HYPERBARIC & WIDER SUBSEA TESTING MARKET ASSESSMENT

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PREPARED FOR

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Executive Summary

Subsea UK was commissioned by Scottish Enterprise to undertake a Market Scoping Study to examine the potential for a range of different subsea testing facilities in Scotland. The study encompassed the areas of;

1. Large scale hyperbaric testing;
2. Vibration table testing;
3. Environmental chamber testing
4. Test pit access;
5. Hyperbaric rescue services;
6. Additional qualifications for trained divers;

Key Findings

The market for Hyperbaric Testing

It is clear that there has been an increase in the amount of hyperbaric testing being done in the past five years. This seems to be the case across the board, from small size product or component testing such as cameras, cable glands etc to large size complete assembly testing such as control systems, manifolds & valve assemblies etc. This includes a noticeable growth in the requirement for deeper testing capability as offshore developments in deepwater increase.

Testing is of particular importance to the subsea sector. All interviewees reported an increase in testing requirements, the general view being that there is not only more testing being done, but that the testing is becoming ever more stringent. Part of the reason for the amount of testing increase is that post-Macondo there has been an across-the-market change in at least four specific aspects of testing practice;

- Batch testing:.....whereby maybe 1 in every 10 valves were tested, is not now generally acceptable. Now, every system or main component being installed sub-surface has to be tested.
- Scaling:.....in the past, operator's would accept scaling, i.e.; a 2 inch valve tested, so a 5 inch valve of the same design would justify. But this no longer the case. Every unit of each design, type & size must now be tested.
- Test cycles:....have been substantially increased. Where previously a component might have been subjected to say, 200 cycles, the same component is now more likely to be subjected to up to 600 cycles.
- Wider range of testing:.....Every system or main component being installed sub-surface invariably now has to undergo pressure, temperature and EMC testing.

The result of these changes in approach is difficult to quantify across the supply chain because of the different "batch %" ratio's, but a figure of say, ten-fold, would be conservative.

It has not been possible to precisely quantify figures for the whole market sector because of the reluctance of most interviewees to provide commercial information. However, The National Hyperbaric Centre provided detailed statistics for hyperbaric testing for the two periods of 2005 to

2010 and 2011 to 2015 (to date) and these numbers have been taken as being representative of the sector.

The NHC statistics on numbers of enquiries for hyperbaric testing and number of those enquiries converted to sales, for 2005 to 2010 and 2011 to 2015 (to date), have been analysed and (if extrapolated to 2015), show an increase of circa 65% on sales enquiries of hyperbaric testing business done between 2010 and 2015.

Additionally, both those interviewees who were users of testing services and those who provided testing services, reported that there is a shortage of large size hyperbaric pressure vessels with "deepwater equivalent" pressure rating, i.e.; between 300 Bar (approximately 3,000 meters of seawater depth) and 450 Bar (approximately 4,500 meters of seawater depth).

An interesting fact learned during the course of the Study was how many of the manufacturers have pressure vessels for testing their own products but who also accept outside organisations items for testing, whilst never marketing this as a service.

The North East of Scotland is a Global Centre of Excellence in subsea engineering. To maintain this world leading position, it requires world class facilities to ensure this position continues. There are other countries around the world investing in these types of facilities to attract inward investment. Subsea UK highlighted in its manifesto to Government in 2013 that to remain internationally competitive; we have to invest in R&D which includes facilities for proving and testing subsea equipment.

Having facilities close to the manufacturers is a real benefit as it reduces the time to transport equipment for test and the need to send client company engineers on long trips to test facilities.

The NHC has the title of a "National" testing centre but it lacks the deepwater test capability that is required for today's marketplace. A new testing facility in Aberdeen would help "anchor" and secure the future of the Subsea Global Centre of Excellence in the UK and North East Scotland. A new facility would fill a need and also be complimentary to the other test facilities located in the UK.

The hyperbaric testing knowledge is very strong in Aberdeen and this expertise would be sought after around the world as the next generation of hyperbaric chamber is developed. This has the potential to be developed as the global centre for knowledge and training in hyperbaric testing.

The market for Vibration Table testing, Environmental Chamber testing & Test Pits

The situation regarding these areas of activity is less clear. We have not been able to gather any real proof that the market for Vibration Table testing and Environmental Chamber testing has increased, although we can say with a reasonable degree of certainty that Test Pit use has grown roughly in line with hyperbaric testing.

The market for Hyperbaric Rescue Services

In terms of size and value, the market for Hyperbaric Rescue Services has probably not increased over the duration of the past five years. In fact, it may have contracted in the past twelve months because of the reduced level of DSV activity with the general downturn in the industry.

However, within the market there are two issues of concern about hyperbaric rescue service provision in the UKCS which could offer market opportunities. These are;

1. The safety of Self Propelled Hyperbaric Lifeboats (SPHLs) after launch,
2. Hyperbaric Rescue Facilities (HRFs) and their Life Support Packages (LSPs) for launched SPHLs.

These issues are addressed in detail in Section 3.

Recommendations

Regarding Hyperbaric testing

The situation exists that there are at least a dozen manufacturing companies around the UK who have hyperbaric testing facilities which they make available to outside companies but never market as a business line.

This could present an opportunity for a supply chain initiative to establish some form of coordination and management of these facilities. That might include, for example;

- Establish a listing and geographic map of the facilities available,
- Set up a standard "use of the testing facilities" contract with all owners,
- Agree a set schedule of charges for hyperbaric testing,
- Market the "club" testing facilities,
- Manage the bookings and payment for use of the "club" facilities,
- Remunerate the "club" facilities owners on an agreed basis.

Regarding Hyperbaric Rescue

On: The safety of SPHLs after launch;
The Norwegian Rapid Response Recovery Vessel (RRRVs) service established by Statoil works very well (See Section 3). With the initial modelling, trials and nearly ten years of operational experience the service of "SPHL capture after emergency launch" is now well understood and many lessons have been learned.

The IOGP Diving Sub-committee (DOsC) document Report No: 478 clearly specifies the requirements for Hyperbaric Rescue Services, but because suitable RRRVs type facilities have never existed and individual Diving Companies have resisted funding the establishment of them for UKCS diving operations, these requirements have never been stringently enforced.

It is clear that the DOsC have concerns about;

a) the safety of a SPHL in the event of it being launched following a major incident and how it reaches a port within an acceptable time-frame, and
b) the locations of HRFs and LSPs.

This being the case, it is only a matter of time before the Operators begin to put pressure on the Diving Contractors to improve on their arrangements.

With the above situation, coupled with the current market down-turn which is forcing austerity, the climate exists for an industry-wide initiative to address both of the issues raised here;

i.e.; i A RRRV type service

Adoption of a RRRV type service for the UKCS if established correctly, could result in substantial cost savings and would significantly improve the survival chances of Divers in a launched SPHL.

i.e.; ii Industry sharing of HRFs

If the Diving Contractors could agree an industry wide arrangement, under which their HRFs and LSPs were shared and strategically located in ports around the UK for the reception of any launched SPHL, the results could benefit the diving industry per se, in a number of ways;

- With the number of units available pooled, there could be HRFs with their support LSPs located in more strategic ports around the UK thereby giving better coverage in the event of a hyperbaric incident. This would greatly enhance the safety of divers compared to todays arrangements.
- Even with all geographic bases covered, there would be surplus HRF/LSP units which could be deployed to other regions where saturation diving is taking place.
- With a central “management of assets”, there would be opportunities to begin standardisation, something the industry has been wanting to do for years but never been able to agree on.
- A “pooling agreement” might enable negotiation of a centrally managed maintenance arrangement. This could then facilitate the introduction of a “pay as you use it” scheme, resulting in significant cost savings per Diving Contractor.

1. INTRODUCTION

1.1. OVERVIEW

Subsea UK was commissioned by Scottish Enterprise to undertake a Market Scoping Study to examine the potential for a range of different subsea testing facilities in Scotland. The study encompassed the areas of;

1. Large scale hyperbaric testing: *capable of simulating water depths of 4000 metres or more.*
2. Vibration table testing: *including shock; random; sine sweep; and resonance search and dwell testing capabilities.*
3. Environmental chamber testing*: such as thermal cycling.*
4. Test pit access*: including deepwater pits with capabilities for hydro and gas testing.*
5. Hyperbaric rescue services.
6. Additional qualifications for trained divers*: e.g.; medical and supervisory roles and training for some of the more onerous subsea tasking.*

This Report provides the findings on each of the above markets, reflecting the current and likely future market conditions.

A list of the definitions and acronyms used in this Report is provided in Appendix 1.

Subsea UK is the industry body and focal point for the British subsea industry. Its aim is to increase business opportunities at home and abroad for the sector, bringing together operators, contractors, suppliers and people in the industry. Subsea UK currently has some 320 member Companies.

The production of this Report was supervised by the Chief Executive Officer of Subsea UK. The interviews undertaken to collect information for the Report were conducted by two independent Senior Industry Consultants who are commissioned regularly by Subsea UK and the Report was authored by one of these.

Scottish Enterprise is Scotland's main economic development agency whose role includes helping to identify and exploit opportunities for economic growth. This market scoping study was commissioned by Scottish Enterprise to help it better understand the potential opportunities for Scottish based companies in the subsea testing and training markets.

The case was made clearly in the SE report commissioned five years ago[1] that hyperbaric testing was an integral part of the quality and safety assurance process of proving and readying equipment for installation underwater offshore. One of the outputs of this Report is to review the market forecasts made in 2010 and determine whether these have been met or exceeded in the meantime.

Section 3 briefly reports on the following questions posed by Scottish Enterprise;

[1] Feasibility study for a large high pressure hyperbaric facility: June 2010

- Whether the industry currently needs and can support additional hyperbaric testing facilities?
- Whether Aberdeen is most appropriate location for them bearing in mind that large equipment manufacture is distributed across Scotland and the UK?
- Will (SE) supporting new hyperbaric testing facilities improve or generate additional opportunities for the supply chain? or do existing arrangements satisfy the current market?
- Are there limitations to the existing facilities?
- Is it the case that the NHC "centre of excellence testing facilities" serves to anchor the subsea sector in the UK /Scotland? Might new facilities simply duplicate existing facilities?
- Is there an increased demand for testing?
- Would the cost (investment) by public sector be justified?
- Is there an opportunity for SMEs? Is the apparent "decrease in numbers of SMEs reported by some pundits" actually happening?

1.2. THE SUBSEA MARKET

The UK has a significant market share in provision of subsea products and services on an international basis which has been built up over some 40 years, with the main phase of international growth being since 1995. The fifth **Subsea UK** review of the oil and gas industry subsea sector (published summer 2013) which reported on manufacturing, services, employment and exports, provided the following statistics;

On the sector generally

Since 2010 the UK subsea sector market output has grown by £3B to c£8.9B despite the general economic climate. This trend is forecast to continue through 2015 then slow from 2016.

The global subsea sector has also grown since 2010 and is forecast to double again by 2017, equating to c15% CAGR. The majority of expenditure will be on deepwater developments in West Africa, Brazil and the Gulf of Mexico.

On the UK subsea supply chain

The largest UK subsea supply chain sectors are Services at 26%, Manufacturing at 25% and Consulting & Recruitment at 13%.

The Services sector primary role is providing offshore services such as diving, ROV inspections, underwater construction, installation, survey, etc. The Manufacturers include those companies whose primary role is the manufacture of subsea goods and technology. It should be noted here though, that another category is Multidisciplinary who are large companies having major divisions operating in more than one category and some of these also have manufacturing capability by virtue of acquisition or grouping with subsidiaries etc. Consulting & Recruitment companies include those that provide engineering design and project management consultancy and provision of specialist personnel for subsea projects and applications.

The total value of 2012 UK subsea output (sales to operators + exports) is £8.9B. The largest proportion of this is in Scotland due to the high concentration of companies operating in the Aberdeen/Shire area. 44% of the UK subsea companies are based in North East Scotland.

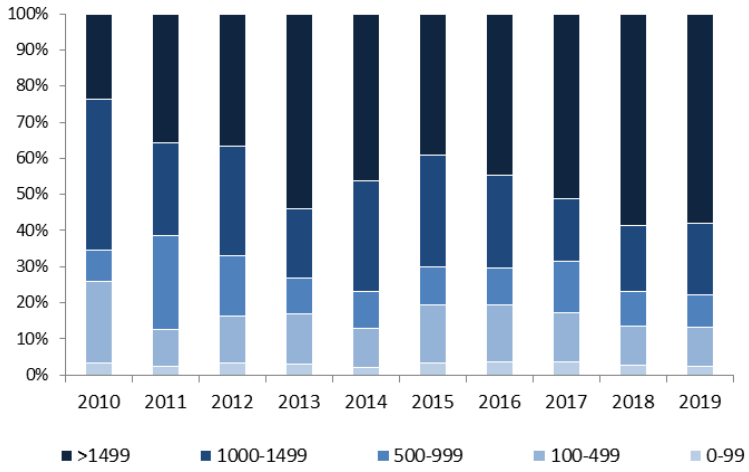
UK exports of subsea goods and services makes up 43% of the sector's total value of £4.4B.

Approximately 53,000 people are employed in the UK subsea sector. Of the total, services companies employ 48%, manufacturers 19% and multidisciplinary companies (those who provide both engineering & offshore services) 7%.

1.3. The Subsea Market Growth

The growth of subsea investment over time has been closely associated with the movement into deeper waters across the globe. Over recent years subsea spend in ultra-deepwater areas has increased significantly; from 23% of the total global subsea market in 2010 to 46% by 2014.

Until the current oil price slide began in June 2014, ultra-deepwater subsea spend had been forecast to increase up to 58% by 2019, with development at these depths expected to continue to be driven by projects offshore Brazil and the US Gulf of Mexico. Other key countries anticipated to demand a high level of ultra-deepwater subsea spend over the forthcoming five years had included the West African producers of Angola, Nigeria and Equatorial Guinea with key fields including Terra (2,328 metres), Egina (1,550 metres) and Ophir's Fortuna development at 1,691 metres.



Global Subsea Capex (US$m) 2010-2019 by Water Depth (m)
(Graphic courtesy of Infield)

1.4. Depth of Subsea Installations - Relevance to Testing

Currently, depths of 3,000 metres are seen as the maximum for subsea installations, with developments at these outer limits expected to include the Rocksource Gulf of Mexico Corp (RGOM) Trident field; anticipated to come on-stream in 2019 with subsea infrastructure at depths of 2,953 metres. However, there have also been studies looking at installations of lines at even greater depths of 3,500 metres.

The relevance of this to testing is that all equipment to be installed at these depths will be hyperbaric tested prior to installation (See Section 2).

1.5. CURRENT INDUSTRY DOWNTURN & ITS EFFECT

The offshore upstream oil & gas industry is cyclical and since 1975 has seen five cycles of high activity followed by "down turns" such as that currently being experienced.

However, the industry consensus is that the market conditions currently being experienced are unprecedented. Virtually all industry forecasters are predicting that the price of crude oil will not recover to above $100 per barrel within the next five years and most believe that for the next one to two years the price will stay around the $50 to $60 per barrel range, possibly recovering to circa $80 per barrel in the longer term.

With this forecast, and most North Sea oil fields needing at least $70/barrel to break even, most deepwater oilfields requiring at least $90/barrel to do so and virtually all ultra deepwater oilfields economics based on $100 plus per barrel, the Oil & Gas Company Operators have initiated cost cutting regimes which will result in significant long term changes to the industry.

The first and most obvious changes have been in the following three areas;

1) Operators reducing the number of "contract" personnel they employ and pruning their staff workforces;

   - Chevron announced in July 2015 it was reducing its worldwide workforce by 1,500 (2.3 percent of global staff) to curb spending by about $1 billion.
   - ConocoPhillips have said they'll have laid off "close to 1,500" jobs since the downturn began in June 2014, to reduce expenditure by $1 billion over two years.

   * It is interesting to note that having learned from the experience of past down turns that cutting back on key technical staff such as Geologists and Engineers makes "re-starting" projects much harder, time-consuming and therefore costly, industry observers are reporting that the Operators are this time primarily culling lesser-skilled personnel posts.

2) Forcing the Contracting Companies to reduce their prices across the board.

   This is having the knock-on effect that the Contractors are also laying off large numbers of contract personnel and some staff positions.

3) Postponing or cancelling planned capital expenditure on existing infrastructure upgrading and new field development projects;

   - BP announced in August that it will spend less than $20 billion this year, having said earlier in the year it planned to spend as much as $26 billion.
   - Norway's Statoil ASA reduced its spending forecast for this year by $500 million to $17.5 billion.
   - ConocoPhillips, which has already cut 1,000 jobs this year, recently announced a further 1,810 job cuts - 10 percent of its workforce.
   - The Financial Times reported recently that;

     1. US oil producers were cutting an estimated 15,000 jobs per month.

2. Apache reported a $6 billion loss for the latest quarter, $5.6 billion compared to $505 million profit in same period last year.

- On 9th September 2015 Oil & Gas UK published their latest annual Economic Report in which they reported that;
  - Oil and gas firms in the UK are on track to cut £2billion from their cost bases as the industry grapples with low global commodity prices, new research has revealed.
  - The cuts have resulted in the loss of 65,000 jobs in the UK continental shelf since the price of a barrel of oil peaked at $110 in 2014.
  - The jobs figure represents a 15% cut in jobs across the supply chain, including direct, indirect and "induced" jobs which include those that are supported by oil and gas income.

  The report revealed that the offshore trade body expects oil and gas production to reach a 15 year high this year following four years of "record" investment.

  But as operators bring their costs in line with the current oil price, O&GUK predicts capital investment (capex) in the UKCS will reduce by between £2billion to £4billion each year for the next three years. Last year investment in the North Sea reached a high water mark of £14.8 billion, the highest on record for the fourth successive year.

  O&GUK expects this to fall sharply this year to between £10-11 billion.

  The organisation bases its figures on the widely reported 5,500 direct North Sea jobs that have estimated to have been lost in recent months.

The focus on cost cuts is likely to intensify at time of writing, as Total SA, Royal Dutch Shell Plc, Exxon Mobil Corp and Chevron are all preparing to update investors on their plans

In the immediate short term this has had limited effect on the manufacturing supply chain servicing the industry, with manufacturers still delivering long lead item products ordered in the past two years.

* In fact, virtually every manufacturer we've interviewed said that last year or this year had been their best ever. However, every one that we interviewed also advised they were forecasting a significant drop in sales this year and that 2016 looked even worse.

The contracting side of the industry however, has seen dramatic changes this year. Some key examples include;

- Consultant Wood Mackenzie Ltd recently[2] estimated some $200 billion of projects have cancelled or delayed since mid-2014.
- Subsea 7 have announced plans to reduce their worldwide workforce this year by some 2,700 jobs, more than 1,000 of these in the UK.
- Saipem SpA announced in August this year it plans to cut 8,800 jobs.

[2]: August 2015

1.6. 2015 Pareto Oil & Gas Industry E&P Research Report

On 24th August 2015 Pareto Securities published their 2015 Oil & Gas Industry Exploration & Production Research Report. The text below is reproduced from their report for two reasons;

1) To provide further insight into the nature of the industry downturn,
2) To point out that whilst the main message is that the O&G industry is contracting across the board in the current downturn, the reduction in costs necessitated by the market conditions has also resulted in some postponed projects being put back on stream.

Excerpt from the 2015 Oil & Gas Industry Exploration & Production Research Report

This year, we expect E&P spending to drop the most since the mid 1980s with our estimate of a 25% drop. The drop will extend into 2016 with an estimated 10% decline. We maintain our view that the current downturn longer term will have a significant negative effect on underlying production that eventually will kick start activity again. Short to medium term uncertainty will persist particularly due to the high debt level in the industry and we remain cautious to the sector.

E&P spending to decrease significantly in 2015 and 2016

We expect E&P spending to decrease with 25% this year with US Onshore spending seeing the largest cuts. Early indications for 2016 are for a continued decrease and we estimate it to be down 10% at current. Planning prices are down 40% y/y to USD 60/bbl with the average hurdle rate for new projects at 65/bbl and falling.

Cost cutting and USD 65/bbl oil needed for cash flow breakeven

Current oil prices are triggering severe spending cuts with material cash flow short falls seeing leverage levels up, somewhat mitigated by asset sales at close to all time high levels. With the above mentioned spending cuts and only smaller dividend cuts, we estimate that an oil price USD 65/bbl is needed for our oil company sample to be cash flow break even.

Worst downturn since the mid-1980s with balance sheets a concern

The current downturn in demand is the worst on record since the mid-1980s, which had dramatic consequences for the oil services industry. The oil market backdrop and demand decrease coupled with the excess capacity in the oil services industry have caused a reset of supply/demand balances that are yet to be determined. As the industry adapts, we continue to see a high level of uncertainty short to medium term.

Given the current uncertainty, our main concern is the relatively high leverage as asset intensive sectors such as rigs and OSV have historically funded growth in new investments with debt. Coupled with cyclically low earnings, this could make the funding situation challenging going forward.

In total, we currently have no rating for on 11 names within the offshore drilling, OSV and seismic sectors or ~30% of the 38 the companies covered by this report. The unrated companies are typically very thinly capitalized, with a cumulative market cap equal to 3.6% of the fully invested enterprise value, and in need of incremental financing which makes valuation difficult and speculative.

Significant cost deflation underway

The oil price drop has further forced oil companies to revise and rethink development concepts, with the average planning price dropping from USD 100/bbl to USD 60/bbl. This has resulted in revised project scopes, with a lower oil price environment forcing operators to move from the "nice to haves" to the "need to haves" and more standardized solutions taking overall development costs down. Coupled with cost deflation throughout the supply chain, this has resulted in the break-even cost for a typical deepwater development coming down from the USD 60-80 range towards the USD 40-60 range, seeing overall offshore costs at the end of the day coming down 20-35%+.

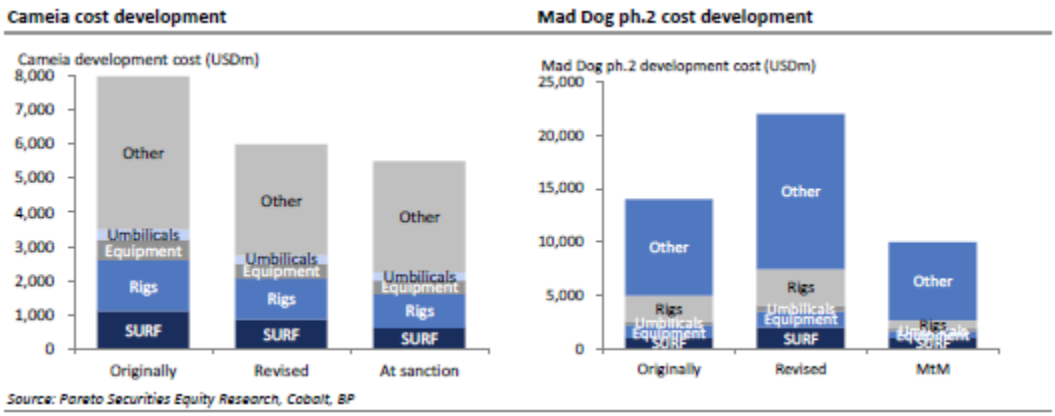
This cost deflation and improved economics has resulted in a number of projects re-entering the pipeline recent months, with oil companies looking to take advantage of lower development costs and more optimal project scopes. The areas that have seen the largest pressure on overall costs are rigs, SURF and subsea equipment. An example is Cobalt's Cameia development offshore Angola, in which Cobalt have identified over USD 2bn in cost savings, taking the IRR in the high 20% in an USD 75/bbl oil environment. Another example is Shell's Appomattox, in which Shell is targeting FID by 2015, with 20% targeted cost savings taking the break-even cost to USD 55/bbl. Shell is also targeting FID for the nearby Vito development.

The need for increased efficiencies, standardization and cost optimization across the supply chain have resulted in a number of new alliances and joint ventures being announced the past year, with contractors teaming across segments teaming up. An example is the Forsys Subsea JV (FMC Technologies/Technip), addressing projects in the early FEED phase and proposing a development solution comprising FMC Technologies' SPS and Technip's SURF capabilities, targeting overall development costs down 25-30%.

Projects previously postponed now being re-evaluated for development

Four projects that have previously been deferred to due poor project economics have re-emerged in the pipeline the past months. These projects were all deferred at an oil price of USD 80-110/bbl, but have proven economic in the current oil price environment. These include Wintershall's Maria development offshore Norway, BP's Mad Dog ph.2 in the US GoM, Cobalt's Cameia development and Chevron's Rosebank development.

As can be seen below overall project costs for these developments have come down materially while on the drawing board. As can be seen for Cameia, Cobalt has identified some USD 2bn of cost savings on the project since 2013, with the majority of these being a change in scope, but also helped by lower costs for rigs, subsea equipment and installation. Mad Dog ph.2 was placed in hold in 2013 as costs had ballooned from USD 14bn to USD 22bn, with BP originally opting for a large spar, the largest to have ever been constructed if sanctioned. The project is now targeted below USD 10bn, and cost reductions have come from various elements of the development, including simplification of the design of the platform, now likely a semi instead of a spar, standardization of the wellheads and other equipment, outsourcing some of the fabrication to Asia and phasing of the project.



The Kaombo development offshore Angola is another example of revised project scopes taking down development costs significantly. Total reduced total development costs on Kaombo from USD 20bn to USD 16bn ahead of sanctioning in April last year. A large part of these cost savings were related to utilizing two converted FPSOs rather than two newbuilds, and with lower local content. We estimate that the total project cost would have come down some additional 15-20% if sanctioned today with cost deflation taking down rig costs, subsea equipment and installation.

When looking at the aggregated costs for these five developments, we have identified some USD 11bn in cost savings on revised projects scopes, accounting for 18% of the initial aggregated projects costs. Cost savings account for USD 16bn, or 24% of the initial aggregated project costs, taking the MtM development costs for these five projects down in total 42% today.

This is supporting the current trend we are seeing in the market today, with not only operators asking for contractors to lower bids and implicitly margins, but working together with contractors to lower overall development costs.

2. OVERVIEW - TESTING

2.1. TESTING DONE IN THE OFFSHORE OIL & GAS INDUSTRY

Testing

Testing subjects products to stresses and dynamics expected in use. This controls the uniformity and quality of products or components and validates product for end use.

Tests are undertaken against various industry standards. For the offshore oil and gas industry a number of international and national organisations undertake the development of these standards, normally by standards committees with expert representatives from across industry. These industry bodies / organisations include;

- **ISO** (International Organisation for Standardisation). An independent, non-governmental membership organisation based in Geneva, Switzerland. Members are the national standard organisations from over 160 countries. The UK membership is held by BSI.
- **API** American Petroleum Institute is a national trade association that represents all aspects of America's oil and gas industry. API works with industry subject-matter experts to maintain an inventory of over 600 standards and recommended practices. API standards assist industry to improve the efficiency of operations, comply with legislative and regulatory requirements, safeguard health, and protect the environment.
- **DNV GL** is an international certification body with expertise in technical assessment, research, advisory, and risk management. DNV GL was created in 2013 as a result of a merger between two leading organizations in the field - Det Norske Veritas (Norway) and Germanischer Lloyd (Germany). The company develops industry standards and best practice through joint industry projects (JIPs), Around 65% of the world's offshore pipelines are designed and installed to DNV GL's technical standards.
- **ABS**, The American Bureau of Shipping, undertakes the development and verification of standards for the design, construction and operational maintenance of marine-related facilities. ABS core service is the provision of classification services through the development of standards called ABS Rules. These Rules form the basis for assessing the design and construction of new vessels and the integrity of existing vessels and marine structures.

For the subsea sector the following industry standards are of importance in that they reference subsea production systems and equipment;

- ISO 13628; and the equivalent
- API 17 series

The standards specify requirements and give recommendations for the design, material selection, manufacture, design verification, testing, installation and operation of equipment for the petroleum and natural gas industries. Compliance with these industry standards ensures that critical equipment is subjected to a structured test programme. This validates the equipment against the standard as "fit for" operational requirements.

One particular test often referenced within the subsea sector is the API 6A Appendix F PR2 A qualification specifically designed for components which will be commissioned in remote and hostile environments and gives engineers confidence that their components can withstand the most arduous environments throughout their working life. The PR2 test elevates the component to extreme high and low temperatures whilst dynamically cycling it under various pressure conditions to ensure the integrity of the seals and mechanics of the component.

Within the subsea sector of the offshore O&G industry, many different categories of test are available, including;

- Hyperbaric / pressure testing;
- Environmental Chamber test;
- Vibration table test;
- EDC test
- Bend and stress testing
- Xyz testing.

Hyperbaric testing

Testing across all manufacturing and engineering industries follows a process or sequence that can be summarised as follows:

- Initial Materials test
- Production testing during manufacture - a quality control activity
- Factory Acceptance Test (FAT). Prior to delivery or final installation, clients want to make sure that equipment operates as intended. FAT test allows clients to verify that all specifications and contractual requirements have been met.
- System Integration Test (SIT) (at subsystem) small sub components - connections
- SIT testing (overall system) completed system test

Tests are carried out against industry standards.

Almost all companies providing subsea equipment and components will require hyperbaric testing of equipment at some stage. In most cases, for the oil and gas industry, the operational depth for subsea equipment will not exceed 3000 metres. A normal test requirement would test to 1.1 x operational pressure to give headroom so a hyperbaric test rating to 4000 metres or 400 bar will cover almost all requirements. Much of the testing will cover hyperbaric test of valves and actuators, controls equipment and umbilicals.

Subsea valves and actuators are typically qualification tested to 200 operational cycles (break outs under Design DP) while under hyperbaric pressure – to comply with requirement of latest revision of API 17D (rev 2)

Subsea controls equipment has typically to comply with ISO13628-6 which requires that pressurised components e.g.; Subsea Control Modules (SCMs) should be subjected to qualification hyperbaric test pressures of 1.1 times design subsea ambient pressure.

Subsea umbilical insulated conductors should be subjected to a minimum hyperbaric pressure of 35 barg (bar gauge) or maximum hydrostatic pressure at service depth – whichever is greater for a minimum 22 hour period. Insulation resistance is then measured at pressure and is required to meet criteria – typically defined in ISO13628-5

There are several current providers of hyperbaric testing, including the UKAS accredited NHC.

Environmental testing

This is used to verify a piece of equipment can withstand the rigours of harsh environments, for example: extremely high and low temperatures; large, swift variations in temperature; wet environments; and electromagnetic interference (EMI).

Temperature changes underwater can affect the operation of hydraulic, mechanical, electronic equipment and materials.

Environmental test is carried out in an environmental chamber an enclosed chamber that can vary temperature between – to + : -40oC to +180oC

Subsea valves are subject to stringent environmental test. Many operators will no longer accept testing at scale as valid across the complete range of valves. This has led to a demand from the main valve manufacturers for qualification testing and several companies have now enhanced their in-house environmental test facilities to meet this requirement.

External environmental factors to be considered for subsea valves, over regular land based valves include, waterproofing, increase in ambient pressure measured in decibars (dbar) and construction materials that are able to withstand long-term corrosion effects from high salt content seawater.

Internal factors to consider for subsea valves are related to the type of flow material (what passes through the valve apparatus). Typically in subsea environments, the flows will either be liquid or gas based but due to location of the operation, the flow can contain a significant amount of sand and debris. This can present internal structural challenges.

One of the most challenging aspects for subsea valve deployment is cavitation. This is a process when liquid, being pumped through various pieces of machinery including the subsea valve, contains bubbles (or cavities). When the bubbles move through the system into areas of higher pressure they will collapse or through areas with lower pressure, they expand. This can have several negative effects including:

- An increase in noise and more importantly vibration, which can cause damage to a number of machinery components including the subsea valve and in extreme cases cause total pump failure.
- The pump can undergo a reduction in capacity.
- Pressure cannot be maintained, potentially causing fracturing within the pump.
- Overall pump efficiency drops.

Due to the location of the subsea valve not being easily accessible, it is of paramount importance that it can function without hindrance, as replacement can be extremely costly.

Most major manufacturers within the sector have some capability in environmental test. Oceanlab at Newburgh and SengS at Ellon, both near Aberdeen, provide independent test facilities.

Vibration testing

Vibration testing is used to simulate in a controlled laboratory environment the extreme conditions that a product may face during use. Vibration testing allows designs to be tested for shocks or mechanical resonances. In addition, vibration testing can be used to simulate accelerated-life testing of land and air and sea transportation stresses, including stresses from rough handling of equipment during deployment at sea.

Vibration table testing is normally controlled with associated software that allows a variety of tests that simulate potential shake or shock incidents

The following types of test are commonly used-

- Sine Sweep
- Resonance Search and Dwell
- Random
- Shock

A Vibration test can be used to simulate a compressed life time test. This type of test is often used for subsea/ downhole tool electronic component PCBs. PCBs contain DC to DC converters, usually a small sealed unit on a PCB that stands proud to other weakness in the fixing of DC to DC unit.

The following industry standards typically apply to vibration tests;

- BS EN ISO 13628-6:2006
- US MIL801F
- IEC 60068-2-6
- ASTM D3580

Vibration test is provided by major independent test houses and also by Ocean lab at Inverurie, near Aberdeen.

EMC Testing

Electromagnetic compatibility is the ability of equipment or systems to function satisfactorily in their electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment. EMC testing is a series of tests to ensure the product's electromagnetic compatibility meets the requirements of the EMC Directive 2004/108/EC; (to be replaced by 2014/30/EU in April 2016) and is an essential part of the CE Marking process.

EMC test is used by several companies manufacturing communications and positioning and control systems.

In Scotland YORK EMC at Grangemouth is the main provider.

Immersion Tank Tests

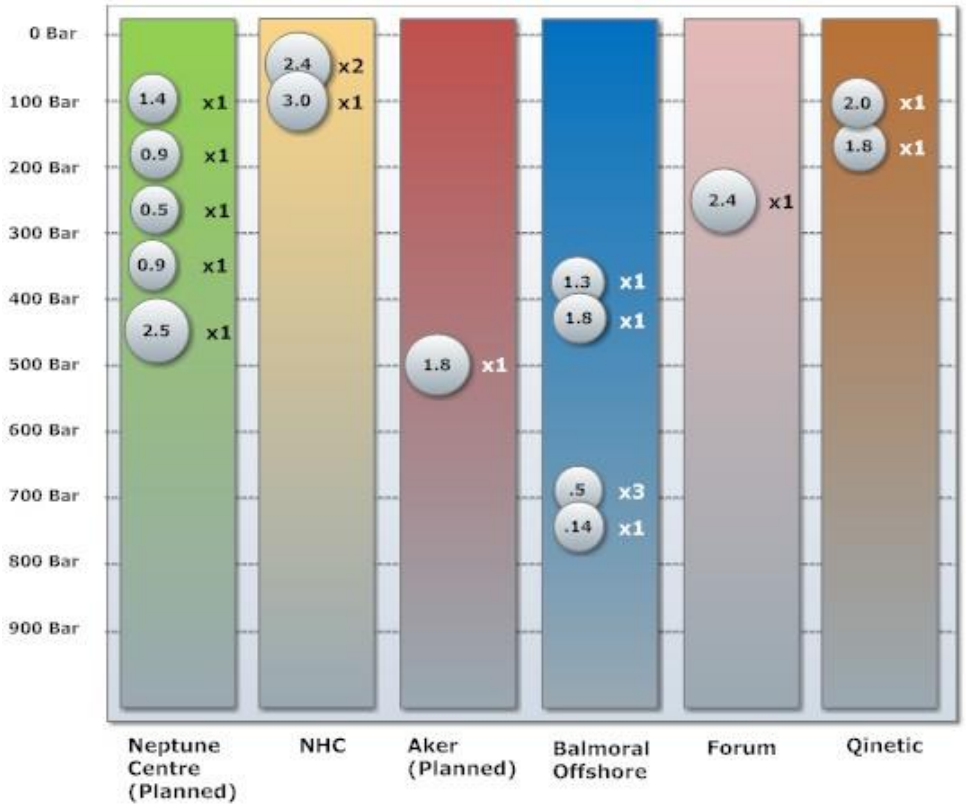
Companies manufacturing small components including lights, cameras and ROV tools may make use of an immersion tank or test pit as part of a test process.

2.2. MARKET SUPPLY: TEST FACILITIES UK & INTERNATIONAL

In discussion with Companies a number of test facilities and organisations were consistently mentioned as providing important test facilities and services to the oil and gas industry in general and the subsea sector in particular. These include independent and open access facilities that provide testing services and facilities to the industry and companies with spare capacity within their in-house test facilities that can be made available to companies in –need of test facility and expertise.

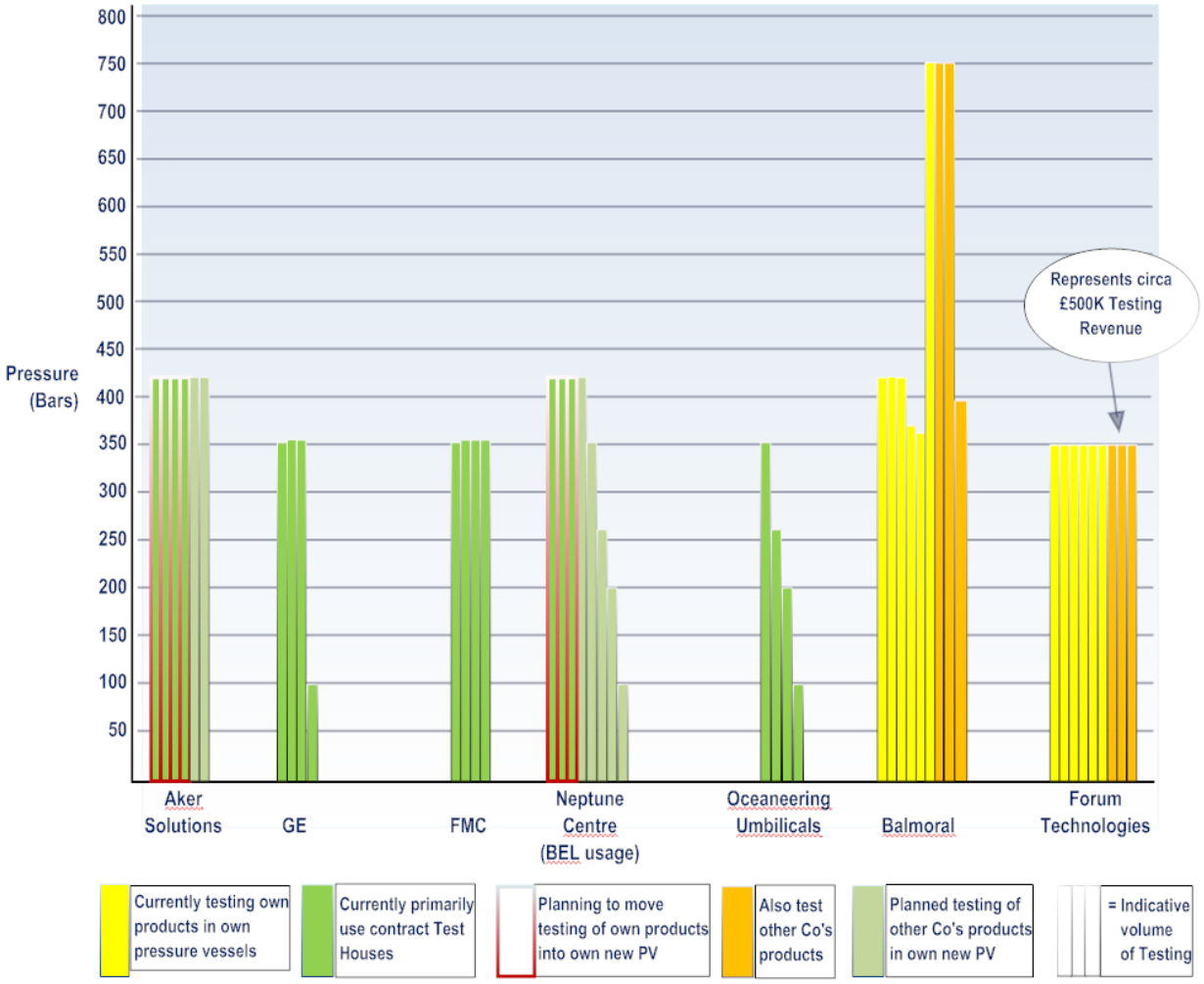
In most cases Interviewees identified UK facilities but given the international nature of the industry several companies made mention of overseas facilities either those within company or independent facilities.

A comparison of the main large scale pressure test pots in the UK is provided here.



Comparison of larger diameter Hyperbaric Testing Facilities in UK
(showing main pressure vessels only)

- Figs in circle = pressure pot diameters in Metres
- x value = number of pressure pots
- Height on scale = max pressure in Bar



Key UK based Manufacturers & their approach to Hyperbaric Testing

2.2.1. UK Test Centres

The following Test / Research Centres in the UK were mentioned by interviewees and seen as significant or potentially significant suppliers of services;

- National Hyperbaric Centre
- Oceanlab
- SengS
- York EMC
- Doosan Babcock
- TUV NEL
- TWI
- Neptune Centre (under development) in Newcastle.

A brief description of each follows:

National Hyperbaric Centre, Aberdeen

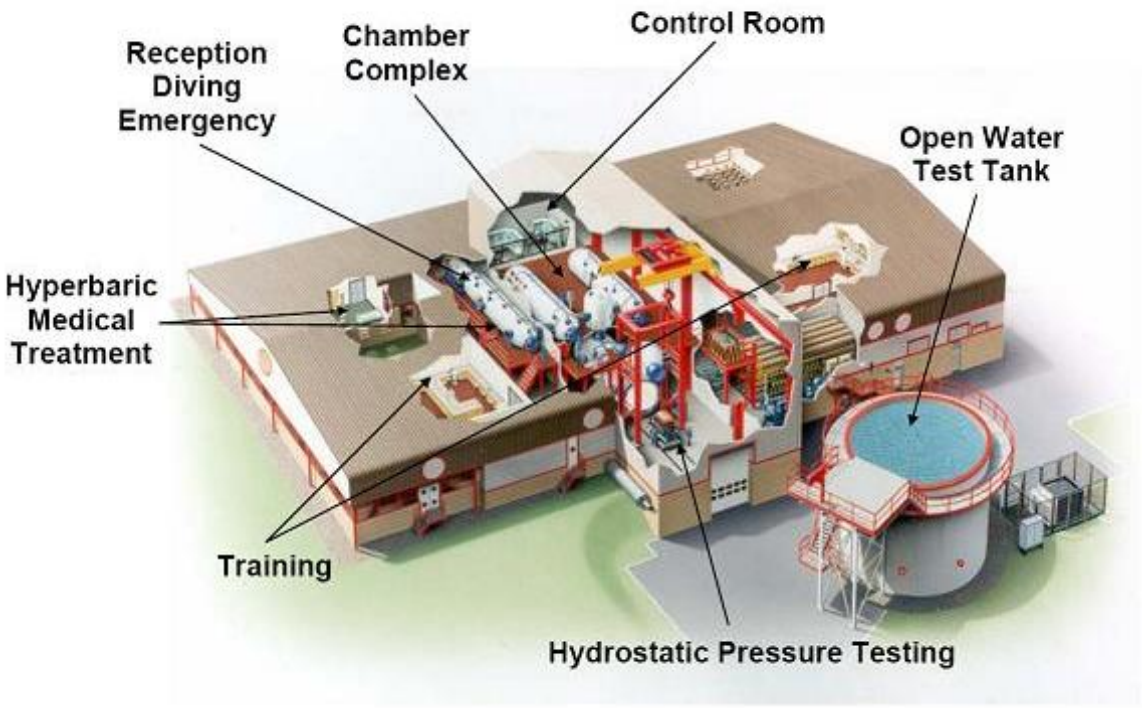
The National Hyperbaric Centre (NHC) is now a part of the James Fisher Group having been acquired from its previous owners in early 2015. The NHC has been incorporated into the business of James Fisher Defence Limited (JFD).

The NHC was commissioned in 1987 as an integrated centre for hyperbaric testing, targeted at the offshore and marine diving sector. The centre was established to cover a number of key aspects including development of commercial diver safety, utilisation of high performance diving gas mixtures to allow deeper and longer diving and to research and provide a means of treating decompression illness (bends). Through its existence, the centre has had a close relationship with Aberdeen Royal Infirmary and the Aberdeen University medical school, and continues to work closely with these bodies to provide facilities for Hyperbaric Oxygen Therapy (HBOT) for carbon monoxide poisoning, osteoradionecrosis and other wounds and infections.

In earlier days the centre was operated by Stolt Comex on behalf of the ownership trust but ownership of the National Hyperbaric Centre was now passed to ISM Ltd who owned and operated the facilities as a private business until it was acquired by the James Fisher Group.

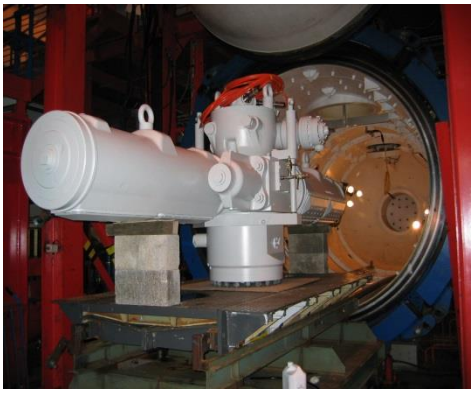
The NHC Site

The NHC is located near the centre of Aberdeen city adjacent to Aberdeen Royal Infirmary. The facilities are contained on one site, which is also used for training purposes. The management team is located on this site. A small portion of office space is allocated to hospital staff who manage and operate the medical hyperbaric treatment facility, and to Aberdeen University researchers.



Current Test Facilities

The current facilities at the NHC include three saturation living quarter modules and a central work chamber that can be used for both wet and dry testing, with a further medical hyperbaric chamber for patient treatment. There are further test tank facilities to allow immersion of equipment for functional testing and smaller test chambers that are used for hydrostatic testing of smaller test pieces.



Subsea Actuator being loaded into Hyperbaric Chamber

The main test chamber is rated to 100 bar (approx. 1,000 metres water depth), and is mounted horizontally with a rail system to facilitate loading and unloading of test pieces. This chamber is used for a wide range of purposes including hyperbaric weld qualifications that are conducted in the pressurised gas environment that the actual work will be conducted in and hyperbaric testing of subsea equipment up to the 1,000 metre limit of the test chamber.

Test Weld in progress in the Hyperbaric chamber

The NHC carries UKAS (UK Accreditation Service) approval for hyperbaric testing.

In addition to pressure testing, the NHC provides weld qualification facilities where it creates a saturation diving environment equivalent to that in which the diver would be operating on the seabed. The main use in this configuration is to qualify diver welding techniques for pipeline repair or modification, and these tests may be conducted either in wet or dry conditions. Welding of exotic materials in a pressurised diving gas environment is a highly skilled task and as pipeline integrity is critical, both the divers and the weld procedure must be qualified prior to a weld taking place.

The facility is unique in the UK and has penetrations to allow welding cables to pass through the pressurised bulkhead and the diving gas mixture is set to that which would be used in the field, such that the conditions are identical to that in real life.

In addition to servicing the upstream oil and gas sector, the NHC also receives orders for testing of military, ocean science and other underwater equipment.

When testing procedures are carried out on equipment, there is typically a “testing protocol” designed by engineers to ensure the equipment follows a defined test procedure. Often these tests

require a third party witness organisation such as Lloyds Register, DNV or similar and requested by the end user to satisfy their certification audit trail. This additional witness service can be costly and often the witness is not an expert in hyperbaric testing protocols but merely there to ensure the testing protocol has been followed and any pressure readings verified. Some test houses such as the NHC have UKAS (United Kingdom Accreditation Service) accreditation. The United Kingdom Accreditation Service is the sole national accreditation body recognised by government to assess, against internationally agreed standards, organisations that provide certification, testing, inspection and calibration services. Accreditation by UKAS demonstrates the competence, impartiality and performance capability of these evaluators.

Oceanlab (Aberdeen University)

Oceanlab is a part of Aberdeen University. The facility is located at Newburgh near Aberdeen where it has hyperbaric, environmental chamber, test pit and vibration table test facilities.

Being part of Aberdeen University, the facility is not really a commercial venture but is principally an ocean science research centre with spare capacity which is made available to industry.

Oceanlab provides ad hoc testing services to companies mainly in the subsea or downhole/subsurface sectors of the offshore oil and gas industry. With a Test Technician on site they can support product development and product qualification testing.

Clients include Aker Solutions, Subsea 7, Fugro and a number of smaller component / equipment manufacturers including those developing ROV tools and underwater equipment such as cameras.

Whilst not being a full commercial enterprise, Oceanlab is an important facility that has scope for greater industry engagement.

York EMC Services (YES), Grangemouth

YES is a specialist provider of ElectroMagnetic Compatibility testing services. Their clientele are primarily product manufacturing companies in the subsea sector of the oil and gas industry such as Nautronix, Kongsberg and Sonardyne who provide acoustic communication, positioning and control systems and need their products tested to meet the requirements of various directives related to EMC testing to meet worldwide regulatory compliance requirements and approvals including;

- Electromagnetic Compatibility testing to International (IEC), European (EN) and National (BS) standards and the EMC Directive (EMCD 2004/108/EC);
- Safety Testing: Electrical safety testing to International, European and National standards including CB Certification and the Low Voltage Directive (LVD 2006/95/EC);
- EMF Testing: Electromagnetic Field Assessment to International, European and National standards and EMF Directive (EMF 2004/40/EC).

YES is recognised as a leading independent provider of compliance testing services in the UK and as such provide UKAS accredited electrical test for emissions and immunity of electrical products. Their suite of services range from pre-production (pre-compliance) testing through to full UKAS accredited compliance, diagnostic and production testing.

Doosan Babcock, Renfrew

Doosan Babcock provides a range of fully integrated component qualification programmes including subsea pipeline, subsea wet insulation, flexible riser, wellhead completion and intervention systems and structural testing.

Doosan also undertakes full-scale component testing, risk-based inspection and structural integrity services and offshore component qualification to ensure that an organisation can fully qualify the structural integrity of their assets prior to deployment.

Doosan has capability in design, manufacture and operation of full-scale tests appropriate to;

- - Oil and Gas
- - Subsea wet insulation systems
- - Subsea pipelines
- - Flexible risers/pipes
- - Wellhead completion and intervention systems

The company provides hyperbaric test, environmental chamber fatigue & bend tests.

TUV NEL East Kilbride

NEL provides independent consultancy, on-site measurement, testing and calibration, research and development and training services to the global oil & gas sector.

Their services include;

- Flow Measurement Support - meter selection, system audit, uncertainty studies, interpretation of standards;
- Development and Calibration – single phase, wet gas and multiphase systems, valves and subsea equipment;
- Erosion – assessment and validation;
- Environmental – produced water, oil-in-water, emissions and Carbon Capture & Storage;
- CFD Modelling – flow assurance, measurement and uncertainty, erosion modelling.

Neptune Test Centre

A new testing facility called the Neptune Test Centre is being developed on the site of the derelict Spillers mill on the quayside in Newcastle Upon Tyne.

The Centre is planned to be completed in late-2015, with a large deep water chamber being installed later in mid-2016. As well as the testing facilities the centre will also house dedicated research and development offices for the university, training rooms, conference rooms and visitor facilities such as break out rooms and a canteen.

Whilst there is no information in the public domain yet other than a marketing brochure, the information below was gleaned in telephone interviews with key project individuals Ms Alison Ennis of Bel Valves (acting Project Director), Richard Dodd (COO of British Engines) and Professor Nick Wright (pro-vice-chancellor for research and innovation at Newcastle University);

Alison Ennis said;

"The Neptune Test Centre facility is being developed jointly between BEL Valves and Newcastle University at a cost of £10m with part funding provided by the North East's regional growth fund.

6 chambers will be housed in the facility eventually with 4 of these currently being operated under the Neptune banner, from the BEL Valves facility. The smallest chamber is 0.5m diameter testing to an equivalent water depth of 2,500m and the largest being commissioned will be 2.5m diameter testing to an equivalent water depth of 4,500m

All chambers are designed to facilitate the testing of mechanical, hydraulic and electrical equipment – valves, pumps, actuators, subsea components etc.

None of the chambers are designed for human access – i.e. no diver or medical type testing, but The University of Newcastle Upon Tyne have another chamber commissioned as part of the Neptune energy park, and this will also be used for Research and Development – including the use for medical applications."

Richard Dodd said;

"Work on the facilities, backed by Newcastle University and the North East Local Enterprise Partnership, could start as soon as early 2015, with the help of £5m Regional Growth Fund cash.

Two of the sub-sea chambers - 4.5 metres long and 2.5 metre in diameter - would be owned by BEL Valves and the third by Newcastle University.

Academics would use the site for research and manufacturers of sub-sea components would also want to use the valves.

There is a known bottleneck in the industry due to the lack of easily available, large diameter, high pressure hyperbaric facilities, which is only being exacerbated as oil and gas developments move into deeper waters and more high pressure environments. Our business, BEL Valves, has certainly experienced this in trying to gain access to facilities in a timely and cost effective way.

We already have close links with Newcastle University, collaborating with them on many projects, as well as developing our future engineers. This facility will improve our research and development capability, allowing us to continue developing world-first technology from the north east and further strengthen our links with the university."

Professor Nick Wright said;

"This new facility will complement the new Neptune National Centre for Sub-sea and Offshore Engineering being led by the University.

This is an incredibly exciting project - bringing together industry and academia to create a unique facility that will significantly enhance research capacity, providing crucial infrastructure for emerging research opportunities. It will also provide a unique training ground for highly skilled graduates, addressing key skill shortages currently faced by UK industry."

TWI (The Welding Institute)

TWI is a membership organisation which has been in operation for more than 50 years. Their members include Oil & Gas industry operators, contractors and manufacturers. The organisation

provides a range of services across the disciplines of structural integrity, materials selection, corrosion, non-destructive testing (NDT) and welding engineering.

The stated main aim of TWI is to help its members to improve safety, enhance best practice and reduce their operational costs through the effective use of advanced technologies and techniques.

In particular, providing;

- Technological solutions for the reliable extraction of 'difficult oil';
- Advice and consultancy to reduce the cost of compliance with regulations;
- Support throughout the project life cycle – from the front-end engineering design (FEED) stage through to installation, in-service performance monitoring and troubleshooting.

Exova, Aberdeen

Exova has recently opened a new purpose-built facility in Dudley, Aberdeen, it says "*In response to increasing demand for mission-critical testing in the oil and gas sector*".

The new facility will double the Company's weld services capacity, be a 70% increase in mechanical testing and a 50% increase in forensics and failure analysis.

It will also be Exova's North Sea Hub coordinating its customers with a connected network of 11 specialist oil and gas laboratories in the UK, Netherlands and Italy.

Exova services include;

- Independent assurance on safety and performance, specialising in corrosion & coatings asset life management;
- Failure analysis;
- Hardness testing;
- Environmental testing;
- State-of-the-art corrosion testing;
- Specialist mechanical & materials testing;
- Weld-testing;
- Weld procedures;
- Weld certification;
- Training and qualification facilities;
- Metallurgy for pipelines and other oil and gas assets.

2.2.2. UK Companies with Test Facilities

In addition to the recognised test centres / facilities, several companies have in–house test facilities which they make available to outside organisations. These are invariably operated on a loose commercial basis, i.e.; not as profit centres, being not specifically marketed or promoted.

The following companies all fit into this category and have capacity that is, or could be, available to others with test requirements;

- Avantac;
- Balmoral;
- Forum Energy Technologies (who trade as Moffat);
- FMC;
- MacArtney;
- NOC, Southampton;
- Oceaneering;
- Oilstates;
- Proserv;
- Seacon, Great Yarmouth;
- Score
- Siemens;
- Sengs;
- Teledyne, Worthing;
- Tronic;

Six of the above companies were interviewed as part of this study, Balmoral, Forum, FMC, MacArtney, Proserv and Score.

The following answers are representative of the views most manufacturers gave during interview;

Question 2 ..... *Do you have a view on the importance of testing within the industry*?

Answer 2..... *Testing is critical for the industry, as the market moves to deeper water the expense of recovery due to something going wrong is far higher than that seen on shallow water fields, hyperbaric testing ensures that the products can handle the extreme pressure that products will see during operation*

Question 3 ..... *Is the level (volume) of testing increasing? If yes, what is driving this? Macondo? Environment?*

Answer 3..... *All of the above, Macondo has definitely had an effect and we saw an increase after that event, however the higher percentage of deep water projects and their associated costs has also increased the need of getting it right first time*

Question 4 ..... *What's been the trend within your own company - comparison over last 5 years*?

Answer 4..... *Over the past 5 years our own product testing requirements have stayed pretty stable at 10% of our products having to be pressure tested, however our external customer need has increased along with the depth products have to be tested at,*

this has led to Balmoral investing in vessels from 6 vessels 5 years ago to 11 vessels at end 2015

Question 11 ..... *What's the current Pressure Bar/Water depth rating most commonly asked for*?
Answer 11..... *Typical testing at present is around 200 bar*

Question 12 ..... *What do you think is the future Pressure Bar/Water depth requirement trend*?
Answer 12..... *We expect pressures to increase to 300 bar and beyond*

Question 14 ..... *Typical duration of tests?*
Answer 14..... *Typically 1 – 3 days per test*

2.2.3. UK Universities

During some Company interviews mention was made of the importance of some of the Scottish universities in relation to testing capability.

Both Aberdeen University, with their facility at Oceanlab and Herriot Watt, were mentioned as being providers of good facilities and expertise for testing autonomous systems and also for pipe bending stress measurement.

2.2.4. International Test Research Centres

One subsea, FMC and GE all have large diameter hyperbaric testing facilities in the USA.

Two other notable international providers of testing services are;

SWResearch Texas.

The Southwest Research Institute (SwRI) has flow component testing facilities which were expanded in July 2012 to meet increasing demand. The SwRI customer base includes owners of pipelines, refineries, offshore platforms and chemical processing plants. SwRI tests various products to API, ASME, ANSI, and ISO standards.

Marintek in Trondheim

The Norwegian Marine Technology Research Institute (MARINTEK) performs research and development for companies in the field of marine technology. MARINTEK is a company in SINTEF, the largest independent research organization in Scandinavia which develops and verifies technological solutions, business and operating concepts for the shipping, marine equipment, ocean energy and petroleum industries.

MARINTEK's headquarters and laboratories are in Trondheim, Norway, with subsidiaries in Houston, Texas and Rio de Janeiro, Brazil. They say "*210 people from 24 countries work in MARINTEK - developing "ocean space technology for the future*". Although their main market is the oil and gas industry, with subsea (offshore pipelines) and floating production systems (risers, umbilicals and power cables) as main application areas.

MARINTEK also works in close cooperation with the Norwegian University of Science and Technology (Faculty of Engineering Science and Technology, Department of Marine Technology).

3. MARKET SCOPING REPORTS & VALUE CHAINS

This section reports on the outputs of each of Work Task and provides a Value Chain for Hyperbaric Testing and a note of the value chain elements of Hyperbaric Rescue.

3.1. WT 1 MARKET FOR LARGE SCALE HYPERBARIC TESTING

The object of this WT was to review the current and future market demand and supply for large scale hyperbaric testing capable of simulating water depths of 4000 metres or more.

A total of 45 companies were questioned on the current and future market for "testing". These comprised of;

- 4 international Oil & Gas Operators
- 26 Manufacturers
- 9 Contractors
- 3 Testing companies
- 1 University
- 2 Public sector

Of these, some 12 are SMEs.
(NB: If the EC definition were applied, many more would fit the category)

The general view of Operators

All operators interviewed indicated that their procurement policies drove equipment test requirements. The general consensus was that total responsibility for testing was always placed with the supplier, with Operators only adding additional requirements when their procurement policies dictated the need to. The Standards mentioned most often by Operators were RP-A203 and API 17-N, which do not actually relate directly to testing, but are to do with projects risk management and risk mitigation.

Questioned on whether Macondo had influenced their policies on testing, all Operators confirmed that whilst pre-Macondo it was accepted industry standard practice to batch test equipment like valves and subsea control systems etc, it is now standard practice that every item of equipment to be installed subsea needs to be fully tested, with hyperbaric testing being the usual final testing done. This change in strategy alone has increased the market for testing these types of equipment by up to tenfold!

The following comments were typical of statements made by Operators interviewed;

1. *"We have no specific policy requirements on hyperbaric testing of subsea components. We are generally using tried & tested components that will have been tested & qualified by the*

contractors. Any new or innovative products will be discussed with contractors regarding testing requirements on a case by case basis."

2. *As an Operator we typically assume that our Contractor/Suppliers will perform or arrange hyperbaric testing as may be needed to satisfy our business requirements."*

The general view of Manufacturers

For the purpose of this Report we have identified two levels of Manufacturer.

We define Main Manufacturers are those who design and manufacture major Production Systems and capital items such as large valves, ROVs etc and have a base in the UK.

We define Equipment Manufacturers are those who design and manufacture product items such as; umbilicals, small valves, electrical connectors, cameras etc and have a base in the UK.

Interviews were held with senior individuals in the following eight Main Manufacturers; Aker Solutions, FMC Technologies, Cameron, Proserv, Kongsberg, Oceaneering, Forum Energy Technologies (who trade as Moffat) and Freudenberg Oil & Gas Technologies.

All advised they are wholly responsible for ensuring their products integrity and whilst they relied on sub-vendors doing individual product testing, particularly in the areas of subsea connectors, instruments and tooling, each had a full test programme that aligned with their structured manufacturing plans and this invariably included undertaking various testing including hyperbaric tests, some used vibration table testing and most employed flooded test pits.

At time of last Market Report in 2010, Aker Solutions said they had considered building a dedicated test facility, but elected not to do so. This decision was to a large part, driven by their withdrawal from the buoyancy market, and by the high number of variants of subsea control products that they manufactured – driven in turn by legacy compatibility requirements.

However, Aker Subsea are now re-considering this decision and may install a hyperbaric test vessel in their new manufacturing facility being built in Aberdeen.

* Technical details on the test vessel they are considering are included in the List of Hyperbaric Test facilities in Appendix 5.

Cameron confirmed that they had a dedicated hyperbaric test facility at their manufacturing plant in Germany, specifically created to test their subsea Control modules.

Until the price of oil began to fall all the main manufacturers were reporting buoyant sales and forecasting significant growth. However, the situation has now reversed. Whilst all manufacturers said they had had excellent sales in 2014 with record levels of equipment delivery last year and this year, the prospects for new sales are very different. Since the start of the oil price reduction the market has effectively been "drying up", as the Operators cut costs by cancelling or postponing development projects.

With most industry commentators predicting that the price of oil will remain below $60/barrel this year and is unlikely to rise to more than $80/barrel for 2016, there has been a virtual shut down of

development projects and therefore new orders for capital equipment will be at a low level for at least the next 18 months.

The general view of Equipment Manufacturers

Interviews were held with senior individuals in twenty-eight Equipment Manufacturing companies, these included; Balmoral Offshore Engineering, Teledyne Bowtech, C-Technics, Nylacast, Macartney, Caley Ocean Systems and Seatronics.

As with the Main Contractors, all advised they are fully responsibility for ensuring their products integrity. They also stressed their reliance on sub-vendors for ensuring that material sources were identified and traceable and individual component were tested. They also confirmed that their manufacturing processes included comprehensive test programmes aligned with their warranty terms.

The general view of Contracting companies

Interviews were held with senior individuals in twelve Contracting companies, these included; ROVOps, Bibby Offshore, Subsea 7, Technip, Cutting Underwater Technologies and CRE Marine.

As with Operators, the Contractors view their equipment testing in terms of ensuring their procurement objectives covered the risk profiles of all contracts undertaken and that their equipment suppliers fully complied with all the agreed purchasing Ts & Cs and provided comprehensive proofs of this. As a part of this strategy all of the major Contractors advised they always witness specific tests mandated under a contract, although they did not themselves specify these. This approach was prevalent for large components, e.g.; manifolds, pipeline isolation valves etc and in procurement of ROV's and other equipment they would operate within their fleet. In a number of cases, main Contractors also had an associated manufacturing capability (i.e.; ROV tooling, subsea umbilicals, valve equipment etc) and these were subjected to qualification test and production testing requirements.

All the contractors providing diving services related to hyperbaric testing for weld and other operational qualifications that they needed to demonstrate to their clients. Subsea contractor requirements therefore differ substantially between diver operations support and equipment provision/operation.

3.2. WT 2: Market for Vibration Table Testing

The object of this WT was to review the current and future market demand and supply for vibration table testing, including shock; random; sine sweep; and resonance search and dwell testing capabilities.

Whilst it is the case that vibration table testing is done on a regular basis for small components, we found no evidence to show that this was a significant part of the testing market.

3.3. WT 3: Market for Environmental Chamber Testing

The object of this WT was to review the current and future market demand and supply for environmental chamber testing.

Whilst it is the case that Environmental Chamber Testing services are provided in Scotland, we found no evidence to show this was a significant part of the testing market.

3.4. WT 4: Market for Test Pit Access

The object of this WT was to review the current and future market demand and supply for test pit access, including deepwater pits with capabilities for hydro and gas testing.

Whilst Test Pits are used extensively in Scotland, we found no evidence to show that this was a significant stand-alone part of the testing market.

3.5. WT 5: Market for Hyperbaric Rescue Services

The object of this WT was to hold discussions with relevant industry stakeholders and key industry players to endeavour to quantify the areas shown in Work Tasks 5.1 to 5.4 below.

Interviewees from twelve companies were questioned about hyperbaric rescue services & diver on-training. The companies comprised of;

- 6 international Oil & Gas operator companies,
- 4 service contractor companies,
- 2 training companies, 1 of which (The Underwater Centre) is an SME.

The list of interviewees is provided in Appendix 4.

How information was obtained from contributors

There are a small number of players in this market and all of those who are UK based were interviewed and asked the following questions;

Q: *Can we have a copy of your Co Profile or an overview of history, track record etc?*

Q: *What are yr views on "hyperbaric rescue strategy"?*

Q: *What equipment / systems do you own / operate? & where is yr kit currently located?*

Q: *Who are yr clients?*

Q: *What's the value of yr Hyperbaric Rescue activities? i.e.; cost to you?*

Q: *Have yr Hyperbaric Rescue activities grown in past 5 yrs?*

Q: *Do you anticipate / forecast growth of yr Hyperbaric Rescue activities in next 5 yrs?*

Most of those interviewed provided useful answers to the questions, although invariably interviewees declined to provide any figures or statistics saying this was commercially sensitive information. However, the discussions held were invariably earnest and it was clear that all participants in this niche area hold strong views and are committed to the safety of commercial Divers.

All of the equipment owners interviewed operate their systems under formal standards, mostly Lloyds Register ISO 9001-2008 covering the Design, Manufacture and Operation of hyperbaric chamber and life support systems.

Consensus on Responsibility

The clear consensus of all in the UK is that the Diving Contractor is responsible for the safety of their commercial divers, so it is they who determine what their Hyperbaric Rescue plans will comprise.

NB: In Norway the opposite is true. The Operators have vested responsibility for the safety of the commercial divers working for the Diving Companies they contract with.

However; it is also clear that the Operators have ultimate veto of all Hyperbaric Rescue plans as they audit every saturation diving worksite and are becoming ever more insistent on Diving Contractors complying to the letter with the requirements of their IOGP Report No 478; Performance of saturation diving emergency hyperbaric evacuation and recovery, prepared by their Diving Operations Subcommittee (DOsC) after consultation with diving companies, trade associations, classification societies, regulators and divers and published in September 2014.

A copy of the IOGP Report No 478 front page & contents page is provided in Appendix 6.

The Hyperbaric Rescue Services Market

There is general agreement “in the industry” that;

- ✓ There has been no real growth in the Hyperbaric Rescue activity over the past 5 yrs, although the amount of diving has always been dynamic, within limited parameters.
- ✓ There is zero anticipated / forecast growth of Hyperbaric Rescue activity in the next 5 yrs. In fact, with the low oil price impacting all aspects of the market, a further slump in diving operations in support of projects is expected - proof being the number of DSVs being laid–up and or taken out of service.

Hyperbaric Rescue strategy

Whilst the industry is in general agreement about current Hyperbaric Rescue strategy of utilising SPHLs (Self Propelled Hyperbaric Lifeboats) and that the standards applied to and specifications of these is currently adequate, there are three distinct “camps” regarding what should come next in the process;

1. The “Norwegian (Statoil)” approach is that as soon as possible after being launched, the SPHL will rendezvous with one of their two purpose designed RRRVs (Rapid Response Rescue Vessels) which will take it in tow, pull it inboard up it’s stern ramp, then handle it into docking with the onboard HRF (Hyperbaric Rescue Facility), when the divers will TUP (transfer under pressure) into it’s decompression chamber complex to decompress, supported by the onboard LSP (Life Support Package).

2. The traditional "NHC approach"[3] has been that the SPHL will make its own way to the nearest UK port then be lifted out of the water onto a truck and be road transported to the National Hyperbaric Centre HRF in Aberdeen where it will be handled onto a frame and docked with the decompression chamber complex which the divers will transfer through to for decompression.

   It is clear however, that James Fisher Defence will be changing this strategy to align with the "Mimir" approach described next, as industry players increasingly support this option.

3. The "Mimir" approach is that the SPHL will "steam" its own way to the nearest UK port where a HRF will have been pre-located (or road transported there once the emergency was declared), where it will be lifted out of the water onto a frame and docked with the HRF decompression chamber complex which the divers will transfer through to for decompression.

At this time none of the Operators (other than Statoil for saturation diving operations in Norwegian waters) have taken a stance on which of the above modus operandi they prefer, but, particularly for saturation diving operations around the UK, they are increasingly tightening their requirement for conformity with IOGP Report No 478. It is probably also only a question of time (& availability of HRFs in those areas) before they do the same for their saturation diving operations outwith the UK.

Authors observations on HRF's

Whilst some of the major Diving Contractors remain contracted with the NHC to provide the Hyperbaric Centre's SPHL reception facilities (i.e.; HRF) for their North Sea saturation diving activities, some others have opted to contract with Mimir Marine with their portable HRF approach.

However, in the current atmosphere of cost cutting and austerity, the time could be right for the industry to accept a "club type approach" to sharing use of the inventory of HRFs around the UKCS and maybe even a shared SPHL rescue service modelled along the lines of the Statoil RRRVs setup.

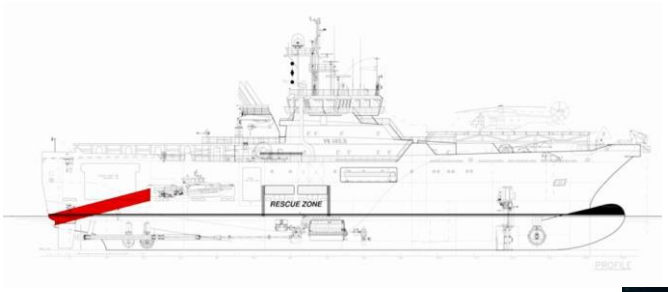
The Statoil Rapid Responds Rescue Vessels Service

The first RRRV on the Norwegian Continental Shelf was the Stril Poseidon put into service by Statoil in 2003. The RRRV was a ship equipped specifically to recover any lifeboats at sea launched in an emergency from an offshore oil installation or vessel. Modus operandi was to rapidly steam to the lifeboat location, take it under tow & winch it inboard up the stern slipway, then lift it inboard off the slip to be ready to go and rescue the next lifeboat. The Stril Poseidon and her successors have at minimum the capacity / facilities for saving 300 persons.

In 2003 Norsk Hydro took into service the RRRV Havila Troll which was equipped with a standard LSP for saturation divers. In addition, her slip was modified to avoid damage to the SPHLs camber flange along its base. The Havila Troll diving related equipment was designed and installed by Stolt Offshore.

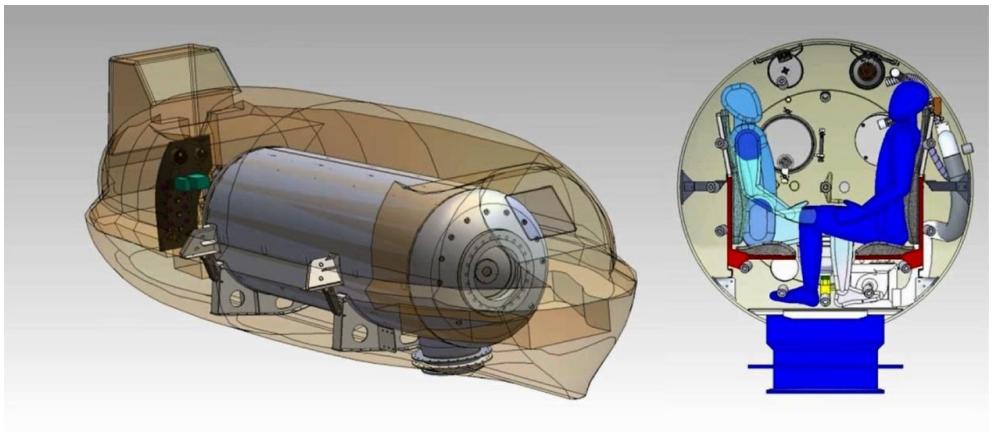
[3] Up to the time when James Fisher Defence acquired the NHC.

With experience gained from some 5 years of operations, in 2008 Statoil took into service the Stril Hercules and in 2011 the Stril Mercur (shown above), which are equipped for conventional and hyperbaric lifeboats. Technip was responsible for the diving related equipment onboard these two vessels.



Schematic showing RRRVs stern ramp

A SPHL under way



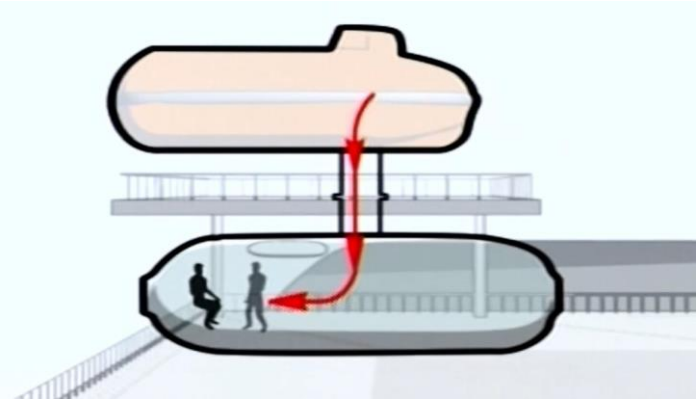
Typical SPHL arrangement

All saturation diving operations for Statoil in the NCS are now subject to the NORSOK standards which stipulate requirements far in advance (some say too far) of anything required anywhere else in the world, other than maybe Australia.

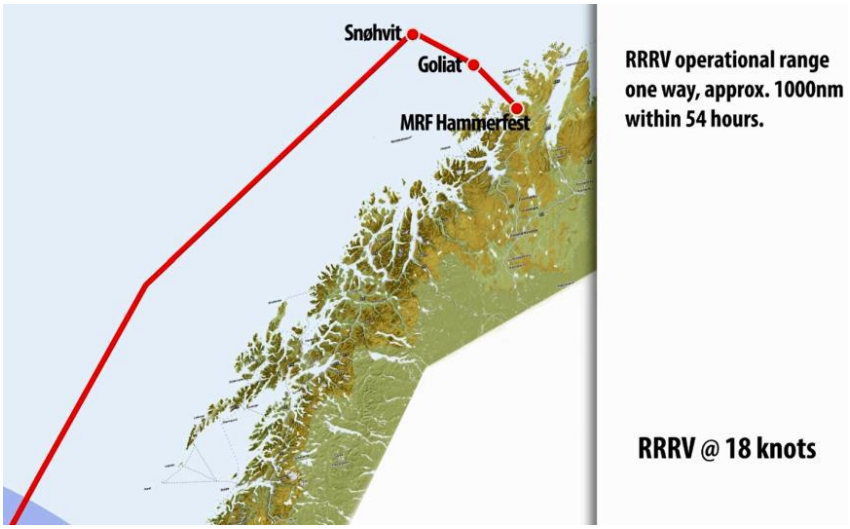
The Norwegian HEP defines all aspects of the evacuation in phases;

1. Launch of SPHL
2. Bringing the SPHL to shore/reception facilities
3. Decompression of divers

The design and Principe of the RRRV's was extensively model-tested. One major difference between the conventional freefall lifeboats and the SPHLs is the hull, which for the freefalls are steel while the hull of a SPHL is fibre glass (GRP). The weight of an SPHL is also much higher. Further, the SPHL once onboard the RRRV, has to be delivered to the HRF for TUP and decompression of the divers before the RRRV can continue rescue services.



Graphic illustrating divers TUP (transferring under pressure) into the DDC (deck decompression chamber) to decompress from saturation



Statoil funded full scale testing of the systems, with lessons learned including;

- ✓ Use of sea anchor,
- ✓ Winch speed and wire steering device in slipway,
- ✓ Good communication between Master & Coxswain,
- ✓ Training of involved rescue personnel.

The Statoil conclusion / summary was;

- Rescue of conventional lifeboats as well as SPHLs is a challenging task,
- Bringing the SPHL onboard a RRRV is one good solution, and probable the best method known today,
- The method could be a good starting point for new ideas,
- Full scale training is essential.

Observations from the NCS experience of RRRVs

It seems to be the case that if facilities something along the lines of the RRRVs were available in the UKCS, the Operators would probably begin to insist on the utilisation of these services being a part of their Diving Contractors HEP (Hyperbaric Evacuation Plan).

WT 5.1

The object of this WT was to endeavour to determine the number of diving days being conducted in given geographical regions e.g.; UKCS, Norwegian sector, Middle East, West Africa etc.

Unfortunately, not one of the interviewees were prepared to provide their diving days statistics, say these were only provided to IMCA and then under specific conditions.

The only data available is therefore historical data published annually by IMCA mid year and one year in arrears. The IMCA Diving & ROV utilisation statistics for 2013 are provided in Appendix 7.

At time of writing the 2014 figures had not been published by IMCA.

WT 5.2

The object of this WT was to plot the locations of hyperbaric rescue equipment across the world and who owns them.

However, because all interviewees declined to provide any figures or statistics saying this was commercially sensitive information, this WT was not able to be completed.

WT 5.3

The object of this WT was to determine where the main growth areas of diving are likely to take place and their scale, i.e.; water depths, temperatures, diving days etc.

For reasons previously given, it has proved impossible to get any statistical data on diving days.

It truth, it is difficult to name any real areas of growth in the diving industry at this time.

The current main geographic areas for saturation diving (listed approximately in reducing levels of activity, determined from anecdotal information) are in the deepwater areas of;

- North Sea, UK & Norwegian sectors,
- West Africa
- Brazil
- USA/Gul of Mexico
- India
- Mexico
- Australia
- Middle East/Arabian Gulf
- SE Asia
- Trinidad

WT 5.4

The object of this WT was to determine and quantify future demand for additional qualifications Diver training and how this might be being affected by changes in legislation or changes in industry requirements for more competency-based skills and development type training.

Overview

The current amount of and future growth of, diver related training undertaken in the Oil & Gas industry is very much reliant on the position taken by various Legal Bodies (HSE) and other organisations (Including IMCA, OGP, DMAC, IMO & IDSA) on whether competency, currency and correct training is a main driver in reducing the risks in Diving, to give the Duty Holder (that single person who holds the risk) the assurance that his/her diving activities are ALARP.

It would be reasonable to assume that Competency training should be encouraged in the diving industry, but it invariably boils down to who pays for it!

UK Military diving regulations state clearly that periodic competency training on various activities must be undertaken to ensure lack of “skill fade”. For example, navy Divers must practice in the water every two months and if they’ve not carried out any diving currency in a 24 month period, they must carry out a dedicated re-training. However, the offshore diving industry has no such requirement.

Certainly, re-fresher training enhances a person’s competency, but it is not yet the norm in UK commercial diving, for example, whilst it would be assumed that Mixed Gas and Air Supervisors should be tested on their competencies, there are currently no UK competency assessments on specifics for their roles.

Neither has legislation directed the Industry in a number of activities that are carried out underwater such as Cutting and Burning, Lifting Operations using straight lift or lifting bags most of

which if this activity is carried out on the surface a formal qualification is required (OPITO). So, with no formal training for that type of activity, it is difficult to measure competency.

It would be pragmatic for company policies and regulations to encourage competency training as a standard, but in the O&G industry at this time, it is difficult to see whether any faction will pay for this and it is therefore the case that unless there were some other "outside influence, e.g.; like a fatal diving accident resulting from inadequate training, the current situation is unlikely to be changed.

An example of a Diving Operations in Appendix 13.The Companies involved in diver related training in the UK and the range of diving related training being provided, or which could be provided, in the UK are listed in Appendix 13.

Is the market for Diver on-training competitive?

There are three main Companies in the Diver on-training market who compete directly in their core retail training courses offerings of Client Rep, Auditing Courses and DMT Courses.

However, apart from these areas, each differentiates quite successfully from the rest so to a degree they each effectively "have their own markets".

When interviewed, the Training Manager in each of these Companies said that they believed the market was large enough for all three businesses to thrive and grow globally.

Is the market for Diver on-training increasing?

When interviewed, the Training Manager in each of the three main training Companies said that their training business had increased over the past five years. However, only the NHC were prepared to provide figures to substantiate this.

The NHC advised that their growth of business in Training activities had increased over past 5 years but could only provide records for the past two years, which showed;

2013 Training revenues - £600k.

2014 Training revenues - £800k.

Appendix 9 shows the General Specification for Dive Team Personnel. Courtesy of Total.
Appendix 10 shows a Typical Diving Project Diving Personnel Lifting Competency Matrix. Courtesy of Total.

3.6. WT 6: Pressure Testing Market Growth

The object of this WT was to assess the progression (or otherwise) made against the targets reported on in the 2010 report i.e.;

- 50% increase in pressure testing,
- jobs growth of 15-20,000 etc. within the next five years,

and to;

- To confirm whether or not these targets have actually been achieved,

- Explain how this upsurge (or otherwise) may have affected the demand for hyperbaric pressure testing.

The following information can be gleaned from the spreadsheet files provided by NHC of the Testing Business quoted for and won in the periods of 2005 to 2010 and 2011 to 2015;

1. A growth in Hyperbaric and Pressure testing over the past 5 years with a slight blip in 2012. However, 2012 had an excellent conversion rate of enquiries to jobs.
2. To date (August) in 2015 there have already been 167 enquiries for HT/PT in 2015. If this were extrapolated out for the full 12 months it would equate to 250 enquiries, a +30% growth on 2014 and a +65% growth on 2011 enquiry levels.
3. The NHC conversion rate for HT/PT is strong, at an average of 61% over the past 5 years.

HT/PT testing				
YEAR	ENQUIRIES	JOBS WON	CONVERSION	
2015	167	79	**47%**	**Jan-Aug**
2014	191	132	**69%**	
2013	188	115	**61%**	
2012	132	101	**77%**	
2011	151	76	**50%**	
TOTAL	829	503	**61%**	

The figures for the Altitude/DiveTank also show a high success/conversion rate from 2011 of a 50% average (with 2015 figures extrapolated out to the full year).

Altitude/DiveTank testing				
YEAR	ENQUIRIES	JOBS WON	CONVERSION	
2015	24	10	**42%**	**Jan-Aug**
2014	27	10	**37%**	
2013	41	18	**44%**	
2012	32	25	**78%**	
2011	23	11	**48%**	
TOTAL	147	74	**50%**	

The conclusions that can be derived;

- Re the forecast 50% increase in pressure testing
  Exceeded:- Actual figure has been 65%.
- Jobs growth of 15-20,000 etc. within the next five years.
  We have no accurate figures for the full five year period. However, the 2013 Subsea Business Activity Review published by Subsea UK showed;

- ✓ **In 2010 there were 40,000 direct jobs in the Subsea Industry, plus an additional 10,000 indirect jobs supported.**
- ✓ **In 2013 the directly employed figure had risen to 53,000 and the indirect had risen to 13,000.**

This shows an increase of 16,000 jobs over that three year period.

- To confirm whether these targets have been achieved.
  Target 1 was achieved – the growth figure was 65% based on enquiries
  Target 2 can be said to have been achieved too - if it is accepted that the market growth shown by the Subsea UK figures for 2010 to 2013 could be extrapolated to the two years of 2014 and 2015; the total growth in jobs would have exceeded 25,000.
- Explain how this upsurge (or otherwise) may have affected the demand for hyperbaric pressure testing.
  The general growth in the subsea industry and people employed in it includes equivalent growth in manufacturing and projects and both of these activities have an element of Hyperbaric testing requirement.

3.7. WT 7: Market Area Value Chains

The object of this WT was to provide Value Chains for the six market areas which are the subject of the Study. However, following discussion with SE and based on the findings described in previous WTs it was agreed that Value Chains would only be produced for the market areas of Hyperbaric Testing and Hyperbaric Recue.

Value Chain Vs Supply Chain

The difference between a value chain and a supply chain is that a supply chain is the process of all parties involved in fulfilling a customer request, while a value chain is a set of interrelated activities a company uses to add value and create a competitive advantage.

The Value Chain

The idea of value chain was pioneered by Michael Porter. The five steps in the value chain give a company the ability to create value that exceeds the cost of providing its good or service to customers.

Maximizing the activities in any one of the five steps allows a company to have a competitive advantage over competitors in its industry. The five steps or activities are inbound logistics, operations, outbound logistics, marketing and sales, and service.

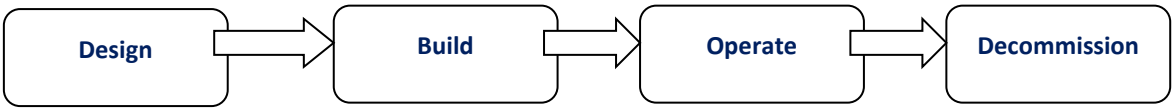
1. Inbound logistics include receiving, warehousing and inventory control.
2. Operations include value-creating activities that transform inputs into products.
3. Outbound logistics include activities required to get a finished product to a customer.
4. Marketing and sales are activities associated with getting a buyer to purchase a product.

5. Service activities include those that maintain and enhance a product's value, such as customer support.

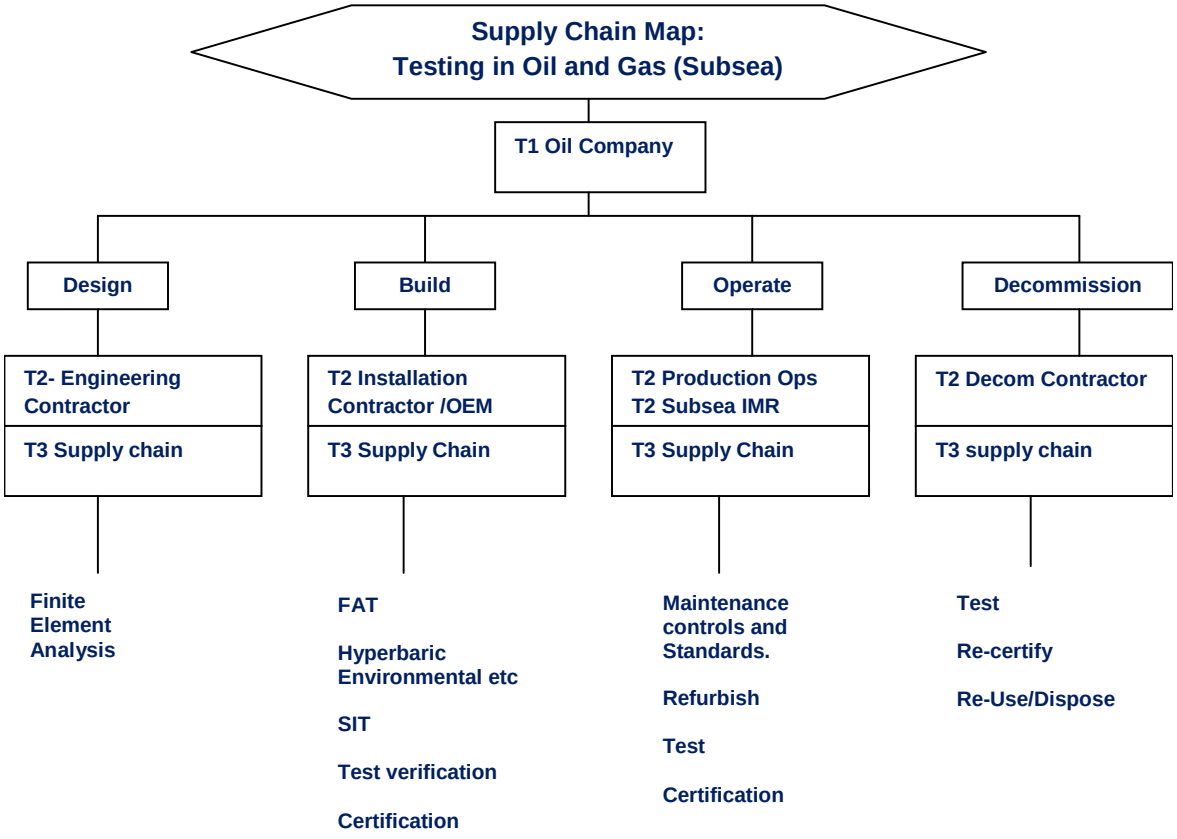
The Supply Chain

The complexity of the upstream oil and gas supply chain can be simplified by describing the industry under 4 discrete but inter-related phases as follows:

A Testing Value Chain



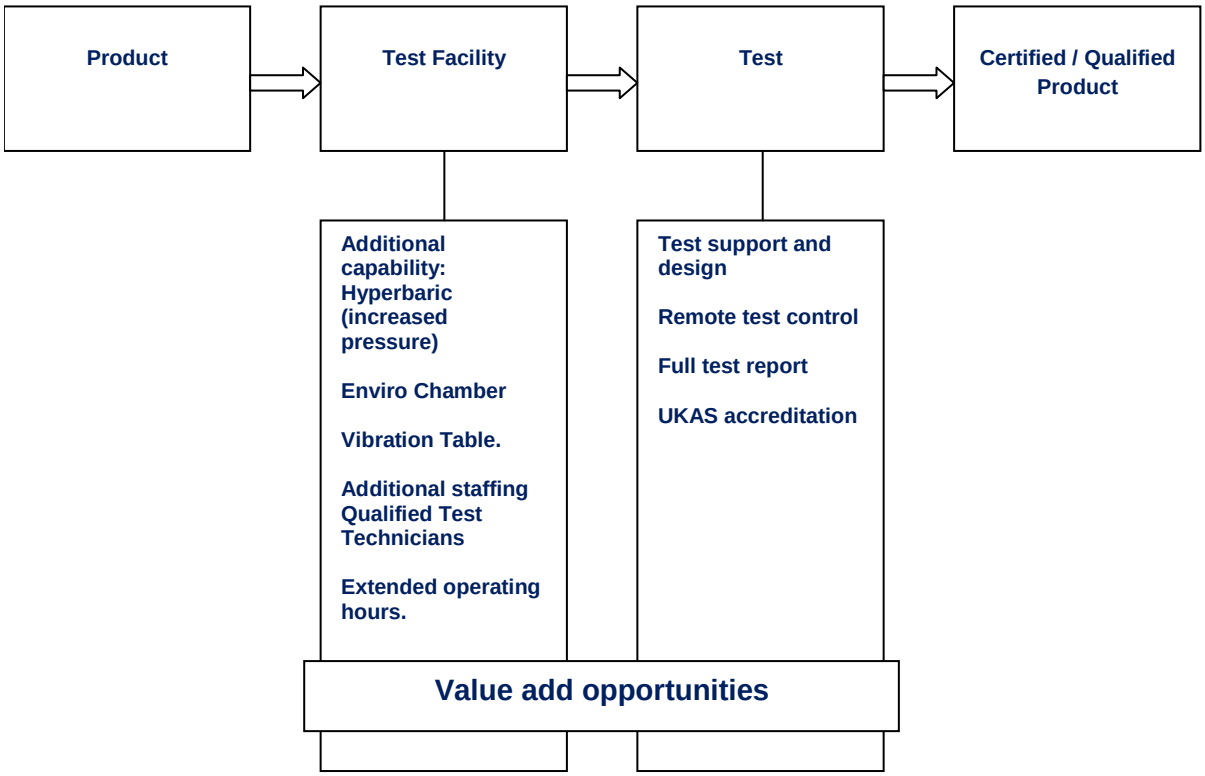
In terms of Testing this is often shown as a support activity but more properly is an integral part of the supply chain, across all phases of the upstream industry - and could be illustrated as follows;



Testing can be shown as a simple “value add” at each stage of product development. From materials test / and, component FAT, Sub-system SIT, full system SIT, refurbishment and retest. The tested and certified product has a value added as a result of testing to a standard.

For many manufacturing companies however, testing is a mandatory process that is a cost of manufacture rather than opportunities for value add.

Of more relevance is an understanding of where companies that provide testing can add value to existing arrangements. Where can a test facility add value? In many respects the opportunities appear to be somewhat limited and can be summarised as improved facilities, improved staffing, and enhanced accreditation through UKAS.

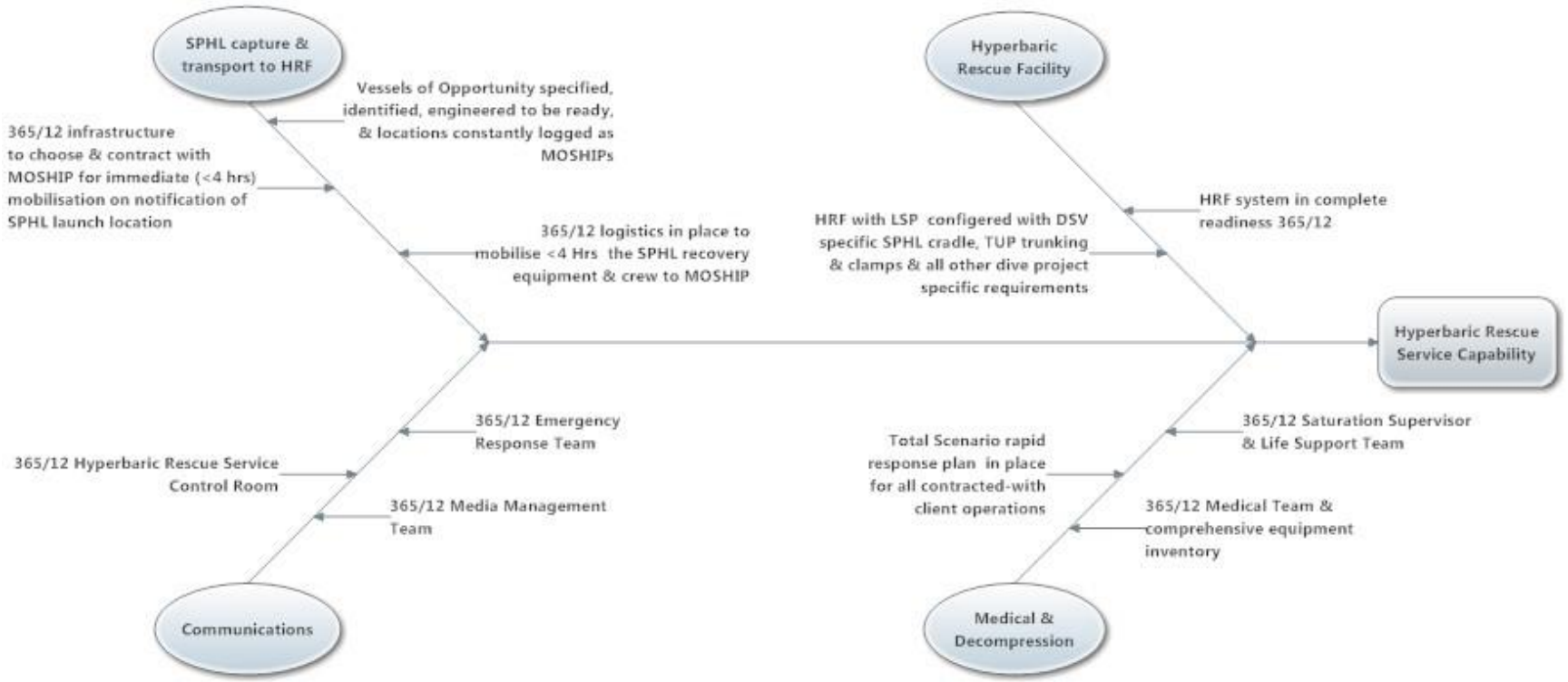


Where test facilities do have advantage is the high cost of entry into the market. This is particularly true of larger scale hyperbaric test facilities. The importance of competent and qualified staffing should not be underestimated.

One area where Scotland and the UK could gain some competitive advantage is through a closer linking of complementary test facilities and capabilities, i.e.; the building of a network of collaborating test facilities and capabilities.

3.7.1. Constituent elements of the Hyperbaric Rescue Service Value Chain

The constituent elements of the Hyperbaric Rescue Service value chain would include the following;



3.8. WT 8: ADDITIONAL OPPORTUNITIES

The object of this WT was to Identify any additional opportunities which may include non oil & gas applications.

The opportunities in other industries would appear to be limited.

- Nuclear power generation / decommissioning: .....Very specialised. Quite different standards to the offshore oil & gas industry. Higher rates but difficult and lengthy process to enter.
- Aeronautical:.....Quite different standards to the offshore oil & gas industry and appear to operate on a much different and lower rates structure. Difficult to bridge the technical gap & no justifiable commercial reason for doing so.
- Chemical / Pharmaceutical: .....Have their own test infrastructure and standards.
- Food: .....May be some opportunity areas around the hydrostatic test of pipes and vessels (low pressure) but little appetite for chasing this work, because of lower rates structure to the offshore oil & gas industry.

4. CONCLUSIONS

4.1. CONCLUSIONS RE TESTING

Of the four areas of testing being evaluated in this Study it is only the Hyperbaric Testing market which has grown appreciably, with Test Pit use probably following the same growth trend as it is associated (in that many items which are pressure tested are also subsequently immersed in a water filled tank to test for air or hydraulic leaks).

Testing is of particular importance to the subsea sector. All interviewees reported an increase in testing requirements, the general view being that there is not only more testing being done, but that the testing is becoming ever more stringent. This includes a noticeable growth in the requirement for deeper testing capability as offshore developments in deepwater increase. Part of the reason for the amount of testing increase is that post-Macondo there has been an across-the-market change in at least four aspects of testing practice;

- Batch testing: .....whereby maybe 1 in every 10 valves were tested, is not now generally acceptable. Now, every system or component being installed sub-surface has to be tested.
- Scaling: .... in the past, operator's would accept scaling, i.e.; a 2 inch valve tested, so a 5 inch valve of the same design would justify. But this no longer the case. Every unit of each type, size and design must now be tested.
- Test cycles: ....have been substantially increased. Where previously a component might have been subjected to say, 200 cycles, the same component is now more likely to be subjected to say, 600 cycles.
- Wider range of testing: ..... Every system or component being installed sub-surface invariably now has to undergo pressure, temperature and EMC testing.

The result of these changes in approach is difficult to quantify across the supply chain because of the different "batch %" ratio's, but a figure of say, ten-fold, would be conservative.

The markets of Vibration Table testing and Environmental Chamber testing are so small as to have been hardly mentioned in the interviews with industry, so are ignored here.

It has not been possible to directly quantify the increase in the Hyperbaric Testing market across the board, because of the reluctance of interviewees to provide statistics or commercial information. However, as we already had the NHC market information for 2005 to 2010 on file from the previous study and NHC provided their enquiries and work done records for 2011 to 2015 we can make the comparison and it can be assumed that the type of increase in business seen by the NHC will be broadly representative of the rest of the testing services providers.

On this basis, we can say the market for Hyperbaric Testing has grown by some 65% in the past 5 years based on the enquiries.

It can also be confirmed that the Hyperbaric Testing market has currently unfulfilled requirements for large scale deepwater (up to 450 bar – approximately equivalent to 4,500 of sea water) testing facilities.

It has also been noted that there are many manufacturers with testing facilities who make these available to outside companies, but do not market the service as a separate business line.

The North East of Scotland is a Global Centre of Excellence in subsea engineering. To maintain this world leading position, it requires world class facilities to ensure this position continues. There are other countries around the world investing in these types of facilities to attract inward investment. Subsea UK highlighted in its manifesto to Government in 2013 that to remain internationally competitive; we have to invest in R&D which includes facilities for proving and testing subsea equipment.

Having facilities close to the manufacturers is a real benefit as it reduces the time to transport equipment for test and the need to send client company engineers on long trips to test facilities.

The NHC has the title of a "National" testing centre but it lacks the deepwater test capability that is required for today's marketplace. A new testing facility in Aberdeen would help "anchor" and secure the future of the Subsea Global Centre of Excellence in the UK and North East Scotland. A new facility would fill a need and also be complimentary to the other test facilities located in the UK.

The hyperbaric testing knowledge is very strong in Aberdeen and this expertise would be sought after around the world as the next generation of hyperbaric chamber is developed. This has the potential to be developed as the global centre for knowledge and training in hyperbaric testing.

4.2. KEY FINDING RE TESTING

Of the manufacturers who were asked whether they'd be prepared to discuss the possibility of allowing a third party to market and coordinate their "spare testing capacity", most said they'd consider this.

Coordination of the "spare testing capacity" in the market would directly benefit the supply chain.

4.3. CONCLUSIONS RE HYPERBARIC RESCUE

The main conclusion from the Study is that the market for Hyperbaric Rescue per se is static, it may even see a decline over this year and next.

However, the secondary conclusion is that there are currently two areas of deficiency in service in the hyperbaric rescue market. These are;

1. Lack of a standard industry approach to HRF strategy.
2. No standard industry approach to the support of a launched SPHL.

4.4. KEY FINDINGS RE HYPERBARIC RESCUE

There is one key area where the current arrangement for UKCS Hyperbaric Rescue is clearly deficient and that is "how the SPHL gets to a HRF within an acceptable time-frame".

The UKCS diving industry needs to give this matter urgent attention, before a real-time emergency Hyperbaric Lifeboat launch shows up the flaws in the present arrangements.

Copying the Statoil RRRVs model is one option. However, this has not been trialled with a SPHL in anything other than a flat calm sea. There is general industry concern that in rougher seas the SPHL mating trunking stands a high chance of being damaged, which would be catastrophic.

The ideal solution would be establishment of a service in which a number of suitable "vessels of opportunity", were available to respond within an agreed period to a diving emergency, each equipped with or engineered to accept in a quick mobilisation, a heave compensated deployment system capable of lifting the SPHL onboard in heavy weather sea-states and conveying it to the nearest HRF equipped port.

4.5. Conclusions re Diver On-training

The conclusion on this is that whilst the Training companies have aspirations to develop a new regime of experienced Diver on-training which would carry a formal qualification, the industry per se has no appetite for this in the current economic climate. In all probability, it would be an uphill struggle to put this training and accreditation framework in place even if the industry were in a bull market phase – as evidenced by the fact it has not been done already.

4.6. Answers to key Study questions

Q1: Whether the industry needs and can support additional hyperbaric testing facilities?

The answer to this question is a qualified yes;

1. The qualification is that the new hyperbaric testing facilities should be different to that already existing and available for use in the open market, i.e.; in terms of physical size, pressure rating and environmental conditions capable of being created within them.

   i.e.; The new facilities should be complementary to rather than competitive with, existing facilities.

   NB: See the large capacity hyperbaric testing facilities comparison graphic in Section 2.2.1. of this Report.

2. A number of key interviewees advised that whilst they managed with the existing facilities, there were regular occasions when either;

   - they could not get availability to suit their ideal project time-lines
   - they could not test to the "full depth" they would like to, because no pressure vessels existed which were large enough, with high enough pressure rating.

   NB: This is precisely the reason why Aker Solutions are building their new hyperbaric testing facility.

Q2: Whether Aberdeen is most appropriate location for them bearing in mind that large equipment manufacture is distributed across Scotland and the UK?

Aberdeen is probably the best choice of any location in Scotland because;

1. It is where the most subsea equipment Manufacturers have their facilities.

2. It is where the UKCS Oil & Gas industry is headquartered and where all Operators, Manufacturers and Contractor organisations have a presence.
3. It is the most utilised "service port" for supply boats delivering equipment to the North Sea.
4. Siting any new hyperbaric facilities in Aberdeen will help enforce the "Aberdeen Subsea Industry cluster" widely promoted and supported by SE and Subsea UK.

Q3: Will (SE) supporting new hyperbaric testing facilities improve or generate additional opportunities for the supply chain? or do existing arrangements satisfy the current market?

New hyperbaric testing facilities will both improve or generate additional opportunities for the supply chain.

Proof of this is the fact that in this Study, interviewees have confirmed;

- The amount of industry testing has been increasing year on year for the past 5 years,
- There is a need for large scale testing vessels with a higher pressure rating (up to 450 Bar) than is currently available on the open market

Q4: Are there limitations to the existing facilities?

Yes; As stated above. There is a market need for large scale testing vessels with a higher pressure rating than is currently available - up to 450 Bar.

Q5: Is it the case that the NHC "centre of excellence testing facilities" serves to anchor the subsea sector in the UK /Scotland? Might new facilities simply duplicate existing facilities?

Yes. As clearly stated already in the answer to Q2 above.

Q6: Is there an increased demand for testing?

Yes. As clearly stated already in the answer to Q3 above.

Q7: Would the cost (investment) by public sector be justified?

That is really a question only Scottish Enterprise can answer, after having applied their criteria.

However, as a contribution to the discussion, the author would point out the following;

- Provided any new hyperbaric facilities developed in Aberdeen were complementary to and not competitive with existing facilities (See the answer to Q1 part 1 above) they would be providing the supply chain with a service that is needed.

  NB: See the large capacity hyperbaric testing facilities comparison graphic in Section 2.2.1. of this Report.

Q8: Is there an opportunity for SMEs? Is the apparent "decrease in numbers of SMEs reported by some pundits" actually happening?

Two different questions here. The authors answers are;

Q8.1: *Is there an opportunity for SMEs?*

Yes; Provision of new hyperbaric testing house in Aberdeen with up to 450 Bar pressure rating capacity would provide the SME manufacturing supply chain with "deepwater" product testing & proving facilities.

There are a large number of SME Manufacturers who need to use hyperbaric testing services on a regular basis in their business. All of these Companies target the deepwater subsea market because it is in this sector where greatest profit (contribution) can be made on their products. These are all therefore potential users of any new high pressure rated hyperbaric facilities opened in Aberdeen.

Some Aberdeen based SME Manufacturers who could potentially be users of the facilities would include;

C-Technics: ..... Subsea communications, cameras & lighting systems: Pressure test of camera housings and cable glands etc.

All Oceans: ..... ROV deployment systems: Pressure test of electronics bottles, oil-filled hydraulic control boxes, cable glands etc in ROV TMS (Tether Management Systems).

Searchwise: ..... Diving Equipment: Pressure test of umbilical connectors, camera & lights housings etc.

Schoolhill Hydraulics: ... Hydraulic systems: Pressure test of valves, oil-filled hydraulic control boxes, etc.

Plexus Subsea:..... Wellheads & mudline systems: Pressure test of valves etc.

Q8.2: Is the apparent "decrease in numbers of SMEs reported by some pundits" actually happening?

Yes; It is the case that since the start of the current economic downturn, with it's resultant round of bankruptcies and corporate consolidations, there have been a number of instances of SME's either going out of business or having been "consumed" into large corporate entities.

However; there is no proof that this phenomenon has been detrimental either to the SME supply chain community or the industry competitiveness.

Some examples of significant SME's (using the EC definition) going out of business in the past year include;

- Red7marine Offshore
- Specialist Subsea Services
- Reef Subsea
- Technocean Subsea
- X-Subsea

Some examples of SME's "consumed" into large corporate entities in the past year include;

- NHC..... Now part of James Fisher Group
- Nautronix ..... Now part of Proserv
- Bowtech..... Now part of Teledyne
- J & S marine..... Now part of Cohort
- Escape Business Technologies..... Now a part of Cegal
- Polyoil Roxar..... Now part of Emerson

APPENDIX 1: DEFINITIONS & ACRONYMS

SPHL ..... Self-propelled Hyperbaric Lifeboat

DSV..... Dive Support Vessel

HRF..... Hyperbaric Rescue Facility

COP ..... Conoco Phillips

IOGP ..... The International Association of Oil & Gas Producers

SE ..... Scottish Enterprise

NHC ..... National Hyperbaric Centre

CAGR ..... Compound Annual Growth Rate

FAT ..... Factory Acceptance Test

Ts & Cs..... Terms & Conditions

PV ..... Pressure Vessel

JFD..... James Fisher Defence Limited

ALARP..... As low as reasonably practical

IMCA ..... International Marine Contractors Association

DMAC..... Diving Medical Advisory Committee

IMO ..... International Marine Organisation

IDSA..... International Diving Schools Association

HEP..... Hyperbaric Evacuation Plan

RRRV..... Rapid Responds Rescue Vessel

NCS..... Norwegian Continental Shelf

UKCS..... United Kingdom Continental Shelf

ISO..... International Organisation for Standardisation

BSI ..... British Standards Institute

API..... American Petroleum Institute

DNV GL..... Det Norske Veritas Germanischer Lloyd

ABS..... The American Bureau of Shipping

RHIB ..... Rigid Hulled Inflatable Boat

ACOP ..... Approved Code of Practice

TMS ..... Tether Management System

SME ..... Small & Medium Enterprises

APPENDIX 2: STUDY SCOPE & METHODOLOGY

Scope

The study comprised the following Work Tasks;

WT 1 Market for large scale hyperbaric testing

A review of the current and future market demand and supply for large scale hyperbaric testing capable of simulating water depths of 4000 metres or more.

WT 2 Market for vibration table testing

A review of the current and future market demand and supply for vibration table testing, including shock; random; sine sweep; and resonance search and dwell testing capabilities.

WT 3 Market for environmental chamber testing

A review of the current and future market demand and supply for environmental chamber testing.

WT 4 Market for test pit access

A review of the current and future market demand and supply for test pit access, including deepwater pits with capabilities for hydro and gas testing.

WT 5 Demand for hyperbaric rescue services

Discussions with relevant industry stakeholders like Subsea UK, IMCA, Oil & Gas Industry Leadership Group and key industry players etc to endeavour to quantify the following;

WT 5.1 The number of diving days being conducted in given geographical regions e.g.; UKCS, Norwegian sector, Middle East, West Africa etc.

WT 5.2 The spread of hyperbaric rescue equipment across the world e.g.; where are the fixed and mobile facilities and who owns them etc.

WT 5.3 Where the main growth areas of diving are likely to take place and their scale, i.e.; water depths, temperatures, diving days etc.

WT 5.4 Future demand for additional qualifications Diver training and how this might be being affected by changes in legislation or changes in industry requirements for more competency-based skills and development type training.

WT 6 Pressure testing market growth

Assess the progression (or otherwise) made against the targets reported on in the 2010 report (i.e.; 50% increase in pressure testing; jobs growth of 15-20,000 etc. within the next five years), confirming whether or not these targets have actually been achieved and how this upsurge (or otherwise) may have affected the demand for hyperbaric pressure testing.

WT 7 Market areas value chains

Provide an overview of the value chain for each of the areas listed in 2.WT1 to 2.WT6 above.

WT 8 Additional opportunities

Identify any additional opportunities which may include non oil & gas applications.

This study will take a high level approach using readily available public sources of information plus access to primary data readily available to **Subsea UK** through its membership and other private sources. The study whilst estimating the potential economic scale of the markets, the constraints of available budget will not allow fully detailed econometric forecasting of all the chosen subsea sectors.

Output

The output for this work will be a Final Report covering the findings of each of the Work Tasks described above. The report will contain an executive summary which can be published separately from the detailed report content.

Methodology

The primary approach taken to collect market information in the Study was to hold face to face interviews with "key UK industry players" identified by Subsea UK Researchers as senior management people in organisations known to be either users or providers in the six areas of the Study.

Where it was not possible to arrange face to face interviews, but still considered important to collect the persons view, a small number of interviews were undertaken by telephone.

Whilst the majority of the interviewees were identified by Subsea UK from knowledge of the market and key people in it, an on-line survey was also conducted to identify additional people who. The survey was put out to all Subsea UK member companies plus another circa 100 companies in UK identified by Subsea UK and the Study.

FACE TO FACE INTERVIEWS

Each interview took the form of a structured discussion within which a number of specific questions were asked. All answers contributed toward quantification of markets and the Companies activities in these markets.

Copies of the question lists developed as "aide memoire for interviews" are provided in Appendix 4.

A list of all Interviewees is provided in Appendix 5.

ON-LINE SURVEY

A total of some 260 Companies were contacted and asked to undertake an on-line survey in which the following questions were asked;

1. Does your Company undertake hyperbaric testing in-house?
2. Does your company purchase hyperbaric testing services
3. Is other testing such as environmental test or vibration table test important to your company.
4. Could you or a colleague give a view on the importance of testing within the industry?
5. Are you willing to discuss this issue with our researchers?

This survey resulted in identification of 15 additional companies with an interest in hyperbaric testing who were not on the list of interviewees put together by Subsea UK and each of these were subsequently interviewed.

DESK RESEARCH

Desk research was undertaken to collect information from secondary data sources and to review relevant literature, published studies, econometrics, and statistical data.

STUDY WORK TASKS

The Study was divided into the following eight Work Tasks;

WT 1 Market for large scale hyperbaric testing

A review of the current and future market demand and supply for large scale hyperbaric testing capable of simulating water depths of 4000 metres or more.

WT 2 Market for vibration table testing

A review of the current and future market demand and supply for vibration table testing, including shock; random; sine sweep; and resonance search and dwell testing capabilities.

WT 3 Market for environmental chamber testing

A review of the current and future market demand and supply for environmental chamber testing.

WT 4 Market for test pit access

A review of the current and future market demand and supply for test pit access, including deepwater pits with capabilities for hydro and gas testing.

WT 5 Demand for hyperbaric rescue services & diver on-training

Discussions with relevant industry stakeholders like Subsea UK, IMCA, Oil & Gas Industry Leadership Group and key industry players etc to endeavour to quantify the following;

- The number of diving days being conducted in given geographical regions e.g.; UKCS, Norwegian sector, Middle East, West Africa etc.
- The spread of hyperbaric rescue equipment across the world e.g.; where are the fixed and mobile facilities and who owns them etc.
- Where the main growth areas of diving are likely to take place and their scale, i.e.; water depths, temperatures, diving days etc.
- Future demand for additional qualifications Diver training and how this might be being affected by changes in legislation or changes in industry requirements for more competency-based skills and development type training.

WT 6 Pressure testing market growth

Assess the progression (or otherwise) made against the targets reported on in the 2010 report (i.e.; 50% increase in pressure testing; jobs growth of 15-20,000 etc. within the next five years), confirming whether or not these targets have actually been achieved and how this upsurge (or otherwise) may have affected the demand for hyperbaric pressure testing.

WT 7 Market areas value chains

Provide an overview of the value chain for each of the areas listed in WT1 to WT6 above.

WT 8 Additional opportunities

Identify any additional opportunities which may include non oil & gas applications.

APPENDIX 3: INTERVIEW QUESTIONS

Because the first four areas of the study (re testing) were quite different to the fifth and sixth areas (these being diver related) two distinct interviewee lists were prepared;

List 1: Interviewees primarily involved with testing. A total of 49 face to face interviews and 9 telephone interviews were conducted.

List 1: Interviewees involved in commercial diving. . A total of 10 face to face interviews and 2 telephone interviews were conducted.

LIST 1 QUESTIONS

Re General

Q1: Role of within company?

Q2: Involvement/ responsibility for testing?

Re Industry Trends re testing

Q3: Could you give a view re the importance of testing within the industry?

Q4: Increasing? What is driving this? Macondo/ environment/ cost of failure

Q5: Trend within your own company comparison over last 5 years

Re Company Policy

Q6: What is your company policy re testing?

Q7: Where does responsibility lie- expectation on manufacturers / subcontractors.

Q8: Standards/ ISO/ Risk Management/CE marking

Q9: Type of testing undertaken?

Re Large scale hyperbaric testing specific

Q10: Responsibility?

Q11: What is tested? Items? Weld tests?

Q12: Where is testing carried out?

Q13: Awareness of other test facilities (Vetco/Balmoral/Neptune/ international)

Q14: Weight Dimensions scale of items

Q15: Current Pressure Bar/Water depth (100bar=1000 metres)

Q16: Future Pressure Bar/Water depth requirement trend

Q17: Description of test

Q18: Wet/ dry

Q19: FAT/ SIT

Q20: Duration of tests

Q21: Can you quantify- Numbers? / Number of days per annum

Q22: Costs?

Q23: Contract arrangements with test facility

Q24: Any issues re availability, access/ transport / time /cost/ rating?

Q25: How improve these issues

Q26: Would a large scale hyperbaric test facility in Aberdeen /Scotland be of interest?

Q27: What would it look like to be of interest to your company?

Q28: Any issues that would preclude your company from using facility

Q29: Would you support a new facility through-

i. Initial investment

ii. Commitment to usage

Re Other testing important to your company

Q30: Vibration table

Q31: Environmental chamber testing

Q32: Test Pit

Re Other Issues

Q33: Have you any other comments re hyperbaric testing

Q34: Anyone else within your organisation or elsewhere that would have a view on this

LIST 2 QUESTIONS

Re Hyperbaric Rescue

Q1: Your Co Profile (if you have such a document), or overview of history and track record etc.

Q2: Yr views on the "strategy of hyperbaric rescue",

Q3: No & Technical description of the equipment/systems your Co owns/operates

Q4: The range of services provided?

Q5: The range of clients you service?

Q6: Value of Hyperbaric Rescue contracts in terms of either, per contract type, per call-out, any other commercial type information you'd care to provide.

Q7: Geographic location of equipment/systems your Co owns/operates

Q8: The growth of Hyperbaric Rescue business over past 5 yrs?

Q9: Anticipated/forecast growth of Hyperbaric Rescue business in next 5 yrs?

Re In-water hyperbaric testing

Q10: What is the type & range of in-water hyperbaric testing you are doing now?

Q11: The growth of in-water hyperbaric testing over past 5 yrs?

Q12: Anticipated/forecast growth of in-water hyperbaric testing in next 5 yrs?

Re Diver "on-training"

Q13: Type and range of on-training your Co does with experienced divers?

Q14: Type and range of training your Co could do?

Q15: Who are the your Co competitors in Training (contact details if poss as I'd like to speak to them too),

Q16: Do you compete directly with these competitors? Or is their offering slightly different?

Q17: Is there business enough out there for your Co & its competitors to thrive & grow, or are you all chasing same client pool?

Q18: How does your Co differentiate from its competitors?

Q19: Do you have records showing growth of Training at your Co over past 5 yrs?

Q20: Do you have a Training "business plan" for the next 5 yrs?