DEVELOPMENT OF A CONTROLLABLE GRAB SYSTEM FOR DEEP WATER RECOVERY

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ABSTRACT

Grab devices have been extensively used for commercial cargo salvage and sensitive military recovery projects throughout much of the past century. Early grabs suffered from a lack of positional control and remote intelligence and thus were not very efficient. The first truly controllable grab was developed in the early 1970s by the CIA in their partially successful attempt to recover a Russian 'Golf' class submarine. This concept of a controllable Grab deployed from a modified drillship was commercialised in 1994 by Blue Water Recoveries (BWR) with development of a 3,000 metre rated Grab used to recover 18 tonnes of silver coins from the *SS John Barry*. Although technically successful, it was soon apparent that this prototype Grab 3000 would need to be improved to be able to recover cargo at even higher rates of efficiency. What was required was a blending of an extremely strong mechanical Grab that exerted forces of up to 200 tonnes with a very highly specified ROV control system and sensor suite. Reliability and efficiency were the key design parameters of the new 6,000 metre rated Grab and bucket recovery system that was completed and sea-tested by BWR in late 1996. The new 150 horsepower Grab 6000 was run from a unique fibre-optic cable and utilised twice the number of sensors found on most work-class ROVs. Within weeks of it's deployment the Grab 6000 was setting new standards in deep water salvage by recovering over 50 tonnes of cargo from a depth of 3,800 metres in a single lift.

INTRODUCTION

The first deep water grab system developed by Blue Water Recoveries (Grab 3000 System) was instigated by the requirement to deploy a tool to the depth of the *SS John Barry* (2,600 metres), accurately position it on the wreck, and then remotely operate it to remove the deck and extract a specific cargo from within the cargo holds. By deploying a tool from a drilling vessel on the end of the drill pipe the strength and control of the drilling system is harnessed to the tool and creates a powerful system with almost fingertip control. This concept of operating tools other than drill bits from the end of a drill pipe is not new and has been utilised routinely since the very early days of oil exploration. Most uses of this technique have been 'down hole' or carrying out a wide range of complex tasks but tools for use outside the hole have also been widely used.

The design of the Grab 3000 system evolved from previously used technology. In particular the secret CIA operation to attempt to recover in one piece the Russian 'Golf' class submarine sunk off Hawaii in the 1960s. This operation involved the design and build of the *Glomar Challenger* (now converted into a modern drillship) and the design of a special derrick and drill pipe system capable of lifting 7,000 tonnes.

Deep water, which we consider as depths greater than approximately 1000 metres, excludes the effective use of explosives which was the accepted method in the shallow water salvage community for 'opening' steel-hulled wrecks to allow access to the cargo holds. For the *John Barry* lying in 2,600 metres, and for any other steel-hulled vessels in deep water another opening force was required. The logical option is a mechanical force and in the case of the Grab 3000 this was provided by a combination of the pulling strength of the drill pipe and the closing force of the Grab itself.

The contract for the design engineering of the Grab 3000 system was awarded by BWR to the French Government Institution for Marine Exploration and Research (IFREMER). IFREMER subcontracted Perry Tritech of Miami to build the Grab's control system while the umbilical winch was supplied by Dynacon of Houston. The umbilical was a multi-conductor copper cable manufactured by Alcatel.

The subsequent *John Barry* salvage operation undertaken with the Grab 3000 was a technical success that effectively pushed the limit for commercial shipwreck salvage down to 3,000 metres. This prototype system was repeatedly deployed to the wreck and in a controlled manner using a combination of the ship's DP system, vertical adjustments of the drill pipe, and two thrusters to position the Grab inside cargo holds was able to recover over 18 tonnes of paying cargo (1.3 million Saudi Arabian silver Riyals). Once the vessel was stabilised in position movements of 1 metre was standard. The design mechanical strength of the Grab, at 200 tonnes closing force and vertical pull, was confirmed and proved capable of dismantling a steel –hulled wreck.

Despite this successful demonstration of the Grab 3000 the overall operational experience on the *John Barry* salvage operation highlighted a number of deficiencies of the system which can be listed as follows: 1) inadequate lighting with no intensity control; 2) insufficient number of cameras and poor resolution; 3) no facility for zoom, focus or colour video; 4) no sonar for navigation and obstacle identification or avoidance in poor or zero visibility; 5) no depth sensor; 6) inaccurate compass; 7) inadequate hydraulic power – grab closing and opening too slow; and 8) horizontal movement of the Grab in only one axis.

Based on operational experiences and identification of the shortcomings of the Grab 3000 BWR commissioned an in-house study on the development of a new system based on fibre optic control, greater power and a vastly improved camera, lighting and sensor array. The new system would have an operational depth rating of 6,000 metres, to meet the depth requirement of the company's future salvage targets, and thus was named the Grab 6000. The specification developed for the Grab 6000 system included the following main requirements.

- 6,000 metre depth rating
- Fibre optic umbilical
- 150 total hydraulic horsepower
- Sector scanning sonars
- Profiling sonars
- Video cameras, colour, focus, low-light SIT
- Lights and dimmer control
- HMI lights
- Altimeter
- Depth sensor
- Gyrocompas
- Pitch and roll sensor
- Hydrophone
- Load cell
- Hydraulic thrusters giving omni-directional thrust controlled by joystick
- Automatic spooling umbilical winch

Several pre-qualified ROV manufacturers were invited to submit technical and commercial bids and after a stringent evaluation process Slingsby Engineering Ltd. of Yorkshire were awarded the contract for the design engineering and construction of the system. Dynacon was again contracted to supply the umbilical winch and Rochester Corporation of Virginia was contracted to supply the two 6,300 metre fibre optic umbilicals (one operational and one spare).

THE GRAB 6000 RECOVERY SYSTEM

The Overall Concept

The overall concept of the Grab 6000 recovery system is very simple (see Figure 1). The tool, in this case the Grab, is fixed to the end of the drill pipe deployed from a drilling platform (drillship, barge, semi-submersible, etc.) The control module which houses the hydraulic power plant, thrusters, electrical junction boxes, etc., is situated a few metres above the Grab and is secured to the drill pipe – the drill pipe actually passes through the centre of the module. The umbilical which runs from the control van on the surface to the control module is clamped to the drill pipe. The system is controlled by the Grab operator or pilot from the control van on the support vessel. Positional changes are made directly by the Grab pilot or by his requesting movements on the drill pipe or the vessel dynamic positioning.

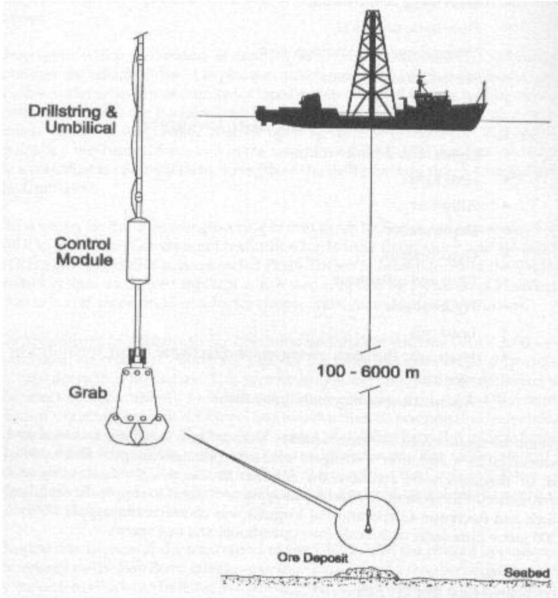

Fig. 1 The Overall Concept

THE GRAB

The Grab was built to be able to dismantle steel-hulled vessels and penetrate the holds to recover the cargo to the surface (see Figure 2). The jaws have a closing force of 200 tonnes and the Grab can sustain a vertical pulling force of the same amount. The Grab weighs nearly 50 tonnes when complete. It stands nearly 6.0m tall, is 2.0m wide and when fully open there is a 3.8m spread between the jaws. Its internal capacity in a closed position is 5.0 cu.m.

At the top of the Grab is a Cardon universal joint which secures the Grab to the drill pipe. The Cardon joint comprises two hinges that allow deflection of the Grab in any direction off the horizontal (630 degree movement), thus allowing the Grab to engage targets from the side. Pitch and roll sensors are fitted on both the Grab and control module so the operator can monitor the attitude of the Grab.

The Grab can also be fitted with side plates for cutting action or 'gums' to cover the teeth for tasks requiring a scraping action. A low-pressure centrifugal type water pump housed in the control module can supply a constant flow of water to flush the Grab interior clean to improve visibility.

Fig. 2 The Grab

The Grab is instrumented with a suite of video cameras (2 x CCD monochrome, 3 x SIT and 1 x zoom colour), lights (10 x 250 watt spotlights, 2 x 400 watt HMI lights), sonars (2 x scanning sonars and 2 x profiling sonars) and a variety of sensors (pressure/depth, altimeter, load cell, compass, hydrophone) to permit the pilot to work in both good visibility and zero visibility conditions.

THE CONTROL MODULE

The subsea power plant, known as the control module is clamped to the drill pipe 3-4m above the Grab (see Figure 3). It measures 4.5m high, has a diameter of 1.8m and weighs 8 tonnes. Because of the nature of its work in dismantling steel hulls, all components housed in the control module have been specified for high strength and durability (stainless steel rather than aluminium) and can withstand vertical accelerations of 4g, horizontal accelerations of 1g and pinpoint impacts of 10 tonnes.

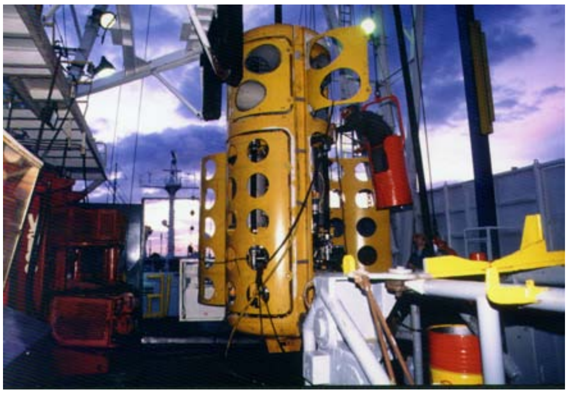

Fig. 3 The Control Module

The control module provides power, instrumentation and control to the Grab. The control module is equiped with two 75 SHP electro-hydraulic power packs that operate together to produce 150 HP of hydraulic power that drive four 16.5 inch diameter thrusters, positioned in the upper section of the module. The four bi-directional thrusters are controlled by the pilot's joystick to make precisely controlled movements in any horizontal direction.

The fibre optic umbilical is terminated at a large junction box in the control module. The junction box also houses an instrument transformer that feeds power directly to the two power packs. A second junction box distributes signal and data lines to the valve packs and sensors. Between the Grab and the control module an extension piece provides protective structure for the hydraulic hoses and electrical lines that supply power and control to the Grab and its associated sensors.

A video camera and two lights are fitted to the lower end of the control module to look down on the Grab and monitor it while it is working.

VIDEO CAMERA, LIGHTING AND SENSOR SUITE

A broad range of video cameras, controllable lights, sonars, navigation devices and other sensors are used to operate the Grab in an effective and efficient manner.

The relatively high number of cameras (7), lights (12) and sonars (4) on the Grab and control module allow the pilots to view and monitor the work site from a variety of angles. They also provide a built in redundancy in case of failure. The full number of cameras, lights and sensors are summarised with Figure 4.

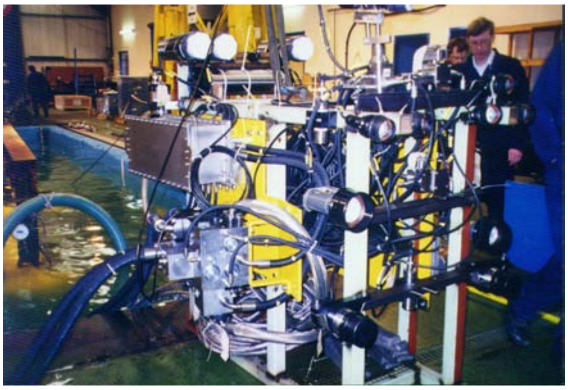

Fig. 4 Video camera, lighting and sensorsuite: 2 Insite Systems monochrome CCD cameras; 3 Insite Systems low light SIT cameras; 1 Insite Systems high resolution colour camera with 8:1 zoom; 10 Deepsea Power & Light 250 watt spotlights with independent dimmer control; 2 Deepsea Power & Light 400 watt HMI lights with dimmer control; 2 TriTech SeaKing dual frequency scanning imaging sonars; 2 TriTech SeaKing DFP profiling sonars; 1 200kHz hydrophone with broad band amplifier; 3 TriTech pan and tilt units; 1 Paroscientific Digiquartz pressure/depth sensor; pitch and roll sensors; 2 strain gauges; and 1 AIM 205 gyro heading sensor.

FIBRE OPTIC UMBILICAL AND STORAGE WINCH

The electro-optical umbilical is made of a centre core of seven optical steel-light fibres that is surrounded by six ~6 gauge power singles and a further six #16 gauge power singles in a symmetrical design, with an outer strength member / jacket. The outer diameter of the cable is 40mm.

The umbilical was manufactured by Rochester (acquired by Tyco) and is approximately 6,300m long. Prior to delivery the umbilical passed a series of electrical, optical attenuation, break strength, torque / rotation, and cyclic bending tests.

Only three of the seven fibre optic wave guides are used to transmit data, video and control signals, the remaining four are spares. The umbilical's strength is provided by two bands of spaced GIPS wires embedded in a jacket of HDPE. Breaking strength is 12,609 Kg and working strength is 3,175 Kg.

The umbilical is deployed from a powered storage winch that incorporates an automatic level wind with a Lebus groove shell to facilitate optimum spooling (see Figure 5). An innovative feature of the winch was an automatic spooling facility that would enable it to pay-out or haul-in umbilical at a rate in keeping with deployment of drill pipe. This feature essentially allowed hands-off operation of the winch and resulted in a reduction of the deck crew required to operate the system. The winch is hydraulically powered from a separate 50 HP hydraulic power unit. Its dimensions are 4.3m long, 3.35m wide, 4.25m high. Weight is approximately 30 tonnes including the umbilical.

Fig.5 Umbilical and storage winch

SURFACE CONTROL SYSTEM

The Grab 6000 system is operated from a surface control van housed in a customised 20 foot ISO container (see Figure 6). The van provides a controlled, low noise environment for the pilot and co-pilot. The primary components of the surface control van are the Grab control console, a power distribution panel, and a small office work area. The surface control system is largely PC based and the Grab control console incorporates the following features:-

Fig.6 Surface control system

- 3 bay 19" rack unit providing a double pilots and co-pilots bay
- Pilot controls, switches and alarms
- Joystick propulsion control
- Grab open / close control
- Grab control computer and keyboard
- Sonar computer and keyboard
- Camera / system control computer and keyboard

- 5 x 14" monitors
- 4 x 42 black and while monitors and DP and system monitors
- Video graphics overlay unit and switcher unit
- Quad video unit
- Heading repeater panel
- Hydrophone speaker unit

THE DEPLOYMENT SYSTEM

As discussed earlier the Grab 6000 salvage system was designed for deployment from a drilling vessel with the grab being attached to the end of the drill pipe and the control module being situated a few metres above the grab. The umbilical is clamped to the drill pipe every stand (three joints) of pipe.

Deployment in this manner enable precise control of the depth of the grab at any water depth by raising or lowering the drill pipe. Vertical movement on the drill pipe can be controlled by the derrick operator (The Driller) by incremental adjustments as little as 2-3".

Positional or horizontal accuracy of the grab at working depth relative to the work site is a direct function of the surface vessel to maintain station on a fixed point. In deep water this requires a Dynamically Positioned (DP) vessel receiving its geographical position by the Global Positioning System (GPS). In good weather with standard performance of the GPS and receipt of differential corrections the vessel position can be maintained plus or minus approximately 3 metres.

The safe working lad (SWL) of offshore drilling rigs is usually not less than 1,000,000 lbs – 454 tonnes. On present generation drilling rigs the SWL can be as high as 2,000,000 lbs. Utilising high grade pipe this power allows the operator to exert a pulling or lifting force on the Grab equal to the designed capability of the Grab of 200 tonnes to its maximum operational depths of 6,000 metres.

BULK RECOVERY SYSTEM

Despite the improved production with the Grab 6000 the recovery rate was largely determined by the speed at which the grab could be recovered to the surface, emptied and returned to the work site. With a trained crew the average rate of deployment and recovery was 1000 metres per hour. Thus, a round trip in 4000 metres would take a minimum of eight hours without any allowance for work time on the site.

To improve our recovery rate we conceived and built a bulk recovery system combined with a cargo handling system on the vessel (see Figure 7). This system consisted of an articulated skip with a total capacity of 28 cu.m., which was transported to the seabed by the Grab and laid on the seabed adjacent to the worksite. The Grab then filled the skip with successive grabs and when the skips were full retrieved them to the surface. On the support vessel the Grab delivered the skip to an automated handling system which emptied the skip into a cargo processing area and then returned the skip to the Grab ready for the next trip.

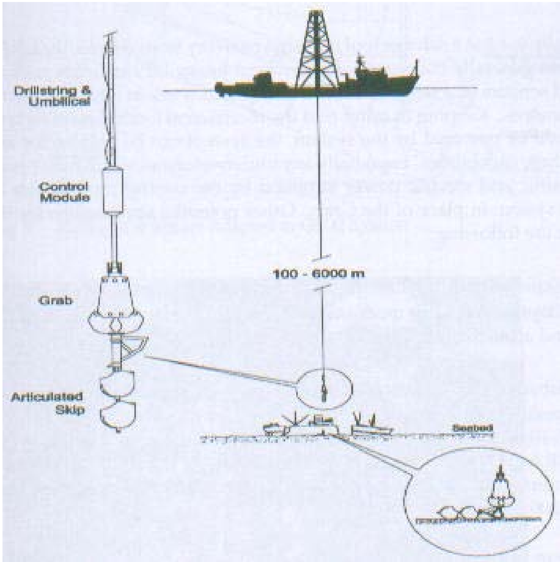

Fig.7 Bulk Recovery system

The Grab 6000 and bulk recovery system were installed onboard the salvage vessel, *Deepsea Worker* and being used operationally within nine months following the start of construction. The Grab 6000 was a vastly improved system over its prototype and it made an immediate impact in the rate of recovered cargo. On average with all conditions being equal (i.e. wreck depth, wreck condition, etc.) the cargo recovery rate increased from about 3-5 tonnes per day to 30-50 tonnes per day. Importantly, the system was also extremely reliable with few primary subsystem failures. The failures that did occur in nearly all cases did not necessitate recovery of the Grab because there was ample backup on the Grab.

During its time in active salvage operations the Grab 6000 system was used by Blue Water Recoveries to establish the following new standards for deepwater commercial salvage.

- Heaviest single load recovered: 125 tonnes
- Heaviest single lift of paying cargo: 53.9 tonnes (tin)
- Heaviest and deepest single lift of paying cargo: 45 tonnes from 3770 metres

FUTURE

Although initially used as a salvage tool for cargo recovery from wrecks, the Grab 6000 system was generally conceived of as a robust heavy lift capability with all the control and sensors of a work class ROV that could work in ultra deepwater down to 6000 metres. Keeping in mind that the mechanical Grab is just one type of tool that could be powered by the system, the system can be utilised for any task requiring these capabilities. Essentially any underwater tool which an operate with hydraulic and electric power supplied by the control module can be adapted to the system in place of the Grab. Other potential applications for the system include the following:

- Platform and pipeline decommissioning: preliminary studies for adaptation of large mechanical shears to the system have been made and attracted interest from the Oil and Gas Industry (see Figure 8).

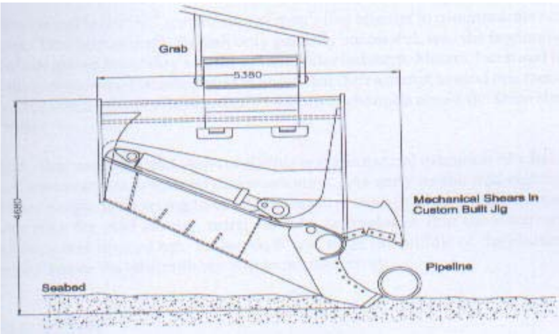

Fig.8 Mechanical Shears Adapted to G6000 System

- Subsea Mining: several mining projects around the world are considering making use of the system for recovery of bulk sample (5-10,000 tonnes) orebodies from deep water sites. Currently the Grab 6000 is the only proven system that has been used commercially for repeated recoveries from water depths approaching 4,000 metres.
- BOP and lost equipment recovery: an increasing number of BOPs and other large equipment have been dropped by accident in very deep water beyond the reach of divers. With drilling now becoming increasingly common in water depths of 3,000 metres there are few options for recovery if the rig is unable to retrieve the equipment by its own means. The Grab 6000 has been used in a couple of object recoveries in water depths to 1,200 metres but so far these have been limited to relatively light objects like the SCORPIO ROV.
- Installation of subsea equipment modules: utilising either the Grab or other specially designed tools the Grab 6000 system is capable of transporting loads of up to 200 tonnes to any depth within 6,000 metres and accurately positioning them on the seabed.