lap-type joint in the butt strap is not as flexible as the butt-welded seam to absorb the required strains induced while containing the internal pipeline pressure.

- 7.4.2.1 Non-pressure containing repair sleeve shall be according to Standard Drawing [AB-036029](#).
 - 7.4.2.2 Hardenable fillers such as epoxy or polyester shall be used to fill the gaps between the sleeve and the pipe in all defect locations.
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- 7.4.2.3 The circumferential welds to the carrier pipe are not mandatory. However, the annulus shall be sealed from dirt and debris. The sealant compound shall be appropriate for the conditions and expected life of the repair.
- 7.4.3 Corrugated Weld Repair Sleeves sleeve ([Figure 3](#), [Appendix A](#)) may be used for repair of leaking girth welds
 - 7.4.3.1 The repair sleeve shall be vented through the ½ vent to a safe location.
 - 7.4.3.2 The repair sleeve shall be according to Standard Drawing [AC-036279](#).
- 7.4.4 Weld over Sleeves repair sleeve ([Figure 4](#), [Appendix A](#)) may be used for Corrugated Weld Repair Sleeves suffering leaks. It is specially designed according to Standard Drawing [AB-036526](#).

Pressure containing repair sleeves, when experience cracking at the toes of the fillet welds, may be repaired by installing bridge sleeve-on-sleeve ([Figure 5](#), [Appendix A](#)). This configuration may also be used as for repair of non-leaking girth weld.
- 7.4.5 Epoxy filled repair sleeve may be used instead of non-pressure containing repair sleeve. Epoxy fill repair sleeves do not require welding to the carrier pipe. Installer shall be certified by the repair sleeve manufactures.

Commentary Note:

The repair comprises two oversized steel half-shells that are joined to encircle the damaged area, leaving an annular gap. The annulus is sealed at each end of the sleeve using a simply applied fast-setting material, and then filled at very low pressure with a stiff epoxy-based compound.

- 7.4.6 Bolt on Clamps may be used on blowouts or punctures which cannot be readily sealed by plugs.
 - 7.4.6.1 Bolt on Clamps should not be used instead of pressure containing repair sleeve unless it is economically justified.
 - 7.4.6.2 Bolt on Clamps shall not be used for pipe with general corrosion of 70% metal loss or more unless it meets manufacturer recommended thickness.
 - 7.4.6.3 Bolt on Clamps packing material shall be compatible with the service fluid.
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- 7.4.6.4 Permanent Bolt on Clamps may be welded. The maximum interpass temperature shall not exceed the maximum design temperature for packing material.
 - 7.4.6.5 Saudi Aramco's approved bolt on Clamps are acceptable for use up to their rated pressure and temperature.
 - 7.4.6.6 All coatings, rust and scale shall be removed from the pipe surface where the Bolt on Clamps circumferential seals will contact the pipe.
 - 7.4.6.7 The Bolt on Clamps seals shall not be installed in surface irregularities greater than $\pm 1/32$ ".
 - 7.4.7 Bolt on Clamp with injection sealant may be used as a temporary repair for leaking flanges or pipe to avoid plant shutdown.
 - 7.4.7.1 Formal analysis shall be conducted to evaluate the additional clamp weight on the piping system.
 - 7.4.7.2 The injection sealant shall be compatible with the service fluid and shall not affect the downstream components.
 - 7.4.7.3 The clamp shall be qualified to PCC-2 for use up to their rated pressure and temperature.
 - 7.4.7.4 The Clamp shall be monitored periodically for leaks.
 - 7.4.8 Saudi Aramco approved non-metallic repair may be used for external metal loss and plain dents. Use of non-metallic repair for other defects shall be reviewed and approved by the Chairman of the Non-metallic Standards Committee.
 - 7.4.8.1 Non-metallic repair sleeve installation procedure shall be reviewed per SAEP-345. Workers shall be certified by the non-metallic repair sleeve manufacturer..
 - 7.4.8.2 Non-metallic repair shall be used on a temporary basis for internal metal loss with inactive corrosion or known corrosion rate provided that it meets all the requirements of the SAEP-345.
 - 7.5 Bolted patch clamp (bolted clamp with elastomeric material) are permitted only in low pressure utility piping.
 - 7.6 Epoxy patch repair batch is permitted only to restore the original external profile. It shall not be used as repair by itself.
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- 7.7 Pipe defects may be removed by hot tapping. For hot tap procedure refer to SAEP-311.

8 Repair Applications

- 8.1 All in-plant piping repairs are temporary until replacement can be carried out in the next available shutdown window.
- 8.1.1 The selection of repair method for in-plant piping shall take into consideration not only the design condition, but other perceivable conditions such as upset condition and emergency.
- 8.1.2 Repair methods consist of non-metallic material such as elastomeric seals are not permitted in piping system intended to retain their integrity under external fire loading.
- 8.2 Plant piping and pipelines repair methods should be according to [Table A-1](#), [Appendix A](#). Selection of the repair method should be evaluated on the economics and the practicality of the repair methods.
- 8.3 Pipe defects that are not addressed in [Table A-1](#) should be reviewed by the Engineering Division of the Operating Department to select the proper corrective action(s).
- 8.4 When repair is required for internally coated pipes as per SAEP-306, the below options can be used:
- 8.4.1 Pressure containing and non-pressure containing welded repair sleeves based on an approved welding procedure specifications (WPS) that assures no coating damage will occur.
- 8.4.2 Bolted on Clamps for leaks, internal or external corrosion in accordance with [paragraph 7.4.6](#).
- 8.4.3 Replacing the defected segment with flanged spool.
- 8.4.4 Non-metallic repair for external corrosion, or for internal corrosion if the corrosion is mitigated.
- 8.5 Pipe with an unacceptable crack. Crack assessment shall be per SAEP-306.

9 Welding on Pipelines and Process Piping for Repairs

- 9.1 Welders and welding procedures shall be qualified according to SAES-W-011, Welding Requirements for On-plot Piping and SAES-W-012, Welding Requirements for Pipelines.
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- 9.2 All welding of patches, sleeves, and weld build-up shall be in accordance with applicable Saudi Aramco Welding Procedure Specification.
- 9.3 Welding longitudinally to the axis of the pipeline is not permitted except as approved by this procedure.
- 9.4 For carbon steels with minimum specified yield stresses (SMYS) greater than 60,000 psi, the Consulting Services Department shall be contacted for welding procedure approval.
- 9.5 Pipeline retaining residual magnetism above 20 Oe (Oersteds) shall be demagnetized before conducting any welding.

Commentary Note:

Pipelines often retain residual magnetism following a cleaning run by a Magnetic Cleaning scraper, or an inspection by MagneScan or other magnetic Flux leakage tool.

- 9.6 Welding on pressurized pipeline.
- 9.6.1 The pressure in the pipe during welding shall not exceed that calculated by the following formula:

$$P_{\max} = \frac{2S(t - 0.10)F}{OD} \quad (1)$$

Where:

- $P_{\max}$ = Maximum operating pressure of the pipeline during welding, psig
- S = Specified minimum yield strength of the pipe (SMYS), psi
- t = Minimum measured wall thickness of the pipe at the weld area, inches
- F = 0.72
- OD = Outside diameter of the pipe, inches

Commentary Notes:

- 1. The minus 0.10 inch wall thickness takes into account the molten and heat affected portion of the base metal which does not contribute to pressure containment.*
- 2. For in-plant piping designed to ASME B31.3, replace S and F in the formula with the allowable stress in Table A-1 of ASME B31.3.*

To ensure the wall thickness is thoroughly measured, a continuous ultrasonic thickness (UT) scan shall be conducted around the circumference of the pipe weld areas.

9.6.2 To further minimize the possibility of “burn through,” no welding shall be allowed in areas with a wall thickness below 5 mm or below the pressure design thickness of the pipe. Welding can be carried out on pipe containing hydrocarbon, only when there has been no combustible mixture.

9.6.3 In cases where a pipeline has been cut or ingress of air has otherwise been allowed, the air must be removed from the pipeline before welding can be performed. One method of removing the air is by putting the line in service with an adequate flow rate to ensure that the air is displaced from the pipeline. Once this has been achieved, welding can proceed with or without flow.

9.7 Non-destructive Examination

9.7.1 All welds made for the installation of pipe sleeves or patching for pressure containment, and for weld metal build-up, shall be inspected by MT or PT.

9.7.2 Welds within 19 mm or 3 times the wall thickness of the pipe from an existing girth weld shall be inspected by MT or PT.

9.7.3 Additional inspection may be requested as required by the assigned the responsible Inspection Organization.

9.7.4 Thickness measurement using ultrasonic thickness (UT) shall be taken on all pipe areas where welding is to be done.

9.7.5 The defect removal shall be verified by the same methods that detected it originally.

10 Pressure Testing

10.1 When the new pipe replacement section is to be hydrotested prior installation, the hydrotest shall be according to SAES-A-004 and SAES-L-150.

10.2 When the piping system with replacement section is to be hydrotested, the test shall be in full compliance with SAES-A-004 and SAES-L-150.

10.3 When the hydrotest is not practical, full compliance of SAES-A-004 shall be adhered to along with the following requirements:

- 1) Verification of the pipe mechanical properties through the mill certificate.
- 2) Visually inspect all mill applied welds of the spiral or longitudinally welded joint(s) of new pipe prior to installation in the pipeline.
- 3) Radiograph or ultrasonically check all suspect areas of the manufacturers' welds found to be defective by visual inspection.
- 4) Repair all manufacturers weld defects and radiograph repairs to assure defects are removed.
- 5) Visually inspect the pipe ends for proper bevel and evidence of no laminations. Repair as required.
- 6) Radiograph all butt welds required to install the new pipeline section and repair defects as required.
- 7) Provide an approve NDE In-Lieu-of Pressure Test.

11 Coatings

- 11.1 Refer to SAES-H-002 and SAES-H-002V for selection and application of internal and external coating systems.
- 11.2 Refer to GI-0006.021, "Abrasive Blast Operations," when preparing pipe surfaces for coating using abrasive blast cleaning.

12 Cathodic Protection

- 12.1 When repairs are made due to external corrosion, the proponent cathodic protection unit within the operating organization shall determine when and where supplemental "Hot Spot" cathodic protection will be used.
- 12.2 A minimum of two (2) magnesium anodes shall be used for supplemental cathodic protection. The anodes shall be installed on alternate sides of the pipeline. The placement shall be such that one anode is installed at each end of the repair area.
- 12.3 Anode requirements and installation details are found in Standard Drawings AB-036478, "Magnesium Anode Installation at Pipeline Repair Locations; Layout, Sections and Details," and AA-036352, "Galvanic Anodes for Roads and Camel Pipeline Crossing."
- 12.4 Anode connections to the pipeline shall be Thermit welded as per Standard Drawing AB-036381, "Cathodic Protection Cable Connections to Pipelines and Structures."

Revision Summary

14 March 2012	Revised the "Next Planned Update." Reaffirmed the content of the document, and reissued with no other changes.
20 July 2017	Major revision is for the normal revision cycle, and to reaffirm the contents and requirements against company needs according to latest related industry practices. Changes include: 1) Addressing the repair of internally coated pipelines. 2) Introduce new technology for mechanical pipeline isolation plug. 3) Clarify the engineering requirements for bolted-clamps with injection sealing. 4) Remove offshore from the scope due to issuance of <u>SAEP-79</u>. 5) Clarify the requirements of non-metallic repair and align with <u>SAEP-345</u>.
25 January 2018	Editorial revision paragraphs indicated in the right margin

Appendix A – Typical Metallic Repair Sleeve

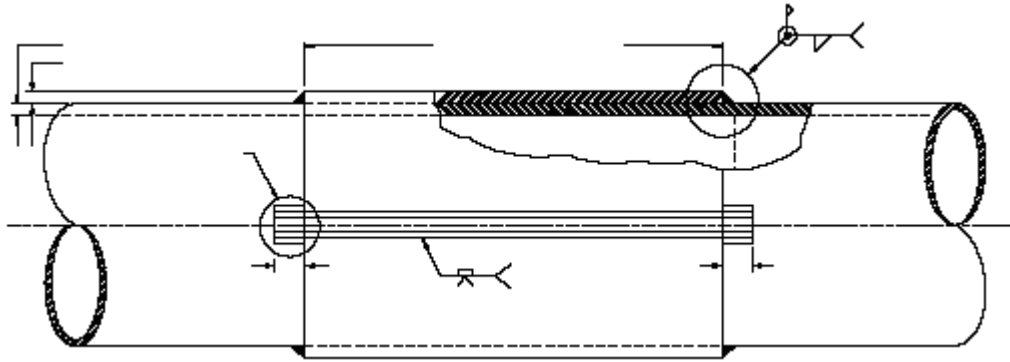


Figure 1 – Sleeve, Pressure Containing Full Encirclement Sleeve

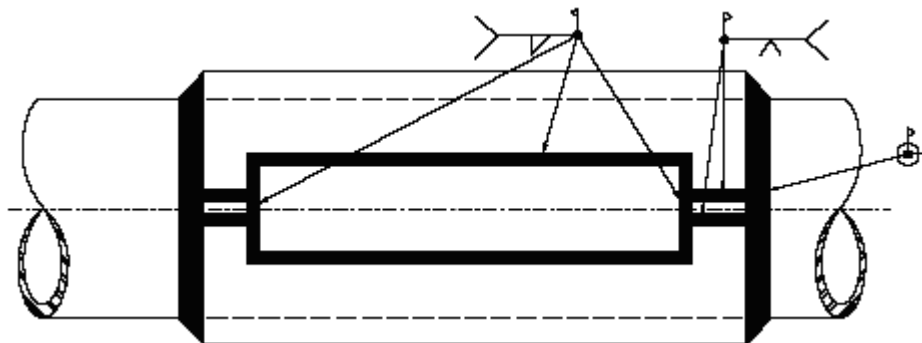


Figure 2 – Sleeve, Butt Strap Non-Pressure Containing Sleeve

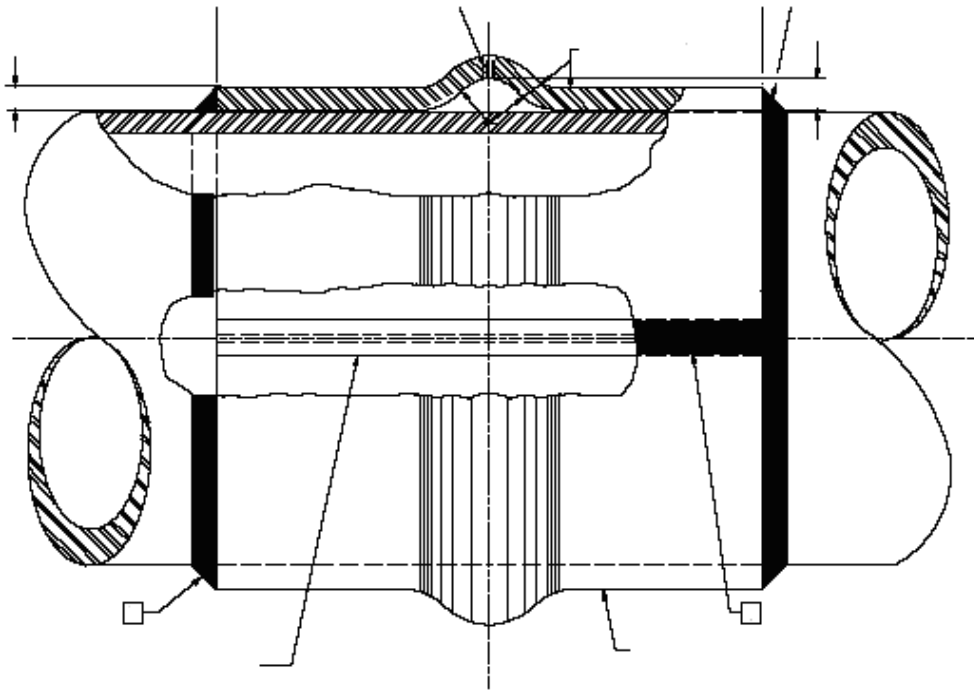


Figure 3 – Sleeve, Corrugated Weld Repair Sleeve

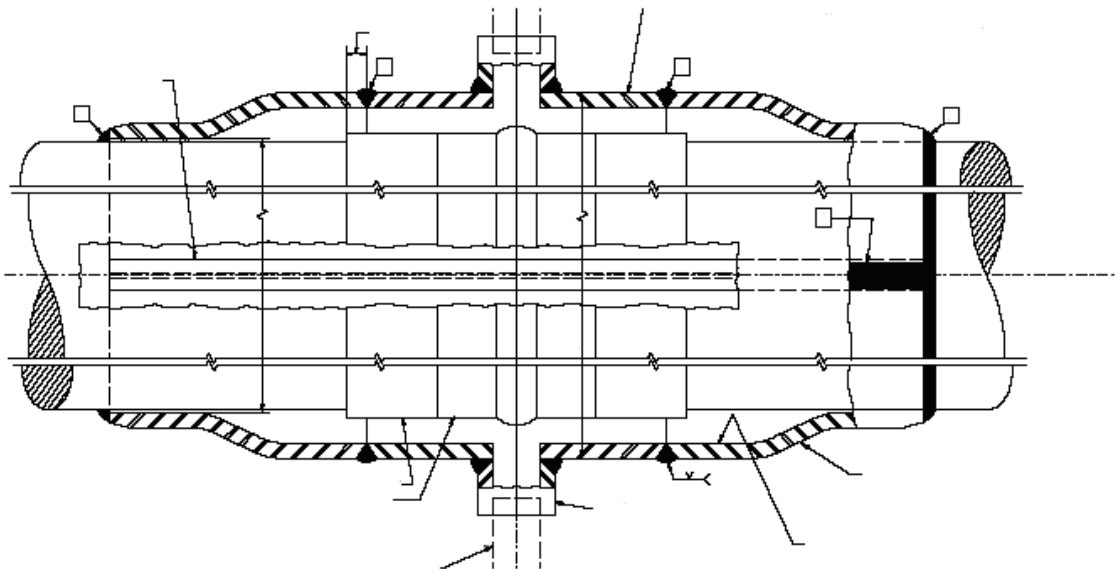


Figure 4 – Sleeve, Weld over Sleeve

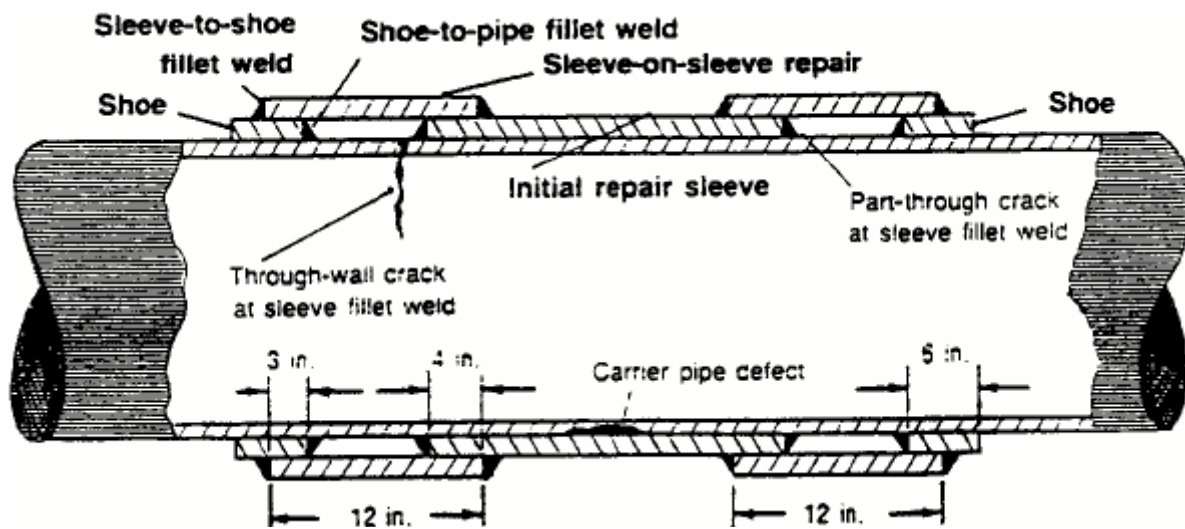


Figure 5 – Sleeve, Bridge Repair (sleeve-on-sleeve)

Appendix A-1 – Repair Method Selection Table

Table A-1 – Saudi Aramco Repair Applications¹

		Grinding	Weld metal build	Welded Patches or half Sleeve	Pressure Containing Sleeve	Non-Pressure Containing Sleeve	Epoxy Filled Repair Sleeve	Bolt on Clamps	Bolt on Clamp with Injection Sealant	Non-metallic repairs	Hot Taping
Pipe Application	Plant Piping ²	Yes	No	Yes	Yes	No	No	Yes	Yes	No ⁵	Yes
	On shore Pipeline	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Off Shore Pipeline	Yes	No	No	No	No	Yes	Yes	No	Yes	No
Defect Size	Small defect <0.5D	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Large Defect > 0.5D	No	No	No	Yes	Yes	Yes	Yes	No	No ⁵	No
Corrosion Defects	Leaks	No	No	No	Yes	No	No	Yes	Yes	No	Yes
	External Corrosion	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Pitting Lake < 0.80t	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No ⁵	No
	Pitting Lake > 0.80t	No	No	No	Yes	No	No	Yes	No	No	Yes
	Internal corrosion	No	No	No	Yes	No	No	Yes	No	No ^{5,6}	No
Mechanical Damage	Dents	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No
	Dents/ Gouge	No	No	No	Yes	Yes	Yes	Yes	No	No	No
	Wrinkle Bend	No	No	No	Yes	Yes	Yes	Yes	No	No	No
Cracks ³	Shallow Cracks ⁴ < 0.4t	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Deep Cracks > 0.4t	No	No	No	Yes	No	No	Yes	No	No	Yes
Others	Blisters	No	No	No	Yes	No	No	Yes	No	No	No
	Girth Weld Defects	Yes	Yes	No	Yes	No	No	No	No	No	No

¹ This table shall not be used without addressing the repair techniques limitations in sections [7](#) and [8](#) of the SAEP-310.

² All plant piping repair are temporary maximum until the next plan shutdown.

³ All crack defects require a qualified corrosion /metallurgy engineer to investigate the cause and review the corrective action or repair procedure

⁴ Shallow cracks shall be grinded before applying any repair techniques.

⁵ Exception to these recommendations shall be reviewed and approved by the Chairman of Non-metallic Standards Committee.

⁶ Refer to [paragraph 7.4.8.2](#) for using non-metallic repair for internal metal loss on temporary basis.

Notes: 1. Assigned inspection unit shall review the repair procedure, add any quality requirements, attend all hold points specified by inspector and approve repair work when completed.

2. For dents and external metal loss, the pipe original external profile shall be restored by applying hardenable fillers.

Table A-2: Vents/Drain Sizes

Size (in)	Approx. Capacity (barrel/hr)
1	15 - 30
2	65 - 130
3	145 - 300
4	260 - 500
6	600 - 2000
8	1,000 - 4,000

EXAMPLE: Consider 609.6 m of 6 in flow line. Contents are approximately $2,000/1,000 \times 6^2 = 72$ barrels. A 2 in drain should be provided.

Appendix B – Protection against Electric Shock from Induced Voltage and Underground Cables

This Appendix contains mandatory practices which safeguard personnel against the hazards of electric shock during the installation, operation, or maintenance of above ground and buried pipelines routed near overhead, high-voltage power lines. These practices apply to pipelines routed within 152.4 m of any energized 115-kV and 230-kV power lines, and also to 69-kV lines if parallel lengths are 1.6 km or greater.

Safety precautions to prevent shock due to induced voltage, as stated in this Appendix, for pipelines routed in the vicinity of lower voltage power lines, i.e., (4.16-kV and 13.8-kV), are normally not required.

All work on pipelines shall stop during lightning and thunderstorms.

The following conditions are not exempt from the mandatory practices of this section:

- a) Line not cathodically protected.
- b) Line section isolated by insulation flanges.
- c) Cathodic protection rectifiers and generators shutdown.

B-1 Buried Pipelines

B-1.1 No special precautions need to be taken during local excavations exposing less than 15.24 m of pipeline except when cutting into an existing line and/or removing a section of the pipeline, then Paragraph B-2.4 shall be observed. Paragraph 5.4 limits the length of pressurized piping, which can be exposed in a single excavation to 15.24 m.

B-1.2 When work on existing buried pipelines requires the exposing of 15.24 m or more of the line, it shall be regarded as an above ground pipeline. Appropriate precautions, taken in accordance with Section B-2, shall be implemented.

B-1.3 Prior to the start of excavation, the Operations Department shall identify all underground cables crossing in the vicinity of the pipeline excavation, and notify the appropriate authorities, i.e., (Power Distribution Dispatchers, SEC), to assist in the supervision of the excavation. A minimum spacing of 914 mm is required between the bottom of the pipeline and the top of the cable duct bank. Therefore, extreme care must be taken when excavating below the pipe. Normally, buried cable markers indicate the location of the cables, but they may have been inadvertently removed or never installed. When cable markers are not

shown, a safe maximum distance of 610 mm from the bottom of the pipe should not be exceeded.

B-2 Above Ground Pipelines

- B-2.1 All work on exposed pipelines shall be carried out from a wire mat that is electrically bonded to the pipeline at each end of the repair area.
- B-2.2 If the ground mat can not be bonded to the pipeline, two (2) carbon steel, 13 mm diameter studs shall be welded at each end of the pipeline repair area to provide the required grounding connections. The areas where the studs are to be welded shall be cleaned prior to welding as per SAES-W-012. If studs are removed, the weld areas shall be ground flush with the pipe and a Liquid Penetrant or Magnetic Particle Test (PT or MT) inspection shall be made to insure no harmful defects remain.
- B-2.3 Rubber gloves shall be worn for all operations on the line until the mat is properly positioned and bonded to the line. Similarly, rubber gloves shall be worn when removing the bonds.
- B-2.4 When the repair of a pipeline requires cutting an existing line or unbolting flanged connections, a flexible bonding cable, no less than No. 2 AWG, shall be attached across the section of line to be separated prior to cutting or unbolting. Bonding cables may be thermit welded to the pipe as per Standard Drawing AB-036381. The cable shall remain attached until after the line is repaired. After the removal of the of the bonding cable, the attachment areas shall be ground flush with the pipe surface and a Liquid Penetrant or Magnetic Particle Test (PT or MT) inspection shall be made to insure no harmful defects remain. Grounding mats shall not be used as a bonding cable. The cable shall be installed so that it is fully protected from movement of workers and equipment. Refer to NACE RP0177 Item No. 53039.
- B-2.5 All electric arc welding operations shall be carried out with the welding machine bonded to the ground mat and pipeline, with the welder working on the ground mat.
- B-2.6 When working on lines supported on steel structures, such as at road crossings, etc., ground mats are not necessary. However, the lines should be bonded to the steel structure to ensure a proper ground and the requirements of Paragraph B-2.4 implemented.

B-3 Valves on Above Ground and Buried Pipelines

- B-3.1 Unless noted otherwise on the Work Permit, no special precautions need to be taken when operating or maintaining valves located below ground and form part of a buried pipeline.
- B-3.2 Where metal platforms or temporary scaffolds are installed to provide access to valves on an above ground pipeline, the platforms shall be electrically bonded to the pipeline on each side of the valve before work starts. The requirements of Paragraph B-2.4 shall be observed when making and removing the bonding connection.
- B-3.3 The electrical bond shall consist of a No. 2 AWG flexible conductor, such as a welding cable, connected to the platforms at one end and terminated at the free end by a 50 amp rated test clip with insulator. Access to the platform shall be by a 36 inch square rubber mat.

Appendix C – Types of Isolation Plugs

Saudi Aramco stocks three types of plugs: Balloons, Mud Plugs and Mechanical Pipeline Isolation Plugs. However, there are many other plugs available in the market which could be used if they were proven to be equivalent or better than the types described in this Appendix. Any plug, other than a mud plug, shall be removed before the line is closed. Mud plugs normally remain in the line but may be removed, if circumstances dictate or must be removed if they contain Gypsum Plaster see C-2.5 below.

C-1 Balloons (Stopper)

The inflatable balloons have polyester cover and gum rubber bladder, bag type. They are also fitted with inflating valve nipple and hose clamp. Balloons are available in Saudi Aramco material system for nominal pipe sizes 2 through 60 inch.

C-1.1 The canvas covers of the balloons are at best only moderately fire resistant. Additional precautions that make their use safer include mud dams and inert gas purges.

C-1.2 Balloons shall be inflated carefully so as to ensure that the relatively low allowable pressures are not exceeded. A suitably graduated pressure gauge shall be utilized during inflation. For sizes 22 inch and larger, the pressure gauge shall be graduated in inches of water. [Table C-1](#) gives the maximum inflation pressure of the balloon.

C-1.3 The balloon can withstand only a small differential pressure (up to 10 psig for small diameters and only up to 1 psig for large diameters), and therefore, the job must be planned to have zero line pressure.

C-2 Mud Plugs

Mud plugs are a mixture of special types of mud with water. After preparation in the field, the mud is erected to provide the required seal. [Table C-2](#) shows a comparison between the balloon plug and mud plug.

C-2.1 The mud plug is composed of the following components:

Bentonite (clay), 23 kg sack, Material no. 1000021551

Cottonseed hull, 23 kg sack, Material no. 1000021603

Expanded Vermiculite, 15 kg sack, Material no. 1000248228

Gypsum Plaster, 45 kg sack, Material no. 100188115

- C-2.2 In building a mud plug, Bentonite should be mixed with only sufficient water to make a very stiff paste, refer to Table B-3 for guidelines of the Bentonite and water quantities.
- C-2.3 For lines larger than 305 mm diameter, light-weight material such as expanded Vermiculite can be added to reduce the tendency of the plug to slump. Mix the Bentonite and Vermiculite dry, in a mortar box. Add only enough water to make a very stiff paste as per guidelines of [Table C-3](#). The Vermiculite will shrink when handled, so try to avoid excessive mixing.
- C-2.4 Avoid the use of heavy materials in the mud mixture, such as Baryte (Baroid). They are not sticky and can only make it more difficult to build the plug up to the top of the pipe.
- C-2.5 If Gypsum plaster is used to increase the strength of the plug, it must be removed prior to closing the line.
- C-2.6 Structural support for starting a mud plug can be provided by a balloon. Effectiveness of the balloon can be increased by running a rope through the end ring to hold the balloon while the mud is forced against it. A balloon should not be used unless provisions are made for removing it after closing the line.
- C-2.7 In very large lines, a dam can be started with full sacks of Bentonite or Baryte. However, the sacks must be removed after welding is completed. As an added precaution, it may be advisable to use two plugs separated by a purged section of line.

C-3 Mechanical Pipeline Isolation Plugs

These are proprietary isolation plugs that provide high integrity isolation for in-service pipelines. These plugs shall be used in compliance with GI-0006.012, “Isolation, lockout and use of hold tags”. Any deviation to GI-0006.012 shall be approved by Loss Prevention Department. The following conditions shall be met for Mechanical Pipeline Isolation Plugs use:

- C-3.1 The isolation plug shall be contracted to a qualified vendor with extensive experience in similar applications. The actual field implementation shall be carried out by the vendor, and all personnel carrying out the isolation job shall be experienced and certified.
- C-3.2 The vendor shall provide a complete procedure for review and approval by the operating department prior to commencing any isolation activities.

- C-3.3 Vendor personnel shall be present at site for the entire duration of the mechanical isolation plug deployment.
 - C-3.4 The mechanical isolation plug shall only be used to the size, pressure, and temperature limits certified by a 3rd party such as DNV. Any deviation shall be reviewed and approved by CSD Piping Engineer.
 - C-3.5 A comprehensive Job Safety Analysis (JSA) shall be prepared and approved prior to tool utilization detailing contingency plans to be implemented for all possible scenarios.
 - C-3.6 The mechanical isolation plug shall only be used on internally bare carbon steel pipelines. Using the tool on internally coated or clad pipelines is not permitted.
 - C-3.7 The mechanical isolation plug shall have a minimum of two independent seals and zero-energy zone between the seals. The zero-energy zone pressure shall be monitored during the full duration of tool utilization. The seals shall be activated/energized via a minimum of two independent mechanisms such as hydraulic activation and differential pipeline pressure seal energization.
 - C-3.8 Seal material shall be reviewed by the vendor and accepted to be compatible with the service fluid in the pipeline.
 - C-3.9 The tool should pass a Factory Acceptance Test (FAT) at the vendor facility prior to deployment on Saudi Aramco pipelines. The FAT shall mimic the exact deployment conditions. This includes, but not limited to, pipeline size, material, thickness, pressure, and temperature. The FAT should also include strength test, seal leak test and self-energization test. A certificate of successful FAT completion shall be issued by the vendor and submitted to Saudi Aramco.
 - C-3.10 Vendor shall carry out full inspection of the pre-determined location on the pipeline where the tool will be locked in place. It is the responsibility of the vendor to determine if additional pipeline reinforcement utilizing mechanical clamps is required to provide additional pipeline structural strength. Vendor shall specify the pressure and velocity required for the plug. In addition, vendor to confirm the noise and/or vibration levels will not interfere with the mechanical isolation plug communication system.
 - C-3.11 The mechanical isolation plug should only be inserted through completely isolated scraper traps. All measures shall be taken to ensure no presence of hydrocarbon liquids, gases or vapors during the insertion and retrieval of the isolation plug.
-

C-3.12 The tool should be remotely operated with the travel and final location of the mechanical isolation plug accurately reported.

C-3.13 Mechanical pipeline isolation plug shall not be used on NGL or LPG pipelines.

Table C-1 – Maximum Inflation and P/L Pressure for Balloons of Size 2-60"

Nominal Size (in)	Maximum Inflation		
	Kpa	Psig	Water (in)
2, 3, 4, 6	03	15	413
8	83	12	330
10	69	10	275
12	55	8	220
14	48	7	193
16	41	6	165
18	38	5.5	151
20	34	5	138
22	28	4	110
14	24	3.5	97
16	22	3	83
18	17	2.5	70
20	14	2	55
22	12	1.5	41

Table C-2 – Comparison between Balloon and Mud Plug

	Balloon	Mud Plug
Location from weld	It has to be far from end of line. Balloon could rupture from heat or inadvertent puncture if close to end of line. (D)	Closer to end of line (A)
Installation	Easier to install	For large lines, mud plugs are difficult to erect. It needs careful and skillful erection Mud shrinks as it dries. Plugs that are too wet may slump and fail. For these last two reasons, cutting and welding work must be completed as soon as possible after the plug is completed. (D)
Sealing pressure	Between 1 and 10 psig	Cannot be estimated, 0 psig must be assumed. (D)
Removal	Balloons require special hot taps for insertion and removal except when they are used to weld flanges or valves to the open end of the line.	Mud plugs can be left in the line after welding. They can be washed away by the line fluid. (A)

Note: (A) is advantage (D) is disadvantage

Table C-3 – Composition of Mud Plugs

Nominal Size (in)	Bentonite (sacks)	Vermiculite (sacks)	Water		
			(m ³)	(ft. ³)	(U.S. gal)
6	1	-	0.03	1	7.5
10	2	-	0.06	2	15
12	3	-	0.08	3	2.5
16	3	2	0.08	3	22.5
20	6	4	0.17	6	45
24	9	5	0.25	9	67.5
30	14	8	0.40	14	105
36	22	13	0.62	22	164.5
40	28	17	0.80	28	209.5
42	33	20	0.93	33	247
48	50	30	0.93	50	374