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Temporary/permanent pipe repair - Guidelines

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Temporary/permanent pipe repair - Guidelines

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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.

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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.

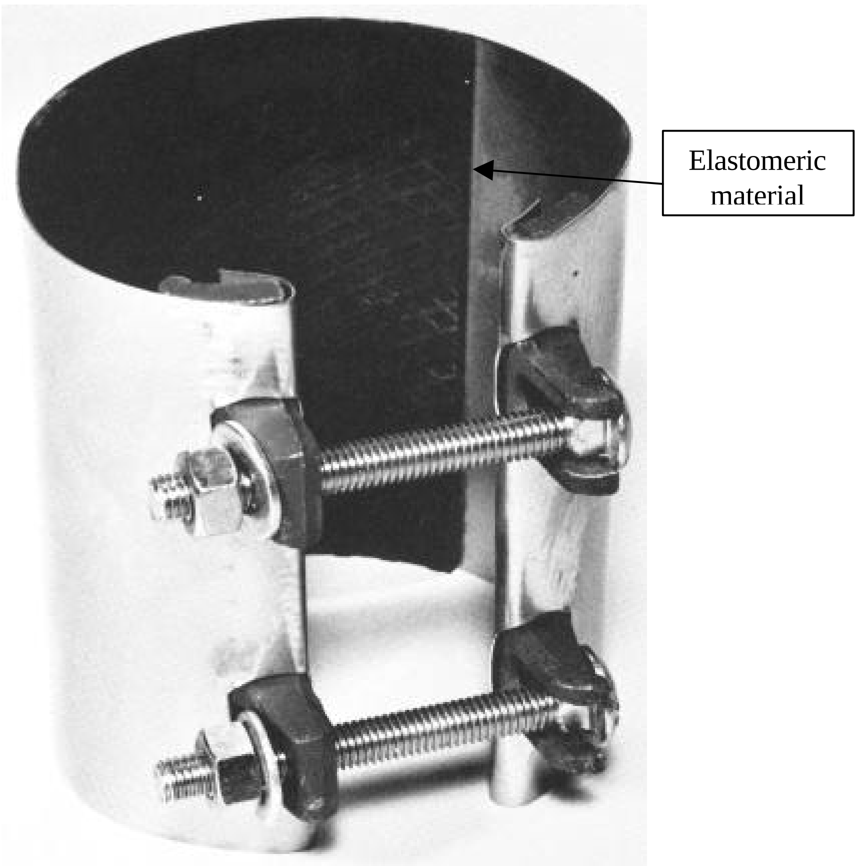

Figure 1
Patch clamp

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.

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.

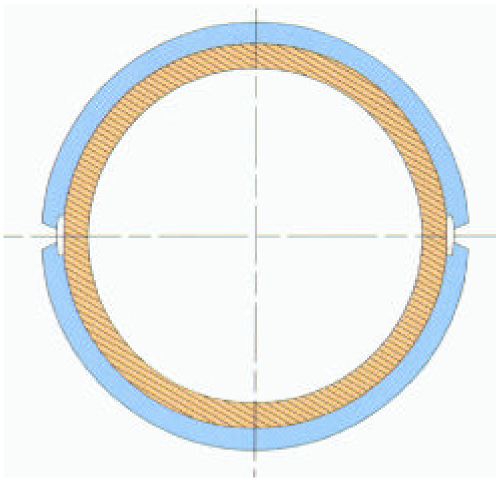

Figure 3
Encircling sleeve type repair

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.

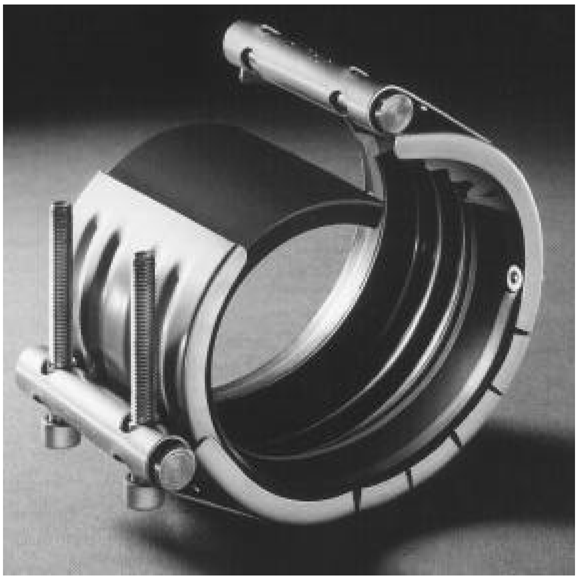

Figure 4
Medium duty 'stand-off' type repair clamp

Figure 5
Heavy duty 'stand-off' type repair clamp

Enclosure type repair components are also capable of repairing/sealing damaged flanges and bends/elbows, as illustrated below.

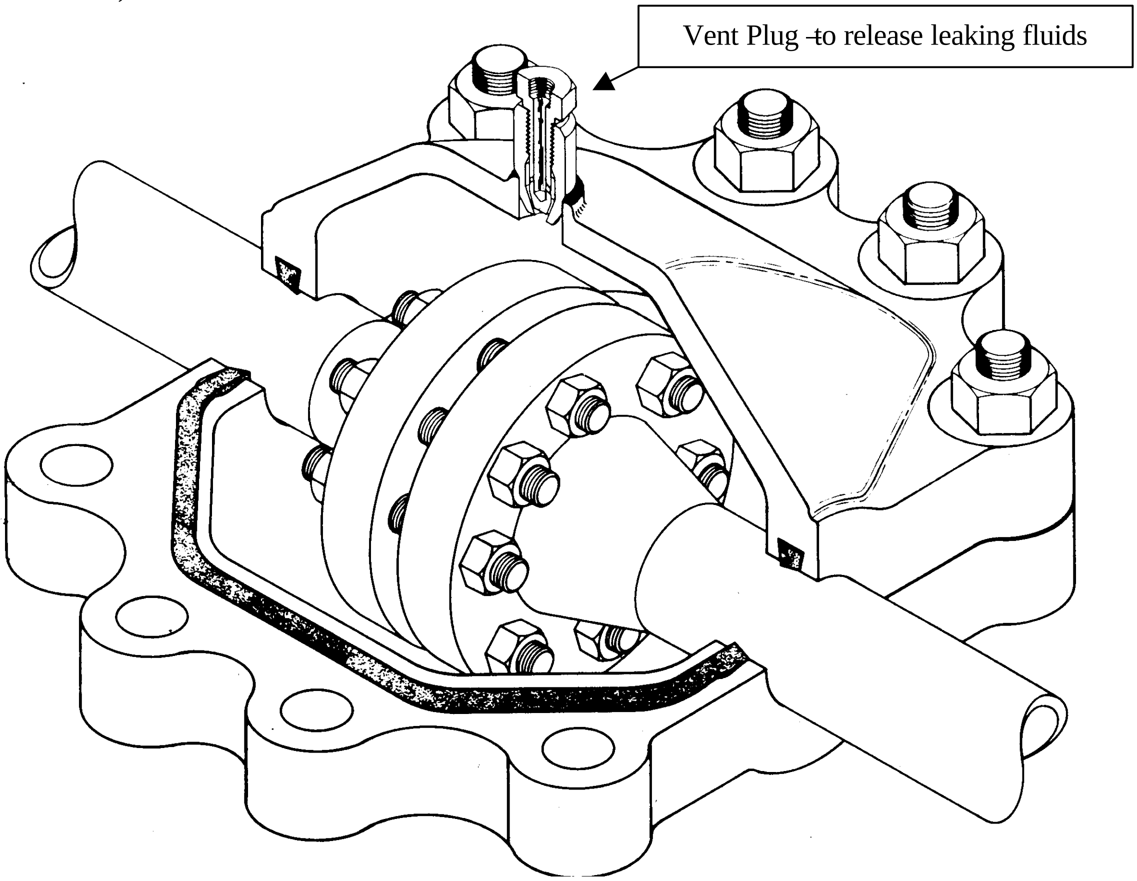

Figure 6
'Self-seal' type repair enclosure

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.

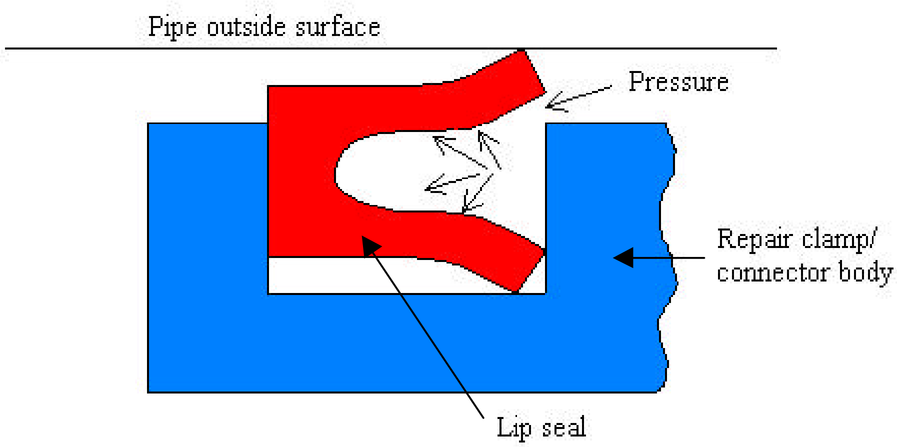

Figure 7
Lip-type seal used within 'self-seal' type repair clamps/connectors

In the case of a leaking flange, special enclosures, which seal on the outside diameter of the flange halves, are available as illustrated below.

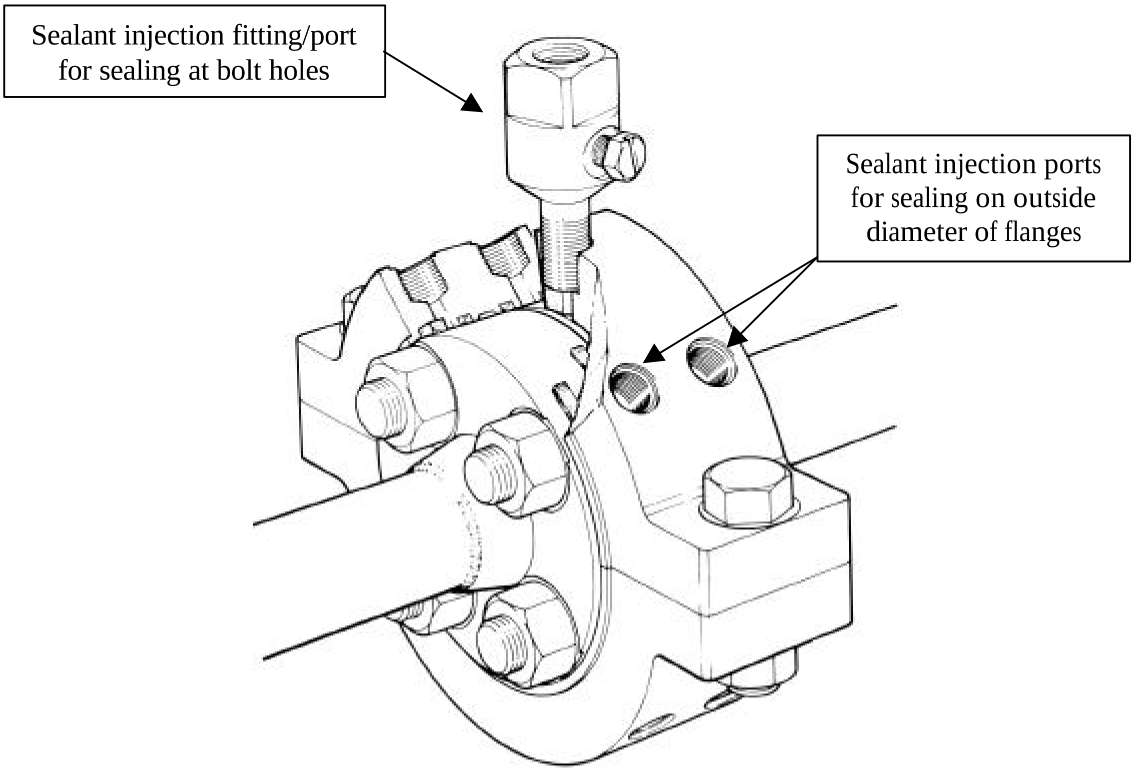

Figure 8
'Outside diameter' type flange repair enclosure

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.

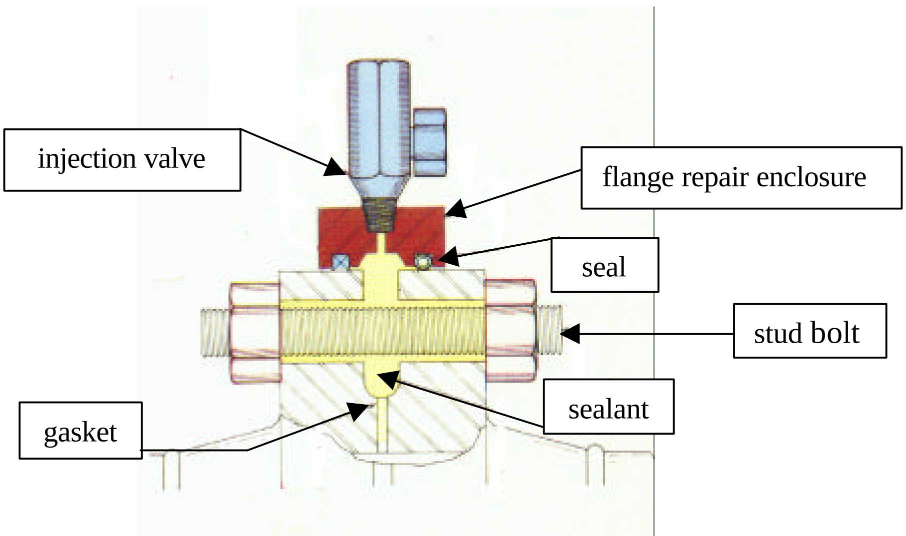

Figure 9
Sealant injection at flange bolt hole area

4.2 REPAIR COUPLINGS AND CONNECTORS

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 straight forward 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.

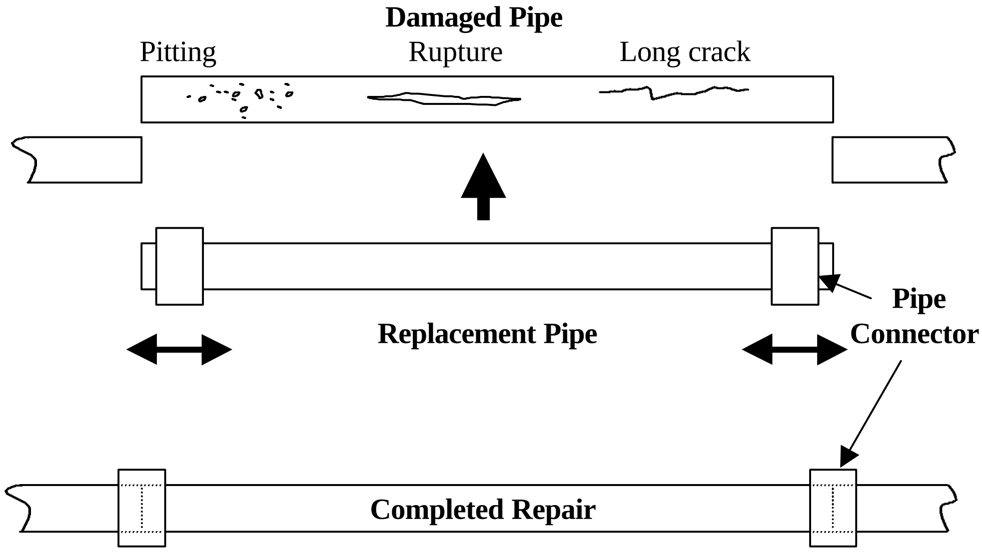

Figure 10
Pipe repair using pipe connectors

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.

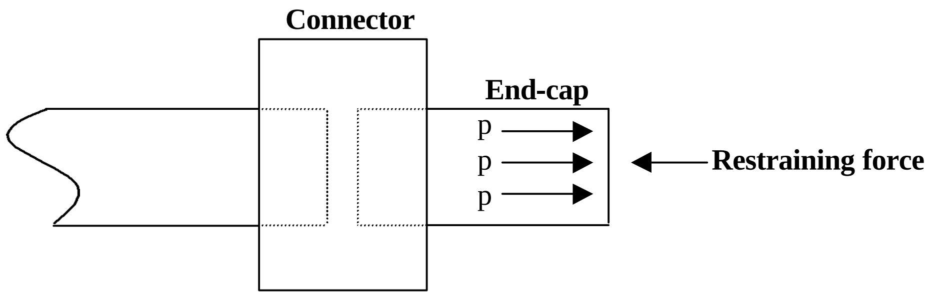

Figure 11
Longitudinal/axial pressure forces acting on an end-cap

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).

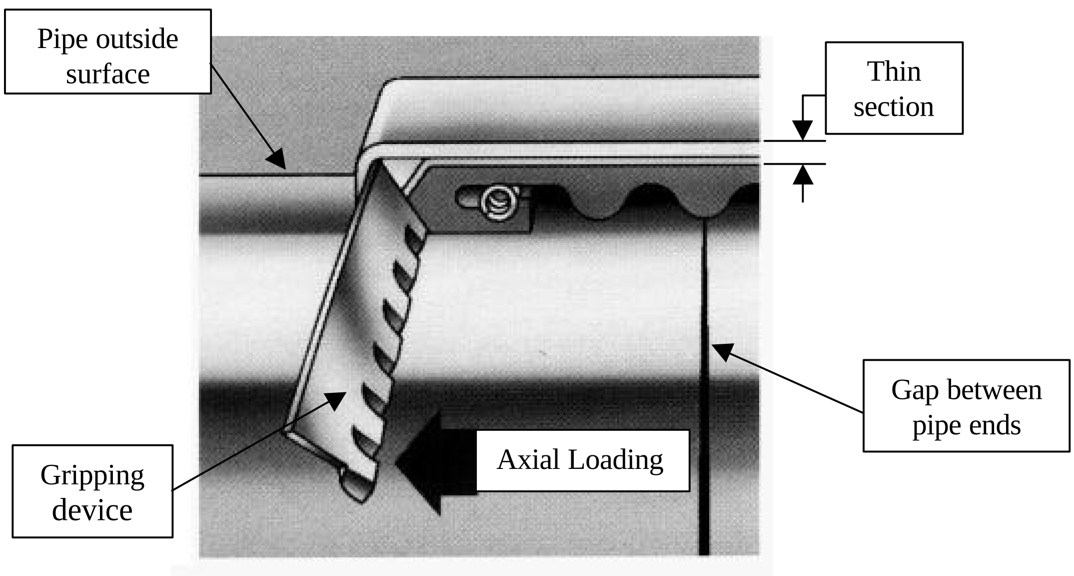

Figure 12
Flexible one-piece connector c/w gripping device

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.

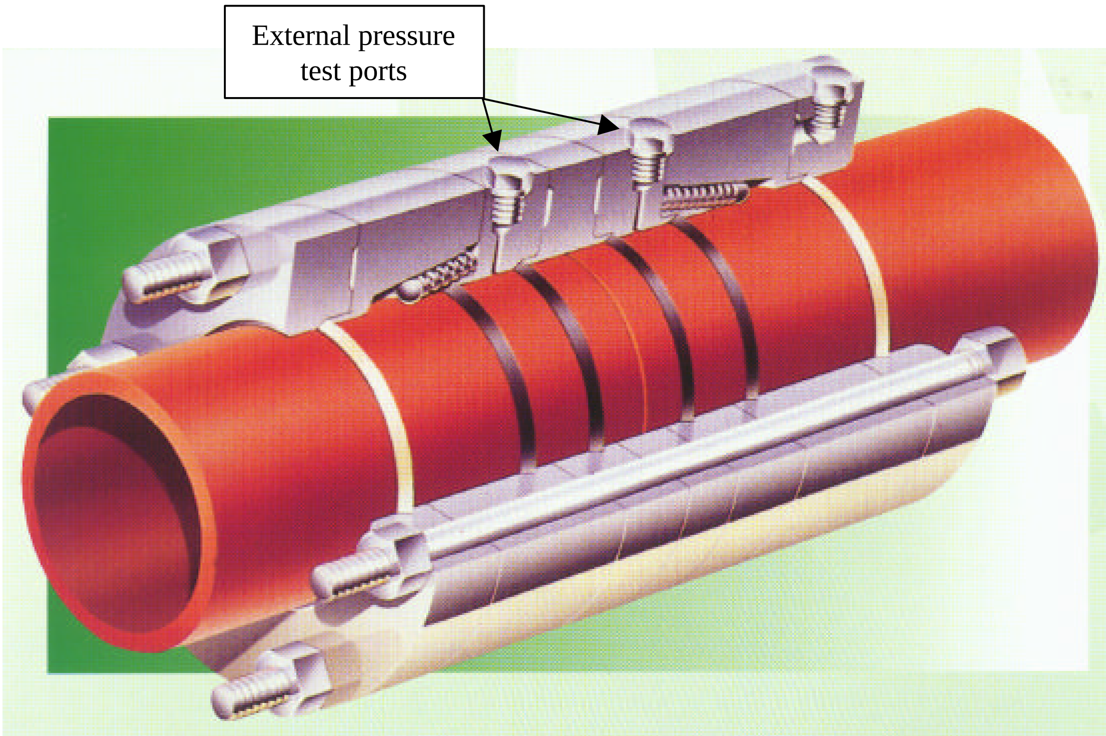

Figure 13
Heavy duty pipe connector

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.

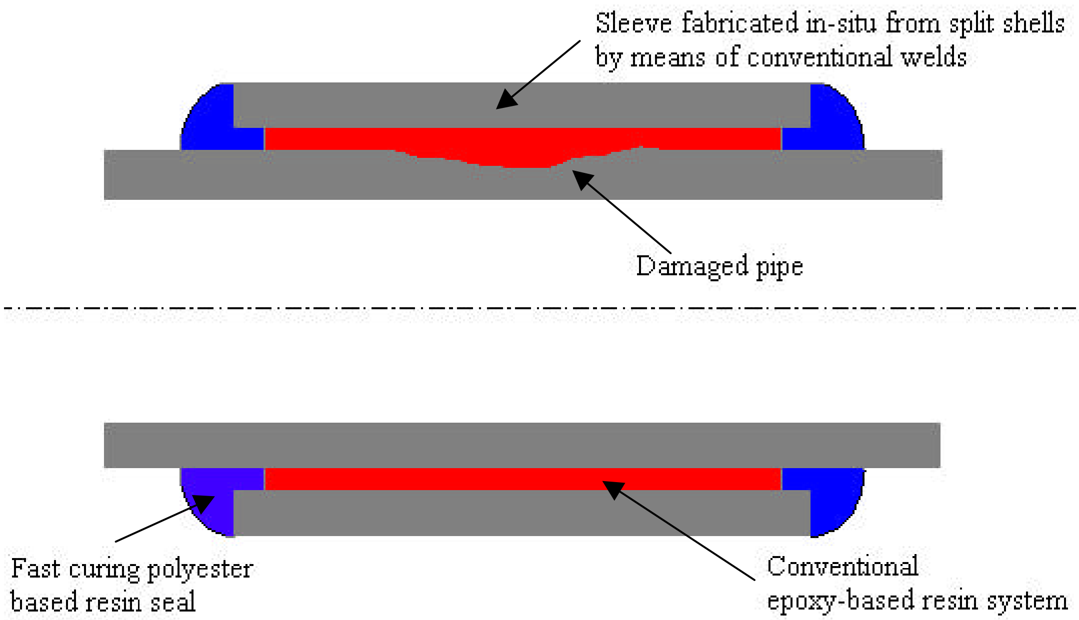

Figure 14
Epoxy-filled repair sleeve

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 1
Applicability of repair components to repair scenarios *(straight pipe sections)*

Repair Scenario	Patch	Encircling Sleeve	'Stand-off' clamp/connector	Epoxy-filled sleeve
External metal loss - localised	Yes	Yes	Yes	Yes - consider cost effectiveness
External metal loss - extensive	No	Yes	Yes - c/w new pipe section	Yes
Internal metal loss - localised	Yes	Yes	Yes	Yes - consider cost effectiveness
Internal metal loss - extensive	No	Yes	Yes - c/w new pipe section	Yes
Leak	No	No	Yes - consider seal material suitability	Yes

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 3
Temperature, size and longevity capabilities of various repair components

Repair method/component	Maximum pressure rating	Temperature range	Size (nominal diameter) range	Temporary or permanent repair 7
Patch clamp (see Figure 1)	7 bar (100 psi)	Depends on seal material 1	½ ” to 42” (13 to 1000mm)	Temporary
Pin-hole clamp (see Figure 2)	140 bar (2000 psi)	Depends on seal material 1	½ ” to 48” (13 to 1200mm)	Temporary
Encircling sleeve (see Figure 3)	Same rating/size as the original piping			Permanent
Complete circle clamp c/w 360^o patch gasket 9	16 bar (230 psi)	Depends on seal material 1	Up to 30” (800mm)	Permanent
One-piece stand-off clamp (see Figure 4)	20 bar (300 psi) 2	Depends on seal material 1	2” to 48” (50 to 1200mm)	Permanent
Stand-off type (enclosure) clamp (see Figure 5)	ASA Class 900lb 3	Depends on seal material 1	4” to 48” (100 to 1200mm)	Permanent
Flange repair enclosure (see Figure 6)	ASA Class 600lb 3	Depends on seal material 1	½ ” to 12” (13 to 300mm)	Permanent
Outside diameter flange clamp (see Figure 8)	ASA Class 600lb 3	400^{o}C 4	½ ” to 24” (13 to 600mm)	Temporary
One-piece stand-off connector (see Figure 12)	16 bar (230 psi) 2, 5	Depends on seal material 1	Up to 30” (800mm)	Permanent
Heavy duty connector (see Figure 13)	ASA Class 2500lb 3	-50^{o}C to +230^{o}C 6	All diameters	Permanent
Epoxy-filled sleeve (see Figure 14)	100 bar (1450 psi)	3^{o}C to 100^{o}C	Same size as the original piping	Permanent
Composite repair	50 bar (725 psi)	-20^{o}C to +60^{o}C 8	All diameters	Temporary 8 and permanent

1 *Ethylene-Propylene (EPDM) -40^{o}C to +90^{o}C; Nitrile-Butadiene (NBR), for example BUNA-N, -20^{o}C to +100^{o}C; Neoprene up to 150^{o}C; AFLAS™ up to 232^{o}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^{o}F (455^{o}C). For example, ASA 600lb refers to a max. non-shock operating pressure of 600 psi (41 bar) at 850^{o}F (455^{o}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 ^{o}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^{o}C to 60^{o}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^{o}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

	Up to 5 barg		Up to 20 barg/Class 150				Up to 50 bar/ Class 300	
			Non-safety critical		Safety critical			
	Temp.	Perm.	Temp.	Perm.	Temp.	Perm.	Temp.	Perm.
Basic material documentation	✓	✓	✓	✓	✓	✓	✓	✓
Design capability		✓	✓	✓	✓	✓	✓	✓
Surface preparation:								
- surface abrasion	✓	✓	✓	✓	✓			
- chemical primer						✓	✓	✓
Short-term test data:								
- overwrap material	✓	✓	✓	✓	✓	✓	✓	✓
- bonded joint				✓	✓	✓	✓	✓
Long-term durab. data:								
- overwrap material				✓		✓	✓	✓
- bonded joint						✓	✓	✓
Training documentation	✓	✓	✓	✓	✓	✓	✓	✓
Health & Safety documentation	✓	✓	✓	✓	✓	✓	✓	✓

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 PERFOMANCE

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 requirement’s of British Gas’ BG/PS/LC8 Part 4 Specification[5]. 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 fluorelastomers, 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^{o}C (450^{o}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.

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APPENDIX 1

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

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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)
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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
BT ALLOYS; ARC WELDING; CHROMIUM ADDITIONS; CHROMIUM ALLOYS; FABRICATION;
GAS METAL-ARC WELDING; HARDNESS; IRON ALLOYS; IRON BASE ALLOYS; JOINING;
LIFETIME; LOW ALLOY STEELS; MECHANICAL PROPERTIES; MOLYBDENUM ADDITIONS;
MOLYBDENUM ALLOYS; NICKEL ADDITIONS; NICKEL ALLOYS; STEELS; TUBES;
WELDING
ET Cr*Mo; Cr sy 2; sy 2; Mo sy 2; Cr-Mo; Cr; Mo

L20 ANSWER 2 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
DUPLICATE 7
TI Pipeline incidents and emergency repair in the North Sea.

CC *022000; 032000; 420205
CT *PIPELINES: *FAILURES; *NORTH SEA: *PIPELINES; EMERGENCY PLANS; REPAIR;
UNDERWATER OPERATIONS
BT ATLANTIC OCEAN; SEAS; SURFACE WATERS

L20 ANSWER 3 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
DUPLICATE 9
TI Emergency pipeline repair.
CC *032000; 420205; 423000
CT *OFFSHORE OPERATIONS: *PIPELINES; *UNDERWATER OPERATIONS: *PIPELINES;
*PIPELINES: *REPAIR; *NATURAL GAS: *TRANSPORT; CONTRACTS; DIVING
OPERATIONS; EMERGENCY PLANS; NATURAL GAS DISTRIBUTION SYSTEMS; PLUGGING;
RESEARCH PROGRAMS; RISK ASSESSMENT; UNITED KINGDOM; WATER REMOVAL;
WELDING
BT ENERGY SOURCES; ENERGY SYSTEMS; EUROPE; FABRICATION; FLUIDS; FOSSIL
FUELS; FUEL GAS; FUELS; GAS FUELS; GASES; JOINING; REMOVAL; WESTERN
EUROPE

L20 ANSWER 4 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Quality control systems for construction, repair, and alteration of
pipelines.
CC *022000
CT CONSTRUCTION; MAINTENANCE; PIPELINES; QUALITY CONTROL; REPAIR; STANDARDS
CTDE KONSTRUKTION; WARTUNG; PIPELINES; QUALITAETSKONTROLLE; REPARATUR; NORMEN
BT CONTROL

L20 ANSWER 5 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Guidelines for weld deposition repair on pipelines. Final report.
CC *032000
CT DEPOSITION; LOSSES; METALS; PIPELINES; PROGRESS REPORT; RECOMMENDATIONS;
REPAIR; WALLS
CTDE ABSCHEIDUNG; VERLUSTE; METALLE; PIPELINES; FORTSCHRITTSBERICHT;
EMPFEHLUNGEN; REPARATUR; WAENDE
BT DOCUMENT TYPES; ELEMENTS

L20 ANSWER 6 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Pipeline rehabilitation surveys for prioritizing coat/wrap repairs of old
cross-country pipelines.
CC *032000; 022000
CT COAL TAR; DEFECTS; DETECTION; ELECTRIC LOGGING; NONDESTRUCTIVE TESTING;
PIPELINES; PROTECTIVE COATINGS; REPAIR; UNDERGROUND FACILITIES
*PIPELINES; *NONDESTRUCTIVE TESTING; *PROTECTIVE COATINGS
CTDE KOHLENTEER; MATERIALFEHLER; NACHWEIS; ELEKTRISCHE BOHRLOCHMESSUNG;
ZERSTOERUNGSFREIE PRUEFUNG; PIPELINES; SCHUTZUEBERZUEGE; REPARATUR;
UNTERIRDISCHE ANLAGEN
BT COATINGS; MATERIALS TESTING; ORGANIC COMPOUNDS; OTHER ORGANIC COMPOUNDS;
TAR; TESTING; WELL LOGGING

L20 ANSWER 7 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Application of composite repair for pipeline anomalies.
CC *032000
CT COMPILED DATA; COMPOSITE MATERIALS; CORROSION PRODUCTS; DAMAGE;

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; LEISTUNGSFAEHIGKEIT; PIPELINES; REPARATUR;
DURCHBRUECHE; MUFFEN; ZUGEIGENSCHAFTEN; TRANSPORT
BT COMPOSITE MATERIALS; DATA; ENERGY SYSTEMS; FAILURES; INFORMATION;
MATERIALS; MECHANICAL PROPERTIES; NUMERICAL DATA; TESTING

L20 ANSWER 8 OF 86 ENERGY

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

TI Encirclement sleeves reduce pipeline repair costs.
CC *032000
CT COST BENEFIT ANALYSIS; DESIGN; INSTALLATION; NATURAL GAS INDUSTRY;
PERFORMANCE; PIPELINES; REPAIR; SLEEVES
*PIPELINES: *REPAIR; *PIPELINES: *SLEEVES; *NATURAL GAS INDUSTRY:
*PIPELINES; *SLEEVES: *PERFORMANCE; *SLEEVES: *INSTALLATION
CTDE KOSTEN-NUTZEN-ANALYSE; AUSLEGUNG; INSTALLATION; ERDGASINDUSTRIE;
LEISTUNGSFAEHIGKEIT; PIPELINES; REPARATUR; MUFFEN
BT ECONOMIC ANALYSIS; ECONOMICS; INDUSTRY

L20 ANSWER 10 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Update on pipeline repair methods.
CC *032000
CT COMPOSITE MATERIALS; CONTAINMENT SYSTEMS; FILLER METALS; NATURAL GAS;
PIPELINES; PRESSURIZATION; REPAIR; TRANSPORT; WELDING
*PIPELINES: *REPAIR
CTDE VERBUNDSTOFFE; SICHERHEITSEINSCHLUSSSYSTEME; ZUSATZMETALLE; ERDGAS;
PIPELINES; DRUCKBEAUFSCHLAGUNG; REPARATUR; TRANSPORT; SCHWEISSEN
BT CONTAINMENT; ENERGY SOURCES; ENGINEERED SAFETY SYSTEMS; FABRICATION;
FLUIDS; FOSSIL FUELS; FUEL GAS; FUELS; GAS FUELS; GASES; JOINING;
MATERIALS

L20 ANSWER 11 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Robotic equipment for pipeline repair.
CC *022000; 032000
CT ARC WELDING; NATURAL GAS INDUSTRY; NORTH SEA; OFFSHORE SITES; PETROLEUM
INDUSTRY; PIPELINES; REMOTE HANDLING EQUIPMENT; REPAIR; WELDING MACHINES
*PIPELINES: *REPAIR; *PIPELINES: *ARC WELDING; *NORTH SEA: *PIPELINES;
*WELDING MACHINES: *REMOTE HANDLING EQUIPMENT
CTDE LICHTBOGENSCHWEISSEN; ERDGASINDUSTRIE; NORDSEE; OFFSHORE-STANDORTE;
ERDOELINDUSTRIE; PIPELINES; FERNBEDIENUNGSGERAETE; REPARATUR;
SCHWEISSGERAETE
BT ATLANTIC OCEAN; EQUIPMENT; FABRICATION; INDUSTRY; JOINING; MATERIALS
HANDLING EQUIPMENT; SEAS; SURFACE WATERS; WELDING

L20 ANSWER 12 OF 86 ENERGY COPYRIGHT 2000 USDOE/IEA-ETDE
TI Sleeve installations speed pipeline defect repair.
CC *022000; 032000
CT CONTAINMENT SYSTEMS; DESIGN; GAS UTILITIES; INSTALLATION; LEAKS;
MATERIALS TESTING; NATURAL GAS INDUSTRY; PERFORMANCE; PETROLEUM INDUSTRY;
PIPELINES; PROTECTIVE COATINGS; REPAIR; SLEEVES
*PIPELINES: *REPAIR; *PIPELINES: *SLEEVES; *SLEEVES: *INSTALLATION;
*SLEEVES: *DESIGN
CTDE SICHERHEITSEINSCHLUSSSYSTEME; AUSLEGUNG; GASWERKE; INSTALLATION; LECKS;
WERKSTOFFPRUEFUNG; ERDGASINDUSTRIE; LEISTUNGSFAEHIGKEIT; ERDOELINDUSTRIE;

PIPELINES;
SCHUTZUEBERZUEGE; REPARATUR;
MUFFEN
BT COATINGS; CONTAINMENT;
ENGINEERED SAFETY SYSTEMS;
INDUSTRY; PUBLIC
UTILITIES; TESTING
ET Co

L20 ANSWER 13 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Repair of inadmissible defects in tubes of mineral oil pipelines
especially by use of shells.
Sanierung von Fehlstellen an Rohren von Mineraloelfernleitungen,
insbesondere durch Einsatz von Manschetten.
CC *022000
CT COATINGS; COVERINGS;
DAMAGE; GROUTING; PIPELINES;
REPAIR; RESINS; TUBES
*TUBES: *REPAIR
CTDE BESCHICHTUNGEN;
ABDECKUNGEN; SCHADEN;
ZEMENTEINSPRITZUNG; PIPELINES;
REPARATUR; HARZE; ROHRE
BT ORGANIC COMPOUNDS;
ORGANIC POLYMERS;
PETROCHEMICALS; PETROLEUM
PRODUCTS;
POLYMERS

L20 ANSWER 14 OF 86 ENERGY
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TI Review of repairs to offshore structures and pipelines.
CC *423000
CT CONTINENTAL SHELF;
DAMAGE; EUROPE; OFFSHORE
OPERATIONS; OFFSHORE
PLATFORMS; PIPELINES; REPAIR;
UNDERWATER OPERATIONS
*OFFSHORE PLATFORMS:
*REPAIR; *OFFSHORE PLATFORMS:
*UNDERWATER
OPERATIONS; *PIPELINES:
*REPAIR; *PIPELINES:
*UNDERWATER OPERATIONS;
*PIPELINES: *OFFSHORE
OPERATIONS
CTDE KONTINENTALSCHELF;
SCHADEN; EUROPA; OFFSHORE-
ARBEITEN;
OFFSHORE-PLATTFORMEN;
PIPELINES; REPARATUR;
UNTERWASSERARBEITEN
BT CONTINENTAL MARGIN

L20 ANSWER 15 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Deepwater pipeline repair technology: A general overview.
CC *022000; 032000; 420205
CT DESIGN; NATURAL GAS
INDUSTRY; OFFSHORE SITES;
PETROLEUM INDUSTRY;
PIPELINES; REMOTE HANDLING
EQUIPMENT; REPAIR; TECHNOLOGY
ASSESSMENT;
UNDERWATER OPERATIONS
*PIPELINES: *REPAIR; *PIPELINES:
*UNDERWATER OPERATIONS;
*PIPELINES:
*REMOTE HANDLING
EQUIPMENT; *REMOTE HANDLING
EQUIPMENT: *TECHNOLOGY
ASSESSMENT; *REMOTE
HANDLING EQUIPMENT: *DESIGN
CTDE AUSLEGUNG;
ERDGASINDUSTRIE; OFFSHORE-
STANDORTE; ERDOELINDUSTRIE;
PIPELINES;
FERNBEDIENUNGSGERAETE;
REPARATUR;
TECHNOLOGIEBEWERTUNG;
UNTERWASSERARBEITEN
BT EQUIPMENT; INDUSTRY;
MATERIALS HANDLING EQUIPMENT

L20 ANSWER 16 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Subsea repair of gas pipelines without water flooding. Final report.
CC *032000
CT COST; DAMAGE; NATURAL GAS;
NATURAL GAS DISTRIBUTION
SYSTEMS; NATURAL GAS
INDUSTRY; PIPELINES; REPAIR;
SEAS; TOOLS; UNDERWATER
OPERATIONS; WATER

*PIPELINES: *REPAIR; *PIPELINES: *UNDERWATER OPERATIONS; *NATURAL GAS
INDUSTRY: *PIPELINES
CTDE KOSTEN; SCHADEN; ERDGAS; ERDGASVERTEILUNGSSYSTEME; ERDGASINDUSTRIE;
PIPELINES; REPARATUR; MEERE; WERKZEUGE; UNTERWASSERARBEITEN; WASSER
BT 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/IEA-ETDE
TI Factors affecting heat affected zone root strains in pipeline girth welds
and repairs.
CC *360103; 032000; 420205
CT CRACK PROPAGATION; DATA; HEAT AFFECTED ZONE; HYDROGEN EMBRITTLEMENT;
MATHEMATICAL MODELS; PARAMETRIC ANALYSIS; PIPELINES; STRESS ANALYSIS;
TENSILE PROPERTIES; WELDED JOINTS
*PIPELINES: *WELDED JOINTS; *WELDED JOINTS: *HEAT AFFECTED ZONE; *HEAT
AFFECTED ZONE: *HYDROGEN EMBRITTLEMENT
CTDE RISSWACHSTUM; DATEN; WAERMEEINFLUSSZONE; WASSERSTOFFVERSPROEDUNG;
MATHEMATISCHE MODELLE; PARAMETERSTUDIEN; PIPELINES; SPANNUNGSANALYSE;
ZUGEIGENSCHAFTEN; SCHWEISSVERBINDUNGEN
BT EMBRITTLEMENT; INFORMATION; JOINTS; MECHANICAL PROPERTIES; ZONES

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

L20 ANSWER 19 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Effects of repair welding on the residual stess distribution and fracture
toughness in pipeline girth welds.
CC *022000; 032000; 360101
CT FRACTURE PROPERTIES; GRAIN REFINEMENT; MICROSTRUCTURE; ORBITS; PIPELINES;
PIPES; REPAIR; RESIDUAL STRESSES; SHIELDED METAL-ARC WELDING; WELDED
JOINTS; WELDING
*PIPELINES: *WELDING; *WELDED JOINTS: *FRACTURE PROPERTIES; *WELDED
JOINTS: *RESIDUAL STRESSES
CTDE BRUCHEIGENSCHAFTEN; KORNVERFEINERUNG; MIKROSTRUKTUR; UMLAUFBAHNEN;
PIPELINES; 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
TI In-situ repair methods for interior gas piping. Final report, July
1991-January 1992.
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;

OFFSHORE OPERATIONS;
PETROLEUM; PIPELINES; PIPES;
REMOTE CONTROL; REPAIR;
UNDERWATER OPERATIONS;
VEHICLES; WELDED JOINTS
*PIPELINES: *REPAIR; *VEHICLES:
*REMOTE CONTROL
BT CONTROL; DIMENSIONS;
ENERGY SOURCES; FLUIDS; FOSSIL
FUELS; FUEL GAS;
FUELS; GAS FUELS; GASES;
JOINTS

L20 ANSWER 25 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Overview of Chinshan Nuclear Power
Station recirculation pipe repair and
replacement.
CC *210100; 210200; 210700; 220900;
293000; 360103; 420500; E3100; E3200;
F2200; B2230; E1700
CT DESIGN; FAILURE MODE
ANALYSIS; GAS TUNGSTEN-ARC
WELDING; GOVERNMENT
POLICIES; INTERNATIONAL
ORGANIZATIONS; LOSS OF
COOLANT; MATERIALS
TESTING; MODIFICATIONS;
NUCLEAR POWER PLANTS; PIPES;
REACTOR COOLING
SYSTEMS; REACTOR
MAINTENANCE; REGULATIONS;
RESEARCH PROGRAMS; SHIELDED
METAL-ARC WELDING;
STAINLESS STEEL-316; TAIWAN
*NUCLEAR POWER PLANTS:
*REACTOR COOLING SYSTEMS;
*REACTOR COOLING
SYSTEMS: *LOSS OF COOLANT
BT ACCIDENTS; ALLOYS; ARC
WELDING; ASIA; AUSTENITIC
STEELS; CHROMIUM ALLOYS;
CHROMIUM-NICKEL STEELS;
CHROMIUM-NICKEL-MOLYBDENUM
STEELS; COOLING
SYSTEMS; CORROSION
RESISTANT ALLOYS; ENERGY
SYSTEMS; FABRICATION; HEAT
RESIS; HIGH ALLOY STEELS;
IRON ALLOYS; IRON BASE ALLOYS;
ISLANDS;
JOINING; MAINTENANCE;
MOLYBDENUM ALLOYS; NICKEL
ALLOYS; NUCLEAR
FACILITIES; POWER PLANTS;
REACTOR ACCIDENTS; REACTOR
COMPONENTS;
STAINLESS STEELS; STEEL-
CR17NI12MO3; STEELS; SYSTEM
FAILURE ANALYSIS;
SYSTEMS ANALYSIS; TESTING;
THERMAL POWER PLANTS;
WELDING

L20 ANSWER 26 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI State-of-the-art ROV and control
system for deepwater pipe repair.
CC *022000; 032000; 420205; 423000
CT *SUBMARINES: *DESIGN;
*UNDERWATER OPERATIONS:
*PIPELINES; *PIPELINES:
*REPAIR; *PETROLEUM:
*TRANSPORT; *NATURAL GAS:
*TRANSPORT; CONTROL
SYSTEMS; HYDRAULICS;
MODULAR STRUCTURES; NATURAL
GAS WELLS; OIL WELLS;
THRUSTERS
BT ENERGY SOURCES; FLUID
MECHANICS; FLUIDS; FOSSIL FUELS;
FUEL GAS; FUELS;
GAS FUELS; GASES; MECHANICS;
SHIPS; WELLS

L20 ANSWER 27 OF 86 ENERGY
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TI Pipeline coatings - Evaluation, repair,
and impact on corrosion
protection design and cost.
CC *022000; 360105
CT *PIPELINES: *CATHODIC
PROTECTION; *ALLOYS: *CATHODIC
PROTECTION;
*PIPELINES: *PROTECTIVE
COATINGS; *ALLOYS: *PROTECTIVE
COATINGS;
COMPARATIVE EVALUATIONS;
DATA ANALYSIS; PERFORMANCE;
PETROLEUM; REPAIR;

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; *PIPELINES:
*PIPE JOINTS; *NATURAL GAS
DISTRIBUTION
SYSTEMS: *PIPELINES; *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
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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: *PIPES;
*STAINLESS STEELS: *PIPES;
*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
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TI A diverless pipeline repair system
using hyperbaric welding and remote
vehicle.
CC *423000
CT OFFSHORE OPERATIONS;
PIPELINES; REMOTE HANDLING
EQUIPMENT; REPAIR;
UNDERWATER OPERATIONS
*PIPELINES: *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.
Final report, April 1982-September
1983.
CC *032000
CT *PAINTS; *PROTECTIVE
COATINGS; *PIPES: *PAINTS;
*NATURAL GAS DISTRIBUTION
SYSTEMS: *PIPES; *PIPES:
*PROTECTIVE COATINGS;
MAINTENANCE; PLASTICS
BT COATINGS; ENERGY SYSTEMS;
MATERIALS; PETROCHEMICALS;
PETROLEUM PRODUCTS;
SYNTHETIC MATERIALS

L20 ANSWER 32 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI BWR pipe repairs in Sweden.
CC *210100; 360101
CT *PIPES: *CRACKS; *REACTOR COOLING SYSTEMS: *PIPES; *RINGHALS-1 REACTOR: *REACTOR COOLING SYSTEMS; *CRACKS: *REPAIR; AUSTENITIC STEELS; CONTROL ROD DRIVES; CORE SPRAY SYSTEMS; FEEDWATER; HEAT AFFECTED ZONE; INSPECTION; INTERGRANULAR CORROSION; LEAKS; MAINTENANCE; METALLOGRAPHY; NOZZLES; RADIATION HAZARDS; REACTOR SHUTDOWN; RETROFITTING; STRESS CORROSION; SWEDEN; ULTRASONIC TESTING; WELDED JOINTS
BT ACOUSTIC TESTING; ALLOYS; BWR TYPE REACTORS; CHEMICAL REACTIONS; COOLING SYSTEMS; CORROSION; ECCS; ENERGY SYSTEMS; ENGINEERED SAFETY SYSTEMS; ENRICHED URANIUM REACTORS; EUROPE; HAZARDS; HEALTH HAZARDS; HYDROGEN COMPOUNDS; IRON ALLOYS; IRON BASE ALLOYS; JOINTS; MATERIALS TESTING; NONDESTRUCTIVE TESTING; OXYGEN COMPOUNDS; POWER REACTORS; REACTOR COMPONENTS; REACTOR PROTECTION SYSTEMS; REACTORS; SCANDINAVIA; SHUTDOWNS; STEELS; TESTING; WATER; WATER COOLED REACTORS; WATER MODERATED REACTORS; WESTERN EUROPE; ZONES

L20 ANSWER 33 OF 86 ENERGY
COPYRIGHT 2000 USDOE/IEA-ETDE
TI Repair procedures for dented or corroded pipe.
CC *032000
CT *PIPELINES: *REPAIR; CORROSION; DEFORMATION; NATURAL GAS DISTRIBUTION SYSTEMS; PERSONNEL; RESEARCH PROGRAMS; SLEEVES
BT CHEMICAL REACTIONS; ENERGY SYSTEMS

L20 ANSWER 34 OF 86 COMPENDEX
COPYRIGHT 2000 EI DUPLICATE 3
TI Update on pipeline repair methods.
CC 619.1 Pipe, Piping and Pipelines; 913.5 Maintenance; 812.3 Glass; 415.4 Other Structural Materials; 538.2 Welding; 603.2 Machine Tool Accessories
CT *Pipelines; Defects; Welds; Clamping devices; Pipeline codes; Filler metals; Steel pipe; Repair; Glass fibers; Fiber reinforced materials
ST American Gas Association; Steel sleeve; Full encirclement sleeves

L20 ANSWER 35 OF 86 COMPENDEX
COPYRIGHT 2000 EI DUPLICATE 4
TI Deepwater pipeline repair technology: a general overview.
CC 619.1 Pipe, Piping and Pipelines; 913.5 Maintenance; 539.1 Metals Corrosion
CT *Gas pipelines; Offshore pipelines; Maintenance; Corrosion; Planning; Repair
ST Deepwater pipeline; Sealines; Deepwater installations

L20 ANSWER 36 OF 86 COMPENDEX
COPYRIGHT 2000 EI DUPLICATE 5
TI Development of in-situ PE gas pipe repair methodology.
CC 619 Pipes, Tanks & Accessories; 817 Plastics, Products & Applications; 913 Production Planning & Control
CT *GAS PIPELINES; PLASTIC PIPE; REPAIR; POLYETHYLENES
ST IN SITU GAS PIPE REPAIR; POLYETHYLENE GAS PIPE; FIELD REPAIR; THERMOCHEMICAL MATERIAL; VIBRATION FUSION; SPIN FRICTION FUSION

L20 ANSWER 37 OF 86 COMPENDEX COPYRIGHT 2000 EI DUPLICATE 6
TI Development plan deepwater pipeline repair using explosive welding
technique.
CC 619 Pipes, Tanks & Accessories; 538 Welding & Bonding; 913 Production
Planning & Control
CT *PIPELINES, SUBMARINE:Repair; WELDS:Repair; WELDING, ELECTRIC
ARC:Explosive
ST DEEPWATER PIPELINE REPAIR; PIPELINE REPAIR TOOLS; PIPELINE REPAIR
PREPARATION; REPAIR PROCEDURE SPECIFICATIONS
ET O

L20 ANSWER 38 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Weld repair of aged Cr-Mo steel piping - a review of literature.
CC 619.2 Tanks; 545.3 Steel; 619.1 Pipe, Piping and Pipelines; 931.2 Physical
Properties of Gases, Liquids and Solids; 537.1 Heat Treatment Processes;
913.5 Maintenance
CT *Pressure vessels; Creep; Heat treatment; Repair; Tensile strength;
Toughness; Gas metal arc welding; Steel pipe; High temperature operations
ST Temperbead method; Post weld heat treatment (PWHT); Gas tungsten arc
welding (GTAW); Shielded metal arc welding (SMAW)
ET Cr*Mo; Cr sy 2; sy 2; Mo sy 2; Cr-Mo

L20 ANSWER 39 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Weld repair of steam turbine casings and piping - an industry survey.
CC 619.2 Tanks; 619.1 Pipe, Piping and Pipelines; 538.2 Welding; 913.5
Maintenance; 617.2 Steam Turbines
CT *Pressure vessels; Welds; Piping systems; Filler metals; Repair; Steam
turbines
ST Steam turbine casings

L20 ANSWER 40 OF 86 COMPENDEX COPYRIGHT 2000 EI
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 Treatment; 732.2 Control
Instrumentation
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

ST Probabilistic integrity assessment methods; Inspection planning; Corrosion damage

L20 ANSWER 44 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Evaluation of temporary non-code repairs in safety class 3 piping systems.
CC 619.1 Pipe, Piping and Pipelines; 913.5 Maintenance; 902.2 Codes and Standards; 914.1 Accidents and Accident Prevention; 902.3 Legal Aspects; 408.1 Structural Design (General)
CT *Piping systems; Codes (standards); Accident prevention; Structural analysis; Nuclear power plants; Laws and legislation; Repair
ST Noncode repairs

L20 ANSWER 45 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Robotic equipment for pipeline repair.
CC 538.2.1 Welding Processes; 619.1 Pipe, Piping and Pipelines; 713.5 Other Electronic Circuits; 913.5 Maintenance; 538.2 Welding
CT *Underwater welding; Robotics; Repair; Petroleum pipelines; Construction; Carbon dioxide arc welding; Welds; Gas pipelines
ST Subsea pipelines; Hyperbaric welding; Gas tungsten arc welding

L20 ANSWER 46 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Underwater pipeline repair.Problems and solutions.
CC 512.2.2 Development Operations; 619.1 Pipe, Piping and Pipelines; 538.2 Welding; 472 Ocean Engineering
CT *Natural gas pipelines; Underwater welding; Electric arc welding; Submarine pipelines; Cofferdams; Excavation; Ocean habitats
ST Underwater pipeline welding; Hyperbaric welding; Dry habitat chambers; Protective cofferdams; Seabed excavation; Underwater welding time reduction

L20 ANSWER 47 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI WATER PIPELINE INFRASTRUCTURE: DESIGN NOW FOR FUTURE EASE OF REPAIR.
CC 443 Meteorology; 619 Pipes, Tanks & Accessories; 545 Iron & Steel; 421 Materials Properties; 484 Seismology
CT *WATER PIPELINES:Design; JOINTS:Repair; PIPELINES:Repair; PIPE, CAST IRON:Failure; EARTHQUAKE RESISTANCE
ST RESTORATION; PIPELINE INFRASTRUCTURE

L20 ANSWER 48 OF 86 COMPENDEX COPYRIGHT 2000 EI
TI Developments in pipe repair clamps and collars.
CC 512 Petroleum & Related Deposits; 522 Gas Fuels; 619 Pipes, Tanks & Accessories; 605 Small Tools & Hardware
CT *NATURAL GAS PIPELINES:Repair; SEALS; PIPE:Repair; CLAMPING DEVICES:Reviews
ST REPAIR CLAMPS/COLLARS; GAS-TIGHT SEAL

L20 ANSWER 49 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER DUPLICATE 2
TI Extension of service life for trunk oil pipelines on the basis of inspection and effective methods of repair
CC ENVIRONMENT, TRANSPORT & STORAGE; PIPELINE CORROSION; PIPELINE MAINTENANCE; SAFETY; TRANSPORTATION AND STORAGE
CT ABSTRACT; ACTIVITY; CARGO; CONSTRUCTION; CORROSION; CORROSIVITY; CRUDE OIL; CRUDE OIL (WELL); DAMAGE; DEFECT; DETERIORATION; DISBONDING;

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

DUPLICATE 8
TI STATE-OF-THE-ART ROV ((REMOTELY 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
LT COMPUTER CONTROL; COMPUTING; REMOTE
LT DEEP WATER; MAINTENANCE
LT OFFSHORE; PIPELINE
LT SHIP; SUBSURFACE; UNDERWATER

L20 ANSWER 51 OF 86 APILIT2

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; GROUP VIA; HYDROCARBON; 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

CHAIN; SINGLE STRUCTURE
TYPE; SUBSTANCE DETERMINED; WASTE MATERIAL
LT 115-10-6; AIR POLLUTANT; C2; ETHER; METHYL ETHER; POLLUTANT; SATURATED
CHAIN; SINGLE STRUCTURE
TYPE; SUBSTANCE DETERMINED; WASTE MATERIAL
ATM Template not available

L20 ANSWER 52 OF 86 APILIT2

TI Pipeline Rehabilitation surveys for prioritizing coat/wrap repairs of old
cross-country pipelines
CC PIPELINE CORROSION; PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; ALTERNATING CURRENT; COATING MATERIAL; COATING PROCESS;
*CORROSION; DIRECT CURRENT; ECONOMIC FACTOR; ELECTRIC CURRENT; ELECTRIC
POTENTIAL; ELECTRICITY; *MAINTENANCE; MATERIALS TESTING; *MEASURING;
OPERATOR; PERSONNEL; PIPE; *PIPELINE; REVIEW; SOIL (EARTH); WRAPPING
ATM Template not available

L20 ANSWER 53 OF 86 APILIT2

TI Pipeline repair based on diagnostic inspection - Investment return
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; ASME; ASSOCIATION; DEFECT; ECONOMIC FACTOR; FAILURE; IN LINE;
*INSPECTING; INVESTMENT; *MAINTENANCE; MEETING PAPER; PAYOUT; *PIPELINE;
PROFITABILITY
ATM Template not available

L20 ANSWER 54 OF 86 APILIT2

TI Inspection and repair of a sour crude oil pipeline
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ASIA; CARGO; CASING; COMPOSITION; *CRUDE OIL; *CRUDE OIL (WELL); DEFECT;
EFFICIENCY; EPOXY RESIN; GROUT; IMMERSION; *INSPECTING; MAINTENANCE;
MECHANICAL PROPERTY; MEETING PAPER; OMAN; OPERATING CONDITION; PHYSICAL
PROPERTY; *PIPELINE; PRESSURE; REVIEW; SLEEVE; SOUR; SULFUR CONTENT;
SYNTHETIC RESIN; TENSILE STRENGTH; TOUGHNESS; TRANSPORTATION; WALL; WATER
LT CARGO; CRUDE OIL; CRUDE OIL (WELL)
LT EPOXY RESIN; GROUT; SYNTHETIC RESIN
ATM Template not available

L20 ANSWER 55 OF 86 APILIT2

TI Pipeline tie-in and repair by surface U-spool connection
CC PIPELINE CONSTRUCTION; TRANSPORTATION AND STORAGE
CT ABSTRACT; COMBINATION; *CONSTRUCTION; DEPTH; ECONOMIC FACTOR; FAILURE;
HIGH PRESSURE; JOINT; *LINE PIPE; *MAINTENANCE; OFFSHORE STRUCTURE;
OPERATING CONDITION; *PIPE; *PIPELINE; *PIPELINE CONSTRUCTION; PRESSURE;
RISK; SEA FLOOR; *SEDIMENT; SUBSURFACE; SURFACE; TEMPERATURE; UNDERWATER;
WATER; WELDING
LT JOINT; SUBSURFACE; UNDERWATER
LT DEPTH; SURFACE; WATER
LT COMBINATION; SEDIMENT
ATM Template not available

L20 ANSWER 56 OF 86 APILIT2

TI Pipeline repair development in support of the Oman to India gas pipeline
CC PIPELINE CONSTRUCTION; PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ARRESTER; ASIA; BUCKLING; CARGO; *DAMAGE; DEFORMATION; DEPTH; END;
EQUIPMENT; EQUIPMENT TESTING; FORGING; FORMING; INDIA; JOINT; LINE PIPE;
MACHINING; *MAINTENANCE; MAP; MEETING PAPER; MODEL; *NATURAL GAS; OMAN;
PIPE; *PIPELINE; PROTOTYPE; REPLACEMENT; SUBSURFACE; SURFACE; THICKNESS;
UNDERWATER; WALL; WATER
LT CARGO; NATURAL GAS
LT EQUIPMENT; MODEL; PROTOTYPE
LT DEPTH; SURFACE; WATER
LT END; LINE PIPE; PIPE
LT THICKNESS; WALL
LT PIPELINE; SUBSURFACE; UNDERWATER
ATM Template not available

L20 ANSWER 57 OF 86 APILIT2

TI Robotic Equipment for Pipeline Repair
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; CARGO; CRUDE OIL; CRUDE OIL (WELL); DEPTH; GAS; HIGH PRESSURE;
JOINT; *MAINTENANCE; NATURAL GAS; NORTH SEA; OFFSHORE; OPERATING
CONDITION; *PIPELINE; PLASMA; PLASMA JET; PRESSURE; SEA; SUBSURFACE;
UNDERWATER; *WELDING
LT CARGO; CRUDE OIL; CRUDE OIL (WELL); NATURAL GAS
LT DEPTH; OFFSHORE; PIPELINE; SEA; SUBSURFACE; UNDERWATER
ATM Template not available

L20 ANSWER 58 OF 86 APILIT2

TI Deepwater Pipeline Repair Technology: A General Overview
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; ASME; ASSOCIATION; AUTOMATIC; CARGO; *CONSTRUCTION; CONSTRUCTION
EQUIPMENT; COST; CRUDE OIL; CRUDE OIL (WELL); DAMAGE; DEEP WATER; ECONOMIC
FACTOR; EFFICIENCY; ENI; EQUIPMENT TESTING; INSPECTING; *MAINTENANCE;
MEDITERRANEAN SEA; MEETING PAPER; MODEL; NATURAL GAS; NONE; OFFSHORE;
PERSONNEL; *PIPELINE; *PIPELINE CONSTRUCTION; PROTOTYPE; SEA; SEASONAL;
SUBSURFACE; SUMMER; TRANSPORTATION; *TRUNK PIPELINE; UNDERWATER
LT CONSTRUCTION; OFFSHORE; PIPELINE; PIPELINE CONSTRUCTION; SUBSURFACE; TRUNK
PIPELINE; UNDERWATER
LT CARGO; CRUDE OIL; CRUDE OIL (WELL); NATURAL GAS
LT ECONOMIC FACTOR; NONE; PERSONNEL; SUBSURFACE; UNDERWATER
LT AUTOMATIC; CONSTRUCTION EQUIPMENT; MODEL; PROTOTYPE
LT EQUIPMENT TESTING; SEASONAL; SUMMER
ATM Template not available

L20 ANSWER 59 OF 86 APILIT2

TI Hyperbaric pipeline repair system: Current achievements and new deep water
challenges
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; BUSINESS OPERATION; CARGO; COMPOSITION; COMPUTING; CONTROL; DEEP

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

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

TI Underwater pipeline repair: difficult seabed conditions
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; BRITISH GAS CORP; BURYING; CLEANING; COATING MATERIAL;
COMPOSITION; CONSTRUCTION; CONTROL; CUTTING; DAMAGE; DIAMETER; DRY;
EXCAVATING; FORMING; HIGH PRESSURE; LINE PIPE; *MAINTENANCE; MEETING
PAPER; OPERATING CONDITION; PIPE; *PIPELINE; PIPELINE CONSTRUCTION;
PRESSURE; PRIOR TREATMENT; REPLACEMENT; SEA FLOOR; SUBSURFACE; SURVEYING;
TIME; UNDERGROUND; UNDERWATER; USE; *WELDING
LT DIAMETER; PIPELINE; SUBSURFACE; UNDERGROUND; UNDERWATER
LT MAINTENANCE; TIME; WELDING
LT BURYING; CONSTRUCTION; PIPELINE CONSTRUCTION; PRIOR TREATMENT
ATM Template not available

L20 ANSWER 62 OF 86 APILIT2

TI Aging of pipelines: risk assessment, rehabilitation and repair
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; AGING; ASME; ASSOCIATION; CATHODIC PROTECTION; COATING MATERIAL;
COATING PROCESS; CORROSION CONTROL; COST; ECONOMIC FACTOR; ELECTROCHEMICAL
PROTECTION; EQUIPMENT TESTING; HYDROSTATIC TESTING; INSPECTING; LEGAL
CONSIDERATION; *MAINTENANCE; MEETING PAPER; NORTH AMERICA; ON STREAM;
OPERATING CONDITION; OPERATING COST; OPERATOR; OUTSIDE; PERSONNEL;

*PIPELINE; REPLACEMENT; RISK; RISK ASSESSMENT; SAFETY; US DEPARTMENT OF TRANSPORTATION; USA; USE
LT OUTSIDE; PIPELINE
ATM Template not available

L20 ANSWER 63 OF 86 APILIT2

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 64 OF 86 APILIT2

TI Advances in underwater technology to significantly reduce pipeline repair times
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT BRITISH GAS CORP; CARGO; COATING MATERIAL; COMPOSITION; CUTTING; DAMAGE; DRY; ECONOMIC FACTOR; EXCAVATING; FORMING; HIGH PRESSURE; MACHINE TOOL; *MAINTENANCE; MEETING PAPER; NATURAL GAS; OPERATING CONDITION; PERSONNEL; *PIPELINE; PRESSURE; PROCESS CONTROL; REPLACEMENT; SEA FLOOR; SEALING; SUBSURFACE; SURVEYING; TIME; TRANSPORTATION; UNDERGROUND; UNDERWATER; USE; WELDING
LT PIPELINE; SUBSURFACE; UNDERGROUND; UNDERWATER
LT CARGO; NATURAL GAS
LT MAINTENANCE; TIME
LT ECONOMIC FACTOR; PERSONNEL; SUBSURFACE; UNDERWATER
ATM Template not available

L20 ANSWER 65 OF 86 APILIT2

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; CONTROL; CUTTING; DAMAGE; DIAMETER; DRY; ECONOMIC FACTOR; EXCAVATING; FORMING; HIGH PRESSURE; IN SITU; *MAINTENANCE; MEETING PAPER; OPERATING CONDITION; PERSONNEL; *PIPELINE; PRESSURE; PRIOR TREATMENT; REPLACEMENT; SEA FLOOR; SEALING; SUBSURFACE; SURVEYING; TIME; UNDERGROUND; UNDERWATER; 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

L20 ANSWER 66 OF 86 APILIT2

TI [A discussion of] the principles for renovation or repair of gas pipelines
Grundsaetze fuer die Erneureung oder Instandsetzung von Gasrohrleitungen
CC PIPELINE CONSTRUCTION; PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT BUSINESS OPERATION; CARGO; CONSTRUCTION; DAMAGE; GASEOUS FUEL; GERMANY;
HEATING FUEL; *MAINTENANCE; MANAGEMENT; MANUFACTURED GAS; MODERNIZATION;
MODIFICATION; *NATURAL GAS; *PIPELINE; PIPELINE CONSTRUCTION; PLANNING;
REVIEW; TOWN GAS; TRANSPORTATION; USE; WESTERN EUROPE
LT CARGO; NATURAL GAS
LT CARGO; GASEOUS FUEL; HEATING FUEL; MANUFACTURED GAS; TOWN GAS; USE
ATM Template not available

L20 ANSWER 67 OF 86 APILIT2

TI Cost-effective on-line repair of pipeline damage using epoxy-filled shells
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT 8002-05-9; ABSTRACT; BRITISH GAS CORP; BURYING; CARGO; CORROSION; COST;
CRUDE OIL; CRUDE OIL (WELL); DAMAGE; DEFORMATION; ECONOMIC FACTOR;
EFFICIENCY; EPOXY RESIN; FAILURE; FULL SCALE; HIGH TEMPERATURE;
INVESTMENT; LEAK; *MAINTENANCE; MATERIALS TESTING; MEETING PAPER; NONE; ON
STREAM; OPERATING CONDITION; PETROLEUM FRACTION; *PIPELINE; REPLACEMENT;
REVIEW; SERVICE LIFE; SPLITTING; SUBSURFACE; SYNTHETIC RESIN; TEMPERATURE;
TRANSPORTATION; UNDERGROUND; WELDING
LT PIPELINE; SERVICE LIFE; SUBSURFACE; UNDERGROUND
LT NONE; WELDING
LT 8002-05-9; CARGO; CRUDE OIL; CRUDE OIL (WELL); PETROLEUM FRACTION
ATM Template not available

L20 ANSWER 68 OF 86 APILIT2

TI (A discussion of) systems for ROV actuation and repair of pipeline ball
valves
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT *BALL VALVE; CONTINENTAL OIL; CONTRACT; DEPTH; *DESIGN; DU PONT; ECONOMIC
FACTOR; *ENGINEERING; FORCE; GRAPHICS; GULF; GULF OF MEXICO; INJECTION;
LEGAL CONSIDERATION; LOCATION; *MAINTENANCE; MEETING PAPER; NORTH AMERICA;
OFFSHORE STRUCTURE; *PIPELINE; PIPELINE PIG; *REMOTELY OPERATED VEHICLE;
REVIEW; SEALANT; SEALING; SERVICE LIFE; SIZE; SUBSURFACE; TORQUE;
UNDERWATER; USE; *VALVE; WATER; WELL
LT PIPELINE; SUBSURFACE; UNDERWATER
LT BALL VALVE; SIZE; VALVE
LT DEPTH; WATER
LT LOCATION; REMOTELY OPERATED VEHICLE; SERVICE LIFE

L20 ANSWER 69 OF 86 APILIT2

TI Emergency pipeline repair connects subsea pipelines--1
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE

CT API; ASSOCIATION; BRITISH GAS CORP; CYCLE; DEEP WATER; DEFORMATION;
ECONOMIC FACTOR; ELF AQUITAINE; *EMERGENCY; END; EQUIPMENT TESTING;
FITTING; FORCE; FORGING; FORMING; GAS; GUIDELINES; HYDROSTATIC TESTING;
LINE PIPE; LIQUID; *MAINTENANCE; MECHANICAL PROPERTY; NONE; OIL AND GAS
FIELDS; OPERATING CONDITION; PERSONNEL; PHYSICAL PROPERTY; PIPE;
*PIPELINE; PRESSURE; PRESSURE 1500 PSIG AND HIGHER; PRIOR TREATMENT;
PROCESS TESTING; REVIEW; SUBSURFACE; TORQUE; UNDERWATER; WELDING; YIELD
POINT
LT PIPELINE; SUBSURFACE; UNDERWATER
LT ECONOMIC FACTOR; NONE; PERSONNEL; SUBSURFACE; UNDERWATER
LT PRIOR TREATMENT; WELDING
LT END; LINE PIPE; PIPE
LT CYCLE; DEFORMATION
LT PROCESS TESTING; SUBSURFACE; UNDERWATER
ATM Template not available

L20 ANSWER 70 OF 86 APILIT2
COPYRIGHT 2000 ELSEVIER
TI Developments in Hyperbaric Welding Technology for Pipe Line Repairs Beyond
600 MSW
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; AUTOMATION; COMPOSITION; CONTROL; CYCLE; DEPTH; FLUID FLOW; GAS;
HIGH PRESSURE; LINE PIPE; *MAINTENANCE; MEETING PAPER; OPERATING
CONDITION; PIPE; *PIPELINE; PRESSURE; REVIEW; SCIENCE/TECHNOLOGY;
SUBSURFACE; UNDERWATER; WATER; *WELDING
LT AUTOMATION; SUBSURFACE; UNDERWATER; WELDING
LT DEPTH; WATER
LT CONTROL; CYCLE
ATM Template not available

L20 ANSWER 71 OF 86 APILIT2
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TI Development plan deepwater pipeline repair using explosive welding
technique
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; DEEP WATER; ECONOMIC FACTOR; *EXPLOSIVE WELDING; *MAINTENANCE;
MEETING PAPER; PERSONNEL; *PIPELINE; REVIEW; *WELDING

L20 ANSWER 72 OF 86 APILIT2
COPYRIGHT 2000 ELSEVIER
TI TRANSMISSION PIPELINE REPAIR.
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; BRITISH GAS CORP; CASING; COST; DAMAGE; ECONOMIC FACTOR;
EFFICIENCY; EQUIPMENT; GAS INDUSTRY; HEALTH/DISEASE; *MAINTENANCE;
OCCUPATIONAL HEALTH; *OPERATING CONDITION; PERSONNEL; *PIPELINE; REVIEW;
*SAFETY
ST FULL ENCIRCLEMENT SHELL; GRINDING

L20 ANSWER 73 OF 86 APILIT2
COPYRIGHT 2000 ELSEVIER
TI Cold forged tubular joints in pipeline repair
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; ASME; ASSOCIATION; CYLINDER; EQUIPMENT; FORGING; FORMING; JOINT;

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

TI Remote Underwater Excavation - A New Approach to Sensitive Pipeline Repair, Reinstatement 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

TI PIPELINE REPAIR - SUBSEA CONTRACTOR"S VIEW.
CC PIPELINE MAINTENANCE;
TRANSPORTATION AND STORAGE
CT ABSTRACT; AUTOMATION;
*CONSTRUCTION; CONTRACTOR;
CONTROL; CONTROL
EQUIPMENT; COST; DEEP WATER;
ECONOMIC FACTOR; EQUIPMENT;
*MAINTENANCE;
MONITORING; NONE; NORTH SEA;
PERSONNEL; *PIPELINE
CONSTRUCTION; REMOTE;
REMOTELY OPERATED VEHICLE;
REVIEW; SCIENCE/TECHNOLOGY;
SEA; SUBSURFACE;
UNDERWATER; WELDING
LT CONSTRUCTION; PIPELINE
CONSTRUCTION; SUBSURFACE;
UNDERWATER
LT CONTROL; CONTROL
EQUIPMENT; REMOTE
LT ECONOMIC FACTOR; NONE;
PERSONNEL; SUBSURFACE;
UNDERWATER

L20 ANSWER 76 OF 86 APILIT2

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

TI COLD TAPPING FROM A REPAIR TO A DEVELOPMENT TOOL TO PROLONG PIPE LIFE.

CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; ANCHOR (MARINE); CAPACITY; CARGO; COLD TAP; CORROSION; DAMAGE;
ECONOMIC FACTOR; EQUIPMENT; FITTING; HOT TAP; INSIDE; *MAINTENANCE;
MEETING PAPER; OFFSHORE; ONSHORE; OPERATING CONDITION; OPERATOR;
PERSONNEL; *PIPELINE; PIPELINE PIG; POLLUTION CONTROL; PRESSURE RELEASE;
REPLACEMENT; REVIEW; SAFETY; SERVICE LIFE; SUBSURFACE; TRANSPORTATION;
UNDERWATER
ST COLD TAPPING; HOT TAPPING; JAMMING; SLACK LOOP
LT INSIDE; OFFSHORE; ONSHORE; PIPELINE; SERVICE LIFE; SUBSURFACE; UNDERWATER

L20 ANSWER 78 OF 86 APILIT2

TI PIPELINE REPAIR TECHNIQUES - THE STATE OF THE ART.
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; CEMENT; CONCRETE; DEFECT; DEPTH; ECONOMIC FACTOR; EQUIPMENT;
HIGH PRESSURE; *MAINTENANCE; MEETING PAPER; MODULAR; OPERATING CONDITION;
OPERATOR; PERSONNEL; *PIPELINE; PIPELINE INDUSTRY; PRESSURE; SAFETY;
SCIENCE/TECHNOLOGY; STATE OF THE ART; SUBSURFACE; TRANSPORTATION INDUSTRY;
UNDERWATER; USE; *WELDING
ST HYPERBARIC WELDING; POSITIONING
LT DEPTH; PIPELINE; SUBSURFACE; UNDERWATER
LT EQUIPMENT; MODULAR

L20 ANSWER 79 OF 86 APILIT2

TI PIPELINE EMERGENCY REPAIR SYSTEM AND COLD TAPPING DEVELOPMENT TOOL.
CC PIPELINE MAINTENANCE; TRANSPORTATION AND STORAGE
CT ABSTRACT; BUOYANCY; BUSINESS OPERATION; COLD TAP; CONTRACTOR; DAMAGE;
ECONOMIC FACTOR; EMERGENCY; EMPLOYEE RELATIONS; EQUIPMENT; FRIGG FIELD;
*MAINTENANCE; MEETING PAPER; MULTIPLE; NONE; OIL AND GAS FIELDS;
*OPERATING CONDITION; PERSONNEL; PHYSICAL PROPERTY; *PIPELINE; PRESSURE;
REVIEW; *SAFETY; SUBSURFACE; TRAINING PROGRAM; TWO; UNDERWATER; *WELDING
ST SAINT FERGUS, SCOTLAND
LT BUOYANCY; NONE; PHYSICAL PROPERTY
LT ECONOMIC FACTOR; PERSONNEL; SUBSURFACE; UNDERWATER
LT MULTIPLE; PIPELINE; SUBSURFACE; TWO; UNDERWATER

L20 ANSWER 80 OF 86 TULSA2

DN 659779
TI PIPELINE REHABILITATION SURVEYS FOR PRIORITIZING COAT/WRAP REPAIRS OF OLD
CROSS-COUNTRY PIPELINES
CC PIPELINING, SHIPPING & STORAGE
SH *PIPELINE REPAIR
CT *CATHODIC PROTECTION; *COATING MATERIAL; *COATING PROCESS; *CORROSION
CONTROL; *DETECTION; *DETECTOR; *EXTERNAL COATING; *FLAW DETECTION;
*HOLIDAY DETECTOR; *INSTRUMENT; *MAINTENANCE; *REPAIR; ATTENUATION; BURIED

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
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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
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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

L20 ANSWER 83 OF 86 TULSA2

DN 399246
TI TAPS (TRANS-ALASKA PIPELINE) REPAIR SHOWS VALUE OF DEFORMATION MONITORING
CC PIPELINING, SHIPPING & STORAGE
SH *FLAW DETECTION
CT *CONSTRUCTION; *DETECTION; *INSPECTING; *PIGGING; *PIPE INSPECTION;
*PIPELINE CONSTRUCTION; *PIPELINE SURVEYING; *SURVEYING; *TERRAIN PROBLEM;
*TESTING; ARCTIC AREA; AUTOMATION; CHART; DEFORMATION; DIAGRAM; DIAMETER;
INDEX MAP; MAINTENANCE; MAP; MONITORING; PIPE DEFORMATION; PIPE DIAMETER;
PIPELINE; PIPELINE AUTOMATION; PIPELINE CROSSING; REPAIR; SETTLING

L20 ANSWER 84 OF 86 TULSA2

DN 405362
TI CALCULATIONS AND REPAIR STRATEGIES FOR WAX BLOCKED PIPELINES
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
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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
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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 alterative 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.; Shrake, B.; Stripling, T.; Zipp, K.
New York, NY: American Society of Mechanical Engineers. 1995. p. 37-45 of 124 p. Society of Mechanical Engineers, 22 Law Drive, Box 2900, Fairfield, NJ (United States) Order No. H00924 $72.00.
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.

L36 ANSWER 48 OF 86 COMPENDEX COPYRIGHT 2000 EI
AN   1989(1):1746 COMPENDEX   DN 89014465
TI   **Developments in pipe repair clamps and collars**
AU   Ayres, Caroline (British Gas plc, Engl)
SO   Gas Eng Manage v 28 n 6 Jun 1988 7p
CODEN: GEMABL   ISSN: 0306-6444
AN   1989(1):1746 COMPENDEX   DN 89014465
AB   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. (Edited author abstract).

L36 ANSWER 67 OF 86 APILIT2 COPYRIGHT 2000 ELSEVIER
AN   92:4875 APILIT;APILIT2
DN   3981301
TI   **Cost-effective on-line repair of pipeline damage using epoxy-filled shells**
AU   Corder I
CS   british Gas Eng Res Stat
SO   Pipe Line Ind. & Pipes Pipelines Int. Pipeline Risk Assessment, Rehabil, &
Repair Int. Conf. (Houston, 5/20-23/91) Proc. Pap. No. 23, (1991) 13P
Petroleum Abstracts ABSTR. NO. 520,206 V32 N.9 (2/29/92) ISSN: 0031-6423
ISBN: 0-88415-013-5
AB   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.

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