



RP 6-1

CORROSION MONITORING

August 1993

Amended September 1993

Copyright © The British Petroleum Company p.l.c.

All rights reserved. The information contained in this document is subject to the terms and conditions of the agreement or contract under which the document was supplied to the recipient's organisation. None of the information contained in this document shall be disclosed outside the recipient's own organisation without the prior written permission of Manager, Standards, BP International Limited, unless the terms of such agreement or contract expressly allow.

BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING											
Doc. No. RP 6-1	Issue Date Latest Amendment Date	August 1993 September 1993									
Document Title											
CORROSION MONITORING (Replaces BP Engineering CP 50)											
APPLICABILITY Regional Applicability: International											
SCOPE AND PURPOSE This document covers general requirements for monitoring of corrosion within pipes and vessels for refineries, chemical works, offshore installations, onshore terminals, pipe lines, pumping stations, oil and gas gathering stations and LNG plants. It gives guidance on available techniques and the requirements for safe and reliable design and operation.											
AMENDMENTS <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Amd</th> <th style="text-align: left;">Date</th> <th style="text-align: left;">Page(s)</th> <th style="text-align: left;">Description</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sep 1993</td> <td>6, 19</td> <td>Warning re ER probes with velocity shields used with low pressure access fittings</td> </tr> </tbody> </table>				Amd	Date	Page(s)	Description	1	Sep 1993	6, 19	Warning re ER probes with velocity shields used with low pressure access fittings
Amd	Date	Page(s)	Description								
1	Sep 1993	6, 19	Warning re ER probes with velocity shields used with low pressure access fittings								
CUSTODIAN (See Quarterly Status List for Contact) Materials Engineering											
Issued by:- Engineering Practices Group, BP International Limited, Research & Engineering Centre Chertsey Road, Sunbury-on-Thames, Middlesex, TW16 7LN, UNITED KINGDOM Tel: +44 1932 76 4067 Fax: +44 1932 76 4077 Telex: 296041											

CONTENTS

Section	Page
FOREWORD	iii
1. INTRODUCTION.....	1
2. SCOPE	1
3. GENERAL	2
3.1 Strategy	2
3.2 Equipment	3
3.3 Safety	3
4. TECHNIQUES.....	4
4.1 Weight Loss Coupons.....	4
4.2 Spool Pieces	5
4.3 Field Signature Method (Electric Fingerprint)	5
4.4 Electrical Resistance Probes.....	6
4.5 Electrochemical Probes.....	7
4.6 Electrochemical Noise	8
4.7 Solid Particle Impingement Probes.....	8
4.8 Hydrogen Probes and Patch Monitors.....	9
4.9 Galvanic Probes.....	10
4.10 Electrical Potential Monitoring	10
4.11 pH Probes.....	11
4.12 Measurement of Dissolved Gases.....	11
4.13 Pipeline Inspection Tools	12
4.14 Ultrasonic Thickness Measurement	13
4.15 Radiography	14
4.16 Sidestream Monitoring.....	14
4.17 Visual Inspection	15
4.18 Failure Analysis	15
5. BACTERIAL METHODS.....	15
6. MEASUREMENT OF DISSOLVED SOLIDS.....	17
7. MEASUREMENT OF SUSPENDED SOLIDS	18
8. CORROSION PRODUCT ANALYSIS	18
9. DESIGN REQUIREMENTS.....	19
9.1 General	19



9.2 Access Fitting Location	19
9.3 Access Fitting Design	20
9.4 Materials Selection	22
10. AUTOMATED SYSTEMS	22
10.1 General	22
10.2 Manual Methods.....	23
10.3 Data Loggers/Collection Units.....	23
10.4 Transmitter Units.....	23
10.5 Computers.....	23
11. DATA ANALYSIS AND REPORTING.....	24
TABLE 1	25
GENERAL GUIDE TO THE APPLICATION OF	25
CORROSION MONITORING TECHNIQUES	25
FIGURE 1	26
LOW PRESSURE ACCESS FITTING SYSTEM	26
FIGURE 2	27
ARRANGEMENT OF COUPONS AND PROBES INSTALLED.....	27
IN HIGH PRESSURE ACCESS FITTINGS	27
APPENDIX A.....	28
DEFINITIONS AND ABBREVIATIONS	28
APPENDIX B.....	29
LIST OF REFERENCED DOCUMENTS.....	29
APPENDIX C.....	30
GUIDELINES FOR SAFE ON-LINE INSTALLATION	30
AND RETRIEVAL OF CORROSION MONITORING DEVICES.....	30



FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This document provides guidance on safe and reliable methods for corrosion monitoring appropriate to the system requirements, using BP's knowledge and experience worldwide.

Application

Text in italics is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an asterisk (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

The principal changes from the previous edition (BP CP 50) are as follows:-

- LP access systems have been included
- acceptable new techniques have been added and some older non-viable techniques have been eliminated
- the classification of techniques has been discontinued

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

- 1.1 This Recommended Practice gives guidance on BP's general requirements for monitoring internal corrosion in plant associated with oil, gas and chemical production and processing.

These methods utilise established and industrially proven methods including:-

Weight loss coupons
Corrosion probes
Solid particle impingement probes
Hydrogen probes and monitors
Galvanic probes
Bacterial probes
Potential measurement
Ultrasonic thickness measurements
Radiography
Intelligent pigs
Chemical analysis

- 1.2 Corrosion monitoring techniques involving the use of coupons and probes provide a measure of the corrosivity of a process fluid.

Corrosion rates measured by these techniques are not necessarily those that will be experienced by the pipe or vessel walls which contain the fluid.

These techniques should be supported by non-destructive testing and visual inspection methods, which should be routinely used to determine plant condition.

The corrosion monitoring data may be used to assess the effect of changes in operating conditions on process fluid corrosivity and optimise the process conditions accordingly. The Plant Inspector may use the data to complement the plant inspection records and to assist in planning inspection programmes.

In the United Kingdom the corrosion monitoring programme may also form part of the Written Scheme of Examination required by the Pressure Systems and Transportable Gas Containers Regulations.

2. SCOPE

- 2.1 This Recommended Practice is applicable to:-

(a) Onshore installations



- (b) Offshore installations
- (c) Refinery operations
- (d) Chemical process plant
- (e) Steam generating plant
- (f) Cooling water systems
- (g) Any new or existing plant where internal corrosion is anticipated.

2.2 It does not include techniques for:-

- (a) Downhole monitoring of tubing or casing
- (b) Internal inspection of heat exchanger tubes
- (c) The monitoring of cathodic and anodic protection systems
- (d) The monitoring of Corrosion Under Insulation (CUI)

2.3 Additional specific guidance on corrosion monitoring may be given where appropriate in other BP Group Recommended Practices related to a particular system or application.

3. GENERAL

3.1 Strategy

3.1.1 A comprehensive review of the process plant materials, corrosion allowances and operating conditions should be carried out to identify all areas which could be susceptible to significant corrosion within the projected lifespan of the plant. An assessment of the consequences of a corrosion failure occurring will be an integral part of the review. The identification of the specific corrosion processes likely to occur is essential to the selection of particular on-line corrosion monitoring devices to be used. The review should also identify those parameters which are instrumental in causing corrosion and which are likely to influence the corrosion rate. The results of the review should be used to develop a corrosion monitoring strategy encompassing the following:-

- Identification and location of monitoring devices and their location.
- Prescribed monitoring frequencies.
- Agreed monitoring procedures.
- The allocation of responsibilities for:-
 - (a) ensuring that monitoring is carried out in accordance with the defined procedures,
 - (b) the interrogation, storage and retrieval of the information recorded,



- (c) the presentation of detailed reports at the required frequency.

3.1.2 For new projects the corrosion monitoring requirements shall be established during the early development of the design.

- * 3.1.3 Where corrosion inhibitors or other performance chemicals are used to control corrosion, the chemical supplier may be appointed to undertake the required corrosion monitoring to determine the effectiveness of the product(s) in service. In this case the chemical supplier shall have a proven track record of carrying out such duties. The chemical supplier shall submit detailed corrosion monitoring procedures for BP's approval.

3.2 Equipment

3.2.1 The selection of the specific on-line corrosion monitoring devices will be determined by the known or perceived corrosion processes taking place.

3.2.3 Individual corrosion monitoring devices provide only a limited amount of information. A minimum of two techniques should be used to monitor corrosion in order to provide complementary data. In addition the information provided by the corrosion monitoring devices should be supplemented by detailed operational data covering the monitoring period, chemical analysis of process fluids and equipment inspection records.

3.2.4 On-line internal corrosion monitoring should be undertaken using proprietary access fittings which permit the installation and removal of probes and coupons without the need for plant shutdown. The design and mechanical properties of such fittings must meet the requirements of the appropriate Standard(s) and Code(s) used for the design and construction of the plant being monitored.

3.3 Safety

3.3.1 Statutory and BP safety regulations relevant to the specific area where corrosion monitoring activities are being carried out must be followed.

3.3.2 Corrosion monitoring hardware, cabling and instrumentation shall comply with Sections 2 and 3 of BP Group [RP 30-1](#).

3.3.3 Recommended procedures for the safe on-line retrieval and installation of probes and coupons are given in Appendix C

4. TECHNIQUES

4.1 Weight Loss Coupons

- 4.1.1 Coupons may be used to determine the average fluid corrosivity by measurement of weight loss. Susceptibility to pitting, bimetallic corrosion, stress corrosion cracking, crevice corrosion, corrosion in weldments or heat affected zones (HAZ), hydrogen embrittlement, scaling, erosion and cavitation may also be determined. The method facilitates an assessment of the corrosivity of an environment with respect to the specific material of construction of that part of the plant in which the corrosion monitoring is taking place.

The chemical composition and metallurgical condition of the coupon material should be as close as possible to that of the plant material. The results may be influenced significantly by the monitoring location within the plant and the position of the coupon(s) in the process stream, see [NACE RP0775](#).

Careful consideration should be given to the proposed monitoring location and coupon position during the development of the corrosion monitoring strategy.

- 4.1.2 The two most common types of weight loss coupon are strip and flush disc, although rods and rings may also be used in certain circumstances. Guidance on coupon selection, handling exposure times and evaluation are given in [NACE RP0775](#).
- 4.1.3 Each coupon shall carry its own individual identification mark and be degreased and uniformly grit blasted prior to exposure. Where considered appropriate 'as finished' metal surfaces may be evaluated but these are likely to give inconsistent results.
- 4.1.4 For purposes other than weight loss from a single metal or alloy, (e.g. bimetallic corrosion, weldment corrosion, stress corrosion cracking) novel coupon designs will be required, appropriate to the corrosion phenomena being evaluated.
- 4.1.5 Coupons shall be attached to holders suitable for installation in low pressure or high pressure (2 inch) access fitting systems as appropriate. (See Figures 1 and 2)
- 4.1.6 Exposed coupons should always be visually examined for the type and uniformity of the attack both before and after chemical cleaning. Samples of corrosion product should be removed for detailed chemical analysis. Where pitting is the predominant form of attack the extent and type of pitting may be evaluated in accordance with [ASTM G46-76](#).

4.2 Spool Pieces

- 4.2.1 To obtain a direct assessment of the corrosivity of a process stream the piping system may be configured to include short lengths of flanged pipework (0.3 to 1.0m) which can be removed periodically for internal inspection. These spool pieces should be fabricated from an identical piping material to the adjacent pipework.
- 4.2.2 Where spool pieces with different piping materials are to be evaluated, the extent of any galvanic couple between adjacent piping spools must be assessed and electrical insulation requirements established as appropriate.
- 4.2.3 The piping spools shall be cleaned prior to exposure and may also be weighed, where the measurement of weight loss is considered practical. If weight loss is to be determined then the spools must be protected from external corrosion or mechanical damage while in service.
- 4.2.4 After exposure, the spool piece shall be cleaned internally using the methods described for corrosion coupons in [NACE RP0775](#) and, where appropriate, re-weighed in order to calculate the overall corrosion rate. Sectioning will be required to enable a detailed visual assessment of the metal loss to be made. Localised corrosion shall be evaluated in accordance with [ASTM G46-76](#).

4.3 Field Signature Method (Electric Fingerprint)

- 4.3.1 This comprises the measurement of the changes in an applied electric field within a pipe spool, caused by the loss of material from the inner wall due to internal corrosion.

One commercial field signature method is available from Corrocean Ltd.

- 4.3.2 Thin contact pins typically up to 64 in number are welded or cemented to the outside of the pipe wall in a configuration which will be determined by the position and the pattern of internal corrosion expected. Each pin is connected to a data acquisition unit which monitors the potential difference generated between individual pairs of pins as a consequence of the application of an external current between two auxiliary pins spanning the measurement pin configuration. Using appropriate software the change in the 'fingerprint coefficient' with time for each pair of pins enables a graphical representation of the corrosion pattern to be developed with quantitative estimates of the loss in wall thickness across the area covered by the pin array.
- 4.3.3 The technique has the advantage that it measures the actual corrosion taking place within the process system regardless of process fluid type

and with a high degree of sensitivity without the need for access fittings, intrusive probes and retrieval operations.

- 4.3.4 Removal of the spool piece for confirmation of the pattern and extent of corrosion being indicated is recommended. This will normally have to coincide with a plant shutdown.
- 4.3.5 Careful thought must be given to the overall pattern and the individual spacing of the pins in order to generate the optimum information from the data recorded.
- 4.3.6 The magnitude of the current applied between the auxiliary pins is dependent upon wall thickness and needs to be adjusted accordingly to maximise the accuracy of the data.

4.4 Electrical Resistance Probes

- 4.4.1 Electrical resistance (ER) probes measure the change in electrical resistance of a sacrificial element exposed to the process fluid relative to a reference element sealed within the probe body. If the probe corrodes uniformly the change in resistance of the exposed element over a fixed time period is directly proportional to the average corrosion rate for that period.

Successive readings must be compared in order to determine fluid corrosivity over the intervening period.

- 4.4.2 Electrical resistance probes may be used to measure the corrosivity of both conductive and non-conductive liquids and vapours. There are three main types:-

Tubular element
Wire loop
Flush

- 4.4.3 *Of the three types the tubular element is the most commonly used. Wire loop probes are less robust than their tubular element counterparts and are more susceptible to mechanical damage. Flush mounted probes can suffer preferential crevice attack at the steel element/potting compound interface which can give rise to unrepresentative corrosivity data.*
- 4.4.4 Under high velocity process conditions tubular element and wire loop probes may require velocity shields for protection. However, velocity shields are prone to debris accumulation with attendant spurious results from the probe and their use should be limited accordingly.

Wire loop or tubular element electrical resistance probes, fitted with velocity shields which extend the full length of the probe body, shall not

be used in conjunction with low pressure access fittings on hydrocarbon, or other hazardous duty.

There is a risk that an uncontrolled fluid release could occur on retracting the probe, should the velocity shield fail by a corrosion related or other mechanism.

4.5 Electrochemical Probes

- 4.5.1 The linear polarisation resistance (LPR) technique is based upon the measurement of the 'apparent resistance' of a corroding electrode when it is polarised by a small voltage of the order of 10 millivolts. The 'apparent resistance' is determined from the current flowing as a consequence of the small applied voltage and is inversely proportional to the corrosion rate. LPR probes have the advantage over electrical resistance probes in that they provide an instantaneous measurement of fluid corrosivity. However, they can only be used to measure the corrosivity of 'clean' low resistivity process fluids under conditions of continuous immersion.

The limits of operation of the technique are also governed by the expected corrosion rate and advice should be sought from the probe supplier.

- 4.5.2 As the electrochemical characteristics of LPR probe elements may change with corrosion of the elements, probes should be replaced on a more frequent basis (than for electrical resistance probes) in order to ensure that consistent data is being produced.

LPR probes may also suffer from 'shorting out' due to the accumulation of debris or corrosion products bridging the gap between the electrodes.

- 4.5.3 LPR probes are available in the form of two or three rod like electrode assemblies with the rods protruding into the process stream. Three electrode assemblies are used where a high corrosion rate is anticipated in a low conductivity fluid and where there would be a significant contribution to the measured polarisation resistance from the electrolyte resistance. Three electrode probes are normally used where the fluid conductivity is less than 100 micro mhos (fluid resistivity greater than 10^4 ohm cm) Flush mounted versions are also available in various two electrode configurations. As with electrical resistance probes the flush mounted versions can be susceptible to crevice corrosion at the electrode/potting compound interface and may give unrepresentative corrosivity values.

4.6 Electrochemical Noise

- 4.6.1 This technique of corrosion monitoring utilises three electrode linear polarisation probes but is more sensitive than LPR measurement. It records the random fluctuations in current and/or potential

(electrochemical noise) generated by corrosion reactions taking place at the surfaces of the probe elements. Unlike the LPR method the electrodes are not polarised but allowed to corrode freely in the process stream. The technique is very sensitive to changes in processing conditions which affect the corrosivity of the fluids and is particularly useful for optimising corrosion inhibitor/chemical treatment programmes.

However, as the same probe configuration is used for the measurement of electrochemical noise as in the LPR method the technique suffers from the same disadvantages.

4.7 Solid Particle Impingement Probes

4.7.1 Sensors for the evaluation of solids entrained in fluid systems are available in two versions, intrusive and non-intrusive as follows:-

4.7.2 Intrusive solid particle impingement probes are available which can be located within standard 2 inch high pressure access fittings. These probes work on a similar principle to electrical resistance probes in that the change in electrical resistance with time due to the abrasive wear of the probe element is taken as proportional to the solids concentration of the fluid.

Derived formulas which include the average particle size, the flow velocity and, where applicable, gas liquid ratio enable a measure of the solid particle concentration to be made. In general this type of probe suffers from a problematic sensitivity-lifespan relationship. Probes sensitive enough to give useful data require frequent change out due to their finite lives.

4.7.3 Non-intrusive solid particle impingement probes comprise a sensor which is strapped to the outside of the pipe wall in an area where particle impingement is judged to be greatest. Two types of sensor can be used to detect particle impacts; ultrasonic and stress wave.

Ultrasonic sensors record the magnitude of the noise generated by the particle impacts and appropriate computer software is used to convert the ultrasonic signals to give a measure of solid particle content. In the alternative technique stresswave sensors in acoustic contact with the pipe wall count the number of acoustic pulses generated by the particle impacts on the inner wall of the pipe. The acoustic pulses or stress waves generated have a typical frequency of 500 kHz. Stress wave sensors have the advantage that the pulse counting method suppresses the influence of erroneous signals produced by, for example, pipe vibration, which can be a significant problem with ultrasonic sensors.

4.8 Hydrogen Probes and Patch Monitors

4.8.1 Hydrogen is the product of corrosion reactions in many systems, but most significantly where the process streams contain water and H₂S, HCN or HF. Atomic hydrogen produced by the electrochemical

reduction of hydrogen ions at the inner wall of the pipe or vessel can diffuse into the pipe or vessel material and give rise to hydrogen embrittlement, hydrogen blistering or stress corrosion cracking.

The combination of hydrogen atoms to form hydrogen gas at the corroding metal surface is retarded by certain anions, the most common being sulphide, cyanide and fluoride. These anions thereby promote the diffusion of atomic hydrogen into the steel substrate.

4.8.2 Methods of measuring the rate of diffusion of atomic hydrogen into structural materials are available in two forms, either as thin walled tubular probes inserted directly into the process stream through standard 2 inch high pressure access fittings or as patch detectors clamped or welded to the outer pipe or vessel wall.

4.8.3 Intrusive thin-walled hydrogen probes collect the hydrogen diffusing through the wall of the probe element. An integral pressure gauge is used to monitor the pressure build up arising from arrival of atomic hydrogen at the inner wall of the probe element where the atoms combine to form hydrogen gas. The rate of pressure build up can be related to the potential for hydrogen damage occurring in the vessel or piping materials. A period of stabilisation is required to enable the tubular element to saturate with atomic hydrogen before meaningful data can be accumulated.

4.8.4 There are two types of non-intrusive hydrogen patch probes. The first comprises a carbon steel patch contoured to fit the outside of the vessel or pipe and welded to it.

The patch is fitted with temperature and pressure gauges and the quantity of hydrogen diffusing directly through the vessel or pipe wall is measured by logging the rate of increase in pressure within the patch envelope in an analogous manner to the tubular element hydrogen probe.

The second type of patch probe is mounted directly onto the vessel or pipe wall using mechanical straps.

The probe comprises a small electrochemical cell with one electrode, a thin inert metal foil, usually palladium, in direct contact with the pipe wall. As the hydrogen diffuses through the vessel or pipe wall and the metal foil it is electrochemically oxidised on the inner face of the foil which is in contact with the cell electrolyte. The current flowing in the cell is directly proportional to the rate of hydrogen permeation through the wall of the equipment and provides a direct measure of hydrogen activity.

As with the other types of hydrogen probes described above the electrochemical patch probe requires an initial stabilisation period. In addition it requires regular maintenance in the form of electrolyte replenishment and/or renewal.

4.9 Galvanic Probes

- 4.9.1 Probes comprising two dissimilar metals may be used to assess the corrosivity of a conductive process fluid. The natural current flow between the two metals is measured using a zero resistance ammeter and the magnitude of the current gives a measure of fluid corrosivity.

Direct correlations between the corrosivity of the fluid measured by a galvanic probe and the performance of the less noble constituent of an equivalent bimetallic couple which exists within the process plant should be made with care as the surface area ratio between the two metals is critical in determining the magnitude of the galvanic effect.

- 4.9.2 Conventional galvanic probes comprising a brass cathode and mild steel anode are sensitive to the concentration of oxidising species in conductive fluids and may be used to monitor the level of dissolved oxygen and the effectiveness of oxygen scavengers in water injection and cooling water systems.

- 4.9.3 Galvanic probes comprising parent metal, weld metal and heat affected zone combinations may be used to assess the potential for preferential weldment corrosion within the process streams.

Such probes may comprise either 5 or 6 elements with the galvanic current between the various combinations of electrodes being recorded using a zero resistance ammeter.

Care is required in the manufacture of the probe elements to ensure that the welding processes used are comparable with those used in plant fabrication.

Such probes are able to indicate the effect of changes in composition of the process fluids on the relative susceptibility of parent metal, heat affected zone and weldment to internal corrosion.

4.10 Electrical Potential Monitoring

- 4.10.1 The measurement of the electrical potential between the piece of process equipment (or a probe of the same material) and a fixed reference electrode will provide information on the corrosion risks. The technique requires that the process fluid be conductive and the electrochemistry of the system well understood. Potential monitoring does not give a measure of the corrosion rate, but will indicate the onset of active corrosion from an otherwise passive state due to changes in the processing conditions where a clearly defined active-passive transition exists.

4.10.2 *For practical purposes a robust and stable reference electrode must be selected. The location of the test probe and the reference electrode may be critical to the provision of reliable information and require careful consideration.*

4.10.3 *High impedance voltmeters (> 1 megohm) should be used to record potentials in combination with a chart recorder.*

4.11 pH Probes

4.11.1 In aqueous process streams where the control of pH is critical either to the efficiency of the process or the resistance of the plant materials to corrosion, pH measurements may be used in conjunction with chemical treatment programmes.

4.11.2 *The removal of process fluid samples to a laboratory for pH measurement is not a reliable method of determining the system pH since the pH of the sample may alter considerably as a consequence of the sampling procedures. For many applications on-line monitoring using pH probes is the only reliable method of monitoring unit or system pH.*

4.11.3 The distance between the off-take point and the probe location should be kept as short as possible to minimise pressure drops which will affect the reliability of the pH measurement. The flow control and flow monitor should be placed downstream of the probe location to avoid sudden pressure drops which will encourage the release of gas from solution, the formation of gas pockets and gas blocking of the probe element. For similar reasons long and tortuous sidestreams should be avoided. High flow rates through the sidestream will be beneficial in preventing the fouling of the probe element.

pH probes are prone to fouling, require frequent cleaning and calibration and are more suited to installation in sidestreams or off-take lines rather than in a main process line or vessel.

4.12 Measurement of Dissolved Gases

4.12.1 Electrochemical probes are available which measure the concentration of dissolved oxygen in both conducting and non-conducting media. Care has to be taken in the selection of probe type as with some the elements are easily poisoned by certain species within the process fluid.

The more reliable probes comprise a thin membrane which is porous to oxygen. The oxygen diffuses through the membrane and dissolves in the small body of electrolyte within the probe. The oxygen within the electrolyte is electrochemically reduced at an inert electrode and the corresponding current which flows between this and an auxiliary electrode gives a measure of the concentration of dissolved oxygen in the process fluid.

4.12.2 Dissolved oxygen probes should not normally be inserted directly into the process stream but fitted into a small flow chamber connected to a side stream or a process fluid off-take point.

4.12.3 Proprietary kits may be used for the rapid on site determination of oxygen, carbon dioxide and hydrogen sulphide levels in aqueous process fluids.

The kits employ vacuum sealed glass ampules containing chemical reagents. Breaking the glass tip on the ampule while the tip is submerged in a process fluid test sample admits a small volume of the sample into the tube where a chemical reaction occurs resulting in the development of a characteristic colour. The intensity of the colour is used to determine the concentration of dissolved gas in the sample either by using a multifilter photometer and calibration chart or directly using a series of comparators.

4.13 Pipeline Inspection Tools

4.13.1 The corrosivity of fluids being transported along subsea or buried onshore pipelines can be assessed using standard monitoring techniques at accessible locations, which are usually limited to each end of the pipeline. However, detection of localised corrosion of the pipe wall requires the use of intelligent pigs.

4.13.2 There are two principle types of inspection vehicle used to survey the internal and/or external condition of steel transmission pipelines. The first involves the direct measurement of wall thickness by ultrasonics. The second uses an induced magnetic flux in the pipe wall to assess the defect size from the perturbation caused by defects. Both techniques require the pipe internals to be thoroughly cleaned and free of deposits for them to function successfully.

4.13.3 Ultrasonic pigs have the advantage that they measure wall thickness directly. There is also no practical limit to the pipe wall thickness that can be measured and the results are not affected by the proximity of girth welds.

They have the disadvantage that as with all ultrasonic measurements a couplant is required between the sensing head and the pipe wall. This means that for successful use in gas lines ultrasonic pigs require to be run in slugs of a couplant such as methanol or glycol, or behind a gel pig.

In older pipelines where significant internal wastage has occurred the reliability of ultrasonic pigs is questionable due to the reduced intensity of the reflected signal from the non-planar surface.

4.13.4 Magnetic flux pigs can be run in liquid and gas lines, but rely upon previous wall thickness calibrations taken by direct measurement using

ultrasonics, or by reference to pipe manufacturer's data sheets. The maximum wall thickness capabilities for the more sophisticated designs are typically 15 mm for 10 inch ID pipe and 30 mm for 30 inch ID pipe.

The assessment of the material thickness in the weld area is affected by changes in the profile and the thickness of the pipe material and accuracy is therefore reduced at these locations. In addition the results are also affected by external welded attachments.

4.13.5 For new pipelines a base line survey should be considered during the pre-commissioning phase to enable construction defects to be discounted in future surveys.

4.13.6 Surveys using intelligent pigs should be carried out throughout the life of a pipeline. More frequent surveys are to be expected during the early part of the life of a pipeline, becoming less frequent once a level of confidence has been established regarding the corrosivity of the fluids and/or the effectiveness of any corrosion inhibitor treatment programme.

4.13.7 Before a pipeline is surveyed using an intelligent pig for the first time, the feasibility of the pipeline for pigging must be assessed. This must include a review of pig launcher and receiver suitabilities and pipeline contours along the full length.

A comprehensive cleaning programme will normally be essential prior to the survey for optimum data capture. Internal gauging may also be justified.

4.14 Ultrasonic Thickness Measurement

4.14.1 Conventional compression wave ultrasonics may be used to measure the residual wall thickness in pipework and vessels handling potentially corrosive fluids. The measurement accuracy depends upon the actual wall thickness and the condition of the outer surface of the pipe or vessel in contact with the probe, but will typically be +/- 0.5 mm.

4.14.2 *Correlations of actual pipe wall wastage can be made with data from the installed intrusive corrosive monitoring devices, but care has to be taken in deriving corrosion rates from ultrasonic wall thickness data in view of the limited accuracy of the technique.*

4.14.3 The precise locations on the pipe or vessel being examined should be permanently marked in order to ensure that successive ultrasonic readings are always taken at the same location.

* 4.14.4 In critical situations where high corrosion rates are anticipated over a small area, solid coupled probes may be welded directly onto the pipe or vessel at the suspect locations in order to permit continuous

monitoring of wall thickness. The proposed welding procedures shall be submitted to BP for approval prior to the probe attachment.

One commercial solid coupled probe is available from AGA Technology.

- 4.14.5 Where internal metal loss occurs over a wide area, automated and manual ultrasonic scanning techniques are available to develop visual displays of the extent and depth of the metal loss.

These methods are commercially available and include Seescan and Zipscan from Sonomatic Ltd.

4.15 Radiography

- 4.15.1 As an alternative to ultrasonics, radiography may be used to examine the internal condition of process pipework and supplement the information on fluid corrosivity received from other monitoring methods.

- 4.15.2 It is particularly useful for the examination of preferential corrosion at weldments and erosion at bends, but the limited accuracy renders it suitable only for the detection of significant changes in pipe wall thickness.

- 4.15.3 Due to the absorption of the incident radiation by liquids as well as the pipe wall, its use on-line is limited to small diameter process streams containing vapours or gases. Under normal circumstances radiography is impractical for examining pipework larger than 8 inch diameter.

4.16 Sidestream Monitoring

- 4.16.1 Sidestream monitoring is referred to in a number of places within this Recommended Practice. It encompasses the temporary use of a by-pass spool or off-take from the main process stream being monitored to provide supplementary information to that produced by the on-line monitoring devices. Sidestream monitoring may be used to examine the short term effect of chemical additives or process changes upon the electrochemistry of the plant material - process fluid system.

- 4.16.2 *The sidestream equipment should comprise one or more probe or coupon holders and flow control and metering devices. It should be used to supplement on-line corrosion monitoring methods and should not be used in isolation unless on-line methods are not practical.*

4.17 Visual Inspection

The visual inspection of vessel and equipment internals during periods of plant shutdown should be used to supplement information from on-line corrosion monitoring activities.

4.18 Failure Analysis

All plant and equipment failures should be thoroughly investigated, documented and reviewed in conjunction with the results of on-line corrosion monitoring activities.

5. BACTERIAL METHODS

5.1 In order to measure the propensity for microbial corrosion in a process system it is necessary to quantify both the mobile (planktonic) bacteria and the surface adhering (sessile) bacteria.

5.2 The mobile bacteria may be enumerated by removing a sample of liquid from the process stream into a clean sterilised container and carrying out a serial dilution test in the laboratory.

5.3 The tendency for sessile population development within a system should be assessed by using a bioprobe exposed to the process stream through a standard 2 inch high pressure access fitting. Biofilms may also be removed from standard strip coupons protruding into the process stream.

As bacterial corrosion relies upon the development of bacterial colonies upon the metal surface it is the determination of sessile populations which is most important in deciding whether or not a problem exists.

Bioprobes typically carry 6 removable studs on which the biofilms are allowed to develop. Removal of the studs from the bioprobe enables the growth of sessile populations to be quantified and may provide additional information on the morphology of the corrosion to be expected in the system. Typical exposure times for bioprobes for development of biofilms is 2 to 4 weeks.

5.4 The corrosion of mild steel as a consequence of the growth of sulphate reducing bacterial populations is characterised by the formation of iron sulphide scale, which can be fairly easily detached to reveal shiny, almost hemispherical confluent pits. As sessile microbial populations tend to develop predominantly in areas where flow rates are very low, probes should be fitted into deadlegs or other stagnant locations.

- 5.5 The recommended method for examining water samples for evidence of sulphate reducing bacteria in the laboratory is described in [API RP 38](#). In the field a technique known as serial dilution testing may be used to determine order of magnitude concentrations of mobile microbial populations in water samples.

The serial dilution method uses the same media to culture bacterial populations as does the method described in [API RP 38](#). The technique may be modified slightly to interrogate surface deposits removed from bioprobe studs.

- 5.6 The serial dilution test for a liquid sample is as follows:-

A sample of water is removed from the process stream into a clean sterilised and stoppered borosilicate glass container. A 1 ml sample of this liquid is introduced into a sterilised syringe and injected into a sealed bottle of a selected culture medium (serial bottle). Following vigorous shaking a 1 ml sample is taken from the serum bottle and introduced into a second serum bottle using a fresh sterilised syringe. This procedure is repeated with a sample from the second serum bottle introduced into a third bottle, and so on until 5 serum bottles have been inoculated. The 5 bottles are then incubated at a temperature within 5°C (9°F) of the process stream for a 28 day period. Bottles indicating bacterial growth will discolour. The data relating to the concentration of bacteria is dependent upon the number of bottles that have discoloured and is reported as the number of colonies over a range from 10/ml to 100,000/ml if a 5 bottle series is used.

The main drawback with the serial dilution method is the time taken to incubate the colonies.

The serial dilution test should be carried out at least twice on each sample of water or surface deposit.

- 5.7 More rapid semi-quantitative techniques are available in kit form for detecting bacteria responsible for corrosion where their presence within a process stream or storage area is suspected.

These techniques are as follows:-

- 5.7.1 A test using the enzyme hydrogenase is available to measure the activity in the bacterial population. In this test sulphate reducing bacteria employ the hydrogenase in a microbially induced corrosion reaction.

Samples of corrosion product or sludge from bioprobes or the internal surface of the process equipment are exposed to an enzyme extracting solution. After filtering, the enzyme is chemically reduced in an anaerobic chamber. The hydrogenase activity and hence the level of bacteria is assessed by the intensity of colour from an indicator dye in the enzyme extracting solution.

Results are available within 24 hours. The results obtained from this test cannot be compared directly with results from other test methods.

One commercial kit is the Hydrogenase Test (Caproco).

- 5.7.2 Another indirect test measures the bacterial population density by determination of the enzyme adenosine phosphosulphate reductase, present in the bacteria.

Measurement of this enzyme, is again by colour intensity, but uses a colour interpretation card. The approximate population density can be determined with a detection threshold of 10^3 sulphate reducing bacteria per ml of liquid sample.

Test results can be available within 15 minutes of sampling and show reasonable correlation with those from serial dilution tests.

One commercial kit is the Rapidcheck Test (Conoco).

- 5.8 Enumeration of sessile bacteria begins with the removal of the bacteria from the monitoring stud. This may be accomplished on site by scraping with a scalpel, or by swabbing. A sterile field water solution should be used to collect the removed bacteria for enumeration by one of the above methods.

- 5.9 Sampling for bacterial populations should be accompanied by the following:-

Recording of the date, time and sampling location. Measurement of the sample temperature, pH, dissolved oxygen and H_2S in the sample. Recording of the concentration of any production chemicals present. Recording of the appearance of the sample in particular the presence of slimes, turbidity, colour, and smell.

- 5.10 Since bacterial populations may undergo quantitative changes within sample bottles, samples should be analysed with minimum delay to obtain reliable information.

6. MEASUREMENT OF DISSOLVED SOLIDS

- 6.1 The measurement of process fluid corrosivity should be supported by measurements of the chemical composition of the different fluid phases present since fluid composition can have an important influence upon corrosion rates, hydrogen damage, stress corrosion cracking, etc.

- 6.2 In aqueous solutions the determination of ions such as Fe^{++} , Cu^{++} , Zn^{++} , Al^{+++} , Ca^{++} , Cl^- , SO_4^{--} , S^{--} , CO_3^{--} may be carried out either by spectrophotometry, colorimetry or by conventional analytical techniques.

The quantitative analysis of non-aqueous samples should be carried out after first ashing the sample in accordance with [ASTM D482](#).



- 6.3 Samples of liquid for analysis shall be taken from the process stream into clean, stoppered borosilicate glass container(s). Reagents shall be used so that the ions under test form stable suspensions or complexes. The resulting turbidity or intensity of colour change shall be determined by photoelectric colorimeter or spectrophotometer and compared to a curve prepared from standard solutions.

Care shall be taken to ensure that other dissolved ions do not interfere with the formation of the suspension(s) or complex(es), giving rise to spurious results.

- 6.4 Detailed test methods and procedures are given in ASTM publication '[Water and Environmental Technology](#)' Section II, Volumes 01 and 02 and [API RP45](#).

7. MEASUREMENT OF SUSPENDED SOLIDS

- 7.1 The measurement of suspended solids should be carried out where necessary as part of a water quality assessment.

In oilfield water injection systems for example, where plugging of a tight formation could result, suspended solids must be kept to a minimum. The measurement may also be used as an indication of deteriorating water quality due to bacterial action and/or corrosion in the system.

- 7.2 The measurement of suspended solids may be undertaken by filter analysis, turbidity meter or other instruments measuring size and density of particles. Membrane filters are the most suitable for carrying out suspended solid determinations on water which is allowed to flow directly from the process stream.

Methods of determining oilfield water injection quality are described in [NACE Standard TM0173](#).

8. CORROSION PRODUCT ANALYSIS

- 8.1 The measurement of fluid corrosivity using probes and coupons should be supplemented by the chemical analysis of any corrosion products or deposits which are found either on the probes and coupons or on the internals of the process equipment during plant inspections.

The following techniques may be used to examine corrosion products.

- Visual examination
- Magnetic examination
- Microscopy
- Wet chemical analysis
- Spectroscopy
- X-ray diffraction and elemental analysis



- 8.2 The collection, handling and storage of corrosion products should be in such a manner as to avoid contamination and/or degradation of the sample. Detailed examination should be carried out as soon as possible after removal from the system.

Recommended procedures for the collection and identification of corrosion products are given in [NACE Standard RP0173](#).

9. DESIGN REQUIREMENTS

9.1 General

A corrosion monitoring philosophy shall be established based upon a detailed review of the process conditions and plant materials. The potential corrosion problems arising from both routine and non-routine operation of the plant shall be assessed in order to determine areas which may be affected. The actual process streams to be monitored and the monitoring devices to be used shall be based on this assessment.

9.2 Access Fitting Location

- 9.2.1 As far as practical access fittings should be installed on horizontal process lines in a vertical aspect as shown in Position 1 in Figure 2.

Bottom of the line access fittings show a tendency to accumulate debris which may give unrepresentative monitoring results. It can also result in galling of the threads on the monitoring device and/or the fitting which could ultimately render the fitting unusable.

Where bottom of the line fittings are unavoidable, flanged access fittings may be used in place of flare weld fittings to enable the fitting to be replaced should problems be encountered.

- 9.2.2 In sour systems iron sulphide deposits may cause galling problems regardless of the position of the access fitting and flanged fittings should always be used on such service.

- 9.2.3 Access fittings should be located a minimum distance of 7 pipe diameters downstream and a minimum of 3 pipe diameters upstream of any changes in flow caused by bends, reducers, valves, orifice plates, thermowells, etc. Where access fittings are installed in pairs there should be a minimum distance of 1 metre between each fitting. Where the monitoring devices are intrusive and comprise a probe and a coupon holder, the probe should be located in the upstream fitting to minimise turbulence around the second monitoring device.

9.2.4 Intrusive monitoring devices aimed principally at the measurement of fluid corrosivity should not be located in high velocity process streams where vortex shedding could result in fatigue of the probe or coupon holder. For the same reason the length of the probe or coupon holder should be kept as short as possible, particularly in large diameter lines.

9.2.5 The positioning of corrosion monitoring fittings should be such as to allow routine access for probe interrogation and coupon and probe retrieval.

Ideally fittings should be located in pipework situated at floor level or immediately adjacent to permanent walkways.

The locations of all monitoring points should be marked on the process flow diagrams, materials selection diagrams and isometric piping drawings.

9.3 Access Fitting Design

9.3.1 For operating pressures up to 137 barg (2000 psig) on-line internal monitoring shall be undertaken using proprietary 2 inch high pressure access fittings which permit the installation and removal of probes and coupons without the need for plant shutdown. Typical high pressure access fitting assemblies with coupon holders and coupons fitted are shown in Figure 2.

9.3.2 Where on-line retrieval and installation of monitoring devices installed in 2 inch high pressure access fittings is required, the fittings shall be located where adequate clearance is available for installation and operation of a service valve and retriever attached to the access fitting body. The following clearances are recommended based upon the use of fully extended telescopic retrievers.

Retriever Stroke in (mm)	Clearance (From Top of Access Fitting in (mm)
26 (660)	74 (1880)
34 (1270)	90 (2290)
42 (1070)	105 (2670)
50 (1270)	122 (3100)

The required clearance with respect to the outer wall of the pipe in which the fittings are located will be determined by the type of fitting, i.e. flareweld or flanged. For a flareweld fitting the additional clearance will be typically 6 inch (150 mm) and for a flanged fitting 15 inch (380 mm). It is recommended that the

above figures be used for guidance only and all required clearances be checked by reference to the specific dimensions of the actual equipment to be used.

- 9.3.3 Low pressure access fittings should consist of a weldoflange, a flanged full port valve, a threaded nipple welded into a slip-on flange and a stuffing box, see Figure 1. For this system the maximum recommended operating pressure is 10 barg (146 psig).

See clause 4.4.4 with regard to the selection of electrical resistance probes for use with low pressure access fittings.

The nipple between the valve and the stuffing box should be the same length or longer than the probe element or coupon to facilitate removal of the monitoring device clear of the ball within the valve. The stuffing box should be fitted with a ferrule and locking nut and chevron PTFE seals. A 1 inch (25 mm) full port valve will normally be large enough to permit the probe or coupon holder to pass freely through the valve body, in fouling duties a 1.5 inch (37.5 mm) valve is recommended.

- 9.3.4 Figure 1 shows approximate dimensions of a typical low pressure access fitting assembly and gives guidance on the clearance required for retrieval operations based upon probe or coupon holder length.

The exact dimensions of the assembly should always be confirmed before checking that adequate clearance exists.

- 9.3.5 All probes and coupon holders to be used in low pressure access fittings shall be fitted with a blow out preventer to limit the extent of slide out of the monitoring device through the stuffing box during installation and retrieval operations on-line.

- 9.3.6 Safety clamps shall be used with low pressure access fittings to secure retractable probes and coupon holders while on line.

- 9.3.7 The maximum operating temperature for each of the two access systems will be governed mainly by the performance of the non-metallic components of the pressure sealing devices utilised within the various parts of the fitting assemblies and probes. The suitability of the non-metallic seals for pressure containment at the requisite operating temperature shall be confirmed prior to procurement.

- 9.3.8 All 2 inch high pressure access fittings shall be fitted with heavy duty covers to protect the access fitting threads from damage and contamination. Each cover should have an integral pressure gauge and relief valve so that any leaks between access fitting body and the monitoring device can be readily identified.

- 9.3.9 Sample points for the collection of process fluids for chemical/bacterial analysis shall include two isolating valves in series and shall comply

with the requirements of clause 322.7 of BP Group [RP 42-1](#) 'Piping Systems'. In horizontal pipework sample points shall be installed at Positions 2 and 4 shown in Figure 2.

9.4 Materials Selection

- 9.4.1 Material selection for access fitting bodies shall conform to the requirements of the piping specification for the process line being monitored.
- * 9.4.2 Solid and hollow plugs used in 2 inch high pressure access fittings shall be fabricated from a material which is resistant to corrosion under the process conditions within the line being monitored. In most circumstances type 316 stainless steel will be suitable, but the final choice shall be approved by BP.
- 9.4.3 The elastomeric components used for pressure sealing shall be demonstrated to have satisfactory performance in the expected process fluids.
- * 9.4.4 Access fittings shall be welded onto the process pipework in accordance with a BP approved welding procedure. The inspection and testing of the attached fitting shall comply with the appropriate piping fabrication code. On successful completion of the pressure test the access hole shall be cut in the pipe wall centrally within the access fitting using a 1 3/8 inch (38 mm) milling cutter. Proprietary drilling machines mounted on the access fitting may be used for this purpose. The flame cutting of access holes prior to the attachment of the fitting is not permitted.

10. AUTOMATED SYSTEMS

10.1 General

Methods for the interrogation of corrosion probes range from hand held analogue or digital meters to multichannel dataloggers linked directly to microprocessor driven data analysis units. The selection of the data collection method will be governed by the following considerations:-

- The number, range and distribution of corrosion monitoring devices.
- The required frequency of data collection.
- The availability of manpower for data retrieval.
- A comparison of the capital and operating costs associated with the various options.

10.2 Manual Methods

- 10.2.1 Hand held instruments for the interrogation of corrosion probes range in versatility from simple direct reading meters dedicated to one probe type and with no data storage facility to multifunction meters with direct read out, data storage and retrieval and computer interface capabilities for optimum data recording and data analysis.
- 10.2.2 Rack mounted instruments providing direct analogue or digital read out of the corrosivity readings from a number of probes are also available.

10.3 Data Loggers/Collection Units

Data logging instruments hard wired to the monitoring devices may be single or multichannel.

Single channel instruments have the advantage that they may be mounted local to the monitoring point to minimise the length of the cable run.

Removable memory modules allow manual transfer of the recorded data to the office where it is downloaded to a personal computer for interrogation.

10.4 Transmitter Units

Individual or multi-probe transmitter units are available which are mounted local to the probe and used to receive, process and transmit the probe signals to a remote interrogation unit. The interrogation unit may be either a dedicated chart recorder, a digital display unit or a process computer.

10.5 Computers

Computers dedicated to corrosion monitoring may be used to receive data from corrosion probes either via transmitter units or multiplexers. The computer facilities enable selection of recording frequency and alarm setting. Sequential scanning through the active channels provides a display of 'real time' probe values. They are primarily concerned with data collection and display and data storage capabilities vary according to manufacturer, but are generally limited. Further data analysis and permanent storage of data is catered for by interfacing with a personal computer, programmed using dedicated software.

11. DATA ANALYSIS AND REPORTING

- 11.1 The methods used to analyse the corrosion monitoring data will be determined by the number, location and variation in monitoring devices used and the method of data collection.

Suitable computer software may be available commercially for this purpose or may be modified to suit the particular application.

- 11.2 In selecting computer software consideration should be given to the inclusion of plant process data and plant inspection results.

- 11.3 The frequency and format of reporting the results of corrosion monitoring activities should be agreed between the Corrosion Engineer and BP. The reports should make reference to significant processing parameters and any chemical treatment programmes carried out during the time interval covered and highlight any significant change in fluid corrosivity. Detailed corrosion monitoring reports should be issued annually, but may be required more frequently where on-line monitoring is used to assist in plant control.



GENERAL GUIDE TO THE APPLICATION OF
CORROSION MONITORING TECHNIQUES

TABLE 1

	Weight Loss Coupons/ Spool Pieces	Corrosion Product Analysis	Electrical Resistance Probes	Electrochemical (LPR) Probes	Galvanic Probes	Bacterial Monitoring	Suspended Solids	Dissolved Solids	Dissolved Gases	pH	Potential Measurement	Hydrogen Probes /Patch
Seawater Injection and Cooling Systems	✓	✓	✓	✓	✓	✓	✓ ₃	✓	O ₂ only	✓	✗	✗
Produced Water Treatment and Injection Systems	✓	✓	✓	✗	✗	✓	✓ ₄	✓	CO ₂ O ₂ ,H ₂ S	✓	✗	✗
Aquifer Water	✓	✓	✓	1	✗	✓	✓	✓	CO ₂ , H ₂ S	✓	✗	✗
Unstabilised Crude Oil	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓
Hydrocarbon Gas	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓
Crude Distillation Units & Associated Pipework	✓	✓	✓	✗	✗	✗	✗	✗	✗	✓	✗	✓
Fluidised Catalytic Cracker Unit, Fraction- ation and Light ends	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓ ₇
Effluent Water	✓	✓	✓	✗	2	✓	✗	✓	O ₂ ,H ₂ S	✓	✗	✗
Process Units Reactor Columns Pipework	✓	✓	✓	✗	✗	✗	✗	✗	✗	Aquestus Systems Only	✓ ₅	✗
Strage Vessels with Seperated Water Bottom	✓	✓	✓	✗	✗	✓	✗	✗	H ₂ S	✓	✗	✗

1. Depends on water quality. LPR unsuitable where there is a strong scaling tendency or other form of electrode contamination possible
2. May be used where oxygen current is high.
3. Sea Water injection systems only.
4. Produced Water injection systems only.
5. Where plant materials display a pronounced active to passive transition.
6. Where fluids are sour, in accordance with BP [Group 136-1](#).
7. For sulphur containing feedbacks.

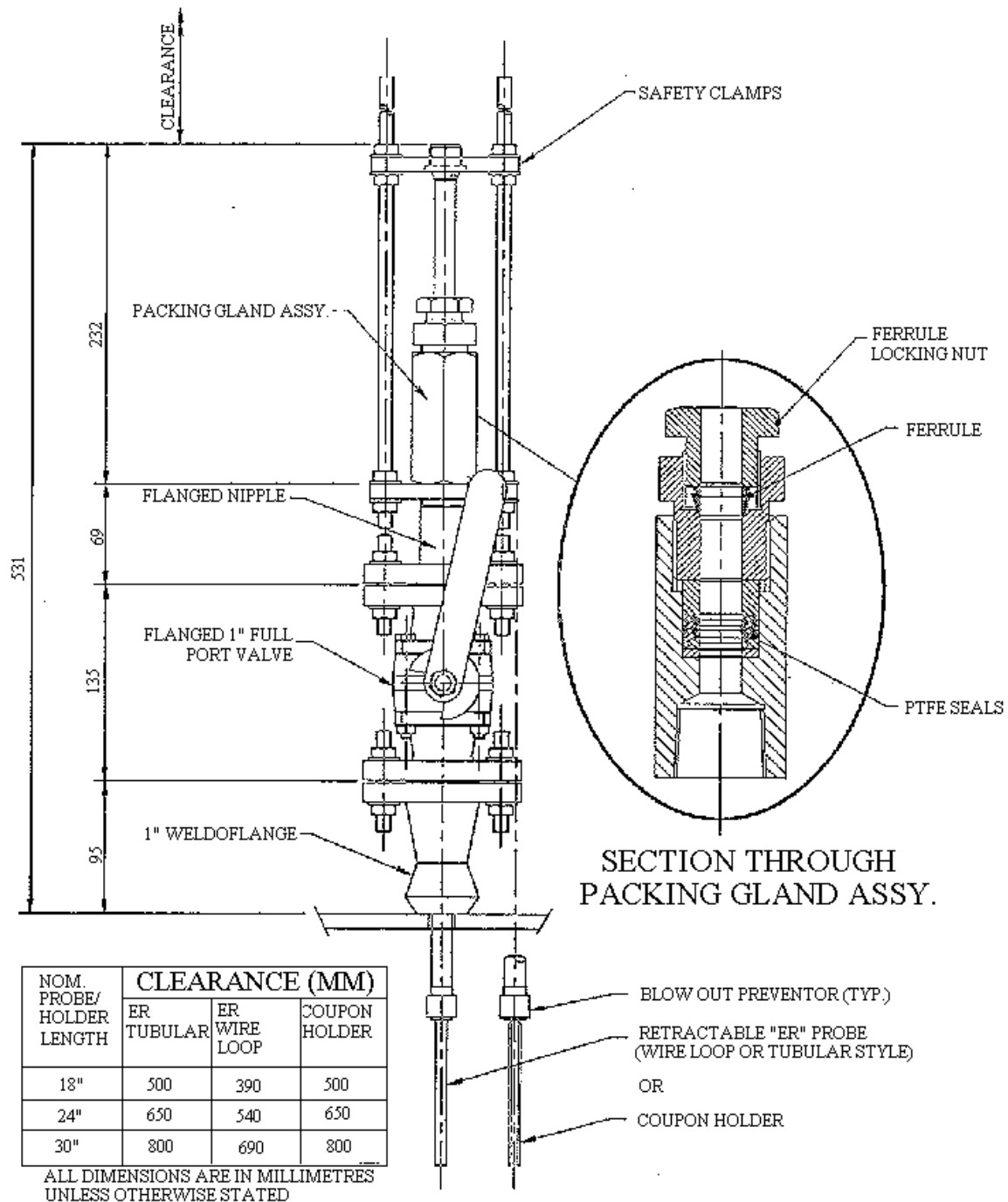
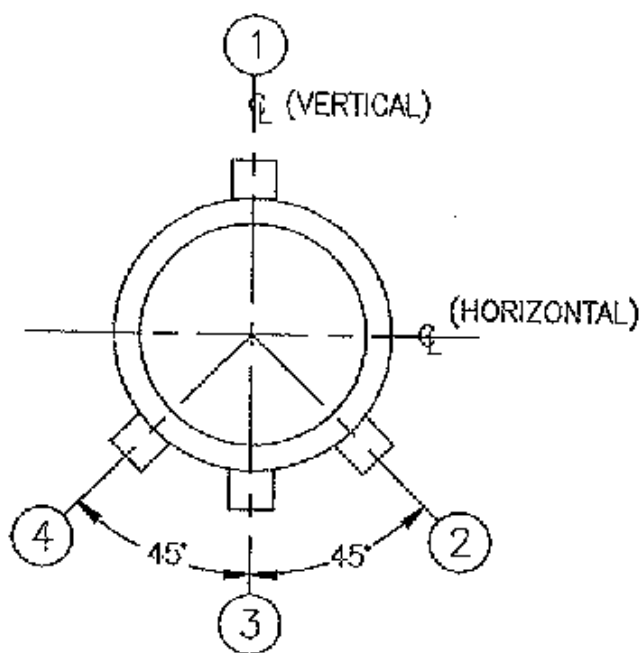
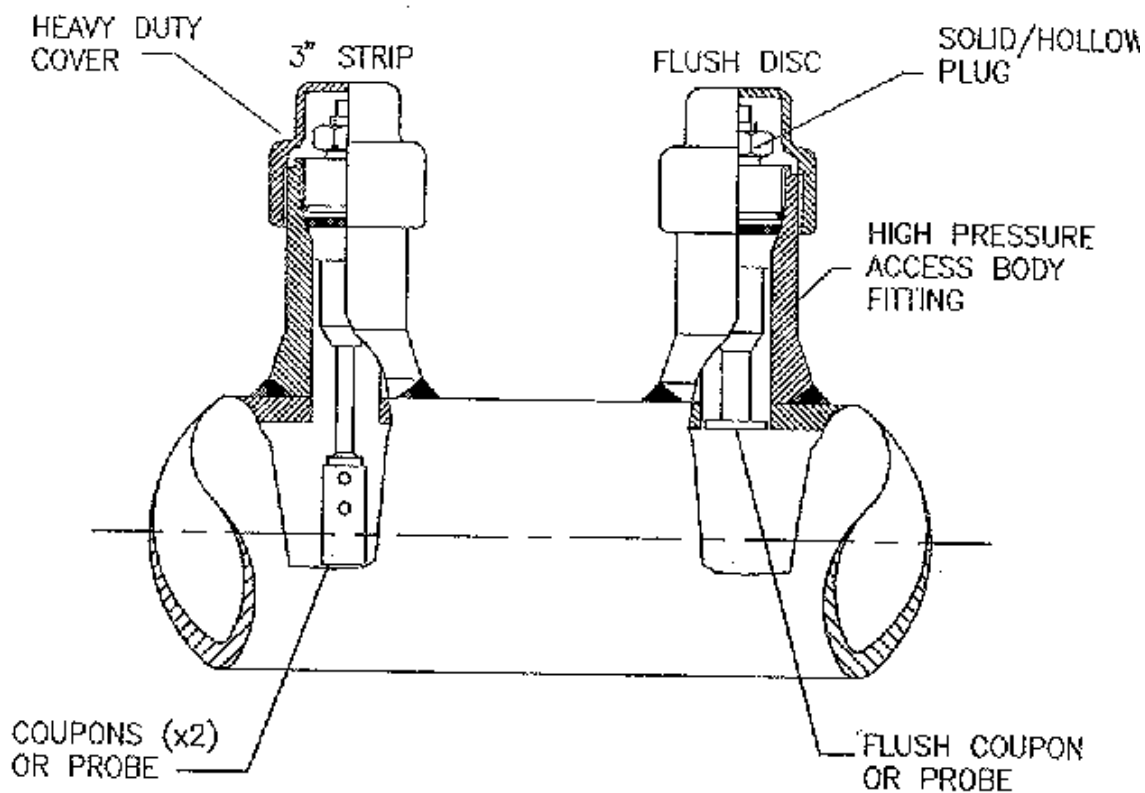


FIGURE 1

LOW PRESSURE ACCESS FITTING SYSTEM



BODY ORIENTATION SECTION

FIGURE 2

ARRANGEMENT OF COUPONS AND PROBES INSTALLED
IN HIGH PRESSURE ACCESS FITTINGS

DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

corrosion engineer:	the person or persons responsible for carrying out the corrosion monitoring and interpretation of data produced.
plant inspector:	the person or persons responsible for carrying out plant inspection and certification.
produced water:	water produced with crude oil or gas.

Abbreviations

ASTM	American Society for Testing and Materials
API	American Petroleum Institute
CUI	Corrosion Under Insulation
DLA	Double Layer Activation
ER	Electrical Resistance
HAZ	Heat affected zone
HF	hydrofluoric acid
HCN	hydrogen cyanide
H ₂ S	hydrogen sulphide
ID	inside diameter
LPR	Linear Polarisation Resistance
NACE	National Association of Corrosion Engineers
NDT	Non-Destructive Testing
PTFE	Polytetrafluorethylene
pH	A scale indicating the acidity of a solution
SI	Système International d'Unités

LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

ASTM	Water and Environmental Technology (Section II Volumes 01 and 02)
ASTM D482-87	Standard Test Method for Ash from Petroleum Products
ASTM G4-84	Practice for Conducting Plant Corrosion Coupon Tests in Plant Equipment
ASTM G46-76	Recommended Practice for Examination and Evaluation of Pitting Corrosion
API RP 38	Recommended Practice for Biological Analysis of Subsurface Injection Waters
API RP 45	Recommended Practice for Analysis of Oilfield Waters
NACE TM0173	Methods of Determining Water Quality for Subsurface Injection using Membrane Filters
NACE RP0173	Recommended Practice for Collection and Identification of Corrosion Products
NACE RP0775	Recommended Practice for Preparation and Installation of Corrosion Coupons and Interpretation of Test Data in Oil Production Practice
BP Group RP 42-1	Piping Systems (Issue date : April 1989) (replaces BP CP 12)
BP Group RP 30-1	Instrumentation and Control Design and Practice (replaces BP CP 18 Part 2)
BP Group GS 136-1	Materials for Sour Service to NACE Std MR0175-90 (replaces BP Std 153)
Health and Safety Commission	<i>Approved Code of Practice - Pressure Systems and Transportable Gas Containers Regulations.</i>



GUIDELINES FOR SAFE ON-LINE INSTALLATION AND RETRIEVAL OF CORROSION MONITORING DEVICES

C1. LOW PRESSURE SYSTEMS

These guidelines are to be read in conjunction with Figure 1.

C1.1 Probe/Coupon Removal Procedure.

- C1.1.1 Loosen and remove the nuts holding the upper safety clamp plate. Remove the plate taking care to ensure that the safety clamp rods are supported.
- C1.1.2 Loosen the ferrule locking nut taking care in case the probe or coupon holder stem is forced up through the packing gland assembly by the line pressure.
- C1.1.3 Slide the probe or coupon holder stem out through the packing gland assembly until the probe element or coupons clear the valve ball or gate. There should be a mark or label on the stem to indicate when this position has been reached.
- C1.1.4 Close the valve.
- C1.1.5 Slowly release the pressure contained within the assembly above the valve by loosening the bolts on the upper flange of the valve.
- C1.1.6 Remove the bolts from the upper flange on the valve and lift off the flanged nipple, clamp and packing gland assembly with the probe or coupon holder.
- C1.1.7 Fully withdraw the probe or coupon holder from the packing gland. Complete removal of coupon holders may not be necessary. The coupons may be removed, the holder cleaned and new coupons fitted with the packing gland etc. still in place.

C1.2 Probe/Coupon Installation Procedure

- C1.2.1 Slide the coupon holder or probe stem through the flanged nipple and into the stuffing box having first checked that the bottom plate of the safety clamp is in place around the nipple. If this is not the case then the nipple and packing gland assembly will need to be split, the plate fitted and the two reconnected.

- C1.2.2 Adjust the position of the probe or coupon holder so that the bottom of the probe element or the coupons will be clear of the valve ball or gate when the assembly is in place above the valve. Mark the stem of the probe or coupon holder where it emerges from the top of the ferrule locking nut to record the 'clear of the valve' position.
- C1.2.3 Check that the flange faces on the flanged nipple and upper valve flange are clean and the gasket in good condition.
- C1.2.4 Mount the assembly on top of the valve and bolt up the mating flanges securely.
- C1.2.5 Partially open the valve and check for leaks. If a leak is evident at the top of the packing gland, tighten the packing retaining nut until the leak stops.
- C1.2.6 Once the assembly is leak free, open the valve fully and slide the probe or coupon holder through the valve and into the process stream. The distance of travel of the probe should be checked to ensure that the monitoring position is correct and that the probe element or coupons are not damaged by contact with the opposite wall of the pipe.
- C1.2.7 Where coupons are being installed ensure that they are correctly orientated parallel with the direction of flow of the process stream.
- C1.2.8 Tighten the ferrule locking nut securely with a wrench or spanner while preventing the packing retaining nut from moving with a second tool.
- C1.2.9 Assemble the safety clamp ensuring that the upper clamp plate fits securely over the top end of the probe or coupon holder and prevents any upward movement of the same.

C2. HIGH PRESSURE SYSTEMS

The following constitutes guidelines for the installation and retrieval of on-line corrosion monitoring devices using a high pressure telescopic retriever and pressure test valve. On-line retrieval/installation of corrosion monitoring devices shall only be carried out by operators skilled in use of the equipment. The owner of retrieval tools and service valves used in retrieval operations shall be in possession of valid certificates confirming that tests have been carried out which demonstrate that the equipment is suitable for the pressures and temperatures at which it will be used.

C2.1 Valve Integrity Test: Fittings without integral service valve installed

- C2.1.1 If a pressure gauge is fitted, check and note the pressure gauge reading. Bleed off any pressure and monitor the rate of subsequent pressure build up. Notify the plant operator if there is a significant leak on the fitting and abort the retrieval operation. Where no pressure gauge is fitted gradually remove the threaded heavy duty cover from the fitting, carefully noting any obvious leakage. Notify the plant operator if there is evidence of significant leakage and abort the retrieval operation, replacing the cover. Where no leakage is found remove the cover completely, clean the access fitting threads and install the service valve.
- C2.1.2 Install the retrieval tool; pressure up the entire assembly with the service valve open to 110% line pressure. This checks the connection between service valve and access fitting.
- C2.1.3 Close the service valve, depressurise and remove the retrieval tool, keeping the service valve closed.
- C2.1.4 Check that the service valve is not passing - if nitrogen is used as the test medium, use soap solution to check for leaks.
- C2.1.5 If no leakage is observed, bleed off the pressure using the by-pass valve and proceed to C2.3.
- If leakage is observed, suspend operations.

C2.2 Valve Integrity Test: Fittings with integral service valve installed

- C2.2.1 Remove the threaded heavy duty cover and clean the threads. Check the integrity of the plug fitting by cracking open the by-pass valve.
- C2.2.2 Install the retrieval tool and pressure up the entire assembly with the service valve open. (To 110% line pressure).
- C2.2.3 Close the service valve; depressurise and remove the retrieval tool, keeping the service valve closed.
- C2.2.4 Check that the service valve is not passing - if nitrogen is used as the test medium use soap solution to check for leaks.
- C2.2.5 If no leakage is observed bleed off the pressure using the by-pass valve and proceed to C2.3. If leakage is observed, suspend operations.

C2.3 Coupon/Probe Retrieval

- C2.3.1 Make up the retrieval tool to the service valve and open the service valve.
- C2.3.2 Pressure test the entire assembly to 110% line pressure.
- C2.3.3 Engage the retriever mandrel in the plug fitting.
- C2.3.4 Back-off the plug until a small product bleed is observed - allow pressure in the retriever to equalise to line pressure.
- C2.3.5 Unscrew the plug completely and withdraw into the retriever body.
- C2.3.6 Close the service valve (ensure mandrel is clear of valve). Depressurise the retrieval tool.
- C2.3.7 Remove the retrieval tool and change out the probe/coupon as required.

C2.4 Coupon/Probe Installation

- C2.4.1 Make up the retrieval tool (with the probe/coupon holder installed) to the service valve.
- C2.4.2 Pressurise the tool to 100 % line pressure. Check for leaks.
- C2.4.3 Crack open the by-pass valve to allow line pressure into the retrieval tool. Allow pressure to stabilise and check for leaks.
- C2.4.4 Fully open the service valve.
- C2.4.5 Insert the probe/coupon holder into the fitting and screw home.
- C2.4.6 Depressurise the retrieval tool and check for any pressure build-up. This checks the integrity of the plug seal.
- C2.4.7 Disengage the tool from the plug.
- C2.4.8 Remove the retrieval tool - ensure pressure is zero.

Note: If coupons are being installed, their final orientation may have to be adjusted at this stage - use the retrieval tool or a socket wrench.

- C2.4.9 Clean the plug top, service valve, etc. and replace the threaded cover.

On completion the retrieval tool should be stripped down, cleaned and re-greased prior to storage.

