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EXPERIENCE OF A UK SHIPYARD IN THE 1990s OFFSHORE MARKET

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SUMMARY

This paper describes the experiences of a large UK shipyard in the offshore vessel market of the late 1990s. During this period the yard worked on newbuildings and conversions of both floating production and drilling vessels. The various projects executed are described, and are set in context by reference to previous UK offshore shipbuilding projects. The major differences between shipbuilding and offshore practice are highlighted, and the impact of this type of activity on the yard's engineering and construction techniques, and on its labour and financial situation is outlined.

1. INTRODUCTION

1.1 GENERAL

In 1989, the Harland & Wolff shipyard in Belfast emerged from a long period of government control, and was privatised. A management and employee buyout resulted in the ownership of the yard transferring to a Norwegian industrial concern and the workforce (who purchased their shares with their own money!).

In the period prior to privatisation, the yard was engaged in the completion of a number of very sophisticated vessels. The dynamically positioned oil production ship (SWOPS) *Seillean* [1] was being built for BP, and the missile armed Auxiliary Oil Replenishment ship *Fort Victoria* was being built for the Royal Fleet Auxiliary.

After completion of these vessels, the yard focused on the construction of Suezmax tankers and Capesize bulk carriers. This programme occupied the early part of the 1990s, and allowed the yard to measure progress in productivity, and benchmark itself against foreign yards (principally Kawasaki Heavy Industries, with whom a co-operation agreement was signed).

During this period, major improvements were made in the areas of terms of employment, open management, removing demarcation, and increasing co-operation and teamwork. By way of example, the technical office was moved nearer the building dock, an open plan office style was adopted for all staff including directors, and union officials were elected to the company Board.

However, in the early 1990s, several Korean shipyards embarked on a massive expansion of their facilities, with new shipbuilding docks being constructed in several locations. This increased capacity had to be filled, and a drop in prices for conventional ships ensued. By way of example, double hulled VLCCs were selling for $95m in the early 1990s, and could be obtained for about $65m in early 2000. Large LNG carriers which were once the preserve of Japanese and European builders at $250m per vessel, have been quoted at around $140m.

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For Harland & Wolff, these difficulties in the conventional shipbuilding market were offset by a resurgence during the mid 1990s in demand for sophisticated, high value vessels for the offshore market. Initially this market centred on floating production vessels for North Sea oilfields, then focused on deepwater drilling vessels, and there is now considerable interest in large floating production vessels for locations such as West Africa.

Apart from the often complex specification and performance of the vessels themselves, the market for large offshore vessels exhibits the following main differences from the conventional ship market:

- the exact specification of the vessel is often not known at the time of contract;
- the governing rules/regulations are not so clear cut as in the case of merchant vessels (e.g. UK Safety Case, Norwegian Quantitative Risk Assessment etc);
- the owner often has a large project team who may not be able to provide quick, firm approvals;
- there are often few precedents (existing designs) from which sound estimates of workscope can be made.

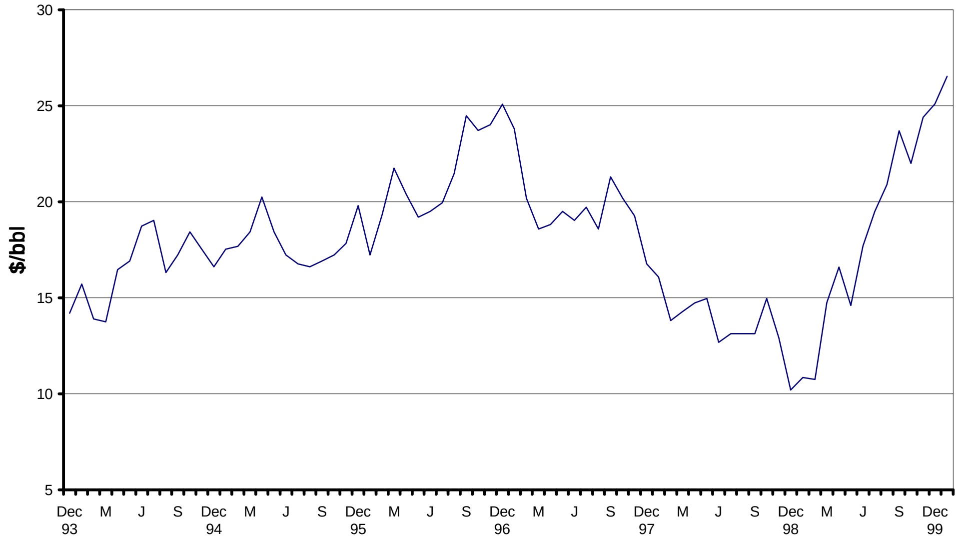
These issues often bring difficulties in project execution for conventional shipyards, which are usually focused on achieving high productivity and low overheads in the building of relatively standard products.

This paper describes how H&W entered this market, the conditions in the market place, the projects which were executed by the yard, and the major impacts which the move into offshore projects had on the yard's engineering, construction, procurement and financial operations. Where possible, these activities of the late 1990s are placed in context by reference to offshore projects executed by UK shipyards in the 1970s and 1980s.

1.2 THE OFFSHORE MARKET OVERVIEW

One of the key indicators of activity in the area of offshore construction is the oil price. Fig. 1 illustrates the movements in the oil price in the second half of the 1990s.

Fig. 1 - Brent Crude Oil Price



A relatively long period of stability followed the drop in prices of 1986, and the industry adjusted to these lower levels. This led to a fairly sustained period of offshore development in the early part of the 1990s. In the UK, a number of substantial oil fields were developed in this period.

Around this time, the CRINE (Cost Reduction In the New Era) initiative was launched to drive down costs in the UK offshore industry, and thus make the industry more competitive worldwide, and also open up the prospects for development of UK fields which would otherwise have been uneconomic.

There is no doubt that the latter part of this policy succeeded, and many of the UK oilfields to which FPSOs were applied in the middle/late 1990s were developed because of this change in approach.

This period of activity was followed by the fall in the oil price in late 1997 and early 1998. This combined with a number of high profile mergers/acquisitions of oil companies and had the effect of delaying budget approvals for many project developments. This is one reason for the lack of orders available for offshore construction yards at the turn of the century.

Because most contracts are made in US dollars, currency exchange rates are a key factor in determining the location of shipbuilding and offshore construction activity.

Fig. 2 and Table 1 illustrate the strengths of the UK pound, the Japanese Yen, the Korean Won and the Spanish peseta in the second half of the 1990s.

Figure 2 - Exchange Rate Movement v US Dollar

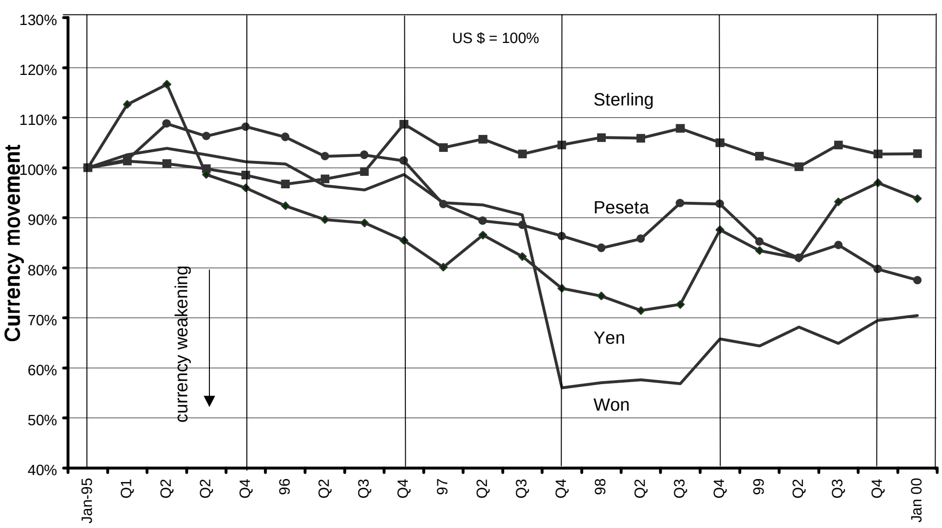


TABLE 1 Exchange Rates to the US Dollar

Year	1995				1996				1997			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4
US$ v £	1.596	1.588	1.572	1.552	1.524	1.54	1.563	1.712	1.638	1.665	1.618	1.647
Sterling v $	0.627	0.630	0.636	0.644	0.656	0.649	0.640	0.584	0.611	0.601	0.618	0.607
Yen v $	88.03	84.99	100.5	103.3	107.3	110.6	111.5	116.0	123.8	114.6	120.5	130.6
Won v $	769.6	759.9	769.3	780	783.5	818.4	826	800.2	848.4	852.9	871.4	1408
Peseta v $	129.6	121.0	123.8	121.6	124.1	128.7	128.4	129.8	142.0	147.3	148.6	152.4

TABLE 1 (contd) Exchange Rates to the US Dollar

Year	1998				1999			
Quarter	1	2	3	4	1	2	3	4
US$ v £	1.67	1.668	1.699	1.654	1.611	1.578	1.647	1.618
Sterling v $	0.599	0.600	0.589	0.605	0.621	0.634	0.607	0.618
Yen v $	133.3	138.7	136.4	113.2	118.8	121.1	106.4	102.3
Won v $	1384	1370	1389	1200	1226	1158	1216	1135
Peseta v $	156.8	153.4	141.7	141.9	154.4	160.6	155.7	165.1

It can be seen that the UK currency has been strong against the dollar since the third quarter of 1996, while the currencies of competing nations have weakened in the same period, with a few short lived exceptions. This has seriously damaged the competitive ability of UK contractors, and counteracted improvements in efficiency or reductions in profit margin.

The marked strengthening of the Japanese Yen against the dollar in mid 1995 forced the Japanese builders to examine all possible remedies to improve their competitiveness, particularly with respect to the Koreans. This extended to searching in Europe for cheaper equipment procurement, as well as the traditional Japanese capacity for straightforward productivity improvement. This drive succeeded, to a greater or lesser extent, and when the Yen subsequently weakened, the Japanese yards were in a stronger position.

The Asian financial crisis of late 1997 and early 1998, meant that for a short time Korean shipyards were unable to offer financial guarantees to prospective Western buyers. Some pending construction contracts were cancelled at that time, as a consequence. With the intervention of the IMF, this problem disappeared, and the Korean Won subsequently weakened, leaving the Korean yards stronger than before.

Many other factors affect the price of offshore vessels and ships, and the relative competitiveness of the different nations. For example, the capacity expansions of the early 1990s are referred to in Section 1.1 above. In the later 1990s, the fall in prices for conventional ships, the ever present drive to fill the recently expanded capacity, and the fear of emerging shipbuilding nations such as China and Vietnam has encouraged the Korean yards to enter the offshore vessel market.

The pace of entry of the Korean builders to the offshore market has been rapid. Both Daewoo and Hyundai had built semi-submersibles in the 1980s, but Samsung was to emerge as the lead Korean offshore yard of the 1990s.

Samsung Heavy Industries delivered their first large oil/products tanker in 1986, their first VLCC in 1995, and a budget class FPSO in 1993 (the *Griffin Venture* for BHP Petroleum). They secured their first order for a drilling vessel in late 1996 (a drillship for Conoco/Reading & Bates) and their first order for a first class FPSO hull at the same time (for Woodside Petroleum's Laminaria Field). By 2000, they will have delivered more dynamically positioned drillships than any builder in the world.

The presence in the offshore market of enormous yards such as this (each processing 600,000 to 1,000,000 tonnes of steel per year) is a very severe challenge to the remaining European and Japanese builders.

After a tremendous contribution in terms of building the offshore fleet, very few Japanese yards displayed a desire to remain in the offshore market during the 1990s. There are a number of reasons for this, including some bad contract experiences during the 1980s, and a general reduction in the design capacity at the yards.

1.3 FLOATING PRODUCTION, STORAGE AND OFFLOADING VESSELS

By the early 1990s, the floating production, storage and offloading vessel (FPSO) was already well proven as an economic field development tool elsewhere in the world, but it was not fully accepted in the UK and Norwegian sectors, due mainly to technical concerns related to the harsh environment.

In the North Sea, the monohull floating platform was confined to a few sporadic examples. The Fulmar field had used a floating storage and offloading unit (FSO) since 1981, and the Harland & Wolff built dynamically positioned *Seillean* [1] produced and stored oil from BP's Cyrus Field in April 1990 (but did not offload by shuttle tanker or pipeline).

It was the leasing of Golar-Nor's *Petrojarl 1* by Amerada Hess for the small Angus Field in 1991 which paved the way for the use of permanently moored floating production, storage and offloading vessels (FPSOs) for full UK field development. The success of Kerr McGee's *Gryphon Alpha* FPSO shortly afterwards reinforced this experience.

These two vessels proved that the technical solutions to the perceived problems were available, and could work in practice. These developments have been described elsewhere, and include the following:

- satisfactory test and service experience with the flexible riser technology required to accommodate the movements of a moored monohull in a harsh environment;
- establishment of confidence in swivel and drag chain technologies required for a weathervaning monohull;
- establishment of confidence in the operability of production equipment under the motions experienced by a monohull;
- emergence of FPSO leasing contractors, thus removing part of the risk from the oil company;
- growing oil industry willingness to consider platform solutions coming from a marine background rather than a civil engineering i.e. originally land based) back-ground.

TABLE 2 Purpose Built FPSO and FSO Hulls of the 1990s

Vessel	Oil field	Oilfield Location	Year of Hull Delivery	Hull Yard
FPSO (*Bohai Chang Ping*) [1]	BZ-34	China	1990	Hudong, China
FPSO (*Anoa Natuna*) [1]	Anoa	Indonesia	1990	IHI, Japan [5]
FSO (*Puteri Dulang*) [1]	Dulang	Malaysia	1991	Mitsubishi, Japan
FSO (*Palanca*) [1]	Palanca	West Africa	1991	Mitsubishi, Japan
FPSO (*Bohai Ming Zhu*) [1]	SZ-36	China	1993	Hudong, China
FPSO (*Griffin Venture*) [1]	Griffin	NW Australia	1993	Samsung, Korea [5]
FSO (*Alba FSU*)	Alba	UK North Sea	1993	Astano, Spain
FPSO (*Gryphon Alpha*) [2]	Gryphon	UK North Sea	1993	Astano, Spain
FSO (*OSI*)	Liverpool Bay	UK Irish Sea	1995	Ishibras (IHI), Brazil
FPS [3]	N'Kossa	West Africa	1995	Marseilles, France
FPSO (*Anasuria*)	Gulliemot/Mallard	UK North Sea	1996	Mitsubishi, Japan
FPSO	Captain	UK North Sea	1996	Astano, Spain [5]
FPSO	Norne	Norway	1996	FELS, Singapore
FPSO [2]	Balder	Norway	1996 [4]	FELS, Singapore [5]
FSO	Njord	Norway	1997	Masa, Finland
FPSO	Schiehallion	UK West Shetland	1997	H&W, UK
LPG FSO	Escravos	West Africa	1997	IHI, Japan
FPSO	Asgard	Norway	1997	Hitachi, Japan
FPSO (*Ramform Banff*)	Banff	UK North Sea	1997	Hyundai Mipo, Korea
FPSO (*Northern Endeavour*)	Laminaria	NW Australia	1998	Samsung, Korea
FPSO	Varg	Norway	1998	FELS, Singapore [5]
FPSO	Jotun	Norway	1998	Masa, Finland
FPSO [2]	(Rasmussen T550)	Not employed	1999	Mitsui, Japan
FPSO	Girassol	West Africa	2000	Hyundai, Korea
FPSO	Terra Nova	NE Canada	2000	Daewoo, Korea

1) these vessels were generally designed and built to less rigorous standards than the later UK and Norway vessels;
2) speculative build hull;
3) concrete hull, no oil storage;
4) this was the first delivery date – considerable extra work was undertaken in Europe;
5) hull yard scope included topsides work.

TABLE 3 Tanker Hulls Newbuilt for Eventual Use on UK North Sea FPSO Projects

Vessel	Oil field & Oil Company	First Oil	Year of Hull Delivery	Tanker Type	Hull Yard	Marine Conversion Yard	Topsides Yard
Glas Dowr	Durward/Dauntless (Amerada Hess)	1997	1996	Double hull Aframax	Namura, Japan	H&W, Belfast	Heerema, Hartlepool
Bleo Holm	Ross (Talisman)	1999	1997	Double hull Aframax	Hitachi, Japan	N/A	UIE, Clydebank
Triton 1	Triton (Amerada Hess, Shell)	2000	1998	Double hull Aframax	Samsung, Korea	Sembawang, Singapore	Kvaerner, Tees

TABLE 4 Vessels Converted for UK FPSO Projects

Vessel name (as FPSO)	Oil Field	First Oil	Year of Original Hull Delivery	Basis Vessel Type	Original Hull Yard	Marine Conversion Yard	Topsides Yard
Uisge Gorm	Fife	1995	1983	Double sided, products tanker	Odense, Denmark	AESA, Cadiz	McNulty, Tyne
Maersk Curlew	Curlew	1997	1983	Double sided, products tanker	Odense, Denmark	A&P, Tyne	AMEC, Tyne
North Sea Producer	MacCulloch	1997	1984	Double sided, products tanker	Odense, Denmark	A&P, Tyne	SLP, Tees
Petrojarl Foinaven	Foinaven	1997	1989	Bow and stern of Russian support ship	Wartsila, Finland	Astano, Spain	Astano, Spain
Berge Hugin	Pierce	1999	1997	Double hull, multi-purpose DP tanker	Samsung, Korea	N/A	Aker McNulty, Tyne

In the North Sea area, this technical acceptance coincided with the declining size of field discoveries on the UK sector and a resulting need to use more economic development techniques, and a general move towards deeper water, especially West of Shetland and offshore Northern Norway.

These factors meant that the number of FPSOs in service or under development for the UK and Norway increased considerably during the middle 1990s.

Once some initial concerns regarding structural integrity, cargo pump rooms and accommodation location had been addressed, converted tankers were used for a lot of the smaller UK developments (Tables 3, 4). Newbuildings (Table 2) were the universal choice on Norwegian oilfields and were used in a number of cases on the UK shelf.

The UK FPSO boom was characterised by a succession of new contractors seeking entry to the business. For almost every new project, the oilfield developer was able to find a new contractor willing to offer aggressive pricing and schedule. Many of these projects experienced financial problems of one sort or another.

In the Norwegian sector, the FPSO business was characterised by the use of Far Eastern built hulls, claims of technical problems in meeting Norwegian requirements, and the publication of large cost overruns.

It should be noted that many FPSO projects have been set far more difficult targets in terms of budget and schedule than previous conventional projects, and it is somewhat unfair to categorise them as failures in this regard.

During the 1990s, H&W participated in one FPSO newbuilding project and one conversion project.

However, the declining size of the UK fields, and the fall in oil price during 1998 has sharply reduced FPSO activity in the North Sea area.

Meanwhile, large FPSOs and FSOs continued to be used in other parts of the world, as illustrated by Table 2. To date, European yards have not been successful in penetrating this market, although several strong bids have been made against Far Eastern competition.

The West African region had always employed large converted tankers as FPSOs and FSOs, but has now started to employ purpose designed newbuildings to deal with the very large fields being discovered.

1.4 DRILLING UNITS

During the 1960s, a number of UK shipyards were engaged in the construction of semi-submersible drilling units. The Sedco 135 class unit *Sea Quest* was completed by H&W in 1966 [2} and went on to discover the Forties oilfield.

Later, in the middle 1970s, there was a huge worldwide boom in the construction of drilling vessels, principally semi-submersibles. The UK failed to take part in this activity, with the exception of two dynamically positioned drillships (*Ben Ocean Lancer, Pacnorse 1),* ordered in 1974 and delivered by the Scott Lithgow group in the late 1970s [3].

This building boom was brought to an end by the collapse in charter rates for drilling vessels in 1975.

There was a smaller peak in rig building activity during the middle 1980s, which focused on semi-submersibles rather than drillships. The fall in the oil price of 1986 helped to end this mini-boom, but UK yards [4] built three sophisticated semi-submersibles in this period (*Sea Explorer, Sovereign Explorer, Ocean Alliance*).

There was very little drilling vessel construction activity during the late 1980s and early 1990s, but the decline in oil and gas reserves in shallower water, and the belief that the remaining substantial reserves are located in deep water encouraged interest in deep water exploration towards the end of the 1990s.

Technically, both semi-submersibles and drillships may be dynamically positioned to drill in deep water.

However, the semi-submersible cannot significantly reduce environmental loads by weathervaning into the weather, and the drillship can offer greater deckload capacity and deck area. The large quantities of riser, tubulars and drilling fluids associated with deep water operations place heavy demands on these parameters, and this created renewed interest in the drillship concept.

Combined with the temporarily high drilling charter rates from 1996 to 1998, these factors resulted in a number of newbuild drillship orders being placed around the world [5].

By May 1998, the new generation of drillships on order totalled fourteen vessels (Table 1). More than two thirds of this work was placed in Korea (not a single order in Japan !), but H&W secured orders for two of this fleet.

These vessels are all designed for operations in about 10,000ft water depth, although the actual water depth capacity as-delivered varies depending on the length of on-board riser initially fitted. The new drillships have variable deckload capacities in the range 15,000 to 25,000 tonnes, compared with the 6000t to 9000t of the earlier generation of ships.

In addition to drillship newbuilds, the late 1990s saw considerable activity in the upgrading of older semi-submersibles and drillships (one was converted in the NW of England), and, to a smaller extent, newbuilding of modern semi-submersibles.

Most of the semi-submersible newbuildings were ordered in the Far East, but several of the major conversions/completions were carried out in Europe and the USA. H&W secured work on two major semi-submersible conversions.

TABLE 5 New Generation Drillship Newbuildings

Vessel	Owner	Design	Shipyard	Delivery
Deepwater Pathfinder	Conoco/R&B	R&B/Samsung	Samsung	1998
Deepwater Frontier	Conoco/R&B	R&B/Samsung	Samsung	1999
Deepwater Millennium	R&B Falcon	R&B/Samsung	Samsung	1999
Deepwater "Drillship IV"	R&B Falcon	R&B/Samsung	Samsung	2000
Discoverer Enterprise	Transocean	Transocean/Astano	Astano (hull only)	1998 (hull)
Discoverer Spirit	Transocean	Transocean/Astano	Astano (hull only)	1999 (hull)
Discoverer Deep Seas	Transocean	Transocean/Astano	Astano (hull only)	2000 (hull)
Glomar C R Luigs	Global Marine	Glomar 456	H&W	2000
Glomar Jack Ryan	Global Marine	Glomar 456	H&W	2000
Navis Explorer	Navis ASA	Sea Prince	Samsung	2000
Pride Africa[1]	Pride/Sonangol	Gusto 10000	Hyundai Mipo	1999
Pride Angola	Pride/Sonangol	Gusto 10000	Hyundai Mipo	1999
Saipem 10000	Saipem	Saipem 10000	Samsung	2000
West Navion[2]	Navion/Smedvig	MST	Samsung (hull only)	1998 (hull)

Note 1: based on an existing hull midbody from heavy lift ship *Anadyr* (also used for *Petrojarl Foinaven* FPSO conversion);

Note 2: based on a multi-purpose shuttle tanker (MST) hull.

2. PROJECTS AT HARLAND & WOLFF

2.1 OVERVIEW

The first entry of H&W into the 1990s offshore business was the shuttle tanker *Knock An*. This had started as another entry in the series of Suezmax tanker newbuildings. During the design/build period it was altered by the addition of a bow loading station, tunnel thrusters and controllable pitch propeller. When delivered it was the largest DP type shuttle tanker in the world.

Table 6 lists the recent projects carried out by H&W, while Table 7 gives an overview of the dimensions of the vessels involved. Fig. 3 illustrates the phasing of the major projects in that list.

TABLE 6 Summary of Recent Projects at H&W

Project	Type of Project	H&W Delivery (client acceptance)
Knock An	Shuttle tanker newbuild	1996
Glas Dowr	Tanker/FPSO marine conversion	1996
South Arne steelwork	Fabrication of steel skirts for gravity base platform	1997
Schiehallion	FPSO hull newbuild	1997
Bideford Dolphin	Major semi-submersible conversion	1998
Borgland Dolphin	Major semi-submersible conversion	1999
VSEL 01	Fabrication of hull units for naval tanker	1998
VSEL 02	Fabrication of hull units for naval tanker	2000
Glomar C R Luigs	Newbuild DP drillship	2000
Glomar Jack Ryan	Newbuild DP drillship	2000

* This is the date the vessel arrived in Belfast.

TABLE 7 – Physical Dimensions of the Vessels

Project	Type of Project	LOA (m)	Breadth extreme (m)	Keel to main deck height (m)	Keel to derrick/mast top (m)
Knock An	Shuttle tanker newbuild	276.9	44.4	24.1	N/A
Glas Dowr	Tanker/FPSO marine conversion	241.0	42.0	21.2	N/A
Schiehallion	FPSO hull newbuild	224.8	45.0	27.25	96.05 to top of flare
Bideford Dolphin	Major semi-submersible conversion	106.2	79.6m (with helideck)	36.58	95.78
Borgland Dolphin	Major semi-submersible conversion	119.67	75.51 (ex. helideck)	36.58	99.57
Glomar C R Luigs	Newbuild DP drillship	231.5	36.0	17.8	99.88
Glomar Jack Ryan	Newbuild DP drillship	231.5	36.0	17.8	99.88

2.2 *GLAS DOWR* FPSO CONVERSION (Fig. 4)

In February 1996, the Dutch contracting company Bluewater obtained a contract from Amerada Hess UK for the provision and operation of an FPSO for the Durward and Dauntless fields in the North Sea.

It was decided to use a tanker hull as the platform for the field. Bluewater had taken ownership of a building slot for an Aframax tanker at the Namura yard in Japan, and a design was prepared for the conversion of this into a North Sea FPSO.

The conversion was to be executed in two main phases; the marine conversion of the tanker, followed by the installation of the topsides equipment.

H&W obtained the contract for the marine conversion phase, and the tanker *Glas Dowr* arrived in Belfast on 2nd May 1996.

The scope of work consisted of the following main elements:

- removal of equipment originally built in to the tanker, but not required in the FPSO;
- the addition of steelwork, piping and equipment associated with the new FPSO role (e.g. stern thruster, offloading equipment);
- work associated with the mooring turret;
- installation of new accommodation decks and a heli-deck.

The principal removal works carried out were as follows:

- main engine;
- steelwork in way of turret/moonpool area;
- steelwork in way of new stern thruster;
- steelwork/outfit in way of new accommodation decks.

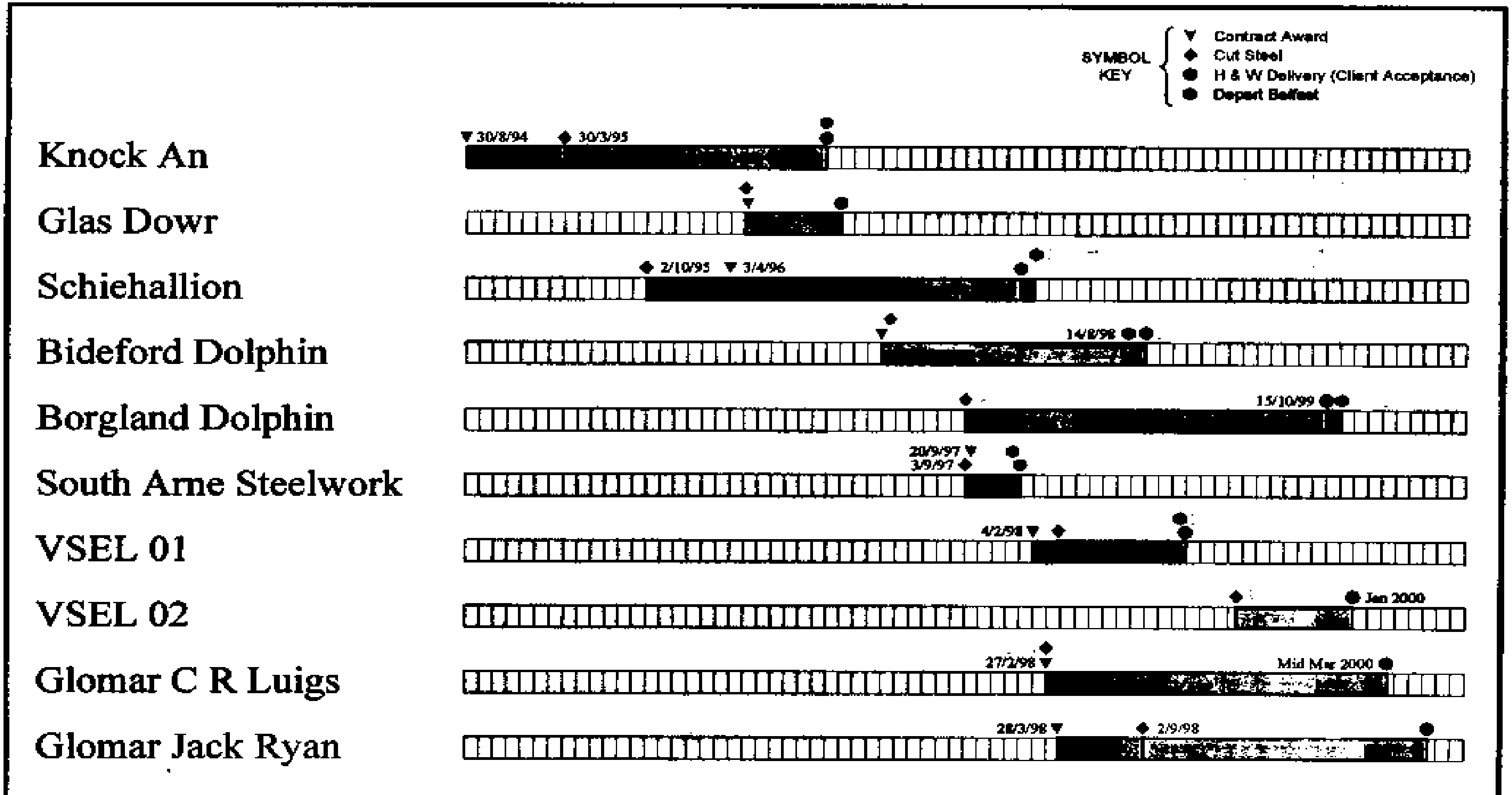


FIGURE 3 **PROJECTS AT H&W (1994 -2000)**

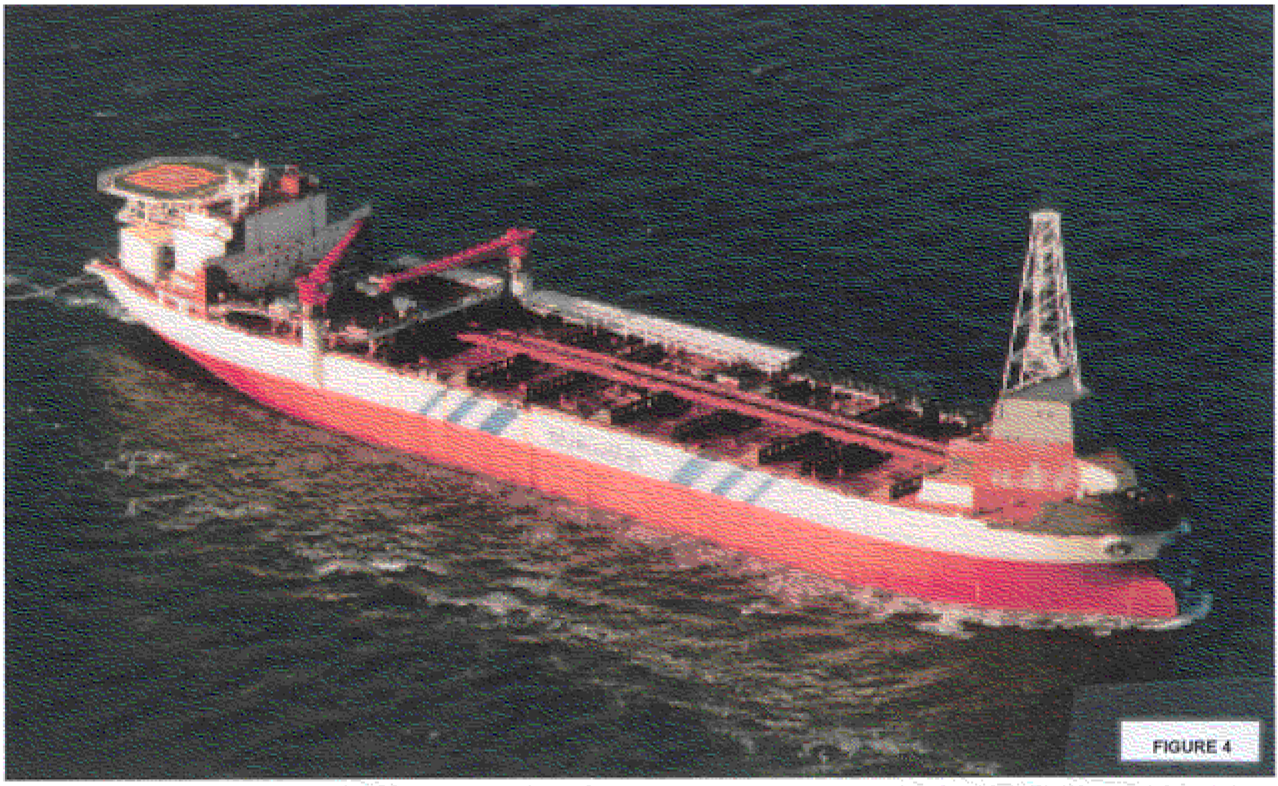


Fig. 4 *Glas Dowr FPSO*

Fig. 5 *Schiehallion FSPO*

Principal additions made to the vessel were the mooring turret moonpool structure, forward breakwater and turret protection structures, additional accommodation decks, heli-deck and thruster integration structures.

The work associated with the mooring system included the removal of existing steelwork in the new mooring system area, the installation of the Owner furnished mooring turret cylinder and chaintable, and the provision of a protective structure for the turntables/manifolds together with a raised forecastle/breakwater structure in front of the turret.

The other works involved were as follows:

- installation of piping and valves in the engine room to service new equipment;
- outfit of additional accommodation decks including new sprinkler system;
- fabrication of structural steel supports on the main deck for future topsides platforms;
- modification of ballast system pipework and valves;
- upgrade of coating systems.

The vessel departed Belfast eight months later in December 1996 (Fig. 4) for installation of the topsides at Heerema, Hartlepool.

First oil was achieved in late 1997, but the reservoir performance proved to be disappointing and the *Glas Dowr* was removed from the field and is currently (early 2000) stacked on Tyneside. This is an extreme example of the risks involved in oilfield development.

2.3 *SCHIEHALLION* FPSO NEWBUILDING (Fig. 5)

The *Schiehallion* project actually started before the *Glas Dowr* project. In 1994, BP Exploration engaged in discussions with a number of contractors capable of providing a floating production platform for the Schiehallion oilfield West of Shetland. During 1995, Harland & Wolff, Single Buoy Moorings and Brown & Root formed the Atlantic Frontier Alliance (AFA) for the purposes of tendering a turret moored steel hulled FPSO to BP.

In this alliance, H&W were to provide the vessel hull, marine systems and accommodation, while SBM provided the anchoring system and the turret installed in the vessel, and Brown & Root supplied the topsides oil production and power generation equipment. Other Owner contractors were to supply the subsea and riser systems.

A pre-sanction contract was awarded to the AFA in June 1995 to permit optimisation of the concept, followed by a Front End Engineering Design contract. Subsequently full sanction was obtained to proceed with the project and the associated contracts were awarded. The project was finally completed under a contracting arrangement different from the original alliance concept. This project history and some of the lessons learned relative to different FPSO contracting models have been described elsewhere [10].

The vessel was designed as a simple barge form, with flat plates utilised as far as possible.

The dimensions of the vessel resulted from application of normal naval architectural considerations to the particular design requirement, and resulted in a hull which has (approximately) the length of an Aframax tanker, the beam of a Suezmax tanker, and the depth of a VLCC. The selection of these proportions was driven by a number of different factors.

The principal design decision taken was to locate the accommodation block and heli-deck at the stern. There are different viewpoints regarding the best accommodation location on FPSOs, but for this vessel it was decided that the safety of personnel was best served by placing the accommodation as far as possible from the mooring/riser turret (which represents the highest risk of hydrocarbon leakage), rather than upwind of the turret but close to it (i.e. at the bow).

On the *Alba* FSU and *Anasuria* FPSO, the mooring turret was located at the forward end of the cargo section. However, the deeper water at the Schiehallion location gave rise to concerns about the dynamic amplification of loads in the mooring lines and risers as a result of vessel motion. Studies indicated that the turret should be moved as far aft as possible without compromising the free weathervaning ability of the FPSO. Eventually, the turret centreline was located 19% aft of the forward perpendicular. This meant that the 16m turret moonpool was located aft of the first pair of cargo tanks.

The cargo pumping system was based around hydraulically driven submerged pumps of 700m^3/hr capacity, located in each tank. No cargo discharge piping was located in the tanks, although each tank could be connected by valves located in the centreline longitudinal bulkhead.

Off-loading is an occasional operation to a shuttle tanker which holds position about 50m off the FPSO stern by means of DP and the FPSO mooring hawser. During off-loading up to eight of the cargo pumps (giving a nominal discharge rate of 5600m^3/hr) discharge into a common main on the deck which leads to the Fiscal Metering Unit on the process deck and then to an off-loading hose reel at the stern of the vessel. Oil is transferred to the shuttle tankers by means of a flexible hose of 20” nominal bore.

On Schiehallion, two electrically driven variable speed fixed pitch azimuthing thrusters of 1.5MW capacity each were fitted at the aft end of the unit. These served to provide the vessel with steering and transit capability, and have some operational value.

The principal active fire protection system took the form of a 16” bore copper-nickel ring main arranged by the shipyard between the process deck and the vessel’s upper deck. This main is routed around the upper deck with sectional isolating valves, and is connected to three large (1950 m^3/hr) fire pumps located in aft machinery space beneath the accommodation.

The design of the HVAC system was radically different from that applied in conventional tanker practice, since the HVAC systems are integral to the safety of the installation and the management of emergencies, in addition to their role in providing a habitable environment. The accommodation system maintains the living quarters at an overpressure relative to ambient of about 0.5mbar (by means of air lock doors), and maintains the corridors at a higher pressure than the rooms (i.e. exhaust from the rooms is via the toilets only and not into the corridors via the door).

The accommodation area itself was designed to meet the standards of the UK’s HSE 4th Edition Guidance Notes for Design & Construction of Offshore Installations. The maximum complement of 75 persons and a normal crew of 38 was achieved with 1 single berth cabin (for the Offshore Installation Manager) and 37 double berth cabins. A high standard of furnishing was applied, in order to provide a pleasant working and living environment (the Owner considered that with this approach the best and most highly motivated crew would be attracted to work

West of Shetland). This was achieved by close liaison with the client and the involvement of a specialist interior design group from a very early stage in the project.

During construction, block erection was planned to progress from the mid part of the vessel towards the bow and stern simultaneously. This provided two work faces, and the earliest possible opportunity to deliver a deck on which the topsides could be installed. This was a different approach to the construction of a conventional ship, where erection usually begins with the machinery space and works forward, in order to give the longest time for completion of the most complex part of the ship.

The building dock location was used for the installation of the turret mooring cylinder and turntables, and the fixed parts of the turret gantry. Similarly, the building dock and gantry cranes were used for the installation onboard of the topsides packages. These items were brought into the building dock by barge and offloaded by the shipyard's large gantry cranes.

The vessel was maintained afloat in the building dock for commissioning of vessel and topsides systems. The vessel was handed over to the Owner on 31st December 1997, and moved to Shetland in January for further work on the topsides, while subsea installation work continued offshore.

First oil was achieved from the FPSO on 29th July 1998.

2.4 *BIDEFORD DOLPHIN* CONVERSION (Fig. 6)

Bideford Dolphin is an Aker H3 type semi-submersible, originally completed as a drilling rig in the 1970s. During 1996 and 1997, the Owners started to convert the *Bideford Dolphin* into a modern drilling unit. Design work was performed by engineering contractors in Norway, and strip-off and conversion work started in Norway.

For various reasons, including the difficulties caused by parallel design and conversion activities, the rig was moved from Norway and arrived in Belfast on 16th March 1997. A contract was for the work was placed at around the same time.

The rig was brought into the building dock and work commenced. One of the initial tasks was the removal and replacement of a large amount of under deck scaffolding which had been installed in Norway, but did not meet UK safety standards!

The principal steel fabrication and installation activities included the addition of sponsons on the inboard side of each pontoon, and the addition of triangular sponsons on each of the four corner columns. These sponsons differ from the more normal "rocket" columns added to Aker H3 rigs. They have the advantage of providing space for machinery in the upper decks, but have the disadvantage of having a more extensive interface with the existing structure (i.e. the corner columns).

It was necessary to fabricate and install foundations for the drilling derrick, and reinforce and make modifications of the tubular bracings and their connections to the columns to improve fatigue life.

A new modular accommodation block was installed, with associated steelwork for accommodation support frames and deck reinforcement. The drilling area was completely reworked, centred on the installation of a new RamRig drilling package.

A large amount of work was required on piping, ventilation and electrical systems in order to service the new facilities, and comply with the latest Norwegian legislation. For example, the rig was fitted with two electrically driven azimuthing thrusters for mooring assistance.

Fig. 6 *Bideford Dolphin*

Initially, the Owner and his engineering contractors were responsible for many elements of design, and for both major and minor procurement. The yard was to be responsible for producing workshop drawings. As the project developed, the yard took over more and more responsibility for basic engineering and procurement tasks, in an effort to expedite the delivery of production drawings to support the construction activities.

When the dock was flooded in August 1997 for commissioning of the *Schiehallion* FPSO, the *Bideford Dolphin* remained in the dock, with water underneath, ballasted onto the keel blocks.

In January 1998, the rig was undocked to permit *Schiehallion* to depart and the *Borgland Dolphin* to be docked at the head of the dock. *Bideford Dolphin* relocated to the building dock on 28th January 1998 and remained there until undocked on 26th May 1998 when she relocated to a quayside berth at the yard's ship repair facility for commissioning and completion works.

The scope of this task is illustrated by the fact that the commissioning planning staff considered 170 different systems. The inspection and test records (ITRs) for construction activities totalled 8,779, and the ITRs for commissioning were 3,600.

Habitation status of the accommodation was achieved on 7th June 1998, and on 13th August the rig departed for sea trials, fitting of thrusters and completion at sea (in Bangor Bay, Belfast Lough and the Sound of Jura).

Bideford Dolphin was re-delivered to the Owner on 22nd September 1998, eighteen months after arrival in Belfast.

2.5 *BORGLAND DOLPHIN* CONVERSION (Fig. 7)

Borgland Dolphin is an Aker H3 type semi-submersible, originally completed as an accommodation rig by A/S Bergens Mekaniske Verksteder, Norway in 1976. During 1997, the Owners considered various options for converting the *Borgland Dolphin* into a modern drilling unit, with the capability of operating world-wide and on the Norwegian continental shelf. After a number of design exercises, which examined conversion scopes of varying complexity and cost, H&W obtained the contract for the conversion.

The *Borgland Dolphin* arrived in Belfast on 29th September 1997. By this time, a number of commitments had been undertaken by the Owner in the area of major procurement (accommodation module, drilling derrick, new deck crane etc). Other than this, the responsibility for design, procurement, execution and setting to work was the responsibility of the shipyard.

Several design solutions adopted on *Borgland Dolphin* were selected because of the influence of the previous conversion of the *Bideford Dolphin*. Some solutions, which would not otherwise have been employed, were adopted because of this synergy.

The initial scope of work for the conversion included the following general tasks:

- engineer a semi-submersible modification design to meet the functional, deckload and mooring capability requirements of the Client and the Charterer;
- strip off existing accommodation, davit launched lifeboats, telescopic gangway, starboard crane and under-deck gymnasium/sauna house;
- Install a complete suit of drilling facilities, centred around a Ramrig type drilling derrick;
- obtain DnV Class notation ✠1A1 Column Stabilised Drilling Unit Helideck and Crane (note that the Drill and then the more stringent Drill (N) notations were added during the project growth).

Initially, the major steel fabrication and installation activities included the following:

- additional columns, pontoon sponsons and column sponsons;
- fabricate and install accommodation support frames, deck reinforcement etc;
- fabricate and install deckhouses for mud treatment, shale shakers, HPUs etc;
- fabricate and install foundations for the Ramrig drilling derrick, tubular and riser setbacks fore and aft of a central moonpool;
- reinforcement and fatigue modification of tubular bracings.

The major marine system and utility activities initially included the following:

- procure and install a new accommodation module with capacity for 93 persons;
- Overhaul Existing Power Generation Plant;
- Refurbish Existing Switchboards and utilise power cables;
- Refurbish and reinstall air compressors ;
- Refurbish/modify ballast system to meet current criteria;
- Remove existing boiler and steam system;
- Refurbish and reinstall (if possible) existing valves;
- Refurbish and reinstall (if possible) existing pumps and motors;
- Refurbish and reinstall existing starboard crane on port side;
- Install new 70t crane on starboard side;
- Refurbish and relocate helideck and refuelling facilities;
- Existing lifeboats to be refurbished and reinstalled;
- Refurbish mooring system;
- Provide integrated control system;
- Install safety, fire and gas protection and detection systems;
- Apply 8 year corrosion protection and painting system.

As far as drilling systems were concerned, the following was required:

- Install a new drilling package of RamRig type;
- Install and outfit mud treatment modules, with mud pumps etc;
- Procure and install a new 15000 psi BOP stack;
- Install BOP/Xmas tree handling and storage facilities;
- Install hydraulic power packs for Ramrig and BOP control.

From a marine/shipbuilding point of view, this scope was to be the most extensive carried out on a semi-submersible drill rig in the UK since the construction of the newbuild *Ocean Alliance* in the late 1980s. Also, the scope was to increase yet further.

As the strip-out operation proceeded at H&W in the autumn of 1997 and detail design and analysis work advanced, it became clear that several major increases in the work scope were inevitable.

The main additional workscope identified during this period was as follows:

- Procure and install new main generators due to the greatly increased power requirements of the drilling systems;
- Procure and install new switchboards;
- Procure and install new air compressors;
- replacement of all existing cable (this arose due to the above changes and the poor state of the electrical systems, discovered on arrival in Belfast);
- procure and install freefall lifeboats and launching facilities as the existing lifeboats were not self-righting type;
- replacement of all existing pipework, excluding ballast system;
- provision of major deck strengthening in way of the Ramrig;
- replacement of the aft horizontal brace with a new member of greater diameter;
- some form of upgrade of the mooring system.

The vessel was re-delivered to the Owners on 22nd September 1999. It was taken on charter for a drilling contract on 31st December 1999. The scope had grown and the project had therefore taken longer and cost more than originally intended, but it had still managed to provide a modern drilling vessel for less money and comparable time to a newbuild.

2.6 SOUTH ARNE STEELWORK

The South Arne oilfield is located in the Danish sector of the North Sea. Amerada Hess took over operator-ship of the field in 1994, and sanctioned the development in 1997.

Brown & Root in the UK obtained the EPIC contract for the platform, with BARMAC securing the fabrication work in June 1997.

Overall, the platform consists of a 550,000 bbls capacity concrete gravity base (110m x 90m), with a single integral concrete tower supporting the topsides.

Taylor Woodrow Construction Ltd obtained a subcontract from BARMAC for part of the work, and in September 1997, they in turn subcontracted the steel skirt for the gravity base platform to H&W.

The H&W workscope consisted of the fabrication and loadout of a corrugated steel skirt, 1030m long by 3m deep. The work was made up of 135 individual panels/junctions, representing approximately 913 net tonnes of steel.

Work started in Belfast in September 1997. The last of five load-out operations was completed on 8th December 1997, two weeks ahead of the required contract date.

The concrete gravity base was floated out from BARMAC's facilities in NE Scotland in May 1999, and first oil from the field followed in mid 1999.

This was a simple, straightforward and profitable contract.

2.7 DP DRILLSHIP NEWBUILDINGS (Fig. 8)

In 1997, Global Marine Drilling invited tenders from a number of shipyards for a large DP drillship. Revised tenders were invited for a smaller design, and in October 1997 Harland & Wolff were awarded a Bridging Contract to permit engineering work and ordering of material pending a full contract award. A full contract for a vessel (*Glomar C R Luigs*) capable of operations in 12,000ft of water (but initially outfitted for slightly lower depths) was finally signed on 27th February 1998, following a period in which the basic design was further developed. An option for a second vessel (*Glomar Jack Ryan*) was converted into a contract on 28th March 1998.

The initial project concept was that the Owner would provide the basic design, and would also specify and procure the drilling equipment. Drawings for such equipment were to be supplied to the shipyard by the Owner. It was to be the responsibility of the shipyard to obtain all outstanding class approvals and perform detailed engineering. All fabrication, construction (with the exception of the drilling derrick erection) and systems integration was to be executed by the shipyard.

The new generation of deepwater drillships are all large vessels and this gives them good motion characteristics. The first vessels (*Discoverer Enterprise* and *Deepwater Pathfinder*) were based on tanker hullforms readily available to the shipyards. This approach provided large capacity hulls for carrying drilling equipment and variable load but, other things being equal, the full hullforms would also demand more power for stationkeeping and transit.

Focusing on this aspect, other designers developed hulls of smaller dimensions, and lower block coefficients than the tanker hullforms. The *Glomar C R Luigs* is one of this family of drillship designs [8]. A useful description of the naval architectural design process for a drillship is given in [7], while [6] provides a good overview of the mechanical systems employed on different types of drilling vessels.

The *Glomar C R Luigs* incorporates a forecastle deck <u>and</u> a poop deck. Drilling structures such as the mud module, substructure/drillfloor, warehouse module are elevated above the main deck.

An accommodation block is fitted in the fore part of the ship. The accommodation area consists of 8 levels, and is designed for a maximum complement of 150 persons. This is achieved with 14 single cabins and 68 double cabins.

The HVAC system on board the ships is of a chilled water type. The chilled water is generated from two sets of skid mounted plant (one aft, one forward). Each set consists of two 100% fresh water cooled, reciprocating compressor water chiller units operating on refrigerant R134a. Each chiller unit provides some 1.1MW of cooling per duty set, with a potential 2.2MW at peak load. Twenty-six Air Handling Units (AHUs) provide cooling via a chilled water cooling coil, and heating via electrical elements.

For propulsion and stationkeeping, the vessels are fitted with six variable speed electrically driven 5MW azimuthing thrusters. Four of the six thrusters project beneath the hull when in operation. However, all six thrusters are mounted on canisters which may be retracted into the hull if required.

Fig. 7 *Borgland Dolphin*

Fig. 8 Two DP Drillships under construction

Electrical power is generated by 6.6kV, 60Hz alternators coupled to eight (8) four stroke medium speed marine diesel engines, with electrical output rated at 4184kW each.

The generators are located in two separate engine rooms, with independent auxiliary supplies to each room. The vessel is designed to Class 3 DP standards (i.e. it must be able to maintain position following the loss of any compartment or component). The *Glomar C R Luigs* has a considerably greater thruster power to displacement ratio than the larger drillships based on tanker hullforms.

From the main switchboards, AC power at 6.6kV is supplied to the six variable speed drives for the propulsion thrusters. Power is also distributed and transformed to 480V and 600V for general use and drilling loads respectively. The principal drilling drives are fourteen 858kW DC motors; one for the rotary table, one for the top drive, two on each of the four mud pumps, and four on the drawworks.

The derrick is a National Oilwell-Dreco unit, rated for a static hook load capability of 2,000,000 lbs (907 tonnes). This derrick capacity may be compared with the 1,400,000 lbs static hook load rating of the derricks on the UK built heavy duty semi-submersibles *Sovereign Explorer* and *Ocean Alliance*.

For deep water wells, a significant portion of the drilling schedule is controlled by pipe handling activities. In order to increase vessel efficiency, the Owner decided to focus on enhanced pipe handling concepts for the *Glomar C R Luigs*. The vessel is equipped with a powered drill pipe and collar racking system centred on two main devices:

1) Varco PRS4I vertical pipe racking and finger board system located in the derrick/drillfloor, which handles drillpipe of 3 ½" OD to 9 ¾" OD, and drill collars/casing up to 13-3/8" OD.

2) Global Marine/CE Marine horizontal pipe racking system, located forward of the drillfloor on top of the warehouse module, which stores 30,000ft of 5”, 5-1/2”, or 6-5/8” drillpipe.

Initially, the vessel was to be fitted with ten 200 kip riser tensioners (i.e. total capacity 2 million lbs). During the project this was increased to twelve 250 kip units (total capacity 3 million lbs), and the drillfloor substructure was actually built with foundations for fourteen riser tensioners (total potential capacity 3.5 million lbs). These figures may be compared with the 1,280,000lb system (eight tensioners) installed on the semi-submersible *Ocean Alliance*.

The overall vessel control system consists of a number of discrete sub systems which can function autonomously but are linked by data highways to form an apparently seamless integrated system. Structurally, the Vessel Management System (VMS) is a distributed system with remote input/output (I/O) stations located as close as possible to the process to reduce long cable runs. Data processing is performed independently in Process Stations.

These vessels represent an extremely complex shipbuilding challenge. For example, there are 372 compartments to be outfitted and painted, 730 piping sub-systems to be mechanically completed and hydro-tested, and 528 systems to be handed over for commissioning.

The first vessel departed for sea trials on 21st February 2000 (just under 24 months after contract) and was delivered on 16th March 2000. The ship departed for operations in the Gulf of Mexico, and discovered oil on her first well. The second vessel went on sea trials in June 2000. Her delivery was subject to a very complicated dispute, but she departed the yard on 13th August 2000.

3. DESIGN & ENGINEERING

3.1 GENERAL

For a shipyard engaged in the offshore market, the engineering effort is different in terms of the technologies applied, the basic design methods, and the magnitude of the design task.

As far as technology is concerned, various references [6, 7] are available as introductions to the naval architecture and marine engineering aspects of offshore drilling vessels. Fundamentally, the principles of structural and mechanical engineering apply as well to the drilling equipment on a drillship, as they do to the engine room of a tanker. The difference lies in the application. A good knowledge of the actual equipment operation is often more important for an offshore vessel designer.

As far as basic design methods are concerned, the major impact is the much greater application of first principles methods, as opposed to the rule based design approach which is adequate for most conventional ships. This is discussed elsewhere.

A large design capacity is a critical factor in dealing with offshore projects. This is required to overcome the problems mentioned in the Introduction to this paper. The massive design resource of the Korean yards (1000 at Samsung, 2000 at Hyundai) is one advantage they have for offshore projects (assuming it is not being deployed on design tasks for the many other ships these yards build each year).

The design resource applied to the offshore projects at Belfast was indeed large. It was obtained from a combination of the core design workforce, recruitment of temporary personnel, subcontracting of design work to sites in the UK mainland and elsewhere, and the use of overtime and shift working.

In order to support pre-outfit ambitions, modern commercial ship design offices seek to perform detailed design in multidisciplinary zone based teams, to reflect the physical way in which the vessel is built.

The project sequence is thus intended to be:

1) basic design/class approval by system;

2) detailed design by zone;

3) build by zone;

4) commission by system.

For practical reasons, this can rarely be applied 100%. It is common for structural steel and electrical design to remain outside the zone teams considering the detailed design of piping, ventilation, miscellaneous steel etc. In these cases, the entire vessel is effectively the zone in which the team works.

For example, Table 8 lists the zone teams deployed on the detailed design of the DP drillships.

In general, detailed engineering at Belfast is carried out in a 3D product model format using the TRIBON CAD system.

The system enables the steel structure, equipment, ventilation ducting, piping and cabling to be modelled simultaneously by different teams, and potential clashes detected at an early stage. On the DP drillship project, a subcontracted design team located in Newcastle was able to work in the same 3D model as the shipyard's designers in Belfast by means of an electronic link. They were also able to access the yard's computer processing power.

Once the space management of the design is settled, manufacturing information can be extracted from the model in the form of NC plate burning and marking information, 3D drawings of steel blocks, steel weight and weld length calculations, pipe bending information, cable length calculations etc. Fitting plans can also be extracted to assist the installation of outfit components.

Unlike many CAD systems which aim to produce a draughting capability, the TRIBON system focuses on delivering this type of three dimensional manufacturing information, with the drawing available almost as a by-product.

TABLE 8 Organisation Of Zone Based Detailed Design Teams

Discipline/Zone	Scope	Party Responsible
Structural Steel	All of the ship hull (excluding forward machinery spaces) and accommodation block	H&W Hull Steel department
Drillfloor	All disciplines including structural steel	Joint Owner/H&W drillfloor team, plus West Engineering (Darlington) and Heerema (Hartelepool) for steel shop drawings
Accommodation	All disciplines excluding structural steel	H&W Hull Accommodation department
Aft hull machinery spaces	All disciplines excluding structural steel	H&W Machinery/Piping department
Hull Midbody	All disciplines excluding structural steel	H&W Machinery/Piping department
Forward Hull Midbody	All disciplines including structural steel	Conmarque, Newcastle
Mud Module, Riser Racks etc	All disciplines including structural steel	Conmarque, Newcastle
Warehouse Module	All disciplines including structural steel	Conmarque, Newcastle
Electrical	All parts of ship	H&W Electrical & Automation department

3.2 BIDDING

As well as the execution of actual projects, the bidding and estimating work for offshore projects demands a far greater effort than is normal in conventional shipbuilding. This is dependent to some extent on the client, but some of the larger oil companies can issue 13 large volumes in their Invitation to Tender, and demand a response of similar dimensions.

Over the last few years, Harland & Wolff have developed a good ability to respond to such requests, and their bid packages for major projects are almost certainly better technical packages than those from the principal Far Eastern competitors. This degree of experience and understanding may have a negative side, in that if the project is too well understood or anticipated, the estimators may build in costs which the competitors do not.

This level of bidding effort cannot be applied to all possible inquiries, and it is necessary for a yard to carefully select which projects it wishes to target. Table 9 lists a few major projects which H&W bid for, but did not contract for.

3.3 PRODUCT DEVELOPMENT

In addition to work on projects in hand, and bidding for potential projects, the yard invested in the development of its own designs. A large DP drillship with capability of drilling in 10,000ft of water was designed, known as the *DS3000*.

Work was also carried out on the design of a simple floating platform utilising damping skirts to limit motions. The initial work focused on a combined drilling and production unit, capable of operation in most parts of the world.

Latterly, work has been carried out on a variant intended for supporting dry production trees in deep water (c. 1500m) locations offshore West Africa, Gulf of Mexico and Brazil.

3.4 IMPACT OF THE OFFSHORE PROJECTS

The impact of the offshore experiences on design staff occurred mainly on the *Schiehallion* FPSO project, but has continued since then.

On Schiehallion, the offshore "language" was learned for the first time by many of the staff. Many staff were also exposed for the first time to design "without the rule book", as Schiehallion required the full range of alternative approaches such as HAZOPS, Safety Cases, Risk Analyses, Fatigue Analyses etc.

After a period of building standard tankers and bulk carriers, the greatest impact has been felt as a result of design complexity. The *Schiehallion* FPSO presented a challenge in this regard, and also because there was no "rule book" from which the design could be extracted. However, the FPSO hull was a relatively straightforward vessel compared to the DP drillships, which are very complex ships (the number of different compartments and systems onboard is very large).

After the design and construction of the DP drillships, an FPSO would be relatively "simple" and considerable improvements would be expected compared to the performance on *Schiehallion*.

There has also been learning in most areas of project management, and the number of staff exposed to the practice of this discipline has continued to grow.

TABLE 9 Major Bidding Efforts for Offshore Projects

Project	Year of Major Bid Effort	Client	H&W scope of work	Comments
Curlew FPSO	1996	Fred Olsen companies	Conversion of a tanker to FPSO, for contractor seeking to supply the FPSO to the oil company (Shell)	Maersk, AMEC and SBM Alliance won the contract to supply the FPSO
***Jotun* FPSO**	1996	Esso Norge	Newbuild hull, as part of an alliance/consortium for entire FPSO	Project awarded to competing prime contractor (Kvaerner), and hull built in his yard in Finland
***Pierce* FPSO** *(600,000 bbl newbuild)*	1996	Fred Olsen companies	Newbuild FPSO, for contractor seeking to supply the FPSO to the oil company (then BP)	Project later developed by conversion of multi-purpose tanker *Berge Hugin*, leased to oil company Enterprise
***West Guillemot* FPSO**	1997	Texaco UK	Provision of an FPSO, including tanker conversion and topsides	A FEED study was awarded, but the entire project was cancelled in favour of the Abbot/Triton FPSO option
***Bingo 9000* semi-sub drill rigs**	1997	Ocean Rig, Norway	Completion of two bare deck semi-submersible hulls	Awarded to US Gulf Coast yard
***Terra Nova* FPSO**	1997	Brown & Root, for Petrocanada	Newbuild hull of a DP, ice strengthened FPSO	Awarded to Daewoo, Korea (their first FPSO project)
***Abbot/Triton* FPSO**	1997	Amerada Hess UK	Newbuild hull as part of a consortium for entire FPSO	Awarded to Kvaerner (their first UK FPSO project), with tanker hull from Samsung
GVA 5800 semi-sub drill rigs	1998	Dolphin A/S, Norway	Newbuilding of drill rigs for a contractor seeking charter from oil company (Statoil)	The project did not proceed.
Vinga FPSO	1998	Statoil, Eire	Conversion of a tanker to an FPSO for field west of Ireland	The field development was cancelled owing to poor reservoir results
***Bonga* FPSO**	1999	Shell Nigeria	Newbuild hull	Awarded to Korea

TABLE 10 Offshore Engineering Model Tests with H&W Involvement (1995-1999)

Project	Year	Model Basin	Scope of Tests	H&W Involvement
***Schiehallion* newbuild FPSO project**	1995	Marintek, Norway	Mooring loads, motions, green water, slamming, shuttle tanker mooring	H&W attending as part of FPSO alliance
***Schiehallion* newbuild FPSO project**	1996	BMT Fluid Mechanics, UK	Helideck wind flow, GT exhaust, gas dispersion and turret ventilation, smoke dispersion, wind loading	H&W tests
FOBOX (1) floating drilling and production concept	1996	Marintek, Norway	Decay tests, damping in heave and pitch, current loads	H&W tests
600,000 bbl newbuild FPSO design development	1996	Marintek	Mooring loads, motions, green water, slamming, shuttle tanker mooring	H&W tests
***West Guillemot* converted tanker FPSO bid/FEED**	1997	Marintek	Mooring loads, motions, green water, slamming, shuttle tanker mooring	H&W/APL tests
***West Guillemot* converted tanker FPSO bid/FEED**	1997	DMI, Denmark	Wind tunnel testing	H&W tests
***Borgland Dolphin* semi-submersible conversion project**	1998	DMI, Denmark	Wind tunnel testing	H&W tests
Global drillship Hull 456 project	1998	MARIN, Netherlands	R&P, motions, seakeeping, DP, wind tunnel	Global Marine test (H&W in attendance)
FOBOX (2) floating dry tree production/drilling concept	1999	Universities of Glasgow, Newcastle, UK	Motion behaviour with different damping skirts	tests

3.5 MODEL TESTING

As part of the development of designs for offshore applications, H&W has been involved in model testing associated with this type of work. This has resulted in the gaining of experience in fields not normally required in conventional shipbuilding, although well known in the offshore field. Table 10 lists the key features of these tests.

4. FABRICATION & CONSTRUCTION

4.1 DIFFERENT STANDARDS

The execution of offshore projects has not meant much difference to the shipyard in pure manufacturing or construction terms. That is because the steel structures, pipes, ventilation objects required in the offshore units are not fundamentally different from the work required for ships.

However, the yard's quality systems and standards must be made suitable for offshore projects so that the manufacturing and construction quality is appropriate. Since the prime competitors of H&W in the offshore field are Far Eastern shipyards (not offshore yards), permanent and complete application of offshore standards to ship type products would result in a competitive disadvantage.

In H&W this has been dealt with by reinforcing the core standards for shipbuilding, supplemented by a special set of project specific standards for offshore applications, which are applied as needed.

Some projects will require special standards (e.g. for steelwork edge preparation prior to painting), but this can be dealt with by the issue of a project specific standard. It can sometimes be difficult to get personnel to revert to the normal standard after a period applying the higher standard.

In general, the yard's own systems have been easily adapted to meet any new requirements. For example, yard procedures which were created for the purposes of material control and monitoring of welder performance provided a good baseline for traceability of steel material or non-destructive testing results on special and primary structures of semi-submersibles.

The major differences between shipbuilding and offshore practices lie in the methods for planning and recording commissioning & mechanical completion. The North Sea offshore world expects a far greater degree of documentation of these activities compared to commercial shipbuilding. It should be noted that offshore projects executed in other parts of the world for other oilfield areas do not necessarily follow this North Sea approach.

4.2 ELECTRICAL WORK

A major difference between most conventional merchant shipbuilding and offshore work is the balance of workload. In the latter business, the outfit trades are relatively more important than the steel trades, and electrical work is a major part of the outfitting work.

H&W has developed the ability to install larger and more complex scopes of E&I work than normal in most shipbuilding. This has been achieved by a combination of external contractors, agency labour, and increasing the number of the yard's workforce engaged in the electrical work.

For the more sophisticated offshore newbuildings, more than 650,000 metres of cable may be installed, consisting of around 15,000 cables, all of which must be terminated. The complexity of the electrical work involved in these projects may further be gauged by reference to Table 11, which compares the magnitude of some of the control systems and electrical machines with those on land based installations.

In terms of installation rates, some very creditable performances have been achieved. Consistent cable pulling rates of 25,000 to 30,000 metres per week were achieved on the vessels, with more than 45,000m/week being achieved regularly in early 2000.

TABLE 11 Comparison of Some Electrical and Control Characteristics

Vessel	Control System I/O	Installed Generator Power	Highest Generating Voltage	Largest Electric Motor	Motor Power	Motor Diameter
Schiehallion FPSO	9,347	84 MW	13.8 kV	Water injection pump (topsides)	5.20 MW	1.6m
Glomar C R Luigs drillship	4,599	35 MW	6.6 kV	Thruster motor	5.00 MW	2.0m
Seillean (SWOPS)		24.5 MW	6.6 kV	Thruster motor	3.00 MW	1.8m
Kilroot power station	c. 4,000	520 MW	17 kV	Boiler feed pump motor	5.00 MW	2.0m
Railway locomotive	100	2.6 MW	1 kV	Traction motor	0.44 MW	0.7m

4.3 SUBCONTRACTING

In view of the large volumes of work and the extremely short timescales associated with the offshore projects, considerable portions of the work were subcontracted. This took the form of external lump sum subcontracts, or contracts executed within the Belfast yard.

In the case of the DP drillships, major examples are as follows:

- fabrication of hull weldments (Kvaerner Govan, Glasgow);
- fabrication of drilling related module weldments (Wear Engineering, Sunderland);
- fabrication of drilling substructure (Heerema, Hartlepool);
- pipe fabrication (various);
- external fabrication of outfit steel (various);
- fabrication of steel elements such as riser racks, module supports etc (various UK mainland and Northern Ireland subcontractors);
- electrical installation onboard ship (several contractors);
- outfitting in Belfast of selected weldments or areas of the ship (various subcontractors).

4.4 PRE-OUTFITTING & THE OFFSHORE INDUSTRY

People seeking to execute offshore projects in shipyards at shipyard costs must bear in mind that shipyard cost efficiencies are very dependent on the achievement of pre-outfitting before dock erection, often at levels of 60 to 80% of the outfit. This is because the work can be done many times more efficiently at that stage. If a proportion of the work is transferred to later stages, the increase in manpower (and thus usually time) required is enormous.

For conventional shipbuilding projects, the product is so well defined at the start of the contract that there are relatively few uncertainties to be resolved in the design, and the dock construction stage is entered with the vessel pre-outfitted to a large extent.

For offshore projects, the nature of the business often means that more design uncertainties have to be resolved in the initial phases. If these are not addressed sufficiently quickly, then prefabrication and pre-outfitting work will not occur to the extent planned. In other words, the pre-outfit ambition may fail because detailed engineering was late as a consequence of delayed basic design decisions or interface information.

This issue does not seem to be particularly well understood in the offshore community.

The response to this problem is different depending on the type of yard in which the project is executed. In the large Far Eastern ship factories, the large number of projects executed each year means that the schedule for the central asset (the building docks) must be rigidly controlled. Thus, a delay on one project cannot be allowed to affect the other following projects.

These yards must float the vessel from the dock on the planned date regardless of its state of pre-outfitting. Thus, one can have a floating hull which is far from complete. An FPSO project can then complete the marine workscope at the shipyard if the overall schedule permits, or may have to take it to the topsides yard and complete the marine work there.

Yards which are not driven by the same imperative to move the vessel out of the dock can adopt different strategies, depending on the float in the project programme (not other vessel schedules). They could possibly delay the start of steel erection in the dock slightly in order to allow pre-outfitting to catch up, and/or retain the vessel in dock for longer to deal with the increased work-scope.

5. ORGANISATION & PERSONNEL

Two of the most important impacts of the offshore industry are related to project organisation and to numbers of temporary people employed.

With regard to organisation, the traditional shipyard functional organisation with one person nominated as the yard representative for each project (or for several ships) is usually not acceptable to offshore Owners. They will usually have a large project team, part of which will be resident at the shipyard. They will expect one to one contact with a suitably large shipyard project team which is dedicated to their project.

H&W provided project organisations to interface with the client on each of the offshore projects. The size and self-sufficiency of these teams varied depending on the project. The *Bideford Dolphin* project placed virtually all engineering work inside the project team. Table 12 illustrates how engineering responsibilities were arranged for a number of different projects.

The size of the labour force also increased dramatically to cope with several projects. In late 1997, the yard was working simultaneously on the completion of the *Schiehallion* FPSO, the *Bideford Dolphin* and *Borgland Dolphin* semi-submersibles, and was engaged in a bridging contract for the Global Marine drillships.

The yard employed 5500 people at the peak situation during 1999, of whom nearly 3000 were temporary workers recruited through agencies. The organisation had to be developed to administer these large numbers of people, most of them from Scotland and the North East of England. The movements of these people brought a considerable trade to the air and ferry companies serving Northern Ireland, and the accommodation and transport services in the vicinity of the shipyard.

The increase in temporary labour in a yard used to working with a more or less constant number of permanent core employees raised some issues. The strong company culture which had been developed in the early 1990s was introduced to another working culture. Also, the increase in total numbers brought a demand for increased numbers of supervisory staff.

At the same time, the yard's core workforce was strengthened in key areas. Table 13 shows how the average numbers employed varied over the period. It can be seen that the percentage of permanent technical and management employees increased steadily over most of the period, reflecting the different nature of the work in which the yard was involved.

Throughout this period up until 1999, the yard continued to recruit and train a significant number (ten to twenty) of apprentices each year. In 1999, the company decided to review its position in this regard, and a number of options are being considered. Table 14 illustrates the numbers involved.

In order to deal with the new technologies and practices involved it was also necessary to recruit experienced personnel from the offshore industry, educate the existing staff, and recruit new graduate engineers.

With regard to university graduates, the shipyard sought to recruit significant numbers over the period under review, many from Newcastle University. Table 14 shows the numbers involved. Over the years, several of these young people have moved from the technical area into project and production roles. Their contribution to the various projects has been significant.

6. FINANCE & PROCUREMENT

In the financial area, the obvious impact of the offshore business has been a large increase in turnover, as shown in Table 15. The overall group turnover was more than doubled during the period, with the vast majority of it generated by the shipbuilding company.

The company's activities in building Suezmax tanker and Capesize bulk carriers had latterly been loss making, and the yard's considerable overhead costs required an increased turnover in order to provide an opportunity to generate profits.

It was the move into the offshore industry which started to bring profits to the privatised yard, although these were very small in comparison to the volume of business. The year 1996 was the first profit making year, largely on account of the *Schiehallion* FPSO project. The results of the following projects were profitable or breakeven; *Glas Dowr* FPSO, *Schiehallion* FPSO, South Arne steel work, VSEL AO tanker steel work, *Borgland Dolphin* conversion. Considered in isolation, the smaller steel work projects generated a higher percentage profit than the larger, more complex projects, but would of course have been insufficient to cover the overhead by themselves.

The increased risk associated with the nature of offshore projects also brought the potential of unpredictable losses. The Ship Repair subsidiary incurred extra costs on the conversion of an offshore derrick/lay barge, a loss of £6.9m was recorded in 1997 on the *Bideford Dolphin* conversion, and heavy costs were incurred on the completion of the two DP drillships for Global Marine. These extra costs brought the yard into a very difficult financial position.

The ultimate judgement on who is liable for the drillship costs has not yet been determined, and is not an appropriate subject for this paper. However, it is worth noting that the bulk of the increased costs were incurred in an attempt to preserve/recover a very tight schedule in the face of considerable difficulties, rather than allow a large delay to occur.

TABLE 12 Organisation of Engineering Activities on various Projects

Project	Scope of engineering by the H&W project team	Scope of engineering by H&W Technical Department
VSEL AO tanker steelwork	None	Detailed engineering (basic design by client)
DP Drillships – post May 1999	All, with Technical Department directed by the Project Team	All (basic and detailed) under direction of Project Team
DP Drillships – pre May 1999	None, except for client interface	All (basic and detailed)
Borgland Dolphin	Basic design and some detailed engineering (e.g. E&I)	Detailed engineering (steel, piping etc)
Bideford Dolphin	Basic design (client also provided basic design) and detailed engineering	Some detailed engineering (steel)
***Schiehallion* FPSO**	None	All (basic and detailed)

TABLE 13 Average Personnel Employed by Group (inc. Ship-repair, etc)

Accounting Year	1994	1995	1996	1997	1998	1999
Production	1,567	1,410	1,334	1,294	1,492	2,165
Technical, management and administration	384	363	379	407	428	462
Total "Core" Employment*	1,951	1,773	1,713	1,701	1,920	2,627
White collar percentage of total	19.7%	20.5%	22.1%	23.9%	22.3%	17.6%

* This total includes temporary labour supplied through H&W companies/agencies, but excludes other agency labour.

TABLE 14 Personnel Recruitment

Accounting Year	1994	1995	1996	1997	1998	1999
Apprentices recruited	15	10	20	18	16	0
Graduates recruited	0	2	11	12	24	3
Graduates recruited to technical areas	0	2	11	12	14	1
Graduates leaving	0	1	3	3	4	0

TABLE 15 Financial Results (from Annual Reports)

Accounting Year	1994	1995	1996	1997	1998	1999
Holding company turnover (million)	£89.179	£82.116	£118.130	£178.251	£222.897	£406.403
Turnover per core employee	£45,709	£46,314	£68,960	£104,791	£116,092	£154,702
Gross Profit/(Loss) (million)	(£16.636)	(£4.380)	£7.309	£2.378	£7.203	£6.526
Profit/(Loss) after tax for the Financial Year (million)	£36.540*	(£6.769)	£3.020	(£1.516)	£5.102	-
Operating Profit/(Loss) (million)	(£21.974)	(£9.906)	£2.121	(£2.804)	£0.911	(£1.053)

* From loan stock restructuring.

TABLE 16 Schedules for Some UK Built Offshore Vessels

Vessel	Type	Year of delivery	Yard contract to delivery (months)	Cut steel to delivery (months)	Keel lay to delivery (months)	Float to delivery (months)	Start sea trials to delivery (months)
Sea Quest	Semisub	1966	NA	18 ½	15 ½	6	NA
Ben Ocean Lancer	DP drillship	1977	36 ½	32	30	14	NA
Pacnorse 1	DP drillship	1979	60	51	50 ½	26	6 ½
Iolair	DP semisub ESV	1982	42 ½	40 ½	31 ½	16	4
Sovereign Explorer	Semisub	1984[3]	35	32	29	4 ½	½
Sea Explorer	Semisub	1985	50 ½	46	45	20	2
Ocean Alliance	DP semisub	1988[1]	76	73 ½	NA	21	NA
BP SWOPS	DP monohull FPS	1990[4]	59 ½	52	42	NA	4
Schiehallion	FPSO	1997	30 ½ [2]	27	18	4 ½	no sea trial
Glomar C R Luigs	DP drillship	2000	24 ½ [5]	24	17 ½	9[5]	1
Glomar Jack Ryan	DP drillship	2000	27 ½[6]	22 ½	16	1.5	1

1) Vessel sailed for completion at Invergordon 1 month after the delivery date used here.
2) This is from the start of the early optimisation phase in June 1995 (construction contract was signed 7th March 1996).
3) This vessel's delivery was delayed by accidental damage incurred after float-out.
4) Delivery date used is the interim handover date, 2.5 months after vessel sailed from Belfast in December 1989, and 1.5 months prior to first oil.
5) This was an initial float-out (re-positioning) rather than final float out.
6) Delivery assumed to occur in mid July 2000 (i.e. ignoring contractual dispute).

A large part of the yard's turnover is due to procurement items. The greatest element of shipyard costs is usually procured material, but in the case of offshore projects executed in a short time-scale, labour subcontracts also have a large value. The procurement department must therefore be able to properly administer the volume and value of orders processed by the company. This is a large task.

With regard to the position of the UK yards versus foreign competition it should be noted that the large size/throughput of the Korean super yards means that have an additional form of leverage over suppliers. This purchasing power contributes in no small way to the competitiveness of these yards.

Another point related to materials procurement is the need for storage space. The large quantities of equipment associated with the drillships required large storage areas, both covered and open.

7. DISCUSSION

7.1 GENERAL

Many FPSO projects have found difficulty in merging shipbuilding and offshore technology and practices. These difficulties can only be overcome if the parties involved (oil companies, offshore contractors, shipbuilders and the classification/verification bodies), openly discuss the differences, each being prepared to compromise where appropriate within the boundaries of efficient and safe operations. There are areas where the offshore industry can learn from shipbuilding, but shipbuilders must equally be prepared to accept that FPSOs are different to conventional ships, and learn from some of the techniques used by the offshore industry in dealing with complex, high value, one-off projects.

7.2 SCHEDULE PERFORMANCE

Schedule performance is critical in the offshore industry, and to secure orders for FPSOs and drilling vessels, a shipyard must be willing and able to quote delivery dates within less than 24 months of order.

The FPSO industry has had a lot of adverse publicity regarding delays, but a large part of this is due to unrealistic schedules being set.

Also, the worldwide drilling unit construction experience of the late 1990s has not been as successful as that of the previous booms in the 1970s and 1980s, with a lot of schedule slippage. This is probably due to a loss of experienced personnel at all levels of the industry, in the drilling companies, shipyards, and vendors.

The amount of schedule overrun is often related to the extent of change during the contract, for which the offshore industry is notorious.

In May 1999, the *Offshore Engineer* magazine [9] reported on the execution of projects for newbuilding and conversion of semi-submersibles and drillships initiated since 1996. At that time, there were 43 newbuilds and 23 conversions underway. These 66 projects were then a total of 26 years late compared with the original schedules.

The newbuildings (both semis and ships) were expected to take an average of 29 months compared with the planned 25 months. This average slippage of four months was a better achievement than that of the conversions which were expected to take 24 months on average, compared with the planned 18 months. It is probable that these figures worsened as the projects were actually completed.

These figures may be compared with the data in Table 16, where the last three entries provide the project schedules for the three recent H&W newbuilds.

If the H&W schedules are compared with the above averages, and with the performance of previous offshore projects in UK shipyards it can be seen that it is a generally creditable performance, especially when the complexity of the vessels is considered. In particular, these projects have executed a larger workscope in a shorter time than the previous UK endeavours.

This should not give rise to complacency, especially as the UK performance in the 1970s and 1980s was almost universally dismal. However, in this regard it is interesting to note the good performance achieved by the H&W during the 1960s on the construction of the *Sea Quest*, at a time when the yard was also engaged in the construction of the pioneering LNG ship *Methane Progress* (delivered 1964).

It is in the Far East that the most aggressive schedules of today can be found (although there are also several problematic projects there). It is against these that UK yards must measure themselves.

7.3 CLOSURE

On the positive side, it is worth reflecting that the H&W yard delivered in a three year period more (four) sophisticated floating drilling vessels than the whole UK shipbuilding industry achieved in the 1970s or in the 1980s. A total of six major offshore vessels were completed in the four years from late 1996 to mid 2000.

There are a number of down sides of the offshore market, of which perhaps the most important are the following:

- few, high value contracts (difficult to maintain constant workload);
- market subject to big peaks and troughs;
- demanding Owners (many American).

At one time or another, these factors have placed many yards around the world in difficult financial positions, and during 1999/ 2000 one of H&W's contracts brought it into this condition. It is believed that the few offshore vessel contracts executed in Japan during the mid/late 1990s have also proved difficult for the yards.

In this regard, it is necessary to remember that the Belfast venture into offshore construction is not a new thing for UK yards. The decades of the 1960s, 1970s and 1980s all saw some form of involvement. A move towards total reliance on the offshore industry may have been responsible for the demise of some of the famous names in UK shipbuilding, and there are other lessons to be learned.

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The views expressed in the paper are those of the author, and do not necessarily represent the views of Harland & Wolff or Fred Olsen Energy.

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