# Piping Maintenance And Repair

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**Note:** The source of the technical material in this volume is the Professional Engineering Development Program (PEDP) of Engineering Services.

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Identifying the Typical Types of Piping System Defects and Their Acceptance Criteria

Once a defect is identified through the examination methods that were discussed in MEX 101.09, the engineer must reference the applicable ASME/ANSI B31 Code to determine the acceptability of the defect. The piping codes provide acceptance criteria for the various types of defects. However, their focus is on new piping systems and the quality level required before a piping system can be placed into service for the first time. In existing piping systems, engineering evaluations are necessary to determine if the system still can be safely operated with unrepaired defects. The applicable piping code is normally the starting point for such evaluations, but it is often necessary to go further. Discussion of the evaluations that are needed to operate systems with defects that do not meet piping code requirements is beyond the scope of this course.

This section discusses the primary types of defects and their acceptance criteria based on ASME/ANSI B31 Code requirements.

Weld Defects

The types of weld defects that were discussed in MEX 101.09 are as follows:

- Lack of fusion between weld bead and base metal.
- Lack of fusion between adjacent weld passes.
- Incomplete penetration due to internal misalignment.
- Incomplete penetration of weld groove.
- Concave root surface.
- Undercut.
- Excess external reinforcement.

Acceptance criteria for weld defects are specified in the applicable code and are discussed in the sections that follow.
ASME/ANSI B31.3 Systems

ASME/ANSI B31.3, Table 341.3.2A, identifies acceptance criteria for welds by type of imperfection, weld type, service conditions, and required examination methods. This table is illustrated as Figure 1.

### ASME/ANSI B31.3 ACCEPTANCE CRITERIA FOR WELDS

<table>
<thead>
<tr>
<th>Kind of Imperfection</th>
<th>Normal Fluid Service</th>
<th>Severe Cyclic Conditions</th>
<th>Category D Fluid Service</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Methods</td>
<td>Types of Weld</td>
<td>Methods</td>
</tr>
<tr>
<td>Crack</td>
<td>X X</td>
<td>A A A A</td>
<td>X X X X</td>
</tr>
<tr>
<td>Lack of Fusion</td>
<td>X X A A A A</td>
<td>X X - -</td>
<td>A A A A A</td>
</tr>
<tr>
<td>Incomplete Penetration</td>
<td>X X B A NA B</td>
<td>X X - -</td>
<td>A A NA A</td>
</tr>
<tr>
<td>Internal Porosity</td>
<td>- X E E NA E</td>
<td>- X - -</td>
<td>D D NA D</td>
</tr>
<tr>
<td>(a) Slag Inclusion or Elongated Indication</td>
<td>- X G G NA G</td>
<td>- X - -</td>
<td>F F NA F</td>
</tr>
<tr>
<td>(a) Undercutting</td>
<td>X - H A H H</td>
<td>X X - -</td>
<td>A A A A A X I A H H</td>
</tr>
<tr>
<td>Surface Porosity or Exposed Slag Inclusion [Note (5)]</td>
<td>X - A A A A</td>
<td>X - - -</td>
<td>A A A A X A A A A</td>
</tr>
<tr>
<td>Surface Finish</td>
<td>- - - - - X - - -</td>
<td>J J J J J J</td>
<td>- - - -</td>
</tr>
<tr>
<td>(a) Concave Root Surface (Suck-Up)</td>
<td>X X K K NA K X - - K K NA K X K K NA K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforcement or Internal Protrusion</td>
<td>- L L L L X - -</td>
<td>L L L L X</td>
<td>M M M M</td>
</tr>
</tbody>
</table>


FIGURE 1
## ASME/ANSI B31.3 Acceptance Criteria for Welds, Cont'd

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Criterion</th>
<th>Measure</th>
<th>Acceptable Value Limits (Note 6a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Extent of imperfection</td>
<td></td>
<td>Zero (no evident imperfection)</td>
</tr>
<tr>
<td>B</td>
<td>Depth of incomplete penetration</td>
<td>Cumulative length of incomplete penetration</td>
<td>( \leq \frac{1}{4}\text{ in. (0.8 mm)} ) and ( \leq 0.2T_w )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \leq 1.5\text{ in. (38 mm)} ) in any 6 in. (150 mm) weld length</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Depth of lack of fusion and incomplete penetration</td>
<td>Cumulative length of lack of fusion and incomplete penetration (Note 71)</td>
<td>( \leq 0.2T_w )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \leq 1.5\text{ in. (38 mm)} ) in any 6 in. (150 mm) weld length</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Size and distribution of internal porosity</td>
<td></td>
<td>See BPV Code, Section VIII, Division 1, Appendix 4</td>
</tr>
<tr>
<td>E</td>
<td>Size and distribution of internal porosity</td>
<td></td>
<td>For ( T_w \leq \frac{1}{4}\text{ in. (6.4 mm)} ), limit is same as D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For ( T_w &gt; \frac{1}{4}\text{ in. (6.4 mm)} ), limit is ( 1.5 \times D )</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Slag inclusion, tungsten inclusion, or elongated indication</td>
<td>Individual length</td>
<td>( \leq \frac{T_w}{3} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Individual width</td>
<td>( \leq \frac{1}{4}\text{ in. (2.4 mm)} ) and ( \leq \frac{T_w}{3} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cumulative length</td>
<td>( \leq T_w ) in any 12 in. (300 mm) weld length</td>
</tr>
<tr>
<td>G</td>
<td>Slag inclusion, tungsten inclusion, or elongated indication</td>
<td>Individual length</td>
<td>( \leq \frac{1}{4}\text{ in. (3.2 mm)} ) and ( \leq \frac{T_w}{2} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Individual width</td>
<td>( \leq \frac{7}{6}\text{ in. (1.6 mm)} ) and ( \leq \frac{T_w}{2} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cumulative length</td>
<td>( \leq T_w ) in any 6 in. (150 mm) weld length</td>
</tr>
<tr>
<td>H</td>
<td>Depth of undercut</td>
<td></td>
<td>( \leq \frac{1}{4}\text{ in. (0.8 mm)} ) and ( \leq \frac{T_w}{4} )</td>
</tr>
<tr>
<td>I</td>
<td>Depth of undercut</td>
<td></td>
<td>( \leq \frac{1}{8}\text{ in. (0.8 mm)} ) and ( \leq \frac{T_w}{4} ) or ( \frac{1}{4}\text{ in. (6.4 mm)} )</td>
</tr>
<tr>
<td>J</td>
<td>Surface roughness</td>
<td></td>
<td>( \leq 500 \text{ min. Ra per ASME B46.1} )</td>
</tr>
<tr>
<td>K</td>
<td>Depth of root surface concavity</td>
<td></td>
<td>Total joint thickness, incl. weld reinforcement, ( \geq T_w )</td>
</tr>
</tbody>
</table>

(a) \( L \) Height of reinforcement or internal protrusion (Note 83) in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces.

For \( T_w \), in. (mm) | Height, in. (mm) |
---|---|
\( \leq \frac{1}{4} \text{ in. (6.4 mm)} \) | \( \leq \frac{1}{4}\text{ in. (1.6 mm)} \) |
\( \frac{1}{4} \text{ in. (6.4 mm)} \) | \( \frac{1}{4}\text{ in. (3.2 mm)} \) |
\( \frac{1}{2} \text{ in. (12.7 mm)} \) | \( \frac{1}{2}\text{ in. (6.4 mm)} \) |
\( \frac{3}{4} \text{ in. (19.0 mm)} \) | \( \frac{3}{4}\text{ in. (12.7 mm)} \) |
\( \geq 1 \text{ in. (25.4 mm)} \) | \( \geq 1\text{ in. (25.4 mm)} \) |

(b) \( M \) Height of reinforcement or internal protrusion (Note 88) as described in L. Note (9) does not apply.

Limit is twice the value applicable for \( L \) above

\[ \times = \text{required examination} \quad \text{NA} = \text{not applicable} \quad \ldots = \text{not required} \]


**FIGURE 1, CONT'D**
For example, under normal service conditions:

- The presence of cracks of any kind or size is completely unacceptable for all weld types.

- The maximum depth of incomplete penetration in girth-groove welds is limited to 0.8 mm (1/32 in.) and 0.2 $T_w$ over a maximum length of 38 mm (1.5 in.) in any 150 mm (6 in.) weld length. $T_w$ is the nominal wall thickness of the thinner of two components that are joined by a butt-weld.

Note that the requirements for longitudinal-groove welds are more stringent. No amount of incomplete penetration is at all acceptable. This greater conservatism is understandable since the longitudinal weld resists the circumferential pipe pressure stress, and that typically determines the required wall thickness of the pipe. Thus, any incomplete penetration of a longitudinal weld could easily result in pipe overstress.

- Depth of undercut is limited to 0.8 mm (1/32 in.) and $T_w$/4 in girth-groove welds, but no undercut is permitted in longitudinal-groove welds.

**ASME/ANSI B31.4 Systems**

ASME/ANSI B31.4 requires that API 1104, *Welding of Pipelines and Related Facilities*, be used as weld acceptance criteria for inadequate penetration and incomplete fusion, burn-through, slag inclusions, porosity or gas pockets, cracks, accumulation of discontinuities, and undercut. ASME/ANSI B31.4 requires that all arc burns, cracks, and other defects exceeding the acceptance criteria be removed or repaired.

**ASME/ANSI B31.8 Systems**

For ASME/ANSI B31.8 piping systems, the degree of weld inspection and associated inspection criteria is based on the intended operating conditions of the system.

For welds on piping systems intended to operate at less than 20% of the specified minimum yield strength:

*The quality of welding shall be checked visually on a sampling basis and defective welds shall be repaired or removed from the line.*
No specific weld acceptance criteria are provided, indicative of the *low-risk* nature of the services involved.

For piping systems operating at higher stress levels, more stringent criteria are specified. The minimum extent of weld inspection is specified based on Location Class, and acceptance criteria are to be per API-1104.

**Dents**

A dent is a gross disturbance in the curvature of the pipe wall that typically is caused by an external blow or pressure. Acceptance criteria for dents is specified best in ASME/ANSI B31.4, Paragraphs 434.5 and 451.6.2, and ASME/ANSI B31.8, Paragraph 841.243. ASME/ANSI B31.3 does not contain acceptance criteria for dents.

- The depth of a dent is measured as a gap between the lowest point of the dent and a prolongation of the original pipe contour in any direction.
- Dents which affect the pipe curvature at the pipe seam or any girth weld shall be removed as a cylinder by cutting out the damaged portion of the pipe.
- Dents that contain a stress concentrator, such as a scratch, gouge, groove, or arc burn, shall be removed by cutting out the damaged portion of the pipe as a cylinder.

**ASME/ANSI B31.4 Systems**

- Dents that exceed a depth of 6 mm (0.25 in.) in pipe NPS 4 and smaller, or 6% of the nominal pipe diameter in sizes greater than NPS 4, shall be removed in pipelines that operate at a hoop stress greater than 20% of the specified minimum yield strength of the pipe.
- Insert patching, overlay, or pounding out of dents are not permitted in pipelines that operate at a hoop stress greater than 20% of the specified minimum yield stress.
ASME/ANSI B31.8 Systems

- Dents that exceed a depth of 6 mm (0.25 in.) in pipe NPS 12 and smaller, or 2% of the nominal pipe diameter for pipe over NPS 12, are not permitted in pipelines that operate at a hoop stress greater than 40% of the specified minimum yield strength.
- When dents are removed, the damaged pipe section is to be removed as a cylinder.
- Insert patching and pounding out dents are not permitted.

Cracks

Cracks represent linear separations of metal under stress. Although sometimes large, cracks are often very narrow separations within the weld or adjacent base metal. Typical cracks are illustrated in Figure 2.

TYPICAL CRACKS IN WELD METAL

FIGURE 2
Cracks of any kind or extent are always unacceptable in new piping system construction. However, as noted earlier, it is sometimes acceptable to continue operating an existing piping system on a temporary basis with the cracks unrepaired, provided that a thorough engineering evaluation has found this to be safe.

Corrosion

Corrosion is the deterioration of metal by chemical or electrochemical attack. It may occur in many interrelated forms. Listed below are the most prevalent forms of corrosion that are encountered in process plant and pipeline piping systems, and their acceptance criteria.

Uniform Corrosion

This is the most common form of corrosion and is characterized by uniform attack over the entire surface of the metal. Uniform corrosion most prominently occurs in acid, caustic, and hydrocarbon services. The rate of uniform corrosion commonly is expressed as penetration in mils (.001 in.) per year (MPY) or millimeters (mm) per year (mm/a). This is the only form of corrosion for which the corrosion rate (MPY or mm/a) is significant.

Pipe shall be replaced, repaired if the area is small, or operated at a reduced pressure if general corrosion has reduced the wall thickness to less than the calculated required design thickness (as discussed in MEX 101.03). The actual pipewall thicknesses, determined by measurement, are compared to the required value in order to make this replacement/repair/downrating decision. Ideally, the needed inspections and engineering evaluations are done periodically so that these needs can be anticipated and planned for.

Pitting

This is a form of localized corrosion that occurs at small areas randomly located on a metal surface. The initiation period that is required for visible pits to appear depends on both the specific metal and the corrosive environment. This period can extend from several months to years. However, once a pit is initiated, rapid penetration of the metal may occur.

Detection of pits can be difficult because of their small initial size, and because pits are often covered by corrosion products. Detection difficulty, coupled with the highly localized nature of pitting, often results in the sudden failure of components.
Pitting is most likely to occur in stagnant or low-velocity fluids where there is a break in the electrical continuity of a metal surface in contact with an electrolyte. Examples of such discontinuities are rough spots, scratches, or indentations.

ASME/ANSI B31.4 is the only B31 Code that has specific criteria for evaluating pitting. These are discussed below.

**ASME/ANSI B31.4 Pitting Evaluation** — Pipe shall be repaired, replaced, or operated at a reduced pressure if localized corrosion pitting has reduced the wall thickness to less than the calculated minimum required design thickness, decreased by an amount equal to the manufacturing tolerance applicable to the pipe or component. This applies if the length of the pitted area is greater than that permitted by the equation shown below. The following method applies only when the depth of the corrosion pit is less than 80% of the nominal wall thickness of the pipe. This method does not apply to corrosion in the girth or longitudinal weld or related heat-affected zones. The corroded area must be clean to bare metal. Care shall be taken in cleaning corroded areas of a pressurized pipeline when the degree of corrosion is significant.

\[
L = 1.12B \sqrt{D} t_n
\]

\[
B = \sqrt{\left(\frac{c}{t_n} - 0.15\right)^2 - 1}
\]

where:  
L = Maximum allowable longitudinal extent of the corroded area as shown in Figure 3, in.  
B = A value not to exceed 4.0, which may be determined from the above equation or Figure 3.  
D = Nominal outside diameter of the pipe, in.  
t_n = Nominal wall thickness of the pipe, in.  
c = Maximum depth of the corroded area, in.
PARAMETERS USED IN ANALYSIS OF THE STRENGTH OF CORRODED AREAS

Source: ASME/ANSI B31.4 - 1989. With permission from the American Society of Mechanical Engineers.

FIGURE 3
Hydrogen Blisters

Another type of corrosion phenomenon which can occur in piping is hydrogen blistering. In this case, hydrogen, in atomic form, diffuses into the surface of the carbon steel pipe. The atomic hydrogen then collects in discontinuities of the metal and forms molecular hydrogen. Because molecular hydrogen will not diffuse through the steel, the pressure builds up inside the voided area and causes a rupture of the metal. The ruptured area is confined to a local area and appears on the surface of the metal in the form of blisters or fissures. Hydrogen blistering occurs most commonly in an aqueous medium which contains cyanides and a mild corrosive.

Evidence of hydrogen activity can sometimes be detected on the external surfaces of pipe by the blistering or flaking of paint films, or even by blistering of the steel itself. If test probes are, or can be, located in the suspect areas, hydrogen activity can be confirmed by cleaning the surface back to bare metal and applying two coats of a flexible paint.

Hydrogen blisters do not necessarily affect the strength or integrity of a pipe. However, there are no simple criteria that may be used to evaluate their acceptability. An engineering evaluation is required to determine if there is adequate local strength remaining in the pipe with the blisters. Discussion of this evaluation is beyond the scope of this course. Blisters typically will be vented to the inside or outside of the pipe to prevent a continuing pressure buildup, which could cause more extensive damage.

Of more concern is whether blisters are accompanied by cracking, since this condition could lead to a more extensive pipe failure. GI No. 434 provides general guidelines and a decision tree regarding hydrogen blisters. The following highlights several aspects of this.

- Determine the complete extent of blistering by visual and ultrasonic inspection. Measure the size and shape of the blister; note whether blisters are small and isolated or are in nearly continuous fields.

- Inspect the affected areas by radiography and/or ultrasonic examination to determine the extent and depth of internal cracking or laminations.

- Extensive blistering or ultrasonic evidence of cracks requires an engineering evaluation of the line by the CSD/CCD/Materials Engineering Unit. Periodic monitoring may be required to determine whether the cracked area is growing. Derating or removal from service may be required, depending on the extent of the problem and whether it is growing.
Identifying the Various Repair Methods and Techniques and Their Applications

Once an unacceptable defect is found, it must be repaired, the pipe must be replaced, or the piping system must be downrated. There are several options available, and the choice of which one to use is based on the type of defect, service conditions, and individual circumstances. For example, repair options that require welding may not be suitable for services with a flammable fluid. Saudi Aramco General Instructions 434 and 441 specify safety requirements for specific repair methods. These are beyond the scope of this course and will not be discussed in this module; however, the Saudi Aramco engineer must refer to GI 434 and 441 for special repair instructions.

The table below summarizes the various repair methods that may be considered with each type of defect. Work Aid 1 outlines a process for determining a suitable repair method for a particular situation. The paragraphs that follow discuss specific repair techniques.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Potential Repair Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld Defect</td>
<td>Weld Repair</td>
</tr>
<tr>
<td>Dent</td>
<td>Pipe Replacement</td>
</tr>
<tr>
<td>Nick, Scratch, Gouge</td>
<td>Weld Overlay</td>
</tr>
<tr>
<td>Crack</td>
<td>Weld Repair, Welding Ring</td>
</tr>
<tr>
<td>General Corrosion</td>
<td>Pipe Replacement, Overlay Patch, Repair Sleeve, Welding Ring</td>
</tr>
<tr>
<td>Pitting Corrosion</td>
<td>Pipe Replacement, Overlay Patch, Repair Sleeve, Welding Ring, Fitting</td>
</tr>
<tr>
<td>Hydrogen Blisters</td>
<td>Pipe Replacement, Repair Sleeve</td>
</tr>
</tbody>
</table>

Weld Repairs

If a weld defect is not acceptable, it must be repaired. Weld repair is similar to new-construction welding. The same procedures and safety guidelines must be followed. General weld repair procedures are specified in the appropriate ASME/ANSI B31 Code and Saudi Aramco standards. However, a detailed discussion of weld repair is beyond the scope of this course. In general, weld repair is performed in the following manner:

- Remove or grind out the defective portion to get to sound base metal.
- Using an appropriate weld procedure, repair the weld in the same manner as used for new-construction welding.
- Inspect the weld as discussed in MEX 101.09.
Weld repair sleeves with a corrugation to accommodate the girth weld may be used for repair of leaking girth welds for nominal pipe sizes 150 through 1,200 mm (6 in. through 48 in.).

Pipe Plugs

Depending on the context, pipe plugs are used to:

- Temporarily block off the contents of a pipe from the remainder of the system to permit needed repairs or modifications.
- Repair holes that are caused by corrosion through a pipe that result in leaks.

To stop relatively small leaks, a metal plug may be driven into the opening and secured by welding.

There are three types of pipe plugs that may be considered for system isolation:

- Balloons
  - For NPS 2 to NPS 60
- Mud
  - For NPS 6 to NPS 48
- Mechanical
  - For NPS 3 through 12, with larger sizes available on special order.

Saudi Aramco GI 434.000 specifies use and acceptance criteria for each type of system isolation plug. For example, a mud plug can be located close to the end of a line where welding is done, where the location would be a fire hazard for a balloon plug.
Repair Clamps

Plidco repair clamps, manufactured by the Pipeline Development Company, as shown in Figure 4, are handy and efficient for stopping pit leaks in pipe where it is known or expected that plugs will be ineffective. Based on GI 441.013, repair clamps may be used for:

- Temporary repair of pipe operating at a temperature between -7°C (20°F) and 107°C (225°F) if authorized by the Operations Superintendent. However, in many areas, an ordinary steel plug, or a gasket applied with banding strap, may be more economical and effective.

- Permanent repairs of water lines, or oil and product lines. In the case of water lines, the unwelded clamp may be left as a permanent repair. In the case of oil and product lines, the clamp may not be left as a permanent repair unless it is installed and welded based on GI 441.013 requirements using a weld-cap-type cover. In this case, the welded cap becomes a primary pressure-containing boundary placed over the plug/clamp assembly. A permanent repair must be made within three months of installing the repair clamp on oil or product lines.

Refer to Figure 4. A repair clamp is installed by loosely bolting the clamp onto the pipe near the leak, positioning the plug over the leak, inserting the pilot pin into the leak, tightening the clamp, and screwing the steel packing force-screw down into the leak. The pointed cone of the elastomeric material, such as Buna-N, seals the leak by acting as packing. The thrust washer permits the force-screw to turn without also rotating the cone.

**PLIDCO REPAIR CLAMP**

![Diagram of PLIDCO Repair Clamp]

A. Pilot Pin [1.5 mm (1/16"") Diam. Stainless Steel Wire]
B. Steel Packing Force-Screw
C. Thrust Washer
D. Pointed Cone of Buna-N (or Silicone, Fluoro-carbon or Other Specified Material) Serves as Leak Packing

**FIGURE 4**
Welded Pipe Sleeves

Welded pipe sleeves shall be used to provide full-encirclement reinforcement for corroded areas larger than those that can be covered with patches, and to stop leaks that cannot be plugged. Either standard or field-fabricated sleeves may be used per GI 434.000.

Welded Pipe Patches

Welded patches may be used to repair nonleaking sections of pipe that have experienced excessive external thinning. The patch must be fabricated from a material grade that is equal to or higher than that of the pipe. The patch dimensions must not exceed 152 mm (6 in.), it must have rounded corners, its thickness must be at least 1.25 times the nominal pipewall thickness, and conform to the pipe curvature. Refer to Standard Drawing AE-036265 and GI 434.000 for fabrication and welding requirements.

Weld Overlays

Weld metal overlays may be used to repair small areas of pipe or fittings that have experienced excessive external corrosion, nicks, scratches, gouges or grinding. The maximum length or width of any individual repair area is 102 mm (4 in.). The deposited weld metal shall be at least three passes wide and 50 mm (2 in.) long. Each weld-repaired area must be at least 102 mm (4 in.) from any other weld-repaired area.

Plidco Weld+Ends

Weld+Ends couplings are used when it is virtually impossible to make a quick and safe repair by other means. Weld+Ends join pipe as shown in Figure 5 so that flow can be resumed in the fastest possible time without the need for preparing the pipe ends for welding and then making the circumferential closure weld. Weld+Ends couplings are high in cost compared to other methods of connecting pipe ends. However, their use permits the rapid installation of a replacement pipe section and resumption of flow without welding. Welding may be done after resuming the operation. GI 441.011 contains installation requirements, temperature and pressure limitations. The MAOP of an installed Weld+Ends coupling depends on the specific coupling design details, and whether it is welded to the pipe.

Refer to Figure 5. The clamping screws are initially used to tighten the coupling to each of the pipe ends. The thrust screws are then tightened against each thrust ring. The thrust ring advances to compress the packing against both the central portion of the coupling body and the pipe surface. The compressed packing forms a tight seal and prevents leakage.
PLIDCO WELD-ENDS COUPLING

FIGURE 5

PLIDCO SPLIT SLEEVE

FIGURE 6
Plidco Split Sleeves

Plidco split sleeves are used to:

- Permanently repair small splits, holes, or ruptures which cannot be plugged or patched readily and where downtime for draining oil from a line is excessive.

- Provide quick, temporary repairs without welding on urgently required pipelines, which can be removed from service later for permanent repairs.

- Provide temporary repairs to process lines within plant limits where economically justified. However, in these cases, sleeve pressure and temperature limitations must be considered, and the sleeve must be removed for permanent repair in approximately three months.

As referenced in Figure 6, the split sleeve halves are positioned around the pipe such that the leak is located between the two rings of packing. When the sleeves are bolted, the packing is compressed against the pipe surface which contains the leak.

Plidco split sleeves are high in cost compared to other methods of repair. Therefore, their use should be restricted to those cases where speed of repair will provide sufficient economic justification. GI No. 441.012 contains installation instructions, and pressure and temperature limitations for split sleeves. Split sleeves cannot be used to connect two sections of pipe.

Pipe Replacement

If a pipe cannot be repaired by any of the repair methods discussed, it must be replaced. Pipe replacement is necessary if:

- The defect is well beyond repair.

- The defect is too expensive to repair.

- The repair method cannot work.

In most cases, the pipe may be replaced using the same material, diameter, and wall thickness as in the original installation. However, in some cases, the nature of the defect may indicate that some change is necessary. For example, if a pipe section must be replaced due to general corrosion in half of its anticipated design life, then thicker and/or different pipe material may be required.
Sample Problem 1

A 305 m (1000 ft.) long section of an aboveground 900 mm (36 in.) outside diameter crude oil pipeline has recently been inspected. Decisions are required regarding what to do with the inspection results, i.e., nothing, repair, or replace. If repair will be done, an appropriate approach must be determined in each case. If any pipe sections must be replaced, the line cannot be taken completely out of service since it is critical. Minimum crude oil flow needs can be provided if a temporary 600 mm (24 in.) diameter bypass is placed around the pipeline section that is to be removed.

The following design information is available:

- Design pressure = 5,171 kPa (750 psig)
- Design temperature = 49°C (120°F)
- Pipe material: API 5L, Gr. B, Electric Resistance Welded, E = 1.0, Minimum Yield Strength = 241 MPa (35,000 psi)
- The nominal (new) wall thickness of the 900 mm (36 in.) pipeline was 15.9 mm (0.625 in.), and the minimum required thickness for pressure is 13.5 mm (0.53 in.)
- If a new 600 mm (24 in.) bypass line is required, it will have a nominal wall thickness of 14.3 mm (0.562 in.) and a minimum required thickness for pressure of 9.1 mm (0.36 in.).

The following inspection results are available.

- A 30 m (100 ft.) section of pipe has been corroded to a relatively uniform thickness of 12.2 mm (0.48 in.).
- There are pitted sections of the pipe in areas of otherwise sound metal having the original design thickness. This occurs in small sections of the line where the flow is sometimes stagnant. The maximum pit depth is 10 mm (0.4 in.) over a maximum length along the pipe axis of 50 mm (2 in.).
- A 13 mm (0.5 in.) deep dent was made in one portion of the line by a piece of construction equipment. There are no scratches, gouges, grooves, or other stress risers in the dent. The dent is 3 m (10 ft.) from the nearest circumferential-weld seam, and on the opposite side of the pipe from the longitudinal-weld seam.
Solution

The inspection results identified three defects in the pipeline: uniform corrosion, pitting, and a dent. These must be evaluated individually for acceptance.

- The uniform corrosion to a depth of 12.2 mm (0.48 in.) is not acceptable since the minimum required pipe thickness for pressure is 13.5 mm (0.53 in.). The pressure in the pipeline should be downrated until this situation is resolved. Since the minimum required thickness for the 5,171 kPa (750 psig) design pressure is known, a safe downrated pressure can be calculated from the following equation, based on the current amount of corrosion.

\[
P = \frac{0.48}{0.53} \times 750
\]

\[
P = 679 \text{ psig}
\]

However, if the cause of the corrosion cannot be eliminated, the pressure must be further reduced to account for future corrosion.

- A calculation must be made to determine if the length of the pitted area is acceptable.

\[
B = \sqrt{\left(\frac{c}{t_n}\right)^2 - 1}
\]

\[
B = \sqrt{\left(\frac{0.4}{0.625} - 0.15\right)^2 - 1}
\]

\[
B = 0.57
\]
The maximum length of the pitted area is 50 mm (2 in.) and is less than L. Since the maximum pit depth of 10 mm (0.4 in.) is less than 80% of the pipe nominal thickness, nothing needs to be done immediately. However, the cause of the pitting should be found and corrected, the inspection interval shortened, and/or repair of the line planned before the pipe holes through.

- This is an ASME/ANSI B31.4 piping system since it is a crude oil pipeline. For such a system, a dent may be up to 6% of the pipe diameter before it must be removed, $0.06 \times 36 = 2.16$ in. in this case, if the system is operating at over 20% of the pipe specified minimum yield strength. Since the dent is smaller than this, it is acceptable. Note also that the pipe stress did not need to be calculated in this case since the dent is well below the limit anyway. However, for completeness, the hoop stress can be calculated from the following equation.

$$S = \frac{PD}{2Et_n}$$

$$S = \frac{750 \times 36}{2 \times 1 \times 0.625}$$

$$S = 21600 \text{ psi}$$

$$\frac{S}{S_y} = \frac{21,600}{35,000} = 0.617 = 61.7\% \text{ of the yield strength}$$.

- Of the three defects found and evaluated, only the 30 m (100 ft.) section of unacceptable uniform corrosion requires immediate attention. The only practical repair alternative in this case is to replace the section of pipe.
Identifying the Design, Calculation, Inspection, and Testing Requirements for a Hot Tap

Hot tapping is another method that is used for repair, maintenance, or making system modifications. Hot taps provide a means to add connections to piping, pressure vessels, and other process equipment and tankage without disrupting normal operating conditions. Hot taps can also be used to make connections into equipment where it would be impractical to prepare the equipment for hot work, such as for large pressure vessels or storage tanks, or long runs of piping. Connections that are attached by hot tapping can also be used for plugging or stoppling to isolate sections of piping. Stoppling, or pressure plugging for the installation of plugs, is performed for repairs on (or to remove) a section of line without interrupting service. However, hot taps should be used only where it is impractical to take the equipment out of service.

A hot tap is performed by:

- Welding a suitably sized and reinforced nozzle to the pipe. This nozzle has a flanged end.
- Pressure testing the nozzle branch connection.
- Bolting a full-port valve to the flanged nozzle, and bolting a hot-tap machine to the valve.
- Opening the valve and using the hot-tap machine cutter to cut an opening in the pipe and to hold the cut piece.
- Extracting the cut piece of pipe (i.e., the coupon) through the valve and into the cutting machine housing.
- Closing the valve and removing the hot-tap machine.
Figure 7 illustrates the basic arrangement for making a hot tap and illustrates the primary components. These are highlighted as follows:

- **Stopple or tapping fitting**: A specially designed branch connection that is welded to the pipeline.

- **Tapping Valve**: A full-bore valve that permits closing off the branch connection after the hot tap has been completed. A new pipe section can be bolted on to the flanged valve as required after the hot tap has been completed.

- **Pilot**: A relatively small-diameter drill that is attached to the cutter and makes the initial cut into the pipeline. The pilot also contains the mechanism that will retain the coupon after the cut has been made.

- **Cutter**: The drill bit that makes the required diameter hole into the pipeline.

- **Cutter Holder**: The end of the boring bar to which the cutter is attached. This arrangement permits the attachment of different sized cutters to the boring bar.

- **Boring Bar**: The shaft that is attached to the tapping machine which transmits the applied force and rotation from the machine to make the cut.

- **Tapping Machine**: The powered or hand-operated unit that performs the hot tap operation.

- **Adapter**: A fitting which provides a flanged interface between the standard flange diameter at the bottom of the hot-tap machine and the required flange diameter of the new branch connection.
BASIC ARRANGEMENT OF A HOT TAP

FIGURE 7
A stoppling operation is conceptually illustrated in Figure 8.

- Four hot taps are made such that the section of pipeline that is repaired or replaced is located between them.

- A temporary bypass line is installed between the two outer hot-tapped connections. The bypass line is used to continue flow while the pipeline section is repaired or replaced.

- The inner two hot-tapped connections are used to install stopple-plugging machines. These machines insert plugs into the pipeline which block flow. The section of pipeline may be repaired or replaced once the flow has been blocked and the bypass line is in operation.

- After the new or repaired section of pipeline has been installed, the plugs and bypass line may be removed.

The Saudi Aramco Engineer may be asked to approve a hot tap, identify if a hot tap is necessary, or develop the hot tap design details. Therefore, he must know the design, inspection, and testing requirements for a hot tap. This information can be found in SAES-L-052, ADP-L-052, GI 441.010, GI 441.015, and Form A-7627.
TYPICAL PROCEDURE OF PLUGGING WITHOUT SHUTDOWN

FIGURE 8
Procedural and Design Requirements

The following are general procedural and design requirements for a hot tap.

- The Initiating Engineer completes Section 1 of Form A-7627, *Hot Tap/Stopple & Reinforcement Calculation Request*, by providing general descriptive information. The form is routed to the Area Operations Engineer.

- The Area Operations Engineer completes Section 2 of Form A-7627 by supplying operating data. The form is routed to the Area Projects or Operations Inspector.

- The Inspector supplies header data, including wall thicknesses, in Section 3 of Form A-7627. If special provisions are required for access to make the needed inspection, the Initiating Engineer makes arrangements with Maintenance.

- The Initiating Engineer forwards completed Form A-7627 to the controlling party, who assigns responsibility to the appropriate engineering group.

- The Initiating Engineer is responsible for revising existing drawings, or preparing new ones, as required due to the hot tap.

- The Engineering Group is responsible for preparing all needed calculations, drawings and specifications, obtaining needed approvals, and completing Section 4 of the form. A later section discusses these calculations.

- The Engineering Group provides a design package to the Initiating Engineer.

- The Initiating Engineer distributes design documents to Operations, Maintenance, Inspection, Drafting files, and the Area Loss Prevention Engineer. The Initiating Engineer shall also prepare and forward Form A-7235, *Hot Tap Data and Checklist*, to the appropriate maintenance group who will actually perform the hot tap.
The following design information is needed for a hot tap and Form A-7627:

- Hot-tap location.
- Will hot-tap valve be removed?
- Orientation of branch pipe.
  - Horizontal
  - Vertical
  - Inclined
- Design pressure, kPa (psig).
- Design temperature, °C (°F).
- Flange rating.
- Fluid.
- Header pipe and branch pipe.
  - Diameter, mm (in.)
  - Nominal Thickness, mm (in.)
  - Material
The following summarizes several additional design considerations. Participants are referred to ADP-L-052 and SAES-L052, *Hot Tap Connections*, and GI 441.010, *Installation of Hot Tapped Connections*, for more details.

- Hot taps are not performed in cases where the welding or cutting operations can cause fires, explosions, detrimental changes in material properties (such as hardness, impact strength, or yield strength), damage to linings or coatings, accelerated corrosion, burning through thin pipe or vessel walls, or brittle fracture. Quenched and tempered steels, chromium alloy steels, and 400-series stainless steels are examples of materials that require special consideration.

- Hot taps on hydrocarbon tanks are performed at least 1 m (3.3 ft.) below the liquid level to reduce the risk of fires and explosions in the vapor space.

- Air lines must not be hot tapped nor welded on while in service. A flammable mixture may exist in the line due to air compressor lubrication oil that might be present. This mixture could be ignited by the heat generated by cutting or welding.

- Metal temperatures increase during welding. Therefore, the maximum permitted stresses and pressures are reduced from the normal allowable values to prevent failure of the pipe or equipment being hot tapped. This is discussed in a later section.

- Test pressure in the hot-tap nozzle should not cause buckling of the pipe or equipment being tapped. Therefore the allowable differential external pressure should be checked. This is discussed in a later section.

- Fluid flow velocity in a pipe during the hot tap must be within the following ranges:
  - Liquid: 0.4 m/sec. (1.3 ft./sec.) minimum
    4.5 m/sec. (15.0 ft./sec.) maximum
  - Gas: 0.4 m/sec. (1.3 ft./sec.) minimum
    9.1 m/sec. (30.0 ft./sec.) maximum

  However, no-flow conditions are acceptable for hot tapping if there is definitely no possibility of a hydrogen and oxygen mixture, such as for seawater injection lines. However, additional conditions that are specified in GI 441.010 must be satisfied.
• The minimum flow velocity is set to provide adequate heat dissipation during welding and cutting. The maximum flow velocity is set to help prevent spinning of the coupon after cut-through, which could cause it to drop into the line.

• Hot taps shall not be made upstream of rotating machinery or inline rotating instruments, unless chips and shavings from the cutting can be prevented from entering the equipment.

• The Consulting Services Department shall be contacted if a hot tap is being considered in the following situations:
  - Carbon steel pipe with a minimum specified yield strength over 414 MPa (60,000 psi).
  - Situations where welding preheat is required due to hardenable or high strength steels, or wall thickness.

• Hot taps that are within 450 mm (18 in.) of a flange or threaded connection, or 19 mm (0.75 in.) of a girth-weld seam, are to be avoided.

Inspection Requirements

The engineer responsible for inspection must do the following:

• Inspect weld areas, and 50 mm (2 in.) on each side of them, using continuous ultrasonic examination to determine minimum pipewall thickness. The measured thickness must be at least that calculated for the hot tap conditions, and no less than 5 mm (0.2 in.).

• Identify laminations or cracks in the area.

• Approve welding procedure.

• Inspect connection before and during installation for compliance with specification.

• Confirm that hydrostatic test pressure conforms to that specified.

• Witness and approve the hydrostatic test of equipment and connection.

• Confirm that the connection is opened, drained, and vented after completing hydrostatic test.

• Inspect the removed coupon. Evaluate the extent of header internal corrosion and verify wall thickness.
Testing Requirements

The engineer responsible for testing must apply the following test requirements:

• The hot-tap machine must be periodically pressure tested based on GI 441.010 requirements.

• The hot-tap valve shall be pressure tested prior to installation.

• Pressure test the branch-to-pipe weld, and then pressure test the final branch assembly.

• The reinforcing pad of a welded branch shall be tested with air at 173 kPa (25 psig) through a tapped vent hole.

• The pressure for the test of the hot-tap connection shall be 1.5 times the system design pressure (1.25 times for cross-country pipelines), however, not to exceed the following:
  - The design hydrostatic test pressure of the pipe or vessel being hot tapped, or
  - The minimum pressure in the pipe or vessel being hot tapped, while the test is in progress, plus a calculated differential pressure. The differential pressure shall be 1.25 times the allowable external pressure calculated per the ASME Code Section VIII Division 1. The length, L, that is used in this calculation shall be the total length of a split tee, or the inside diameter of the welded nozzle, based on the actual design detail used.

• The test pressure of the hot-tap connection may be lower than the original hydrostatic test pressure. This is acceptable since the purpose of the test is to provide some assurance of the integrity of the connection weld, not a proof test of the weld. The system being tapped need not be downrated if a lower test pressure is used at a hot-tapped connection.
Calculations

The calculations that are necessary for a hot tap are:

- **Branch reinforcement calculations**, as discussed in MEX 101.05.
  
  Calculating branch reinforcement is necessary to confirm if branch reinforcement is acceptable. Calculations are necessary if a nozzle is welded directly to the pipe, with or without additional reinforcement. Branch reinforcement calculations are not necessary if pre-engineered hot tap fittings are used. In this latter case, the fittings have already been designed to be suitable for the specified design conditions. This is analogous to the forged tees or integrally reinforced connections that were discussed in MEX 101.05.

- **Internal pressure calculations**, as discussed in MEX 101.03.
  
  Determining maximum allowable internal pressure identifies any pressure limitations that must be imposed during the hot tap. For hot taps, the MAOP is calculated using 35% of the pipe material minimum specified yield stress at design temperature as an allowable stress in the following equation:

\[
P_{\text{max}} = \frac{2SEt}{D}
\]

where:
- \(P_{\text{max}}\) = Allowable pressure in the pipe during welding, psig.
- \(S\) = 35% of yield stress at header design temperature, psi.
- \(E\) = Weld-joint efficiency if hot-tap nozzle passes through a longitudinal pipe weld.
- \(t\) = Minimum measured thickness of header, in.
- \(D\) = Header outside diameter, in.

This lower than normal allowable stress is used to account for some local heating of the pipewall during welding, with resultant strength reduction. "P" must be greater than or equal to the actual operating pressure of the hot tap in order to perform the hot tap. It may be necessary to reduce the system operating pressure, while maintaining flow, to meet this requirement.
If the previous formula results in an unacceptably low allowable pressure, the following formula may be used. This second formula is based on experimental tests, but its use requires more extensive thickness measurements that are specified in GI 434.000.

\[ P_{\text{max}} = \frac{2S (t - 0.1) F}{D} \]

where: \( F = \) Pipeline Design Factor

- Pressure test calculations.

The normal hydrostatic test pressure causes a hoop stress of 90% of the specified minimum yield stress, and ranges from 1.25 to 1.5 times the system design pressure, depending on the applicable piping code. However, this may be reduced as previously discussed if the original hydrottest pressure was less, or if there could be a problem with buckling the pipe due to external pressure. Determining the maximum allowable external pressure is required for pressure testing. Work Aid 2 provides tables from ADP-L-052. These tables provide the maximum allowable test pressure less the internal header pressure (i.e., the net external pressure) for various sizes of nozzles welded to headers. These tables may be used for carbon steel material through 1,050 mm (42 in.) header diameter, and Type 405 and 410 stainless steel through 149°C (300°F). External pressure calculations must be made for other materials or higher temperatures. These calculations were discussed in MEX 101.03.
Sample Problem 2

Based on the evaluations done in the earlier problem, it is known that the uniformly corroded section of pipeline must be replaced. Since maintaining a certain amount of flow through the pipeline is critical, it is necessary first to install a 600 mm (24 in.) diameter bypass line around the section of pipeline to be removed. To do this, two 600 mm (24 in.) diameter hot taps must be made into the pipeline to permit installation of the bypass. Refer to Work Aid 2 in solving this problem.

If pre-engineered hot-tap fittings are used at the branch connections, no branch reinforcement design calculations are necessary. If welded-on branch reinforcement will be used, design calculations as discussed in MEX 101.05 are necessary to design the reinforcement. This aspect of the hot-tap design will not be discussed here, and Participants are referred to MEX 101.05 for additional information.

The two other calculations that are necessary for a hot-tap installation are to determine the maximum allowable operating pressure during the hot tap and the required hydrotest pressure.

• Maximum Allowable Operating Pressure

This is determined using the following equation:

\[ P_{\text{max}} = \frac{2SE_t}{D} \]

where: \( S = 35\% \) of the specified minimum yield stress of the pipe material at the operating temperature during the hot tap.

Since the operating temperature is only 49°C (120°F), the yield stress may be taken as 241.3 MPa (35,000 psi). Note that ASME/ANSI B31.4 does not require considering any strength reduction up to 121°C (250°F). The reduction in yield strength with temperature must be considered for higher temperatures.

\[ S = 0.35 \times 35,000. \]

\[ = 12,250 \text{ psi}. \]
The hot taps must be made in sections of the pipeline that have adequate wall thickness for the service, i.e., not appreciably corroded. This is confirmed by ultrasonic thickness measurements. For our purpose, assume that the hot taps will be made into pipe sections that have the original wall thickness of 15.9 mm (0.625 in.).

\[
P_{\text{max}} = \frac{2 \times 12,250 \times 1 \times 0.625}{36}
\]

\[
P_{\text{max}} = 425 \text{ psig.}
\]

Therefore, the pipeline pressure must be reduced to a maximum of 2,930 kPa (425 psig) during the hot tap. Note that if this pressure reduction causes operations difficulties, an alternative value for \(P_{\text{max}}\) may be calculated using the second formula that was discussed, provided additional ultrasonic thickness measurements are made.

- **Hydrotest pressure**

The tentative hydrotest pressure is 1.25 times the design pressure or, in this case, \((1.25 \times 750) = 938\) psig. For now, we can assume that this is no higher than the original system hydrotest pressure and does not need to be reduced for that reason. However, it should be checked to confirm that it will not buckle the pipeline.

Note that the tables in Work Aid 2 may be used as a first step since the pipe material and design temperature are within their limiting parameters. The only problem is that the maximum header wall thickness contained in the table is 12.7 mm (0.5 in.) and this pipeline is 15.9 mm (0.625 in.) thick. Thus, if we use the table for this problem, we will be conservative (but safe).

Referring to the table for a 900 mm (36 in.) header that is 12.7 mm thick and for a 600 mm (24 in.) diameter nozzle, the allowable external differential pressure is 2,600 kPa. Convert this to psi and get \(2,600/6.895) = 377 \text{ psi}\). Therefore, in order to use the 938 psig test pressure, the pipeline pressure must be raised back up to \((938-377) = 561 \text{ psig}\).

Raising the header pressure to this level now would be acceptable since no cutting or welding is being done, and this is just under the original design pressure. If, for some reason, it is not practical to raise the pipeline pressure to this level, then external pressure design calculations may be made using the actual 15.9 mm (0.625 in.) pipeline wall thickness to arrive at a higher acceptable external differential pressure. These calculations were discussed in MEX 101.03.
WORK AID 1: Checklist for Identifying Repair Methods and Techniques
Checklist for Pipe Repair

This checklist should be used in conjunction with Saudi Aramco General Instruction 434.000, Pipeline Repair and Maintenance. Additional details and considerations are included in that document and must be adhered to.

1. Identify location and design information for the damaged pipe section.
   
   Location:_________________________________________
   
   Pipe diameter, mm (in.):_____________________________
   
   Pipe material:_____________________________________
   
   Nominal wall thickness, mm (in.):_____________________
   
   Design pressure, kPa (psig):_________________________
   
   Design temperature, °C (°F):_________________________
   
   Fluid:___________________________________________

2. Is damaged area at a road or railway crossing?
   
   Yes ________ No ________

   If yes, immediate action is required to minimize hazardous conditions for both people and motor traffic.

3. Is the pipe internally coated or cement-lined?
   
   Yes ________ No ________

   All internal coatings used by Saudi Aramco, except cement lining, are destroyed by welding. Welding, brazing, and torch cutting are not permitted on internally coated pipe, other than cement-lined pipe, without concurrence of the Operating Department.
4. Identify type of pipe damage.

[ ] Crack:
  - Circumferential
  - Longitudinal

[ ] Corrosion

[ ] Pitting

[ ] Hydrogen blistering

[ ] Hole

[ ] Nick, scratch, or gouge

5. Locate pipe damage.

[ ] Within 19 mm (3/4 in.) of weld

[ ] Away from weld

6. Measure extent of damage.

[ ] Crack length: _____ mm (in.)

Extent of corrosion or pitting:
  - Size: _____ x _____ mm (in.)
  - Depth: _____ mm (in.)

Hydrogen blistering:
  - Size: _____ x _____ mm (in.)
  - Internal cracking? Yes ___ No ___

Hole diameter: _____ mm (in.)

Nick, scratch, or gouge:
  - (Length) x (Width) x (Depth): ____ x ____ x ____ mm (in.)
7. Is the pipe leaking?

Yes ________ No ________

If pipe is leaking, leak must be stopped or diverted before any welding is done.

8. Is repair necessary? Utilize ASME/ANSI B31.3, Table 341.3.2A, included herein as Figure 1, ASME/ANSI B31.4 or ASME/ANSI B31.8 as appropriate.

Yes ________ No ________

Engineering evaluation may be required to make this decision.

9. Evaluate repair options based on damage found.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Potential Repair Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld Defect</td>
<td>Weld Repair</td>
</tr>
<tr>
<td>Dent</td>
<td>Pipe Replacement</td>
</tr>
<tr>
<td>Crack</td>
<td>Weld Repair, Welding Ring</td>
</tr>
<tr>
<td>General Corrosion</td>
<td>Pipe Replacement, Overlay Patch, Repair Sleeve, Welding Ring</td>
</tr>
<tr>
<td>Pitting Corrosion</td>
<td>Pipe Replacement, Overlay Patch, Repair Sleeve, Fitting, Welding Ring</td>
</tr>
<tr>
<td>Hydrogen Blisters</td>
<td>Pipe Replacement, Repair Sleeve</td>
</tr>
<tr>
<td>Nick, Scratch, Gouge</td>
<td>Weld Overlay</td>
</tr>
</tbody>
</table>

*Welded patch.*

- For nonleaking areas with excessive external thinning.
- Maximum 152 mm (6 in.) diameter size with rounded corners.
- At least 1.25 times pipe nominal thickness.
- Material equal to or better than pipe.
- Conform to pipe curvature.
- Standard Drawing AE-036265.
Weld overlay.

- For excessive external corrosion, nicks, scratches, and excessive grinding.
- Must be at least three weld passes wide, 51 mm (2 in.) long.
- 102 mm (4 in.) maximum length or width.

Repair sleeve.

- For corroded or pitted areas, or for hydrogen blisters.
- Provides full-encirclement reinforcement for areas too large for a patch.

Replace pipe.

If pipe repair is not possible, the damaged pipe section must be removed and a replacement section installed.

10. Which repair option will be used?

11. Prepare detailed repair procedure based on established Saudi Aramco requirements.

12. Identify and implement all necessary safety precautions.

13. Obtain all necessary approvals before beginning repair.

14. Inspect pipe repair as required.

15. Pressure test pipe repair as required.
WORK AID 2: Checklist for Identifying Design, Calculation, Inspection, and Testing Requirements for a Hot Tap

General information:

Design pressure, kPa (psig):
Design temperature, °C (°F):
Corrosion allowance, mm (in.):
Original hydrotest pressure, kPa (psig): 

Material specification
Nominal size, mm (in.)
Minimum measured thickness, mm (in.)

1. Calculate minimum required header thickness for design pressure, th. See MEX 101.03.
   \[ t_h = \text{__ mm (in.)} \]

2. Calculate minimum required branch thickness for design pressure, tb. See MEX 101.03.
   \[ t_b = \text{__ mm (in.)} \]

3. Select nominal thickness for branch, Tb, considering tb, mill tolerance and corrosion allowance. See MEX 101.03.
   \[ T_b = \text{__ mm (in.)} \]

4. Will a pre-engineered hot tap fitting be used?
   Yes _______  No _______ 

If yes, then branch reinforcement calculations as discussed in MEX 101.05 are not required and Steps 5 and 6 may be skipped. If No, then branch reinforcement evaluation is necessary. See Steps 5 and 6.
5. Is additional branch reinforcement required? See MEX 101.05.

   Yes ________ No ________

6. If additional branch reinforcement is required, design the reinforcing pad. See MEX 101.05.

   Pad material specification: ____________
   Pad diameter: _____ mm (in.)
   Pad thickness: _____ mm (in.)

   Will the pad be a complete-encirclement-type?

   Yes ________ No ________

7. Set maximum permitted operating pressure during hot tap. Stress in header limited to 35% of the specified minimum yield stress at operating temperature. See MEX 101.03.

   Operating temperature during hot tap: _____ °C (°F)
   Minimum yield stress at operating temperature: _____ MPa (psi)
   Maximum permitted operating pressure: _____ kPa (psi)

8. Set hot-tap hydrotest pressure. Consider original hydrotest pressure and limitations contained in ADP-L-052. Tables providing maximum allowable external pressure from ADP-L-052 are provided on the following pages. Note that the allowable pressure in psi is obtained by dividing the pressure in kPa contained in the tables by 6.895. Tentative hydrotest pressure is 1.5 times the system design pressure (1.25 for pipelines).

   Hydrotest Pressure _____ kPa (psig)
## CALCULATED TEST PRESSURE LESS INTERNAL HEADER PRESSURE (KPA) ON NOZZLES WELDED DIRECTLY TO PIPE PRIOR TO HOT TAPPING

<table>
<thead>
<tr>
<th>HEADER SIZE IN.</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
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### NOTES:

1. The test pressure must not exceed valve-rated pressure.
2. These tables are to be used for carbon steel [specified yield strength up to and including 289.6 MPa (42,000 psi)] and Type 405 and Type 410 stainless steel only, and are applicable up to 149°C (300°F).
3. Pressures have been calculated in accordance with Paragraph 5.3 of SAES-L-052.
4. Example: 250 mm (10 in.) header, 12.7 mm (0.500 in.) wall thickness, and 200 mm (8 in.) nozzle
5. \( L/D = 0.74; d_o/t = 21.5, A = 0.02, B = 120.7 \text{ MPa} (17,500 \text{ psi}) \)  
   \( \text{P(T)} = 1.25 \text{ P(A)} = 1.25 \left( \frac{4}{3} \right) \left( \frac{B}{d_o/t} \right) = 1.25 \left( \frac{4}{3} \right) (17) 1357 \times 6.89 = 9350 \text{ kPa}; \) Rounded to 9400 kPa.
GLOSSARY

**blow-through**  
A blow-through occurs when the unmelted metal beneath the weld pool no longer has the strength to contain the internal pressure of the pipe, vessel or table. A rupture occurs allowing the contents to escape.

**defect**  
An imperfection of sufficient magnitude to warrant rejection.

**hot tap**  
Any connection made to a pipeline, vessel or tank which is under pressure or has been depressured but has not been cleared for conventional construction methods.

**imperfection**  
A discontinuity or irregularity which is detected by inspection.

**stoppling**  
A procedure where a section of pipe is isolated for repair or revision without depressuring or clearing the entire line.