RESEARCH NEEDS FOR HEALTH AND SAFETY OF WORKERS DURING DECOMMISSIONING AND REMOVAL OF FIXED OFFSHORE INSTALLATIONS

Authors

Ray Street and Judith Mirzoeff

HSE BOOKS

Health and Safety Executive - Offshore Technology Report
This report is published by the Health and Safety Executive as part of a series of reports of work which has been supported by funds provided by the Executive. Neither the Executive, or the contractors concerned assume any liability for the report nor do they necessarily reflect the views or policy of the Executive.

Results, including detailed evaluation and, where relevant, recommendations stemming from their research projects are published in the OTH series of reports.

Background information and data arising from these research projects are published in the OTI series of reports.
SUMMARY

Over the next twenty years, some 200 platforms will have to be abandoned in the UK sector of the North West European Continental Shelf. HSE commissioned this study to identify any outstanding research needed to ensure that the work can be done safely.

Abandonment options identified ranged from leave in place through partial removal to complete removal. The removal options can be achieved by various methods, depending on the size and nature of the structures, their location and water depth and the legal requirements. In spite of the wide range of possible methods, only a limited number of types of operation are involved, as follows:

- planning and surveying
- cleaning the topsides
- cutting
- lifting and handling
- transporting
- clearing the site
- disposing of the arisings
- provision of accommodation and services.

Some of these operations would be similar to construction or maintenance operations, but in some respects abandonment is special and subject to unknowns. It will not be the reverse of installation.

Two activities requiring special techniques are:

- freeing gravity bases and mud mats
- toppling jacket structures.

During the course of the study, a great deal of research was identified that addresses the special needs of abandonment. Most of it is not specific to safety, but safety is often addressed. Many of the projects are concerned with specific installations or are confidential to the participants, but they would be generally applicable. HSE participated in or initiated some of the more important projects. By and large research needs appear to be covered, but there could be problem of access to the results of some of the current industry-funded projects.

Conflicting evidence needs to be resolved on the reliability of explosive charges, the possibility of refloating some concrete structures, and preferences for piece small removal involving a large offshore workforce, or piece large removal involving heavy lifts. Some uncertainties remain about the behaviour of toppling structures.

The report concludes that as there is insufficient experience of removal of large structures that is relevant to the North West European Continental Shelf, some additional research into safety aspects is needed. The report makes a number of detailed recommendations on research needs.
CONTENTS

SUMMARY i

CONTENTS iii

1. INTRODUCTION AND SCOPE OF WORK 1

2. LEGISLATIVE REQUIREMENTS 3

3. THE SCALE OF THE ABANDONMENT EFFORT 5

4. STAGES IN ABANDONMENT 7
   4.0 Introduction 7
   4.1 Planning 8
   4.2 Surveying 9
   4.3 Provision of Temporary Services 9
   4.4 Isolating the Installation from External Energy Sources 10
   4.5 Decommissioning 10
   4.6 Removing the Topsides 10
   4.7 Disconnecting the Structure from the Seabed 11
   4.8 Dividing the Underwater Structure 11
   4.9 Clearing the Site 12
   4.10 Disposing of the Arisings 12

5. ABANDONMENT TECHNIQUES 13
   5.0 Introduction 13
   5.1 Planning and Survey 13
   5.2 Cleaning 16
   5.3 Cutting 17
   5.4 Lifting and Handling 20
   5.5 Transporting 22
   5.6 Clearing up 22
   5.7 Disposal of Arisings 23
   5.8 Accommodation and Services 24
   5.9 Gravity Bases and Mud Mats 25
   5.10 Toppling 26

6. OTHER CONSIDERATIONS 29
   6.1 Platform Wells 29
   6.2 Pipelines, Pipeline Risers and Flowlines 29

7. RESEARCH IN HAND OR COMPLETED 31
   7.0 Introduction INTRODUCTION 31
   7.1 MTD Managed Programme, 1985 -1989 31
   7.2 PACT Project 32
   7.3 UMITS _ Thermie Explosive Cutting Under Water 32
   7.4 Platform Removal Study, by Harris and Partners for the Department of Energy, 1980 32
7.5 Refloating Gravity Platforms, by McAlpine Offshore 33
7.6 Evaluation, Selection and Development of Subsea Cutting Techniques, by AMB for the Department of Energy, 1990, (to be published as OTH 91 349) 33
7.7 Norwegian Model Concrete Studies 34
7.8 Other Investigations 35
7.9 Knowledge-based Safety Advice System (Portsmouth University) 35
7.10 Accident Statistics 36
7.11 US Papers 36

8. CONCLUSIONS AND RECOMMENDATIONS 39
8.1 Conclusions 39
8.2 Recommendations 41

ACKNOWLEDGEMENTS 45

REFERENCES 47

A1 PROGRAMME OF WORK 51

A2 ACTIVITIES UNDERTAKEN IN THE STUDY 53

A3 DEEP WATER PLATFORMS ON THE UKCS 55

GLOSSARY 61
1. INTRODUCTION AND SCOPE OF WORK

In the next few years, the first of the very large offshore installations on the United Kingdom continental shelf will be abandoned," probably NW Hutton, an eight legged platform in 145 metres of water with a jacket weight of 12 700 tonnes. Plans are known to be in hand to abandon Heather (1997) Auk (2000), Fulmar (2000), Highlander, Petronella, Tartan, Maureen and Murchison. A recent study by Grampian Regional Council (ref 26) estimated that the rate of abandonment will be 7 platforms per year by the year 2005. The number of deep-water platforms eventually needing to be abandoned is addressed in section 2.

As yet, there is little experience of abandonment that is directly relevant to the very large northerly structures in deep water. Some platforms have already been abandoned on the NWECs, but they were either small platforms in shallow water (BP West Sole E, Hamilton Bros Forbes, the Netherlands K 13/D), or floating systems (Hamilton Bros Argyll, Duncan). In the case of Piper Alpha, an already badly damaged structure was topped for safety reasons, without concern for the state of the remaining topsides. In the Gulf of Mexico 600 platforms had been abandoned by 1990, and another 600 will go by the year 2002. The US National Research Council estimated that by 2020, over 5 000 platforms would have been removed (refs 3, 14). Most were in shallow water and, while extreme hurricane conditions in the Gulf are bad, average conditions include long periods of calm weather unknown in our northern waters, when construction or demolition work can be done with assurance.

The scale of the abandonment operation is such that HSE-OSD wishes to be assured that any lack of knowledge is addressed by suitable research, although they believe that industry will probably be able to conduct the operation safely. Several research projects have already been completed for HSE-OSD on the subject, but the HSE-OSD concerns were reinforced by a study of future economic and technological trends in the offshore industry, undertaken by MAI Consultants Ltd. in 1994, which recommended abandonment as a topic possibly needing research.

In 1988, the authors of this report, then directors of the firm Hollobone Hibbert and Associates Ltd (HHA), produced a report for the Department of Energy Petroleum Engineering Division (ref 20), on safety aspects of abandonment.

In 1992, the Safety Case Regulations (ref 40) were made, requiring a safety case for abandonment. This is further discussed in section 3.

The 1988 report did not consider whether the information needed to make the safety cases and safely to abandon installations was available to the industry.

In August 1994, R. Street and J. Mirzoeff made a proposal to HSE-OSD to identify the research needed to ensure the safety, health and to a lesser extent welfare of workers during abandonment. The proposal was accepted, and work started on 24 August.

* Abandonment is the term used in UK Legislation for decommissioning and removal. It will be used throughout this report, except where specific activities of either decommissioning or removal are meant.
The Contractors were required to:

- identify methods of abandonment and their hazards
- research industry practices
- identify research already completed or in hand
- identify outstanding research needs
- report in an agreed form.

There is very limited experience of offshore abandonment in the UK, so other sources were to be investigated, including US offshore abandonment and UK onshore demolition.

The work programme (terms of reference) for the project is given in full in Appendix A1 and the activities undertaken during the project are in Appendix A2.
2. LEGISLATIVE REQUIREMENTS

The 1982 United Nations Convention on the Law of the Sea (ref 41), states that any installations which are abandoned or disused must be removed to ensure safety of navigation. This position has been clarified by IMO guidelines (ref 47). The IMO guidelines state that in water depths of less than 75 m, installations weighing less than 4 000 t should be entirely removed; in water depths of more than 100 m, structures may be partially removed to provide clear water of 55 m above any submerged remains. This also applies to all structures weighing more than 4 000 t. After January 1998, the water depth for total removal will be increased to 100 m, and jackets designed after the same date must be designed for total removal. In the UK, a House of Commons Energy Committee proposed slightly more stringent removal conditions than those current in 1991; to the north of a line eastwards from St. Fergus, partial removal must leave 75 m of clear water, rather than the 55 m proposed by IMO. This is intended to help safe submarine navigation. There are grounds for believing that these requirements may be relaxed, as the ending of the cold war has reduced submarine operations in these areas.

The primary UK legislation is the Petroleum Act 1987, (ref 42) which requires operators to submit to the Secretary of State for Trade and Industry costed abandonment programmes for offshore installations and pipelines, and makes them responsible for carrying out the programmes when they have been approved.

The DTI have stated that they will consider each abandonment plan as a separate case, but it is clear from discussions that operators would prefer some general rules. The trend in environmental legislation has been for requirements to become more onerous on the industrialist, particularly in the United States, where long-abandoned land sites have had to be re-opened and cleaned up. This is also a popular area for litigation. Most North Sea operators have American parent companies and will be aware of the risk in partial abandonment, toppling or dumping that in future the rules will change and their liability will remain.

The London Dumping Convention (ref 46), to which the UK is signatory, prohibits the dumping at sea of some materials found offshore (listed in Annex I to the Convention) and limits the dumping of many others (listed in Annex II). These constraints may affect the cleaning activities needed during abandonment. Other relevant dumping legislation is discussed in the paper by Bartlett (ref 7).

The safety of platform abandonment is provided for in the Offshore Installations (Safety Case) Regulations of 1992 (ref 44) requiring that a safety case be made, and accepted, for every installation abandonment operation. The purpose of the safety case is to demonstrate the adequacy of the operator's safety management system. One purpose of the present study is to see how far operators and the HSE have sufficient information available to them for the preparation and assessment of safety cases for abandonment.
3. THE SCALE OF THE ABANDONMENT EFFORT

There are about 200 installations in the UK sector of the North Sea.

It is probable that the installations in the southern North Sea, in water depths less than 50 metres will have to be removed completely. Deep-water platforms in the central and northern North Seas will have to be partly removed or toppled to give a clear depth of at least 55 metres or possibly 75 metres above the stumps of the structure or any toppled debris. In future there may be a requirement for the remains to be cleared completely (see section 2). This will involve about 59 steel platforms which are already in place in water depths over 50 metres and 9 concrete platforms. No more platforms in deep water are projected for installation by the year 2000.

Appendix 3 is a print out, supplied by Infield Systems Ltd., London, of UK platforms classified as steel or concrete in 50 metres to 75 metres water depth and over 75 metres. Water depth, total weight and jacket or sub-structure weight are given for each platform. Thirty-two of the steel jackets weigh more than 10 000 tonnes, and eight of these weigh more than 20 000 tonnes. Seven of the platforms (including one concrete) are in water depths of 150 metres or greater. This confirms the Heerema analysis (ref 3) that the number of large platforms is a small proportion of the total.

In addition to the UK platforms, there are about as many again in Norwegian, Netherlands and Danish waters. While the Dutch and Danish platforms are in shallow water, some of the Norwegian platforms, particularly Statfjord B and C and Gullfaks C are very large. All three have concrete gravity bases of about 800 000 tonnes, more than twice the weight of the largest UK concrete platform.

The total weights are significant because the "abandonment industry", if it ever comes into being, as such will consider North West Europe as a single market.

The following table, adapted from figures supplied by Heerema in 1994, show the quantities of concrete, jacket steel, topsides materials and piles in the UK and on the North West European Continental Shelf, in tonnes.

<table>
<thead>
<tr>
<th></th>
<th>Concrete</th>
<th>Jacket Steel</th>
<th>Topsides</th>
<th>Piles</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>1 900 000</td>
<td>825 000</td>
<td>1 230 000</td>
<td>380 000</td>
</tr>
<tr>
<td>Total NWECs</td>
<td>7 000 000</td>
<td>1 200 000</td>
<td>2 250 000</td>
<td>600 000</td>
</tr>
</tbody>
</table>

The figures broadly agree with figures quoted by Laver (ref 30), in 1992.

The Laver paper also gives a typical breakdown of weights in tonnes for the components of UK topsides modules. The total module weight of 1 059 473 tonnes used by Laver agrees well with the Heerema figure of 1 230 000 tonnes which includes support frames. In his paper, Laver gives weights of topsides material "available for scrap", about 75% of the total. The following table derived from Laver, contains total quantities in tonnes.
<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steelwork</td>
<td>590 000</td>
</tr>
<tr>
<td>Equipment</td>
<td>200 000</td>
</tr>
<tr>
<td>Piping</td>
<td>100 000</td>
</tr>
<tr>
<td>Architectural</td>
<td>55 000</td>
</tr>
<tr>
<td>Electrical</td>
<td>53 000</td>
</tr>
<tr>
<td>HVAC</td>
<td>25 000</td>
</tr>
<tr>
<td>Instrument</td>
<td>18 000</td>
</tr>
<tr>
<td>Loss Control</td>
<td>14 000</td>
</tr>
</tbody>
</table>
4. STAGES IN ABANDONMENT

4.0 INTRODUCTION

Scenarios considered for abandonment in this report range from:

- leave in place to decay naturally; it has been estimated that it could take 100 to 200 years for a steel structure to collapse, and up to 400 years for a concrete structure (ref 30); through

- partial removal, probably down to a safe depth for navigation, by toppling or cutting and lifting off the topsides and upper part of the jacket; to

- total removal and clearing the seabed.

Even if an installation could be left in place, there would need to be some abandonment work done, as harmful materials which could not be “dumped” when the installation collapsed would have to be cleaned. All other options would involve disposing of topsides and structure by taking them ashore or dumping in deep water. Disposal is not the concern of this study, but the final destination could influence on-board work during the abandonment process and this is discussed in section 5.2.

In addition to the many papers on abandonment, the following records of actual abandonments in NW Europe, the Bay of Biscay and the Gulf of Mexico were studied, to determine the nature of an abandonment.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Date removed</th>
<th>Operator</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Sole</td>
<td>1978</td>
<td>BP</td>
<td>Wimpey Offshore</td>
</tr>
<tr>
<td>K13/D (Netherlands)</td>
<td>1988</td>
<td>Pennzoil</td>
<td></td>
</tr>
<tr>
<td>Piper Alpha</td>
<td>1989</td>
<td>Occidental</td>
<td>Acsosmit</td>
</tr>
<tr>
<td>Argyll, Duncan, Innes*</td>
<td>1993</td>
<td>Hamilton</td>
<td>Stena Offshore</td>
</tr>
<tr>
<td>Forbes</td>
<td>1993</td>
<td>Hamilton</td>
<td>Seaway Heavy Lifting</td>
</tr>
</tbody>
</table>

Outside NWECs

<table>
<thead>
<tr>
<th>Platform</th>
<th>Date removed</th>
<th>Operator</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amposta, 2 platforms</td>
<td>1989</td>
<td>Shell Expana,</td>
<td>Marine Offshore Management</td>
</tr>
<tr>
<td>pipeline and manifold,</td>
<td></td>
<td>Bay of Biscay</td>
<td></td>
</tr>
<tr>
<td>SBM, control lines, steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and flexible flowlines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W Cameron, Eugene Island and Ship Shoal**</td>
<td>1990</td>
<td>Consolidated</td>
<td>Rockwater National Gas Producing Co, Gulf of Mexico</td>
</tr>
</tbody>
</table>

* 18 subsea wells, wellheads recovered and debris cleared, cost £5M, took 2 ships and 4 months
** 340 ft depth, 2 x 850 ton, 1 x 650 ton. The work took 30 days, 8 pile platforms toppled, one with 4 main piles and 4 skirt piles was toppled and removed (refs, 14, 16).
It appears that all southern North Sea installations will have to be removed down to seabed level. The following options, identified by SLP John Brown Engineers (ref4), are for northern deep-water platforms, but the disposal options will apply to the shallow platforms. Similar options are identified in Bartlett (ref8).

<table>
<thead>
<tr>
<th>Topsides</th>
<th>Jacket</th>
</tr>
</thead>
<tbody>
<tr>
<td>remove piece small</td>
<td>lift piece large</td>
</tr>
<tr>
<td>remove piece large</td>
<td>refloat</td>
</tr>
<tr>
<td>topple</td>
<td>topple</td>
</tr>
<tr>
<td>leave in place</td>
<td>leave in place</td>
</tr>
</tbody>
</table>

**Final Disposal**

- re-use at new location
- dump in deep sea
- dump locally
- take onshore for scrap or refurbishment

The abandonment process can be broken down into stages, to simplify discussion of the work to be done. In the 1988 report (ref20), the authors identified four main stages, which were further sub-divided, and other authors also break down the process into similar tasks (refs4 and 12 for example). After discussions with operators and contractors, the authors have identified nine stages, which agree with current industry practice:

- planning
- surveying
- provision of temporary services
- isolating pipelines, flowlines and wells
- decommissioning
- removing the topsides
- disconnecting the structure from the seabed
- dividing the underwater structure for toppling or lifting
- clearing the site.

Although it was not part of this study, a tenth stage that may affect the earlier stages has been considered:

- disposing of the arisings.

The ten stages are discussed in sections 4.1 to 4.10.

**4.1 PLANNING**

Before abandonment can begin, the operation must be planned. In addition, the operator must satisfy the HSE, by means of the safety case for abandonment, (ref 44) that the operation will be done safely (see section 3).
In addition to HSE, other authorities, for example DTI, Scottish Office, local authorities onshore, fishing authorities may have requirements that affect the methods of disposal but these are unlikely to have serious safety implications for offshore workers.

The final destination of the arisings from the abandonment, for example to shore for re-use or scrap, or to an offshore dumping ground will influence the plan.

UNOCAL commented on the sparse data available and expressed concern that quantification of risk could result in spurious risks becoming the norm. The safety case regulations do not require QRA for abandonment, but do require a “risk based” approach.

The plan and safety case will be interdependent with the survey of the installation’s condition. The plan will require certain things to be surveyed and the survey may throw up uncertainties that will cause the plan to be modified.

Surveying is discussed in section 4.2.

4.2 SURVEYING

There are four principal objectives of a survey:

i) to establish inventories of substances that must be removed;

ii) to establish the structural condition and weights and centres of gravity of any modules or topside structures that must be lifted off;

iii) to establish the state of the seabed;

iv) to establish the state of the subsea structure.

Depending on the abandonment method, not all of these will need to be considered. For example, if a deep-water structure is to be removed only down to safe navigational depth, the seabed condition will be largely irrelevant.

The earliest UK platforms were installed in the 1960s. Topsides surveys will be similar to surveys of any other petroleum or petrochemical plant in principle, but are likely to be less efficient because of the confined space, congestion of equipment and adverse weather offshore. Operators survey their submerged structures during routine maintenance, and the UK certification scheme, in place since 1975, requires annual surveys and special surveys in the event of suspected damage, so there are 20 to 30 years of experience in topsides and underwater surveys of offshore installations.

4.3 PROVISION OF TEMPORARY SERVICES

Depending on the amount of on-board work planned during decommissioning, and where the workers are accommodated temporary services may need to be provided for those on board.

If the installation is to be toppled with the topsides structure in place, little work will need to be done on board after the services are disconnected. The existing provisions can be left in place until late in the proceedings.
Regardless of the extent to which the topsides and above-water structure is to be removed, at some time the prime movers will be decommissioned. No power will be available for the electrical or diesel fire pumps, or the navigational aids. There will be no domestic services. Buoyant objects will have to be removed before toppling the platform, so there will no longer be lifeboats, liferafts or lifejackets on board; and the helideck will be unusable. Persons on board will be dependent on the support vessel or vessels for life-saving, fire-fighting, sanitary and other domestic services.

Provision of the necessary services is discussed in section 5.8.

4.4 ISOLATING THE INSTALLATION FROM EXTERNAL ENERGY SOURCES

The Piper Alpha disaster was made much worse by the contribution to the fire of the pipeline inventories, and possibly leaks from the wells. Before any major decommissioning, HSE would require wells to be plugged and abandoned and pipelines and flowlines to be isolated (see sections 6.1 and 6.2).

Some installations are supplied with lift gas for the wells from adjacent installations. As the platform wells will be abandoned, this supply will have been discontinued, and should be isolated.

A few installations are supplied with main power by cable from nearby installations. This power may be needed during the earlier stages decommissioning. There appear to be no problems with this arrangement.

No research needs could be identified.

4.5 DECOMMISSIONING

Before the topsides can be disposed of, they will have to be rendered safe and harmless to the environment, to the extent appropriate to the means of disposal.

This will involve:

i) Removing or making safe for on-shore removal any harmful substances such as hydrocarbons, asbestos, LSA scales, other radioactive materials and any other substances that either cannot legally be dumped, or could harm the workforce.

ii) Progressively taking the machinery and equipment out of use, leaving the necessary services available to those on board as long as possible.

Cleaning of the platform of harmful materials is discussed in section 5.2. Temporary provision of services to replace those taken out of service was discussed in section 4.3, and is expanded in section 5.8.

4.6 REMOVING THE TOPSIDES

Once the topsides have been made safe, they will be removed to some extent for any method of abandonment. Even if an installation is to be toppled complete with its topsides, any elements that could become detached and float to the surface, or could perturb the trajectory of the topping body would need to be removed. Examples are lifeboats and wind walls. High value items may be removed intact for re-use.
Various removal methods have been proposed, from lifting off in one piece - Forbes topsides were reportedly removed in this way - to cutting the topsides into small pieces, and back-loading onto ordinary supply vessels, when initially the platform cranes would be used. Piece small removal is discussed in the Bartlett paper (ref 8). According to the FT North Sea Letter of 12 October 1994, Shell is proposing a maximum lift of 1 600 tonnes during abandonment of its southern basin gas installation Leman BK.

Phillips is investigating several methods of removal of the topsides of its steel gravity base installation Maureen A. These include floating the unit complete with topsides into sheltered inshore waters, ballasting down and floating off the topsides by barge - the reverse of its installation. Suitable liaison between the offshore and the onshore branches of HSE would be important.

Cutting of the topsides is discussed in section 5.3; lifting is discussed in section 5.4.

4.7 DISCONNECTING THE STRUCTURE FROM THE SEABED

Deep water structures that are to be dismantled to give a clear water depth of 55 metres or 75 metres will not be disconnected. Neither will concrete structures, if they must remain in place, as Ninian Central and other Jarl Wall structures may have to be, or if only the towers of a Condeep or Seatank structure are to be removed, leaving the base tanks in place. Techniques exist to cut piles, that are tried and tested. Explosives can be used, but a favoured method is likely to be abrasive water jetting. Recently the Fulmar SALM buoy was cut free using abrasive jetting, deployed by ROV and guided by a specially designed track, without diver intervention. All shallow water steel structures will need to be cut at around the mud line.

Some structures have very large mounds of drill cuttings around the lower bracings that may interfere with cutting. In addition, in the southern sector of the North Sea, where scour has been a problem, rock dumping and mats of artificial seaweed have been used as scour control methods.

If large gravity base structures, all except one of which are concrete, are to be removed, they must be broken free of the seabed. All the gravity structures have skirts that penetrate the seabed, to a depth of 1 to 5 metres. Some bases have been grouted after installation.

Cutting is discussed in section 5.3; clearance of drill cutting mounds in section 5.6 and freeing of gravity bases in section 5.9.

4.8 DIVIDING THE UNDERWATER STRUCTURE

Unless the structure is to be taken out in one piece, it will have to be cut up underwater, and in any case, conductors will have to be severed. Even for toppling, this will involve multiple cuts. Whatever method is used for the weakening cuts, it is likely that the final severance would be by explosives.

Severance of the towers of a concrete structure, which could be several metres in diameter and up to 1 500 mm thick may be difficult to achieve using currently available techniques.

Cutting is discussed in section 5.3.
4.9 CLEARING THE SITE

The site may need to be cleared for environmental reasons over an area with a radius of 500 metres. Even if the structure is to be toppled this may be necessary as the London Dumping Convention (see section 5.2) requires the removal of all material that may float or remain in suspension in the sea or may, while on the bottom, interfere with fishing or navigation.

Materials to be cleared could include a mound of drill cuttings as described in section 4.7.

Clearing the site is discussed in section 5.6.

4.10 DISPOSING OF THE ARISINGS

Final disposal, away from the site of the installation, is not the concern of this study nor of HSE-OSD. The final destination may affect the extent of cleaning needed offshore, so the effect of disposal on the safety of the offshore workforce may be important. Disposal of the arisings from abandonment is discussed, therefore, in section 5.7.

Some operators and contractors have commented that it would be a help to safety offshore if the offshore and onshore authorities co-operated to the maximum extent possible. Disposal, particularly of hazardous substances, could then be managed so that the more dangerous aspects were carried out at the site which exposed workers to the least risk - probably onshore.
5. ABANDONMENT TECHNIQUES

5.0 INTRODUCTION

Regardless of the method of abandonment chosen, some offshore activity will be required (see section 4.0). Not all of the ten stages of abandonment discussed in section 4 will be required in every case, though all would probably be undertaken for complete removal. If the installation could be left in place, very little planning or surveying would be needed, and the topsides would only need to be decommissioned.

The actual operations needed to complete the stages can be summarized as:

- planning and survey (interdependent)
- cleaning
- cutting
- lifting and handling
- transporting
- clearing-up
- disposing ofarisings.

To protect the safety, health and welfare of workers on board:

- accommodation life-saving and fire-fighting services will be needed.

These eight operations are discussed in sections 5.1 to 5.8.

The problems associated with gravity bases and suction under the mud mats of jackets are discussed in section 5.9. The problems associated with toppling of jacket structures are discussed in section 5.10.

Divers will be involved in many tasks. Remotely Operated Vehicles (ROVs) are excellent for observation, and for working in conjunction with planned deployment systems. They are less effective at remedial work that will inevitably occur, or at work in confined spaces, where a ROV cannot deploy its relatively rigid arm. In the Piper Alpha recovery, work was mostly done by divers, at some risk to themselves. Development of ROVs to perform more complex tasks is, however, continuing.

5.1 PLANNING AND SURVEY

Planning for a work of engineering construction, which commonly includes demolition, is well established, and the techniques are understood by the industry. Responsibility for planning for safety, including preparing the statutory safety case, rests with the operator but the work will be done by a contractor with the specialized knowledge and equipment. In turn, the contractor may appoint sub-contractors, for example explosives specialists.

The offshore industry is used to planning for activities allied to abandonment including the Ekofisk jacking operation and the removal of redundant modules at Brent (ref36).
Some contractors are trying to extend the practices of partnering and alliancing, whereby a contractor manages the upkeep of an installation, including arranging statutory surveys and re-certification on behalf of the operator, to include abandonment and disposal of risings. During operation, the operator remains responsible for hydrocarbon production and transport (i.e. reservoir engineering, metering and so on). For abandonment the contractor would expect the operator to arrange for plugging and abandoning of wells, produced hydrocarbon disposal and decommissioning of pipelines.

An HSE contact confirmed that it would be acceptable for the contractor to follow his own safety management system and to base the safety case on it. The operator would still be responsible for the content and implementation of the safety case and would have to exercise due care in:

* selecting the contractor
* informing the contractor of everything relevant to safety, health and welfare
* verifying the safety practices
* monitoring the work.

HSE and DTI would jointly monitor the abandonment. The contractor could, if required, arrange for the survey needed to complete the abandonment programme.

One operator (ref6) has summarised the initial planning process as:

* set out the strategy, philosophy, goals and objectives for the abandonment programme
* identify the relevant legislation
* identify the hazards (including environmental - not relevant to this study)
* identify the cost drivers
* communicate the magnitude of potential problems to the company’s top management
* communicate with the responsible government departments.

A formalized study of decommissioning hazards (DEHAZ) has been used by a contractor (ref12), which is the equivalent of the HAZAN/HAZOP procedures for construction and operation. It comprises five stages:

i) sequence  
ii) methods  
iii) waste control  
iv) safeguards  
v) temporary services and life support.

If the DEHAZ procedure could be developed as an industry-wide tool, it would serve two useful purposes:

i) it would provide HSE-OSD with a common model when considering the safety case  
ii) it would help a contractor to work for more than one operator without having to make radical changes to its safety procedures.
The survey will need to be fully integrated with the planning process and into the DEHAZ. As discussed in section 4.2, there is a great deal of experience of surveying UK installations. For decommissioning, the emphasis may need to change, as the structure may have to be considered as progressively damaged by the removal process, but the survey techniques are tried and tested.

HSE-OSD has done a good deal of research into the residual strength of damaged structures (ref 25) which could be used to determine the nature of surveys needed for progressive demolition.

If the topsides are to be lifted off, it will be necessary to consider two important aspects:

- weight and its distribution
- strength.

Equipment may well have been added subsequently to installation, and the additional items may alter the centres of gravity of modules. The structures of the modules themselves may have been modified to allow for changes of use and, though they may be perfectly sound to support their contents during operation, they may not be adequate for lifting. The Lloyd's Register contact confirmed that the industry is aware of the potential problem and software for analysis is available. There are companies that specialise in ascertaining weights and centres of gravity. The capacity of offshore lifting equipment is sufficient that great accuracy is unlikely to be necessary. Subsea surveys are regularly undertaken to ascertain structural condition, as part of the ongoing maintenance activity, or to investigate suspected damage.

Operators, contractors and university departments are all involved in computer simulation, particularly of toppling and explosive cutting. It is considered to be an essential part of planning such operations to be able to predict their outcome with a high degree of accuracy.

While planning removal of a series of Gulf of Mexico platforms, Occidental formulated a comprehensive salvage plan (ref 16) that enabled them:

- to group similar tasks, which permitted savings based on economies of scale and shared mobilization costs
- to perform certain tasks from workboats, while the derrick barge was otherwise engaged (a production line approach that minimized use of expensive plant for trivial work)
- to use available regulatory options to minimize approvals for platform and pipelines abandonment
- to maximise the salvage value

In addition to its economic advantages, grouped removal could make the use of large cranes, and other heavy plant with a great factor of safety, more economic. This is discussed in section 5.4 in relation to heavy lift vessels. Lloyd's Register would like clarification of the status of the Certificate of Fitness if platforms are unused prior to grouped removal.
5.2 CLEANING

As discussed in section 4.5, the topsides will need to be cleaned-up to some extent, regardless of their final destination. If the topsides are to be dumped offshore, they will need to be cleaned to meet all environmental legislation. If they are to be brought ashore for final disposal, they will only need to be rendered safe. Cleaning is discussed in detail in a paper by Barlett (ref.7), and by Corcoran and Shaw (ref.12).

An oil or gas installation will, by definition, have a large inventory of hydrocarbons on board during its operation. This will pose the greatest on-board threat to safety, but it is also the easiest to counter. The platform equipment is designed to handle process hydrocarbons and they can be pumped away for disposal before the pipeline and flare system are decommissioned. This would leave only limited quantities of hydrocarbon fuels on board, to operate diesel generators and fire pumps. These fuels should pose no problem, providing they are allowed for in the DEHAZ.

Final cleaning will involve the use of power washing with detergents and mechanical cleaning to remove residual oils and gases, sediments and contaminants such as LSA radioactive scales to tanks for safe disposal. Some problems arose when Shell abandoned its Amposta platform in 1989. The topsides were cleaned up to ISO standards. While in general vessels were cleaned effectively, small amounts of oil still remained in valves, filter housings and some pipework. Gas and oil accumulations caused some blowbacks when pipes were flame cut (ref33).

Other harmful materials in place may pose no hazards to the decommissioning crew, but one of the most important decommissioning tasks is to remove them. If this can be done onshore, specialist contractors can be brought in. Offshore, either large numbers of specialists, who may be unfamiliar with offshore working, or offshore workers with lesser experience of handling hazardous substances may be involved. Either way, suitable training and supervision would be required. Amoco believe that it is safer to use persons experienced in offshore working and give them special training. This was confirmed by Hamilton Bros in connection with handling flexible pipelines.

Some of the systems to be decommissioned will contain hazardous and toxic substances, including chemical storage, distribution and injection systems including:

• water treatment chemicals
• scale inhibitors
• corrosion inhibitors
• deoxidants
• biocides
• glycol systems (MEG and TEG).

Pyrophoric deposits can occur in some offshore systems. A particular example is a produced water system on a sour gas platform, even downstream of the sulphur removal plant. If, during decommissioning, the interior of the piping is exposed to the atmosphere it can spontaneously ignite when it dries out. Equipment containing zirconium may also be susceptible.
Research into pyrophores is understood to have been done and techniques are available to destroy the pyrophores or render them inactive. Industry is aware of the problem to some extent but a more detailed investigation of possible problems may be needed.

Many older installations have large quantities of asbestos on board, as insulation or fire proofing. The London Dumping Convention (ref46) prohibits dumping only of organosilicon compounds; asbestos is inorganic.

Almost all the materials listed in the Dumping Convention either in Annex I (dumping prohibited) or Annex II (subject to special permission), are present offshore, although mostly in small quantities. Some materials that could require special treatment are:

- asbestos (see above)
- radioactive sources (in gas and fire detectors)
- mercury vapour lamps (up to 10 tonnes in some installations)
- PVC cable sheathing
- Low Specific Activity scale
- PCBs in transformer fluid (all such fluid has now been replaced, but sufficient residues remain in the replacement fluid to exceed the permitted limit until the fluid has been changed about ten times)
- electrical accumulators.

The other main aspect of decommissioning is the progressive shut down and removal of systems, machinery and equipment. These will include:

- electrical
- water systems (fire, potable, cooling)
- storage
- drains
- domestic
- safety systems
- emergency systems.

This decommissioning will have to be done according to plan, which will take account of the extent of the decommissioning prior to disposal, the numbers of persons on board and the support vessels available. The appropriate method of decommissioning would need to be addressed as part of the safety case. Any problems with this aspect would relate to planning, rather than availability of techniques or equipment.

5.3 CUTTING

Cuts will need to be made under water:

- to free a piled structure from the seabed
- to divide a structure for lifting or toppling
and above water:

- to divide topsides for lifting-off.

A 1990 study by AME Ltd (ref23) identified four main types of cutting method:

- Mechanical (10 methods)
- Thermal (6 methods)
- Explosive (4 methods)
- Electrochemical (1 method)

Failure mode, effect and criticality analysis of the techniques identify some risks, particularly to divers in respect of explosives, but possibly more significantly, danger to operators from an unstable structure in the event of failure of the cut.

Techniques for underwater cutting are well developed in the Gulf of Mexico. Heerema (ref3) has established that out of a total of 916 structures - which included a large number of monopile caissons - 622 were removed using explosives, 207 were cut mechanically, 42 were cut by abrasive jet, the remaining few were cut manually by divers, cut cryogenically using liquid nitrogen, or were milled. Although explosives were the most commonly used method, Mr Williams of Heerema (UK) considers that they could be superseded.

It has been accepted that explosives would be the favoured underwater cutting method in UK waters (refs 1 and 11). This may still be the case, but two recent abandonments reinforce Mr Williams’ views.

The Hamilton Bros Forbes platform was cut free using the Stolt Comex Seaway 700 Bar Diajet abrasive cutter. The same method, deployed and guided remotely by ROV, was used to cut free the Shell Fulmar SALM in a water depth of 80 metres. Over 30 metres length of steel plate, varying in thickness from 65-75 mm, but up to 140 mm thick at the intersections between plates, was cut. In previous experience with abrasive jetting, orifices sometimes clogged, leading to catastrophic failure, but this problem may have been solved. Explosives were installed as a back-up, at Fulmar. These were not needed and were subsequently recovered intact.

Mechanical cutting methods can be very effective, but locked-in stresses in the member to be cut can cause the cutter to jam. They can also cause uncontrolled releases of energy, with consequent risks to those in the vicinity.

Diamond-wire cutters can cut a typical jacket leg in a couple of hours. Automated deployment systems are being developed, and reliability is very high, according to contractors. Heerema has successfully tested diamond wire cutting equipment on large members under compression.

Hydraulic scissors capable of cutting tubular members up to 600 mm dia and 30 mm wall thickness at a single stroke are available.
None of the above methods, with the possible exception of abrasive-water jetting if used manually, threatens the safety, health or welfare of users. There is a well-established code of practice for diver-deployed water-jetting, published by AODC (the International Marine Contractors Association) (ref48). Automated systems are clearly desirable for safety, provided that they are reliable.

Explosives remain the focus of research on methods for cutting large members under water. Methods of explosive cutting are being continuously refined. The development of shaped charges and focussed shock wave devices enhances the probability of a successful cut. DRA/AME have confirmed the ability of such charges to cut tubulars, by a series of tests. Reverse Engineering Ltd is proposing to make experimental in-water cuts of tubular members around 2,400 mm diameter and 100 mm wall thickness. Detonation systems can be designed with a high degree of reliability. Concern has been expressed that in a sequence of explosives, the shock wave or bubble pulse from an early explosion could displace a later charge, before its explosive effect has been fully developed. With the speed of modern detonation systems this problem can be overcome, according to Dr. Ellinas of AME. AME has developed a computer-based simulation to assist in the necessary design process.

Unlike mechanical cutters, explosives can cause direct collateral damage, to divers in the water, or to nearby vessels. The AME report (ref23) discusses the effects of explosive cutting on the safety of jackets, vessels and nearby installations. The AME report also discusses general safety aspects of cutting including safe diving practice and the safe use of electricity under water which are not the concern of this study. The HSE-OSD Chief Inspector of Diving has commented that divers should not be in the vicinity when explosives are fired. Current practice is to err on the side of safety, but the effects of water depth and bottom conditions on the shock wave are still not well understood. MTD Ltd is currently preparing guidance on the safe use of explosives under water (ref49).

Readings of the shock waves created by the toppling explosives at Piper Alpha are available to HSE-OSD, which could be used to calibrate existing software.

On the surface, more conventional cutting techniques can be used, such as oxy-fuel cutting. Reverse Engineering Limited has proposed mounting hydraulic “nibblers” on the decks, that could cut almost any structural member currently installed. Such machines, commonly used in scrapyards, are available to cut up to 150 mm thick steel. More realistically, portable nibblers, mounted on crawler chassis, could be accommodated on most installations. They would be small enough to manoeuvre, and light enough to operate within the permissible deck loading. They can cut up to about 100 mm. For the parts to be transported in standard containers (see sections 5.5 and 5.7), a great number of cuts would need to be made.

Amoco confirmed that they were considering the use of nibblers to remove environmentally sensitive parts of the topsides, possibly prior to toppling the structure with the topsides in place. NW Hutton is large enough and strong enough to support the equipment.

The Lloyd’s Register contact had knowledge of proposals to use explosives for topsides cutting. He believed there was insufficient knowledge of the safe distances and sizes of exclusion zones needed inside a complex area with the possibility of blast being focused.
Both AME and the Defence Research Agency were sure that the towers of concrete structures could be cut using explosives. Heerema has conducted tests which confirm that reinforced concrete and grouted sections can be cut by diamond wire.

5.4 LIFTING AND HANDLING

The capability of the marine construction fleet has grown in line with the increase in platform size. Very large floating cranes, mounted on semi-submersible hulls, slightly smaller cranes on ship-shaped hulls, and civil engineering shear-legs on barge hulls are available with the capability to install and also to remove very large structures.

<table>
<thead>
<tr>
<th>Name</th>
<th>Vessel Type</th>
<th>Maximum Crane Capacity (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thor</td>
<td>ship</td>
<td>2 000</td>
</tr>
<tr>
<td>Odin</td>
<td>ship</td>
<td>3 000</td>
</tr>
<tr>
<td>Stanislav Yudin</td>
<td>ship</td>
<td>1 600</td>
</tr>
<tr>
<td>Balder</td>
<td>semi-sub</td>
<td>3 600 + 2 700</td>
</tr>
<tr>
<td>Hermod</td>
<td>semi-sub</td>
<td>4 500 + 3 600</td>
</tr>
<tr>
<td>DB102</td>
<td>semi-sub</td>
<td>6 000 + 6 000</td>
</tr>
<tr>
<td>M7000</td>
<td>semi-sub</td>
<td>7 000 + 7 000</td>
</tr>
<tr>
<td>Shear leg</td>
<td>barge</td>
<td>3 000</td>
</tr>
<tr>
<td>(typical)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Their operational capacities vary with the type of lift. As an example, DB102 can lift with either of its two cranes 2 000 tonnes at a radius of 70 metres and can revolve with the load. A typical large shear-leg barge could lift about 800 tonnes at sea, but could, of course, not revolve.

The Stanislav Yudin was recently used to remove the Forbes platform. In 1978, the West Sole E platform was removed, using the civil engineering shear-leg barge Neptune. The maximum lift was 180 tonnes. The weather was good, but there was a swell running and the transfer of the deck section to the transport barge did not go smoothly. The differential movement between crane and barge caused some damage, even though the load was well within the available lift capacity.

At present, there is capacity to lift almost all structures and their topsides out of the sea. The deep water jackets would have to be cut up. The pieces could be large but for a deep water platform around a dozen pieces could be anticipated. The exceptions are the very large concrete sub-structures and one or two jackets designed for barge launch that may not be strong enough to be lifted in large pieces.

There are two problems, the first can be solved by contractors, the second may require wider industry and government input.

During installation the cranes had to lift from a barge onto a stationary platform. During demolition, the crane would lift from the platform onto a moving barge, which is more difficult. After the barge had reached its dumping destination onshore, a crane of the same capacity would be required to lift components, or a suitable handling
system, possibly a skidding system be provided to transfer loads to shore. If the arisings are to be dumped at sea they could not be dropped from a crane hook, or lowered to the seabed but would have to be launched off the barge. The crane vessels themselves could load, carry to shore and off-load large components, but because of the high day rates for crane vessels relative to transport barges it would be an expensive means of working, if long voyages were involved.

The second problem is future availability of the plant. At present the heavy-lift vessels are under-used, because of the downturn in construction work. Most are employed for only about 50 days per year. It is understood that as a result one semi-submersible is to be converted to a floating production unit and one or more of the ship-shaped units may be broken up. In a few years time, given the trend away from large fixed platforms, all may have become uneconomic and may have been scrapped, or moved to other geographical areas. The cost of transporting a large crane back from a remote region would be prohibitive, unless there was a run of work. This work would not need to be on the continental shelf of a single country, but could, for example, straddle the UK/Norwegian median line.

Mr Williams of Heerema (UK), an operator of heavy lift vessels, has proposed that after decommissioning platforms could be mothballed, until several could be removed in succession, using one crane barge. An example of phased abandonment by Occidental in the Gulf of Mexico (ref 16) is discussed in section 5.1. Most persons consulted, including operators, contractors, and a certifying authority, thought that a platform that had a certificate of fitness current at the time of decommissioning could safely remain in place for at least two or three years. The actual craneage time for each platform removal would be quite short, and a planned sequence of removals could be economically completed in one season. The mobilization costs, which are significant, would then be shared.

It is proposed that phased removal by heavy crane should be investigated, and the safety implications of the absence of large cranes should also be investigated.

The piece-small option envisages the use of the platform cranes, so far as possible.

Several other methods of handling have been proposed apart from lifting by crane or in the case of gravity base structures refloating as the reverse of installation. Bartlett (ref 8) describes three novel concepts:

- one piece removal of jacket and topsides using a converted 250 000 tonne tanker. The tanker would be cut in two, and the two halves reassembled using skid beams under the unit to be lifted. Lift would be by de-ballasting the tanker

- ship mounted fork-lift - a specially constructed vessel with a forked transom designed to remove topsides in one piece, again by de-ballasting

- travelling crane vessel (TCV), which would have four 7 500 tonne lifting blocks on two A-frames. The A-frames would traverse the deck of the vessel. The topsides would be transferred to the TCV deck for transport to final destination.

It is known from other sources that EC funds were obtained for development of the "fork-lift" but that the project is now in abeyance. Whether such devices are practicable or whether, in view of the heavy lift vessels available, they are needed could not be established.
5.5 TRANSPORTING

Except in the cases of local dumping or toppling, materials will have to be transported to the dumping ground or to shore.

The marine construction contractors maintain all the necessary service vessels including barges with deck load capacities of up to 60,000 tonnes. Some of the barges are designed to launch jackets. Additionally, the large crane vessels themselves have deck capacities of up to 12,000 tonnes with an available area of around the size of a football pitch (100 metres x 80 metres). All the components could be transported back to shore, or to a dumping ground using available equipment.

Piece-small removal would require only supply boats. Bartlett (ref 8) suggests that the pieces would be transported in standard ISO containers, which are 40ft x 8ft x 8ft. Supply boats are designed to accept these containers. (See section 5.7 for some comments on containerized scrap).

The safety of marine operations is not the remit of HSE, except to an extent within the 500 metre zone.

5.6 CLEARING UP

It is the practice in US waters to clear the site completely, partly because of the risk of residual liability. Many UK operators have US parents, and they may wish to follow suit.

One consultant commented that in his discussions with operators, they had assumed that toppling would be permitted, but that there would be an obligation to clear the site, if subsequently required by government. This had influenced thinking on how toppling should be accomplished to leave the structure on the sea bed in a state so that it could be recovered.

The Heerema (UK) contact pointed out that it may be necessary to inspect a toppled debris pile, and that it would need to be insured until an operator’s liability expired. The insurance market is very concerned about consequential liability, so premiums would be expensive. Remedial clean-up could put divers or other workers at risk.

During the Piper Alpha inquiry, Lord Cullen refused to make a ruling on the recovery of debris, to clear the seabed or for the purposes of recovering evidence or human remains. Evidence, much of it provided by an author of this report, conflicted on the feasibility of recovery. Piper Alpha is not a precedent, as the greater part of the seabed debris collapsed in an already-damaged condition due to the explosion and fire. Only the upper part of the structure was deliberately collapsed in a planned manner. The resulting debris pile was laced together with a mass of pipework and cabling.

If the structure is removed completely, clearance will involve only recovery of items that have been dropped during either operation or the removal process. They should be relatively few, and fairly small, as most objects will be dropped during offloading or back-loading supplies.

One other clearance problem could result from drill cuttings. These can be large, well-consolidated mounds. The largest identified has a volume of about 50,000 m³.
The mounds are usually of consolidated silty clay with shear strengths of around 40/50 kPa. This is quite stiff. Seabed sandy silt typically has a shear strength of 10 kPa. Royal Bos Kalis Westminster NV, a well-known dredging company, has investigated drill cutting removal and considers it highly likely that the mounds will contain metallic and other debris that would interfere with a dredging operation and may involve diver intervention even in a remotely deployed dredging system. There are reports of divers suffering from chemical burns when working on cuttings mounds. Some mounds may include LSA scale from well workover activities.

Equipment is available to clear consolidated material from the seabed. One source gives the following figures for suitable equipment operating in consolidated material:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot; jet pump</td>
<td>Diver deployed</td>
</tr>
<tr>
<td>10&quot; jet pump</td>
<td>Remotely deployed</td>
</tr>
</tbody>
</table>

Tramrod is a remote handling device, operated by Royal Bos Kalis Westminster NV. They confirmed that it could deploy dredging equipment inside a jacket and they have successfully dredged inside jackets, by diverless means.

There appear to be two possible safety implications in clearance:

- if there is a pile of tangled debris left on the seabed as a result of something going wrong with a removal operation, and this must be cleared by divers

- if a drill cuttings mound must be cleared using equipment deployed by divers.

Both appear to be amenable to solution without research by good management, possibly through transfer of technology from other industries.

There is an environmental problem relating to oil-based mud and other contaminants on drill cuttings. Disturbing cuttings mounds may spread these contaminants and may therefore be unacceptable for other reasons than safety.

5.7 DISPOSAL OF ARISINGS

As noted in section 4.10, the final destination of the arisings from abandonment is not the concern of HSE-OSD; it will, however, affect the extent and nature of the work needed offshore to clean the arisings for disposal.

Until quite recently, it was believed that the cost of preserving equipment during abandonment would be more than its value as scrap or for re-use. This appears no longer to be the case. Forbes topsides have been removed intact with the intention of selling them for re-use. Phillips is contemplating recovering the gravity base installation Maureen A to be sold for re-use at a new site.

According to the FT North Sea Letter of 2 November 1994, a new company, IFD Services, a subsidiary of RMS Supplies (Inverkeithing) Limited, has been set up to provide one-stop disposal of facilities from abandoned installations.
Amoco has encouraged the setting up of a dedicated reception area at Teeside, with one section to receive scrap steel, and one to receive materials and equipment that could be reclaimed, refurbished and sold. It would be available to industry generally when NW Hutton arisings have been disposed of.

At least one company can remove radioactive scale from piping and equipment to a standard where it is safe to be handled for refurbishment or scrapping. Radioactive sludges are disposed of by specialist contractors in the nuclear industry.

If topsides are to be brought ashore for refurbishment and re-use or for scrap, minimal offshore cleaning will be required to render the equipment safe to be moved. If they are to be dumped offshore, or topped with the structure, they may have to be cleaned to a high standard to satisfy the dumping regulations (ref46).

The topsides and jackets were designed to be loaded out from the construction sites by particular methods that may no longer be available. The yards used for construction may not be suitable or even available to receive large quantities of modules from abandoned installations. The modules may not have been removed in the reverse manner to installation, and may have been modified during service. The final destination may influence the offshore abandonment process (ref6).

For piece small removal, Amoco (Bartlett) (ref8) quotes an optimum maximum size of 5ft x 2ft x 2ft requested by the steel mill. The pieces would be transported in standard ISO containers. This appears to the authors to be an unrealistic size for offshore cutting. Some individual members have a cross section with dimensions greater than 5ft x 2ft. As a container is 8ft x 8ft x 40ft (or 20ft for a half size), pieces could be larger for transportation. Cutting for final acceptance could be done at a convenient onshore site. This would involve less work offshore, but double handling, so disposal to the steel mill for scrap might become uneconomic. Careful planning would be needed to cut the irregular pieces so that a reasonable number could be carried.

5.8 ACCOMMODATION AND SERVICES

As described in section 4.3, personnel engaged in abandonment will depend on services on board the installation, which will, at some stage, be removed; or on services on an attendant vessel (flotet or crane-barge).

Accommodation on an attendant vessel was considered in detail after the Piper Alpha disaster, and was the subject of a research project by Offshore Certification Bureau (OCB) (ref21). This report investigated five scenarios, including:

- Case C - bridge-linked flotet
- Case D - helicopter-linked flotet.

Progressive decommissioning of life-support and safety systems would leave on-board workers increasingly exposed to risks of safety and health problems. The chief hazard, large inventories of produced hydrocarbons, will have been removed in the very early stages, so much of the fire and gas detection equipment and the fire-fighting capability will no longer be required. There could, however, be a good deal of hot
work involved, so a system of fire detection and some fire-fighting capability would be needed. Arrangements would also have to be in place for escape and rescue. This is largely a planning matter, but may be worth researching.

Domestic systems will need to be maintained to some extent, so long as persons are working on board. Suitable temporary measures should be available.

The crane barges, described in section 5.4, can accommodate large numbers of workers in addition to their own operating crews. For examples DB102 accommodates over 700 and Hermod over 300.

If a crane barge is not constantly in attendance during decommissioning or if an installation is to be removed by some other means than heavy lift, about 30 accommodation vessels are currently available. About two thirds are semi-submersibles, able to accommodate up to 700, and one third are jack-ups able to accommodate up to 300 (ref3). As with the large crane vessels their availability will depend on the continuity of demand. If there is insufficient hook-up and commissioning or refurbishment work, pending the large abandonment effort, they will be taken out of service. It is, however, simpler to convert an offshore unit to accommodation than to build a crane barge, and there are always likely to be suitable hulls available. Accommodation vessels have open deck space, workshops and cranes, but these are more limited than those on the crane barges. Pumps and generators to supply fire-water and power to the installation being abandoned could easily be added, if not already available.

The OCB study found that regular transfer of personnel by helicopter was unacceptably hazardous relative to transfer by bridge. On one occasion, a collapse of a temporary bridge between a semi-submersible (Tharos) and a fixed platform (Piper Alpha) caused three fatalities. The expected level of future risk in transfer by bridge was, however, found to be acceptable.

5.9 GRAVITY BASES AND MUD MATS

Twelve of the platforms in UK waters are gravity-based structures that rest on the seabed and are retained in place by their own weight. Two are small platforms in shallow water in the southern North Sea, the other ten are in water depths of between 94 and 150 metres in the central and northern North Sea. All are of concrete construction, except for Phillips’ Maureen A.

Two problems could arise in recovering gravity-based structures:

- overcoming the base suction
- uncontrolled ascent of the buoyant structure after the base suction has been released.

When the Fulmar SALM was cut free it popped up with considerable vigour (ref37). It was a relatively small structure which could be restrained, but it is known that one operator is considering raising a gravity-based structure, using the on-board pumps to displace water in the tanks to provide buoyancy and on-board compressors to pump air under the skirt to break the suction. This will require the structure to be manned during the break-out operation.
Research has been done into the problem of overcoming the base suction, and of uncontrolled ascent to the surface after the suction force is released. A 1988 report by McAlpine Offshore (ref 19) identified some problems with breaking out a Jardian Wall structure (Ninian Central). The relatively small concrete gravity base platform at Ravenspurn could also pose problems. Installation buoyancy was provided by an open topped box. This was ballasted after installation with rock, which was concreted over.

Phillips is carrying out computer modelling of the Maureen platform refloat and will consider model tests using a centrifuge to determine break out loads should these prove necessary.

Problems of break-out may occur because of suction under the mud mats of a jacket structure. This would only apply to structures to be removed completely. Existing cranes could easily overcome the suction but sudden release could cause severe shock loading on the crane, with risk of damage to the boom.

5.10 TOPPLING

Toppling a steel jacket structure, either with or without its topsides in place, is an option for abandonment favoured by many operators. It is the subject of a good deal of current research.

Piper Alpha was toppled. Its structural condition precluded any other method of reducing the damaged structure to a height that gave sufficient navigational clearance and the Government made it clear that this did not set a precedent for toppling. Neither did the actual toppling operation, which was subject to an enforced timescale and method of working due to the nature of the structure.

An installation is toppled by cutting one side of the structure away, allowing the upper part of the structure to rotate in a controlled manner around hinges that form in the remaining legs. An alternative method involves splitting and toppling outwards. There are a number of problems specific to toppling that may not have been resolved. These include:

- extent of drag and inertia forces on the toppling structure due to the bubble pulse
- shock loading transmitted through the structure
- complex hydrodynamic forces on the toppling structure, particularly at the air/water interface
- structural integrity of the partly destroyed structure
- behaviour of buoyant members that could become detached.

The Piper Alpha abandonment was planned on the assumption that a towing force would be needed to collapse the toppled pieces in the correct place. This proved to be unnecessary, and the wires to the towing vessels slackened, as the structure toppled faster than the slack could be taken up. External forces are not now thought to be needed, but this could depend on the configuration of the structure.

There is still a risk that unplanned secondary hinges could form, resulting in the structure collapsing into itself, rather than falling clear of the truncated base.
A variation of toppling is being investigated at UMIST/REL. This involves severing all the jacket legs, imparting a twisting motion on the top part of the jacket and allowing it to collapse vertically. The relatively fragile bracing would be destroyed as the displaced upper part of the legs drove vertically downwards through the lower parts.
6. OTHER CONSIDERATIONS

6.1 PLATFORM WELLS

It is expected that platform wells will be plugged and abandoned before any important decommissioning work is started. Normal well abandonment procedure is to isolate porous zones including the reservoir by setting cement plugs and to set a top plug below the mud line. Plugging and abandonment of wells has been common practice for many years and the procedures have proved satisfactory.

Although at the time of abandonment the field will usually be depleted, the reservoir may become re-pressurised over a period of time, which may be quite short, depending on geological conditions. If a platform is abandoned because of its structural or mechanical condition, the reservoir may not be depleted in the first place. Should the plug across the reservoir not be completely sound, pressure could build up below the top plug.

The well conductors will be severed below the mud line and removed before the platform is taken out. This could be some considerable time after the wells are plugged, so there could be pressurised top plugs. Although the pressure could be quite high, the volume would be low and the pressure would take time to build up again in the event of a release. For a steel platform, the well conductors would be severed using explosives or internal milling cutters. The conductors which run inside the shafts of concrete gravity structures are designed to disconnect below the foundation. Research is very unlikely to be needed, but this may be worth investigating more fully in the case of explosive cutting. Well abandonment is, however, outside the scope of this study. In the event of the plugs remaining intact after well abandonment, any explosive cutting activities in connection with removal of the installation are not expected to damage them.

6.2 PIPELINES, PIPELINE RISERS AND FLOWLINES

HSE-OSD will require all pipelines, and flowlines from subsea wells to be isolated from an installation before any important decommissioning work is begun. The spool piece that forms the transition between pipeline or flowline and riser will be removed for disposal.

Any risers or other parts of pipelines and flowlines that remain attached to the installation after disconnection of the main parts of the pipelines and flowlines will be purged of hydrocarbons so that hot work can be done safely in their vicinities.

All flexible risers will be disconnected at top and bottom and removed.

HSE-OSD pipelines inspectors have confirmed these requirements. Discussions with industry suggest that no one is proposing a different procedure which would involve decommissioning with live pipelines and risers in place.

There have been anecdotal reports of problems with the safe handling during decommissioning of flexible pipelines by inexperienced personnel. Proper procedures followed by experienced personnel appear to be safe.
It is possible that pipelines connected to redundant installations may be required for another duty. In these cases, the reallocation may have occurred prior to abandonment. The resulting live pipeline could pass close by the installation to be abandoned, adding to the difficulties of abandonment. In some cases, including NW Hutton where it is within 1½ km, live pipelines already pass close to the installation. It seems that any problems would be overcome by operating procedures, but R&D could be needed. The probability of occurrence would need to be established from the operators.
7. RESEARCH IN HAND OR COMPLETED

7.0 INTRODUCTION

A certain amount of research has been identified and is described below. HSE-OSD already has access to projects that it has commissioned, some of which are confidential. Some research programmes were originally confidential but are now out of confidentiality. Most of the current research identified is either in Joint Industry Projects which are accessible only to participants, or directed towards procedures in the removal of a specific installation.

7.1 MTD MANAGED PROGRAMME, 1985 -1989

Decommissioning and Removal of Offshore Structures

This was a Managed Programme of university research in two phases, funded by the Science and Engineering Research Council, and a number of industry participants. The Department of Energy also had a “ticket”. The programme was significant in establishing a research base and some research facilities in the necessary technologies, particularly for explosive cutting. Several companies, e.g. Reverse Engineering and AME, were set up or benefited from the expertise acquired, and the research has been continued with European funding (see 7.3).

Specific topics in relation to explosive cutting were:

- prediction of the structural response of jacket members to explosive cutting charges using the ABAQUS finite element code
- optimisation of the geometry of linear charges, and the best liner material for plastic explosives to give increased depth of cut
- explosive shock and bubble pulse attenuations inside water-filled piles and conductor casings
- modelling the structural vibratory response of large diameter stiffened shells and buoyancy tanks to an underwater explosion
- fracturing steel and concrete by stress-wave focusing techniques, which led to the development of more precise explosive cutting
- prediction of the best radial stand-off for circular shaped charges
- fibre-optic charge detonation (Phase 1).

There was also a UMIST project that investigated the forces encountered during the removal of gravity and related structures, with a series of tests. It showed that skirted platforms sustain suction forces over longer deformations than unskirted ones, but a similar breakout force develops. Suction forces are relieved by the flow of diffusion water at the boundaries, and destroyed once a crack or gap extends to the free water. The mechanisms of breakout were investigated.
7.2 PATC PROJECT

This joint industry project by SLP and John Brown began in August 1994. The current participants are BP, Shell, Unocal, Texaco, HSE and the European Union. Other organizations are considering joining. It has the objective of establishing toppling as a fully feasible abandonment option, by establishing appropriate engineering methods, through testing and validation of software. Future toppling proposals will have to be supported by detailed engineering and environmental studies, but there are many factors which cannot at present be supported by quantitative assessment methods. The study will focus mainly on:

- all aspects of loading, but especially hydrodynamic loading, during a collapse particularly relating to the submergence of the topsides unit

- the integrity and resistance of structures during collapse, especially those undergoing gross distortion at hinges.

- the use of explosives.

Further investigation of the stability of seabed debris, identified as a need in an earlier study of the subject by SLP, is also proposed.

The PATC project aims to use existing methods and tools and simple structured methods, and parametric studies based on a simple generic platform geometry. The results should help to assess safety cases for abandonment that may depend on advanced theoretical analysis.

7.3 UMIST-HERMIE EXPLOSIVE CUTTING UNDER WATER

The £2.4M joint industry project with EU funding now in progress is studying ways to improve the efficiency and safety of toppling by explosive cutting. It is being carried out by Reverse Engineering Ltd, a UMIST company. The study focuses on:

- formation of hinges
- toppling mechanisms after hinges have been cut
- shock loading and high strain rates on jacket nodes.

The energy of an underwater explosion is divided almost equally between an almost instantaneous shock wave and a bubble pulse that collapses and regenerates about 10 times. The project under Professor Al-Hassani is looking at ways to use the shock wave effect to cut by brittle fracture which would need small charges and result in less collateral shock to the structure. It is also looking at the effect on the whole structure of partial cutting, and using the inertial forces to assist the toppling process.

7.4 PLATFORM REMOVAL STUDY, BY HARRIS AND PARTNERS FOR THE DEPARTMENT OF ENERGY, 1980

This study examined the feasibility of removing three types of platform with the technology then current. The platforms considered were the Condeep Brent D, the deep water steel Forties C and the shallower steel Indefatigable J. The analysis was
mainly concerned with feasibility and cost, and also identified possible sites for
dumping. Most of the stages enumerated in section 4 above were detailed in this
study. The overall conclusion was that all three types of platform could be removed
with available technology, although one Condeep might need special consideration
because of the large amount of grout injected beneath it.

One conclusion was that developments in future technology would make operations
less hazardous to life, rather than reduce either costs or the time taken for the
decommissioning and removal operation. One safety consideration was the
improvement in the capability of ROVs to carry out work, rather than merely observe
or make measurements, which had not materialised in a practical way. Other technology
requirements identified were explosive handling frames for large diameter members,
inertial navigation systems and specialised salvage vessels, which have been realised.

Requirements identified were:

- aids to maintain the buoyancy of structures cut by explosives
- drill string operated tool to remove soil plugs from piles for internal cutting
- inflatable plugs for sealing conductors in concrete shafts
- sensitive movement sensors for concrete platforms
- attachment of water overpressure pipes to steel skirts.

A small study could confirm that these objectives remain valid and determine how
far they have been realised in the interim.

7.5 REFLOATING GRAVITY PLATFORMS, BY MCALPINE OFFSHORE

This 1988 study for the Department of Energy examined the feasibility of refloating
four different concrete gravity-based platforms by six selected methods. It
recommended a general method of reducing topside weight, followed by deballasting
to near neutral buoyancy and water injection to break the platform away from the
suction of the sea bed. The water injection pressure would be monitored to indicate
the point of break-out, and would then be reduced, avoiding sudden vertical movement.
It was also concluded that risks during refloating could be reduced to acceptable
levels, and that other methods of refloating, while technically feasible, would be
more expensive and less technically reliable.

While safety problems were not addressed specifically, the criterion of avoiding an
uncontrolled break-out has evident safety implications.

7.6 EVALUATION, SELECTION AND DEVELOPMENT OF SUBSEA
CUTTING TECHNIQUES, BY AME FOR THE DEPARTMENT OF
ENERGY, 1990, (TO BE PUBLISHED AS OTH 91 349)

This study examined the performance, limitations and safety and reliability of a range
of subsea cutting techniques suitable for use in removing offshore structures. It includes
detailed assessments of the available techniques as applicable to a range of platform
removal methods, which was intended to provide a comprehensive source of reference
to help in consideration of platform abandonment proposals.

33
The report emphasises the importance of planning and training to the safety of subsea cutting, and advocates the use of ROVs instead of divers wherever possible. The cutting methods are divided into four main types - thermal, mechanical, explosive and electrochemical, which each have particular associated hazards. Thermal methods entail an explosion risk from a variety of possible causes, while mechanical cutting can cause manoeuvring problems and jamming as result of member movement. The use of explosives requires special attention because of the extreme consequences of misfires or accidents. If charges are to be placed by divers, they will require special training in the handling of explosives.

The report considered that there was no single preferred cutting method and recommended the following:

- explosive cutting for final release cuts, particularly in toppling operations
- abrasive water jetting for most tubular members and piles, in cases where speed and simultaneity are not essential, and a support vessel is available on-site
- mechanical casing cutters for severing conductors
- ultrathermic electrode cutting for miscellaneous small tasks
- pyromechanisms for remote cutting of cables and chains used to anchor or support structural elements.

7.7 NORWEGIAN MODEL CONCRETE STUDIES

Norwegian Contractors have installed a number of concrete platforms in the UK and Norwegian sectors, and have also done tests on models and platforms sections to establish behaviour on removal. Two of these studies were done in 1985 on the Gullfaks field. In the largest offshore soil penetration and removal test (1990 report, ref35) a full-size section of skirt was jacked 22 m into the seabed in 217 m of water. A suction of 4 bar was needed to achieve the full penetration depth, but removal resistance was overcome at 2.5 bar overpressure when it was jacked free again.

The behaviour of a Condeep after removal was tested using a 1/100 scale model of Gullfaks C. The object was to see how a platform in a heave extinction test bobbed up and down after breakout. The model was lowered to a neutral draft of 202 m, then pushed down a further 11 m and released. The test indicated quite rapid reduction of heave amplitude in the initial cycles, and the maximum angle that developed through asymmetrical water flow beneath the platform was 3.3°.

A further series of 49 tests was made on a 1/50 scale model of the Draugen platform, reported in 1992 (ref38). The model was pulled to the bottom of a tank, deepdrafted to provide an uplift force, and snapped loose to simulate release from the seabed. Heave, roll and pitch were recorded. The uplift force represented was between 950 and 26 900 t, and the metacentric height in free-floating conditions was also varied. In some of the tests the model was given an initial tilt of up to 15°. The greatest heel measurement recorded was 34°, from an initial inclination of 10°, but the maximum from a vertical start was 12°. The tests established that there would never be any danger of the platform collapsing during removal.
7.8 OTHER INVESTIGATIONS

DRA (Fort Halstead)

DRA have experience of modelling shaped charges, mainly for warheads against steel or concrete, but also linear charges. The simulation models (hyrdocodes) developed have been validated by field trials and agree to better than 5% over a wide range of designs. An underwater trial on a tubular T-section is proposed to validate hydrocodes for structural response. Recent work has studied the effects on charges of shock from detonations in close proximity.

Rockwater

Three novel hook concepts are being developed specifically for attachment by ROV, to replace the current approach of adapting existing crane hooks which is very slow:

1) A hook with a hydraulic mechanism - a squeeze by the ROV opens the safety gate and holds the hook securely. When released in position it closes automatically. This hook can carry up to 25 t, and several proposals have been made to the OSO for development.

2) This is a novel ‘button’ hook. An elliptical hole is made by electrochemical cutting, and a similarly shaped peg is dropped into it and given a ¼ turn to lock it. It can hold up to 170 t.

3) A variant on (2) in which the hole cut is like a keyhole, and the peg is a ball and shank that goes through the wide bit and is pulled into the narrow bit.

Research on electrochemical cutting is being done for Rockwater by Edinburgh University. The method can penetrate ¼” steel in 6 minutes, using 180 amp at 12v. The only problem is that good contact is needed, through a stud weld, or by cleaning. The (2) method was tested in the Norwegian sector at the end of 1994, although not for abandonment.

7.9 KNOWLEDGE-BASED SAFETY ADVICE SYSTEM (PORTSMOUTH UNIVERSITY)

This academic project sought to tackle the high accident rates in the onshore demolition business by setting up a computerised safety advisor (SADD) for such operations (ref13). The system included expert advice from an industrial dismantling firm and health and safety specialists, and references to legislation and guidance notes. It would clarify hazards and help in the making of design decisions, supported by the information contained in the system. The main thrust of the work was to discover the problems in constructing such a system, and how to overcome them. The system could not be used for platform removal as it stands, but could be adapted for the better understood aspects such as topsides dismantling to make sure that all the necessary factors have been taken into account. It could also be extended to include references to research that would enhance the scarce offshore experience.
7.10 ACCIDENT STATISTICS

The WOAD Offshore Accident Database was searched with the assistance of MaTSU, but no accidents were identified that could be attributed to decommissioning.

A recent (1994) compilation of EC accident data collected by the Committee on Borehole Operations of the Safety and Health Commission for the Mining and other Extractive Industries was also examined. Only a few sheets referred to offshore accidents, and the figures were not broken down in a consistent manner. No accidents could be directly attributed to decommissioning, but a noticeable proportion were due to handling. HSE has confirmed that 50% of offshore accidents were attributable to lifting and handling.

The US Minerals Management Service (MMS) was consulted about US accident experience. MMS does not maintain information on incidents during abandonment, but Dr C. E. Smith confirmed that there had been several major accidents resulting in fatalities during platform removal. He believed that they were associated with divers cutting into the legs of platforms.

The US Occupational Safety and Health Administration (OSHA) was then contacted. OSHA is one of the two bodies responsible for safety on the US Outer Continental Shelf (OCS), that is outside state waters; the other is the US Coastguard. Within OSHA, the Bureau of Labour Statistics, the Office of Maritime Compliance and the Office of General Industry were contacted, but none was able to help. Statistics relate to the petroleum industry generally: production, refining and distribution. Statistics are also available for various occupations such as diving and crane-driving, but they are not industry-specific. Offshore activity cannot be separately identified.

7.11 US PAPERS

A dozen or so papers were provided by Dr C Smith of the US MMS (they will be offered to the Offshore Safety Division on completion of this study). Many of them concern environmental protection and 'rigs-to-reefs' considerations. One paper covering the effects of underwater explosions on marine life includes the effects on swimmers up to 100 feet distant from the detonation, but no divers should be in the water during any underwater explosion. Other papers also consider the effects of explosives, in particular records of the annual GOM Information Transfer Meetings. A 1990 paper records the actual pressures during tests and subsequent removal of a platform in 53 feet of water. A 10-year old paper on Disposal of Offshore Platforms includes the brief statement that the fewer the persons involved the safer the operation.

A long 1987 report on environmental assessment includes the following section on human health and safety, which represents a good summary of US thinking on the problem.

"Structure-removal operations, as well as any other offshore oil field work, may be hazardous to its workers. Lifting and towing operations are an integral part of all current structure-removal activities. The weight of the massive structures and equipment of a structure-removal operation place enormous stresses on mechanical lifting and towing components. Breakage of a line under load or failure of a derrick boom could seriously injure or kill nearby personnel. Even under normal operating
conditions, workers must be cognisant of the potential for crushing or shearing injuries when structures are lifted, swung and loaded on to material barges for transportation to their destinations.

"Minor injuries may occur through thoughtless or careless actions by personnel. Structure-removal operations utilising explosives may leave jagged edges on the legs or pilings. The biofouling community that adheres to the structure may pose a handling hazard to personnel. Cutting and welding operations have special safety precautions to minimise potential injury to workers.

"In addition to these general, potentially hazardous, conditions for workers, in structure-removal activities, both explosive and non-explosive removal methodologies have their own inherent hazards. Handling and transporting explosives have special precautions to avoid unacceptable risks. Handling of Class A explosives should be done by or under the direction and supervision of appropriately trained and experienced personnel. Likewise, transportation of Class A explosives should be conducted in accordance with requirements prescribed by the Department of Transportation and the US Coast Guard.

"Explosives of some type may be used on all structure removals. At present, bulk explosives are routinely used to sever the multiple-string, cemented conductors and casing of permanently abandoned wells. Alternative methods for this particular application are not as successful or preferred by salvage companies over bulk explosive methods. Preparing, priming, placing and detonating explosives should be done by technicians properly trained to conduct these operations.

"Divers face potential hazards from both explosive and non-explosive structure-removal activities. After a crew jets soil out of the structure's leg or piling 16 ft (5 m) below the seafloor, divers descend inside the legs to place explosive charges or to conduct underwater arc cutting operations. Conditions are confining with no ambient light and with poor visibility due to turbid waters. Underwater arc cutting operations also have the possibility of encountering pockets of gas adjacent to the legs or pilings. Ignition of these could result in an explosion that may seriously harm a diver. Divers also face the risk of a piling or leg shifting when stress is relieved as they sever a member of the structure.

"There are numerous ways to mitigate potential hazards to human health and safety. Effective safety and maintenance programs will reduce risks to structure-removal personnel. [References are given to various OCS Orders and API Recommended Practices.] Shallow water surveys... and as-built pipeline data may provide valuable data to the lessees or operators in structure-removal operations.

"The alternative of leaving a structure in place also carries some potential hazards to human health and safety. Failure of a structure's aids to navigation or failure to maintain structural integrity may endanger maritime personnel.

"Sufficient legal and regulatory guidance exists to lessen the hazards faced during structure-removal activities if appropriate precautions are taken by lessees, operators and their contractors."

37
8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

1 There is little North West European Continental Shelf (NWECs) experience of abandonment, and certainly too little to provide sufficient data for meaningful risk analyses. On the other hand, there is a good deal of experience offshore the United States in the Gulf of Mexico, but only a small proportion of it is relevant to the North Sea, and it is sporadically documented.

2 A considerable amount of abandonment activity can be expected in the next twenty years.

3 The toppling of Piper Alpha cannot be considered as a precedent as the structure was already severely damaged and had to be demolished rapidly before further deterioration occurred. Some measurements were made that may be useful.

4 A great deal of research has been done, and continues, on various aspects of abandonment. While its primary objective has rarely been safety, safety aspects were often considered. Some of this research is specific to the abandonment of particular platforms and may not therefore be available for immediate industry-wide use.

5 Information will be required to make an acceptable safety case for abandonment, and operators' current plans to provide this for large steel platforms are based on computer simulation and research on individual cutting operations.

6 There is a particular problem in the case of Joint Industry Projects. Operators outside these programmes may need either to repeat the work or to buy in to the results.

7 There is considerable relevant experience on the NWECs, onshore and in coastal regions, in regard to operations such as installation, heavy lifts, salvage and scrap, dredging, and civil engineering. The onshore demolition industry is used to working on petrochemical plant, refineries, etc, which present similar safety problems to topsides decommissioning, and this expertise should be transferable to abandonment. These industries, however, have little experience of the difficulties of working offshore, and the offshore industry is not always aware of external capabilities.

8 Several platforms have been removed from shallow water on the NWECs, and many in the Gulf of Mexico, and the experience is relevant to all southern North Sea platforms (the great majority by number of the total in the UK sector). Removal of platforms in up to 50m water depth does not appear to pose technical or safety problems if properly planned.

9 Experience of platform removal from water deeper than 50m is confined to the Gulf of Mexico (up to 375', 96 m) and Amposta, off Spain (62 m). A number of documented mishaps occurred during these removals, which may give some lessons to be learned. Problems in the UK sector, reported verbally, include
handling loads at sea and diving. They seem to have been due to failures of planning and organisation rather than lack of knowledge. Platforms that have been removed were smaller, and usually shallower, than some impending North Sea abandonments, which can therefore be expected to pose greater problems.

In our meetings, preference for methods of abandonment depended on the experience of the organisation we were talking to. Heavy lift contractors proposed large-scale removal using their own facilities; operators of fixed platforms preferred piece small removal and toppling; Hamilton has used support vessels and heavy lift vessels.

Future abandonment plans will depend on the facilities available at the time. Some heavy lift vessels are being converted or scrapped, and others may be in the future if there is insufficient demand for them.

Sequential abandonment of a number of platforms, possibly with different owners, could enable heavy lift vessels to be maintained in use as their very high mobilisation costs could then be shared.

Even for the simpler cases in relatively shallow water, abandonment is not merely the reverse of installation and requires considerable engineering input.

A limited number of operations is involved in an abandonment (see section 5), but the way the operation (e.g., cutting) is carried out and its scale will depend on the type of structure.

Toppling is a major new topic which has only been done once, in the case of Piper Alpha, not entirely satisfactorily from the safety point of view. Toppling is being investigated in two major projects. Its outcome depends on successful cutting of members under water, and correct prediction of the resulting behaviour of the severed structure.

Not everyone believes that all concrete platforms could be refloated. There is particular doubt about Ninian Central on account of its size, (but not in the McAlpine 1988 study); the Beryl A Condeep had a great deal of grout injected under the base to fill a void caused by a blow-out (Harris, 1980); and Ravenspurn has open flotation tanks that were ballasted and concreted over.

ROVs are good at observation and assisting in deploying remote handling devices for placing charges, jet cutting and other pre-planned tasks. They are much less efficient at dealing with unplanned situations.

DTI is responsible for abandonment plans, including environmental aspects, and HSE only become formally involved when a safety case is discussed.

During the course of this study, few major research needs on safety aspects of abandonment were identifiable that are not being addressed already.

Some aspects that may need research are listed in 8.2-4 below, together with recommendations on matters of administration and dissemination.
8.2 RECOMMENDATIONS

1. Some assessment of the quality of current research programmes and comparisons between them by people capable of appreciating the finer points of the technology, are advisable. The object would be to identify overlaps, contradictions and omissions of detail.

2. Amoco has offered to take the Offshore Safety Division into its research and planning for removal of the NW Hutton platform (see separate correspondence), in return for safety advice. Their computer simulation may well be in advance of any other and the offer should be accepted.

3. HSE should consider whether a more detailed study of mishaps during abandonment operations would be worthwhile from two points of view: are there lessons still to be learned, and is sufficient information available to be meaningful?

4. The following research was proposed during the course of the study:

---

Explosives

- There is widespread concern about the risk and consequences of misfires during detonation of explosives, but the practitioners claim high reliability. This claim should be validated by examination of records, and of available computer simulation software.

- There should be a compilation of relevant research, e.g. safe stand-off distances for ships and divers during explosions. There is particular concern on the effects of water depth and bottom conditions.

- tests of collateral effects of bulk charges and collision charges

- integrity and reliability of charges in place if the operation is suspended during bad weather

- reliability of charges and firing circuits to avoid misfires; field trials of acoustic detonation and bracelet charges were specifically mentioned

- detection and effects of unsuccessful cuts

- size of exclusion zones and safe distances in explosive cutting of topsides.

---

Other cutting methods

- effects of locked-in stresses on mechanical cutting methods.
Lifting

- dynamic effects on cranes when back-loading heavy lifts onto vessels
- integrity of structures for lifting if they were designed to be barge-launched
- examination of the problem of lifting topsides elements that have been modified or had lifting points removed.

Toppling

- structural integrity prior to, during and after toppling, particularly with respect to the air-sea interface (slamming), and detachment of buoyant members
- calibration of non-linear finite element programs for simulation of toppling
- experimental work on the formation of hinges (but n.b. model tests are proposed in the FATC project).

Concrete and other gravity based structures

- a review of work done on refloating gravity based structures, especially the 1988 McAlpine study for HSE, could help to resolve doubts about the possibility of refloating them (ref 8.1-16), and should also consider safety implications of deballasting a manned platform.

Remote handling

- encouragement should be given to the development of underwater remote handling systems, to minimise the use of divers in potentially hazardous situations.

Phased abandonment

- research into safety and integrity of out-of-use structures which are no longer being maintained to an operational level. The role of a certifying authority in such cases should be defined.

- HSE should consider the safety implications if heavy lift vessels were not available in the future. There is a bigger safety margin in the lifting capacity of a large vessel and larger lifts should also require less time working offshore.

Management

- consideration should be given to ways of presenting knowledge gained, particularly of available research, to make it easily accessible, e.g. the SADI expert system could be adapted to offshore demolition.
5 The dissemination of research results, including the results of work recommended above, would contribute to the safety of abandonment.

6 New platform designs should take account of the need for eventual abandonment, as will be required by the IMO from 1998.
ACKNOWLEDGEMENTS

The authors would like to thank the representatives of the following organizations for providing information and opinions to the study:

Health and Safety Executive - Offshore Safety Division
Amoco (UK) Exploration Company
Auris Environmental
BP Exploration
Brown & Root Engineering
John Burt Associates
Defence Research Agency
E&P Forum
Hamilton Brothers Oil & Gas Ltd.
Heerema Engineering Services (UK) Ltd.
Lloyd's Register of Shipping - Offshore Division
M&M Protection Consultants (US)
McDermott Engineering (Europe) Limited
Minerals Management Service (US)
Mott MacDonald Industroil & Commercial
Phillips Petroleum Company United Kingdom Limited
Reverse Engineering Ltd.
Rockwater Ltd.
Smit International (UK) Ltd.
UMIST
Unocal UK Ltd.

Opinions expressed were personal and may not necessarily reflect those of their organizations. The authors' interpretations, conclusions and recommendations are theirs alone.
REFERENCES

CONFERENCE PAPERS

1 Explosives technology, by T F Grattan, IMechE, 29 September 1994
2 Technology for abandonment, by D Fowler, IMechE, 29 September 1994
3 Re-qualification and decommissioning of offshore installations, by H M Williams, IMechE, 29 September 1994
4 Platform abandonment by in situ demolition, by B L Smith and P M Blair-Fish, IMechE, 29 September 1994
5 Abandonment: Legal requirements, by M Roberts, 26th Offshore Technology Conference, Houston, 1994 OTC 7 476
6 Planning for abandonment, by T W Bartlett, 26th Offshore Technology Conference, Houston, 1994 OTC 7 478
7 Cleaning of process and utility systems, by T W Bartlett, 26th Offshore Technology Conference, Houston, 1994 OTC 7 480
8 Deconstruction of an offshore platform, by T W Bartlett, 26th Offshore Technology Conference, Houston, 1994 OTC 7 481
9 Achieving cost-effective, accurate and safe subsea installation and removal of structures in deep hostile seas, by H M Williams, DEEPTEC '94
10 Safety issues, by P J Waite, Decommissioning and removal of offshore structures, IBC, 15/16 September 1994
11 Considerations for underwater explosive cutting, by T Digges, Sept 1993
12 Decommissioning - the safe approach, by M Corcoran et al, third international conference on decommissioning offshore, onshore, demolition and nuclear works 1992, UMIST
13 A knowledge-based safety advisor for the demolition industry, by D St J Fox & A J Kispa, third international conference on decommissioning offshore, onshore, demolition and nuclear works 1992, UMIST
14 Platform removal method for the larger offshore structures: Case histories, by N Carr & D N McDonald, 23rd Offshore Technology Conference, Houston, 1991 OTC 6 780
15 Removal of concrete gravity platforms, by I L Whyte, second international conference on decommissioning offshore, onshore, demolition and nuclear works 1990, UMIST
16 Case history: Salvage of multiple platforms and pipelines offshore Texas, by W L Thornton, 21st Offshore Technology Conference, Houston, 1989 OTC 6 074

REPORTS

17 Platform removal study, 1980, by Harris and Partners for Department of Energy, OTR 80 092
18 Study of the abandonment of offshore pipelines, by John Brown Offshore Structures Ltd for the Department of Energy, OTN 91 159
19 Refloating gravity platforms, joint industry study, 1988 (2 volumes), by McAlpine Offshore, OTN 88 142
20 Removal of offshore installations - safety aspects, by Hollobone Hibbert and Associates, 1988, E/5B/CON/8 078/2 268
21 Comparative safety evaluation of arrangements for accommodating personnel offshore, by Offshore Certification Bureau for the Department of Energy, OTN 88 175

47
Decommissioning and removal of offshore structures Phase II, by UMIST (MTD managed programme) OTO 91 013

Evaluation, selection and development of subsea cutting techniques, by AME Ltd, OTH 91 349


Aging offshore structures - a review of recent UK research by Dr. J V Sharp, 1992

Oil and Gas Prospects 1994, Grampian Regional Council

Abandonment - a reassessment, 1994, Smith Rea

Investigations into the damage caused to a diver's helmet by an explosion during oxy-arc cutting operations in the North Sea, by P L Wells (ref MaTR135), from HSE

Compilation of accident data, Doc No 5029/1/94 EN, Safety and Health Commission for the Mining and other Extractive industries, Committee on Borehole Operations

ARTICLES

North Sea platform decommissioning, by W G Laver, Civil Engineering, Aug 1992, pp 116-126

Offshore Engineer:

From production platforms to artificial reefs, Sept 1990, pp 26 -7

Placid exits gracefully, July 1990, pp 13 -15

Amposta affords lessons for deepwater abandonment, March 1990, pp 20-1

Safe practice for explosive subsea cutting, March 1990, pp 25-7

Anatomy of a concrete structure removal, March 1990, pp 28-33

Born again Brent, March 1994, pp 22-30

Others:

Cold cut frees Fulmar buoy, Offshore, Nov 1994, pp 166-7

Abandonment - the North Sea's newest industry, Petroleum Review, Sept 1994

Built-in abandonment, Marine Engineers Review (MER), Nov 1992, p 58

Smart thinking for installation, by ETPM, Euroll, August 1994

LEGISLATION


Petroleum Act, 1987

Offshore Safety Act, 1992

The Offshore Installations (Safety Case) Regulations 1992 SI 1992 No 2885, and the associated guidance notes

Draft Offshore Installation and Pipeline Works (Management and Administration) Regulations, 1994, consultative document issued by HSE
GUIDELINES AND CODES OF PRACTICE

47  Guidelines and Standards for the removal of offshore installations and structures on the continental shelf and in the exclusive economic zone, IMO, 1989
48  Code of practice for the safe use of high pressure water jetting equipment by divers, AODC 1988
49  The safe use of explosives under water (in preparation), MTD
A1 PROGRAMME OF WORK

Identify research needed to ensure the safety and health of operatives during decommissioning and removal, by identifying key activities, breaking them down into individual tasks and associating the risks to operatives with each task and identify significant risks that have not been adequately researched.

Methods of abandonment will be examined. The processes for the method of abandonment examined under the headings:

(a) Planning and preparation
(b) Plugging and abandonment of wells
(c) Topsides decommissioning
(d) Removal and disposal of topsides facilities
(e) Removal and disposal of main structure

(i) above sea
(ii) subsea

Industry practices in offshore construction, maintenance and repair of equipment and structures shall be researched in relation to the safety, health and welfare of operatives.

A literature search shall be made to update the review of safety, health and welfare research relating to decommissioning and removal of Installations.

By comparing the hazards identified in Stage 1 with Industry’s Practices and research identified in 2 & 3, areas of uncertainty that may need research shall be identified.
A2 ACTIVITIES UNDERTAKEN IN THE STUDY

INITIAL WORK

The work began on 9 September 1994. The terms of reference are attached as Appendix A1.

Initially a plan was drawn up to:

- make a search of papers, conference proceedings, magazine articles and databases
- interview key industry figures.

The contractors drew upon their 1988 (ref 18) as a source. A list of eight abandonment activities was drawn up. This was described in the initial report. It was modified in the light of discussions, and nine activities are considered in the final report, plus a tenth, disposal of arisings, which, while not the concern of the report, will influence work done in some of the earlier stages.

LITERATURE SEARCHES

An initial search of press cuttings in the Institute of Petroleum library identified many papers. In particular, the University of Manchester Institute of Science and Technology (UMIST) has produced a bibliography of 41 primary references on Decommissioning and Removal. A search of the INFOIL-SESAME database has been made.

A search was made of the Institution of Chemical Engineers (I Chem E) database. I Chem E identified an annual compilation of the hundred largest losses in the hydrocarbon and chemical industries including construction, maintenance and produced demolition by Marsh and McLennan. M&M New York Office provided the most recent version.

A structural bibliographic search was made of the University of Tulsa database through this Institute of Petroleum.

HSE-OSD produced copies of reports on previous research studies relevant to abandonment, and a set of papers presented at a conference on the subject, on 29 September 1994.

A bibliography of the 48 papers and articles obtained is attached as Appendix A4. It also includes references to legislation and guidance. Lists of steel structures and concrete structures, classified into water depths of 50 metres to 75 metres and over 75 metres have been purchased from Infield System Ltd of London. The lists give the operator, year of installation, water depth, total weight and structural weight of each platform. They will assist in assigning relative importance to, for example, lifting or toppling.
PERSONAL CONTACTS

From the literature search, personal contacts, operators known to be contemplating abandonment and the North Sea Directory, a list of possible contacts was drawn up. Meetings were held with representatives, or correspondence exchanged with:

- 2 authorities
- 5 oil companies
- 3 consultants
- 6 contractors
- 1 salvage company
- 1 certifying authority
- 3 academic institutions
- 2 industry associations
- The Norwegian Petroleum Directorate
- The US Minerals Management Service
- Defence Research Agency

It was not possible to see or talk to all the contacts identified in the time available for this study.

Response was very positive. A number of meetings were held and other companies made written submissions. Due to the changing circumstances in the industry, some contacts who were, until recently, key figures in the industry were found to be no longer employed.

A list of contacts, with dates of meetings, is attached as Appendix A5.

REPORTS

- A preliminary report was submitted on 30 September 1994
- An intermediate report was submitted on 18 November 1994
- The draft final report was submitted on 2 February 1995
A3 DEEP WATER PLATFORMS ON THE UKCS
**INFIELD DATA BUREAU**

**UK SECTOR GRAVITY BASED PLATFORMS, WHICH ARE CURRENTLY OPERATIONAL OR SHUT IN, IN WATER DEPTHS GREATER THAN OR EQUAL TO 75M**

<table>
<thead>
<tr>
<th>OPERATOR</th>
<th>PLATFORM NAME</th>
<th>YEAR INST'D</th>
<th>TYPE</th>
<th>WATER DEPTH (M)</th>
<th>TOTAL WEIGHT (T)</th>
<th>JACKET WEIGHT (T)</th>
<th>CON MATERIAL</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEVRON PETROLEUM (UK) LTD</td>
<td>NINIAN CENTRAL</td>
<td>1978</td>
<td>GRAVITY</td>
<td>143</td>
<td>623,000</td>
<td>584,000</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MOBIL NORTH SEA LTD</td>
<td>BERYL A</td>
<td>1975</td>
<td>GRAVITY</td>
<td>117</td>
<td>228,000</td>
<td>200,000</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MOBIL NORTH SEA LTD</td>
<td>BERYL A FL</td>
<td>1976</td>
<td>GRAVITY</td>
<td>117</td>
<td>2,000</td>
<td>1,400</td>
<td>ST/CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>PHILLIPS PETROLEUM CO UK LTD</td>
<td>MAUREEN A</td>
<td>1983</td>
<td>GRAVITY</td>
<td>96</td>
<td>111,750</td>
<td>42,750</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>BRENTE B</td>
<td>1975</td>
<td>GRAVITY</td>
<td>139</td>
<td>195,257</td>
<td>165,654</td>
<td>CON</td>
<td>SHUT IN</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>BRENTE C</td>
<td>1978</td>
<td>GRAVITY</td>
<td>141</td>
<td>319,471</td>
<td>287,542</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>BRENTE D</td>
<td>1976</td>
<td>GRAVITY</td>
<td>142</td>
<td>207,107</td>
<td>177,809</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>BRENTE FLARE</td>
<td>1975</td>
<td>GRAVITY</td>
<td>140</td>
<td>1,250</td>
<td>1,200</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>CORMORANT SOUTH</td>
<td>1978</td>
<td>GRAVITY</td>
<td>150</td>
<td>323,093</td>
<td>294,655</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>DUNLIN A</td>
<td>1977</td>
<td>GRAVITY</td>
<td>151</td>
<td>253,723</td>
<td>228,511</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>FRIGG CDP1</td>
<td>1975</td>
<td>GRAVITY</td>
<td>98</td>
<td>205,000</td>
<td>150,000</td>
<td>CON</td>
<td>SHUT IN</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>FRIGG FP</td>
<td>1978</td>
<td>GRAVITY</td>
<td>109</td>
<td>2,800</td>
<td></td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>FRIGG MCP-01</td>
<td>1976</td>
<td>GRAVITY</td>
<td>94</td>
<td>200,000</td>
<td>150,000</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>FRIGG TP1</td>
<td>1978</td>
<td>GRAVITY</td>
<td>104</td>
<td>178,000</td>
<td>150,000</td>
<td>CON</td>
<td>OPERATIONAL</td>
</tr>
</tbody>
</table>

Produced by INFIELD Systems Limited
for Ray Street
21 March 1995
# INFIELD DATA BUREAU

**UK SECTOR PILED PLATFORMS, WHICH ARE CURRENTLY OPERATIONAL OR SHUT IN, IN WATER DEPTHS BETWEEN 50 TO 75M**

<table>
<thead>
<tr>
<th>OPERATOR</th>
<th>PLATFORM NAME</th>
<th>YEAR INST'D</th>
<th>TYPE</th>
<th>WATER DEPTH (M)</th>
<th>TOTAL WEIGHT (T)</th>
<th>JACKET WEIGHT (T)</th>
<th>CON MATERIAL</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>BEATRICE C</td>
<td>1964</td>
<td>PILED</td>
<td>50</td>
<td>1,350</td>
<td>515</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>CLEETON P/Q</td>
<td>1988</td>
<td>PILED</td>
<td>50</td>
<td>11,400</td>
<td>3,100</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>CLEETON WHD</td>
<td>1987</td>
<td>PILED</td>
<td>50</td>
<td>2,430</td>
<td>1,140</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>RAVENSPURN SOUTH A</td>
<td>1988</td>
<td>PILED</td>
<td>50</td>
<td>4,260</td>
<td>1,740</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>RAVENSPURN SOUTH B</td>
<td>1988</td>
<td>PILED</td>
<td>50</td>
<td>4,000</td>
<td>1,770</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLOSION OPERATING CO LTD</td>
<td>RAVENSPURN SOUTH C</td>
<td>1988</td>
<td>PILED</td>
<td>50</td>
<td>4,180</td>
<td>1,900</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
</tbody>
</table>

Produced by INFIELD Systems Limited
for Ray Street
21 March 1995
# INFIELD DATA BUREAU

UK SECTOR PILED PLATFORMS, WHICH ARE CURRENTLY OPERATIONAL OR SHUT IN, IN WATER DEPTHS GREATER THAN OR EQUAL TO 75M

<table>
<thead>
<tr>
<th>OPERATOR</th>
<th>PLATFORM NAME</th>
<th>YEAR INST'D</th>
<th>TYPE</th>
<th>WATER DEPTH (M)</th>
<th>TOTAL WEIGHT (T)</th>
<th>JACKET WEIGHT (T)</th>
<th>CON MATERIAL</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGIP (UK) LTD</td>
<td>TIFFANY</td>
<td>1982</td>
<td>PILED</td>
<td>125</td>
<td>50,888</td>
<td>18,888</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMERADA HESS LTD</td>
<td>SCOTT JD</td>
<td>1982</td>
<td>PILED</td>
<td>140</td>
<td>45,940</td>
<td>16,155</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMERADA HESS LTD</td>
<td>SCOTT JU</td>
<td>1993</td>
<td>PILED</td>
<td>140</td>
<td>30,934</td>
<td>8,867</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>ARBROATH</td>
<td>1989</td>
<td>PILED</td>
<td>91</td>
<td>8,871</td>
<td>3,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>EVEREST NORTH</td>
<td>1992</td>
<td>PILED</td>
<td>90</td>
<td>19,100</td>
<td>5,000</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>EVEREST NORTH RISER</td>
<td>1992</td>
<td>PILED</td>
<td>90</td>
<td>8,700</td>
<td>2,700</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>LOMOND</td>
<td>1992</td>
<td>PILED</td>
<td>86</td>
<td>19,600</td>
<td>5,200</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>MONTROSE A</td>
<td>1975</td>
<td>PILED</td>
<td>86</td>
<td>14,000</td>
<td>6,500</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>AMOCO (UK) EXPLORATION CO</td>
<td>N W HUTTON</td>
<td>1981</td>
<td>PILED</td>
<td>144</td>
<td>39,000</td>
<td>12,652</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>BRUCE D</td>
<td>1992</td>
<td>PILED</td>
<td>121</td>
<td>19,144</td>
<td>8,046</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>BRUCE PUQ</td>
<td>1992</td>
<td>PILED</td>
<td>121</td>
<td>30,527</td>
<td>8,527</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>CLYDE</td>
<td>1986</td>
<td>PILED</td>
<td>79</td>
<td>23,304</td>
<td>12,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>FORTIES FA</td>
<td>1974</td>
<td>PILED</td>
<td>106</td>
<td>31,602</td>
<td>12,310</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>FORTIES FB</td>
<td>1975</td>
<td>PILED</td>
<td>123</td>
<td>35,721</td>
<td>14,152</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>FORTIES FC</td>
<td>1974</td>
<td>PILED</td>
<td>127</td>
<td>35,674</td>
<td>14,152</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>FORTIES FD</td>
<td>1975</td>
<td>PILED</td>
<td>122</td>
<td>34,177</td>
<td>14,152</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>FORTIES FR (UNITY)</td>
<td>1992</td>
<td>PILED</td>
<td>127</td>
<td>12,500</td>
<td>7,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>MAGNUS</td>
<td>1982</td>
<td>PILED</td>
<td>185</td>
<td>70,000</td>
<td>34,400</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>MILLER</td>
<td>1991</td>
<td>PILED</td>
<td>103</td>
<td>51,800</td>
<td>17,000</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>SE FORTIES FE</td>
<td>1966</td>
<td>PILED</td>
<td>55</td>
<td>15,200</td>
<td>7,000</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>BP EXPLORATION OPERATING CO LTD</td>
<td>THISTLE A</td>
<td>1976</td>
<td>PILED</td>
<td>161</td>
<td>60,000</td>
<td>31,326</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>CHEVRON PETROLEUM (UK) LTD</td>
<td>ALBA NORTH</td>
<td>1993</td>
<td>PILED</td>
<td>138</td>
<td>45,700</td>
<td>17,000</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>CHEVRON PETROLEUM (UK) LTD</td>
<td>NINIAN NORTH</td>
<td>1978</td>
<td>PILED</td>
<td>140</td>
<td>38,300</td>
<td>14,100</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>CHEVRON PETROLEUM (UK) LTD</td>
<td>NINIAN SOUTH</td>
<td>1977</td>
<td>PILED</td>
<td>141</td>
<td>51,000</td>
<td>18,500</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>ELF ENTERPRISE CALEDONIA LTD</td>
<td>CLAYMORE A</td>
<td>1976</td>
<td>PILED</td>
<td>110</td>
<td>35,000</td>
<td>12,200</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>ELF ENTERPRISE CALEDONIA LTD</td>
<td>PIPER B</td>
<td>1991</td>
<td>PILED</td>
<td>144</td>
<td>58,423</td>
<td>22,555</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>OPERATOR</td>
<td>PLATFORM NAME</td>
<td>YEAR INST'D</td>
<td>TYPE</td>
<td>WATER DEPTH (M)</td>
<td>TOTAL WEIGHT (T)</td>
<td>JACKET WEIGHT (T)</td>
<td>CON MATERIAL</td>
<td>STATUS</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------</td>
<td>-------------</td>
<td>------</td>
<td>-----------------</td>
<td>------------------</td>
<td>-------------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>ELF ENTERPRISE CALEDONIA LTD</td>
<td>SALTIRE</td>
<td>1992</td>
<td>PILED</td>
<td>145</td>
<td>33,500</td>
<td>13,700</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>ENTERPRISE OIL PLC</td>
<td>NELSON PDQ</td>
<td>1993</td>
<td>PILED</td>
<td>84</td>
<td>35,600</td>
<td>8,900</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MARATHON OIL (UK) LTD</td>
<td>BRAE A</td>
<td>1982</td>
<td>PILED</td>
<td>112</td>
<td>60,800</td>
<td>18,800</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MARATHON OIL (UK) LTD</td>
<td>BRAE B</td>
<td>1987</td>
<td>PILED</td>
<td>99</td>
<td>66,540</td>
<td>18,900</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MARATHON OIL (UK) LTD</td>
<td>BRAE B FL</td>
<td>1987</td>
<td>PILED</td>
<td>99</td>
<td>2,210</td>
<td>1,500</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MARATHON OIL (UK) LTD</td>
<td>BRAE C</td>
<td>1993</td>
<td>PILED</td>
<td>116</td>
<td>36,000</td>
<td>9,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MOBIL NORTH SEA LTD</td>
<td>BERYL A RISER</td>
<td>1990</td>
<td>PILED</td>
<td>117</td>
<td>9,900</td>
<td>5,823</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>MOBIL NORTH SEA LTD</td>
<td>BERYL B</td>
<td>1983</td>
<td>PILED</td>
<td>120</td>
<td>34,300</td>
<td>12,150</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>OXY UK ENERGY COMPANY</td>
<td>MURCHISON</td>
<td>1979</td>
<td>PILED</td>
<td>156</td>
<td>57,844</td>
<td>20,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>AUK A</td>
<td>1974</td>
<td>PILED</td>
<td>83</td>
<td>14,339</td>
<td>3,454</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>BRENT A</td>
<td>1976</td>
<td>PILED</td>
<td>140</td>
<td>40,164</td>
<td>14,225</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>CORMORANT NORTH</td>
<td>1961</td>
<td>PILED</td>
<td>161</td>
<td>41,285</td>
<td>20,052</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>EIDER</td>
<td>1988</td>
<td>PILED</td>
<td>158</td>
<td>33,100</td>
<td>17,100</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>FULMAR A</td>
<td>1980</td>
<td>PILED</td>
<td>84</td>
<td>44,140</td>
<td>12,400</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>FULMAR AD</td>
<td>1979</td>
<td>PILED</td>
<td>84</td>
<td>3,016</td>
<td>1,498</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>GANNET A</td>
<td>1991</td>
<td>PILED</td>
<td>96</td>
<td>28,600</td>
<td>7,750</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>KITTIWAKE</td>
<td>1990</td>
<td>PILED</td>
<td>85</td>
<td>17,500</td>
<td>5,350</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>SHELL UK EXPLORATION &amp; PROD</td>
<td>TERN</td>
<td>1986</td>
<td>PILED</td>
<td>167</td>
<td>53,250</td>
<td>21,250</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TEXACO (UK) LTD</td>
<td>TARTAN A</td>
<td>1979</td>
<td>PILED</td>
<td>142</td>
<td>38,400</td>
<td>14,500</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>ALWYN NORTH NAA</td>
<td>1985</td>
<td>PILED</td>
<td>131</td>
<td>36,000</td>
<td>15,900</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>ALWYN NORTH NAB</td>
<td>1988</td>
<td>PILED</td>
<td>131</td>
<td>30,000</td>
<td>14,800</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>DUNBAR A</td>
<td>1994</td>
<td>PILED</td>
<td>145</td>
<td>25,500</td>
<td>9,300</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>TOTAL OIL MARINE PLC</td>
<td>FRIGG OP</td>
<td>1975</td>
<td>PILED</td>
<td>104</td>
<td>9,500</td>
<td>5,550</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
<tr>
<td>UNOCAL UK LTD</td>
<td>HEATHER A</td>
<td>1977</td>
<td>PILED</td>
<td>143</td>
<td>45,000</td>
<td>17,000</td>
<td>STEEL</td>
<td>OPERATIONAL</td>
</tr>
</tbody>
</table>

Produced by INFIELD Systems Limited
for Ray Street
21 March 1995
# GLOSSARY

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>DEHAZ</td>
<td>decommissioning hazard analysis</td>
</tr>
<tr>
<td>DTI</td>
<td>Department of Trade and Industry</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>HAZAN/HAZOP</td>
<td>hazard analysis/hazard and operability study</td>
</tr>
<tr>
<td>HSE-OSD</td>
<td>Health and Safety Executive, Offshore Safety Division</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>LSA scale</td>
<td>Low specific activity radioactive scale</td>
</tr>
<tr>
<td>MEG and TEG</td>
<td>monoethylene and triethylene glycol</td>
</tr>
<tr>
<td>NWECs</td>
<td>North West European Continental Shelf</td>
</tr>
<tr>
<td>PATC</td>
<td>Platform Abandonment Technology Consortium</td>
</tr>
<tr>
<td>PCB</td>
<td>polychlorinated biphenyl</td>
</tr>
<tr>
<td>ROV</td>
<td>Remotely operated [underwater] vehicle</td>
</tr>
</tbody>
</table>