SUBSEA ENGINEERS GUIDE TO INSPECTION PROCEDURES
INTRODUCTION ........................................................................ 5

MARINE GROWTH ....................................................................... 6

INTRODUCTION ........................................................................ 6

Reasons for Removal ................................................................. 6

Effects of Marine Growth .......................................................... 6

HARD MARINE GROWTH SPECIES .............................................. 7

Tube Worm Casts ..................................................................... 7

Barnacles .................................................................................. 7

Mussels ..................................................................................... 8

SOFT MARINE GROWTH SPECIES .................................................. 9

Algae ......................................................................................... 9

Seaweed ..................................................................................... 9

Sea Squirts ................................................................................ 9

Anemones .................................................................................. 10

Dead Mans Fingers ................................................................... 10

Bryozoa ...................................................................................... 10

CLEANING TECHNIQUES ....................................................... 11

Hand Cleaning ........................................................................... 11

Mechanical Cleaning (Pneumatic) .............................................. 11

Mechanical Cleaning (Hydraulic) ............................................. 11

High Pressure Water Jet Cleaning ........................................... 11

Grit Entrained ............................................................................ 12

UNDERWATER VISUAL INSPECTION ......................................... 13

General Visual Inspection (GVI) ................................................. 13

Close Visual Inspection (CVI) ................................................... 13

Detailed Visual Inspection (DVI) ................................................. 13

MAGNETIC PARTICLE INSPECTION ........................................ 14

INTRODUCTION ........................................................................ 14

Cleaning .................................................................................... 14

Weld Identification ................................................................. 14

Initial Marking Up ...................................................................... 15

Marking Up ................................................................................ 15

CVI ............................................................................................... 15

Defect Reporting ......................................................................... 16

MPI ............................................................................................... 17

INTRODUCTION ........................................................................ 17

Types of Magnetism ................................................................... 17

Theory ........................................................................................ 19

MPI Terms .................................................................................. 19

British Standards Relating to MPI ............................................ 19

FLUX INDUCING METHODS (BSI 6072) ..................................... 20

MAGNETISING METHODS ......................................................... 21

Encircling Coils .......................................................................... 21

Parallel Conductor (Kettle Element) .......................................... 22

Electromagnet or Yoke ............................................................. 23

Permanent Magnets ................................................................. 23

Prods .......................................................................................... 24

Advantages/Disadvantages ...................................................... 25

Encircling Coils .......................................................................... 25

Parallel Conductor (Kettle Element) .......................................... 25

Electromagnet or Yoke ............................................................. 25

Permanent Magnets ................................................................. 26

Prods .......................................................................................... 26

Demagnetisation ......................................................................... 27

Coils ............................................................................................ 27

Yoke ............................................................................................. 27
## LIVING WITH ROV’S

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>52</td>
</tr>
<tr>
<td>Origins of the ROV</td>
<td>52</td>
</tr>
<tr>
<td>Frame/Chassis</td>
<td>53</td>
</tr>
<tr>
<td>Buoyancy</td>
<td>53</td>
</tr>
<tr>
<td>Control Systems</td>
<td>53</td>
</tr>
<tr>
<td>Propulsion Systems</td>
<td>54</td>
</tr>
<tr>
<td>Deployment Systems</td>
<td>55</td>
</tr>
<tr>
<td>Tether Management Systems</td>
<td>56</td>
</tr>
<tr>
<td>ROV Crew</td>
<td>57</td>
</tr>
<tr>
<td>ROV Supervisor</td>
<td>57</td>
</tr>
<tr>
<td>ROV Pilot / co-pilot</td>
<td>57</td>
</tr>
<tr>
<td>Piloting an ROV</td>
<td>57</td>
</tr>
<tr>
<td>ROV Flying Training</td>
<td>58</td>
</tr>
</tbody>
</table>

## ACKNOWLEDGEMENTS

Page 4 of 59
Introduction

Over recent years much more reliable inspection equipment has become more sophisticated and in some cases much more reliable. Emphasis on how much or how little inspection should be carried out has also changed.

The idea behind this manual, was to make an inspection book/manual that was easily read and understood. It was not my intention to fill this manual with information that would soon detract from it's main propose. To be able to understand the ethos of inspection, whilst able to reference to sections quickly.
Marine Growth

Introduction
The differing type of marine organism’s that attach themselves to platforms are commonly known to most of use as, marine growth or marine fouling.

In most cases these it’s this marine growth cover that hinders either divers or ROV’s from carrying out their primary goals. To locate, identify and report any in-service anomalies, on subsea components or their sub components. As past experience shows, removal of marine growth coverage is both expensive and time consuming. Although in the majority of cases marine growth cover is removed from lift and discharge caissons, the present trend is to use ROV’s equipped with high pressure water jetting units.

However from an engineering and technical view, information on marine growth coverage, thickness and type is essential for structural engineers. As they can analyse information collected offshore and calculate loading, drag, deterioration and possibly failure. All information collected is stored in a baseline database for assessment.

From an engineering point of view, the two type of fouling are expressed as, soft marine growth density is equivalent to that of seawater, where hard fouling density is thereabouts 1.4 time greater than seawater.

Reasons for Removal
Experience has now shown that growth rate, of marine fouling has proved greater than originally anticipated. In certain cases marine fouling has significantly exceeded the structural design parameters. This has lead to great concern amongst structural engineers and installation operators.

Effects of Marine Growth
- Important structural features are obscured, making visual inspection impossible.
- Increases mass, without changing stiffness.
- Increases static load and drag factors.
- Distorts the structures natural designed frequencies.
- Increases ‘Slam effect’ within the splash zone, leading to premature failures and stress related cracking.
- Reduces efficiency service inlets or outlets.
- Accelerates internal corrosion, on control equipment used to supply firewater and cooling water etc.
- Possible effect of accelerating the structure corrosion rate.
Hard Marine Growth Species

Tube Worm Casts
The most stubborn form of hard marine fouling to remove, casts leave a calciferous white patterns almost all metal surfaces.

Barnacles
These tend to grow in dense colonies between El-15 & El-20m, and have a particularly powerful adhesion to any component to which they are attached to.
Mussels
These are hard shelled mollusc, which anchor themselves to the structure by thread sized roots. Coverage is greatest at shallower depths
Soft Marine Growth Species

Algae
Often refereed to as slime, can include short red and green varieties of seaweed.

Waiting on Digital image

Seaweed
Although normally brown in colour, there are many species of this plant, however kelp tends to have the longest fronds.

Sea Squirts
Are soft-bodied animals that normally grow in large colonies.
Anemones
Soft cylindrical boded animals, with tentacles arranged in a radial pattern, which commonly grow in both solitary and in colonies.

Dead Mans Fingers
A colonial type soft coral, which is also an animal, these vary between 10mm and 25mm in length. As in the name, they grow in fleshy finger shapes, colours vary from whites, pink, yellow to even orange.

Waiting on Digital image

Bryozoa
Resembling moss in appearance, these tentacled shaped animals, tend not to grow very tall.
# CLEANING TECHNIQUES

## Hand Cleaning

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to use and deploy</td>
<td>Diver fatigue over long periods</td>
</tr>
<tr>
<td>Inexpensive</td>
<td>Unable to remove tube worm casts</td>
</tr>
<tr>
<td></td>
<td>Possible damage to weld caps</td>
</tr>
</tbody>
</table>

## Mechanical Cleaning (Pneumatic)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy to transport under water</td>
<td>Inefficient at deeper depths</td>
</tr>
<tr>
<td></td>
<td>Can restrict diver visibility</td>
</tr>
<tr>
<td></td>
<td>Risk of damaging weld caps</td>
</tr>
<tr>
<td></td>
<td>Can leave bright metal finish, can leave a highly reflective surface. Unsuitable for photography</td>
</tr>
<tr>
<td></td>
<td>Can be a diver safety hazard</td>
</tr>
</tbody>
</table>

## Mechanical Cleaning (Hydraulic)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>No depth restriction</td>
<td>Cumbersome umbilical</td>
</tr>
<tr>
<td></td>
<td>Risk of damaging weld caps</td>
</tr>
<tr>
<td></td>
<td>Can leave bright metal finish, can leave a highly reflective surface. Unsuitable for photography</td>
</tr>
<tr>
<td></td>
<td>Can be a diver safety hazard</td>
</tr>
</tbody>
</table>

## High Pressure Water Jet Cleaning

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick in removing marine growth over large areas</td>
<td>Will not remove some hard MG, such as tube worm casts</td>
</tr>
<tr>
<td></td>
<td>Can be a diver safety hazard</td>
</tr>
</tbody>
</table>
### Grit Entrained

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes all marine growth</td>
<td>Can remove protective coating</td>
</tr>
<tr>
<td>Leaves matt grey surface, good for photography</td>
<td>Can be a diver safety hazard</td>
</tr>
<tr>
<td>Simple to use</td>
<td></td>
</tr>
</tbody>
</table>
Underwater Visual Inspection

General Visual Inspection (GVI)
This type of inspection does not normally require cleaning, and allows either diver or ROV to carry out a visual inspection of a component or components. However due to marine growth coverage, only major defects may be observed such as, dented, buckled or missing members, gross cracks and any recent abrasions.

Equipment Required: - Tape measure - Hand wire brush/scrapper - Yellow chalk or a suitable marker - CP Meter.

Close Visual Inspection (CVI)
Unlike a GVI, this type of inspection requires marine growth to be removed from a component, and in most cases to bare metal. This will enable either a diver or ROV to establish any visible corrosion, pitting, weld damage and areas of previous grinding.

Equipment Required: - Tape measure - Ruler - Pit gauge - CP meter - Wall Thickness meter.

Detailed Visual Inspection (DVI)
This type of inspection requires minimal cleaning, and can normally be achieved using either hand wire brush/scrapers or HP water jetting. Bear in mind that certain types of hard marine growth, such as tube worm casts will remain. It does however allow either divers or ROV to access the condition of, protective coatings, surface corrosion, clamp/flanges, relative movement and localised damage.

This type of cleaning is also sufficient for Eddy Current Inspection.

Equipment Required: - Tape measure - Ruler - Pit gauge - CP meter - Wall Thickness meter - Spanners.
Magnetic Particle Inspection

Introduction
Various oil companies have differing philosophies regarding contact CP readings, taken prior to weld cleaning for MPI.
In general readings taken before cleaning will be more negative (better protected) than those taken after cleaning.
Prior to cleaning, the structure will be in a state of equilibrium, all metals at this time being in a polarised state. As a result of cleaning, surface dynamics change, which in turn places an increased load on the Cathodic Protection (CP) system. Thus making CP readings, less negative until polarisation once again occurs. This can take minutes or days depending on environmental factors such as biological organics and a structures CP system.
Impressed current systems should achieve polarisation quicker than sacrificial anode systems.

Cleaning
To enable MPI of a weld, all marine growth and protective coatings require removal. This is achieved using a grit entrained jetting system, unlike in the past, low-pressure jetting systems are now preferred as these use dry grit, and have proven more reliable. Rather than wet slurry, as used in the old high-pressure systems, which had a tendency of blocking.
All marine growth and protective coating to be removed not only from the entire length of weld cap, but 75mm either side of the weld toe onto the parent metal, leaving a matt grey finish (Sa 2.5)

Weld Identification
Again differing philosophies of weld identification between oil companies remain, a major contributing factor of how a weld is be marked up at the time of inspection, is cost. Nowadays sophisticated Dynamic Position (DP) vessels are an expensive commodity, so time is of a premium.
Initial Marking Up

As a result, initial ‘marking up’ of a weld has been reduced to, marking only the four cardinal clock positions, member side of the weld. In most cases, unless instructed by the client, 12 o/c position will be datum. At which place a datum mark should be established, if none is present. Normally three punch marks are placed, 25mm away from the weld toe, minor member side. If however anomalies are reported during either CVI or MPI then ‘marking’ up of the weld is essential for accurate reporting. Full details on regarding ‘marking up’ can be found by referencing client’s procedures. Should there not be a procedure for ‘marking up’ available, then this quick and accurate way of marking up could be used.

Marking Up

Using a 10cm rule and starting from datum (12 o/c) member side, move around the weld in a clockwise direction. Mark each 10cm (100mm) increment with a chinagraph pencil or yellow chalk and record distance from datum. Continue until the full circumference is marked and measured, record on the weld data sheet, total length of weld and measurement from datum of each marked clock position.

This method is quicker and appears more accurate than the old articulated tailors tape jobby.

CVI

If possible, prior to a CVI, discuss with the inspection diver how you, the inspection Co-ordinator, data recorder would like the sequence of reporting to be undertaken. Remember it’s you who has to record any data or anomalies, so ensure the diver progresses at your speed.

Keep to a logical sequence throughout a CVI, as an example: -
12 o/c to 3 o/c chord member HAZ
12 o/c to 3 o/c chord toe
12 o/c to 3 o/c weld cap
12 o/c to 3 o/c member toe
12 o/c to 3 o/c member HAZ

Note: - Ensure good communications for accurate reporting
Defect Reporting

If and when a defect is reported the following information must be recorded.

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Description of defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>• It’s start position relative to datum</td>
</tr>
<tr>
<td></td>
<td>• Location, HAZ-CAP-TOE</td>
</tr>
<tr>
<td>Dimensions</td>
<td>• Length of defect</td>
</tr>
<tr>
<td></td>
<td>• Continuous or Intermittent</td>
</tr>
<tr>
<td></td>
<td>• Depth &amp; Width</td>
</tr>
<tr>
<td>Defect Orientation</td>
<td>• If defect is transverse or longitudinal, in relationship to the weld</td>
</tr>
<tr>
<td>Branching</td>
<td>• If branching present, length, direction and locations</td>
</tr>
</tbody>
</table>

Depending on the client, a video record of a CVI is required.
MPI

Introduction
To detect surface breaking defects or in some cases, near surface defects, in ferromagnetic materials, magnetic particle inspection is the method employed.
In the dark ages of inspection, a hammer was used to strike a component, and depending on the tone heard, determined if a defect was present.!! The advance in penetrant inspection came quite by accident. It was noticed one day, that when a railway wheel, which had been lying in a pool of oil, was picked up, it would become covered by a thin layer of dust. This dust tended to draw the oil out of any cracks or cavities, which were on the wheel. This became known as ‘penetrant inspection’. Soon after it was found that if the item was magnetised, then a more sensitive method of inspection could be used. This method is now called ‘Magnetic Particle Inspection’.

Types of Magnetism
Most magnetic properties are determined not only by an electrical structure in the individual atoms, but also the way the atoms are arranged as molecules. This results in three types of magnetism.

Paramagnetic - non-ferrous metals, Platinum etc. - Hard to magnetise
These materials will be slightly attracted by magnetism, almost all metals and some other materials into this group.
Flux lines approaching these materials will not have their courses changed significantly as the flux lines will be relatively unaffected by their passage through the material.
Types of Magnetism (Cont.)

**Ferromagnetism - Steel, Iron and Cobalt - Easy to magnetise**
Atoms in these materials are grouped together in domains, each domain has a north and south pole.
When unmagnetised each domain is randomly distributed, however when exposed to an external magnetic field each domain then aligns with the next, to act as a north and south to the other.

![Diagram of Flux Flow]

**Diamagnetism – Copper - Very hard to magnetise**
When an external magnetic field is applied to these types of metal, it induces a “like for like” magnetic field within that material, resulting in repulsion.
The induced magnet is in the opposite direction to that of the induction applied.
Theory

MPI relies on a flux leakage, which is produced at a defect when a magnetic field is applied to a work piece/weld. This may be accomplished by one of two methods.

- First method relies upon a flux leakage, which is produced whilst a magnetic field is being applied at the time of inspection.
- Second method relies upon a flux leakage prior to magnetism, residual magnetism. However, residual magnetism is normally insufficient to obtain a satisfactory level of flux leakage and therefore not recommended.

**MPI Terms**

<table>
<thead>
<tr>
<th>Term Lost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flux</td>
<td>Lines of force from a magnet.</td>
</tr>
<tr>
<td>Field Strength</td>
<td>The strength of the external magnetising force. (unit Ampere per metre, symbol H).</td>
</tr>
<tr>
<td>Flux Density</td>
<td>Number of lines per unit area, which emerge from a test piece. (unit Tesla, symbol B, the maximum flux density for the application of MPI is 0.72 tesla).</td>
</tr>
<tr>
<td>Flux Leakage</td>
<td>Any point where flux lines leave or re-enter a material or magnet such as poles, defects or discontinuities.</td>
</tr>
<tr>
<td>Flux Indicator</td>
<td>A device (Burmah-Castrol strip) used to check that there is sufficient flux density in the material to enable MPI testing to be carried out.</td>
</tr>
<tr>
<td>Poles</td>
<td>The point at which flux lines leave or re-enter a magnet.</td>
</tr>
<tr>
<td>Consequential Poles</td>
<td>Areas of flux leakage caused by flux lines being forced out of a material at a discontinuity or defect. (It is this area that will be detected when using MPI).</td>
</tr>
<tr>
<td>Permeability</td>
<td>The ease with which a material can be magnetised.</td>
</tr>
<tr>
<td>Vector Field</td>
<td>This is the product of two fields working in a component simultaneously, but at differing angles, and producing a field in a material running at a vector to that of the original field.</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>A representation of the flux density built up in a material for a given field strength (flux density D, always lags behind that of field strength H), and hysteresis means lagging.</td>
</tr>
<tr>
<td>Retentivity</td>
<td>A point on the hysteresis loop that relates to the residual magnetism in a material after the external field has been removed.</td>
</tr>
<tr>
<td>Residual Magnetism</td>
<td>This is the amount of magnetism left in a material after the external field has been removed.</td>
</tr>
<tr>
<td>Reluctance</td>
<td>The resistance to flux flow in a material (reluctance is to magnetism what resistance is to electricity).</td>
</tr>
<tr>
<td>Coercive Force</td>
<td>The amount of force needed to reduce the flux density in a material to zero.</td>
</tr>
<tr>
<td>Saturation</td>
<td>A point at which a material has no more room for extra flux lines and so the excess is forced to run outside the material.</td>
</tr>
<tr>
<td>Electromagnetism</td>
<td>The movement of an electrical charge will create a resulting force at right angles to the direction of current flow.</td>
</tr>
<tr>
<td>Flux</td>
<td>Lines of force from a magnet.</td>
</tr>
</tbody>
</table>

**British Standards Relating to MPI**

- BS 6072  MPI Terms & Definitions
- BS 4069  MPI Detecting Media
- BS 4489  MPI Lighting of an Inspection Site
- BS 5044  Contrast Aids for MPI Testing
- BS 499  Welding Terms & Definitions
Flux Inducing Methods (BSI 6072)

The following pages list the current sources that can be used to produce a magnetic field during MPI.

- Direct Current (DC).
- Alternating Current (AC), either single or three phase (Skin effect).
- Halfwave Rectified Current (HWDC) or halfwave rectified single phase AC.
- Fullwave Rectified (FWDC) or fullwave rectified single phase AC.

Skin Effect

When using AC, the magnetic field is limited to the surface of the material, this is known as the 'skin effect. However DC and rectified AC produce a better penetration of the material.

As the aim most MPI's is surface breaking defects AC current is the preferred method.
Magnetising Methods

Encircling Coils
If a current carrying conductor is bent into a coil, then the resulting flux flow will be longitudinal through the coil.

With the MPI unit in position and prior to commencing :-
- Tightly wrap coils around member side of weld, approximately 50mm from weld toe. Ensure that there are at least two full coils around the member. In some sections there will be three coils present.
- Make U/V light hot, full intensity is achieved in about 5 minutes. This will also help agitate the ink and ensure consistency.
- **DO NOT MAKE COILS HOT at this stage.**
- Place flux indicator (Burmah-Castrol strip) on chord side of weld and check for residual magnetism.
- If none present, make coils hot.
- Commence MPI
- During MPI check for magnetism at each of the four cardinal points using a flux indicator (Burmah-Castrol strip) on chord side of weld.
- On completion of MPI, demagnetise weld.
- Once demagnetised, check for residual magnetism, using a flux indicator (Burma Castrol strip) on chord side of weld.
- De-rig and move to next inspection site.

Note AC current can be used to demagnetise.

![Diagram of encircling coils and weld](image)
Parallel Conductor (Kettle Element)

This method is commonly called the ‘kettle element’ the reason for this can be seen in the drawing overleaf.

The parallel conductor is placed against the test piece surface in such a way that ensures, each cable runs either side of the weld, and parallel to it, in such a way, as to guarantee that when a current is passed through the loop, current flow will be in the same direction along both sides of the weld.

A magnetic field will result running transverse across the weld, the direction of field will be shown by the right hand rule. This method is normally used when testing welds on large flat areas, or very large tubular members, which may be impossible to circle using the loop method.

With the MPI unit in position and prior to commencing :-

- Position coils either side of the weld toes, coils should be between 25mm and 50mm from weld toes.
- Ensure the distance and space between the coils are constant along the entire length of the inspection area.
- Make U/V light hot, full intensity is achieved in about 5 minutes. This will also help agitate the ink and ensure consistency.
- **DO NOT MAKE COILS HOT at this stage.**
- Place flux indicator (Burmah-Castrol strip) on chord side of weld and check for residual magnetism.
- If none present, make coils hot.
- Commence MPI
- During MPI check for magnetism using a flux indicator (Burmah-Castrol strip) on chord side of weld.
- On completion of MPI, demagnetise weld.
- Once demagnetised, check for residual magnetism, using a flux indicator (Burma Castrol strip) on chord side of weld.
- De rig and move to next inspection site.

Note AC current can be used to demagnetise.
Electromagnet or Yoke

The electromagnet is a soft, iron core, often laminated to reduce effects; around this there will be wrapped a large number of insulated copper windings. The result is to make a solenoid, a field which is produced will be similar to that produced by a permanent magnet. However electromagnets can make use of the ‘skin effect’ if they are used with alternating current (AC), making them more versatile than a permanent magnet.

- Before deployment confirm that the required 30 Oe can be obtained, this is the equivalent test to lifting 18 Kg when fully energised (BS6072).
- Make U/V light hot, full intensity is achieved in about 5 minutes. This will also help agitate the ink and ensure consistency.
- Place yoke diagonally across the weld
- During MPI check for magnetism using a flux indicator (Burmah-Castrol strip). Place BCS in contact with the weld midway between pole positions and transverse to the axis of the poles.
- On completion, de rig and move to next inspection site.

Note Only AC current can be used, **DC current is not permitted. WHY NOT add reasons why ?????**

Permanent Magnets

- Before deployment confirm and test that the magnets to be used lift 18 Kg.
- Make U/V light hot, full intensity is achieved in about 5 minutes. This will also help agitate the ink and ensure consistency.
- Place magnet across the weld.
- During MPI check for magnetism using a flux indicator (Burmah-Castrol strip). Place BCS in contact with the weld midway between pole positions and transverse to the axis of the poles.
- On completion, de rig and move to next inspection site.
Prods

In the use of current flow using prods, an electrical current is passed directly through the test piece or material. This produces a circular field transverse across the direction of current flow. It requires high amperage but low voltage.

For every 1mm of prod separation, 4 to 5 amperes of current will be required or 100 to 125 amps per inch (BS 6072)

Not recommended
### Advantages/Disadvantages

#### Encircling Coils

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant and uniform magnetic flux over the full area of inspection</td>
<td>Time taken to deploy and rig</td>
</tr>
<tr>
<td>Field strength can be varied by number of coil turns</td>
<td>Weight of subsea transformer</td>
</tr>
<tr>
<td>In most cases only requires 1 diver</td>
<td></td>
</tr>
<tr>
<td>Area is 100% inspected</td>
<td></td>
</tr>
<tr>
<td>Demagnetisation can be carried out</td>
<td></td>
</tr>
<tr>
<td>Able to carryout MPI photography whilst weld is magnetised</td>
<td></td>
</tr>
</tbody>
</table>

#### Parallel Conductor (Kettle Element)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant and uniform magnetic flux over the full area of inspection</td>
<td>Time taken to deploy and rig</td>
</tr>
<tr>
<td>Field strength can be varied by number of coil turns</td>
<td>Weight of subsea transformer</td>
</tr>
<tr>
<td>In most cases only requires 1 diver</td>
<td>Time consuming to set up</td>
</tr>
<tr>
<td>Area is 100% inspected</td>
<td></td>
</tr>
<tr>
<td>Demagnetisation can be carried out</td>
<td></td>
</tr>
<tr>
<td>Able to carryout MPI photography whilst weld a is magnetised</td>
<td></td>
</tr>
</tbody>
</table>

#### Electromagnet or Yoke

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse defects will be revealed</td>
<td>Only the area bound by the poles can be inspected</td>
</tr>
<tr>
<td>AC or DC can be used</td>
<td>There is a need for a power supply</td>
</tr>
<tr>
<td>Can be run directly from a mains power, no heavy transformer required</td>
<td>Poles MUST have good area contact to ensure a good transfer of magnetic flux to the material</td>
</tr>
<tr>
<td>You have control of the field strength, so control the flux density in the material</td>
<td></td>
</tr>
<tr>
<td>The magnet/Yoke can be switched off, no requirement to pull it off the material</td>
<td></td>
</tr>
<tr>
<td>They are light weight</td>
<td></td>
</tr>
<tr>
<td>Can be used to demagnetise as long as AC power is used</td>
<td></td>
</tr>
</tbody>
</table>

- An AC electromagnet lifting power should not be less than 4.5 Kg
- A DC electromagnet lifting power should not be less than 18 Kg

**NOTE:** It should be remembered that the use of mains power is both an advantage and a disadvantage, and this will depend on the circumstances at a job site. For example, it an advantage not to have to carry around a heavy transformer, but only if there is no risk of electrocution!!
Permanent Magnets

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple and easy to use</td>
<td>Only the area bound by the poles can be inspected</td>
</tr>
<tr>
<td>Transverse defects will be revealed</td>
<td>Field strength varies</td>
</tr>
<tr>
<td></td>
<td>Tend to lose strength with age and storage. Min lifting power 18 Kg</td>
</tr>
<tr>
<td></td>
<td>Technique is time consuming</td>
</tr>
</tbody>
</table>

Prods

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low voltage (3 volts)</td>
<td>Arc burns</td>
</tr>
<tr>
<td>Easy to use</td>
<td>Copper contamination</td>
</tr>
<tr>
<td>Locates transverse &amp; longitudinal indications</td>
<td>Associated hardening cracking possible</td>
</tr>
<tr>
<td>AC or DC can be used</td>
<td>Danger of overheating equipment</td>
</tr>
<tr>
<td>Large objects and complex shapes can be inspected</td>
<td>Low voltage requires heavy transformer</td>
</tr>
<tr>
<td>Control of field strength</td>
<td></td>
</tr>
<tr>
<td><strong>Prod spacing should be limited 232mm for max. sensitivity</strong></td>
<td></td>
</tr>
</tbody>
</table>
Demagnetisation

Coils
Should residual magnetism be noted, demagnetisation can be carried out using the following method. Apply an alternating current magnetic field, to the inspection area, gradually reducing the current to zero.

Remember to check once again for residual magnetism.

Yoke
When using AC electromagnets, pass (strok ing action) the energised yoke over the area under inspection, then before lifting. This stroking action should always be in the same direction, before returning it to the next adjacent area.

Remember to check once again for residual magnetism.
Detecting Media (Inks) - (BSI 4069)

Having now created the right conditions to allow flux leakage, we now have to find a way to make the leakage visible. To achieve this we use either a powder containing very fine ferromagnetic particles, or now more commonly in underwater inspection, a suspension of the ferromagnetic particles.

The particles used are fine ferrous oxides, these are used in preference to iron fillings as they are not only much lighter, but will not settle out of the suspension so quickly. When the particles are applied to the surface of a magnetised test piece they will be attracted to the areas of flux leakage (the consequential poles) in such large quantities that the defect location becomes visible.

The specific mixing instructions for each brand of ink will apply. However past experience indicates that instructions are rarely supplied.

When reporting MPI indications, indications must always be quoted as ‘crack like indications’ and not cracks, as you cannot actually see the cracks. They are not proven to exist until there is a destructive test carried out or the component fails.

Ink Properties

It is stated within BS 4069, that all inks must be:

- Non-toxic.
- Free of contaminates.
- Will not cause discomfort to users.
- Will not corrode the test piece or material.

Plus all inks should possess the following:

- Contain particles with fine grain so reducing gravitational effects, however it is possible that the grains can be too fine, and this will not allow proper dispersion in the ink, as a result they will coagulate.
- Particles should have be of an elongated shape, as this will aid the polarisation of the particle.
- High permeability is essential as the particle must be easily magnetised.
- Low retentivity is also necessary, as this will allow easy removal of particles after testing or between moves.
- Inks must have good contrast against the background, as the defect can only be located if the indication can be easily seen.
Ink Colours

Although red, black and fluorescent coloured inks are available, the most commonly used is fluorescent, as this is more sensitive than the others. Fluorescent ink is made, by coating the particles with a fluorescent salt that will fluoresce under ultra violet light conditions. This increases sensitivity dramatically, providing the lighting conditions are correct, as the indications become minute sources of visible light.

Testing MPI ink

- Prior to making up and testing follow these.
- Check for British Standards number on container.
- Check batch number and record.
- Mix ink powder/liquid as per manufacturers instructions.

Powders

- 45ml (vol) to 10 ltrs of water.
- Add a ‘wetting agent’, no more than 10% by volume, this to aid, easy mix.

Liquids (Ardrox 8560)

- 0.5ltrs of Ardrox 8560 concentrate to 9.5ltrs of water.

NOTE: An easy way to remove the coagulate solution in the bottom of the plastic Ardrox bottles, is to partially fill with warm water, replace top and shake. Remove top, taking care as the warm water may have caused a slightly higher internal pressure, then empty contents into your mixing bucket.

On completion of mixing both powders and liquids:

- Agitate for at least 5 minutes.
- Pour 100ml into a settlement flask (Sutherland Flask).
- Allow to settle for 60 minutes.
- Read of and record the volume from the bottom of the flask.
- The solid content should be between 0.1 to 0.3% volume.
- Should the solids content be greater, dilute mix and test another 100ml using the same procedure as above.
Recommended Ink Concentrates

Fluorescent
There should be between 0.1% and 0.3% by volume of ferromagnetic particles, and no more than 10% by weight of other solids (6-24 grammes per litre).

Daylight
These should have a concentrate of between 1.25% to 3.5% by volume of ferromagnetic particles, and no more than 10% by weight of other solids.

Carrier Fluid
This can be either water or paraffin, in underwater applications it will be water, and should carry no more that 10% by weight of soluble additives such as ‘wetting agents’.

<table>
<thead>
<tr>
<th>Type of MPI</th>
<th>Ink Type</th>
<th>Max Light Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight</td>
<td>Ardrox8560</td>
<td>120 Lux</td>
</tr>
<tr>
<td></td>
<td>MG FPX24</td>
<td>70 Lux</td>
</tr>
<tr>
<td></td>
<td>MG 414</td>
<td>40 Lux</td>
</tr>
<tr>
<td>Night Time (Dark)</td>
<td>Ardrox 8560</td>
<td>10 Lux</td>
</tr>
</tbody>
</table>

Lighting (BS 4489)
The level of light when using daylight inks should be at least 500 lux of white light, this level should be attained using a defused light source, (not a spot light) if possible. To give some idea of what this light level is, an 80-watt fluorescent tube at a distance of 1m gives 500lux.

When using fluorescent ink, the level of ultra violet light (black light) should be at least 800 $\mu$W/cm$^2$ (micro Watts per square centimetre) or possibly 50 lux depending on the standard used. In addition the inspection site must be dark, otherwise there will not be sufficient contrast, so ambient light at the job site should not exceed 10 lux.
**Flux Density**

This is defined as the number of flux lines emerging per unit area from a test piece. The unit used is called TESLA, 1 tesla is equal to 10,000 lines of flux per square centimetre. The minimum flux density required for MPI is 0.72 tesla or 7,200 lines per square centimetre. It is this density of lines that enables MPI to locate fine discontinuities.

**Flux Indicators**

As it is not possible to measure accurate field strength within a material, flux indicators are used to confirm that an applied field strength is adequate. Although there are a variety of flux indicators on the market, only two are approved for underwater applications.

The first is the Berthold Penetrameter, and of course, by far the easiest to use, the Burmah-Strip.

**Berthold Penetrameter**

This is flux indicator with an adjustable sensitivity. The flux indicator is positioned on a flat place centrally located on top of the penetrameter, the amount of flux required to give an indication can be altered by unscrewing the plate from the base. So making it more or less sensitive as the case may be.

The shape of the base draws the flux lines out of the material and past the graticules, these are small man made defects, which then give a flux leakage. An advantage to this kind of indicator is that regardless of angle of flux lines approach, provided there is enough flux density, there will always be an indication as there are two graticules at right angles to one another.
Burmah-Strip
The most commonly used flux indicator for use with magnetic particle inspection is a Brass Burmah-Castrol strip type 1.
Each strip comprises of two layers of brass, sandwich between, is a layer of soft iron, within this iron three 42mm parallel slits have been machined, and spaced evenly apart.
To simulate a defect, the strip is placed across the direction of magnetic flux, ink (magnetic) is applied, and observed with the illumination of an ultra violet light.
It is only when flux lines at a density of 0.72 tesla/30 Oersteds (2400 amp/metre) or more, cross this strip at between 45° and 90° and when a detecting media has been applied, that we see an indication of the location of the slits within a strip
It must be pointed out that Silver Burmah-Castrol strips do exist, these were primarily designed for the aerospace industry and are not acceptable for underwater MPI.

Post Dive
- Rinse each Burmah-Castrol strip off with fresh water, so as to remove any retained magnetic particles.
- Check for kinks, buckling of deformities, as these can impair the planar contact properties.
- Confirm no residual magnetism on Burmah-Castrol strip
Ultra Violet Light

Beware, ultra violet light is dangerous, it can cause amongst other things, cancers and cataracts. The safest wavelength is UV/A that has a wavelength of 360 nano metres, and this is the one used in underwater inspection.

All of the other more harmful wavelengths are filtered out using a filter on the front of the lamp called a ‘Woods Filter’. Even so, it is not advisable to look into a black light or shine it in another persons eyes, as this is not only very unpleasant, but can cause damage.

The ultra violet light is normally produced by means of a mercury vapour discharge bulb, which means that a spark is made to jump between the two terminals and through the mercury vapour within the bulb. This results in an ultra violet light and purple coloured visible light, however the bulb will not always produce an ultra violet light as it tends to have a limited life span.

This makes testing of a black light essential in order to ensure the production of ultra violet is of sufficient intensity. By looking into the is not only dangerous, but ineffective as the purple glow does not mean that there is any ultra violet light being produced, and so the following procedure must be carried out, to prove the production of ultra violet.

Procedure for testing an Ultra Violet Light

- Switch on and allow the lamp to warm up for 15 minutes.
- During this period the lamp must not be left switched on for more than 5 minutes in air, as the heat generated will cause damage to the seals.
- Always ensure the lamp is cooled during this 15 minute warm up and then is allowed to cool prior to emersion afterwards.
- Shine the ultra violet light into a photometer (black light meter) from a viewing distance, approx 400mm.
- Read meter and record the results, these should be at least 800 micro watts (µW/cm²) per square centimetre or 50 lux depending on the standard used.

The above can be checked by using a photometer, and this should be carried out at least once a month or more often if in doubt as to the lamps ultra violet output.
## Defect Types

### Cracks

<table>
<thead>
<tr>
<th>Crack Type</th>
<th>Description</th>
<th>Location Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>Parallel to the weld axis</td>
<td>• Weld Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Weld Junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Parent Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HAZ</td>
</tr>
<tr>
<td>Transverse</td>
<td>Transverse to the weld axis</td>
<td>• Weld Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Parent Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HAZ</td>
</tr>
<tr>
<td>Radiating</td>
<td>Radiating from a common point called ‘STAR’ cracking</td>
<td>• Weld Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HAZ</td>
</tr>
<tr>
<td>Crater</td>
<td>May be either transverse, longitudinal or radiating</td>
<td>• End of a Crater</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• End of Bad pass</td>
</tr>
<tr>
<td>Intermittent</td>
<td>May be either transverse, longitudinal or radiating</td>
<td>• Weld Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Parent Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HAZ</td>
</tr>
<tr>
<td>Branching</td>
<td>A group of cracks originating from a common crack</td>
<td>• Weld Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Parent Metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• HAZ</td>
</tr>
</tbody>
</table>
Cavities
A cavity can occur as become trapped, in voids, pores or packets during solidification of molten metals. These defects are generally repaired during construction phases.
It should be noted that, porosity (essentially a group of gas pores, spherical in shape) is not mistakenly reported as corrosion pitting.

<table>
<thead>
<tr>
<th>Cavity Type</th>
<th>Description</th>
<th>Causes</th>
</tr>
</thead>
</table>
| Blowhole    | A large cavity in the weld, generally 1.5mm in diameter. | • Moisture  
• Contamination on filler or parent metal |
| Wormhole    | Tubular or elongated cavity, form by entrapped gasses during solidification of molten metals | • Gas contamination  
• Crevices formed by joint geometry |
| Gas Pores   | A small cavity in the weld, generally less than 1.5mm in diameter. | • Entrapped gasses during solidification of molten metals |

Porosity
A group of gas pores distributed in a substantially uniformed manner throughout a weld.

<table>
<thead>
<tr>
<th>Porosity Type</th>
<th>Description</th>
<th>Causes</th>
</tr>
</thead>
</table>
| Uniform       | Distributed in an even manner throughout the weld | • Damp fluxes Moisture.  
• Air entrainment in gas shield  
Contamination on filler or parent metal.  
• Hydrocarbon contamination a parent metal/filler. |
| Restart       | Confined to a small area of the weld, normally occurs at the start of a weld run, during either manual or automatic welding | • Unstable arc conditions.  
• Poor manipulative technique. |
| Surface       | Surface breaking gas pores | • Contamination from grease.  
• Dampness.  
• Atmosphere entrainment.  
• Occasionally, excessive sulphur in consumable or parent metal. |
| Crater        | A depression caused by shrinkage at the end of a run, where the sauce of heat was removed. | • Incorrect manipulative technique.  
• Current decay to allow for crater shrinkage. |

Inclusions
Defined as a foreign matter entrapped within the weld material during welding. This type of defect is usually of irregular shape than that of a gas pore.
However, the principle of non-metallic inclusions include, tungsten from TIG electrodes and copper from the MIG contact tube or nozzle. This can be caused by unclean parent metal/filler, slag not removed from a proceeding run, or as a result of poor manipulative techniques, loss of slag control.
Lack of Fusion

This occurs due to a lack of fusion, between weld metal and parent metals, more often than not, it takes place in the side wall of weld multi-run, or at the root of a joint. However, lack of penetration is a more severe, lack of root fusion. This is when the weld metal fails to extend into the root of a joint at all. Both defects are usually due to faulty technique, (heat input to low or rapid travel with the electrode) poor preparation of a joint in the case of root fusion.

Although these are not visible defects in a weld, overlap is sometimes called cold lap, as this is visible when excessive weld metal in the cap fails to fuse with that of the parent metal.

<table>
<thead>
<tr>
<th>Fusion Type</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Fusion</td>
<td>Failure of Union in —</td>
<td>• Side wall between root runs.</td>
</tr>
<tr>
<td></td>
<td>• Weld metal to weld metal.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Parent metal to weld metal.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Parent metal to parent metal.</td>
<td></td>
</tr>
<tr>
<td>Lack of Penetration</td>
<td>Failure of weld metal to extend into the root</td>
<td>• Root joint</td>
</tr>
</tbody>
</table>

Imperfect Shapes

These defects defined as imperfect shape of the external surfaces of the weld or defective joint geometry.

The external surface of a weld, includes the root as well as the weld face or cap. Undercut and overlap are more often than not, detected underwater, although the more serious cases are normally repaired during the construction phase, onshore.

A word of caution, in poor water visibility, the diver/ROV should be careful not to confuse slag inclusion in the weld toe, with the more serious undercut defect.
## Imperfect Shapes (Cont.)

<table>
<thead>
<tr>
<th>Shape Type</th>
<th>Description</th>
<th>Causes</th>
</tr>
</thead>
</table>
| Undercut   | A groove or hollow melted into the parent metal surface or fusion face, at the toe of a weld, then left unfilled by weld material. | • Poor welding technique.  
• Travel speed to slow, excessive weaving.  
• Welding current to high. |
| Overlap    | Imperfection in the toe or root of a weld, caused by, metal flowing onto the surface of the parent metal without fusing to it. | • Poor welding technique.  
• Ineffectual heat input at the toes (current and voltage to low). |

## Misc. Defects

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stray Arc</td>
<td>Accidental arc strike away from the weld.</td>
<td>• Parent Metal</td>
</tr>
<tr>
<td>Excessive Dressing</td>
<td>Removal of weld metal below surface of parent metal, or known as under flushing.</td>
<td>• Weld Face</td>
</tr>
</tbody>
</table>
| Grinding Marks | Localised damage caused by incorrect grinding.                                | • Weld Face  
• Parent Metal                  |
| Chipping Marks | Indentations caused by crude use of a chipping hammer or chisel.             | • Weld Face  
• Parent Metal                  |
| Spatter       | Globules of weld material expelled during welding, and adhering to the metal surface. Can cause surface pitting. | • Weld Face  
• Parent Metal                  |
| Torn          | A surface abnormality, due to, a temporary attachment break off.              | • Parent Metal                |
| Misalignment  | Parallel misalignment of surface planes.                                     |                               |
| Poor Restart  | An irregularity at a weld start.                                             | • Weld Face                  |
| Burn Through  | Collapsed section of weld run, due to excessive penetration.                 | • Weld Face                  |
| Unequal Leg Length | Asymmetrical fillet weld, variation of leg length.                         | • Weld Face                  |
| Incomplete Filled Groove | Either longitudinal or continuous channel, due to, insufficient weld metal deposit or a collapse due to gravity. | • Weld Face                  |
Corrosion

Introduction

A simple explanation to cover this topic would be, the deterioration of a metal caused by an electrochemical reaction within its environment. However as in life, the answer is not a simple one, and I will endeavour try to simplify this subject.

When corrosion is present within seawater the electrochemical process starts, an electrical current flows during the chemical reaction (the source of voltage within the corrosion process, is the energy stored in a metal during the refining process. This due to different metals requiring differing amounts of energy for refining, as a result these metals then tend to corrode at contrasting speeds.

Basic Chemistry of Corrosion

By having corrosion in contact with sea water an electrochemical process is present. To allow a current to flow, there must be a voltage, this is normally referred to as, a potential difference. A complete electrical circuit.

Voltage Source

The corrosion rate of a metal, is governed by the energy stored within during the refining stage. As a result they have different tendencies to corrode.

Corrosion Protection

Generally oil production platforms, pipelines, salms and ships hulls are constructed from ferritic steels. When placed in an electrolyte (seawater) it will start to corrode.

It will corrode because of a chemical reaction with the electrolyte and because and because portions of the steel are more electronegative than others.

This imbalance in potential, combined with the chemical reaction generates a combined electrochemical reaction that results in depletion of the anodic areas.

The electrons flowing into the cathode from the anode have the effect of saturating this section with negative charged electrons. This prevents the iron atoms in the cathode from splitting into ions and electrons, therefore no depletion takes place. The purpose of cathodic protection is to prevent any depletion of the steel taking place.
Types of Corrosion Protection (Offshore Structures)

There are two means of supplying the required cathodic protection current, and although work towards the same ends are different in operation. below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Galvanic Anodes</strong> (Sacrificial)</td>
<td>• These are attached directly onto the structure to be protected.</td>
</tr>
<tr>
<td><strong>Impressed Current Anodes</strong></td>
<td>• These are relatively inert and require an external D.C. power source to force the current to flow.</td>
</tr>
</tbody>
</table>

**Sacrificial Anodes**

Because anode materials have a greater electronegative potential, it will dissolve into a solution at a greater rate than that of iron. As a result the electrons generated by this reaction are free to migrate through the metal towards the iron that, as a result becomes increasingly negative.

Ions are conducted away from the anode material by the electrolyte, allowing the reaction time to continue.

However by raising the electronegative potential of the steel to a point where it no longer corrodes, the anode sacrifices itself into solution.

The two materials commonly used for sacrificial anodes are, aluminium and zinc. Although magnesium is occasionally used, it has a relatively short life span in seawater. Alloy anodes are now the most commonly used, as these are more economical in terms of current output and are lighter than zinc. In turn these reduce the weight loading on the structure.

Anode distribution is dedicated by current distribution requirements, as a result there are three critical areas, which require a greater number of anodes to achieve an even current. These are nodes, conductor guide frames and the splash zone.

**Typical Inspection**

- Is the anode active ??
- What is the extent of wastage ??
Impressed Current

The impressed current system is based on the similar principle as that of the sacrificial anode cathodic protection system. In that it relies upon establishing the structure as a cathode in any corrosion reaction.

As with the sacrificial anode cathodic protection system, it is also accomplished by introducing a greater current and in opposition to the discharging current of corroding steel.

Although a current is applied from an external source, the impressed current electrodes are still composed of metals with a very low corrosive rate, these being titanium/niobium and lead/silver alloys.

There are two basic impressed current distribution systems employed offshore. The first employee’s large anodes (normally between 6 and 12 anodes) placed concentrically around the structure. One of these such anodes, with an output of 500 amps could protect the same area, which would normally require up to 100 sacrificial anodes. The second system uses a series of smaller anodes within the structure, these being at pre selected points to ensure an even current distribution. An operating power of up to 50 amps is typical for this type of impressed current anode.

Typical Inspection

Typical Inspection

• The presence and type of any deposits ??
• The presence of any corrosion, and the extent ??
• The integrity of the electrical continuity, supply cables and cable to anode connections
• Type of marine growth cover, thickness and percentage ??
• Localised CP readings and photographs (ROV)
Advantages/Disadvantages of Sacrificial Anodes

<table>
<thead>
<tr>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No external power supply required</td>
</tr>
<tr>
<td>• Simple installation</td>
</tr>
<tr>
<td>• No danger of over protection (possible hydrogen embrittlement)</td>
</tr>
<tr>
<td>• Once installed, no running costs</td>
</tr>
<tr>
<td>• Active from time submerged</td>
</tr>
<tr>
<td>• Low maintenance costs</td>
</tr>
<tr>
<td>• Very reliable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Output decreases with time</td>
</tr>
<tr>
<td>• Initial cost is high due to high quantities of anodes required</td>
</tr>
<tr>
<td>• Weight loading</td>
</tr>
</tbody>
</table>

Advantages/Disadvantages of Impressed Current

<table>
<thead>
<tr>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fewer anodes required</td>
</tr>
<tr>
<td>• Current output can be varied to compensate for changes such as, coating</td>
</tr>
<tr>
<td>loss and anode wastage of the hybrid system</td>
</tr>
<tr>
<td>• Reduced weight loading</td>
</tr>
<tr>
<td>• Operational factors can be monitored remotely</td>
</tr>
<tr>
<td>• Less of an expense for a large structure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Subject to power supply failure, resulting in loss of protection</td>
</tr>
<tr>
<td>• Continuous monitoring and regular maintenance required</td>
</tr>
<tr>
<td>• Risk of over protection, which could possibly cause hydrogen embrittle</td>
</tr>
<tr>
<td>• Cabling and conduiting are susceptible to damage in extreme weather</td>
</tr>
<tr>
<td>• A wrong power source connection would result in serious corrosion to</td>
</tr>
<tr>
<td>the structure itself</td>
</tr>
<tr>
<td>• Hazardous to divers</td>
</tr>
<tr>
<td>• After installation, structure can be unprotected until such time as</td>
</tr>
<tr>
<td>the system is operational</td>
</tr>
</tbody>
</table>
Forms of Corrosion

Galvanic
This when two dissimilar metals are in electrical contact within an electrolyte. When this occurs, the most electronegative (active) metal will become the anode, and will corrode to a greater degree than if exposed alone.

Crevice
Crevices promote the formation of concentrated cells. This is especially serious in oxygenated systems, where the oxygen in the crevice can be consumed more rapidly than fresh oxygen can diffuse into the crevice. As a result this causes the pH in the crevice to decrease, resulting in more acidic environment, which in turn accelerates corrosion.

Intergranular
As the name implies, intergranular corrosion is preferential attack of a metals grain boundaries, although this type of corrosion has often been confused with stress corrosion cracking. In most cases, cracking results from a metallurgical structure that causes the grain boundaries to be more susceptible to attack than the grains themselves. Proper heat treatment generally can eliminate the grain boundary constituents that render the alloy resistant to intergranular attack.

Erosion
Most metals owe their corrosion resistance to the formation and maintenance of a protective corrosion scale, removal of this scale at local areas can lead to accelerated attack. Turbulence or a high velocity flow, will frequently erode away the high protective scale and expose fresh metal to corrode. This combination of erosion of the scale and corrosion of the underlying metal is termed erosion corrosion. A phenomena similar to erosion corrosion, but even more localised is known as "impingement". This occurs when a stream impinges upon a metals surface and breaks down protective films at very small areas. This resulting attack is in the form of pits that are characteristically elongated and undercut on the down stream end. Impingement often results from turbulence surrounding small particles adhering to a metals surface.

Fretting
This is very similar to that of erosion, in that the wall thickness is reduced, but from the outside. The wearing away of metal takes place when two surfaces rub against each other. Once again corrosion is accelerated when any corrosion film formed is worn away exposing fresh metal to seawater. A common location for fretting corrosion is where debris is in contact with a structure, or areas of relative movement within a clamp/guide.

Biological
Underneath areas of heavy marine growth fouling, oxygen concentration may be produced (especially under shell fish) causing oxygen concentration cell reactions. Another cause can be attributed when marine organisms die, bacteria is produced which can result in direct chemical attack on metal or concrete. The presence of black deposits may indicate biological corrosion.

Corrosion Fatigue
The life of a metal is substantially reduced when the metal is cyclically stressed in a corrosive environment, the simultaneous occurrence of cyclic stress and corrosion.

Stress Corrosion Cracking
When an interaction between chemical and mechanical forces, result in a failure that otherwise would not have occurred. It is caused by the “synergistic” action of a corrosive, and applied tensile stress, the effect of the two is, greater than the sum of the single effects. In the absence of stress, the particular alloy would not corrode, and in the absence of the corrodent, the alloy could easily support the stress. The result of the combined effect is a brittle failure of a normally ductile metal.
General & Pitting
Waiting to be completed

Methods of Corrosion Protection
Waiting to be completed

Polarisation Effects on both Sacrificial Anodes & Impressed Current
Waiting to be completed

Corrosion Monitoring
Waiting to be completed
Reference Half Cell

It is not possible to take a direct measurement of the corrosion rate for localised areas of a steel surface. However the potential or tendency to corrode can be obtained using a reference half-cell.

When two dissimilar metals are connected and bridged by an electrolyte, a corrosion cell is formed, making an electrical circuit complete. An electrical potential is generated and a potential voltmeter placed in the circuit will measure the potential between the anode and cathode of the cell. This will provide a measurement of the tendency to corrode.

For underwater inspection purposes, the steel acts as one half of the cell, and the other half is the reference half-cell.

Normally the silver/silver chloride half-cell is used for underwater inspection. The silver/silver chloride half-cell consists of silver immersed in a solution of silver chloride, which is in contact with seawater via a porous plug.

During inspection a lead or point of contact is earthed to the structure. If the steel is corroding, ferrous (+ve) ions will be in solution leaving behind electrons in the steel.

When the half-cell is placed into this area of positive ions, the distribution of ions inside the porous pot are polarised, in such a way that, silver ions migrate to the silver rod in the middle, and chloride ions migrate towards the porous membrane. This creates an overall positive charge in the immediate vicinity of the silver rod.

Since the half-cell is connected the structure a galvanic cell is again set up, the silver rod becomes the cathode. The area of corroding steel is the anode. The cathode is also the negative pole, and the anode is the positive pole, a voltmeter is connected in parallel to measure the potential difference between them. The potential of the steel surface with respect to the half-cell is always quoted as a negative value.

The following are the expected potential ranges in seawater of the most commonly used metals in offshore structures.

**Expected Range Potentials**

The following are potentials that expected in seawater:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Measured with reference to a silver/silver chloride half-cell in mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprotected Iron &amp; Steel</td>
<td>• -500 to -650mV</td>
</tr>
<tr>
<td>Cathodically protected Iron &amp; Steel</td>
<td>• -800 to -900mV</td>
</tr>
<tr>
<td>Zinc</td>
<td>• -1000 to 1050mV</td>
</tr>
</tbody>
</table>
Calibrating a Half-Cell using Saturated Calomel Cells

Before an Ag/AgCl half-cell can be used for inspection, it MUST be calibrated using a Saturated Calomel Cell (SCE). These must also have been checked prior to use. Information on testing and selecting an SCE can be found in section?

Soak a half-cell or Bathycorrometer in a plastic bucket of, fresh clean seawater for a minimum of 1 hour before attempting to calibrate. NEVER USE A METAL BUCKET.

- Connect the Ag/AgCl half-cell to the positive terminal of a high impedance voltmeter, and then connect the tested calomel cell to the negative terminal.
- Immerse half-cell and the tip of the calomel cell in seawater for 1 hour.
- Read and record the potential difference between the two half-cells from the voltmeter, the acceptance range is between 0mV and -10mV.
- If the reading is outside the specific range, the Ag/AgCl half-cell must be replaced, and the calibration procedure repeated. If the readings still remain unacceptable, replace the calomel cell.
- All calibration readings must be recorded on CP Calibration log sheets.

Contact CP

One type of hand held corrosion meter which works on a similar principle to that of a half cell, is the Bathycorrometer. Instead of using and earth lead and remote multimeter, there is a probe, which is attached to the instrument. It is this probe that must come into contact with a steel surface. Within the casing is a built in digital voltmeter, and instead of a porous pot, there is a diaphragm.

The Bathycorrometer contains within it’s housing, a silver/silver chloride half-cell with both a silver rod & silver (+) and chloride (-) ions in a solution.

When the Bathycorrometer probe touches a steel surface, a circuit is set up, as a result, the ferrous ions outside the ‘Bathy’ alter the distribution of the ions inside the unit, as with a half-cell. The relative potential of the steel surface, with regard to the half-cell is measured by the digital voltmeter; the voltage can normally be read by the diver/inspector.
Calibrating a Bathy using Calomel Cells

Before a Bathycorrometer can be used for inspection, it MUST be calibrated using a Saturated Calomel Cell (SCE). These must also have been checked prior to use. Information on testing and selecting an SCE can be found in section?

Soak a half-cell or Bathycorrometer in a plastic bucket of, fresh clean seawater for a minimum of 1 hour before attempting to calibrate. NEVER USE A METAL BUCKET.

- Connect the calomel cell onto the tip of the Bathycorrometer. There are custom-built calomel cells available, which screw on to the Bathycorrometer tip.
- Immerse Bathycorrometer and the tip of the calomel cell in seawater for 1 hour.
- Read and record the potential difference from the digital readout. Acceptance range is between 0mV and -10mV.
- If the reading is outside the specific range, the Bathycorrometer must be replaced, and the calibration procedure repeated. If the readings still remain unacceptable, replace the calomel cell.
- All calibration readings must be recorded on CP Calibration log sheets.

Expected Range Potentials
The following are potentials that are expected in seawater:

<table>
<thead>
<tr>
<th>Material</th>
<th>Measured with reference to a silver/silver chloride half-cell in mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Calomel Electrode</td>
<td>• 0 to –10mV</td>
</tr>
<tr>
<td>Unprotected Iron &amp; Steel</td>
<td>• -500 to –650mV</td>
</tr>
<tr>
<td>Zinc</td>
<td>• -1000 to 1050mV</td>
</tr>
</tbody>
</table>

Maintenance
Rinse with fresh water after use and dry before re-charging, however the unit can still be charged while soaking in fresh water as long as the plug connection is above the water level and dry. To avoid an algae build up within the semi-porous cell, soak in fresh water. The advantage is that the unit can be transferred to seawater for about 5 mins before calibrating.
Calibrating Calomel Cells

Before Saturated Calomel Cells (SCE) can be used to calibrate Ag/AgCl half cells, they too must be also be checked, the following procedure explains how this is achieved.

- Mark the three cells A, B and C.
- Soak all three cells in fresh clean seawater for at least 1 hour prior to use.
- Connect ‘A’ to the positive side terminal on a voltmeter, and ‘B’ to the negative terminal.
- The tips of each cell should be submerged in a plastic container of fresh clean seawater. **NOT A METAL BUCKET**.
- Read off the potential reading between cells ‘A’ & ‘B’.
- Replace ‘B’ with ‘C’, and read off the potential between ‘A’ & ‘C’.
- Replace ‘A’ with ‘B’, and again read off the potential between ‘B’ & ‘C’.

This following criteria is recommended to select the calibrated cell.

1. If all readings are between –2mV & +2mV, any cell may be used.
2. If one reading is out of the range –2mV & +2mV, the cell not included in this reading should be used.
3. If two or more readings are out of range, the cells must be replaced with new ones and the procedure repeated.

Electrode Potentials
Waiting to be completed

Electrochemical Series
Waiting to be completed

Cathode
Waiting to be completed

Electrolyte
Waiting to be completed

Proximity
Waiting to be completed
Recording Methods

Introduction
As we are all aware no two inspection divers or ROV data recorders can be relied upon to report the same defect in the same magnitude. Underwater measurements are often prone to error and low standards of accuracy. Furthermore, the eye cannot produce a permanent record and it these problems that highlight a need for an effective and cost efficient recording methods.

At the moment there are two methods of permanent recording, still photography and video, however with the advent of modern technology there is now a third, the digital camera. It is now possible to take a digital image from a divers head or an ROV camera that is linked through a computer. The main advantage over still photography is that the results can be seen instantly.

By obtaining a permanent recording of findings it allows both clients and topside engineers to view the inspection results or anomaly. It can also be used as an aid, to monitor future changes. It also verifies that the inspection was carried out, should ambiguities arise after completion of a contract.

Still Photography
As we all know it is the camera that is used to reproduce an image by focusing a controlled light source onto a photosensitive surface (film). The exposure of light onto the film surface is controlled by shutter speeds, aperture control and film speed. The camera lens determines focus and view angle.

Shutter Speed
It is this function that controls the amount of time the film is exposed to light. Shutter speeds are shown in seconds on the camera, for example speeds range from 1 second up to 1/1000 of a second, each position on the shutter speed admits two time the light. E.g. 1/250s admits twice the light of a shutter speed of 1/500s.
Aperture Control

This regulates the intensity of light onto the film by ‘opening up’ and ‘closing down’ of the lens iris. Typical aperture settings are marked on the camera lens as – f/1.8, f/2, f/2.8, f/4, f/5.6, f/11, f/16 and f/22. It is these ‘f’ numbers that represent the simple relationship between focal length and diameter of the aperture.

In simple terms, f/4.5 means that the focal length of the lens is 4.5 times its effective diameter, simple. !

As with the shutter speed, each aperture setting admits twice the light of the previous. E.g., f/8 admits twice the light of f/16.

Remember the smaller the ‘f’ stop number, equals a larger iris opening, this relates to, the smaller the f/ number, the larger the lens diameter for a given focal length and the greater the light gathering power or ‘speed’ of the lens.

A direct relationship exists between the shutter speed and aperture settings, e.g. the required time of exposure increases with f/number. Here are some examples that will yield the same exposure.

<table>
<thead>
<tr>
<th>Shutter Speed</th>
<th>F Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/250s</td>
<td>F/8</td>
</tr>
<tr>
<td>1/125s</td>
<td>F/11</td>
</tr>
<tr>
<td>1/60s</td>
<td>F/16</td>
</tr>
<tr>
<td>1/30s</td>
<td>F/22</td>
</tr>
</tbody>
</table>

Film Speed

A numerical number is used to represent film sensitivity to light, (ASA designation). This means that a more sensitive (faster) film requires less light for an exposure. If a film has a high ASA number e.g. 400 the image produced will have a grainy, on the other had, if the film speed is slow, e.g. 64 the image produced will be sharper. However the slower the film the more light required on exposure. Either opening up/closing down the aperture or reducing/increasing the shutter speeds achieves this. Typical ASA film values are 25, 50, 64, 200, 200, 400 and 1000. ASA 100 film is 1 f/ stop slower than ASA 200, and 1 f stops faster than ASA 50 film. The combinations on the following page yield the same exposure; exposure is determined by light intensity, which in turn is controlled by the three previously factors, shutter speed, aperture control and film speed.

<table>
<thead>
<tr>
<th>Shutter Speed</th>
<th>F Stop</th>
<th>Film Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/250s</td>
<td>F/8</td>
<td>ASA 400</td>
</tr>
<tr>
<td>1/125s</td>
<td>F/11</td>
<td>ASA 200</td>
</tr>
<tr>
<td>1/60s</td>
<td>F/16</td>
<td>ASA 100</td>
</tr>
<tr>
<td>1/30s</td>
<td>F/22</td>
<td>ASA 50</td>
</tr>
</tbody>
</table>

Focus

This is defined as, the point where an optical image is clearly defined. It is the focal length of the lens that determines the angle of view, e.g. a short focal length will produce a wide angle of view, where as a long focal length will have the opposite effect and produce a narrow angle of view.

Depth of Field

This is the distance each side of the focus point in which subjects or objects continue to appear focused. Aperture openings and focal length of the lens achieve this. With smaller aperture openings (higher f/ stops, e.g. f/16 or f/22) and wide angle lenses, the result is a greater depth of field, or a longer range of focus.

C41

Waiting to be completed
Camera Types
Waiting to be completed

E6
Waiting to be completed

CCVC
Waiting to be completed

Digital Image Capture
Waiting to be completed
LIVING WITH ROV’s

Introduction

The ROV (Remotely Controlled Vehicle) has been with us the last 30 years, and used all over the world by differing organisations, to access underwater locations, that are not easily accessible by divers or by other means.

Over recent years however, the ROV has been required, to perform tasks normally carried out by divers. This mainly due to economical, and again in some cases, for safety considerations. Improvements in performance and reliability, has increased over the last few years 10 fold compared with that of the past.

Origins of the ROV

The Remotely Operated Vehicle has been in development since the early 1950’s, in 1959 with the Rebikoff and the ”Chien Plongeur “, to present day, with Perry Tritech.

The ROV was described by the early engineers, and users as, ‘a remotely controlled camera’, which provide a stable platform for a video, still camera and lighting Systems. These visual aids could be used for various inspection tasks. More importantly and a major advantage in using ROV’s was, that the ROV is expendable, compared to that of a diver.

It was the various navies around the world, that first started to use the ROV and it’s derivatives. As the economies of scales applied eventually the cost of this technology made it possible to apply this technology in commercial applications such as oil prospecting, oceanography and fisheries.

The prices of a basic ROV are as low as a few thousand pounds, these can be deployed and operated from a suitcase. This has even lead to the ROV becoming a recreational toy, used from the back of peoples sailing or motor Boats.
Frame/Chassis
The frame or chassis of an ROV provides a firm fixing location for necessary mechanical, electrical and propulsion components. These include special tooling such as, sonar, cameras, lighting, manipulators, and sampling equipment. ROV frames/chassis have been made from various differing materials, such as, plastic composites, mild steel and aluminium tubing. However in general materials used are chosen to give optimum strength, whilst reducing gross weight to a minimum, although weight can to be offset with buoyancy.

Not only does the ROV frame/chassis have to comply with HSE regulations regarding load and vertical lift strength capabilities. Typically in the UK North Sea, a load factor of three (3) is applied and used in the design and load testing of a frame/chassis.

There are no hard and fast rules on the size of an ROV frame/chassis, however, most design concepts tend to lean towards a compact design. This of course is dependent on the following criteria.

- Weight of the complete ROV unit in air
- Amount and type of the onboard equipment
- Size of the Sensors and Tooling
- Size of the Buoyancy
- Load bearing criteria of the frame

Buoyancy
Buoyancy is normally required by any ROV to offset both water weight of the whole ROV, and any additional ancillary equipment, fitted for a specific task. The preferred method of operating is to have the ROV in water weight as near to neutral as can be achieved. Although some ROV pilots prefer a slightly positive (heavy) ROV.

With the ROV buoyancy as near as possible neutral or close to, the ROV is able to optimise its manoeuvring capabilities and utilise it's available propulsion power in an efficient manner. The mass the propulsion system has to move, is only the static load, not an additional dynamic load imposed on the ROV by the equipment fitted to it.

A deciding factor as to what mode the ROV will operate in, depends basically on operational requirements at the time. As a rule of thumb, the smaller the ROV the less choice you have in preference, buoyancy also more or less determines how much real payload an ROV can carry.

Control Systems
This system controls the different functions of the ROV, from controlling the propulsion system to switching on a video camera.

From the fairly simple and primitive relay control systems of the past, today's ROV's now use powerful computers as its brains and a subsystem control interface. This control system has to manage the control input from the operator at the surface, and convert these into actions subsea.

The data required by the operator, to accurately determine the ROV in water position, is collected by sensors and subsequently transmitted back to the operator at the surface.

Over the last 10 to 15 years the computers utilised for these purposes, have been designer computers with highly sophisticated software programs and control sequences. Even now, 486 computers are viewed as 'old hat'. There has however been a shift back to simpler control systems recently, with the commercial advent of the PLC, Programmable Logic Computer.

This is used in numerous manufacturing processes, since it consists of easily assembled modular building blocks, of switches, analogue in / out puts and digital in / out puts.

What designers of the ROV control systems have tried to achieve has been to increase the reliability and serviceability of ROV equipment.
Propulsion Systems

Propulsion systems come in only a few different types, electrical, hydraulic and in rare cases, ducted jet propulsion.

Different types of propulsion have been developed over recent years, to suit not only the size of vehicle, but the type of work it is expected to be perform. In some cases the actual location of the work task, has dictated the type of propulsion used.

The main goal of all types of design for a propulsion system are, high thrust to physical size and power input ratio.

Development of each type, has been progressing slowly, mainly due to the inherent conservative attitude adopted by most ROV operators and technicians, the call word seems to be "let well alone if it works"

One main force in the change has been the desires of most operating companies and users of ROV's, to extend the operating window of the equipment. The theory behind this is, the more powerful the propulsion, the stronger the currents the ROV can operate in. This consequently can extend the working season and thereby increase revenue.

Another factor, has been to extend the reliability of the propulsion system and it's associated sub components, so that the catastrophic failure rate declines. During the early development of ROV's, it was general practice to replace and refit electric motor units after 50 and before 100 hours of in service operations. This not only increased the inventory of parts required offshore and the possibilities of errors by technicians reassembling the motors, but most of all represented a vast amount of dead money.

The propulsion system has, and always will be, a trade off between, what the ROV requires to perform a work task, and it's practical dimensions. Typically, as more power is required, the equipment becomes heavier, subsequently all parts of the ROV system grow exponentially bigger, and the requirement for more power yet again increases.

As a result, a majority of ROV's are restricted to a few work tasks only without major modifications.

The subject regarding the choice of propulsion systems is a very touchy subject within the ROV industry, as most have one or other opinions and will not budge from them.
Deployment Systems

There still appears to be some debate amongst ROV operators and a failure to agree as to what Certifying standards the Deployment Winch and Crane / A-Frame should be made to.

In the past, the approach of many ROV manufacturers was, that the ROV operators will manufacture their own custom made deployment system, however this is getting increasingly difficult since the certifying standards used are not always what the rule book states, decide on.

The AODC has limited guidelines, but these are not always up to date and since the deployment equipment is accepted on a contract to contract basis this can be very difficult to keep track of.

Although the different deployment methods used by different companies and manufacturers vary, there are a few common methods that have proved successful.

Live boating with soft Culver reinforced umbilical
Live boating operations with a larger ROV's, normally use an umbilical winch to connect the ROV with the Surface Control Unit. This winch unit is not normally capable of lifting the ROV out of the water. This is achieved by using a recovery line that has previously been attached to the ROV and umbilical and the actual lifting is done by using a ship based Lifting Crane. The lifting gear has to be certified as standard onshore lifting equipment.

The Umbilical can be as long as 10,000 feet or more common is for it to be around 1,500 feet.

Live boating with steel armoured umbilical
By using a steel armoured umbilical and a winch, the ROV can be lifted out and deployed into the water. This is achieved by using a large sheave wheel attached and suspended on the end of a ship based lifting crane, or alternately. the sheave wheel can be fitted to a lifting A-frame over the side or stern of the ship. Remember the lifting gear has to be certified as standard onshore lifting equipment.

The Umbilical can be as long as 5,000 feet, although 3,000 feet is the more common length.

Live boating with steel armoured umbilical and a Tether Management System
For live boating operations with a larger ROV’s using a Steel Armoured Umbilical, a winch is required to manage the ROV umbilical. By using a large sheave wheel fitted to a lifting A-frame over the side or stern of the ship. The winch unit is capable of lifting the ROV and TMS out of the water.
A tether management system can normally provide a soft Tether Cable with a length of up to 200 meters.

The tether management system (TMS) is fitted to the end of a steel armoured umbilical and can be described as an underwater winch for managing a soft tether cable.

The advantages of this method is that the ROV does not have to rely on it's own propulsion to get down to working depth or seabed. The TMS provides a base from which the ROV can move laterally out to the length of the fitted soft tether cable.

The lifting gear has to be certified as standard onshore lifting equipment.
Deployment Systems (Cont.)

Live boating with Steel armoured Umbilical and a Powered Tether Management System

Again this requires a winch to manage the ROV umbilical. By using a large sheave wheel fitted to a lifting A-frame over the side or stern of the ship. The winch unit is capable of lifting the ROV and TMS out of the water.

The Tether Management System can normally provide a soft Tether Cable with a length of up to 200 meters. In some operating locations, the currents experienced are very strong. To overcome this problem, a propulsion and control system can be fitted, to give the tether management system and ROV the facility to get closer to the work site.

The advantages of this method of operating the ROV is that the ROV does not have to rely on the it's own propulsion to get down to working depth or seabed. The TMS ROV provides a base from which the ROV can move laterally out to the length of the fitted soft tether cable.

The lifting gear has to be certified as standard onshore lifting equipment.

Tether Management Systems

The Tether Management System (TMS), is one of the better developments there has been, in deployment systems for ROV’s. The TMS is comparable to a garage, a safe haven and elevator for ROV deployment and recovery. One main function of a TMS is to, manage a soft tether cable (links for electrical power, sensors, these including video and telemetry), this cable allows the ROV to make excursions at depth, for a distance up to 200 meters from the it's TMS location.
ROV Crew
An ROV crew generally consists of a Supervisor, Pilot and a co-pilot and where required a manipulator operator. The crew is usually made up of personnel with differing technical backgrounds such as, electronics, electrical, mechanical and hydraulic. There is no definitive training available for budding ROV Crew, however, there are some ROV training schools around but these are not formally recognised as official training facilities by the ROV operations.

Training in the operation and maintenance of ROV’s is one of the most important and critical areas, for improvement in the performance of the ROV Crew. If the Crew has a good basic understanding of operation and maintenance of ROV’s, the actual operation at hand will be much smoother and trouble free. Unfortunately in general this is not a priority to the ROV operating companies at this present time.

The responsibilities of the different crew is as follows:

ROV Supervisor
In certain cases the ROV Supervisor discuss work details and requirements with the client or Co-ordinator, to ensure sure the ROV Crew know the job at hand. He also makes sure that the operational criteria and conditions are met for the deployment of the ROV such as wind, wave and currents.

It's the ROV Supervisor who is ultimately responsible for the safety of the ROV Crew and ROV equipment.

The following tasks, are expected to be performed by the ROV Supervisor:

- General ROV operational experience 4 Years or more
- Knowledge of the contractual requirements
- Assist in planning work operations
- Man management
- Complete and keep up to date, paperwork and maintenance logs
- Maintain spares and tools to an operational level
- Pilot the ROV
- Operate/Maintain sonar, manipulators and other special tooling
- Repair the ROV and the associated the equipment
- Be able to navigate and the ROV around the seabed and structures with no or very little through water visibility.

ROV Pilot / co-pilot
The pilot and co-pilot are expected to perform several different tasks such as the following:

- General ROV operational experience 1 Year or more
- Pilot the ROV
- Operate Sonar
- Operate Manipulators
- Operate other special tooling
- Repair the ROV and the associated the equipment
- Be able to navigate around the seabed and structures with no or very little through water visibility.

Piloting an ROV
Imagine playing with the latest space computer game, using the joystick to zap aliens, but the aliens are nothing more than fish and space is actually underwater like in the TV series Seaquest.

Piloting an ROV is a three dimensional experience where you can (fly) the ROV up / down, forward / Aft. and sideways. In general ROV’s are fairly responsive and move fairly fast underwater.
Unfortunately this is the main obstacle to a beginner to ROV piloting. An ROV seems to have a mind of its own and moves in this and that direction without the interference of the pilot. It does not help when the sea, currents and waves add to the scenario to make life even more difficult for the pilot.

Therefore to pilot an ROV is an acquired art, you have to have lots of practice (usually on the job) and many mistakes will be made. The most critical mistake that an ROV pilot can make is to get entangled or lose the ROV. This is quite a frequent occurrence and thanks to good Acoustic tracking devices and bright colouring of the ROV frame and buoyancy the ROV's are generally retrieved fairly soon after a loss.

However if the ROV becomes entangled or otherwise stuck on the seabed or underwater structures the ultimate disgrace is inevitable when you have to call for help from another Vessel with an ROV or even worse a Diver has to come and rescue you.

To pilot an ROV always looks easy when an experienced pilot fly the ROV but like driving a car you need practice to get good.

Typically you would require about 500 hours minimum to get enough experience to cope with most underwater situations, but unfortunately today you some times can not get more than 30 to 40 hours on the stick experience per year. This is usually because the Job is too critical for a trainee to pilot or there are a full crew of four people per 12 hour shift that wants to pilot the vehicle leaving very few piloting hours per individual per day.

In the past there was very few ROV pilots so there was always lots of opportunities to fly the ROV not so any more unfortunately.

**ROV Flying Training**

There are some small independent ROV training schools within the UK that gives some basic piloting skills. The trend however, adopted by a majority of ROV operators, is ‘on the job training’.

An alternative pilot training could be the use of ROV simulators, although these would be cheap and safe to run, for both pilots and ROV, the initial cost of development and manufacture is expensive and at this time prohibitive.
Acknowledgements

Michael Perch - SubSpection

Joe Hamon - APA