

KEYSTONE FOUNDATIONS

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IN THIS ISSUE:

- **KEYSTONE TO DESIGN “BRACED CAISSON” FOR U.S. MET MAST**

Keystone has commenced a “braced caisson” design for US Wind Inc’s meteorological mast tower foundation. The “braced caisson” concept was originally developed by Keystone’s founder Rudolph A. Hall in the 1980’s for minimal platform applications in the oil and gas industry. The structure offers an effective alternative to heavier monopile or jacket type met mast foundations, particularly in regions with weak soils and/or with limited installation vessel availability. *Read more below!*

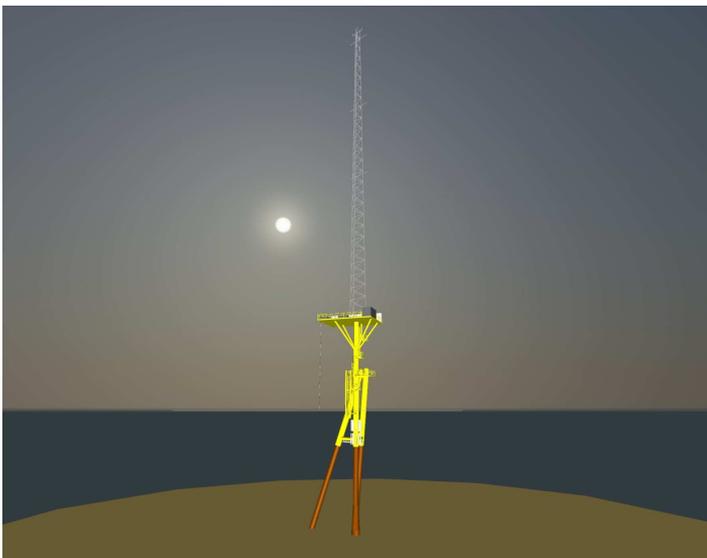


Image: Keystone rendering of braced-caisson supporting a met mast tower

- **KEYSTONE AND FISHERMEN’S ENERGY INNOVATE CREW ACCESS LADDER**

During risk management and design workshops for Fishermen’s Energy’s 24 MW Atlantic City offshore windfarm, a significant health and safety risk was identified in the transfer of workers between a vessel at sea to a stationary access ladder. Working together with Fishermen’s Energy, Keystone has designed an innovative access ladder to mitigate this safety risk. *Read more below!*

Also in this issue:

- **KEYSTONE OPENS NEW OFFICE**
- **KEYSTONE PUBLICATIONS**

KEYSTONE OFFERS TECHNICAL ADVISING AND 3RD PARTY REVIEW FOR OFFSHORE WIND PROJECTS

- ✓ Independent engineering review
- ✓ Offshore installation engineering
- ✓ Fabrication/construction engineering
- ✓ Decommission planning
- ✓ Procurement services
- ✓ Detailed cost estimates/risk studies
- ✓ Design/drafting
- ✓ Feasibility studies

Bringing innovation from offshore oil and gas to offshore wind

THE “BRACED CAISSON” SOLUTION

Braced Caissons have been used to support minimal offshore structures in oil and gas for over 25 years. The original “Braced Caisson” was conceived by Keystone’s founder Rudy Hall in the late 1980’s as a solution for minimum platform applications used to support satellite wells with minimum topside facilities and a small heliport.

Demand for the braced caisson was particularly robust in the U.S. Gulf of Mexico (GoM) due to Self-Standing Caissons (SSCs) in relatively weak soils leaning after significant hurricane events. The “braced caisson” quickly became the most widely used minimum platform concept in the U.S. GoM. To this day, it remains the preferred minimum solution for many applications. Recent surveys indicate that “braced caissons” are the most widely deployed minimum platform concepts. There are currently over 200 installed globally, in water depths of up to 200 meters.⁽¹⁾

DESIGN FEATURES AND ADVANTAGES

The principal design feature of a braced caisson is a guide structure that can be placed over and secured to a self-standing caisson (SSC). This allows the installation of two bracing piles, also secured to the guide structure, which add support to the SSC. This design is an adaptation of the breasting dolphin concept to resist lateral environment loading.

The advantage of a braced caisson is that the lateral base shear and associated overturning moment is resisted much more efficiently by axial pile capacity versus the lateral soil resistance mechanism of a SSC. This reduces member sizes and weights of

components, allowing the braced caisson to be installed with relatively small and low-cost liftboats. These marine vessels are commonly used for operations and maintenance (O&M) in the U.S. GoM and other oil & gas regions around the world.



IMAGE: Keystone-designed minimal facility and topside for ExxonMobil’s West Delta 30 Platform “Bacall”

¹ Other: NAP.EDU “An Assessment of Techniques for Removing Offshore Structures” Chapter 1, pg. 5: Overview of existing Offshore Structures” (1996) <http://www.nap.edu/read/9072/chapter/5>

² Text box: Pilotto, Micaela, Beverly Ronalds and Roman Stocker. “Non linear dynamic analysis with Deterministic and Random Seas: The Case of Minimum Platforms.” <http://ieeeco.org/pubs/newsletters/oes/html/winter04/platforms.html>

Minimal platforms are an increasingly popular solution for the development of marginal oil and gas fields because of their low fabrication cost and the possibility of standardizing the design. Globally, the braced caisson is one of the most widely used structures for oil and gas applications.

APPLICATIONS IN OFFSHORE WIND

For the offshore wind industry, braced caisson structures can provide an alternative to heavier monopile or jacket type met mast foundations in regions with weaker soils and/or with limited installation vessel availability. Over the past decade, Keystone has developed further our patented Inward Battered Guide Structure (IBGS) – a concept which, like the braced caisson, employs a guide structure and battered piles about an SSC. This results in a central core support structure with bracing spokes, which is a departure from the perimeter tube framing of traditional x-braced jackets. These design evolutions have generated substantial manufacturing and installation cost reductions when considering serial deployment of jackets. The IBGS easily scales up with increasing wind turbine generator (WTG) size, and has a reserve strength ratio even greater than that of a standard 4-pile jacket. The IBGS can be particularly advantageous for supporting large offshore WTGs installed in regions with wide ranging site conditions including weaker soils, hurricane force winds and seismic activity. In emerging markets with limited installation vessels (US Jones Act restrictions) and/or a lack of large steel rolling facilities, the IBGS can offer lower lift weights and fewer components for local manufacturing. This provides greater logistical flexibility than a large diameter monopile.

Image: Keystone-designed minimal facility (IBGS) and topside for ExxonMobil's West Delta 30 Platform "Bacall"



NEW ACCESS LADDER DESIGN TO IMPROVE CREW TRANSFER SAFETY

During risk management and design workshops for Fishermen's Energy's 24 MW Atlantic City offshore windfarm, a significant health and safety risk was identified in the transfer of workers between a vessel at sea to a stationary access ladder. When offshore workers transfer from the worker service vessel (WSV) to the access ladder, or from the access ladder to the WSV, there is a possibility that the worker could fall between the vessel deck and the ladder. If the vessel is surging vertically due to wave action, even a fall arrest system will not prevent possible injury.



Image courtesy of Stan White, Fishermen's Energy

Working together with Fishermen's Energy, Keystone designed an innovative access ladder concept to address this potential safety hazard. Unlike traditional ladder access and egress where the worker front steps onto or back steps off of the ladder, the innovative ladder is turned 90 degrees to the worker and the worker side steps onto and off the ladder. This allows the worker to keep one hand firmly on the vessel handrail while the other hand is firmly on the ladder rung as the transfer is begun. If the worker accidentally slips and falls, the fall is away from the vessel deck and behind the foundation fender system offering excellent protection from injury. Furthermore, when the offshore worker descends the ladder, the worker is looking across his/her body at the WSV deckhand while waiting for instructions to initiate the transfer, not over the shoulder and behind. The offshore worker is further protected at all times from a surging vessel because the innovative ladder always puts

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the worker in a safe zone behind the fender system no matter where the person is located on the ladder or the clearance between the vessel deck and the ladder.

Keystone's new office in Baltimore, MD

Keystone's newest office in Baltimore, MD opened its doors on October 1, 2015. This is the first East Coast office for Keystone, and will enable the company to better serve its regional clientele, including the growing U.S. offshore wind industry, upstream oil and gas, midstream and downstream industries. Keystone is also planning a new office in the Lake Charles, Louisiana area to keep pace with growing market opportunities in Southern Louisiana and the US Gulf Coast market.

AWARDS AND RECOGNITION

- May 2015: Keystone Engineering Inc. recongnized as "Top Workplaces in 2015" by NOLA.com/Times Picayune
 - November 2015: Keystone CEO Barry Reed accepts award for Innovation in Offshore Wind and Bentley's "Be Inspired" awards ceremony in London for Deepwater Wind project
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PUBLICATIONS:

1. Integrated Modelling and Loads Analysis of the Keystone IBGS for the VOWTAP Project – Overview of VOWTAP loads methodology

- Rudy Hall and Hiram Mechling (Keystone Engineering) with DNV GL
- See presentation poster at AWEA in May 2016

2. Achieving a cost-competitive offshore wind industry – what is the most effective policy framework?

- Craig Brown and Ben Foley (Keystone Engineering) with Rahmat Poudineh
 - Published by Oxford Institute for Energy Studies, September 2015. Available [here](#)
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Happy Holidays and a happy New Year from Keystone Engineering Inc.!
