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Innovative Design Method for Deepwater Surface Casings

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Abstract

This paper presents a method to calculate the load bearing capacity of surface casings. The method clearly describes how to calculate the immediate capacity of the conductor and how to estimate the soil set-up with time. The recommended equations for set-up calculations are based on the results of three proof-load tests performed on partially set-up conductors. The paper also lists a series of key parameters that need to be controlled for a successful jetting operation. The overall method has been calibrated against 20 successful installation records.

Introduction

When BP and Amoco merged, considerable differences existed between the two companies with respect to deepwater drilling practices. In particular, surface casings (also known as jetted conductors, or surface conductors, or jetted pipes) were designed and installed with drastically different methods, leading to considerable debate and disagreement in the newly integrated drilling community over which method was most appropriate for future wells. Both companies' previous methods had been successful in preventing loss of wellhead equipment.

The work described in this paper consisted of harmonizing past practices by developing and implementing an innovative design and installation method for deepwater surface casings. The work included:

- Clearly documenting and understanding BP and Amoco's pre-merger practices.
- Analyzing each practice and comparing it with actual field installation records.
- Replacing the two practices by a new innovative method that was fully calibrated against pre-merger successful installations.
- Implementing the new method into the design and installation of deepwater surface casings.

The work also defined specific installation procedures for the surface casings and gives clear guidance on how a set of key parameters should be controlled during installation. The shortcomings of past installation processes were also highlighted throughout the project. Should the recommend work process not be followed during offshore installation, the new method also allows the drilling personnel to properly account for the deviation in installation procedure and to calculate the "penalty" to be paid when landing subsequent strings.

Pre-merger Methods:

The pre-merger method used by Amoco to calculate the capacity of jetted conductors was developed and documented by Beck et al (1991). In summary, the method:

- was developed from jetted conductor installation observations made from 1984 to 1986.
- was calibrated at 6 Amoco sites.
- used the undisturbed soil shear strength, MV, and the residual shear strength, RMV, to calculate a lower bound and an upper bound immediate capacity. Both shear strength measurements were done using a minivane.

Some of the limitations of the method were as follows. The method:

- was intended for conductors with squnch joints, not threaded flush connectors.
- assumed that soil data was available for the site. This was usually obtained by means of soil sampling with the drilling vessel immediately prior to jetting the conductor.
- Gave only the immediate capacity and did not provide set-up curves.

The method also assumed that very little to no reciprocation took place during jetting and that the jet head was sitting 1 to 1.5 ft inside the conductor. This procedure was known as "controlled" jetting.

Reciprocation was avoided by having enough weight available during jetting. This was achieved by the use of "donuts" which were cylindrical weights of steel that were stacked up on the drill pipe.

The key advantage of the method was that the weight of the donuts used was greater than the weight to be landed on the conductor. If the conductor was able to carry such weight right after installation, then the conductor was essentially proof-loaded against the weight to be landed. This provided certainty that the wellhead would not move when landing of subsequent strings took place.

The main limitation of the installation was that it was not possible to drill ahead after jetting was completed. The BHA had to be retrieved to the drill floor, the donut weights had to removed, a new BHA had to be assembled, and the drill pipe had to be run again before drilling could resume. As the industry moved into ever increasing water depths, this disadvantage became such that the use of donuts was discontinued.

BP's pre-merger practice was to calculate the immediate capacity of jetted conductors in a manner similar to Amoco's practice. The difference was in the set-up calculations.

The loads to be landed on the surface conductor were also calculated differently by both companies. The key point to note is that both companies calculated the loads to be landed as buoyant weights in water, although it was common practice to have 12-ppg mud in the open hole when landing the first casing string on the surface conductor.

This paper contains the new framework developed for calculating the required length of jetted conductor below mudline. This framework is expected to be applicable worldwide but the actual numerical factors herein have been calibrated and compared with past practices only for the Gulf of Mexico. <u>Further calibration and validation of the method is therefore necessary for applications in deepwater basins outside the Gulf of Mexico</u>.

Innovative method for calculation of jetted conductors' capacity

Immediate capacity.

It is not BP's plan to use donut weights during the installation of future surface conductors. Although the methods has been successfully used in the past, it is believed to be too time consuming and thus costly for future deepwater applications. Therefore during jetting, if the Weight on Bit (WOB) available to penetrate the casing is less than the soil resistance, reciprocation will be necessary to penetrate the casing to target depth.

The above installation technique implies that the immediate capacity is not controlled by the soil conditions but rather by the available weight on bit and the installation method. Physically, the last soil resistance measured during installation, which is given by the last WOB measured, is equal to the immediate capacity. <u>Maximizing</u> the Weight on Bit during jetting is therefore of prime importance.

The immediate capacity is therefore independent of soil properties and totally dictated by the jetting procedure. The proposed design method consequently states that the immediate capacity of the surface conductor is equal to the last WOB recorded during jetting. This last WOB should be maximized and be equal to at least 80% of the available WOB during jetting. The available WOB will typically be calculated by adding the self-weight of the surface conductor, the weight of the wellhead housing, the weight of the drill collars, and the CADA tool.

The above method can be mathematically expressed as follows:

$$Q_0 = WOB_{last} = R \cdot \left(W_{cond} + W_{WH} + W_{DC} + W_{CADA}\right) \quad \text{.. 1)}$$

with:

Q_0:	Surface conductor capacity immediately after jetting (t=0.01 days)
WOB_{last}:	Last Weight on Bit recorded during installation
R:	WOB utilization Ratio, should be between 0.8 and 1.0
W_{cond}:	Weight of the surface conductor, in water
W_{WH}:	Weight of the wellhead housing, in water
W_{DC}:	Weight of the drill collars, in water
W_{CADA}:	Weight of the CADA tool, in water

The WOB utilization ratio, R, should be kept less than 1.0 to avoid compression stresses in the BHA and running string and prevent buckling from occurring. A value of 0.8 is suggested.

The immediate capacity is arbitrarily defined at time equals 0.01 day (on the log cycle graph), which is after 14 minutes. This is consistent with past practice.

Set-up of jetted conductors.

One of the key issue to be addressed was the rate of set-up of jetted conductors. BP's past practice was to increase the immediate capacity by 20% per log cycle of time so after 10 days the capacity was estimated to have increased by a factor of 1.6. Amoco's practice consisted of increasing the capacity by a fixed amount of 100 kips per log cycle of time, irrespective of the diameter and length of the conductor. Neither practice explicitly calculated the increase in unit friction along the conductor with time, nor explicitely accounted for the soil properties.

In order to improve on past practices and make the method fit for a wider range of conditions, it was deemed necessary to explicitly account for soil profile, conductor diameter, and conductor length. The following $\Delta\alpha_t$ factor was thus defined:

$$\Delta\alpha_t = \frac{Q_t - Q_0}{\pi \cdot D \cdot L \cdot Su_{ave}} \qquad 2)$$

with:

- $\Delta\alpha_t$: Change in average friction factor along the conductor, at time = t, due to set-up
- Q_0: Initial Capacity, (at time t=0.01 days)
- Q_t: Conductor capacity at time = t days < 10 days
- D: Surface conductor diameter
- L: Conductor length below mudline
- Su_{AVE}: Average undrained shear strength over the length of the conductor

Su_{AVE} is the average undrained shear strength of the clay over the embedded length L, as determined by a best fit through available data. Ideally, the reference strengths should be measured using the laboratory minivane as recommended by Beck et al (1991).

In order to develop the $\Delta\alpha_t$ relationship with time, the existing database of load tests on jetted conductors was used. The data used are summarized in Table 1 and plotted on Fig. 1. Fig. 1 indicates that $\Delta\alpha_t$ can be calculated with time as follows:

$$\Delta\alpha_t = 0.055 \cdot \left[2 + \log(t)\right] \qquad 3)$$

Substituting Equ. 1 and 3 into Equ. 2 and re-arranging gives the following expression for the total capacity of the conductor:

$$Q_t = WOB_{last} + 0.055 \cdot \left[2 + \log(t)\right] \cdot \pi \cdot D \cdot L \cdot Su_{AVE} \qquad 4)$$

with:

- t: time, in days < 10 days
- Q_t: Conductor capacity at time =t days
- WOB_{last}: Weight on Bit measured at final penetration
- D: Surface conductor diameter
- L: conductor length below mudline
- Su_{AVE}: Average undrained shear strength over the length of the conductor

The above expression for set-up is clearly a lower bound estimate because the data points used to develop it consist of proof-load tests, not load tests to failure. The method is suspected to be conservative, particularly for very short set-up times (i.e. less than 1 day). The author does not recommended increasing the rate of set-up until new data becomes available.

Equation 3 should not be used for times greater than 10 days due to lack of data.

Selection of Soil Profile for Gulf of Mexico Deepwater Sites:

It is no longer common practice for BP to collect site-specific soil data to determine conductor setting depths in the Gulf of Mexico. Therefore the proposed method for designing the surface conductor must assume reasonable site conditions. BP assessed 15 high-quality soil profiles that were obtained in Deepwater GoM by dedicated geotechnical vessels on high-quality 3 in. soil samples or by 4 in. Jumbo Piston Cores (JPC). The data is summarized on Figure 2 that also shows the lower bound, upper bound, and average profiles that were inferred.

The data on Fig. 2 fits in a somewhat narrow range. The upper bound corresponds approximately to a rate of increase of 10 psf per foot of penetration whereas the lower bounds corresponds approximately to a rate of increase of 6.3 psf per foot rate of increase.

To calculate the conductor capacity as per Equation 4, the average shear strength over the length of the conductor is required. Figure 3 represents three profiles of average shear strength, from the mudline to a given depth, as a function of depth. The curves can be approximated with good accuracy by straight lines. All coefficients of correlation are greater than 0.99. Results are summarized in Table 2.

In the absence of site specific boring, and if the available seismic data does not show active or relic large scale geologic processes capable of influencing the shear strength profile (i.e. erosion, faulting, landslides, channeling) <u>the use of the above average shear strength profile is recommended in design</u>**.**

Design method:

The objective of this study was to develop a method simply giving the required length of surface conductor as a function of the weight to be landed and the allowable set-up time. The detailed derivation of the equation giving the required length of the conductor is provided in Appendix 1. The equation is as follows:

$$L = \frac{-B+\sqrt{B^2-4\cdot A\cdot C+4\cdot A\cdot FS_2\cdot W_{landed}}}{2\cdot A} \quad ....5)$$

with:

L : Required conductor length below mudline.

$A = 0.055\cdot\left[2+\log(t)\right]\cdot\pi\cdot D\cdot Su_1$

$B = R\cdot\left(w_{DC}+w_2\right)+0.055\cdot\left[2+\log(t)\right]\cdot\pi\cdot D\cdot Su_0 - FS_1\cdot w_2$

$C = R\cdot\left[W_{WH}+W_{CADA}+L_1\cdot\left(w_1-w_2\right)\right]-FS_1\cdot W_{WH}+FS_1\cdot L_1\left(w_2-w_1\right)$

and

- D: Surface conductor diameter
- L: Conductor length below mudline
- t: Time, in days
- W_{landed} : Weight of casing string to be landed
- FS_1, FS_2: Partial safety factors
- W_{cond} : Weight of surface conductor, in water
- W_{WH} : Weight of the wellhead housing, in water
- W_{DC} : Weight of the drill collars, in water
- W_{CADA} : Weight of the CADA tool, in water
- w_{DC} : Weight per unit length of drill collars
- w_1 : Weight per unit length of upper conductor section
- L_1 : Length of upper conductor section (usually equal to 80 ft)
- w_2 : Weight per unit length of lower conductor section
- R: WOB utilization Ratio, should be between 0.8 and 1.0
- Su_0 : equals 0.0191 ksf for an average Gulf of Mexico soil profile.
- Su_1 : equals 0.0043 ksf/ft for an average Gulf of Mexico soil profile.

All the above parameters should be expressed in a consistent set of units.

The required conductor length below mudline is therefore a function of the square root of the weight to be landed on the conductor. It should be noted that W_{landed} does not include the self-weight of the surface conductor.

The available GoM data suggests that Equation 5 may be valid for conductors installed with and without reciprocation provided the jet head is at least 18" above the conductor tip and the reciprocation strokes are not excessive ('controlled reciprocation').

Conservatism.

The method includes some inherent conservatism. The set-up curves are clearly lower bounds that are based on proof-load tests and not load tests to failure. Also, any drag due to hole deviation and/or doglegs will reduce the weight to be landed

In addition, the shear strength profile used is an average profile that may or may not be conservative depending on individual site location.

Calculation of weight to be landed.

The first step in determining the surface conductor length is to determine the weight to be landed on it. Mud weights in the hole during landing of first casing string are depicted in Fig. 4 which also gives the recommended equation to calculate the buoyant weight of the casing to be landed.

The mud weights, inside the hole, inside the casing, and inside the cementing string all influence the actual buoyant weight landed.

WoB profile.

The recommended Weight on Bit profile to be obtained with penetration depth should be such that reciprocation is started when the WOB reaches about half of the maximum usable WOB during jetting. An example of such WOB profile is given in Fig. 5. After reciprocation starts, the WOB profile should be increased linearly to reach the maximum allowable WOB at target depth.

Fig. 6 shows an example of good WOB record and how it compares with the recommended curve. It should be remembered that the recommended profile uses an assumed soil shear strength at the site, which explains the slight difference between predicted and actual WOB profiles before reciprocation starts.

Fig. 7 shows examples of poor WOB profile during jetting. Either the WOB is maximized too soon, which means that no friction is gained from the lower part of the soil profile, or the WOB is not maximized at all, which means that the immediate capacity calculated by the method herein grossly overestimates the actual immediate capacity.

Although both conductors in Fig. 7 were installed to target depth, their load bearing capacity has been reduced from what is calculated by the proposed method based on the WOB profile of Fig. 5.

Comparison with Past Practices

Both BP and Amoco had been successful in the past with regards to the installation of jetted conductors. A key aspect of the new method is that it had to explain this good record. To do so, a series of 20 successful conductor installation records was analyzed to see if the new method could explain why we had been successful.

Results are presented in Figures 8 and 9 where the weights landed are plotted with the corresponding length of conductor used and associated set-up time. The required conductor lengths, as calculated by Equ. 5 are also shown for various set-up times. The average Gulf of Mexico soil properties of Table 2 were used for this exercise.

All data points below the recommended curves are considered UNSAFE because, for a given weight to be landed, the length of conductor used is less than what is recommended by the design method. All data points above the recommended curves are considered SAFE because, for a given weight to be landed, the length of conductor used is greater than what is recommended by the design method.

Figures 8 and 9 clearly indicate that, if the weight landed on the surface conductor is calculated assuming water is present in the hole (as per pre merger practices), then the proposed design curves do not explain why we have been successful in the past. The required lengths indicated by the curves are longer than the actual length used for the wells.

However, if the weight to be landed is calculated by taking full advantage of the buoyancy due to the mud inside the hole then Figures 8 and 9 explain why past practices have been successful. The required length is less than the actual length used for the well and the actual set-up times were greater than required by the prediction method.

In order to be consistent with past practices, it is therefore recommended to calculate the weights to be landed by taking full advantage of the buoyancy due to the mud inside the hole.

A reasonable safety factor may be used in conjunction with the above-calculated weight. It should be noted that the ultimate choice of safety factor remains with the owner of the well.

Recommendations

The following recommendations summarize how the proposed design method is intended to be used. The steps to follow in the design are:

1. Review high-resolution seismic data over the well area. If data do not show signs of active or relic geohazards such as faults, landslides, buried channel, erosion, capable of influencing the soil shear strength in the top 300 ft, then the use of the average GoM soil properties is suggested. If active geological processes are suggested the soil profile should be modified accordingly by an experienced geotechnical engineer. A soil boring may be required for extreme cases.
2. Calculate the weight to be landed, according to the equation in Fig. 4. The weights of the fluids in the open hole should be carefully considered to take full advantage of the buoyancy provided by the mud.
3. Calculate the required conductor setting depth, as per Equation 5, as a function of weight landed and allowed set-up time. A minimum safety factor, FS_2, of 1.3 is suggested.
4. Using Equation 1 and Figure 5, construct the WOB profile to be followed during jetting. Failure to follow the required WOB profile will reduce the capacity of the jetted conductor in an unpredictable manner.

This method is versatile and can be used in the field to analyze unforeseen conditions and make real-time decisions. For example:

- If the utilization ratio is different than that assumed in design (i.e. the WOB at target depth is lower or higher that anticipated) the method can be used to determine the new capacity.
- If the available set-up time is different than assumed, the new capacity can also be determined. In addition, the weight to be landed can be different than assumed (i.e. the well is flowing and mud weights in the hole are different than what was assumed). By using an appropriate safety factor and measuring the actual load landed in the hole on the hook, it can then be determined if landing the string is safe or not.

It should be kept in mind that the method presented does not account for any hydraulic fracture requirements which may dictate deeper setting depths than determined by the method herein.

Conclusions

A fully calibrated, rational approach to determine the setting depth of jetted conductors has been presented. This method has had the following impact on business:

- Increased safety when landing casing strings on the surface casing. The method, unlike highly empirical past practices, has a more rational and scientific approach to calculating loads that can safely be landed on surface casings. Lower safety factors can therefore be used, when compared to previous methodologies. Unexpected situations can also be analyzed on the rig and installation procedures can be modified accordingly.

- More reliable and cost effective design of surface casings: because of its more scientific based approach and optimized design, the new method leads to reduced setting depths for surface casings, which generate lower material and installation costs.

- Elimination of 26 inch casing string at selected wells locations. Because higher loads can be safely landed, longer strings of 20-inch casings can be used, without, having to set 26 inch casing. Use of 26-inch casings may still be required in areas of high drilling hazards.

Most applications for the new method have been located in the Gulf of Mexico Deepwater. Implementation in other deepwater basins is ongoing.

Acknowledgements

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Reference

Beck, R.D., Jackson, C.W., and Hamilton, T.K. (1991), “Reliable Deepwater Structural Casing Installation Using Controlled Jetting,” Society of Petroleum Engineers, (SPE No. 22542), New Orleans.

Appendix 1 : Derivation of Equation 5) Giving the Required Conductor Length, L

The capacity of the jetted conductor can be expressed as:

$$Q_t = Q_0 + SETUP = WOB_{last} + 0.055 \cdot [2 + \log(t)] \cdot \pi \cdot D \cdot L \cdot Su_{AVE}$$

....Equ. A-1)

with:

t: time, in days
Q_t : Conductor capacity at time =t
WOB_{last}: Weight on Bit measured at final penetration
D: Surface conductor diameter
L: conductor length below mudline
Su_{AVE} : Average undrained shear strength over the length of the conductor

The last Weight on Bit measured is assumed to be proportional to the available weight during jetting. The constant of proportionality, called the WOB utilization ratio, is noted R. A value of R = 0.8 is suggested. The R ratio should not exceed 1.0 in order to maintain tension in the jetting assembly.

Therefore:

$$Q_0 = WOB_{last} = R \cdot \left(W_{cond} + W_{WH} + W_{DC} + W_{CADA}\right) \quad \text{A-2)}$$

with:

Q_0 : surface conductor capacity immediately after jetting (t=0.01 days)
WOB_{last}: last Weight on Bit recorded during installation
R: WOB utilization Ratio, should be equal to 0.8
W_{cond} : weight of the surface conductor, in water
W_{WH} : weight of the wellhead housing, in water
W_{DC} : weight of the drill collars, in water
W_{CADA} : Weight of the CADA tool, in water

The weight of the conductor and the drill collars, W_{cond} and W_{DC}, are functions of the unknown conductor length L. In order to resist bending moments close to the mudline, the surface conductor usually has a thicker wall section in the upper 80 ft close to the mudline. Therefore:

$$W_{cond} = w_1 \cdot L_1 + w_2 \cdot \left(L - L_1\right) \quad \text{................................A-3)}$$

with:

w_1 : weight per unit length of upper conductor section
L_1 : length of upper conductor section (usually equal to 80 ft)
w_2 : weight per unit length of lower conductor section

$$W_{DC} = w_{DC} \cdot L \quad \text{... A-4)}$$

with:
w_{DC} : weight per unit length of drill collars

Combining A-3 and A-4 into A-2 gives:

$$Q_0 = R \cdot \left(w_1 \cdot L_1 + w_2 \cdot \left(L - L_1\right) + W_{WH} + w_{DC} \cdot L + W_{CADA}\right)$$

.... A-5)

where the only unknown is the length of the conductor L.

As explain previously, the average shear strength along the conductor length L can be expressed as

$$Su_{AVE} = Su_0 + Su_1 \cdot L \quad \text{... A-6)}$$

with:

Su_0 : equals 0.0191 ksf for an average Gulf of Mexico soil profile.
Su_1 : equals 0.0043 ksf/ft for an average Gulf of Mexico soil profile.

On the one hand, combining A-5 and A-6 into A-1 gives:

$$Q_t = R \cdot \left(w_1 \cdot L_1 + w_2 \cdot \left(L - L_1\right) + W_{WH} + w_{DC} \cdot L + W_{CADA}\right)$$
$$+ 0.055 \cdot [2 + \log(t)] \cdot \pi \cdot D \cdot L \cdot \left(Su_0 + Su_1 \cdot L\right) \quad \text{............. A-7)}$$

where the only unknown is the length of the conductor, L.

On the other hand, the load to be resisted by the conductor can be expressed as:

$$LOAD = FS_1 \cdot \left(W_{cond} + W_{WH}\right) + FS_2 \cdot \left(W_{landed}\right) \quad \text{...... A-8)}$$

with:

$LOAD$: Load to be resisted by the surface conductor
W_{landed} : Weight to be landed on surface conductor
FS_1, FS_2: Partial safety factors
All other quantities as previously defined

If the quantities W_{landed} , FS_1, and FS_2 are given, the load to be resisted is also a function of one unknown, L.

The fundamental equation giving L simply states that the load to be resisted is equal to the capacity of the conductor:

$$Q_t = LOAD \quad \text{.......... A-9)}$$

Replacing Equations A-3, A-7 and A-8 into A-9 and re-arranging gives the following quadratic equation with one unknown L:

$$A \cdot L^2 + B \cdot L + C - FS2 \cdot W_{landed} = 0 \quad \text{.......... A-10)}$$

with:

L : Required conductor length below mudline.

$$A = 0.055 \cdot [2 + \log(t)] \cdot \pi \cdot D \cdot Su_1$$

$$B = R \cdot (w_{DC} + w_2) + 0.055 \cdot [2 + \log(t)] \cdot \pi \cdot D \cdot Su_0 - FS_1 \cdot w_2$$

$$C = R \cdot [W_{WH} + W_{CADA} + L_1 \cdot (w_1 - w_2)] - FS_1 \cdot W_{WH} + FS_1 \cdot L_1 (w_2 - w_1)$$

All other quantities as previously defined

The solution to Equation A-10 can be expressed as follows, all quantities as previously defined:

$$L = \frac{-B + \sqrt{B^2 - 4 \cdot A \cdot C + 4 \cdot A \cdot FS_2 \cdot W_{landed}}}{2 \cdot A} \quad \text{.........A-11)}$$

The required conductor length below mudline is therefore a function of the square root of the weight to be landed on the conductor. It should be noted that W_{landed} does <u>not</u> include the self-weight of the surface conductor.

Table 1: Summary of load test results on partially set-up jetted conductors

Site	Conductor length (ft)	Conductor Diameter (in)	Immediate capacity (kips)	Set up data		Calculated $\Delta\alpha_t$
				Set-up Time	Measured capacity	
A	135	30	135	4 hrs	>170 kips[1)]	0.07
B	65	30	91	1 day	125 kips	0.11
C	175	36	130	5 days	>300 kips[1)]	0.15

Notes: 1) Conductor was not failed but proof loaded to indicated load, which represents a lower bound estimate of the actual capacity.

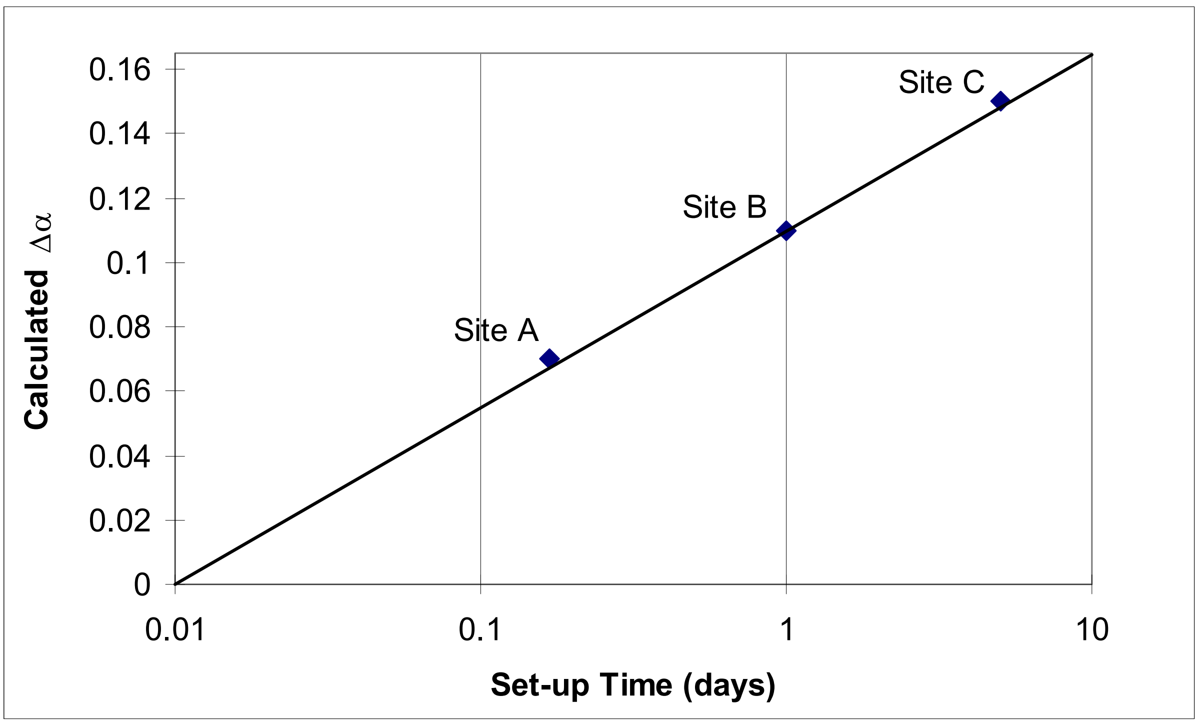


Fig. 1: Measured Set-up Factor , $\Delta\alpha_t$, as a function of set-up time.

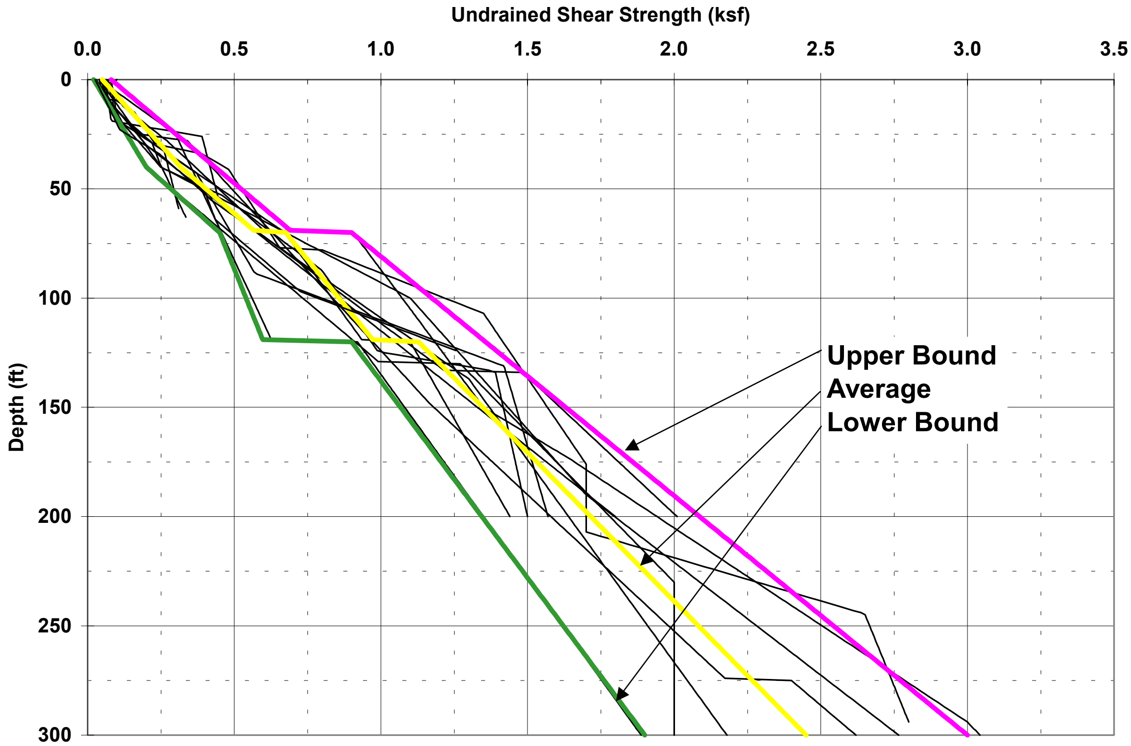


Fig. 2. Selected Deepwater Soil Profiles for Gulf of Mexico Sites

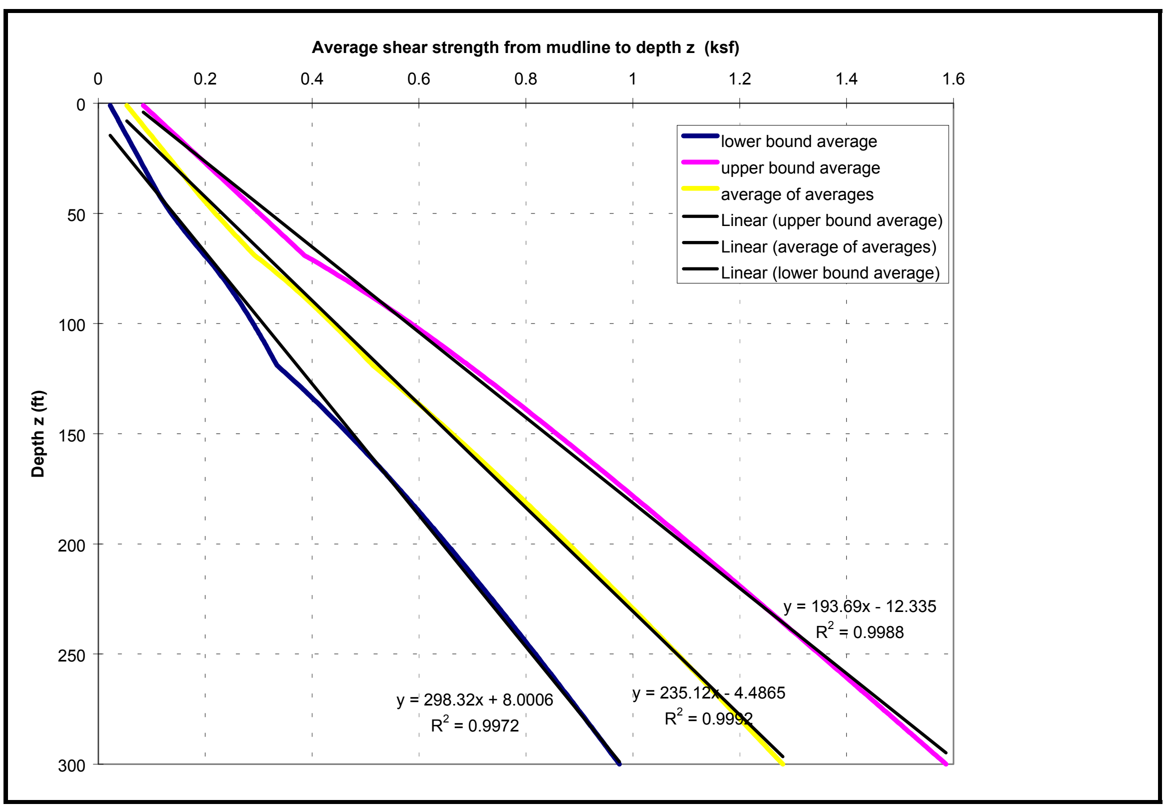
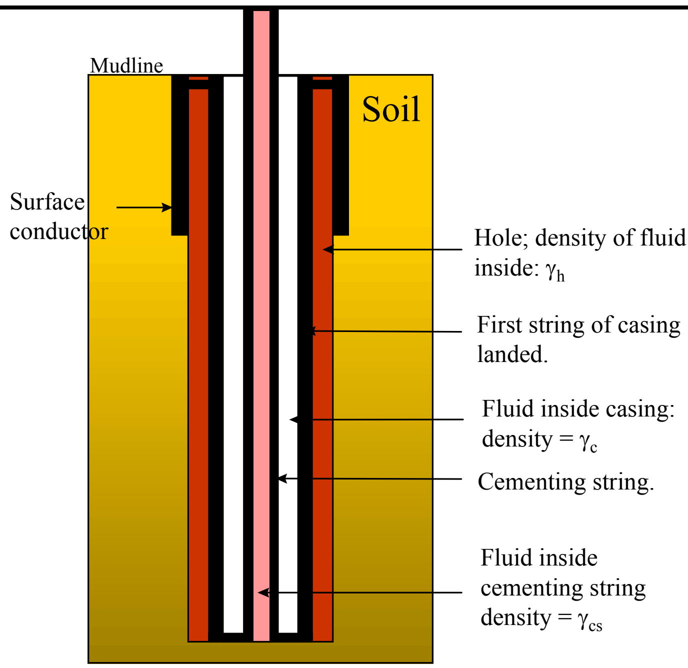


Fig. 3: Average Shear Strength from Mudline to Depth Z, vs. Depth Z.

Table 2: Determination of Average Shear Strength along the Conductor Length (as per Fig. 3)

$Su_{AVE} = Su_0 + Su_1 \cdot z$ Su_{AVE} : average shear strength in ksf z: depth in feet	Su_0 (ksf)	Su_1 (ksf/ft)
Lower bound profile	-0.0268	0.0034
Average profile	**0.0191**	**0.0043**
Upper bound profile	0.0635	0.0052



Weight to be landed =

Weight of casing in air
\+ **Weight of cementing string in air**
\+ **Weight of fluid inside casing**
\+ **Weight of fluid inside cementing string**
\- **Weight of the fluid displaced by casing assembly**

Fig. 4: Mud weights in the hole during landing of first casing string

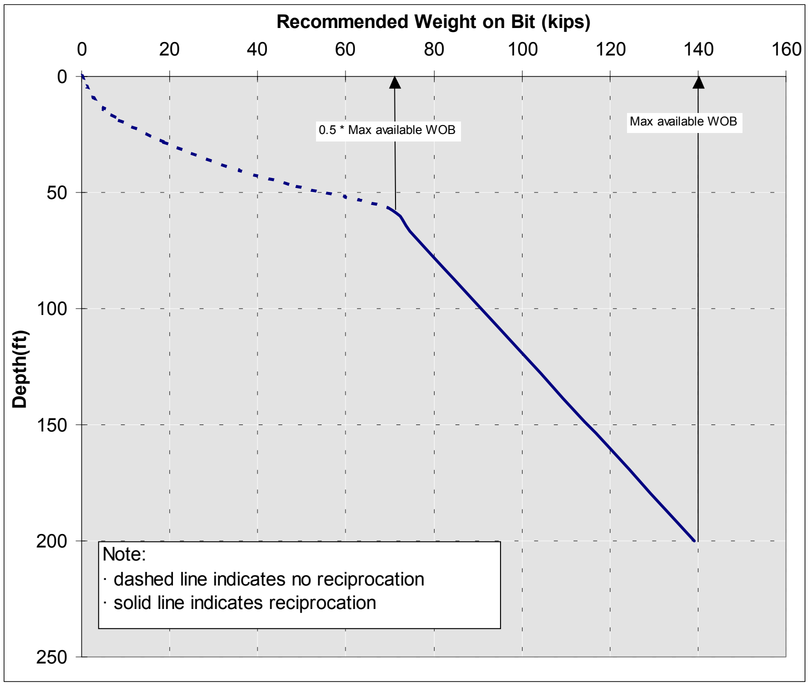


Fig. 5 Recommended Weight on Bit Profile During Jetting Operations

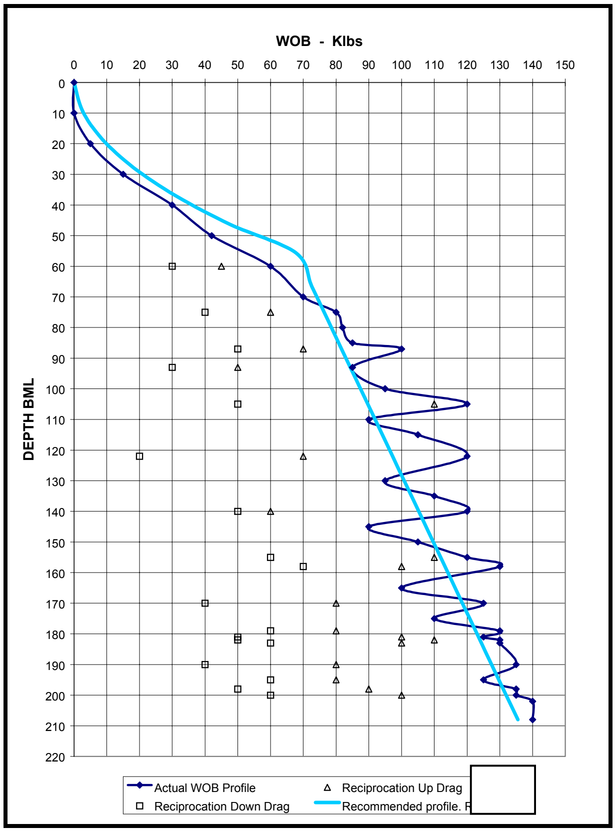


Fig. 6 Example of Good Conductor Jetting WOB Record and Comparison with Recommended Profile

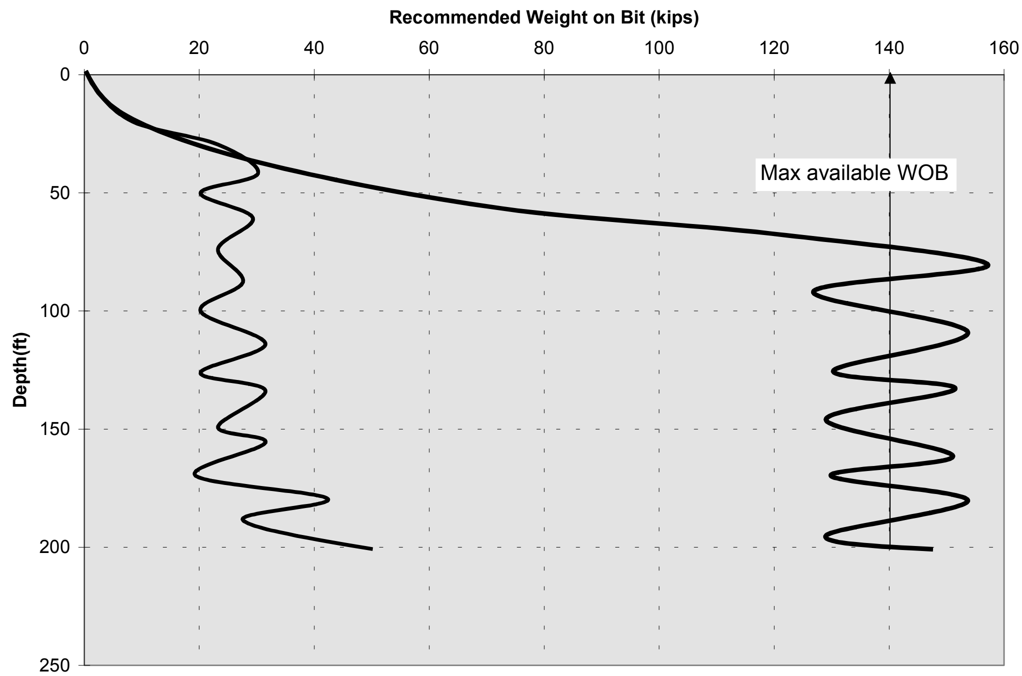


Fig. 7 Examples of Poor WOB profiles

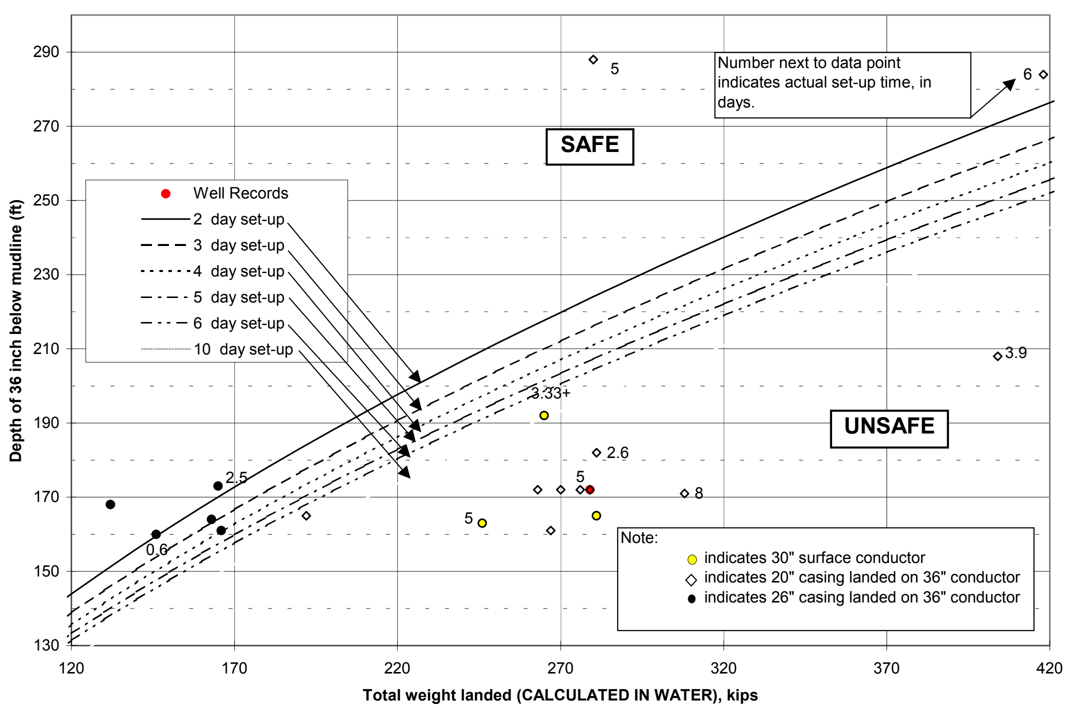


Fig. 8: Comparison of design curves with landed weights calculated buoyant in water for 20 successful installations in GoM Deepwater.

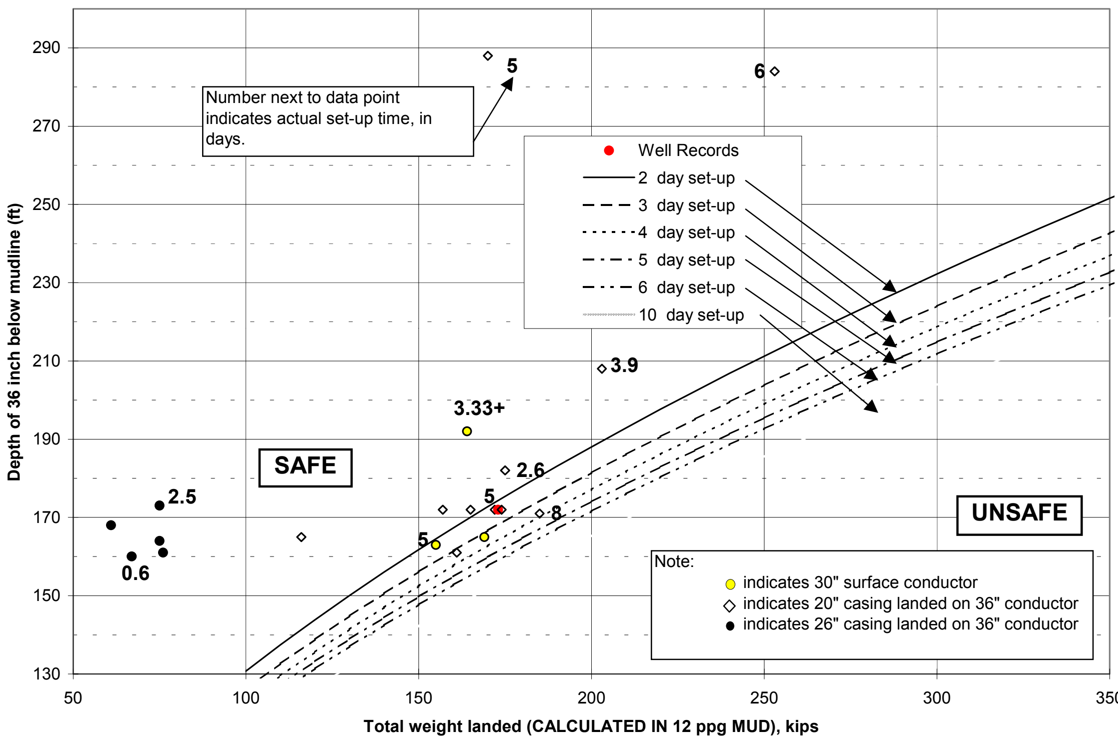


Fig. 9: Comparison of design curves with landed weights calculated buoyant in 12-ppg mud for 20 successful installations in GoM Deepwater.