

Good Engineering, Hot Glue, Combine To Save Time And Add Rig Life

Willingness to "think outside the box" pays off in a safe, efficient dry tow that has increased the life expectancy of the Glomar Labrador I jackup by a factor of at least 10.

Late in the third quarter of 1996, Global Marine Drilling Co. (GMDC) began planning to dry tow the *Glomar Labrador I* jackup to San Sebastian Bay, in Tierra del Fuego, Argentina, to fulfil a new drilling contract. The trip would be a long tow of more than 7,500 nautical miles from Europort (Rotterdam), Netherlands, through the English Channel, across the Bay of Biscay and south, turning southwest past the Azores for the Atlantic crossing, then following the Brazilian and Argentinean coasts to reach the last sheltered waters north of the Straits of Magellan.

The route holds many weather hazards and has few places to hide in a storm. The Bay of Biscay can erupt with steep seas and strong winds and has damaged many vessels through the years. In the Atlantic, tropical storms or even hurricanes are a danger in late summer and early fall. And the coastal rip south of Buenos Aires risks heading into northward blowing Antarctic fronts. Few ports of call offer sheltered waters.

Although others have made the trip before, several aspects of this trip are noteworthy. Profiting from the experiences of previous tows, the GMDC team implemented a plan to carefully define each aspect of the tow, the method of securing the rig to the heavy lift vessel, a unique and innovative method of bracing the rig legs to prevent damage, the combined rig/heavy lift vessel response to the sea and contingencies, which culminated in an undamaged arrival of the tow and readiness to begin drilling in a safe and efficient manner. Certainly, the international effort of GMDC's supporting contractors is noteworthy. Key elements of the planning, risk definition, material, intellectual solutions, management and manpower to implement the plans were provided from The Netherlands, Germany, England, Scotland, France and the USA. No stone was left unturned to ensure the safe arrival of the *Labrador I* and her crew and prevent costly repairs in a remote area of the world.

Planning

The *Labrador I*, while not unique in her design, has few sister vessels. All combined, they have very few dry tow runs upon which to base planning. The recent return of one of her sister vessels to the North Sea provided data on tow-related problems, as well as the structural response of the legs and bull to the waves, the effectiveness of chocking the legs, the critical loadings to expect and the fatigue areas which should be protected.

The planning team had two fundamental challenges: how to safely position the rig on board the heavy lift vessel for maximum seaworthiness and sailing speed, and how to minimize the effects of wind- and wave-induced fatigue on the rig's bull and legs.

The dry tow team was headed by the vice president of operations, support and engineering, and consisted of two master mariners, the manager of engineering, a naval architect, a structural engineer, the manager of marine construction and a project manager, in conjunction with an operations team from the *Labrador I* led by



the vice president of operations, the rig manager and technical staff from Aberdeen. Several consultants prepared detailed analytical studies including structural modelling of the combined heavy lift vessel with the *Labrador I* secured on board. The shipping company prepared studies defining the cribbing, docking points and sea fastening, as well as the best arrangement of the *Labrador I* on board the heavy lift ship, *Mighty Servant II*.



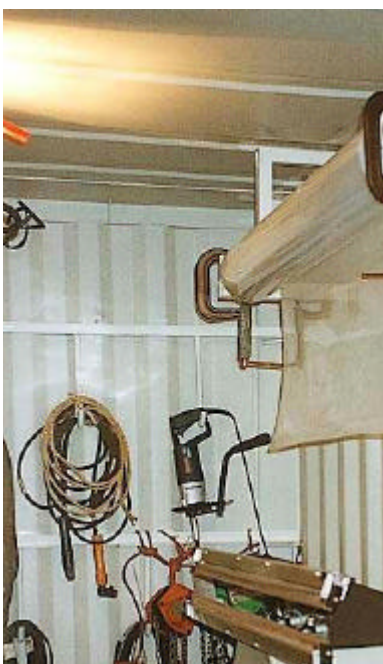
A thorough weather analysis was performed using two independent sources. Historical weather and ocean data were studied to establish a voyage routing that minimized exposure and maximized proximity to available ports of refuge. Detailed weather data enabled the marine structural engineers to develop fatigue models that determined the critical areas of the tow and predicted potential failure points. By studying the dynamic behaviour of the heavy lift vessel with the specific rig as cargo, engineers were able to translate the compound effects of pitch, roll, heave and yaw as well as wind loading to specific rig components. Environmental input criteria for the journey were:

- Significant wave height - 31.2 ft (9.52 m).
- Mean wave period - 8.2 sec to 11.4 sec.
- Mean wind speed - 56 knots.
- 1-minute sustained wind speed - 67.8 knots.

The data were used in a detailed finite element analysis of the rig's legs, jackhouses and leg well structure. Two critical decisions resulted.

Loading And Rigging

Deviating from tradition, the rig was positioned with its starboard leg in an open cargo tank on the forward end of the *Mighty Servant II*'s cargo deck, while the rig's bow and port legs would remain outboard of the heavy lift vessel's hull and extended 17.6 ft below the ship's main deck.



This arrangement places the rig's centre of gravity directly above the ship's which eliminates the requirement for additional ballasting normally needed to counteract offset centres of gravity. Two benefits were realized: a greater contact area resulted for the installation of load distributing cribbing between rig and ship and a reduction in overall vessel motion was predicted. The added stability benefits far out-weighed the reduction in sailing speed caused by the outboard legs dragging in the water-in fact, the tow was able to maintain more than 13 knots over the bottom during the Atlantic crossing.

The second decision was critical in reducing fatigue damage and increased the fatigue life expectancy of the hull and legs from one to three trips to more than 20 trips.

The *Labrador's* legs are held in place horizontally by semi-cylindrical „push-only" type guides which have a lateral clearance of up to 1.5 in. allowing for some movement of the legs during tow. The jacking mechanism allows for up to 3.25 in. of vertical movement. The most critical aspect of towing operations was to restrain



the movement of the legs in the guides both horizontally and vertically to prevent destructive vibration. This restraint is usually accomplished by half-moon-shaped steel chock plates. Recent experience demonstrated that these steel chocks, while quite acceptable for local tows or short duration field moves, were not of sufficient strength or durability to endure the rigors of an extended, open-sea dry tow of about 30-35 days.

Two solutions were implemented. The jackhouses were reinforced by welding angle brackets that distributed the stress to a larger area of the bull, and the requirement for a new chocking system was defined. The chocks had to be easily installed in 3-4 days, removed in 1-2 days, endure both wave and wind loads and survive the cyclic loading encountered during the tow. In addition to the motion caused by wind and waves, there was a real concern that the leg would reach a state of harmonic vibration that would be self-destructive or create permanent damage to the leg guides or hull. A unique solu-

tion was proposed using a self-moulding chock material with the strength and durability of aluminium, but with a superior fit and ease of installation and removal. Chock effectiveness is enhanced by maximizing the contact area, thus distributing the load and reducing point stress. There is no practical way to wedge solid chocks into the air gaps between the legs and their guides. The *Labrador I*'s sister vessel had used a new compound epoxy called **WEIDLING C** which had a matrix of resin and aluminium powder mixed together with a hardener.

First tests revealed a temperature sensitivity to hardening, causing unacceptably long setting times. Initial schedule estimates were 7-9 days to complete the chocking project. This schedule was reduced to 3-4 days by the installation contractor, WILLTECO, by the clever application of beating pads normally used in pre- and post-weld heat treatment. The chocking compound had to be kept at above +15°C to allow proper mixing and pouring consistency. However, for every +10°C increase in temperature, the curing time halved. HW Technics was employed to prepare a beating plan to obtain a minimum temperature of +45°C which cut the hardening time to 3-4 hours, and the complete curing time to 24 hours.



WILLTECO provided a system for chocking the legs consisting of a flexible bag fabricated from a flat tube of specialized plastic sheeting cut to length on board and heat sealed with a portable machine. Eight bags per leg were custom fitted to fill the air gap between legs and guides. They were polyurethane foamed around the edges to distribute hydraulic stress on the bag material during the filling operation and held in place with simple clamps on the leg chords and angle bar retainers. The bags were coated inside and out prior to installation with a mould release agent affectionately known as „penguin oil“ for lack of a lay term understandable in four languages. Once in place, the bags were opened at the top and the **WEIDLING C** was poured in increments of 9-10 lb per pour until the bag was full. WILLTECO used a system of two plastic tubes about 2 in. in diameter - one inside the bag and one outside the bag - to eliminate any air locks during the pouring. This system provided a solid chock, which filled 96% to 98% of the guide gaps, allowing for the bag material and some



minute bubbles entrained during mixing. The top of the bag was allowed to bulge over the top of the guide, and a band of fine steel mesh was inserted to form a cap facilitating chock removal at the end of the tow.



The **WEICON** material hardened in 3-4 hours and the internal heat it generated during curing created a solid chock too hot to touch. The material had extremely high compressive strength (20.6 ksi), and was initially thought to be flexible enough to absorb the slow cyclic loadings imparted to it during the tow. **WEIDLING C** is not resistant to shock loads, such as a blow from a hammer, making it easy to break out when it is time to remove the chocks. The bags, coated with the release agent, allowed the barge master to jack up two to three teeth, pushing the whole chock up and out of the guide slot. Then, workers easily broke off the cap just below the steel mesh with sledgehammers. After jacking back down five to six teeth, the chock stayed up above the guide. Two or three repetitions of this jacking sequence taking 2 to 4 hours per leg, were required for the guide to be free and clear for operations as usual.

During the installation, some bags were broken due to movement in the gap between the guides and the legs. It was necessary to keep the legs relatively still after the bags were filled until they hardened. However, stationary mooring in the „hole" at Europort was problematic. The stern of the heavy lift ship was held fast by harbour tugs fighting the current and wind, which were perpendicular to each other. The harbour tugs had little capacity to carry fuel and had to swap out every 12 hours. During the chocking of the first two legs, the tugs swapped out after the top guide bags had only just completed filling, and pinched the bags open causing the liquid to pour out and down the leg. Fortunately, another special characteristic of **WEIDLING C** is that it must have machine-polished surfaces to „glue" two pieces of steel together. The marine growth and the penguin oil prevented the epoxy from sticking to the legs or the guides. The solution to the burst bags problem was to wait until the edges of the bags sealed with the epoxy, (2-3 hours), then repour the bag. This process slowed down the completion of the installation by a day. However, the revised method proved successful, evidenced by the fact that the tugs swapped out on leg three without recurrence of the problem.

Logistics of equipment and materials for both mobilization and demobilization were reduced to less than 4 hours by Van Esch International's self-loading hydraulic crane barge.

Mid-course Corrections

In fact, the revised pouring method only appeared to solve the problem. Although hard to the touch, the **WEIDLING C** requires at least 24 hours to cure, completely aligning the long-chain polymers. Apparently, the tow departed before curing of the center of the chocks was complete. On the 15th day of the Atlantic crossing, the constant flexural stresses imposed by the legs on the guides started to damage the upper chocks' edges reducing their coverage from 96% to about 80%. It appeared that the guides imparted some shear and bending loads to the chocks, cracking them and



eventually allowing them to shift.

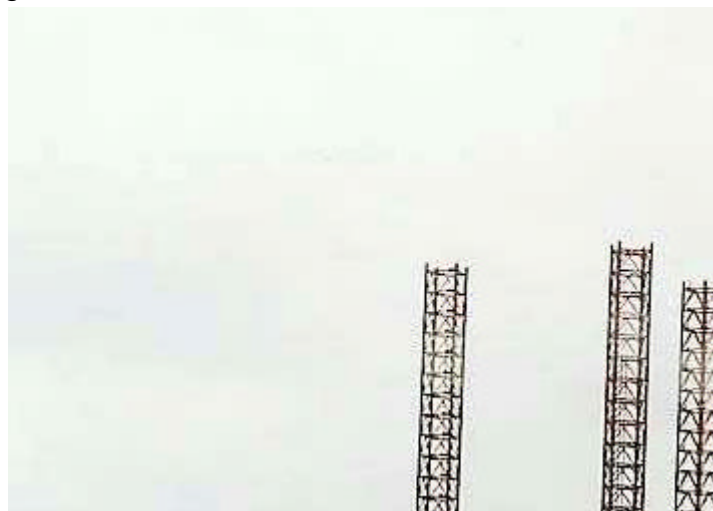
The ability to make field repairs onsite without special equipment proved to be advantageous. Anticipating a stop in Rio de Janeiro, Brazil, the team analysed the problem and redesigned the chocks to include embedding a Kevlar rope around the perimeter to reinforce the edges and eliminate chock shifting. In addition, the formulation of the **WEIDLING C** was altered to build in variable flexibility in the high stress areas. During the 5-day journey from Recife to Rio de Janeiro, temporary wooden chocks and aluminium shims were installed to support the legs in transit. Several coupons were poured and tested, then the damaged **WEIDLING C** chocks were removed and repoured using the new design when the ship arrived in Rio de Janeiro. This time, full curing protocol was observed before the tow continued southward.



Results

By achieving more than 96% distribution of the chock material in the gaps, wear points were eliminated and there was no damage to either the legs or their guides. The reinforcements between the jackhouses and the bull effectively distributed bending stress across a broad area of the bull reducing local stress concentrations to acceptable levels. Through proper planning and the use of computer modelling, engineers were able to optimally design to provide effective protection at an acceptable cost.

At today's nearly 100% global rig utilization, moving rigs great distances to meet contract obligations has become commonplace. By extending predicted leg life from one to three trips to as much as 20 trips, GMDC has engineered a major reduction in downtime and repair costs over the life of the rig.



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