Introduction

The development of the North Sea oil and gas reserves has resulted in the installation of more than 200 offshore platforms together with pipeline networks and offshore loading systems. A number of the fields are located in deep and hostile waters, and in many cases required innovative engineering and construction on a massive scale. Many of the North Sea fields are now in the final phase of production, or have ceased production altogether, and plans for decommissioning involving the removal and onshore disposal or re-use of the installations are underway.

The decommissioning of the platforms in the North Sea has to conform with the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) of 1998 [1].

A comprehensive decommissioning programme for the North Sea oil and gas fields is considered necessary for the following main reasons:

- To fulfil obligations entered into at the beginning of field development, between oil companies and governments.
- To satisfy the requirements of the public at large and in particular the environmental groups.
- To demonstrate to all relevant agencies that the oil industry is entirely responsible in areas of safety and environment.
- To demonstrate a determination by the oil companies to be responsible for environmental issues with a willingness to lead and share in future offshore developments, which will be of economic benefit to communities at large.
The Maureen field ceased production in October 1999, and the Decommissioning Programme has been formally submitted to the DTI for approval in accordance with the requirements of the Petroleum Act 1998.

The Maureen field is the first major oil field to be decommissioned in the North Sea that was originally designed with removal/re-use in mind.

In summary the Maureen and Moira fields consist of the following main elements:
- Maureen steel gravity platform, and drilling template
- Maureen concrete articulated loading column
- Maureen export oil pipeline
- Moira subsea wellhead and pipelines connected to the Maureen platform.

These main elements are shown in Figure 1.
Maureen and Moira field facilities

The Maureen Platform consists of drilling, production, crude oil storage, and accommodation facilities, and is located in 95.6 metres of water in Block 16/29 of the UK sector of the North Sea. The location of the Maureen field with respect to other field developments in the North Sea is shown in Figure 2. The platform is unique and consists of a large steel gravity base structure supporting a steel lattice frame deck, which in turn supports the drilling, power generation, and accommodation modules. The three steel oil storage tanks forming part of the substructure are interconnected at 90 metre centres with a steel lattice frame. The oil storage tanks are each 27 metres diameter and are supported on steel bases of 47 metres diameter at seabed level. The buoyancy available from the oil storage tanks was used in the earlier construction and installation phases of the project. Figure 3 shows a view of the steel gravity substructure in 1982, as it was being towed at shallow draft immediately after construction in the Hunterston dry dock, in Scotland.

Figure 4 shows the complete platform, after the deck was fitted to the substructure, and whilst under tow to the field in 1983. The oil tanks, now partially submerged, provided the
necessary buoyancy. The whole platform weighs about 110,000 tonnes. The same buoyancy compartments that were used during construction and installation will be used during the refloating of the platform and its towing to a safe inshore location.

The Maureen subsea template structure consists of a steel lattice frame weighing about 490 tonnes, which is piled to the seabed. The template was installed in 1979, and this allowed the drilling and subsea completion of Maureen producing wells prior to platform installation. The precise location of the Maureen platform over the subsea template was achieved by the accurate positioning of two large docking piles alongside the template. The pre-drilled subsea wells were subsequently connected to the deck structure after platform installation with the installation of the conductors (or tubing) as shown in Figure 1.

The Maureen articulated loading column, which served as the oil export facility, consists of an articulated concrete gravity-based structure. The column is 9 metres in diameter, and supports a steel-framed rotating head structure including the loading boom (see Fig 1). The weight of the whole column is about 8000 tonnes. The concrete base is of similar construction to the main column element, and is connected to the column through a cast steel articulated joint, which in turn formed the main product fluid flow path. The column was installed in 1982. Export of oil from the column was via a tanker connected to a hose suspended from the rotating boom structure.

A 24-inch diameter pipeline connects the Maureen platform to the articulated loading column. The overall pipeline length is 2.3 km, and it is buried over its entire length to a depth of about 0.6 metres.

The Moira subsea facilities consist of the Moira wellhead and wellhead protection structure and two small diameter infield pipelines and a control umbilical connecting the Moira facility and the Maureen platform over a distance of 10 km.

Selected decommissioning options

**Maureen platform**
The gravity-based platform will be hydraulically abstracted from the seabed, refloated in a controlled manner, and towed to an inshore deep-water mooring where it will either be modified for re-use, or dismantled and recycled, if suitable re-use is not possible. The removal from the seabed and subsequent transport of this fixed structure as a single unit represents the removal of the largest and heaviest existing fixed structure or facility from an original operational location, at the end of planned service life.

**Maureen template**
The template and subsea wellheads will be removed to shore for deconstruction and recycling.

**Loading column**
The gravity-based articulated loading column will be refloated in a controlled manner and towed to a deep-water mooring either for re-use or deconstruction and recycling, if a suitable re-use cannot be found.

**Oil export pipeline**
The buried export pipeline will be internally cleaned by flushing and pigging, and with both ends capped off, will be left in situ. This is considered to be the safest, most environmentally acceptable, and economic option for the decommissioning of this short length of buried large-diameter pipeline.
Moira subsea wellhead and pipelines

All of the Moira facilities will be removed and transported to shore for either re-use or deconstruction and recycling.

The removal of structures and installations located on the seabed removes obstacles to future shipping, and allows the area to be over-trawlable with least risk to fishermen.

Main technical challenges in the selected decommissioning option

The main technical challenges in the decommissioning of the Maureen facilities are considered to be:

- The removal from the seabed and the controlled refloat of the Maureen platform to a suitable towing draft.
- The tow of this platform to a deep-water mooring.
- The modifications and re-use of the platform, or its deconstruction and recycling.

The removal of the structure from the seabed requires careful consideration of the way in which the platform’s foundation system was designed and installed, as well as a knowledge of the seabed on which the structure rests. The removal and refloat of the main platform in a controlled manner is described below and in more detail in Ref. 4.

Platform foundation system and skirt extraction process

The platform’s foundation system consists of the three interconnected 47 metre diameter bases, which are supported at seabed level. Underneath each of the bases is a series of steel skirts and stiffeners. The arrangement underneath one of the bases is shown in a cross-section in Figure 5. During platform installation, the initial seating between the structure and the seabed was on a 0.4 metre high circular ‘shoe’ located directly underneath the storage tank wall. The main outer circular skirts are 3.8 metres high and penetrate the seafloor by about 3.4 metres. The void on the underside of the bases developed after the initial ‘shoe’ contact (of about 0.4 metres) was subsequently filled with grout, with the grout overflow being observed through a total of forty eight small diameter vertical pipes located on the perimeter of each base. Within the underside of each base is an inner circular skirt of 1.4 metres in height and a series of radial skirts of the same height, which connect the inner and outer circular skirts, thus forming a series of underbase compartments.

The soil on the seabed consists of fine sand down to a depth of between 2.2 metres and 2.7 metres, underneath, which is between 0.3 metres and 1.5 metres of interlayered sandy clay material. Below the interlayered sandy clay is a firm layer of clay. The soil layering underneath the perimeter of each base varied, and this is illustrated in Figure 6. The inner skirts only penetrate the upper clean sand layer, whilst the main outer skirts penetrate into the firm clay layer.
During platform removal, skirt extraction from the soils will be achieved by first deballasting the main storage compartments of the structure to achieve a nominal effective on-bottom weight of around 5000 tonnes, followed by controlled water injection on the underside of the bases through the forty eight original grout overflow pipes. Water injection to the inner compartmental area, bounded by the inner circular skirt, will be through a larger diameter grout overflow pipe located at the centre of each base.

During the skirt extraction process there is a possibility of soil failure on the outside of the skirts induced by the water pressure generated within the underbase compartments. This could take the form of water piping around the edges of the skirts or through localised areas of soil heave. These mechanisms have been carefully studied and in order to improve resistance of the soils to possible failure, the seafloor immediately adjacent to the skirts will be loaded with a rock berm. This will consist of graded crushed rock placed around the bases and extending outwards by about 5 metres, and with an overall height of about 1.8 metres.

Controlled skirt extraction will be achieved by controlling the flow rates and pressure of the water injected under the bases, together with a further gradual reduction in the effective weight of the structure by further limited deballasting of the storage tanks. At any stage during the skirt extraction process it is intended that the available buoyancy of the platform will be limited to less than the minimum calculated skirt resistance to further extraction. This procedure will provide for controlled skirt extraction from the seabed soils and prevent any chance of the structure suddenly moving vertically upwards.

Platform refloat

Having achieved a controlled skirt extraction, and with the platform having a very small effective on-bottom weight and in a level condition, the next stage is to continue a limited deballasting of the main tanks to raise the structure from the seabed. The first stage in this process will be to get the domes of the three main storage tanks to penetrate the sea surface. The sequence of these operations is shown schematically in Figure 7. During the ascent of the platform from the condition where the skirts are touching the seabed until the domes of the main storage tanks reach the surface it will be necessary to displace only a further 1200 tonnes of
water from the storage tanks. This relatively small change in displacement is attributable to the relatively small enclosed volume in the lattice frame of the structure above the level of the domes.

The platform has significant levels of hydrodynamic stability whilst the skirts are touching the seabed, but this reduces to a minimum, but acceptable positive level, at the point immediately prior to the domes penetrating the sea surface. After that point, and with the domes penetrating the sea surface the hydrodynamic stability of the platform increases dramatically. With further deballasting of about 10 000 tonnes of water from each of the storage tanks, the platform will reach a suitable towing draft, with a high level of hydrodynamic stability.

The necessary controlled refloat operation, in which the platform is maintained level during all stages of the ascent, is a requirement due to the minimum levels of hydrodynamic stability available to the platform.

Prior to the commencement of skirt extraction and deballasting, a favourable weather forecast extending for 72 hours is required.

From the first stages of underbase pressurisation until the platform is approaching the towing draft, the whole refloat operation will be conducted remotely using telemetry from a nearby control vessel.

Towing of the platform to the deep wet dock location will be with the use of a similar towing fleet to that adopted during installation, as shown in Figure 4.

Summary
The decommissioning of a large North Sea platform requires careful engineering and planning of the offshore removal and onshore deconstruction operations. The Maureen platform was unique at the time of construction and installation, and the decommissioning process has involved several unique engineering solutions. The decommissioning of the Maureen field will be in accordance with the ‘OSPAR Convention’ of 1998.

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References