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## Soil-Structure Interaction During Preloading of Jackup MODU's in Different Soil Conditions

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### ABSTRACT

A new procedure to assess foundation stability of independent leg jack-up drilling units during preloading is presented. This procedure allows assessment of the potential for rapid leg penetrations, taking into account changes in spud can loads due to increase in ballast and shifting of center of gravity.

### FOUNDATION EVALUATION

Prior to MODU installation, specifically for an independent leg jack-up drilling unit, rig foundation stability can be evaluated by analyzing site soil data and developing a curve of soil resistance versus spud can penetrations. During preloading (or preliminary assessment) leg loads are calculated as a function of increasing water ballast, taking into consideration exact fixed and variable loads.

These leg loads are then compared with the soil resistance curve to evaluate penetrations and potential for punch-through.

At this time, it is assumed that leg loads during preloading depend only on the amount and location of water ballast. However, even during simultaneous preloading (all three legs) leg penetrations are not simultaneous. As a leg penetrates, the rig center of gravity moves toward the lower site of the unit with a corresponding increase in the leg load on the lower side. At a location with a punch-through potential or with a low rate of clay strength increase, this leaning can cause an increase in the leg load resulting in uneven and deeper penetration on one leg and, potential for rig physical damage.

### PRELOADING

The conventional preload method is to elevate the unit at its preload air gap (about 2-5 feet above the surface of the water) and then to simultaneously add ballast to all of the preload tanks.

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References and figures at end of paper.

The elevated weight of the unit soon exceeds the rating of the elevating system to level the unit and the unit is allowed to settle. As the unit's legs are penetrating, the possibility exists that the unit may settle with differential leg penetrations resulting in the rig reaching equilibrium in and out-of-level position. A representative out-of-level tolerance for an independent leg jack-up unit might be in the range of 0.3 degrees.

When this out-of-level situation occurs, it is standard to dump preload ballast water until the weight of the unit is reduced to the value at which the elevating system can level the unit and raise it to the preload air gap.

Unfortunately, the results of this procedure can be disastrous. Leaning instability, that is the movement of the center of gravity toward the lower side of the unit with a corresponding increase in load on the lower side of the unit, can exacerbate soil problems. Simply allowing the unit to reach its out-of-level tolerance can increase the loading on the lowered leg by as much as 5 percent; and a punch-through at a 5 foot air gap with maximum preload onboard will result in leg load increases of more than 150 percent. These leg load increases, of course, result in greater values of punch-through before an equilibrium position is achieved. This equilibrium position would be one where the soil would support the load applied to the punch-through can, including all out-of-level loadings.

There are some strategies which can lessen the magnitude of a punch-through in a given soil situation and reduce the possibility of rig leg damage. One strategy is to limit the air gap during preloading; this strategy is sometimes referred to as "preloading in the water". This alters the normal procedure by beginning the preload process at 0 air gap. As preload is applied and the cans penetrate

into the soil, the draft increases. The procedure is continued until all of the preload tanks are filled. However, in order to achieve full preload can loading, the draft on the rig hull must be limited to no more than 2-3 feet. At drafts greater than this, the buoyancy of the hull will not allow full can loading. As shown in Figure 1, this procedure reduces the maximum increase in soil loading from 150 percent for the normal preload procedure to 116 percent. Because the peak value of soil loading is reduced, the final equilibrium position of the can after punch-through is also usually reduced.

Another strategy to lessen the magnitude of a punch-through is to sequentially preload each leg of the rig. Because the total weight of the rig is reduced, the load on the punch-through can is also reduced. When this procedure, termed "sequential preloading", is employed together with "preloading in the water", dramatic reductions in can loading during a punch-through can be achieved. As the attached table and graph show, this combined procedure can reduce the maximum increase in soil loading from 150 percent for the normal preload procedure to 101 percent for "sequential preloading in the water". Notable also is the position of the peak of the load increase. The peak of the increase occurs at a penetration of just 4 feet below the initial position of the can while the maximum increase with the normal procedure occurs at a penetration of 15 feet below the initial can position.

It is also worth discussing the effect of these procedures upon the speed of the punch-through event. The speed of the punch-through depends upon the differences in the soil loading curve and the curve of soil bearing. Because these procedures lessen the soil loading curve, there is a reduction in the speed of the event. When sequential preloading is employed, the preload weight will exceed the

jacking system capacity on the preload leg; but because there is little or no increase in load on the other two legs, these legs can be jacked during a punch-through to lessen the out-of-level condition of the rig and lessen the increase in load on the punch-through leg. A slower punch-through event increased the possibility of maintaining a level condition during a punch-through.

To plan and execute safe preloading operations, a computer model has been developed. This model and the resulting computer program incorporates rig hull and soil resistance curve and allows to analyze changes in spud can loads during preloading taking into account changing ballast and moving center of gravity. The spud can loads can be calculated for various values of rig draft or air gap, and for simultaneous or for sequential preloading. The program is used for preliminary planning or to calculate leg loads and penetrations as they change during preloading on "real-time" basis.

## CASE HISTORY

The case in question concerns a jack-up rig preloading near a platform where the rig's starboard leg rapidly penetrated from about 27 to 40 feet penetration resulting in rig damage. Water depth at the location was 251 feet. Preliminary evaluation of the site included a review of a nearby soil boring indicating an all-clay profile with potential presence of a thin, firm clay crust.

The resulting punch-through required the unit be removed from the location, brought to a repair facility, and repairs conducted.

Based on problems encountered during preloading of the rig onto the location the first time, the rig owner assembled a group of experts to assist in developing a method of safe preloading procedures

for relocation on this specific site. In addition to developing a safe preloading methodology, these individuals attended onboard the unit during the preloading activities which finalized the development of the safe procedures.

After the rig damage had been repaired, the rig transited back to the original site to begin siting on the same location for the second time.

Prior to preloading the rig, a geotechnical soil boring was drilled from the rig at the platform site. The boring disclosed a thin clay crust at about 20 feet penetration underlain by firm clay of almost uniform strength. At this point, it became clear that two potential problems had to be addressed during preloading: 1) to assure safe spud can penetration through the crust, and 2) to achieve minimum possible leg loads after the crust penetration to avoid leaning instability in the underlying uniform clay. To further complicate the matter, a limitation had been placed on maximum leg penetration in that 45 feet final penetration could not be exceeded. This consideration was based on the existing leg length of the rig.

During the second siting of the rig on location, it was determined that the rig would be preloaded one leg at a time while maintaining 0 air gap. During the preloading, the preload program was used to calculate spud can load changes in "real-time" mode. Based on the procedures developed and the careful monitoring of same, each leg successfully penetrated through the crust with the rig at a 1 foot draft. Final leg penetrations were 36' on the bow leg, 36' on the port leg, and 42' on the starboard leg.

Different preloading scenarios are illustrated in Figures 2 and 3.

## CONCLUSIONS

1. The proposed procedure allows the user to understand actual leg loading based on specific fixed and variable load in addition to precise preload onboard on a "real-time" basis.
2. Additional procedures contained in this technology allow the user to understand a variety of conditions that can exist during rapid leg penetration, including graphs of leg-load vs. anticipated penetration and leg bending moment.
3. Further, the user can plot leg load vs. actual penetration on a "real-time" basis.
4. The potential for rapid or uncontrolled leg penetrations can be assessed and solutions provided for on a "real-time" basis.
5. Sequentially preloading or preloading in the water can produce dramatic reductions in can loading during a punch-through, perhaps limiting damage to the rig.
6. The incorporation of this technology may lessen the magnitude of a punch-through or uncontrolled leg penetration and possibly avoid damage previously sustained by jack-ups in similar conditions.

## ACKNOWLEDGEMENTS

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## REFERENCES

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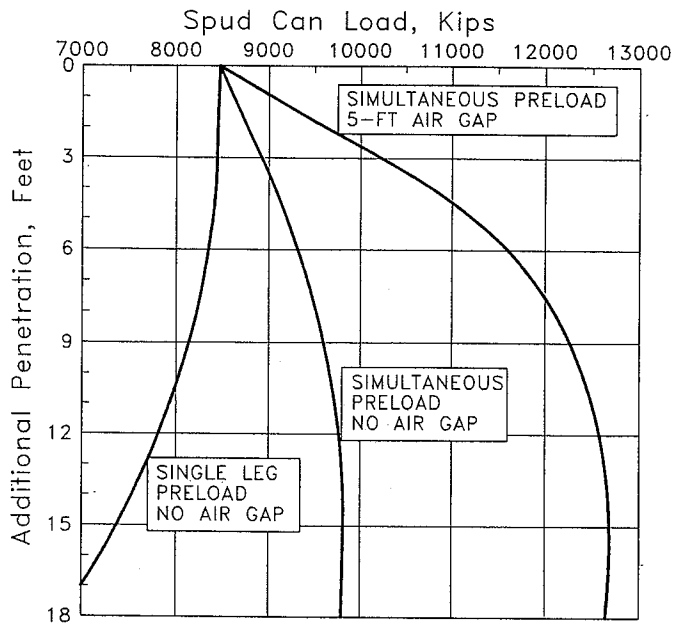


Fig. 1 Leaning Jack Up Spud Can Loads  
(Bow Leg, Friede & Goldman L-780, Mod. II)

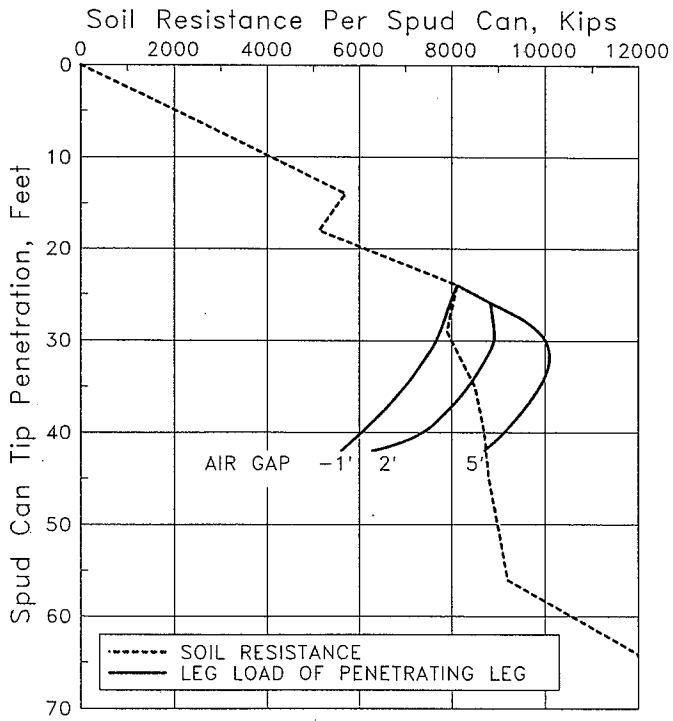


Fig. 2 Soil Resistance and Spud Can Loads  
(Bow Leg, Sequential Preloading)

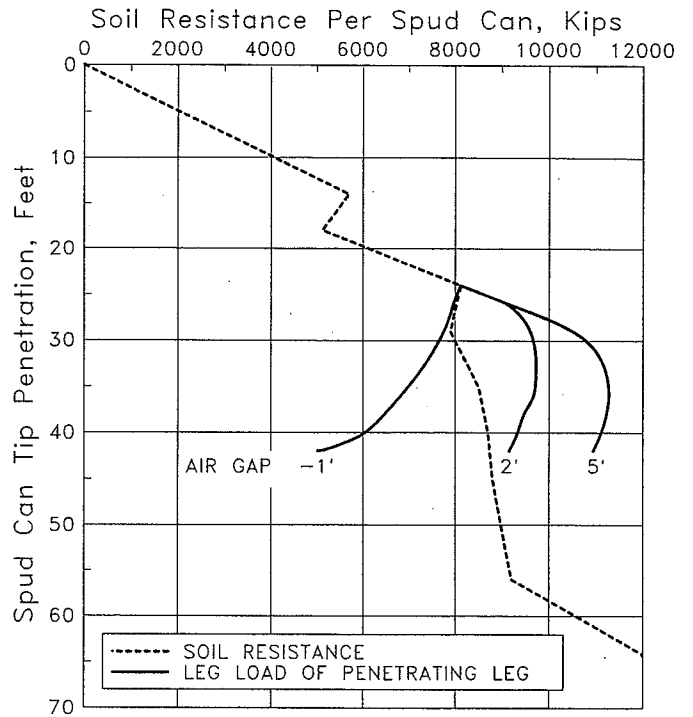


Fig. 3 Soil Resistance and Spud Can Loads  
(Bow Leg, Simultaneous Preloading)

