

Engineering Procedure

SAEP-310

30 November 2005

Pipeline Repair and Maintenance

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Saudi Aramco DeskTop Standards

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1 Scope

This SAEP describes the procedures to be followed for the repair and maintenance of onshore pipelines, as covered by ASME B31.4 and ASME B31.8. 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. Any deviation to this SAEP requires the approval of the Manager, Consulting Services Department, Dhahran.

2 Applicable Documents

2.1 Saudi Aramco References

Saudi Aramco Engineering Standards

SAES-A-004	<i>General Requirements for Pressure Testing</i>
SAES-B-064	<i>Onshore and Nearshore Pipeline Safety</i>
SAES-H-002	<i>Internal and External Coating for Steel Pipeline and Piping</i>
SAES-H-203	<i>Hand-Applied Tape Wrapping of Buried Pipe</i>
SAES-L-046	<i>Pipeline Crossings Under Roads and Railroads</i>
SAES-L-051	<i>Construction Requirements for Cross Country Pipelines</i>
SAES-L-052	<i>Hot Tap Connections</i>
SAES-W-012	<i>Welding Requirements for Pipelines</i>
SAES-X-400	<i>Cathodic Protection of Buried Pipelines</i>

Saudi Aramco Engineering Procedures

SAEP-311	<i>Installation of Hot Tapped Connections</i>
SAEP-312	<i>Plidco Weld+Ends Couplings</i>
SAEP-313	<i>Plidco Split Sleeves</i>
SAEP-314	<i>Plidco Pipeline Repair Clamps</i>
SAEP-315	<i>Stoppling</i>
SAEP-321	<i>Performance Qualification Testing and Certification of Saudi Aramco Welders</i>

Saudi Aramco General Instructions

GI-0002.100	<i>Work Permit System</i>
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<i>GI-0002.102</i>	<i>Pressure Testing Safely</i>
<i>GI-0002.711</i>	<i>Fire and Safety Watch</i>
<i>GI-0006.012</i>	<i>Isolation, Lockout and Use of Hold Tags</i>
<i>GI-0006.021</i>	<i>Safety Requirements for Abrasive Blast Cleaning</i>
<i>GI-0150.001</i>	<i>Asbestos Regulations</i>
<i>GI-1780.001</i>	<i>Atmosphere-Supplying Respirators</i>

Saudi Aramco Standard Drawings

<i>AB-036029</i>	<i>Non-Pressure Containing Repair Sleeves with Welded Buttstraps</i>
<i>AC-036261</i>	<i>Pipeline Corrosion Barrier Patch</i>
<i>AB-036262</i>	<i>Pressure Containing Repair Sleeves with Full Penetration Butt Welded Seams</i>
<i>AC-036263</i>	<i>Weld Metal Build-Up for the Repair of Pipeline Surface Defects</i>
<i>AE-036265</i>	<i>Pipeline Repair Patch for Minimum Wall Thickness Violations</i>
<i>AC-036279</i>	<i>Corrugated Weld Repair Sleeve Pipe Size 6" Through 48"</i>
<i>AA-036352</i>	<i>Details of Installation, Galvanic Anodes for Road & Camel Pipelines Crossing, Pipeline Repair Locations</i>
<i>AB-036381</i>	<i>Cathodic Protection Thermit Welding of Cables to Buried Pipelines</i>
<i>AB-036478</i>	<i>Magnesium Anode Installation at Pipeline Repair Locations, Layout, Sections and Details</i>
<i>AB-036526</i>	<i>Weld Over Sleeve for Repair of Leaking Sleeves On 30" & 31" O.D. Pipe</i>
<i>AC-036655</i>	<i>Tie Rod Arrangement for Weld+Ends Coupling</i>
<i>AC-036660</i>	<i>Road Crossing for P/L Sht. 1, 2, 3, 4</i>
<i>AD-036786</i>	<i>Repair Sleeves (API 5L GR.65) for NGL Pipelines</i>
<i>AB-036788</i>	<i>Safety Ground Mat Plant & Details</i>
<i>AB-036880</i>	<i>Sleeved Crossing for Restrained Pipelines</i>
<i>AE-036833</i>	<i>Detail of Pipe Repair Plug</i>

AB-036899

Shoring Trenches

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 B31.4

*Liquid Transportation Systems for Hydrocarbons,
Liquid Petroleum Gas, Anhydrous Ammonia
and Alcohols*

ASME B31.8

*Gas Transmission and Distribution Piping
Systems*

ASME B31G

*Manual for Determining the Remaining Strength
of Corroded Pipelines*

American Petroleum Institute

API STD 104

*Standard for Welding Pipelines and Related
Facilities*

National Association of Corrosion Engineers

NACE RP0177

*Mitigation of Alternating Current and Lightning
Effects on Metallic Structures and Corrosion
Control Systems (Item 53039)*

American Gas Association

Gas Purging Principles and Practices

3 Instructions

3.1 Safety

3.1.1 General Mandatory Compliance

- 3.1.1.1 The detailed requirements for safe working conditions are too extensive to cover in this instruction. The job supervisor shall be familiar with all the safety equipment and existing procedures applying to work in the vicinity of combustible and poisonous products, and high energy systems. The following requirements furnish a reminder to the job supervisor.

- 3.1.1.2 The Work Permit System shall be followed in strict compliance. Job planning for work in restricted areas should include a contingency plan for possible hazards to personnel and equipment. Refer to paragraph 3.1 and GI-0002.100, "Work Permit System".
- 3.1.1.3 When different crews are working at different locations on the same pipeline, details of precautions and other work being carried out should be mentioned on all work permits.
- 3.1.1.4 Persons permitted at the work area shall be kept to a minimum to prevent congestion and to monitor the job safely. Only personnel who are necessary and/or authorized in the scope of the work shall be allowed in the work area. All work shall cease until the area is cleared of all unauthorized personnel. Refer to paragraph 3.1.4.5.9.
- 3.1.1.5 Combustible gas concentrations shall be monitored continuously in the work area during Hot Work activities such as welding, burning, or using spark producing machinery. Hot Work shall cease if any flammable gas is detected. Hot work can be restarted once the flammable concentration reaches 0% L.E.L. Portable combustible gas indicators are available under SAMS S/N 21-342-456. Refer to Sect. 3.1.4.3 and the Saudi Aramco Work Permit Form 924-2, "Hot Work".
- 3.1.1.6 Should there be any possibility of a hydrogen sulfide, H_2S , release in the area, in excess of 10 ppm concentration, all personnel in that area shall be provided with an adequate fresh air breathing device. Refer to GI-1780.001, "Atmosphere-Supplying Respirators". The hydrogen sulfide concentration in the work area shall be monitored continuously. Refer to Saudi Aramco Work Permit Form 924-1, "Release of Hazardous Liquids or Gases".
- 3.1.1.7 GI-0002.102, "Pressure Testing Safely", shall be followed during pressure testing.
- 3.1.1.8 It is Company policy to substitute safer materials for products containing asbestos. Until that goal is achieved certain interim precautions shall be implemented to minimize this hazard. Refer to GI-0150.001, "Asbestos Regulations".

3.1.2 Excavation and Burial

- 3.1.2.1 Locating of Pipe. Pipelines can be located by electronic locating devices, manual probing, or test excavations. After locating the pipeline, mark alignment with brightly colored flags. If crawler dozers are used to remove dune sand, mark and flag all lines within 60.96 m of the repair site.
- 3.1.2.2 Means of Excavation. When using heavy duty equipment for excavation, such as a dozer, discontinue use when the depth of cover from the top of the pipeline has been reduced to 1219 mm. Likewise, when excavating around the sides of the pipeline, a minimum clearance of 914 mm for a dozer and 305 mm for a Gradall must be retained to prevent accidental damage to the pipeline. All of the remaining excavation shall be done manually.
- 3.1.2.3 Uncovering Restrictions. Underground sections of pipeline requiring repairs may be uncovered, while under pressure, in sections up to 15.24 m, 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 sections. However, for restrictions necessary at transitions, sag bends, over bends and horizontal bends, consult the Area Operations Engineering Supervisor.

If it is necessary to excavate sections of the pipeline longer than 15.24 m, contact the Consulting Services Department (CSD) for the maximum excavation span.
- 3.1.2.4 Clearance for Repair. The minimum working clearance shall not be less than 400 mm all around the pipe. Refer to SAES-W-012.
- 3.1.2.5 Safe Routes of Exit. For excavations over 1219 mm 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 adequately to resist earth movement and protect workers. Minimum requirements for shoring are shown in Std. Dwg. AB-036899. Saudi Aramco Work Permit Form SA-924-4, "Confined Space Entry" is required for excavations 4 ft and deeper. Also refer to the "Saudi Aramco Construction Safety Manual".
- 3.1.2.6 Burial. Backfill to the original requirements or to a minimum of 914 mm shall be with clean sand, free of rocks or other material

which may damage the coating. Refer to SAES-L-051, paragraph 5.

3.1.3 Protection against Electric Shock from Induced Voltage and Underground Cables

This section contains mandatory practices which can safeguard personnel against the hazards of electric shock that can occur 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. Refer to SAES-B-064, paragraph 10.

Safety precautions to prevent shock due to induced voltage, as stated in Section 3.1.3, 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. Vehicles shall not park under power lines.

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

- 1) Line not cathodically protected.
- 2) Line section isolated by insulation flanges.
- 3) Cathodic protection rectifiers and generators shutdown.

3.1.3.1 Buried Pipelines

- 3.1.3.1.1 No special precautions need to be taken during local excavations exposing less than 152.4 m of pipeline except when cutting into an existing line and/or removing a section of the pipeline when Paragraph 3.1.3.2.4 shall be observed.

Commentary Note:

Pressurized pipelines are subject to a maximum excavation of 15.24 m as stated in paragraph 3.1.2.3.

- 3.1.3.1.2 When work on existing buried pipelines requires the exposing of 152.4 m or more of the line, it shall be regarded as an above ground pipeline.

Appropriate precautions, taken in accordance with Section 3.1.3.2, shall be implemented.

- 3.1.3.1.3 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, SCECO), to assist in the supervision of the excavation. SAES-B-064, paragraph 10.5 requires a minimum spacing of 914 mm 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.

3.1.3.2 Above Ground Pipelines

- 3.1.3.2.1 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. The detail of the mat is shown on Std. Dwg. AB-036788.
- 3.1.3.2.2 If the ground mat can not be bonded to the pipeline as per Std. Dwg. AB-036788, 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. Refer to SAES-W-012.
- 3.1.3.2.3 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. Gloves equal to

those specified in SAMS S/N 14-695-546, 549, 561 shall be used.

3.1.3.2.4 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 Std. Dwg. 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.

3.1.3.2.5 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.

3.1.3.2.6 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 3.1.3.2.4 implemented.

3.1.3.3 Valves on Above Ground and Buried Pipelines

3.1.3.3.1 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.

3.1.3.3.2 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

3.1.3.2.3 shall be observed when making and removing the bonding connection.

3.1.3.3.3 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 (SAMS S/N 14-106-521) with insulator (SAMS S/N 14-73-746). Access to the platform shall be by a 36 inch square rubber mat.

3.1.4 Welding and Burning Safety Rules

3.1.4.1 The appropriate Hot Work Permit, signed by the Operations Supervisor/Shift Superintendent, is required prior to the start of work. It should be emphasized that welding and/or burning on hydrocarbon pipelines is a hazardous operation and requires strict adherence to established safety rules. Failure to follow established safety rules and practices is unsafe and may cause injury or loss of life to personnel. Refer to paragraph 3.1.1.4 and GI-0002.100, "Work Permit System".

3.1.4.1.1 Fire protection equipment for the job must be onsite, properly located and manned, and in good working condition. Refer to GI-0002.711 "Fire and Safety Watch".

3.1.4.1.2 In no case shall spilled hydrocarbon be in the general vicinity of Hot Work. Oil saturated sand can be a fire hazard unless it is completely covered with clean sand. An alternative to covering with clean sand is to remove the oil saturated sand. In the case of spilled condensate, remove as much of the condensate saturated sand as possible to a safe distance away from the Hot Work. Cover the excavated area with clean sand and place a plastic cover on it. Cover the plastic with more clean sand.

3.1.4.1.3 In the absence of oxygen, sulfur compounds or hydrogen sulfide in hydrocarbon streams react with steel to form iron sulfide. This material is called "Pyrophoric" because it tends to ignite spontaneously when exposed to air. Pyrophoric material should be kept wet to prevent auto-

ignition. Sludge in pipelines suspected of containing iron sulfide should be drained to an isolated area, at least 30.48 m away from any flammable substance, and the line flushed with water. Flare lines should be inspected carefully for Pyrophoric material.

3.1.4.1.4 Combustible gas tests shall be conducted by the Operations Supervisor or his designated representative prior to and during any welding, burning, grinding or operation of any spark producing equipment in the vicinity of the open hydrocarbon line as stated in paragraph 3.1.1.4.

3.1.4.1.5 All mechanized repair equipment shall be located at a safe distance, preferably upwind and in no case less than 15.24 m from area of repair. If space permits, at least 30.48 m distance is recommended. Idle equipment shall be parked at least 60.96 m from work site. Exceptions to the above would be the use of cranes and side-booms, etc., which must be closer than 15.24 m to accomplish their job. A Hot Work Permit shall be in force when this equipment is in use. Refer to the Saudi Aramco "Crane Safety Handbook" for further safe working practices.

3.1.4.2 If welding is required on opened hydrocarbon pipelines, the line shall be cleaned, preferably by scraping, and vented. The open ends shall be plugged, when possible, to isolate the areas during the welding, burning, or grinding operations. The use of plugs and vents does not eliminate the desirability of using blinds to isolate the line. When removal of plugs after welding is a problem, such as in the case of butt welding replacement sections in a long pipeline, the entire pipeline shall be de-gassed to a safe, permissible concentration of hydrocarbon gases, O₂, H₂S, or other toxic/hazardous gases, prior to any Hot Work. Refer to paragraph 3.1.4.3. Valves, blinds, or plugs used to segregate combustible or poisonous substance from the repair area shall be identified and secured. Likewise, when venting or purging lines during Hot Work operations, associated valves must be kept in the Lock-Open position. Refer to GI-0006.012, "Isolation, Lockout, and Use of Hold Tags".

Saudi Aramco stocks three types of plugs: Balloons, Mud Plugs and Mechanical Plugs. Plugging devices can also be designed and fabricated from steel or wood and braided packing. Any plug containing pieces of metal or wood shall be removed before the line is closed.

- 3.1.4.2.1 Balloons. Inflatable balloons are available for nominal pipe sizes 2 through 60 inch, under the SAMS numbers indicated in Table 1.

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

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.

- 3.1.4.2.2 Mud Plugs

The Advantages of Mud Plugs:

- 1) A mud plug can be located closer to the end of the line where welding is being done. A balloon would be a fire hazard should it rupture from the heat or inadvertent puncture.
- 2) Mud plugs can be left in the line after welding. They can be washed away by the line fluid. 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.

The Disadvantages of Mud Plugs:

- 1) For large lines, mud plugs are difficult to erect. 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.

- 2) There is no sure way to estimate how much pressure a mud plug will hold, so the job must be planned to provide zero pressure on the plug.
- 3) They may be carelessly or unskillfully made so that they do not provide an adequate seal. Mud material is not always readily available.

The following materials used in the construction of mud plugs are available through SAMS:

Bentonite (clay), 23 kg sack
S/N 45-601-101

Cottonseed hull, 23 kg sack
S/N 45-601-323

Expanded Vermiculite, 15 kg sack
S/N 32-180-861

Gypsum Plaster, 45 kg sack
S/N 09- 255-173

In building a mud plug, Bentonite should be mixed with only sufficient water to make a very stiff paste. For lines larger than about 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. The Vermiculite will shrink when handled, so try to avoid excessive mixing. 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. If Gypsum plaster is used to increase the strength of the plug, it must be removed prior to closing the line.

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. 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.

- 3.1.4.2.3 Mechanical Plugs. Saudi Aramco stocks mechanical plugs for nominal pipe sizes 3 through 12 inch. Larger sizes may be obtained on a direct requisition form. These proprietary plugs can withstand considerable pressure, therefore, they create a much better seal than balloons or mud plugs for use in welding flanges or valves onto the open ends of operating lines. The information contained in Table 3 will aid in the use of these plugs.

Additional safety precautions for mechanical plugs can include: venting, use of mud plugs for added sealant, inert gas purges, and water seals.

- 3.1.4.3 Displacing and Purging. Displacing or purging of hydrocarbon gases requires special planning and equipment. A Displacing or Purging Procedure, written and issued by the appropriate Pipelines Operations Engineering Unit and approved by the Loss Prevention Dept., shall be followed. The following information will facilitate planning. Refer to "Purging Principles and Practice", by the American Gas Association for further information and guidance.

- 3.1.4.3.1 Displacing and purging are two methods of ensuring a safe, non-combustible atmosphere in the pipeline. A fire hazard exists when air (oxygen) is allowed to mix with a limited concentration of hydrocarbon vapor. The flammable concentration range for most hydrocarbons is between 1 to 15%.

- 3.1.4.3.2 When purging, the oxygen content shall be measured frequently with the aid of an oxygen

analyzer or an ORSAT apparatus to ensure the oxygen content is below 5%.

3.1.4.3.3 Air movers may be used to displace (remove) hydrocarbon vapors out of long sections of pipeline. Care must be taken to ensure the line is free of any sludge or residue that might produce more vapors. Scraping and flushing with water will usually insure this. It is often advantageous to force liquid out of a short line with carbon dioxide at fairly high pressure before cutting the line.

3.1.4.3.4 Purging with carbon dioxide, CO₂, fire extinguishers or bottles of inert gas, such as CO₂ or nitrogen, N₂, is often used for shorter sections of pipe. An inert gas generator may be used for larger projects. Whenever gas purging is employed, an outlet must be provided for the displaced vapors.

3.1.4.3.5 The following equipment is available under SAMS or through local vendors:

CO ₂ Cylinder, 23 kg	S/N 26-239-305
N ₂ Cylinder, 5.1 m ³	S/N 26-239-324
CO ₂ Fire Extinguisher, 4.5 kg	S/N 21-102-437
Air Mover / Ventilator	S/N 21-302-437
Inert Gas Generator	Available through direct requisition.

3.1.4.4 Venting & Draining. Balloons or mud packs are only safe when an adequate means are provided for venting gases to a place away from the open end of the pipe and monitoring pressure in the line.

3.1.4.4.1 When utilizing a balloon and mud pack as a plug, vent capabilities must be provided within 3048 mm of the repair location. The vent shall draw off vapor from the top of the pipe. If a pipe vent does not already exist, a temporary, hard piped vent line shall be run between the top of the pipe ID surface and the balloon/mud pack interface. The vent line shall be discharged downwind at least 12.2 m from the area being repaired and at least 3048 mm above grade.

3.1.4.4.2 If liquid is standing in the line at the place to be worked on, it may be necessary to tap and drain the line to a remote point at least 30.48 m from the planned Hot Work.

3.1.4.4.3 Drains should be sized to permit draining the line section in one hour with atmospheric pressure. Use the rough guide that the square of the pipeline diameter in inches equals the number of barrels in 304.8 m of pipe. Use Table 4 to determine the size of the drain.

These capacities can be increased if a vent is added to increase suction on the drain, or if an inert gas pressure (not compressed air), such as CO₂, is carefully applied through the vent opening. Care must be exercised not to inadvertently over pressurize the section of line. The vent opening, should be approximately one-fourth the nominal pipe size of the drain.

3.1.4.5 Welding on Pipelines Under Pressure

The need for welding on in-service lines has become a requirement for the repair or modification of most pipeline systems. The greatest hazard encountered with this practice is the possibility of a local "weld burn-through", sometimes called "weld metal blow-out", at the time of welding. This is caused by the heat of welding. Heat reduces the strength of the metal to support the hoop stress created by the pressure in the pipe. One way to reduce the chances of "weld blow-out" is to reduce the pressure in the pipe during welding. Likewise, increasing the wall thickness increases the capability of the pipe to sustain higher pressure and reduces the chances of "weld metal blow-out".

3.1.4.5.1 Although arbitrary, the following Formula No. 1 can be used to calculate the maximum allowable operating pressure (MAOP) of a pipeline while welding on the surface.

Formula No.1

$$P_{\max.} = \frac{2St(0.35)}{O.D.}$$

Where:

- P_{max} = MAOP of the pipeline during welding, (psig)
- S = Specified minimum yield strength of the pipe, (psi)
- t = Minimum measured wall thickness of the weld area, (in)
- OD = Outside diameter of the pipe, (in)

The calculated MAOP of the pipeline during welding is directly proportional to the minimum wall thickness of the weld area. Prior to any welding on pressurized pipelines, the responsible Operations Piping & Valves Unit/M&CED/CSD shall perform an Ultrasonic Testing (UT) inspection to determine the remaining minimum wall thickness in the weld area. As a minimum requirement for using Formula No. 1, UT wall thickness measurements shall be made every inch around the circumference of the pipe weld area.

- 3.1.4.5.2 Some pipeline operating conditions require higher MAOP values than those derived from the Formula No. 1. The following Formula No. 2 has been developed through numerous experiments on pressurized pipe to determine actual, safe pressure and wall thickness requirements for welding on pipelines under pressure. To ensure the wall thickness is thoroughly measured, consecutive, slightly overlapping, individual UT thickness measurements shall be made around the circumference of the pipe weld area.

Formula No. 2

$$P_{max} = \frac{2S(t - 0.10in.)F}{O.D.}$$

Where:

- P_{max} = MAOP of the pipeline during welding, (psig)
 - S = Specified minimum yield strength of the pipe, (psi)
 - t = Minimum measured wall thickness of the weld area, (in.)
 - F = Design factor of the pipeline (Refer to SAES-L-003, paragraph 3.2)
 - OD = Outside diameter of the pipe, (in.)
-

NOTE: 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.

3.1.4.5.3 To further minimize the possibility of "weld blow-out", no welding will be allowed in areas with a wall thickness below 5.1 mm.

3.1.4.5.4 If welding does not begin within Sixty (60) days of the initial UT thickness examination, the weld area wall thickness shall be re-examined.

3.1.4.5.5 The calculated MAOP shall be recorded on the Hot Work Permit prior to any welding on the line.

NOTE: Differences in the head pressure along the pipeline shall be considered when calculating the MAOP at the repair location.

The calculated MAOP shall be monitored during the entire welding operation. Welding shall immediately cease if the line pressure exceeds the calculated MAOP. Refer to paragraph 3.1.4.5.10.

3.1.4.5.6 All welding on pipelines under pressure shall be done with low hydrogen electrodes. For handling and storage of electrodes, refer to SAES-W-012.

3.1.4.5.7 No welding is permitted on compressed air lines while in service since they usually contain flammable, oily deposits. Refer to SAEP-311 and SAES-L-052.

3.1.4.5.8 No leaks shall be evident at the area to be welded. Refer to paragraph 3.2.3.1.

3.1.4.5.9 Repair personnel not required to directly perform the repair work should stand clear, at least 15.24 m or more away from the pipeline. The distance is dependent on the pipeline contents, process conditions, and weather. Personnel should stand upwind and be prepared to evacuate the area, if necessary, to a safe location across wind. Fire watch personnel shall be located at the repair work area as per GI-0002.711.

- 3.1.4.5.10 Prior to the start of welding, the Operations Superintendent or his designee shall ensure that the flow in the line has been established and the internal pressure of the line has been adjusted, without surges, to desired welding pressure. Welding must stop if for any reason the flow or pressure cannot be maintained within the prescribed limits. The minimum flow during welding on pipelines under pressure shall be 0.40 m/sec or the maximum attainable under normal working pressure. For water lines, refer to paragraph 3.1.4.5.11.

A stand-by man, equipped with a radio to allow continuous contact with the flow controller, must be on site throughout the welding operation to warn of flow failure or of pressure which exceeds the maximum allowable for welding purposes.

- 3.1.4.5.11 The purpose of establishing flow is to ensure that no combustible mixtures can exist on the inside of the pipe while welding on the outside. Sufficient flow must be maintained for a sufficient time to ensure that any potentially explosive gas pockets in the line have been swept clear of the weld area. The flow is not intended to keep the weld area cool, since additional cooling of the weld is undesirable. For any system where combustible mixtures are definitely not a possibility, flow is not necessary. "No-Flow" situations shall be approved by the General Supervisor Operations Engineering and the Operations Superintendent. Operations shall verify a non-combustible mixture in the line and arrangements shall be made to prevent any inadvertent introduction of hydrocarbons or oxygen into the line. This must be stated in the remarks section of the Hot Work Permit.

3.2 Pipe Repair Procedures

3.2.1 Responsibilities

Prior to starting repairs, the Maintenance Field Supervisor / Foreman shall consult with the Operations Superintendent / Foreman and the Piping & Valves Unit/M&CED/CSD Supervisor to determine:

- 1) Whether the pipeline repair can be delayed or scheduled to normal working hours.
- 2) Whether the pipeline can be repaired while in service.
- 3) The recommended method of repair and procedure.
- 4) Inspection requirements before, during, and after the repair.
- 5) The type of Work Permit(s) required.

If the decision is made to take the line out of service, the pipeline operator at the site will inform the OSPAS Planner and obtain an operating order to isolate the leak or repair location. If the repair is sufficiently complex, the appropriate Pipelines Operations Engineering Unit will draft a recommended procedure for the job.

3.2.2 Pipe Replacement

For a pipeline crack, rupture or any other case which cannot be repaired by hot tapping, patching or sleeving, the failed section shall be removed by cold cutting and a replacement section installed. Sections of pipeline can be removed during scheduled shut-down, or by using Stopples on lines in operation. Refer to SAEP-315.

3.2.2.1 The repair of cracks, other than their complete removal, shall be reviewed and approved by Consulting Services Department (CSD).

3.2.2.2 Whenever any pipeline containing hydrocarbons is to be cut or separated by opening a bolted connection, a flexible bonding cable (conductor) not less than No. 2 AWG shall be installed across the planned opening. Refer to paragraph 3.1.3.2.4.

3.2.2.3 Butt welding of replacement sections of pipeline or flanges to the open ends of pipelines for installation of spool pieces shall be carried out in accordance with Section 3.1.4, "Welding and Burning Safety Rules", and Section 3.3, "Welding".

3.2.2.3.1 The length of any replacement section (insert piece) into existing piping or pipelines shall not be less than two times the pipe diameter. If limitations do not permit the proper size insert, then both butt joints shall be fully radiographed.

- 3.2.2.3.2 The length of transition or pup pieces welded to other pipe, pipe fittings, or valves shall be 152 mm or longer. If shorter pieces are required, the associated girth welds shall be fully radiographed.
- 3.2.2.3.3 Installation of replacement pipe using Plidco Weld+Ends couplings shall be done in accordance with SAEP-312, "Plidco Weld+ Ends Couplings". These couplings are to be used where it is difficult to make a quick safe connection by any other means. Tie-rod connections, when required in concert with Weld+Ends, shall be installed as per Std. Dwg.AC-036655.
- 3.2.2.3.4 Installation of replacement pipe or the connection of pipe sections using any type of sleeve, including Plidco Split Sleeves, is not permitted.
- 3.2.2.3.5 Sections of cement lined water injection lines may be replaced using specially designed and fabricated couplings. Refer to the Consulting Services Department (CSD) for guidance in material selection and procedures.

3.2.3 Repair of Pipeline Leaks

3.2.3.1 Stopping or Diverting Leaks

Leakage must be mechanically stopped or diverted before welding a pressure containing repair sleeve to the pipe. When possible, the leak may be stopped by using a suitable wooden or steel plug (SAMS S/N 02-913-724 through 751). Refer to Std. Dwg. AE-036833 and Paragraph 3.2.3.1.1.

Alternatively, a Plidco Split Sleeve or a Plidco Repair Clamp may be used for temporary or permanent repairs. In the case where a Plidco Split Sleeve is removed for a permanent repair, it can be checked for damage and returned to stock if suitable for future use. A Plidco Weld Cap may be welded over the repair clamp for a permanent repair. Likewise, the split sleeve may also be welded for a permanent repair. Plidco Split Sleeves are high in cost compared to other methods of pipeline repair, therefore, their use should be restricted to those cases where speed of repair will provide sufficient economic justification. Refer to SAEP-313 and SAEP-314.

- 3.2.3.1.1 Steel, tapered pipe repair plugs will normally extend into the bore of the pipe and will damage the cups of pipeline scrapers, therefore, steel plugs shall not be used on lines designed to be scraped unless the tip of the plug is cut so that after installation it will not protrude more than 3.2 mm inside the pipe. This requires that the plug be screwed in place, marked, removed and cut to proper length before reinstallation. Exceptions to the use of steel plugs without trimming must be approved by the General Supervisor, Operations Engineering Division, Pipeline Department or Producing Department, as appropriate.
 - 3.2.3.1.2 Leakage from splits or holes which cannot be plugged, may be stopped by using repair sleeves with neoprene gaskets which are clamped in place. When gasketed sleeves are used without stopping leaks, a welding boss shall be installed to permit drainage of leaking oil to a point at least 30.48 m downwind from the area being repaired. It may be necessary to purge the void space between the pipe and sleeve with carbon dioxide or nitrogen to avoid a possible flammable mixture of air and hydrocarbons behind the weld area. In which case, another boss shall be installed. A fire and safety watch shall be implemented as per GI-0002.711.
 - 3.2.3.2 Special Leak Repair Sleeves
 - 3.2.3.2.1 Special sleeves may be installed as required for repair of leaks at locations such as flanges, ells, tees, reducers, and valves. Refer to the Plidco Catalog.
 - 3.2.3.2.2 Repair sleeves suffering leaks may be repaired using specially designed "Weld Over Sleeves." Refer to Std. Dwg. AB-036526.
 - 3.2.3.2.3 "Corrugated Weld Repair Sleeves" for nominal pipe sizes 6 through 48 in. may be used for repair of leaking girth welds. Refer to Std. Dwg. AC-036279. The corrugated sleeves are stocked under SAMS S/N 02-578-XXX.
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3.2.3.3 Pressure Containing Repair Sleeves

When sleeving a damaged section of pipeline, special consideration must be taken whether the repair is to contain pressure (leak), act as a barrier from further external corrosion, or to protect the line from damaging stresses, such as dents, gouges, or scratches, which may lead to the bulging and eventual rupture of the pipe.

3.2.3.3.1 If a pipeline is leaking or the minimum design wall thickness has been violated due to internal corrosion, a fully welded encirclement sleeve with longitudinal butt-welded seams shall be used in the repair. Fully welded encirclement sleeves with longitudinal butt-welded seams are preferred over sleeves containing buttstraps. The lap-type joint in the buttstrap is not as flexible as the butt-welded seam to absorb the required strains induced while containing the internal pipeline pressure. These sleeves are more suitable for use as corrosion barriers or to provide added reinforcement to the pipe where minimum design wall thickness has been violated due to external corrosion. Refer to paragraph 3.4.5.

3.2.3.3.2 Fully welded encirclement sleeves with longitudinal butt-welded seams shall use a carbon steel backing strip to avoid fusion of the longitudinal welds to the pipe. Carbon steel sheeting material, currently stocked under SAMS S/N 12-157-XXX, may be used in fabricating backing strips. The backing strips shall be thick enough to prevent burn-through to the pipe wall and wide enough to facilitate fit-up. The recommended dimensions are at least 25.4 mm wide, a minimum of 16 gauge thick, and a length to accommodate the entire sleeve.

The sleeve shall be cut to provide close fit-up dimensions for a root gap of 4.8 ± 1.6 mm, and a maximum gap of 3.2 mm between the pipe and sleeve surface around the entire circumference of the pipe. A bevel of $37 \pm 2\frac{1}{2}$ degrees shall

continue to the inside surface of the sleeve without a land. Refer to Std. Dwg. AB-036262.

The minimum length of fully welded encirclement sleeves with longitudinal butt welded seams shall be at least 102 mm. There is no maximum length limitation and multiple sleeves may be used. Refer to paragraph 3.3.3.7 and 3.2.3.3.3.

- 3.2.3.3.3 To sustain the maximum allowable operating pressure of a pipeline, the minimum design thickness of a fully welded encirclement sleeve, t_s , shall be calculated using the following formula.

Formula No. 3

$$t_s = t_p(4D_p + 1)(SMYS_p)/4[(D_p)(SMYS_s) - 2t_p(SMYS_p)]$$

Where:

D_p	outside diameter of the pipeline (inches)
D_s	outside diameter of the encirclement sleeve (inches)
t_p	nominal wall thickness of the pipeline (inches)
t_s	nominal wall thickness of the encirclement sleeve (inches)
$SMYS_p$	specified minimum yield strength of the pipeline material (psi)
$SMYS_s$	specified minimum yield strength of the sleeve material (psi)

3.2.4 Repair of Surface Defects and External Corrosion

- 3.2.4.1 Unless otherwise stated in this SAEP, the limits and disposition of pipe surface defects shall be as established in ASME B31.4, paragraph 451.6.2 and ASME B31.8, paragraph 851.4. Refer also to ASME B31 G, "Manual for Determining the Remaining Strength of Corroded Pipelines".
- 3.2.4.2 Pipelines, suffering loss of wall thickness due to external corrosion or excessive grinding and not violating minimum wall thickness requirements, require no repair, other than possible coating or wrapping. Refer to Section 3.6, "COATINGS AND WRAPPING".

3.2.4.3 Stress risers such as sharp or deep scratches, gouges, and grooves shall be removed by grinding. Care must be taken to prevent excessive grinding to avoid minimum wall violation. A PT or MT inspection shall be made to ensure these stress risers have been removed.

3.2.4.4 Dents that are in violation of the applicable Code shall be repaired by either removal of the damaged section or by applying a fully welded encirclement sleeve with butt-straps. Refer to Standard Drawing AB-036029.

3.2.4.5 Minimum Wall Thickness Violations

Non-leaking pipelines suffering minimum wall thickness violations due to excessive grinding or external corrosion may be repaired by using either weld metal build-up, specially designed repair patches, fully welded repair sleeves with welded butt straps, or replacement.

Non-leaking sections of pipeline suffering minimum wall thickness violations due to internal corrosion shall either be replaced or repaired with fully welded encirclement sleeves with longitudinal welded seams. Refer to paragraph 3.2.2 and 3.2.3.3.1.

3.2.4.5.1 Patches used to repair pipe minimum wall thickness violations shall be fabricated from a material grade equal to or higher than the pipe. The patch length or width dimensions shall not exceed 152 mm and its thickness shall be at least 1.25 times the nominal pipe wall thickness of the pipe. The patch shall be fabricated to form with the contour of the pipe and its corners shall be rounded with a minimum 51 mm radius. Refer to Std. Dwg. AE-036265.

3.2.4.5.2 Straight sleeves with buttstraps, fabricated with X60 material, are stocked under SAMS S/N 02-579-XXX. Other sleeves, fabricated with X52 material, are stocked under SAMS S/N 02-578-XXX. These sleeves are fabricated in 3048 mm lengths. Do not modify these sleeves without the consent of the Consulting Services Dept. (CSD). Refer to Std. Dwg. AB-036029.

- 3.2.4.5.3 Weld metal build-up may be used to repair small areas on pipe or fittings suffering minimum wall thickness violations due to external corrosion, gouges, grooves, or excessive grinding.

The maximum length or width of any individual repair area is limited to 102 mm. Each repair area shall be separated by at least 102 mm from any other repair area. As a minimum area, the deposited weld build-up shall be at least three (3) passes wide and 51 mm long. There are no limitations, other than economics, to the number of repair areas allowed. A decision should be made whether it is more economical to repair the damaged areas by weld build-up or by sleeving/patching. Refer to Standard Drawing AC-036263 for complete repair details.

3.2.4.6 Corrosion Barrier

External corrosion, not violating minimum wall thickness requirements, on pipelines with a specified minimum yield strength less than 448 MPa may be repaired by using a steel plate patch with rounded corners. A maximum width of one-half the circumference of the pipe and a maximum length of 3048 mm shall not be exceeded. Similarly, pipe with SMYS of 448 MPa or greater may be repaired using patches with a width or length not to exceed 152 mm. Refer to Std. Dwg. AC-036261.

3.2.5 Repairs of Hydrogen Induced Cracking (HIC) in Pipelines

If the replacement of hydrogen damaged pipelines is not chosen, then the requirements of this Section shall be followed.

- 3.2.5.1 Expose the full joint of pipe as well as a portion of the adjacent joint on each side and determine the extent of the defect indications. Continue exposing as much pipe as necessary until the extent of the area with defect indications is determined. The 15.24 m limit of exposed buried pipe as required in paragraph 3.1.2.3 shall be observed.
- 3.2.5.2 Determine the size and depth of the defects with ultrasonic testing. Ultrasonic indications may mean any of several things, including on-going cracking, corrosion damage, the presence
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of pre-existing and rather harmless laminations, or simply elongated inclusions in the steel. When ultrasonic or radiographic inspection reveals crack-like defects, further examination is required to determine the nature of the defects.

- 3.2.5.3 The HIC decision tree, (Attachment 1), assesses the severity of the hydrogen damage and provides recommendation for corrective action. Assessment may require removal by Hot-Tapping of coupons for metallurgical analysis. Refer to SAEP-311. Hydrotesting, monitoring, increased inhibition, sleeving or replacement of cracked areas may be required. No corrective action shall be taken without the concurrence of the Coordinator, Materials Engineering and Corrosion Control Division, Consulting Services Department.

3.2.6 Repairs to Sleeved and Non-Sleeved Pipeline Crossings at Roads and Railways

Pipeline leaks at road or railway crossings require immediate action and repair to minimize hazardous conditions for both pedestrians and motor traffic. After the repairs, all crossings shall be restored to the original required cover and contour.

- 3.2.6.1 Repairs to Leaking Non-Sleeved Road Crossings shall be handled in the same manner as any buried pipeline. In addition, warning signs, traffic barriers, detours, etc., will be required to direct traffic around the hazardous leak area. Refer to Section 3.2 and Standard Drawings AC-036660, Sheets 1 and 4.
- 3.2.6.2 Repairs to leaking road crossings with non-pressured sleeves shall also be handled as in paragraph 3.6.1 above and Standard Drawing AC-036660 Sheets 2 and 3.
- 3.2.6.3 Repairs to leaking road crossings with diesel filled or nitrogen, N(2), pressure sleeves shall be in accordance with Std. Dwg. AB-036880, "Sleeved Crossing for Restrained Pipelines". The existing sleeve shall be removed for inspection and repair of the pipeline, after which a new sleeve shall be installed. It should be noted that these specialized types of sleeves are no longer used.
- 3.2.6.4 A specific Job Procedure shall be prepared to cover repairs in the following situations:

- 1) Leaks inside casing sleeves under Government highways and Saudi Aramco roads that cannot be closed to traffic and railways.
- 2) Leaks in pipelines under concrete slabs.
- 3) Leaks located under pavement, shoulders and high road way berms of Government highways, military roads or Saudi Aramco roads that cannot normally be closed to traffic.

3.2.7 Repairs on Internally Coated Pipelines

- 3.2.7.1 All internal coatings, except possibly cement lining, presently in use by Saudi Aramco, are destroyed by welding. Cement lining, used for water service (including oily water), will not normally be destroyed as long as heat inputs are minimized. Refer to paragraph 3.2.2.3.5. The maximum welding interpass temp. shall not exceed 121°C. Welding (including Thermit welding), brazing, and torch cutting is not allowed on internally coated pipe, other than cement lined pipe, without the concurrence of the Operating Department. If welding is necessary, it shall be kept to a minimum, since it will destroy the adjacent internal coating. Whenever possible, flow shall be maintained during welding in order to minimize the temperature rise on the internal diameter of the pipe.

Commentary Note:

Do not mistake this situation with that of welding on lines carrying hydrocarbons.

- 3.2.7.2 Whenever possible, repairs on internally coated pipe will be made by cutting out the defective section and replacing it with a flanged, internally coated spool piece.
- 3.2.7.3 Flanges welded to the existing sound pipe must be internally coated, including the field girth weld area.
- 3.2.7.4 To minimize repair time on site, the flanges and the spool piece should be internally coated prior to transportation to the site. Remember, all field-applied epoxy paint type coatings require multiple coats and curing times of up to 7 days before they can be put into service. Refer to the SAES-H-101V Data Sheets.

3.3 Welding

Prior to any welding, the following paragraphs shall be reviewed and understood by all personnel involved with the welding operation. Both the welder and welding inspector shall be responsible for ensuring that all parameters of the welding procedure are followed during the entire welding operation. Compliance and verification by the Responsible Maintenance and Piping & Valves Unit/M&CED/CSD shall be documented on the "Saudi Aramco Pipeline Field Welding Checklist", (Attachment 2). Completed checklists shall be kept on file by the Responsible Maintenance Unit for future reference.

3.3.1 Welder and Welding Procedure Qualification

All welding shall be performed in accordance with an approved, qualified welding procedure as specified in SAES-W-012. Welders shall be qualified in accordance with SAEP-321. Also refer to SAES-W-012.

- 3.3.1.1 All welding of patches, sleeves, and weld build-up shall be in accordance with Saudi Aramco Welding Procedure Specification (WPS) Numbers PL-R1 and PL-R2.
- 3.3.1.2 Welding longitudinally to the axis of the pipeline is not permitted except as approved for repairs using patches or weld metal build-up. Refer to paragraphs 3.2.4.5 and 3.2.4.6.
- 3.3.1.3 Should any girth weld on a full encirclement sleeve be welded parallel to an existing girth weld on the pipeline at a distance less than 19 mm or 3 times the wall thickness of the pipe, whichever is greater, a MT or PT inspection will be required on both the girth welds and the heat affected zone. Likewise, patches welded within the same distance as stated above of a girth weld or a longitudinal seam weld of a pipe shall require a MT or PT inspection. It is permissible to weld across an existing longitudinal, spiral or girth weld seam of the pipeline. These welds shall be ground flush with the pipe wall when they interfere with the fit-up the sleeves or patches.
- 3.3.1.4 Procedures for installation and welding of Plidco Split Sleeves, Weld+Ends, and, Weld Caps for pipeline repairs shall be in accordance with SAEP-312, SAEP-313 and SAEP-314 and this SAEP.

3.3.2 Fit-up of Repair Sleeves with Longitudinal Butt Welded Seams

- 3.3.2.1 Refer to Std. Dwg. AB-036262 and paragraph 3.2.3.3.2 for bevel and backing strip dimensions.

- 3.3.2.2 A fit-up root gap of 3.2-6.4 mm shall be maintained for the longitudinal groove weld. If necessary, the sleeve shall be removed and the bevel faces buttered to provide the proper gap. Refer to SAES-W-012 for limitations of buttering.
- 3.3.2.3 Prior to fillet girth welding the sleeve to the pipe, a maximum fit-up gap of 3.2 mm between the two surfaces shall not be exceeded. If the fit-up gap exceeds 3.2 mm, a weld build-up (buttering) shall be made at the deficient area to reduce the distance. Do not start any fillet girth weld or tie-in weld until the fit-up gap has been reduced to 3.2 mm or less.
- 3.3.2.4 If girth clamps are used to facilitate the positioning and fit-up of the sleeves, the welder (s) shall deposit at least 9.6 mm or 25% of the weld thickness, whichever is greater, on both longitudinal welds before removing the clamps.

3.3.3 Welding Sequence of Repair Sleeves

- 3.3.3.1 The longitudinal welds on the sleeve shall be completely welded before commencing with either girth weld.
- 3.3.3.2 The welding sequence shall be such as to minimize the distortion and residual stress in the sleeve and at the same time maintain an adequate interpass temperature. On long sleeves, two welders should be welding simultaneously when possible.
- 3.3.3.3 On sleeve lengths equal to or greater than 1524 mm, both girth welds may be welded simultaneously. For sleeve lengths less than 1524 mm, one girth weld shall be completed and allowed to cool before beginning the other. Refer to Std. Dwg. AB-036262.
- 3.3.3.4 All passes on the girth fillet welds shall be in the following sequence:
 - 1) Weld from the 3:00 to 12:00 o'clock position.
 - 2) Weld from the 6:00 to 9:00 o'clock position.
 - 3) Weld from the 6:00 to 3:00 o'clock position.
 - 4) Weld from the 9:00 to 12:00 o'clock position.
- 3.3.3.5 The girth fillet welds shall be full sized and blend in smoothly with the pipe surface.

- 3.3.3.6 For sleeving pipelines greater than 16 inch diameter, two welders shall be used on opposite quadrants for each girth weld.
- 3.3.3.7 In cases where multiple sleeves are used, the adjoining sleeve ends shall be beveled, before installation, to $37 \pm 2\frac{1}{2}$ degrees without a land. A backing strip, as described in paragraph 3.3.3.2, shall be fit up to avoid fusion to the pipe in the root gap. The root gap shall be 4.8 ± 1.6 mm. For two adjoining sleeves, all of the longitudinal welds shall be completed before the adjoining or either end girth welds are made to the carrier pipe. The girth welds shall be made in order, from one end towards the other end. For sections with more than two adjoining sleeves, each additional sleeve shall be added in sequence after completing the welds on the previous sleeve.

3.3.4 Welding of Repair Patches

- 3.3.4.1 The maximum over-laying gap for all patches shall not exceed 3.2 mm.
- 3.3.4.2 Patches used to repair minimum wall thickness violations shall have full sized fillet welds that blend in smoothly with the pipe surface. The root pass shall be made using a 2.4 mm diameter electrode. Refer to Std. Dwg. AE-036265.
- 3.3.4.3 Patches used to repair external corrosion shall have a minimum 4.8 mm fillet weld around the entire circumference. The welds shall blend in smoothly with the pipe surface. Refer to Standard Drawing AC-036261.

3.3.5 Weld Build-up

- 3.3.5.1 The maximum electrode diameter for any pass shall be 3.2 mm.
- 3.3.5.2 All welds shall be made using overlapping stringers. No weaving is allowed. Refer to Std. Dwg. AC-036263 for repair area limitations, welding sequence and technique.
- 3.3.5.3 The maximum excessive weld build-up above the pipe surface shall be 1.6 mm. It is preferable to have the build-up flush with the pipe surface. In any case, the build-up surface shall be free from discontinuities which will show up during the Magnetic Particle or Penetrant Testing (MT or PT) post weld

inspection. It shall be up to the welding inspector to determine the extent of post weld surface preparation required.

3.4 Non-Destructive Examination (NDE)

3.4.1 All welds made for the installation of pipe sleeving or patching for pressure containment, and for weld metal build-up, shall have a final M.T. or P.T. inspection.

3.4.2 Other than those welds which have been particularly chosen or randomly selected in the repair procedure, additional inspection of any type on any weld may be requested by inspection.

3.4.3 All NDE interpretation shall be to API STD 104.

3.5 Pressure Testing

3.5.1 If the decision is made to hydrotest the new repair section(s) prior to installation into the pipeline, the test pressure and duration shall be as required for new pipe. Refer SAES-A-004. Duration of the test when pipe and all welds are accessible shall be only as long as required to visually inspect the pipe and all welds, but in no case less than 10 minutes.

3.5.2 If the decision is made to hydrotest the new repair section(s) after installation into the pipeline, the test pressure and duration shall be as provided in SAES-A-004, paragraph 6.2.5.

3.5.3 Sections of Pipe Foregoing Pressure Testing

When a replacement section of pipe is not hydrotested prior to being welded into an existing pipeline, a decision must be made whether or not to hydrotest the entire pipeline to test the new section. Sometimes hydrotesting the entire pipeline cannot be justified economically. If the decision is made to forego the hydrotest, full compliance of SAES-A-004, paragraph 3.2(b) shall be adhered to along with the following requirements:

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

3.5.4 Refer to GI-0008.001, "Pressure Testing Safely", prior to commencing any pressure test.

3.6 Coatings and Wrappings

3.6.1 Refer to SAES-H-002 and SAES-H-203 for selection and application of internal and external coating systems and tape wrapping for pipelines.

3.6.2 Refer to GI-0006.021, "Safety Requirements for Abrasive Blast Cleaning", when preparing pipe surfaces for coating using abrasive blast cleaning.

3.7 Cathodic Protection

3.7.1 When repairs are made due to external corrosion, the appropriate pipeline cathodic protection units shall determine when and where supplemental "Hot Spot" cathodic protection will be used.

3.7.2 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.

3.7.3 Anode requirements and installation details are found in Std. Dwgs. AB-036478, "Magnesium Anode Installation at Pipeline Repair Locations; Layout, Sections and Details", and AA-036352, "Details of Installation of Galvanic Anodes for Road and Camel Crossing and Pipeline Repair Locations".

3.7.4 Anode connections to the pipeline shall be Thermit welded as per Std. Dwg. AB-036381, "Cathodic Protection; Thermit Welding of Cables to Buried Pipe lines".

Revision Summary

30 November 2005

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with no other changes.

Table 1 – Balloons Available for Pipe Size 2-60"

NOM. SIZE (in)	MAXIMUM INFLATION			MAXIMUM P/L PRESSURE			SAMS S/N
	(kPa)	(psig)	Water (in)	(kPa)	(psig)	Water (in)	
2	103	15	413	69	10	275	02-945-450
3	103	15	413	69	10	275	02-945-453
4	103	15	413	69	10	275	02-945-455
6	103	15	413	69	10	275	02-945-458
8	83	12	330	48	7	193	02-945-461
10	69	10	275	48	7	193	02-945-465
12	55	8	220	34	5	138	02-945-469
14	48	7	193	28	4	110	02-945-471
16	41	6	165	28	4	110	02-945-473
18	38	5.5	151	21	3	83	02-945-477
20	34	5	138	21	3	83	02-945-481
22	28	4	110	14	2	55	02-945-485
24	24	3.5	97	14	2	55	02-945-490
26	22	3	83	14	2	55	02-945-492
30	17	2.5	70	10	1.5	40	02-945-545
38	17	2.5	70	10	1.5	40	02-945-550
40	14	2	55	7	1	30	02-945-556
46	14	2	55	7	1	30	02-945-560
48	14	2	55	7	1	30	02-945-562
56	12	1.5	41	6	1	30	02-945-570
60	11	1.5	41	6	1	30	02-945-575

Table 2 – Composition of Mud Plugs

NOM. SIZE (in)	BENTONITE (sacks)	VERMICULITE (sacks)	(m ³)	WATER (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

Table 3 – Richmond Wing Nut Test Plugs (A-900 Series)

Unexpanded Nominal Size	Max O.D. of Rubber (In)	Pressure (In)	SAMS S/N (Psig)*
3	2-3/4	20	02-958-074
4	3-5/8	18	02-958-078
6	5-1/2	10	02-958-082
8	7-1/2	5	02-958-086
10	9-1/2	3	02-958-090
12	11-1/2	2	02-958-094

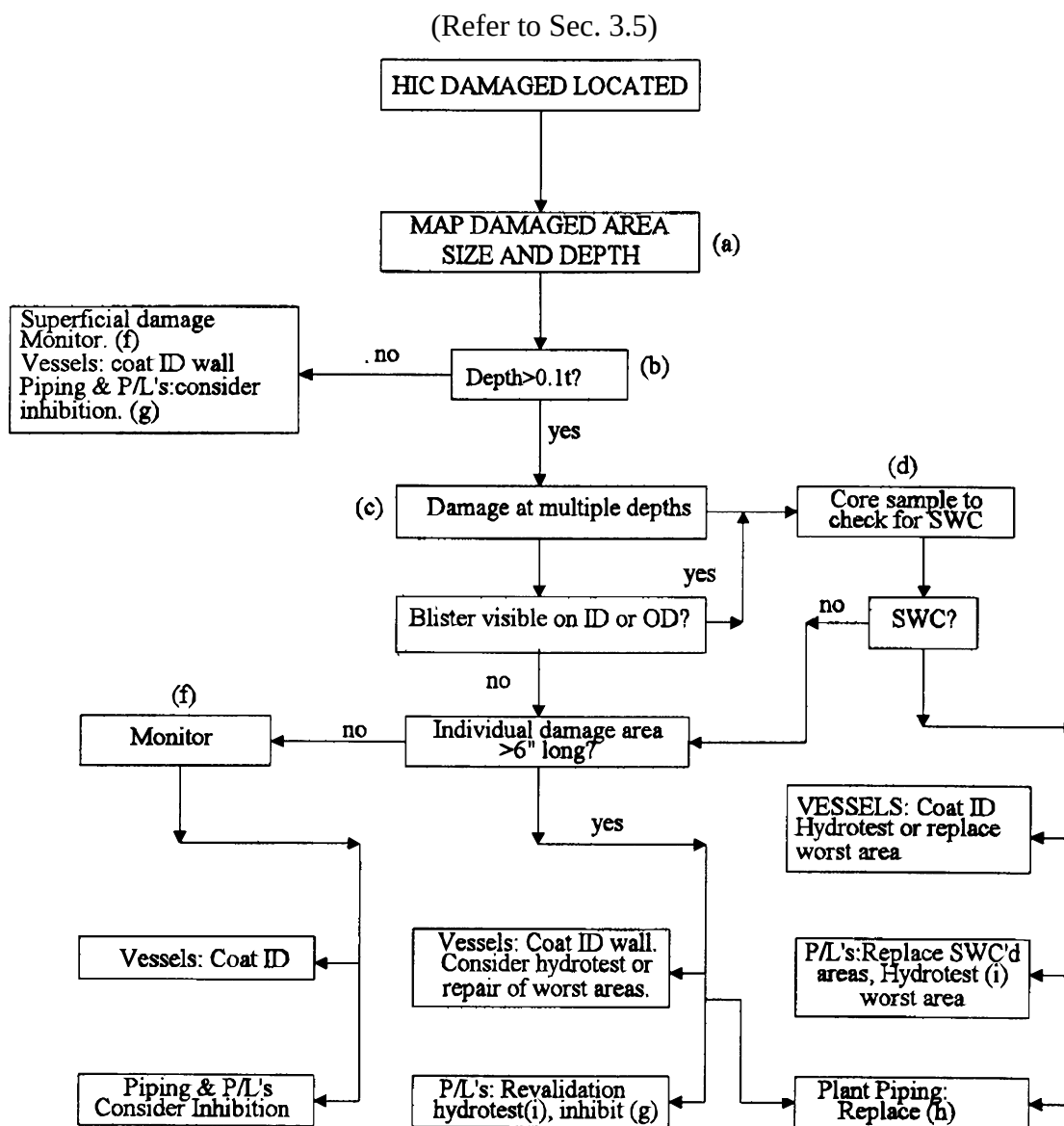
NOTE: One pound per square inch gauge (1 psig) is equivalent to a column of water 704 mm (2.31 ft) high.

Table 4

Size (in)	Approx. Capacity (barrel/hr)
1	15 - 30
2	65 - 130
3	145 - 300
4	260 - 500
6	600 - 2000
8	1000 - 4000

EXAMPLE: Consider 609.6 m of 6 in flow line. Contents are approximately $2000/1000 \times 6^2 = 72$ barrels. A 2 in drain should be provided.

Attachment 1 – Hydrogen Induced Cracking (HIC) Decision Tree



SWC = Step Wise Cracking
t = Wall thickness of vessel or pipe
Depth = defect depth below nearest surface, whether ID or OD
(a through i) See Notes, Page 38

Notes for Attachment 1 – Hydrogen Induced Cracking (HIC) Decision Tree (Cont'd)

- a) Once suspected hydrogen induced cracking (HIC) damage is located, it should be surveyed to determine the size and shape of the damaged area, whether the suspected HIC occurs as small isolated spots or nearly continuous fields, and the depths at which the suspected HIC is detected. Such surveys are normally conducted using ultrasonic examination.
- b) Before assuming that the depth of a defect is less than 0.1 t, the area should be ultrasonically examined from both inside and outside surfaces, when possible, to insure that additional areas of HIC at different depths are not masked from detection by the near-surface defect.
- c) Hydrogen blistering at mid-wall is a common manifestation of HIC. Such mid-wall blistering produces little strength loss unless accompanied by Step-Wise Cracking (SWC), in which blisters are several different depths link up at shear steps.
- d) Contact the CSD/ME&CCD/Materials Engineering Unit, for appropriate sample locations and for the metallographic examination to detect SWC.
- e) High, sharply crowned blisters may have SWC around the blister periphery which may be difficult to detect with ultrasonic examination. Sample such areas as in note (d) to check for SWC.
- f) Monitoring of items with HIC normally involves regular and frequent ultrasonic examination of the damaged area to determine whether the HIC is growing or not. If the HIC continues to grow, periodic reassessment through the decision tree will be necessary. Hydrogen evolution monitoring is used to check the inhibitor effectiveness in pipelines. In general, items with a history of HIC should also be internally inspected more frequently than similar equipment free of HIC.
- g) The inhibitor injection rates required for arresting HIC are much higher than those normally used for suppressing general corrosion. Contact the CSD/ME&CCD, for specific application details.
- h) It is assumed that arresting further HIC in plant piping, which cannot be coated in place and may be difficult to inhibit effectively, may be uncertain and thus replacement will eventually be required. The urgency of replacement will vary widely depending on operational circumstances and the extent of HIC damage. Consult the CSD/ME&CCD/MEU.
- i) If blistering is extensive, or if SWC is observed, the residual strength of the item is best determined by a hydrostatic test at a nominal stress of 90% of yield. After revalidation hydrotesting, vessels or cross-country pipelines with HIC may be continued in service provided further HIC growth is arrested with coatings, inhibitors or both. Intensive monitoring may be required.

Attachment 2 – Saudi Aramco Pipeline Field Welding Checklist

Line No. _____ F.W.: _____
O.D.: _____ Nom. Wall⁽¹⁾: _____ Grade _____

Type of Weld
Butt Weld [] Weld Repair []
Sleeve [] Patch []
Weld Build-Up [] Other [] _____

PRE-WELD INSPECTION

Check List	Maintenance Sign-Off/Date	Inspection Verification/Date
WPS No. _____	_____/_____/_____	_____/_____/_____
Welder Symbol: _____ Qualified to WPS: Y/N	_____/_____/_____	_____/_____/_____
Filler Material: _____ Size (Dia.) _____	_____/_____/_____	_____/_____/_____
Fit-Up & Cleanliness: Acc/Rej.	_____/_____/_____	_____/_____/_____

IN-PROCESS WELD INSPECTION

Check List	Maintenance Sign-Off/Date	Inspection Verification/Date
Pre-Heat: _____ °F	_____/_____/_____	_____/_____/_____
Max. Interpass Temp: _____ °F	_____/_____/_____	_____/_____/_____
Voltage: _____ Amp.: _____	_____/_____/_____	_____/_____/_____
Visual Insp. (Workmanship) Acc/Rej.	_____/_____/_____	_____/_____/_____

FINAL WELD INSPECTION

Check List	Maintenance Sign-Off/Date	Inspection Verification/Date
Final Visual Insp. Acc/Rej.	_____/_____/_____	_____/_____/_____
NDE Completed: RT [] Acc/Rej. MT [] Acc/Rej. PT [] Acc/Rej. UT [] Acc/Rej.	_____/_____/_____	_____/_____/_____

⁽¹⁾ See Notes 1 and 2 on WPS No.s P1-R1 and P1-R2 for electrode diameter and welding technique restrictions for applicable wall thickness measurement.