An Advanced Submersible Handling System

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ABSTRACT

An overview of shipboard submersible handling systems, representing current practice is presented. The simple A-Frame, articulated and pedestal-type cranes, and moon pool systems are evaluated, with attention given to the weather/operations corridor provided by each system. Described is a system particularly suited to research vessels. The system, a hybridized A-Frame, incorporates technology which has proven highly successful in hostile North Sea operations. It comprises a motion compensating lift winch, hydraulically controlled pendulation, and is of light weight, aluminum construction. Further discussion is devoted to emerging technology, and a forecase of future systems.

1.0 INTRODUCTION

The design and construction of a state-of-the-art research vessel, the R/V SEWARD JOHNSON, levied a mandate on Harbor Branch Foundation's (HBF) Ocean Engineering Division: provide the vessel with an equally advanced submersible handling system. Having designed and fabricated submersible handling systems in the past, HBF engineers were faced with the classic "buy or build" decision. The answer, it appears, was to do both.

The support ship's transoceanic capability dictated a handling system designed for world-wide operation, able to recover a submersbile in hostile seas. While HBF has amassed an impressive track record of launch and recoveries with their articulated cranes in the waters of eastern North America, it was deemed prudent to benefit from the experience of over a decade of submersible operations in the hostile environment of the North Sea. Evaluation of needs, both recognized and anticipated, indicated that a hybrid system, incorporating the North Sea proven hydraulic control system developed by Caley Hydraulics, Glasgow, Scotland; and the light-weight, low-maintenance, all-aluminum construction characteristic of the HBF articulated hydrocranes was the optimum solution. A brief description of the problem, some alternatives, and this ultimate solution follows, along with some speculation as to the evolution of future systems.

2.0 THE PROBLEM

The problem at hand is to launch and recover safely with a system that has reliability and failure back-up modes, and greatly increases the available weather corridor. The system must be operator friendly with minimal dependence, if any, on the submersibles crew and operation.

Typically, hydrodynamic characteristics of submersible and support ship differ vastly. Indiscriminate coupling of these vibrating bodies can wreak havoc on the submersible, support ship, and the handling system itself. Once clear of sea state induced excitation, the submersible suspended from a Launch/Recovery device presents yet a third system, with its own unique dynamic characteristics. An optimum system would make this transition, from two floating bodies to one, sympathetically with regard to the differences in phase and amplitude of the vessels.

An initial investigation into the problem of launch and recovery showed that, with many systems, substantial deck crew were required during the operation, and co-ordination could fail in bad weather. It became obvious that one man on board the support vessel should have control. There should be no need to rely on deck crew with steadying lines, secondary winches, fenders or other devices to help control a fragile submersible swinging in the air or surging in a restricted docking well.

3.0 THE OPTIONS

Indeed there are in existence many systems, many ideas. Some work well, and some are very complex. Some are extreme and demonstrate that a vivid imagination has been allowed to outweigh the employment of sound technology. In a search for the BEST WAY a comparison was made of several systems noting the pros and cons of each.

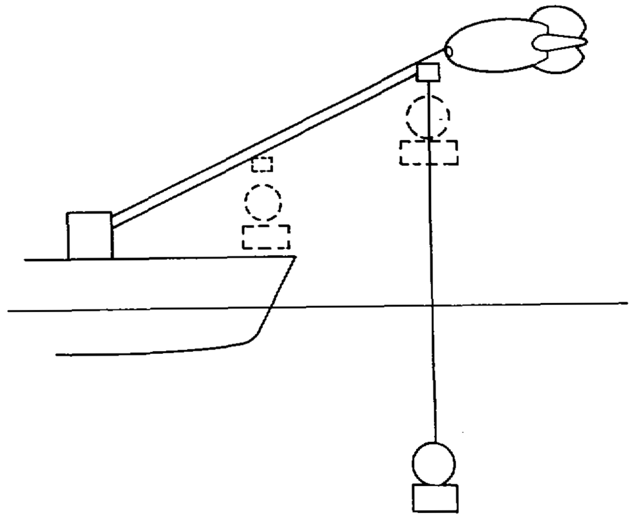

Fig. 1 Balloon Assist, Photo Courtesy F. Busby

SIMPLE A-FRAME

Advantages
a) Good stable structure
b) Easy to install
c) Simple operation
d) Easy to maintain

Disadvantages
a) Load pendulation resonance problem
b) Deck space occupied including winches can be considerable
c) Ropes to deck winches difficult to cope with when moving A-Frame
d) Other uses limited

SLEW TYPE DECK CRANES

Advantages
a) Multi-function lifting device, cargo, gear, etc.
b) Slewing capability very favorable in light sea conditions

Disadvantages
a) Pendulation contro difficult to design due to high torsional reaction loads induced into crane boom.
b) Slewing drive must be massive to cope with high inertias, even during moderate support vessel motion.
c) Good heave compensation essential to eliminate transient loads.

ARTICULATED CRANE

Advantages
a) Boom can be brought down to meet submersible, thereby eliminating pendulation
b) Places no contraints on the size of the submersible

Disadvantages
a) Close proximity of boom tip to submersible at the air/sea interface limits operations to calm sea
b) Location on center line obstructs trawling or similar operations over transom from forward mounted winches.
c) Side loads on this type of structure are severe

CURSOR AND GARAGE (MOON POOL)

Advantages
a) Very capable of launching and recovering through a rough sea interface
b) Good future possibilities

Disadvantages
a) System is more suited to the larger support vessel, particularly to semi-submersibles.
b) System almost totally dependent on submersible's good maneuverability and control of sub-sea docking
c) Garage or Cage requires heave compensation
d) Major development needed and costs very high

WET DOCK VESSEL

Advantages
Good moderate weather capability and track record

Disadvantages
Special purpose vessel not always commercially viable

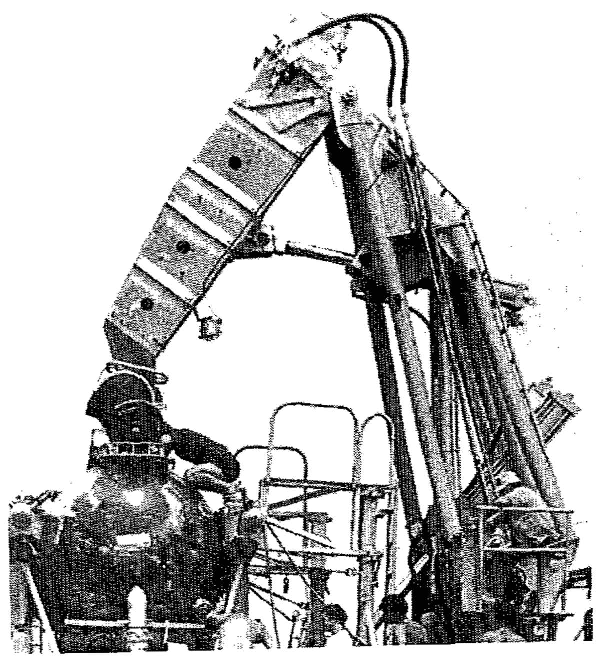

Fig. 2 HBF Built Articulated Hydrocrane

4.0 THE SOLUTION

CALEY A-FRAME WITH CONTROLLED PENDULATION AND A TENSION SENSITIVE WINCH

As engineers of marine hydraulic systems, including transmission and specialized control, Caley Hydraulics, Ltd. had no difficulty in choosing a closed loop, high pressure hydraulic system with proportional control and near 100% redundancy as the best way to power their system.

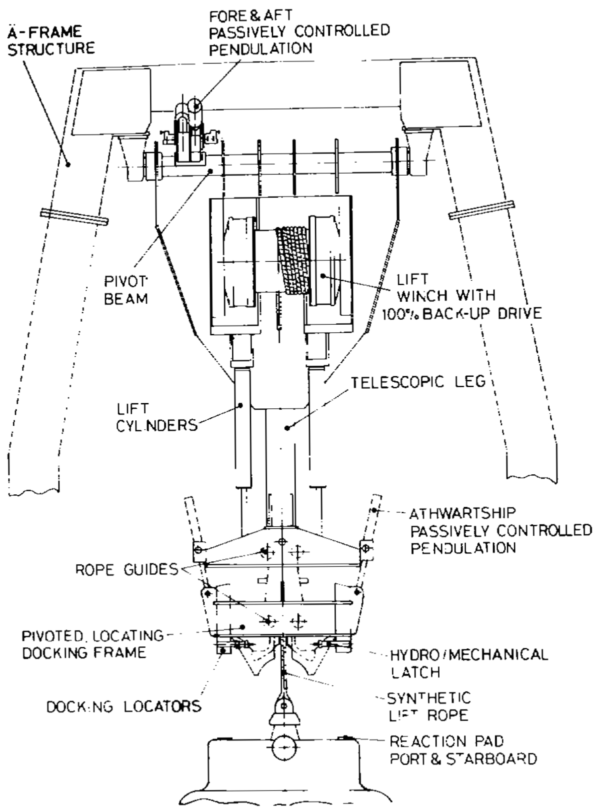

Fig. 3 Lift Winch and Telescopic Leg

A carefully designed A-Frame over the transom has good historic capability. Attention to built-in safety and hydraulic control of the substantial operating cylinders was considered a necessity. A single lift point was identified as being practical. It is easy to release and attach, less likely to snag, will not interact with other lift lines, and the elastic properties of a synthetic lift line help cope with shock load transients.

Optimum placement of the low inertia lift winch proved to be pivoted under the A-Frame top beam, beneath a system which passively controls pendulation fore/aft. Positioning the winch here conserves valuable deck space, installation time and costs, and dispenses with the need to cope with a lift rope during A-Frame movement.

Hanging from the winch is a telescopic vertical leg which carries a pivoted locator-docking frame, complete with a hydro-mechanical submersible latch, rope guides and a passive port/starboard controlled pendulation system. This articulated arrangement allows the docking frame to follow and control compounded submersible pendulation in a manner that prevents interactive overstessing of the submersible and docking frame interface, likely to occur in a system with greater stiffness and restraint.

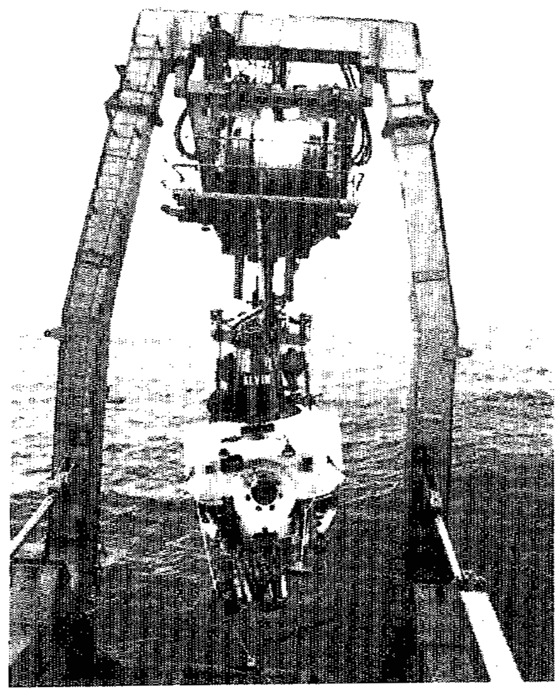

Fig. 4 Steel Caley System on R/V ATLANTIS II, Photo Courtesy WHOI

During Launch/Recovery, the entire system's controls are operated by one man. The support vessel is underway at about two knots. On launch, the submersible is latched at the telescopic leg. This leg provides lift from the deck and acts to limit pendulation and steady the submersible during transit to launch position. At the outboard launch position, the lift winch takes the load of the submersible to enable unlocking the mechanical latches, thereby allowing the submersible to be lowered into the water.

During recovery, the submersible is towed to the transom area by a tow winch and the lift rope is attached by a swimmer. The lift winch is set to raise in its fast response auto-tension mode, preventing a slack rope problem. This also acts to reduce the vertical displacements between submersible and A-Frame, making a phased and sympathetic lift-out relatively easy. The submersible is then hoisted to locate and automatically latch the docking frame at the telescopic leg. Thus, controlled pendulation is achieved. Two very important refinements make the operator's task more simple, particularly in heavy seas creating considerable support ship roll:

i) On recovery, during the lift winch hoist, the docking frame is allowed to "float" and be aligned by the lift rope angulation presenting the docking interface parallel to the submersible.

ii) The telescopic leg has an overhoist feature which dispenses with the need to stop the lift accurately at the latches.

5.0 A HYBRID

THE HBF/CALEY ALUMINUM A-FRAME

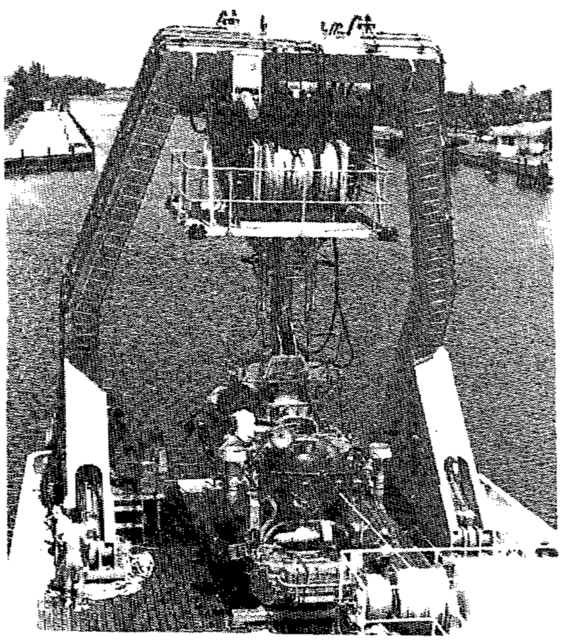

Fig. 5 Aluminum A-Frame with JSL Submersible

HBF/CALEY SYSTEM SPECIFICATIONS

Rated Capacity	18 tons
Max Recommended Operation Support Vessel Roll	30° total
Max Recommended Operational Heave Relative Position Vessel and Submersible (vertical position)	10 ft. 0 in.
Max Hoist Speed	60 ft./min
Tow Winch Capacity	3 tons
Approval	ABS

Harbor Branch Foundation, Inc. (HBF) has installed an all aluminum A-Frame handling system onboard the newest addition to its fleet, the R/V SEWARD JOHNSON. The system represents a collaborative effort by engineers from HBF and Caley Hydraulics.

Over ten virtually maintenance-free years experience, totaling more than 2,000 successful Launch/Recovery operations using aluminum-built articulated cranes, lead HBF to place two requirements on the system installed onboard the R/V SEWARD JOHNSON:

i) That it be capable of handling a heavier submersible in more hostile seas.

ii) If at all possible, the system be made of aluminum.

With plans at HBF to construct a heavier (36,000 lb), deeper diving (8,000 ft) submersible, the need for an upwardly compatible handling system is apparent. An ascent from 8,000 ft can provide time for sea states to double in force. The weight of such a system becomes a significant factor on a support vessel of this size (176 ft, 300 ton) and maintenance is a concern of the six-man crew.

An exhaustive survey of methods and the systems available resulted in the selection of the Caley system. Harbor Branch Foundation's insistence on aluminum construction resulted in the fruitful marriage of Caley Hydraulics, providing the hydraulics, controls, and their years of experience in building and installing massive A-Frames; and Harbor Branch Foundation who, with computer aided techniques and years of aluminum fabrication experience, provided the A-Frame and base structures at a substantial weight savings over a comparable steel system.

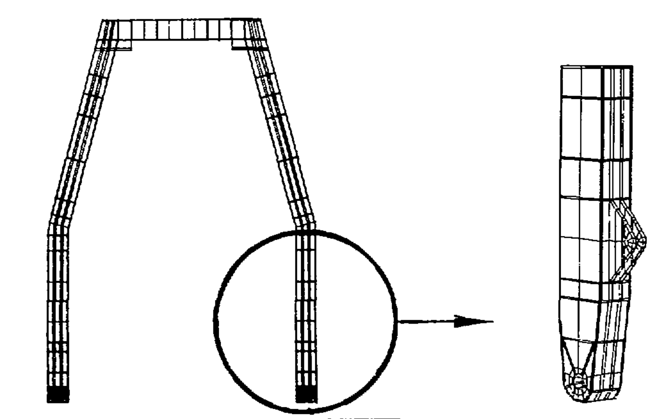

Fig. 6 Finite Element Model of HBF A-Frame

In another effort to reduce weight and undesirable dynamic effects, titanium was used to fabricate the "Drop-Lock" which secures the submersible to the lift line. The Drop-Lock is pneumatically actuated, thereby eliminating the need for a diver during launch.

6.0 THE WAY AHEAD

To date Caley has built and installed 11 systems with rated capacities from 16 to 45 tons. The HBF/Caley aluminum system has been in operation for a year, launching and recovering the JSL-classed submersibles on missions ranging from the Great Lakes to Central America. Recently, in winter conditions of the North Sea, a 36 ton Caley Launch/Recovery system performed a number of spectacular recoveries without damage to the submersible or handling system, where vessel roll often exceeded 50° total.

Such experiences, combined with computer simulation and facilities such as Caley's specially designed 100 ton dynamic test facility, become invaluable when considering the future challange. Adopting aluminum alloys and performing extensive structural analysis employing Finite Element Method (FEM) modeling enabled a weight savings (over steel) on the HBF/Caley structure of more than fifty percent. Weight economy on this scale becomes even more attractive when applied to more portable systems. In addition, the marine series aluminum alloys provide a structure requiring no painting, minimal maintenance, and simplified structural monitoring.

The HBF/Caley system represents, in the authors' opinion, the state-of-the-art in Launch/Recovery systems. The passive damping arrangement of the Caley system provides good control over the problem of pendulation. However, "active" detuning motion compensation is the ultimate solution. The latter will undoubtedly prevail, as micro-processor based systems are developed and proved reliable. However, these sophisticated systems should have a "fail to passive" capability, their back-up mode emulating the present Caley design. At present, and into the forseeable future, the experienced operator is a vital and indispensable component in the feed-back loop.

Present designs are reducing the reliance on surface diver support. Serious consideration is being given to designs which eliminate the need for diver support on recovery. There seems to be a good future for the fast surface support vessel capable of launching and recovering submersibles in a hostile environment. Lastly, but of utmost importance, there is much to be gained by closer cooperation between submersible and deployment designers.

This is Harbor Branch Foundation Contribution No. 391.

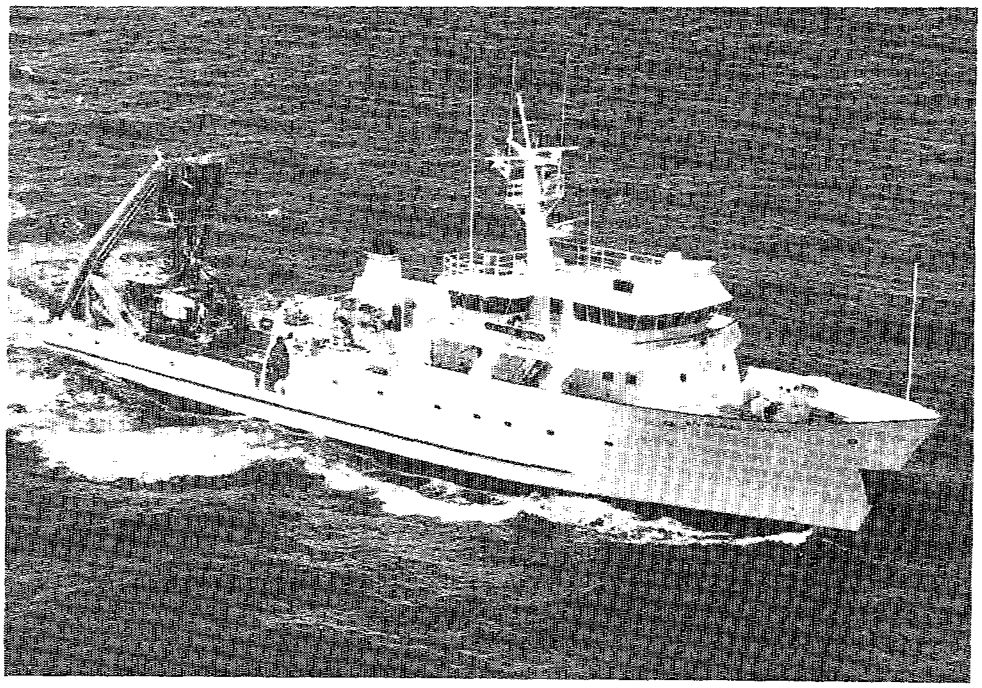

Fig. 7 HBF/Caley System on R/V SEWARD JOHNSON