Temporary/permanent pipe repair - Guidelines

Prepared by AEA Technology Consulting
for the Health and Safety Executive
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EXECUTIVE SUMMARY

This document provides guidance on the applicability of a range of pipe repair clamps and pipe connectors to a range of pipe repair scenarios. These repair scenarios cover the most common types of damage/deterioration to piping systems, such as internal and external corrosion, and also cover situations where the damage is extensive. Repair clamps are typically used where the damage is localised and pipe connectors are used where the damage is more extensive. Examples of the different types of damage/deterioration are explained and the different types of clamps and connectors that are commonly used are illustrated.

The guidance provided in this document includes the limitations of the different types of repair components with respect to operating pressure, operating temperature, and longevity (temporary or permanent repair). Classification of the repair in terms of being a temporary repair or a permanent repair is provided within the context of ‘fitness-for-purpose’ and special consideration is given to the repair of safety critical piping systems.

This guidance document is primarily concerned with the use of metallic repair components, however, as composite materials are finding increasing applications to pipe repair situations, this document also provides a review of the use of composite repair components.
1. INTRODUCTION

This Guidance Document is aimed at providing information on the range of available pipe repair components that are applicable to a range of repair scenarios. Piping systems and pipework can fail in a number of ways. The most commonly experienced failures, or threatened failures, are associated with either internal or external corrosion of the pipe wall. Other failures may involve other metal loss mechanisms, such as erosion, fretting/chafing or gouging. Repairs may be effected on-line using simple band-type clamps or patches or may involve the replacement of a section of pipe or pipework in conjunction with pipe couplings/connectors. There are a number of proprietary repair components/systems in existence, involving both metallic and composite materials, but these systems may have certain limitations regarding their applicability against a range of repair scenarios. This Guidance Document, therefore, is aimed at providing guidelines on the applicability of a range of these devices/systems against the different repair scenarios and service/duty requirements, together with the requirements for the medium and long-term inspection/monitoring of the repair to ensure continuing 'fitness for intended purpose'.

1.1 SCOPE OF DOCUMENT

The scope of this document involves the use of pipe repair clamps and connectors. This document also provides a review of the use of composite materials for the repair of pipework. This document does not, therefore, provide guidelines on other pipe repair methods, such as by-pass repairs using hot-taps and stopples, ‘slip-lining’ repairs using plastic liners, and repairs using weld overlays to re-instate the pipe wall.

Pipe, piping, piping components, and pipework are all terms often used when describing pipework and piping systems. This guidance document is concerned with the repair of pipework – the term pipework referring to an arrangement of pipes and pipe fittings (e.g. elbows, bends, tees, reducers, flanges). This guidance document does not, therefore, cover the repair of non-pipework items such as valves, filters etc.

Pipelines are specific examples of pipework and piping systems used to convey fluids over significant distances. Although these guidelines have been specifically produced to address above ground pipework and piping systems, they may equally be applicable to buried pipelines and submarine pipelines (buried or not). Some of the repair concepts discussed in these guidelines require consideration of the restraint of axial loadings which, in the case of buried pipelines, may be automatically accommodated (restraint afforded by pipe/soil friction etc.).

These guidelines apply to the repair of carbon steel pipe and pipework only. Other metallic pipe/pipework, such as stainless steel, duplex stainless steel, copper nickel etc., may present other factors for consideration (e.g. weldability, surface treatment/preparation agents for composite materials etc.), and are outwith the scope of this document.

1.2 LAYOUT OF DOCUMENT

This document is primarily concerned with metallic mechanical clamps and connectors as used for the repair of damaged/deteriorated pipe components. As composite materials are finding increasing applications to pipe repair situations, a review of their use is presented in section 6 of this document. All other sections of this document, including the section presenting the results of the literature searches, are primarily concerned with the use of metallic mechanical clamps and connectors for the repair of damaged/deteriorated pipe components.
2. LITERATURE REVIEW

A number of sources of information have been accessed in order to glean information concerning the state-of-the-art of pipework repair systems/components. These sources of information consist of, in the main, known databases that hold references of publications (articles etc.), but are supplemented by other non-direct information sources, such as the Internet.

Section 6 of this guidance document presents a review of the use of composite materials for the repair of pipework, and presents the work that is currently being carried out within the Working Group on pipe repairs using composite materials. The literature review presented in this section of the document, therefore, concentrates on metallic mechanical repair sleeves, clamps, and couplings/connectors, but also considers the use of un-reinforced composite materials (e.g. epoxy resin without any reinforcement material) used in conjunction with metallic repair components.

2.1 DATABASE SEARCHES

A number of database searches have been conducted in order to identify current and past activities relating to the use of pipework repair systems/components. The databases chosen were based on knowledge of their popularity and coverage of the subject matter – Engineering, Energy, Science and Technology. The following databases have been accessed:

- The Energy Technology Data Exchange (ETDE) – this database is hosted by the United State’s Department of Energy (USDOE) for the International Energy Agency (IEA) which is an international consortium that collects and exchanges research and technology information through the ‘Energy Database’. The Energy Database covers all aspects of energy technology and its environmental effects, covering all energy sources (including fossil fuels), energy conservation and energy policy.
- ‘COMPENDEX’ – this database is hosted by Energy Information Inc. (Ei). COMPENDEX is the world’s most comprehensive Inter-disciplinary Engineering Database, offering over five million summaries of journal articles, technical reports, conference papers, and proceedings. Ei recently acquired API EnCompass (the premier source of world-wide information for the downstream petroleum, petrochemical, natural gas, and energy industries) thus adding one of the premier online databases for the oil and gas industries to their portfolio: APILIT® - the Technical Literature database. Ei’s internet address is http://www.ei.org
- ‘APILIT2’ – this is Ei’s Technical Literature database for non-subscribers.
- ‘TULSA2’ – this database is hosted by the University of Tulsa and contains references to technical literature on the oil and gas exploration and production industry.

Each of the above databases was searched for relevant references using suitable KEYWORDS. The KEYWORDS used were; PIPE, PIPING, REPAIR, CLAMP, CONNECTOR, COMPOSITE, WRAP, REVIEW, OVERVIEW, STATE ART (2 words) and SURVEY. The databases are searched looking for these keywords, or combinations of the keywords, within the TITLE, ABSTRACT, and CONTROLLED TERM (CT) LISTING. Controlled Terms are Keywords, Indexing Terms (IT) or Subject Terms (ST) added by the database administrator.

In order to set a realistic limit on the number of references revealed by the searches, the date range for the searches was set at 1985 to present day – COMPENDEX holds records dating back to 1970. A large number of potentially relevant references was noted against the individual keywords and the combination of the main keywords of PIPE/PIPING and REPAIR (4760 references). By concentrating the searches on the Titles and Controlled Terms (i.e. ignoring the information contained within the Abstracts) this number was reduced to 763. Combining these results with the keywords of REVIEW, OVERVIEW, STATE ART (state-of-the-art), and
SURVEY revealed a total of 86 references. This was particularly useful to check on the existence of any previously published reviews of pipe/pipeline repairs. The basic details of these references are presented, for information, at Appendix 1 of this document.

The Titles and associated Controlled Terms of the 763 and 86 references were studied to identify the relevance of the references. Study of the Abstracts of 6 relevant references revealed 4 papers to be of particular relevance, and copies of these were obtained through the British Library’s Document Supply Centre. The Abstracts of these 4 papers are presented at Appendix 2 of this document.

In addition to the above databases, AEA Technology’s National Non-Destructive Testing Centre’s database ‘QUALTIS’ was searched for technical literature pertaining to pipe/piping repair. Despite there being some 63,000 separate references in all, dating back to the 1960s, none of the database entries were found to be relevant to the subject of pipe repair components.

2.2 THE INTERNET

As a source of information on pipe repair clamps and connectors, the Internet’s information base is vast. Various ‘search engines’ can be used which, when used with appropriate search words/phrases, guarantee that relevant information is captured. Review of the results of the various searches invariably identified individual companies that offer pipe repair products and services. The information contained within the various individual company web sites is usually of a general nature with little in the way of detailed technical information (e.g. pressure/temperature limitations of repair clamps). However, the individual company web sites invariably contained contact details and these details were used to obtain further information concerning the company’s products and services.

2.3 OTHER SOURCES OF INFORMATION

A number of additional articles have been found indirectly from AEA Technology’s library of technical periodicals (e.g. Offshore Engineer, Pipe Line & Gas Industry etc.), conference proceedings and through other connections. These articles tend to either supplement the information obtained through other sources, or tend to discuss specific applications of a particular repair solution that may not be directly associated with piping or piping components. For example, 1 particular article describes a repair that involved the helium purging of a special habitat placed over a leaking sub-sea pipeline check valve and the subsequent epoxy-resin injection into a sleeve placed over the check valve.

2.4 SUMMARY OF LITERATURE REVIEW RESULTS

A large amount of relevant information has been sourced and reviewed during the production of this guidance document. The vast majority of the existing pipe repair products and services have been available for some time now and various repair components, such as heavy duty repair clamps, are available as standard items (e.g. PLIDCO clamps, Furmanite clamps, IPSCO’s split sleeve repair clamps etc.). These proprietary items are typically designed to comply with, or exceed, the requirements of Industry Standards, such as API 6H: Specification on End Closures, Connectors and Swivels which covers pipeline closures, connections, couplings, misalignment devices (swivels) and split mechanical fittings. These proprietary items, and other repair components, may also have obtained ‘type approvals’ from Certifying Authorities, such as DNV and Lloyd’s Register for use to perform pipe repairs or to perform pipe modifications/tie-ins etc.
One particular repair solution that may be regarded as relatively new, and one which is regarded as being novel in its approach, is the epoxy-filled sleeve repair technique. This technique avoids the potential hazards of welding on an operational pipe/pipeline by using steel sleeves filled with epoxy grout (or resin). The technique, developed separately by a number of operators, such as British Gas\(^1\), Battelle\(^2\) in the USA and Gasunie\(^3\) in Holland, differ in their method of application, but all rely on the same principle—to provide a continuous radial load transfer between the epoxy-resin and the steel sleeve. This repair technique is discussed further, based on British Gas’ experiences, in section 4.2 of this document.
3. PIPE REPAIR SCENARIOS

There are three main repair scenarios considered in this guidance document; pipe subject to external metal loss (caused by corrosion or mechanical damage), pipe subject to internal metal loss (caused by corrosion, erosion or erosion/corrosion), and piping components that are leaking. In addition to these main repair scenarios, the extent of the deterioration or damage (i.e. localised or extensive) will also be considered when choosing the repair methods and repair components. These repair scenarios are described further in the following sections.

3.1 PIPE SUBJECT TO EXTERNAL METAL LOSS

Many pipework failures have been caused by external corrosion. External corrosion may be present in many forms including simple environmental corrosion (e.g. coating breakdown and subsequent corrosion, corrosion under insulation etc.), crevice corrosion, and galvanic corrosion. Regardless of the actual corrosion mechanism that is active, the resulting damage is in the form of metal loss - loss of wall thickness. This metal loss may be localised (as in the case of corrosion underneath a pipe support) or may be extensive (in the case of corrosion under insulation).

Mechanical damage to pipework may, or may not, be accompanied by metal loss. For example, an indentation may have simply deformed the pipe locally without any associated gouging or thinning of the pipe wall. Plain dents up to six percent of the diameter of the pipe do not need to be repaired. Deeper indentations may need to be repaired or may need to be removed if their presence could cause operational problems (e.g. interference with pigging). By virtue of their probable causes, dents are considered to be an example of localised damage.

Cracking (not strictly speaking, damage involving metal loss) of weldments or of the parent pipe itself, but which has not resulted in leakage of the piping system requires special consideration. The repair of a cracked section of pipework would involve arresting any further propagation (providing that the crack itself is not threatening integrity) or removal/repair.

Whatever the cause of the external metal loss, it is assumed that the prevention of further deterioration will automatically be addressed by the combination of realising the presence of the damage/deterioration (measures taken to prevent re-occurrence) and the repair action itself.

3.2 PIPE SUBJECT TO INTERNAL METAL LOSS

Conveyed fluids within piping systems, especially in oil and gas and petrochemical applications, can present problems of internal corrosion, erosion, or a combination of corrosion and erosion. Dependent on the severity and extent of the internal damage/deterioration the pipework may be leaking or be in threat of leaking. The repair scenario considered here, however, is when internal metal loss has not resulted in leakage - the next section deals with pipework leaks.

Unlike external corrosion, it may not be possible to arrest the metal loss mechanism and further time-dependant damage/deterioration will continue. Unless it is possible to arrest the metal loss mechanism, the chosen repair components will need to accommodate the effects of the eventual further deterioration. In these cases the reinstatement of pipe integrity may only be considered to be temporary, unless the design of the repair components specifically address the effects of further deterioration, at least up to the remaining life of the piping system.

Unlike external corrosion, internal corrosion, erosion or corrosion/erosion is more difficult to quantify, both in terms of the absolute metal loss and the extent of this metal loss. Inspection
techniques are available, such as ultrasonics and radiography, to assist in this quantification. What is important is to gain as much information as possible on the damage/deterioration to enable the correct repair method to be chosen. It is particularly important to obtain information regarding the ability of the sustained damage to accommodate the axial stresses which, in complex pipe systems, can be significant. Also, further deterioration of existing internal metal loss may result in the pipe wall being unable to carry these axial loads.

3.3 PIPE SUBJECT TO LEAKAGE

Leakage may be caused by internal or external metal loss (or, very rarely, a combination of the two). Leakage may also be caused by cracking of welded seams or joints or of the parent pipe itself. Depending on the extent of the discovered damage, repair may require the installation of a repair clamp (localised repair) or the replacement of a section of pipe utilising connectors or couplings. In all cases where the pipe contents are leaking, it will be necessary to consider the suitability of the repair component to not only accommodate the pressure containment requirements, but also to accommodate corrosivity and other effects of the fluids. For example, elastomeric seals utilised within certain repair clamps/ connectors may be susceptible to deterioration in the presence of volatile hydrocarbons, aromatics etc. The issues of possible long-term seal degradation/relaxation and any need to first stem/plug the leak need to be considered. In some cases it may be possible to install a repair clamp to an actual leaking pipe - the clamp that encloses the defective, leaking area is provided with a vent plug (as shown in Figure 5) which can be closed once the clamp has been correctly installed and tightened. The ability of the repair component(s) to accommodate the axial loadings of the pipe system, especially in the case of a repair employing connectors, also needs to be considered.

One other scenario that is considered within these guidelines is the case of a leaking flange. The leak will most probably have been caused by corrosion or relaxation of the flange face/gasket area. However, it is possible to experience leakage of the pipe to flange welds (fillet weld in the case of slip-on flanges, and circumferential butt weld in the case of welding neck flanges).
4. RANGE OF AVAILABLE REPAIR CLAMPS AND REPAIR CONNECTORS/COUPLINGS

One of the fundamental aspects of a damaged/deteriorated pipe that dictates the type of repair component to be applied is the external pipe surface condition. If the external surface is damaged to the extent that an elastomeric seal cannot provide sufficient sealing forces in the immediate vicinity of the damage, or in the relatively unaffected areas adjacent to the major damage (these areas being used to effect the sealing of ‘stand’-off repair clamps), the external pipe surface may need to be re-instated using some form of filler material. Developments using epoxy-filled steel sleeves have been shown to accommodate such areas of extensive damage and have applications for a whole range of defects, including corrosion, non-propagating cracks, dents or gouges in both axial and circumferential orientation, and girth weld associated anomalies. The epoxy-filled sleeve repair technique is discussed later within these guidelines.

4.1 REPAIR CLAMPS

The simplest form of repair component is a metallic patch which may be applied to cover a small, non-leaking defect. The repair involves the welding, by fillet welding to the pipe, of a suitably curved patch. The pipe wall in the weld regions, which are away from the defect area, must be of sufficient thickness and must be defect free. This type of repair is very rarely applied to high integrity applications and offers no major advantage over a simple patch clamp -a bolted clamp that holds a patch of elastomeric material adjacent to the defect area. An example of a patch clamp in shown below.

![Patch clamp](image)

**Figure 1**
Patch clamp
In the case of a small pin-hole leak on a section of pipe, a simple patch clamp may be used or a special pin-hole leak repair clamp may be used. The pin-hole leak repair clamp utilises a locator pin which guides a pointed cone seal into the leaking hole. Pressure is then applied to the cone seal by a force screw and once the seal is compressed the pin may be removed thus completing the seal. This type of repair is capable of withstanding working pressures of up to 138 bar (2000 psi). An example of a pin-hole leak repair clamp is shown below.

![Pin-hole leak repair clamp](image)

**Figure 2**

Pin-hole leak repair clamp

A defective section of pipe may be simply reinforced by the use of simple encircling sleeves. The sleeves are in the form of two halves and are a close fit to the outside diameter of the pipe. The two halves are welded together longitudinally (backing strips are used for the longitudinal welds to prevent weld induced damage, or mechanical property changes, at the pipe surface). For pressure containing applications, the sleeve must also be fully seal-welded to the pipe. An example of an encircling sleeve is shown below.

![Encircling sleeve type repair](image)

**Figure 3**

Encircling sleeve type repair
The most common form of pipe repair component is the ‘stand-off’ repair clamp. These repair clamps are usually cylindrical in shape and are formed in two half shells. Low pressure clamps, however, may be furnished in the form of a flexible one-piece assembly that can be ‘sprung’ over the defective pipe. Stand-off repair clamps are sometimes referred to as ‘enclosures’ by virtue of the fact that they totally enclose the defective area within a sealed pressure containment vessel. The sealing of the enclosure is typically by elastomeric seals at the longitudinal joints of the two half shells and seals at the ends of the ‘cylinder’. These seals may be energised by the compression forces caused by the tightening of the two halves or can additionally be energised by any leakage of the pipe contents –acting on a lip-type seal, commonly referred to as a ‘self-seal’ arrangement. Examples of typical cylindrical stand-off repair clamps are shown below.
Enclosure type repair components are also capable of repairing/sealing damaged flanges and bends/elbows, as illustrated below.

Figure 6
‘Self-seal’ type repair enclosure

Figure 7 below is a schematic of a lip-type seal arrangement as used within ‘self-seal’ repair clamps/connectors. The leaking fluid pressure assists the compression type seal caused by the tightening of the two halves of the clamp/connector.

Vent Plug -to release leaking fluids

Figure 7
Lip-type seal used within ‘self-seal’ type repair clamps/connectors
In the case of a leaking flange, special enclosures, which seal on the outside diameter of the flange halves, are available as illustrated below.

Figure 8
‘Outside diameter’ type flange repair enclosure

Unlike the ‘self-seal’ type repair enclosure illustrated at Figure 7 that totally encloses the flange assembly, the ‘outside diameter’ type flange repair enclosure needs to, additionally, seal at the flange’s bolt holes. For this reason, the above illustration features an additional sealant injection port at the centre of the fitting (the other screwed ports are used for injecting sealant should the seal between the outside diameter and the clamp be ineffective). Figure 8 below illustrates the sealing of the flange bolt holes.

Figure 9
Sealant injection at flange bolt hole area
In situations where there has been extensive damage/deterioration of a section of pipework it may not be possible to effect repairs using simple repair clamps or sleeves. Repair clamps tend to be available in standard sizes (diameter and length) and the lead time and cost associated with the production of extra long clamps is usually prohibitive. There are, however, situations where these costs are warranted in order to avoid plant shutdown – that is, of course, providing that the existing damage has been fully quantified and the risks associated with continuing production are acceptable.

Usually the most economical repair solution will involve the replacement of the damaged section of pipework. This may be straighforward where existing flanged connections are available to facilitate the replacement of a section of damaged pipework. Alternatively the repair could simply involve welding in place a replacement section of pipe. In the case of pipework that conveys hydrocarbons, the activities involved in the latter repair solution present particular problems associated with safe working.

The most economical repair solution for situations where extensive damage/deterioration has been found is to utilise repair couplings or connectors in conjunction with a replacement section of pipe/pipework. A typical repair solution involving the use of repair connectors is illustrated below.

It is important to realise that the imposed axial stresses/loading, due to the internal pressure, must be resisted. Pressure thrusts will be produced at all changes in direction (e.g. bends/elbows, tees etc.) and at end-caps, valves and reducers. Unless these loadings are restrained locally at the point at which they are developed, pipe components may move under the loadings. Figure 11 (over page) considers the case of pressure acting on an end-cap. Unless the resulting pressure thrust is restrained there is a possibility that the pipe components would separate.
Where adequate restraint is afforded to the pipe component(s) the connector may take the form of a simple ‘stand-off’ repair clamp. If, however, the connector itself has to provide restraint, the connector must be furnished with some form of gripping device to prevent separation of the pipe components.

There is a wide range of gripping devices utilised within proprietary repair connectors, ranging from simple steel ‘dogs’ that bite into the outside pipe wall through to sophisticated systems using ball bearings that are swaged into the pipe wall. Some of the systems utilising ball bearings are also fitted with a ball retraction system thus allowing full reusability of the connector.

The operating pressure of the pipe system will dictate the choice of connector. In general the flexible one-piece connectors that can be ‘sprung’ over the defective pipe, and which are fitted with axial restraint devices, are limited in their application. This is due to the thin sections employed in their construction which are incapable of resisting very high axial loadings –see Figure 12 below. Depending on the pipe nominal diameter, these simple connectors are capable of operating up to pressures of approximately 16 bar (230 psi).
The more sophisticated connectors are capable of satisfying pressure ratings up to ASA Class 2500lb -690 bar (10,000 psi) -and pipe diameters up to 48”. On some of the sophisticated repair connectors, external pressure connection ports enable the integrity of the radial seals to be checked. This test often eliminates the need to hydrostatically pressure test the line once the connector(s) have been fitted. An example of a sophisticated pipe connector is illustrated at Figure 13. In this example the ball bearings that are swaged into the pipe wall, the twin set of radial fitted to both sides of the pipe joint (the outer seals are environmental seals), and the external pressure test ports, can be seen.

![Heavy duty pipe connector](image)

A novel repair method, originally developed for cross-country pipeline applications, but now considered equally applicable to above ground pipe systems, is capable of withstanding high circumferential and axial stresses without the need to either directly seal weld a repair clamp (e.g. encircling sleeve) onto the pipe or to use a pipe connector with gripping devices.

The repair method, using split-sleeves in conjunction with an epoxy ‘grout’ filled annular gap, has also been shown to be capable of tolerating continuing internal metal loss –including subsequent metal loss growth through the pipe wall. The method itself is best described as a ‘hybrid’ –it is neither a conventional ‘stand-off’ repair clamp/connector, or a composite repair system (the epoxy is not used with any reinforcement material). The operating principle is to prevent the pipe damage bulging radially by providing a continuous transfer of load/stresses, through the epoxy grout, to the steel repair sleeve. The epoxy grout limits the applicability of the repair method to approximately 100 bar (1450 psi) operating pressure with a temperature range of between 3°C and 100°C. However, severe cold temperatures -as, perhaps, experienced during blow-down of a pipe containing natural gas liquid -have been shown not to effect the fitted repair sleeve down to temperatures of -65°C (-85 °C).

The ability of the repair method to tolerate leaking, or future leaking, pipes is due to the careful adherence to the specified pipe and sleeve surface preparation by grit blasting to Swedish...
Standard SA3 – this provides the correct surface key and chemical cleanliness for good epoxy bonding. This repair method is, however, not a rapid repair method since the two half shells require welding longitudinally and the epoxy, once mixed and injected into the annular space, requires approximately 24 hours to cure to 90% of its ultimate strength. The epoxy-filled repair sleeve technique is illustrated at Figure 14.

![Epoxy-filled repair sleeve diagram](image)

This repair method can be applied with a wide range of annular space between the repair sleeve and the pipe outer diameter of between 3mm and 40mm. Repairs have been effected to long-radius field bends using oversize-diameter pipe, bent to the relevant angle and sliced in half.
5. APPLICABILITY OF DIFFERENT REPAIR COMPONENTS

5.1 COMMON REPAIR SCENARIOS

As has been shown in the previous section, there is a large range of repair components that may be suitable to the more common repair scenarios. Each of the repair solutions will have advantages and disadvantages and, possibly, some of the repair components may not be suitable or applicable. Table 1 provides a simple overview of the applicability of the individual repair components against a range of repair scenarios. These repair scenarios are grouped into the three main repair scenarios considered in this guidance document; pipe subject to external metal loss (caused by corrosion or mechanical damage), pipe subject to internal metal loss (caused by corrosion, erosion or erosion/corrosion), and piping components that are leaking. Within each of these repair scenarios groups, the extent of the damage/deterioration has been further categorised in terms of being localised (i.e. isolated pit, small crack) or extensive. The table concentrates on the repair of straight sections of pipe and assumes that further deterioration is avoided and that the remaining pipe wall is capable of accommodating the axial loadings/stresses.

<table>
<thead>
<tr>
<th>Repair Scenario</th>
<th>Patch</th>
<th>Encircling Sleeve</th>
<th>‘Stand-off’ clamp/connector</th>
<th>Epoxy-filled sleeve</th>
</tr>
</thead>
<tbody>
<tr>
<td>External metal loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Yes</td>
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<td></td>
<td></td>
<td>- consider cost effectiveness</td>
<td></td>
</tr>
<tr>
<td>External metal loss</td>
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<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- extensive</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- c/w new pipe section</td>
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<td></td>
</tr>
<tr>
<td>Internal metal loss</td>
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<td>Yes</td>
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<tr>
<td>- localised</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal metal loss</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- extensive</td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- c/w new pipe section</td>
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<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- consider seal material suitability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is important to consider the ability of the remaining wall thickness to accommodate the imposed axial loadings/stresses. It is assumed that in cases involving external metal loss the repair action itself will prevent any further deterioration. In situations where the continuation of internal metal loss can not be prevented it will be necessary to consider the suitability of the repair component to accommodate these loadings/stresses should this continuing metal loss affect the pipe’s ability to carry these loadings/stresses.
The case of leaking flanges has not been covered by the above table. The choice of using an ‘outside diameter type’ repair enclosure or an enclosure type repair component sealing on the adjacent pipe sections (totally enclosing the flange assembly), will depend on several factors. These factors will include, for example, the ability to seal a large leak (sealing at the flange bolt holes) using an ‘outside diameter’ repair enclosure, and the amount of space that is available (the enclosure type flange repair component takes up a considerable amount of space).

### 5.2 APPLICABILITY TO REPAIRS ON SAFETY CRITICAL SYSTEMS

When considering the applicability of the different repair components to repair scenarios involving critical piping systems, high performance and reliability are of prime importance. For example, the Offshore Installations and Wells (Design and Construction, etc) Regulations 1996, are concerned with the integrity of an offshore installation including structures, wells and process plant. Any structure, plant, equipment, system (including computer software) or component part whose failure could cause or contribute substantially to a major accident is deemed to be ‘safety-critical’. This may include hydrocarbon containment systems that must be demonstrated, through a written scheme of verification, to be suitable for their intended purpose and to remain in good repair and condition.

For safety critical piping systems the repair philosophy should, therefore, be:

- replace like-for-like;
- temporary repair until replacement can be carried out;
- permanent repair only where replacement is not practical.

This approach is in line with the principles of prevention as outlined in the Guidance to the Management of Health and Safety at Work Regulations 1999, SI No. 3242 – in particular the principle of “control risks at source, rather than taking palliative measures” is relevant.

On many offshore installations, safety critical systems may include hydrocarbon flow-lines or critical cooling pipework. Repairs afforded to such pipework, using repair clamps or connectors, need to be not only of sufficient integrity and reliability for the normal operating conditions, but also need to be capable of withstanding other perceivable conditions, such as up-set conditions and emergencies. Some systems may need to retain their integrity under such threats as direct fire attack.

The most common form of mechanical pipe repair clamp or connector is the ‘stand-off’ clamp/connector. These repair components invariably utilise a set of elastomeric seals which, when subject to external fire loading, may fail. The epoxy-filled sleeve repair technique, discussed earlier in this document, should not be used in situations where external fire loading of the epoxy-filled sleeve could occur. Careful consideration would, therefore, need to be given to the selection of an appropriate repair solution for such piping systems.

For topside applications, the subject of pipework integrity under conditions of fire loading has been addressed by a number of pipe connector manufacturers. Many of the available designs incorporate high performance metal/graphite sealing systems thus providing a fire-safe pipe connector. These connectors have achieved full Type approvals from Certifying Authorities such as DNV and Lloyd’s Register.
**5.3 QUICK REFERENCE SUMMARY TABLE**

Table 3 (below) provides a summary of the pressure, temperature, size and longevity capabilities of the range of pipe repair components discussed in this report.

<table>
<thead>
<tr>
<th>Repair method/component</th>
<th>Maximum pressure rating</th>
<th>Temperature range</th>
<th>Size (nominal diameter) range</th>
<th>Temporary or permanent repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch clamp</td>
<td>7 bar (100 psi)</td>
<td>Depends on seal material 1</td>
<td>½” to 42” (13 to 1000mm)</td>
<td>Temporary</td>
</tr>
<tr>
<td>Pin-hole clamp</td>
<td>140 bar (2000 psi)</td>
<td>Depends on seal material 1</td>
<td>½” to 48” (13 to 1200mm)</td>
<td>Temporary</td>
</tr>
<tr>
<td>Encircling sleeve</td>
<td>Same rating/size as the original piping</td>
<td></td>
<td></td>
<td>Permanent</td>
</tr>
<tr>
<td>Complete circle clamp c/w 360° patch gasket</td>
<td>16 bar (230 psi)</td>
<td>Depends on seal material 1</td>
<td>Up to 30” (800mm)</td>
<td>Permanent</td>
</tr>
<tr>
<td>One-piece stand-off clamp</td>
<td>20 bar (300 psi)</td>
<td>Depends on seal material 1</td>
<td>2” to 48” (50 to 1200mm)</td>
<td>Permanent</td>
</tr>
<tr>
<td>Stand-off type (enclosure) clamp</td>
<td>ASA Class 900lb</td>
<td>Depends on seal material 1</td>
<td>4” to 48” (100 to 1200mm)</td>
<td>Permanent</td>
</tr>
<tr>
<td>Flange repair enclosure</td>
<td>ASA Class 600lb</td>
<td>Depends on seal material 1</td>
<td>½” to 12” (13 to 300mm)</td>
<td>Permanent</td>
</tr>
<tr>
<td>Outside diameter flange clamp</td>
<td>ASA Class 600lb</td>
<td>400°C</td>
<td>½” to 24” (13 to 600mm)</td>
<td>Temporary</td>
</tr>
<tr>
<td>One-piece stand-off connector</td>
<td>16 bar (230 psi)</td>
<td>Depends on seal material 1</td>
<td>Up to 30” (800mm)</td>
<td>Permanent</td>
</tr>
<tr>
<td>Heavy duty connector (see Figure 13)</td>
<td>ASA Class 2500lb</td>
<td>-50°C to +230°C</td>
<td>All diameters</td>
<td>Permanent</td>
</tr>
<tr>
<td>Epoxy-filled sleeve (see Figure 14)</td>
<td>100 bar (1450 psi)</td>
<td>3°C to 100°C</td>
<td>Same size as the original piping</td>
<td>Permanent</td>
</tr>
<tr>
<td>Composite repair</td>
<td>50 bar (725 psi)</td>
<td>-20°C to +60°C</td>
<td>All diameters</td>
<td>Temporary and permanent</td>
</tr>
</tbody>
</table>

1 Ethylene-Propylene (EPDM) -40°C to +90°C; Nitrile-Butadiene (NBR), for example BUNA-N, -20°C to +100°C; Neoprene up to 150°C; AFLAS™ up to 232°C
2 Upper pressure limit relates to small sizes/diameters
3 American Standard Association (ASA) pressure ratings refer to the primary service pressure ratings, in pounds per square inch (psi), at the max. service temperature of 850°F (455°C). For example, ASA 600lb refers to a max. non-shock operating pressure of 600 psi (41 bar) at 850°F (455°C)
4 Higher temperatures are achievable by injecting proprietary sealants
5 When fitted with a pipe gripping device
6 Satisfies NACE Standard MR0175 and CHARPY impact values for connector materials exposed to process fluids. Higher temperature capabilities can be achieved by the use of metal/graphite sealing arrangements (fire-safe designs)
7 Refer to the repair philosophy detailed in Sections 5.2 and 8
8 For temporary repairs the upper temperature range can be extended to 90 °C due to the degree of post cure experienced with the influence of temperature
9 This clamp, unlike the patch clamp, holds an elastomeric seal over the full circumference of the pipe
6. REVIEW OF THE USE OF COMPOSITE MATERIALS FOR THE REPAIR OF PIPEWORK

This review of the use of composite materials for the repair of pipework is intended to present an overview of the work that is currently being produced within the Working Group on pipe repairs using composite materials. The overall objective of the technical work carried out under the direction of the Working Group is to establish a framework for the design, installation, and operation of composite repair methodologies. The Working Group’s technical work is carried out by AEA Technology and other members of the group represent material suppliers, users and regulatory agencies.

6.1 SCOPE OF REVIEW

This review covers the use of composite materials for the repair of carbon steel pipework on topside systems which have been originally designed in accordance with ASME/ANSI B31.3: Chemical Plant and Petroleum Refinery Piping. Whereas these codes and standards provide rules for the design, fabrication, inspection and testing of new piping systems, they do not address the fact that these systems may degrade in service and require repair. This review of the use of composite materials for the repair of pipework covers the following circumstances:

- external corrosion where there is no leakage and structural integrity needs to be restored. In this case it is probable that with suitable surface preparation the application of a composite overwrap will arrest further deterioration;
- external damage such as dents, gouges, fretting (at pipe supports) where structural integrity needs to be restored;
- internal metal loss through corrosion or erosion (or a combination of corrosion and erosion), which may or may not be leaking, and there is a need to restore structural integrity. In this case it is probable that internal metal loss will continue and the assessment of the damage and the composite repair option must take this into account. Additional considerations for leaking pipes are discussed in section 6.3.1 of this document.

This review considers the following topsides pipework services:

- utility fluids - diesel, seawater, air, process drains and other drains;
- chemicals;
- produced fluids, including gas and gas condensate.

This review has considered the repair of pipework systems with a pressure/temperature envelope of up to 50 bar (725 psi) and continuous 20°C to 60°C. These pressure ratings have been divided into 3 pressure rating categories; up to 5 barg (typically static head, drains etc.); up to 20 barg/Class 150 (typically water service); and up to 50 barg/Class 300 (produced water/hydrocarbons). For up to 20 bar pressures, the range has been further subdivided into safety critical (e.g. fire water and gas service) and non-safety critical duties (e.g. other liquid services).

The repair longevity considered by this review are temporary (a limited period - up to 2 years) and permanent (remaining lifetime of the piping system).

The composite repair materials considered within this review are those with glass (GRP) or carbon (CFRP) reinforcement in a polyester, vinyl ester or epoxy matrix.

All repair methods considered by this review should be capable of operating up to 60°C for the above operating periods. However, as all of the resin systems considered are cured at room
temperature, use above this temperature should be treated with care. For temporary arrangements, extending this to 90°C is possible as there will be a degree of post cure with the influence of temperature. For extended service, or for critical and higher pressure duties, the resin systems should be used to suit the higher level of performance. This will involve post curing of the repair after application. Suppliers will need to provide the appropriate data on these systems. Repair solutions using composite materials can be regarded as a standard repair method for pressures up to 50 bar. Although a system supplied by Clock Spring® is able to accommodate the pressure stresses generated at this level, it is only intended for use where metal loss is on the outside surface and can be arrested with the application of the composite sleeve.

6.2 TYPES OF COMPOSITE REPAIR

The types of composite repair fall into 2 generic types: ‘bandage’ and ‘engineered’. ‘Bandage’ type repairs involve the application of material, often in pre-packed form, which can be held as a stock repair item and can be applied by maintenance personnel on the facility. ‘Engineered’ type repairs are specified and designed on a bespoke basis with the repair being carried out by specialist contractors.

All of the repairs involve the application of an overwrap to the damaged or defective area(s) in order to reinforce the strength/integrity of the remaining pipe wall. This may involve the ‘on-site’ production of a composite laminate—a combination of a network of fibrous reinforcement and a thermosetting polymer matrix that is subsequently subject to a chemical curing process—or the use of a pre-formed composite sleeve that is wrapped around the pipe and adhesively bonded to the pipe and to subsequent wraps. In situation where external metal loss is being repaired, repair applications that use a pre-formed composite sleeve must also involve the application of some form of load transferring filler to the damaged area prior to application of the composite sleeve.

6.3 DESIGN GUIDANCE

Suppliers of composite material or composite material repair services must provide specific guidance that describes the design and application of their repair option. For bandage type material there should be accompanying datasheets containing details such as the number of layers which should be applied for different repair situations. Information expressed as a function of pressure, temperature, diameter etc. would be typical. For low specification duties the governing criteria will not be applied load, but minimum thickness considerations. For example, it would be normal to apply a minimum of 3 layers to ensure that overlaps and edges are properly supported, and that flaws (e.g. tears, damage to fabric reinforcement etc.) caused by the overwrapping operation are adequately covered. For higher specification duties or bespoke repairs that are to be undertaken by a specialist contractor, the design must be supported by calculations carried out by the material supplier. These calculations may require verification by a third party in the conventional way.

Repairs to piping systems that convey hydrocarbons or certain chemicals need to be considered carefully as these fluids may pose difficulties with long-term performance of the composites (e.g. degradation caused by aromatic compounds). Consideration also needs to be given to possible degradation of a composite repair by ultraviolet light.

There are two main approaches used for the design of a composite overwrap, the main difference being whether or not the original pipe is allowed to exceed its original design allowable. For glass reinforcements that are of fabric or random mat type it is unlikely the repair will be designed such that the steel exceeds yield. In this case it is the load share between the composite and the steel
that is the main design issue. For unidirectional glass or carbon fibre materials, on the other hand, the full benefit of the repair may not be achieved unless the system is allowed to operate at relatively high strains. Here it is assumed that the contribution of the steel to the load carrying capability of the repaired section may be ignored.

In order to assess the contribution of the damaged steel pipe to the integrity of a repair API 579: Recommended practice for fitness for service, may be used. This document provides calculation methods for the assessment of the remaining load carrying capability of pipe that has been subjected to corrosion (general and localised, including pitting), mechanical flaws (induced during fabrication or through abuse) and fire. Where the deterioration will continue after repair (e.g. internal corrosion) the document takes this into account through measured corrosion rates. The result of the calculations is a maximum safe or allowable operating pressure (MAOP) for the damaged pipe. This value is used as an input to the design of the repair.

The design procedures for the repair laminate follow those that are well established in the manufacture of composite process plant where the principle is to limit material strains below the point where damage is generated. Whilst this is well below ultimate strengths it is considered necessary for long term performance. Design strains for composite materials currently cited in, for example prEN13121: GRP tanks and vessels for use above ground, are 0.25%. In circumstances where there is potential for upset conditions it is considered acceptable to allow higher strains, up to 0.40%, and these are used where the repair is limited to temporary service. In principal all types of reinforcement can be used (e.g. woven and random fabrics or unidirectional). In some cases the repair laminate will be anisotropic (i.e. the strength and stiffness in the direction of the fibres will be greater than in other directions) and the design procedures address this issue through the specification of different allowable strain values in different directions. Composite strains are not a design issue where the intention is to contain loads such that the steel remains below its allowable as the applied strains will be well below these levels.

The design approach used in the assessment of the repair must take into account all of the applied loads and the ability of the overwrap to carry these satisfactorily. In some of the repair systems the reinforcement is preferentially orientated circumferentially and in these circumstances will only have limited load carrying capabilities in the axial direction. For complex pipe systems where axial stresses can be significant and where there is sufficient parent metal to carry these loads, the alternative repair options that have similar hoop and axial strengths will need to be considered.

6.3.1 Leaking Pipes

Where the pipe to be repaired is leaking, the effect of this on the likely success of the repair needs to be considered. Whilst the mechanical design of the overwrap is important in determining the success of the repair, by far the single most important issue is that of surface preparation of the parent steel prior to laminating. Whilst there are resin systems for which it is possible to achieve an acceptable bonded connection when surfaces are wet, a dry situation is preferred. Isolation and draining of the pipework can provide a dry external surface adjacent to the perforation. Consideration must be given to the compatibility of the composite repair material and the pipework service (transported fluids).

A distinction must be made between wet surfaces and those where there is flowing liquid. In the case of the latter, when it is not possible to isolate and drain the pipework, the leak should be stemmed/plugged prior to the repair being applied. Some repair systems use grommets which are
extruded through the perforation and afford a degree of self-sealing on the inner pipe surface, other systems use patches to surround the perforated area, and others use a combination of the two. The leak stemming method must be considered as an integral part of the repair and the total arrangement should have been demonstrated to be satisfactory by the supplier through qualification.

6.4 IMPORTANT ASPECTS OF COMPOSITE REPAIRS

6.4.1 Surface Preparation

Surface preparation of the pipe to be repaired is the single most important aspect in the achievement of a successful repair. For repairs to carbon steel pipe it is normally possible to achieve a durable bonded connection with mechanical abrasion as the sole surface preparation activity. It is important, therefore, that the nature of the abrasion technique is fully specified (e.g. blast cleaned to Swedish Standard SA3). It is also important to address the health and safety risks associated with the blast cleaning process itself.

Whilst an adequate bond can be achieved for repairs to carbon steel through mechanical abrasion only, it has been demonstrated that added durability can be achieved through the use of silane coupling agents. These are available in solution and can be simply applied by brush. In some case these include a corrosion inhibitor to protect the surface of the abraded steel.

6.4.2 Cure of Repair Laminate

The cure of a repair laminate is strongly influenced by temperature and the correct mixing of the resin constituents prior to lamination. It is important, therefore, that the prevailing temperature conditions are considered. Application outwith the temperature limits and resin catalyst levels, as recommended by the suppliers, must not be carried out without recourse to the suppliers for further information.

6.5 DOCUMENTATION/DATA REQUIREMENTS

In order for a composite material supplier to correctly specify a proposed repair option, the operator should provide the following information:

- pressure duty, including excursions or upset conditions;
- temperature duty, including excursions and upset conditions;
- process media, including trace constituents;
- non-pressure induced loads acting on the pipe;
- required lifetime of the repair.

The documentation and data that should be provided by the composite material supplier is shown in Table 2 (over page).
Table 2

Documentation and data requirements for pipework repairs

<table>
<thead>
<tr>
<th></th>
<th>Up to 5 barg</th>
<th>Up to 20 barg/Class 150</th>
<th>Up to 50 bar/Class 300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic material</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>documentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design capability</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Surface preparation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- surface abrasion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- chemical primer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-term test data:</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- overwrap material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- bonded joint</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Long-term durab. data:</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- overwrap material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- bonded joint</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Training documentation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Health &amp; Safety</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>documentation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Clarification of the terms used in Table 2 is as follows:

- **Basic material documentation.** This should include a statement of the resins and reinforcements used and any standards to which they are supplied. Basic data on material compatibility with the working environment should also be available.

- **Design capability.** Organisations who offer a repair option for pressurised parts need to have an understanding of the design issues associated with their product and be able to provide calculations with supporting data. Suppliers must have a competent engineering capability.

- **Surface preparation.** The durability of a bonded assembly under applied load is determined to a large extent by the quality of the surface preparation used. For the higher specification duties and for those that are critical to safety, a surface treatment is recommended to promote bonding and to retain its integrity over the required operational period. On carbon steel abrasion by shot blasting (or equivalent) will be satisfactory up to 20 barg. Details of surface preparation and how it is to be implemented in service are required.

- **Short-term test data.** These should include tensile strength and modulus values in both the hoop and axial directions as a minimum. For permanent and medium/high (>5 barg) pressure loads bond strength tests to demonstrate the efficacy of the chosen surface preparation methods should also be carried out. These data should provide an input to the design.

- **Long-term durability data.** Satisfactory designs can be achieved for pressures up to 20 barg based on short-term data that has been downrated by a suitable factor. However, for safety critical service and the higher pressure duties (up to 50 barg), long-term durability data should be provided to demonstrate fitness for purpose. Test data should be available which are in excess of 1000 hours. Long-term effects by fluids and exposure to ultraviolet light should be addressed.

- **Health and safety documentation.** Many of the repair methods involve the handling of chemicals which are inflammable and/or toxic and which pose a hazard to personnel. COSHH (Control of Substances Hazardous to Health) Assessments should be available for all the chemical species concerned and the material supplier should provide documentation. Due
attention to suppliers instructions, the use of simple safety equipment, and good housekeeping is necessary.

- Training documentation. Application of even the simplest repair methods, when applied without due attention to training, will result in difficulties. It is emphasised that the preparation of the steel surface before bonding is vital to achieve a successful repair.

In certain cases, third party verification of the proposed design will be necessary. This will depend on the nature of the pipe system being repaired and the need for verification will arise from a hazard assessment carried out by the operator.

### 6.6 FIRE PERFORMANCE

The requirements for fire performance of a composite repair afforded to a pipe should be identified in the risk assessment of the pipe system. Flame spread and smoke generation shall also be considered in the assessment. Due account shall be taken of the fact that in many cases fire protection will not be necessary as the damaged steel pipe may still be able to perform satisfactorily during the short duration of a fire event. Strategies for achieving fire performance include the following:

- application of additional overwrap material such that enough basic composite will remain in tact for the duration of the fire event;
- application of intumescent external coatings;
- application of intumescent and other energy absorbent materials within the laminate;
- use of resin formulations with specific fire retardant properties.

Further guidance on the design and testing of composites for fire performance may be obtained from ISO 14692: Specification and recommended practice for the use of GRP piping in the petroleum and natural gas industries.

### 6.7 INSPECTION OF COMPOSITE REPAIRS

GRP overwrap, if unpigmented, is amenable to visual inspection and the ingress of fluid within the overwrap or at the interface between it and the parent steel can be seen, particularly if unnecessary fillers or pigments are excluded from the repair material. Where this is not possible for reasons of opacity, ultrasonic methods would be effective to locate delaminations between the repair and the parent pipe. Ultrasonic frequencies in the range 0.5 MHz to 1MHz are usually used.

Examination of the original pipe underneath the repair is not straightforward as attenuation at the repair/pipe interface will render use of conventional ultrasonics difficult. Newer techniques such as CHIME (Creeping Head Wave Inspection Method) where the full volume of the pipe can be examined from probes placed outside the repair could be used. Other methods such as transient thermography or low frequency eddy currents could be useful, but not without an element of development in the field. Alternatively, for critical applications, ultrasonic transducers mounted on a flexible printed circuit could be placed on the pipe prior to application of the repair and left in situ.

It is not possible to determine the properties of the actual repair laminate. However, it would be possible to prepare a sample laminate along side the repair using the same materials. This could be used to measure parameters, such as fibre content and mechanical characteristics. Generally, this option would only be considered for the higher specification repairs (50 barg/Class 300).
7. TRACK RECORD OF DIFFERENT REPAIR CLAMPS/CONNECTORS

Pipe repair components—in their simplest forms of reinforcement sleeves and patches—have been used for piping repair applications, in all industries, for at least a century. Many of the original applications will have been applied with little thought on the engineering aspects of the repair, and may well have utilised material that simply happened to be ‘kicking around’ at the time.

With the advent of the oil and gas, and petrochemical industries, piping and pipeline installations became abundant. For example, the cross-country gas distribution system in the United Kingdom (as at 1987) contained some 200,000 kilometres of mains, of which over 50% were furnished in grey cast iron. The average age of this grey cast iron is estimated to be over 50 years.

Until fairly recently, 2 types of repair clamp were used by British Gas to repair fractured or damaged ferrous distribution mains—cast iron split collars and stainless steel pipe repair clamps, both using rubber strip type gaskets. These types of gaskets are necessary to accommodate the large variations in pipe outside diameter, in particular the variations associated with cast iron and ductile iron mains. In the late 1980s, some 35,000 of these clamps were being used by British Gas each year. A series of development projects, undertaken by British Gas to improve the reliability and performance of these clamps, resolved the problems of outside diameter size variations and maintenance of a leak-tight repair. A number of repair clamp manufacturers have specifically designed repair clamps for the gas industry, with many of the products meeting the stringent requirements of British Gas’ BG/PS/LC8 Part 4 Specification. This Specification was drafted with the objective of developing pipe repair clamps and collars that will seal on a wide tolerance band of pipe sizes, can survive all anticipated pipe movements, and maintain a gas-tight seal for a target life of 50 years. These repair clamps/collars are furnished with a complete encirclement gasket which is held in intimate contact with the outside surface of the pipe and are, therefore, not ‘stand-off’ type repair clamps.

‘Stand-off’ (enclosure) type repair clamps and connectors have been used in most industries for many decades. This type of repair clamp/connector has found applications to all pipe and pipeline situations, including sub-sea, buried and above-ground locations. Many thousands of clamps/connectors have been installed to repair damaged pipework/pipelines. Their designs have been refined over many years with their capabilities mainly being extended through the use of different formulations of elastomeric seal materials. For oil and gas applications, modern fluoroelastomers, such as AFLAS™ (based on tetrafluoroethylene and propylene), have excellent resistance to petroleum products, volatile hydrocarbons, and aromatics. AFLAS™, for instance, has an upper temperature application of approximately 230°C (450°F).

The more sophisticated pipe connectors, such as Oceaneering’s ‘Smart Flange’ and Hydratight’s ‘MORGRIP’ coupling, have found applications to particular pipeline repair scenarios, including both sub-sea pipelines and topside risers. These particular products have been available since 1986 and 1990 respectively, and have been installed around most regions of the world. More recently, applications include topside pipework repairs and modifications, including the installation of connectors with fire-safe sealing capabilities.
The novel epoxy-filled sleeve repair technique is not entirely new – British Gas began research and development on their system back in 1979. The epoxy sleeve repair (ESR) technique is now offered by the Pipeline Integrity International (PII) Group, a merger between British Gas’ former Pipeline Integrity International and Pipetronix. Since its introduction in the early 1980s, ESR has been successfully applied in over 2000 repair situations. The ESR technique has been successfully adapted to a wide range of sizes of pipe, operating at pressures up to 100 bar (1450 psi), transporting gas, crude or refined oil and petroleum products, as well as specialist applications in process pipework and topsides pipework.
8. CATEGORISATION OF REPAIRS (TEMPORARY OR PERMANENT)

Previous sections of this document have shown that most of the pipe repair components have a design basis in accordance with internationally recognised codes or standards. In most cases these codes or standards may not concern piping or pipelines, but concern pressure vessel type codes, such as ASME Section VIII: Pressure Vessel Code, or API 6H: Specification on End Closures, Connectors and Swivels. Pressure vessel codes, unlike piping codes, have a greater degree of flexibility in their application.

Many of the proprietary repair clamps and connectors that are available for use on pipe and pipeline repairs have received Type Approvals from various Certifying Authorities. Many of the sophisticated pipe connectors are approved as ‘permanent substitutes for welded connections’. However, when the repair component utilised is in the form of a ‘stand-off’ type repair clamp or enclosure, the repair is very much regarded as placing a pressure vessel around the damaged area – no welding is involved or ‘substituted’. In these situations one must consider the life-cycle of the repaired pipe system – will internal metal loss of the pipe underneath the clamp continue? will degradation of the elastomeric seal material occur? These considerations will dictate the need to afford periodic inspection and/or testing to the repair component. It may be possible to periodically test the integrity of the seal areas, but this may not provide any information on the integrity of the pipe wall -conditions may be approaching the limit of the remaining pipe wall to carry the internal pressure imposed axial stresses when the repair clamp does not have the ability to accommodate these stresses.

For all pipe repairs, the operator needs to perform a structured risk assessment that includes the consideration of all of the potential future damage or deterioration mechanisms. The output from this risk assessment will typically be the specification of the necessary inspection and testing activities, and associated periodicities, to ensure continuing ‘fitness-for-purpose’. The repair component itself may well be regarded as being a permanent repair (a repair component that is intended to remain in place for the remaining life of the piping system), but may require periodic examination. This is particularly important when repairs have been afforded to a safety-critical piping system, where there is a need to demonstrate that the system “remains in good repair and condition”.

For safety critical piping systems the repair philosophy should, whenever possible, be:
- replace like-for-like;
- temporary repair until replacement can be carried out;
- permanent repair only where replacement is not practical.

This approach is in line with the principles of prevention as outlined in the Guidance to the Management of Health and Safety at Work Regulations 1999, SI No. 3242 -in particular the principle of “control risks at source, rather than taking palliative measures” is relevant.
9. PIPE REPAIRS USING PIPE CLAMPS/CONNECTORS - OTHER CONSIDERATIONS

One of the main considerations that need to be taken into account when using a pipe repair clamp or connector—the ability of the repair system to accommodate the pressure imposed axial loadings/stresses—has already been discussed in this document. There are, however, other considerations that need to be addressed, preferably at the design stage of the repair. These will include:

- the need for additional pipe supports. The additional weight provided by the repair component itself may dictate the need for additional pipe supports.
- consideration of vibration. The ‘new’ pipework arrangement (repaired section c/w repair component) may change the whole nature of the stiffness and flexibility of the pipework section at the repair site. This could result in the shifting of areas where vibration ‘hot-spots’ were noted and where adequate support arrangements (e.g. spring-loading pipe supports) were provided. Special consideration should be given to the effect that the repair may have on small bore off-takes. Small bore off-takes are particularly prone to fatigue damage when they carry inadequately supported instrument fittings etc.

The above considerations may introduce the requirement to perform additional inspection activities to those currently conducted (e.g. inspect for corrosion, or other, damage under pipe supports). What is essential is that the existing maintenance/inspection programme for the piping system is re-visited whilst considering all of the potential failure/damage mechanisms and amendments to the programmes (e.g. nature and frequency) are implemented. This could include the need to periodically examine the repair component itself.
REFERENCES

1. CORDER, I
   *Cost-effective on-line repair of pipeline damage using epoxy-filled shells*
   Pipeline Risk Assessment, Rehabilitation and Repair Conference, Texas, May 1991

2. KIEFNER, J F
   *Repair of line pipe defects by full-encirclement sleeves*
   Welding Journal, June 1977, pp 26-33

3. RIETJENS, P
   *Procedures for damage assessment, in-service welding and repair of pipelines*
   IGU 16th World Gas Conference, Munich, 1985

4. HAWKE, B
   *One-stop epoxy-filled sleeve repair technique meets needs*
   Pipe Line & Gas Industry Journal, August 1997, pp 47-51

5. AYRES, C
   *Developments in pipe repair clamps and collars*
   Paper presented to the London and Southern Gas Association, January 1988
APPENDIX 1

PRINT-OUT OF SEARCH RESULTS USING KEYWORDS OF PIPE/PIPING, REPAIR, REVIEW, OVERVIEW, STATE ART (state-of-the-art), and SURVEY

L1  251472 S PIPE?/TI,CT,ST,IT OR PIPING?/TI,ST,CT,IT
L2  33156 S REPAIR?/TI,CT,ST,IT
L3  7460 S L1 AND L2
L4  14804 S CLAMP?
L5  23377 S CONNECTOR?
L6  209296 S COMPOSITE?
L7  8067 S WRAP?
   SET RANGE=(1985,)
L8  4760 S L3
L9  239 S L8 AND L4
L10 346 S L8 AND L5
L11 138 S L8 AND L6
L12 156 S L8 AND L7
L13 462978 S REVIEW? OR OVERVIEW? OR STATE(2W)ART OR SURVEY?
L14 607 S L8 AND L13
L15 586 DUPLICATE REMOVE L14 (21 DUPLICATES REMOVED)
L16 58183 S (PIPE? OR PIPING?)/TI
L17 8779 S REPAIR?/TI
L18 763 S L16 AND L17
L19 97 S L18 AND L13
L20 86 DUPLICATE REMOVE L19 (11 DUPLICATES REMOVED)

L20 ANSWER 1 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
DUPLICATE 1
TI  Performance of repair welds on aged Cr-Mo piping girth welds.
CC  *S36 Materials science
   S42 Engineering
CT  TENSILE PROPERTIES; CREEP;
MICROHARDNESS; GAS TUNGSTEN-ARC WELDING;
   REPAIR; STEEL-CRMO; PIPES;
HEAT TREATMENTS; SERVICE LIFE
CTDE ZUGEIGENSCHAFTEN;
KRIECHEN; MIKROHAERTE;
WOLFRAM-INERTGASSCHWEISSEN;
REPARATUR; STAHL CRMO;
LEITUNGSROHRE;
WAERMEBEHANDLUNGEN;
NUTZUNGSDAUER

L20 ANSWER 2 OF 86 ENERGY
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DUPLICATE 7
TI  Pipeline incidents and emergency repair in the North Sea.
Emergency pipeline repair.

Quality control systems for construction, repair, and alteration of pipelines.

Application of composite repair for pipeline anomalies.
FIBERGLASS; FIELD TESTS; MAINTENANCE; MATERIALS TESTING; MATHEMATICAL MODELS; NATURAL GAS DISTRIBUTION SYSTEMS; PERFORMANCE; PIPELINES; REPAIR; RUPTURES; SLEEVES; TENSILE PROPERTIES; TRANSPORT
*PIPELINES; *REPAIR; *NATURAL GAS DISTRIBUTION SYSTEMS; *REPAIR;
*COMPOSITE MATERIALS;
*PERFORMANCE
CTDE DATENSAMMLUNG; VERBUNDSTOFFE; KORROSIONSPRODUKTE; SCHADEN; FIBERGLAS; FELDVERSUCHE; WARTUNG; WERKSTOFFPRUEFUNG; MATHEMATISCHE MODELLE; ERDGASVERTEILUNGSSYSTEME; LEISTUNGSFÄHIGKEIT; PIPELINES; REPARatur;
DURCHBRÜCHE; MUFFEN; ZÜGEIGENSCHAFTEN; TRANSPORT BT COMPOSITE MATERIALS; DATA; ENERGY SYSTEMS; FAILURES; INFORMATION;
MATERIALS; MECHANICAL PROPERTIES; NUMERICAL DATA; TESTING

L20 ANSWER 8 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE TI Evaluation of temporary non-code repairs in safety class 3 piping systems.
CC *220900; 210200; 210100; 210700; E3200; E3100; F2200
CT AUXILIARY WATER SYSTEMS; BIOLOGICAL FOULING; CONNECTICUT YANKEE REACTOR; ENGINEERED SAFETY SYSTEMS; MILLSTONE-1 REACTOR; MILLSTONE-2 REACTOR; MILLSTONE-3 REACTOR; PIPES; REGULATIONS; REPAIR; STANDARDS; SYSTEMS ANALYSIS

*ENGINEERED SAFETY SYSTEMS: *PIPES; *PIPES; *REPAIR;
*AUXILIARY WATER SYSTEMS: *PIPES; *MILLSTONE-1 REACTOR; *ENGINEERED SAFETY SYSTEMS;
*MILLSTONE-1 REACTOR: *REGULATIONS; *MILLSTONE-1 REACTOR; *AUXILIARY WATER SYSTEMS; *MILLSTONE-2 REACTOR; *ENGINEERED SAFETY SYSTEMS;
*MILLSTONE-2 REACTOR: *REGULATIONS; *MILLSTONE-2 REACTOR; *AUXILIARY WATER SYSTEMS; *MILLSTONE-3 REACTOR; *ENGINEERED SAFETY SYSTEMS;
*MILLSTONE-3 REACTOR: *REGULATIONS; *MILLSTONE-3 REACTOR; *AUXILIARY WATER SYSTEMS;
*CONNECTICUT YANKEE REACTOR: *ENGINEERED SAFETY SYSTEMS;
*CONNECTICUT YANKEE REACTOR: *REGULATIONS;
*CONNECTICUT YANKEE REACTOR: *AUXILIARY WATER SYSTEMS

CTDE NEBENKUEHLWASSERSYSTEME; BIOBEWUCHS; REAKTOR CONNECTICUT YANKEE; TECHNISCHE SICHERHEITSSYSTEME; REAKTOR MILLSTONE-1; REAKTOR MILLSTONE-2; REAKTOR MILLSTONE-3; LEITUNGSROHRE; VORSCHRIFTEN; REPARATUR; NORMEN;
SYSTEMANALYSE
BT AUXILIARY SYSTEMS; BWR TYPE REACTORS; ENRICHED URANIUM REACTORS; FOULING;
POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS

L20 ANSWER 9 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
Encirclement sleeves reduce pipeline repair costs.

Update on pipeline repair methods.

Robotic equipment for pipeline repair.

Sleeve installations speed pipeline defect repair.

Review of repairs to offshore structures and pipelines.

Subsea repair of gas pipelines without water flooding. Final report.
*PIPES: *REPAIR; *PIPES: *UNDERWATER OPERATIONS;
*NATURAL GAS
INDUSTRY: *PIPES: *REPAIR; *PIPES: *UNDERWATER OPERATIONS;
*PIPES: *NATURAL GAS INDUSTRY: *PIPES: *REPAIR;
CTDE KOSTEN; SCHADEN; ERDGAS; ERDGASVERTEILUNGSSYSTEME;
ERDGASINDUSTRIE;
PIPELINES; REPARATUR; MEERE; WERKZEUGE;
UNTERWASSERARBEITEN; WASSERBT ENERGY SOURCES; ENERGY
SYSTEMS; FLUIDS; FOSSIL FUELS; FUEL GAS; FUELS;
GAS FUELS; GASES; HYDROGEN
COMPOUNDS; INDUSTRY; OXYGEN
COMPOUNDS; SURFACE
WATERS

L20 ANSWER 17 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IAE-ETDE
TI Factors affecting heat affected zone
root strains in pipeline girth welds
and repairs.
CC *361003; 032000; 420205
CT CRACK PROPAGATION; DATA;
HEAT AFFECTED ZONE; HYDROGEN
EMBRITTLEMENT;
MATHEMATICAL MODELS;
PARAMETRIC ANALYSIS; PIPES;
STRESS ANALYSIS;
TENSILE PROPERTIES; WELDED
JOINTS
*PIPES: *WELDED JOINTS;
*WELDED JOINTS: *HEAT AFFECTED
ZONE; *HEAT
AFFECTED ZONE: *HYDROGEN
EMBRITTLEMENT
CTDE RISSWACHSTUM; DATEN;
WAERMEEINFLUSSZONE;
WASSERSTOFFVERSPROEDUNG;
MATHEMATISCHE MODELLE;
PARAMETERSTUDIEN; PIPES;
SPANNUNGSANALYSE;
ZUGEIGENSCHAFTEN;
SCHWEISSVERBINDUNGEN
BT EMBRITTLEMENT;
INFORMATION; JOINTS;
MECHANICAL PROPERTIES; ZONES

L20 ANSWER 18 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IAE-ETDE
TI Aging of pipelines: Risk assessment,
rehabilitation and repair.
CC *420205
CT COST; PIPES: PROTECTIVE
COATINGS; REPAIR; RETROFITTING;
SERVICE LIFE;
USA
*PIPES: *RETROFITTING;
*PIPES: *REPAIR; *PIPES: *PROTECTIVE
COATINGS; *PROTECTIVE
COATINGS; *SERVICE LIFE; *USA:
*PIPES: *REPAIR;
CTDE KOSTEN; PIPES;
SCHUTZUEBERZUEGE; REPARATUR;
NACHRUESTUNG;
NUTZUNGSDAUER; USA
BT COATINGS; DEVELOPED
COUNTRIES; LIFETIME; NORTH
AMERICA

L20 ANSWER 19 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IAE-ETDE
TI Effects of repair welding on the
residual stress distribution and fracture
toughness in pipeline girth welds.
CC *022000; 032000; 361001
CT FRACTURE PROPERTIES; GRAIN
REFINEMENT; MICROSTRUCTURE;
ORBITS; PIPES;
Pipes; REPAIR; RESIDUAL
STRESSES; SHIELDED METAL-ARC
WELDING; WELDED
JOINTS; WELDING
*PIPES: *WELDING;
*WELDED JOINTS: *FRACTURE
PROPERTIES; *WELDED
JOINTS: *RESIDUAL STRESSES
CTDE BRUCHEIGENSCHAFTEN;
KORNVERFEINERUNG;
MIKROSTRUKTUR;
UMLAUFBAHNNEN;
PIPES; LEITUNGSROHRE;
REPARATUR; RESTSPANNUNG;
METALL-
LICHTBOGENSCHWEISSEN
UNTER SCHUTZGAS;
SCHWEISSVERBINDUNGEN;
SCHWEISSEN
BT ARC WELDING; FABRICATION; JOINING; JOINTS; MECHANICAL PROPERTIES; STRESSES; WELDING

L20 ANSWER 20 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Diver assisted pipeline repair manual: Volumes 1 and 2.
CC *032000; 360100
CT DIAGRAMS; DIVING OPERATIONS; INFORMATION; MANUALS; NATURAL GAS DISTRIBUTION SYSTEMS; OFFSHORE OPERATIONS; PIPELINES; REPAIR; SPECIFICATIONS; UNDERWATER OPERATIONS
*PIPELINES; *REPAIR; *DIVING OPERATIONS; *MANUALS CTDE DIAGRAMME; TAUCHARBEITEN; INFORMATION; HANDBUechER;
ERDGASVERTEILUNGSSYSTEME; OFFSHORE-ARBEITEN; PIPELINES; REPARATUR;
SPEZIFIKATIONEN; UNTERWASSERARBEITEN
BT DOCUMENT TYPES; ENERGY SYSTEMS; UNDERWATER OPERATIONS
ET I

L20 ANSWER 21 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
CC *032000
CT APARTMENT BUILDINGS; LEAK TESTING; MAINTENANCE; NATURAL GAS DISTRIBUTION SYSTEMS; PIPES; REPAIR; SEALING MATERIALS;
SPECIFICATIONS; STEELS
*NATURAL GAS DISTRIBUTION SYSTEMS; *REPAIR
BT ALLOYS; BUILDINGS; IRON ALLOYS; IRON BASE ALLOYS;
MATERIALS; RESIDENTIAL BUILDINGS; TESTING

ET I

L20 ANSWER 22 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Cost friendly working- and repair methods in district heating pipe works.
Kostenguenstige Arbeits- und Reparaturmethoden an Fernwaermeleitungen.
CC *290800
CT BUILDINGS; COST RECOVERY; DISTRICT HEATING; FIBERS; HEAT DISTRIBUTION SYSTEMS; INSTALLATION; JOINTS; PIPE FITTINGS; REPAIR; RETROFITTING;
THERMAL INSULATION
*DISTRICT HEATING: *REPAIR;
*DISTRICT HEATING;
*INSTALLATION
BT HEATING
ET Am

L20 ANSWER 23 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Unique pipeline repair conducted in North Sea.
CC *022000; 420205
CT INSPECTION; LEAK TESTING; MAINTENANCE; NORTH SEA; OIL FIELDS; PIPELINES;
REPAIR; SURVEYS
*NORTH SEA; *OIL FIELDS; *OIL FIELDS: *PIPELINES; *PIPELINES:
*REPAIR;
*PIPELINES; *SURVEYS
BT ATLANTIC OCEAN; GEOLOGIC DEPOSITS; MINERAL RESOURCES; PETROLEUM DEPOSITS;
RESOURCES; SEAS; SURFACE WATERS; TESTING
ET S

L20 ANSWER 24 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Diverless pipeline repair clamp: Phase 1.
CC *032000; 022000
CT AUTOMATION; COST; DEFECTS; DEPTH; INSPECTION; LEAKS;
NATURAL GAS;
Overview of Chinshan Nuclear Power Station recirculation pipe repair and replacement.

State-of-the-art ROV and control system for deepwater pipe repair.

Pipeline coatings - Evaluation, repair, and impact on corrosion protection design and cost.
SOIL-STRUCTURE INTERACTIONS; TESTING; TRANSPORT; UNDERGROUND BT COATINGS; CORROSION PROTECTION; ENERGY SOURCES; FOSSIL FUELS; FUELS; LEVELS

L20 ANSWER 28 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Development of small excavation low pressure cast iron pipe joint repairing method from outside.
CC *032000
CT *LNG INDUSTRY; *PIPPINES: *PIPE JOINTS; *NATURAL GAS DISTRIBUTION SYSTEMS: *PIPPINES; *PIPE JOINTS: *REPAIR; CAST IRON; ELECTROMAGNETIC SURVEYS; REMOTE HANDLING BT ALLOYS; CARBIDES; CARBON COMPOUNDS; ELECTRICAL SURVEYS; ENERGY SYSTEMS; GEOPHYSICAL SURVEYS; INDUSTRY; IRON ALLOYS; IRON BASE ALLOYS; IRON CARBIDES; IRON COMPOUNDS; JOINTS; NATURAL GAS INDUSTRY; SURVEYS; TRANSITION ELEMENT COMPOUNDS ET In

L20 ANSWER 29 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Constraints on boiling water reactor piping system inspection, mitigation, repair and replacement.
CC *210100; 360103; E3100; B2230
CT *STAINLESS STEELS; *CRACK PROPAGATION; *REACTOR COOLING SYSTEMS: *PIPPES; *STAINLESS STEELS; *PIPPES; *BWR TYPE REACTORS; *REACTOR COOLING SYSTEMS; CRACKS; INSPECTION; MITIGATION; REPAIR; STAINLESS STEEL-304; USA

BT ALLOYS; CHROMIUM ALLOYS; CHROMIUM STEELS; CHROMIUM-NICKEL STEELS; COOLING SYSTEMS; CORROSION RESISTANT ALLOYS; ENERGY SYSTEMS; HEAT RESISTANT MATERIALS; HEAT RESISTING ALLOYS; IRON ALLOYS; IRON BASE ALLOYS; MATERIALS; NICKEL ALLOYS; NORTH AMERICA; REACTOR COMPONENTS; REACTORS; STAINLESS STEELS; STEELS; WATER COOLED REACTORS; WATER MODERATED REACTORS

L20 ANSWER 30 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI A diverless pipeline repair system using hyperbaric welding and remote vehicle.
CC *423000
CT OFFSHORE OPERATIONS; PIPELINES; REMOTE HANDLING EQUIPMENT; REPAIR; UNDERWATER OPERATIONS *PIPPINES; *REPAIR; *UNDERWATER OPERATIONS; *REMOTE HANDLING EQUIPMENT BT EQUIPMENT; MATERIALS HANDLING EQUIPMENT

L20 ANSWER 31 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Repair coatings and durable paints for gas-distribution piping systems.
CC *032000
CT *PAINTS; *PROTECTIVE COATINGS; *PIPES; *PAINTS; *NATURAL GAS DISTRIBUTION SYSTEMS: *PIPES; *PIPPES; *PROTECTIVE COATINGS; MAINTENANCE; PLASTICS BT COATINGS; ENERGY SYSTEMS; MATERIALS; PETROCHEMICALS; PETROLEUM PRODUCTS; SYNTHETIC MATERIALS
Pipeline repair based on diagnostic inspection-investment return.

TI  Pipeline repair based on diagnostic inspection-investment return.
CC 619.1 Pipe, Piping and Pipelines; 913.3.1 Inspection; 913.5 Maintenance
CT *High pressure pipelines; Failure analysis; Defects; Inspection; Repair
ST In line inspection

L20 ANSWER 41 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI  Inspection- and repair robots for waste water pipes - a challenge to sensorics and locomotion.
CC 731.5 Robotics; 731.6 Robot Applications; 723.5 Computer Applications; 741.2 Vision; 452.4 Industrial Wastes
CT *Mobile robots; Computer vision; Wastewater reclamation; Pipe; Repair; Sensors; Robotics
ST Tethered robots

L20 ANSWER 42 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI  Underwater pipeline repair.
CC 619.1 Pipe, Piping and Pipelines; 446.1 Water Supply Systems; 534.2 Foundry Practice; 545.2 Iron Alloys; 913.5 Maintenance; 421 Strength of Building Materials. Mechanical Properties
CT *Submarine pipelines; Cost effectiveness; Leakage (fluid); Repair; Crack propagation; Structural analysis; Gaskets; Pipe joints; Water pipelines; Cast iron pipe
ST Pressurized pipe

L20 ANSWER 43 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI  Probabilistic tools for planning of inspection and repair of corroded pipelines.
CC 619.1 Pipe, Piping and Pipelines; 913.3.1 Inspection; 913.5 Maintenance; 912.2 Management; 539.1 Metals Corrosion
CT *Pipelines; Inspection; Repair; Decision making; Corrosion; Planning
Probabilistic integrity assessment methods; Inspection planning; Corrosion damage

Evaluation of temporary non-code repairs in safety class 3 piping systems.

Evaluation of temporary non-code repairs in safety class 3 piping systems.

Robotic equipment for pipeline repair.

Robotic equipment for pipeline repair.

Underwater pipeline repair. Problems and solutions.

Underwater pipeline repair. Problems and solutions.

Developments in pipe repair clamps and collars.

Extension of service life for trunk oil pipelines on the basis of inspection and effective methods of repair.
EFFICIENCY; FAILURE; FATIGUE; HAZARD; *INSPECTING; INSULATING MATERIAL; LINE PIPE; *MAINTENANCE; MEETING PAPER; NONE; OPERATING CONDITION; PHYSICAL PROPERTY; PIPE; *PIPELINE; PIPELINE CONSTRUCTION; PREVENTION; SAFETY; SERVICE LIFE; SEVERITY; SHUTDOWN; SURVEYING; THERMAL INSULATION; *TRUNK PIPELINE; WELDING LT PIPELINE; SERVICE LIFE; TRUNK PIPELINE LT CARGO; CRUDE OIL; CRUDE OIL (WELL) LT NONE; SHUTDOWN ATM Template not available

L20 ANSWER 50 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER DUPLICATE 8 TI STATE-OF-THE-ART ROV ((REMOVELY OPERATED VEHICLE)) AND CONTROL SYSTEM FOR DEEPWATER PIPE REPAIR CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE CT CAMERA; COMMERCIAL; COMMUNICATION SYSTEM; *COMPUTER CONTROL; *COMPUTING; CONTROL EQUIPMENT; DEEP WATER; DRIVE; DYNAMIC POSITIONING; ECONOMIC FACTOR; ELECTRIC MOTOR; EQUIPMENT TESTING; HORSEPOWER; HYDRAULIC SYSTEM; LIGHTING EQUIPMENT; *MAINTENANCE; MAP; MECHANICAL WAVE; MEETING PAPER; MONITORING; *OFFSHORE; OPERATOR; PERSONNEL; PHOTOGRAPHIC EQUIPMENT; *PIPELINE; POWER; PUMP; REMOTE; *SHIP; SOUND WAVE; STATE OF THE ART; SUBSURFACE; TELEVISION; THRUSTER; UNDERWATER

L20 ANSWER 51 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER TI Smart LDAR [(leak detection and repair)]: A streamlined leak detection and repair technique for refinery valves and other pipeline components CC AIR POLLUTION SOURCES; HEALTH & ENVIRONMENT; MEASUREMENT METHODS CT 115-10-6; 74-98-6; AIR POLLUTANT; ATE; C2; C3; CALIFORNIA; COMPOSITION; CONCENTRATION; DISTRICT 5; ESSO; ETHER; FITTING; FLANGE; *FUGITIVE EMISSION; GROUP IA; GROUP VB; INDUSTRIAL PLANT; LASER; *LEAK; LITHIUM; LOS ANGELES; *MAINTENANCE; MASER; MEETING PAPER; METHYL ETHER; *MONITORING; NIOBIUM; NORTH AMERICA; OIL REFINERY; OXYGEN; PHILLIPS PETROLEUM; PIPELINE; POLLUTANT; PROPANE; PUMP; SATURATED CHAIN; SEAL; SINGLE STRUCTURE TYPE; SUBSTANCE DETERMINED; TRANSITION METAL; USA; VALVE; VOLATILE ORGANIC COMPOUNDS; *WASTE MATERIAL LT AIR POLLUTANT; FUGITIVE EMISSION; POLLUTANT; SUBSTANCE DETERMINED; VOLATILE ORGANIC COMPOUNDS; WASTE MATERIAL LT ATE; GROUP IA; GROUP VB; GROUP VIA; LITHIUM; NIOBIUM; OXYGEN; TRANSITION METAL LT 74-98-6; AIR POLLUTANT; C3; HYDROCARBON; POLLUTANT; PROPANE; SATURATED
Pipeline Rehabilitation surveys for prioritizing coat-wrap repairs of old cross-country pipelines

Pipeline repair based on diagnostic inspection - Investment return

Inspection and repair of a sour crude oil pipeline

Pipeline tie-in and repair by surface U-spool connection
Pipeline repair development in support of the Oman to India gas pipeline

Robotic Equipment for Pipeline Repair

Deepwater Pipeline Repair Technology: A General Overview

Hyperbaric pipeline repair system: Current achievements and new deep water challenges
WATER; DRY; ECONOMIC FACTOR; EQUIPMENT; EUROPE; EXPORT; HIGH PRESSURE; JOINT VENTURE; *MAINTENANCE; MEETING PAPER; MODIFICATION; NATURAL GAS; NONE; NORWAY; OPERATING CONDITION; OPERATOR; ORGANIZATION; OWNERSHIP; PERSONNEL; *PIPELINE; PIPELINE TERMINAL; PRESSURE; REMOTE; SCANDINAVIA; STATOIL; SUBSURFACE; TRADE; TRANSPORTATION; TRANSPORTATION TERMINAL; UNDERWATER; *WELDING; WET LT ECONOMIC FACTOR; NONE; OPERATOR; PERSONNEL; PIPELINE; SUBSURFACE; UNDERWATER LT CONTROL; REMOTE LT CARGO; NATURAL GAS ATM Template not available

L20 ANSWER 60 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER
TI Technological Advances in Pipeline Isolation and Repair CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE CT ABSTRACT; COMMUNICATION; COST; COST REDUCTION; DEMAND; ECONOMIC FACTOR; EMERGENCY; *ENVIRONMENTAL IMPACT; *MAINTENANCE; OFFSHORE; *OPERATING CONDITION; *PIPELINE; RELIABILITY; *SAFETY; SHUTDOWN; SPECIFICATION; SUBSURFACE; UNDERWATER; VALVE LT OFFSHORE; PIPELINE; RELIABILITY; SUBSURFACE; UNDERWATER ATM Template not available

L20 ANSWER 61 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER
TI Underwater pipeline repair: difficult seabed conditions
TI  Decision criteria for acceptance or repair of corrosion defects in pipelines
CC  ENVIRONMENT, TRANSPORT & STORAGE; PIPELINE CONSTRUCTION; PIPELINE CORROSION; PIPELINE MAINTENANCE; SAFETY; TRANSPORTATION AND STORAGE
CT  ACCEPTANCE TEST; ASME; ASSOCIATION; CARGO; COMPUTER PROGRAMING; COMPUTING;
*CORROSION; *DEFECT; DEFORMATION; DEPTH;
*EQUIPMENT TESTING; FAILURE; FLUID FLOW; FORCE;
HYDROSTATIC TESTING; LENGTH; MAINTENANCE; MAP; MEETING PAPER; NATURAL GAS;
OPERATING CONDITION; *PIPELINE; PROGRAMING; REVIEW;
SAFETY; SPECIFICATION; STRESS; WIDTH
LT  CARGO; NATURAL GAS
LT  DEFECT; DEPTH; LENGTH; WIDTH
ATM Template not available

L20  ANSWER 65 OF 86  APILIT2
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TI  Advances in underground technology to significantly reduce pipeline repair times
CC  PIPELINE MAINTENANCE;
TRANSPORTATION AND STORAGE
CT  ABSTRACT; BRITISH GAS CORP; BURYING; COATING MATERIAL;
COMPOSITION;
*MAINTENANCE; MEETING PAPER; OPERATING CONDITION; PERSONNEL;
*PIPELINE; PRESSURE; PRIOR TREATMENT; REPLACEMENT;
SEA FLOOR; SEALING;
SUBSURFACE; SURVEYING; TIME;
UNDERGROUND; USE; WEIGHT; WELDING
LT  DIAMETER; PIPELINE;
SUBSURFACE; UNDERGROUND;
UNDERWATER; WEIGHT
LT  IN SITU; MAINTENANCE; TIME
LT  BURYING; PRIOR TREATMENT
LT  ECONOMIC FACTOR;
PERSONNEL; SUBSURFACE;
UNDERWATER
ATM Template not available
[A discussion of] the principles for renovation or repair of gas pipelines
Grundsaetze fuer die Erneuerung oder Instandsetzung von Gasrohrleitungen

Cost-effective on-line repair of pipeline damage using epoxy-filled shells

Cost-effective on-line repair of pipeline damage using epoxy-filled shells

Emergency pipeline repair connects subsea pipelines--1

(A discussion of) systems for ROV actuation and repair of pipeline ball valves

Emergency pipeline repair connects subsea pipelines--1
LOW TEMPERATURE;
*MAINTENANCE; MEETING PAPER;
OPERATING CONDITION;
*PIPELINE; REVIEW;
SUBSURFACE; TEMPERATURE;
UNDERWATER
ST CONNECTOR
LT CYLINDER; JOINT
LT PIPELINE; SUBSURFACE;
UNDERWATER

L20 ANSWER 74 OF 86 APILIT2
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TI Remote Underwater Excavation - A
New Approach to Sensitive Pipeline
Repair, Reinstallation and Servicing
CC PIPELINE MAINTENANCE;
TRANSPORTATION AND STORAGE
CT 8002-05-9; ABSTRACT;
ACCIDENT; BYPASS; CARGO;
*CONSTRUCTION; CRUDE OIL;
CRUDE OIL (WELL); DRILLING
(WELL); *EXCAVATING;
EXCAVATING MACHINERY;
EXPOSURE; FULL SCALE;
*MAINTENANCE; MEETING PAPER;
OFFSHORE STRUCTURE; OIL
AND GAS FIELDS; OIL RESERVOIR;
OIL WELL; *PIPELINE
CONSTRUCTION; REMOTE;
REVIEW; SHIP; SUBSURFACE;
TIME; TRANSPORTATION;
UNDERWATER; WELL
ST PIPER FIELD
LT CONSTRUCTION; EXCAVATING;
MAINTENANCE; PIPELINE
CONSTRUCTION; REMOTE;
SUBSURFACE; TIME;
UNDERWATER
LT 8002-05-9; CARGO; CRUDE OIL;
CRUDE OIL (WELL)

L20 ANSWER 75 OF 86 APILIT2
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TI PIPELINE REPAIR - SUBSEA
CONTRACTOR’S VIEW.
CC PIPELINE MAINTENANCE;
TRANSPORTATION AND STORAGE
CT ABSTRACT; AUTOMATION;
*CONSTRUCTION; CONTRACTOR;
CONTROL; CONTROL

L20 ANSWER 76 OF 86 APILIT2
COPYRIGHT 2000 ELSEVIER
TI TECHNICAL AND ECONOMIC
CONSIDERATIONS FOR THE
EMERGENCY REPAIR OF OFFSHORE
PIPELINES.
CC PIPELINE MAINTENANCE;
TRANSPORTATION AND STORAGE
CT ABSTRACT; ASSOCIATION;
*BUSINESS OPERATION;
*CONTINGENCY PLAN; CONTRACT;
DAMAGE; *DISASTER CONTROL;
ECONOMIC FACTOR; EXPERIENCE;
FAILURE; LEGAL
CONSIDERATION;
*MAINTENANCE; *MANAGEMENT;
MEETING PAPER; NACE; OFFSHORE;
OIL AND GAS FIELDS;
PERSONNEL; *PIPELINE; *PLANNING;
REVIEW; SOUTHEAST
ASIA; SUBSURFACE;
UNDERWATER
LT OFFSHORE; OIL AND GAS FIELDS
LT PIPELINE; SUBSURFACE;
UNDERWATER

L20 ANSWER 77 OF 86 APILIT2
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TI COLD TAPPING FROM A REPAIR
TO A DEVELOPMENT TOOL TO
PROLONG PIPE LIFE.
PIPELINE; CHART; CHEMISTRY; CORROSION; CORROSION TESTING; DATA; DEFECT; DIAGRAM; ELECTROCHEMISTRY; EXTERNAL CORROSION; FIELD HISTORY; GALVANIC CORROSION; GATHERING LINE; GRAPH; HISTOGRAM; HISTORY; INSPECTING; INSTRUMENTATION; LEASE GATHERING LINE; NONMETALLIC COATING; PHYSICAL PROPERTY; PIPE INSPECTION; PIPELINE; PIPELINE CORROSION; PIPELINE SURVEYING; PIPELINE WRAPPING; PITTING (CORROSION); PLASTIC COATING; PROTECTION; RECONDITIONING; RECONDITIONING (PIPE); SELECTION; SIZE; SOIL CORROSION; SPRAYING; STRUCTURAL INTEGRITY; SURVEYING; SYSTEM (ASSEMBLAGE); TABLE (DATA); TESTING; WAVE PROPERTY; WAVEFORM

L20 ANSWER 81 OF 86 TULSA2 COPYRIGHT 2000 UTULSA DN 673269 TI PROGRAM FOR EVALUATION OF RISKS AND REPAIR APPLIED TO GAS PIPELINES (PROGRAMA DE EVALUACION DE RIESGOS Y REPARACION APLICADO A GASODUCTOS) CC PIPELINING, SHIPPING & STORAGE SH *RISK ANALYSIS CT *CORROSION; *ENGINEERING; *FAILURE ANALYSIS; *MAINTENANCE; *MATHEMATICAL ANALYSIS; *MATHEMATICS; *PIPELINE; *PIPELINE CORROSION; *PIPELINE REPAIR; *REPAIR; *RISK; *SYSTEMS ENGINEERING; ADMINISTRATION; BUSINESS OPERATION;

CATHODIC PROTECTION; CHART; CONTINGENCY PLANNING; CONTROL; CORROSION CONTROL; COST; COST ANALYSIS; COST CONTROL; DAMAGE; DATA; DATA ANALYSIS; DATA PROCESSING; ECONOMIC EVALUATION; ECONOMIC FACTOR; ELECTRICAL PROPERTY; EVALUATION; FAILURE; FLOW CONTROL; FLUID FLOW; FLUID LOSS; GAS FLOW; GAS INDUSTRY; GAS TRANSMISSION INDUSTRY; GRAPH; INSPECTING; LEAK; MAINTENANCE COST; MANAGEMENT; MONITORING; NATURAL GAS; OPERATING COST; OPTIMIZATION; PERSONNEL; PETROLEUM; PHYSICAL PROPERTY; PIPE INSPECTION; PIPELINE DATA; PIPELINE FLOW; PIPELINE INDUSTRY; PIPELINE LEAK; PIPELINE SURVEYING; PLANNING; PREVENTION; PROTECTION; RESISTIVITY; SAFETY; SHUTDOWN; STRATEGY; STRUCTURAL ANALYSIS; STRUCTURAL ENGINEERING; STRUCTURAL INTEGRITY; SURVEYING; TABLE (DATA); TESTING RN 8002-05-9 (PETROLEUM) 8006-14-2 (NATURAL GAS)

L20 ANSWER 82 OF 86 TULSA2 COPYRIGHT 2000 UTULSA DN 566074 TI ADVANCES IN UNDERGROUND TECHNOLOGY TO SIGNIFICANTLY REDUCE PIPELINE REPAIR TIMES CC PIPELINING, SHIPPING & STORAGE SH *PIPELINE REPAIR CT *BURIED PIPELINE; *DEFORMATION; *HYPERBARIC WELDING; *MAINTENANCE; *PIPE
CUTTING; *PIPE DEFORMATION;  
*PIPELINE; *REPAIR; *TIME;  
*UNDERWATER  
PIPELINE; *WELDING; BOOK;  
BRITISH GAS PLC; CAISSON;  
CEMENT COATED PIPE;  
CHART; COATING MATERIAL;  
COMPARISON; COMPUTER  
GRAPHICS; CONTROL; DATA;  
DATA PRESENTATION;  
DIVERLESS OPERATION;  
ENGINEERING DRAWING;  
EXCAVATING;  
EXPERIMENTAL DATA;  
EXTERNAL COATING; FUNCTION  
(MATHEMATICS); ISOLATION;  
LABORATORY TESTING;  
MANIPULATOR; MATHEMATICS;  
OFFSHORE TECHNOLOGY;  
PIGGING; PIPE; REMOTE  
CONTROL; REMOVAL; RESEARCH;  
SEA FLOOR; SONAR;  
SUBMARINE TOPOGRAPHY;  
SURVEYING; SYSTEM  
(ASSEMBLAGE); TESTING; TIME  
FUNCTION; TOPOGRAPHIC  
SURVEYING; TOPOGRAPHY;  
TUBULAR GOODS; UNDERWATER  
TOPOGRAPHY; UNDERWATER  
WELDING

INDEX MAP; MAINTENANCE; MAP;  
MONITORING; PIPE DEFORMATION;  
PIPE DIAMETER;  
PIPELINE; PIPELINE  
AUTOMATION; PIPELINE CROSSING;  
REPAIR; SETTLING

L20 ANSWER 84 OF 86 TULSA2  
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TI CALCULATIONS AND REPAIR  
STRATEGIES FOR WAX BLOCKED  
PIPLINES

CC PIPELINING, SHIPPING &  
STORAGE  
SH *PARAFFIN REMOVAL  
CT *BRANCH PIPELINE; *DEPOSIT  
FORMATION; *PARAFFIN  
DEPOSITION; *PIPELINE;  
*PIPELINE PLUG; *REMOVAL;  
*TAPPING; *UNDERWATER PIPELINE;  
ADMINISTRATION;  
BUSINESS OPERATION;  
CALCULATING; CASE HISTORY;  
CLEANING; COMPOUND; CRUDE  
OIL; CUTTING; DATA;  
DEFORMATION; DETECTION;  
DEWAXING; FLUID FLOW; GEL;  
GELATION; HEATING;  
HYDROCARBON COMPOUND;  
HYDROSTATIC PRESSURE;  
HYDROSTATIC  
TESTING; INSPECTING;  
LOCATING; MAINTENANCE;  
MANAGEMENT; MATHEMATICS;  
MEASURING; MIXTURE;  
NONDESTRUCTIVE TESTING;  
OBSTRUCTION; PARAFFIN BASE  
CRUDE; PARAFFIN WAX;  
PETROLEUM; PHASE BEHAVIOR;  
PHASE CHANGE; PHYSICAL  
SEPARATION; PIPE CUTTING; PIPE  
DEFORMATION; PIPE INSPECTION;  
PIPE TESTING;  
PIPELINE FLOW; PIPELINE  
HEATING; PIPELINE PRESSURE;  
PIPELINE SURVEYING;  
PLANNING; PLUGGING;  
PRECIPITATION; PRESSURE;  
PRESSURE MEASURING;
PROCEDURE; REPAIR; SOLID HYDROCARBON; STRATEGY; SURVEYING; TESTING; WAX
RN 8002-05-9 (CRUDE OIL)
8002-05-9 (PETROLEUM)
8002-74-2 (PARAFFIN WAX)

L20 ANSWER 85 OF 86 TULSA2 COPYRIGHT 2000 UTULSA
DN 596036
TI UNDERWATER PIPELINE REPAIR:
DIFFICULT SEABED CONDITIONS
CC PIPELINING, SHIPPING & STORAGE
SH *PIPELINE REPAIR
CT *ADMINISTRATION; *BURIED PIPELINE; *BUSINESS OPERATION;
*CEMENT COATED PIPE; *COST CONTROL; *LARGE DIAMETER PIPE; *MAINTENANCE;
*MANAGEMENT;
*PIPE; *PIPELINE; *REPAIR;
*TUBULAR GOODS; *UNDERWATER PIPELINE;
ALIGNMENT; ATLANTIC OCEAN;
BUOY; CAISSON; CEMENT; COATING MATERIAL;
CONCRETE; CONSTRUCTION MATERIAL; CURRENT; CUTTING;
DAMAGE; DEFORMATION;
DIAMETER; DITCHING; DIVING;
EURASIA; EUROPE; EXCAVATING;
EXTERNAL COATING;
FLUID LOSS; FLUIDIZED SYSTEM;
HYDRAULIC PRESSURE;
HYPERBARIC WELDING; JET NOZZLE; JET PUMP; LEAK;
NATURAL GAS; NORTH ATLANTIC OCEAN; NORTH SEA;
NOZZLE; OFFSHORE EQUIPMENT;
OFFSHORE STRUCTURE; OFFSHORE TECHNOLOGY;
PETROLEUM; PIGGING; PIPE CUTTING; PIPE DEFORMATION; PIPE DIAMETER;
Pipeline Leak; Pipeline Pig;
Pipeline Plug; Pipeline Surveying; Pressure;
Problem; Pump; Removal;
Replacing; Sea Floor; Seas AND OCEANS; Site

PREPARATION; SOLUTION (PROBLEM); SONAR; SUBMARINE TOPOGRAPHY; SURFACE PREPARATION; SURVEYING;
SYSTEM (ASSEMBLAGE); TAPPING;
TERRAIN PROBLEM;
TESTING; TETHERING; TIME;
TOPOGRAPHIC SURVEYING;
TOPOGRAPHY;
TRANSPORTATION;
TRANSPORTATION TERMINAL;
UNDERWATER TOPOGRAPHY;
UNITED KINGDOM; WATER CURRENT;
WELDED PIPE; WELDING
RN 8002-05-9 (PETROLEUM)
8006-14-2 (NATURAL GAS)

L20 ANSWER 86 OF 86 TULSA2 COPYRIGHT 2000 UTULSA
DN 438711
TI PIPELINE REPAIR TECHNIQUES - THE STATE OF THE ART
CC PIPELINING, SHIPPING & STORAGE
SH *REPAIR
CT *DEEP WATER; *DEPTH;
*HYPERBARIC WELDING;
*MAINTENANCE; *PIPE; *PIPELINE;
*TUBULAR GOODS;
*UNDERWATER PIPELINE;
*UNDERWATER WELDING; *WATER DEPTH;
*WELDED PIPE; *WELDING;
AUTOMATIC WELDING;
AUTOMATION; CHANGE; CONNECTION;
COUPLING (PIPE); DEFORMATION;
DEVELOPMENT; DIVERLESS OPERATION; DIVING
BELL; FITTING; MANNED
UNDERWATER STATION; MARINE TRANSPORTATION; OFFSHORE STRUCTURE; OFFSHORE TECHNOLOGY; PIPE CUTTING; PIPE DEFORMATION; PIPE FITTING; PIPE HANDLING; ROBOT; TRANSPORTATION; UNDERWATER VEHICLE
APPENDIX 2

PRINT-OUT OF ABSTRACTS OF RELEVANT REFERENCES

L36 ANSWER 9 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
AN 1996(13):91414 ENERGY
TI Encirclement sleeves reduce pipeline repair costs
AU Anon.
SO Pipeline and Gas Journal (Jan 1996) v. 223(1) p. 33-35.
   CODEN: PLGJAT    ISSN: 0032-0188
AB Welded sleeve, or replacement of line repair methods have been used successfully for many years in the pipeline industry but can lead to other difficulties for a pipeline operator. Clock Spring's composite sleeves have been used in over ten thousand pipeline repairs with pipe sizes ranging from 6- to 56-inches in diameter, all without costly shutdown, welding or purging. Repairs can be completed while the pipeline is fully operational and require only six inches of clearance under the pipe for wrapping the eight thicknesses of the coil. This minimizes costly digging and backfilling over long runs of pipe and necessary shoring for personnel safety. Also it provides a more cost-effective alternative to conventional pipeline repair since special handling, lifting, or installation equipment is not needed. This paper reviews the installation and performance of these sleeves.

L36 ANSWER 10 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
AN 1996(3):13429 ENERGY
TI Update on pipeline repair methods
AU Kiefner, J.F. (Kiefner and Associates, Inc., Worthington, OH (United States)); Bruce, W.A. (Edison Welding Inst., Columbus, OH (United States)); Stephens, D.R. (Battelle, Columbus, OH (United States))
NR CONF-950116--
SO Pipeline engineering 1995. PD-Volume 69.
   Editor(s): Williams, B.; Flanders, B.; Holter, B.; Shackle, B.; Stripling, T.; Zipp, K.
   Conference: 1995 American Society of Mechanical Engineers (ASME) energy sources technology conference and exhibition, Houston, TX (United States), 29 Jan - 1 Feb 1995
   ISBN: 0-7918-1292-8
AB A comprehensive review of pipeline repair methods has been recently completed under the sponsorship of the American Gas Association's, Pipeline Research Committee. This paper is intended to summarize the important results of that review. First and foremost, two relatively new methods of repair are reviewed. One involves the use of a continuous-fiber fiberglass composite material which can be applied as an alternative to a steel sleeve for the reinforcement of nonleaking defects. The second is the use of deposited weld metal to replace metal lost to external corrosion. This latter technique is not new in principle, but recent research has shown how it can be done safely on a pressurized pipeline. The other significant outcome of the comprehensive review was a set of guidelines for using all types of repairs including full-encirclement sleeves and repair clamps. Pipeline operators can use these guidelines to enhance their current repair procedures, or to train new personnel in maintenance techniques.
Developments in pipe repair clamps and collars

This paper looks at the use of pipe repair clamps in British Gas, discusses their past poor performance and unreliability and looks at the work carried out to improve the performance of the clamps. The PS/LC8 Part 4 specification was drafted with the objective of developing pipe repair clamps and collars that will seal on a wide tolerance band of pipe sizes, can survive all anticipated pipe movements and maintain a gas-tight seal for a target life of 50 years. Work carried out at London Research Station (LRS) and in conjunction with clamp and collar manufacturers has led to the development of clamps which meet the rigorous demands of the specification.

Cost-effective on-line repair of pipeline damage using epoxy-filled shells

Cost-effective on-line repair of pipeline damage using epoxy-filled shells. Buried pipeline systems represent a large capital investment, expected to have long operational lifespans. Damage which occurs during operation can be expensive, particularly if it needs to be cutout without interrupting the product flow. A cheap, easily-applied alternative repair method to cutouts is described. The epoxy repair method can provide permanent repairs to a wide range of damage, including cracking, corrosion, gouges and gouged dents. It avoids costly welding to the live pipeline and fitup problems associated with other methods. The development of the repair method and the results of an extensive test program and field experience are described. Consideration is given to future application of the technique to girth welds, leaking defects and hot-oil-pipelines.