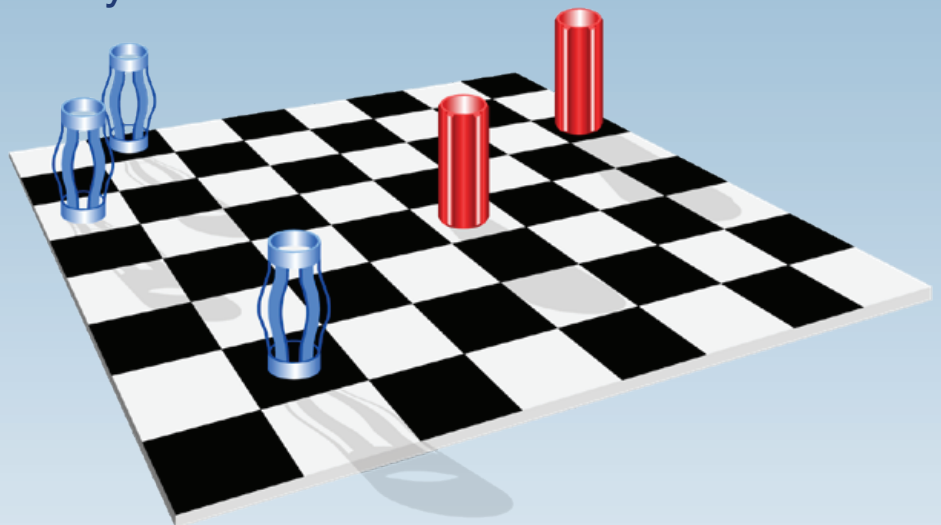


WHITE PAPER

# Casing Centralizers:

Are We Using Too Many or Too Few?



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## I. Challenges

Casing centralizer is a mechanical device secured around the casing at various locations to keep the casing from contacting the wellbore walls. As a result of casing centralization, a continuous annular clearance around the casing allows cement to completely seal the casing to the borehole wall.

Casing centralization is one of the key elements to ensure the quality of a cementing job by preventing mud channeling and poor zonal isolation. Centralizers can also assist in the running of the casing and the prevention of differential sticking. Its usage is extensive! It is estimated that 10 million centralizers are manufactured and used every year globally.

Centralizer manufacturers likely want to increase the demand for centralizers. However, operators on the other hand, may wonder: “Should we use that many?”

While centralizers are used extensively, well problems continue to arise due to poor cementing jobs. Centralizer properties and placements directly or indirectly affect the quality of the cementing job.

The challenges that both operators and service companies face is to choose the right type of centralizers and place the right amount at the optimum positions on the casing to achieve a good standoff profile.

## II. Background

### Types of Centralizers

There are 4 types of centralizers (Fig. 1): bow-spring, rigid, semi-rigid, and mold-on; each with its own pros and cons.

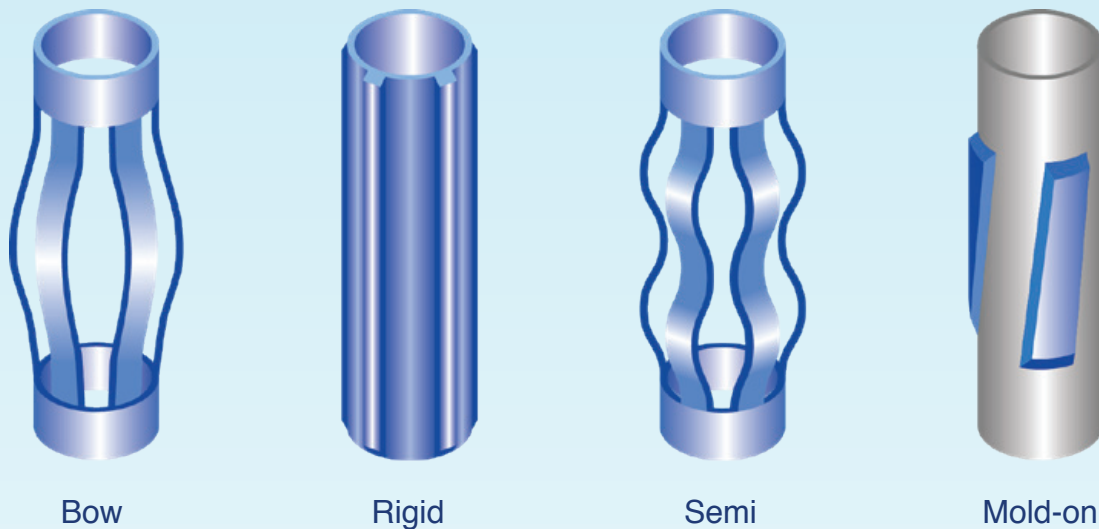


Fig. 1. Types of centralizers

### 1. Bow-Spring

Since the bow springs are slightly larger than the wellbore, they can provide complete centralization in vertical or slightly deviated wells. Due to the flexibility of bows, they can pass through narrow hole sections and expand in the targeted locations.

The shape and stiffness of the bows determine the restoring force, which is defined as the resistance force when a bow is compressed by 1/3 of its uncompressed height. The effectiveness of this type of centralizer is heavily dependent on the restoring force. When the casing is heavy and/or the wellbore is highly deviated, they may not support the casing very well. For example, on a riser tieback casing string, a helically buckled casing could create a side force of 50,000 to 100,000 lbf (222 to 445 kN), well beyond the capabilities of the spring-bow centralizer. A solid centralizer would be able to meet the requirements.

## 2. Rigid

Rigid centralizers are built out of solid steel bar or cast iron, with a fixed blade height and are sized to fit a specific casing or hole size. This type is rugged and works well even in deviated wellbores, regardless of the side force. They provide a guaranteed standoff and function as bearings during the pipe rotation, but since the centralizers are smaller than the wellbore, they will not provide a good centralization as the bow-spring type does in vertical wells.

## 3. Semi-Rigid

Semi-rigid centralizers are made of double crested bows, which provide desirable features found in both the spring bow and the rigid centralizers. The spring characteristic of the bows allows the semi-rigid centralizers to compress in order to get through tight spots and severe doglegs. The double-crested bow provides restoring forces that exceed those standards set forth in the API specifications and therefore exhibits certain features normally associated with rigid centralizers.

## 4. Mold-On

The mold-on centralizer blades, made of carbon fiber ceramic materials, can be applied directly to the casing surface. The blade length, angle and spacing can be designed to fit specific well applications, especially for the close tolerance annulus. The non-metallic composite can also reduce the friction in extended reach laterals to prevent casing buckling.

### III. Standoff

The term standoff (SO) describes the extent to which the pipe is centered (Fig. 2). If a casing is perfectly centered, the standoff is 100%. A 0% standoff means that the pipe touches the wellbore. Regardless of the centralizer type, the goal is to provide a positive standoff, preferably above 67%, throughout the casing string.

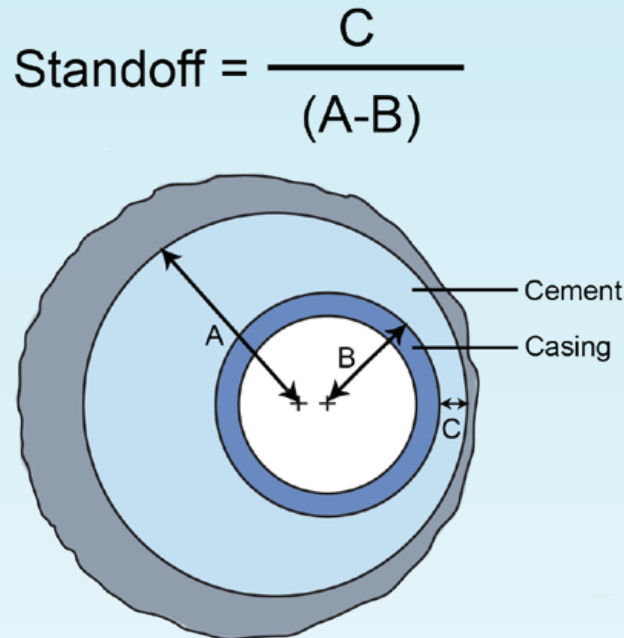


Fig. 2. Definition of standoff

The casing deflection between centralizers obeys the laws of physics. An engineering analysis can help both operators and service companies arrive at the optimized number and placement of centralizers for a particular well.

The casing standoff depends on the following conditions:

- Well path and hole size
- Casing OD and weight
- Centralizer properties
- Position and densities of mud and cement slurries (buoyance)

## IV. Casing Deflection

Between centralizers, the casing string can sag or deflect the side force. To study the casing deflection, one should study the force balance for a pipe segment. (Fig. 3)

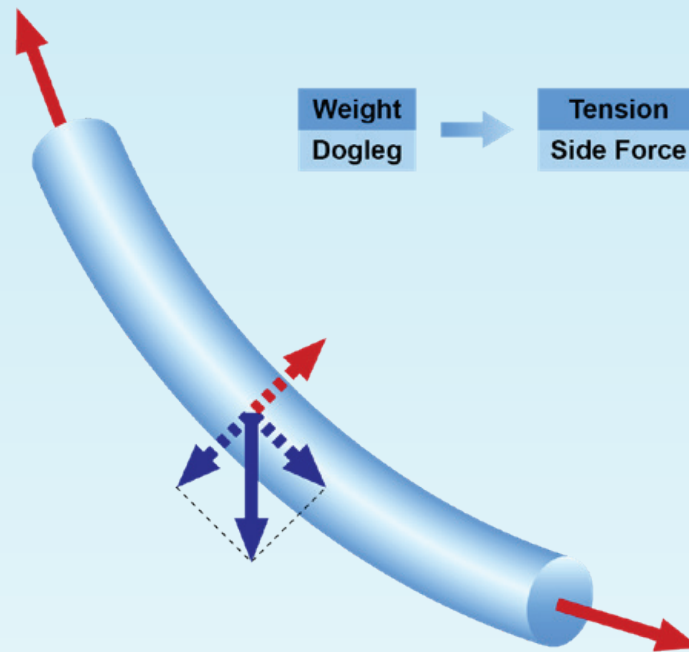


Fig. 3. Force balance

There are 2 types of forces on the casing:

- Gravitational force on the pipe body, pulling the casing downward
- Axial tension force at the end, pushing the casing upward

Depending on the weight and tension, the net side force is either upward or downward.

To obtain the side force, we start the analysis from the bottom and perform the calculations for each element. Step by step, we move upward to obtain the side force profile, as shown below in Fig. 4.

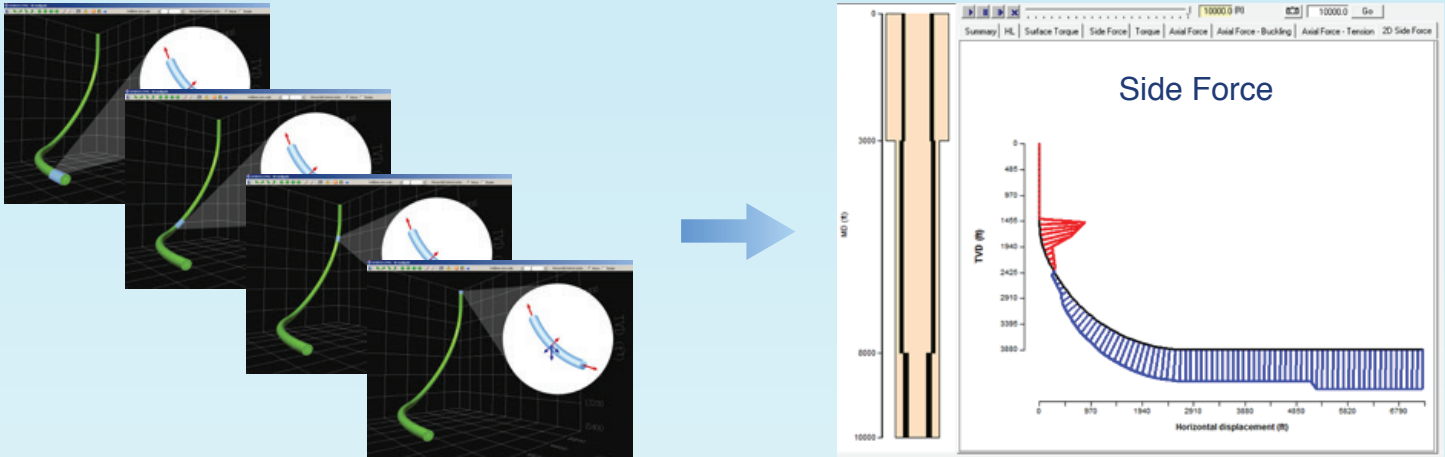


Fig. 4. Side force calculation and profile

In the profile, the red lines indicate that the side force is acting upward and that the casing touches the upper side of the well. The blue lines indicate that the side force is acting downward and that the casing touches the lower side of the well.

In a typical wellbore (build-and-drop), the standoff profile of the casing without a centralizer looks like the one shown in the Fig. 5.

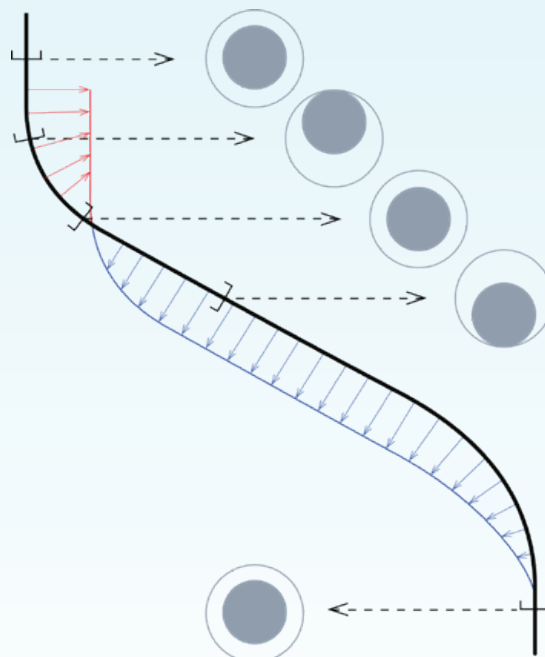


Fig. 5. Standoff profile without centralizers



## V. Buoyance

Any fluids present in the wellbore create an up-lifting force (buoyancy) on the casing, making the force acting on the wellbore less. During a cementing job, when heavy cement slurry is inside the casing, and the drilling mud is outside the casing, the casing is at its “heaviest”. As the cement slurry turns at the corner and light displacement fluids occupy the casing interior, the casing is at its “lightest”. Centralizer design considers the “lightest” casing condition. Fig. 6 illustrates the buoyancy conditions at various stages of the cementing job.

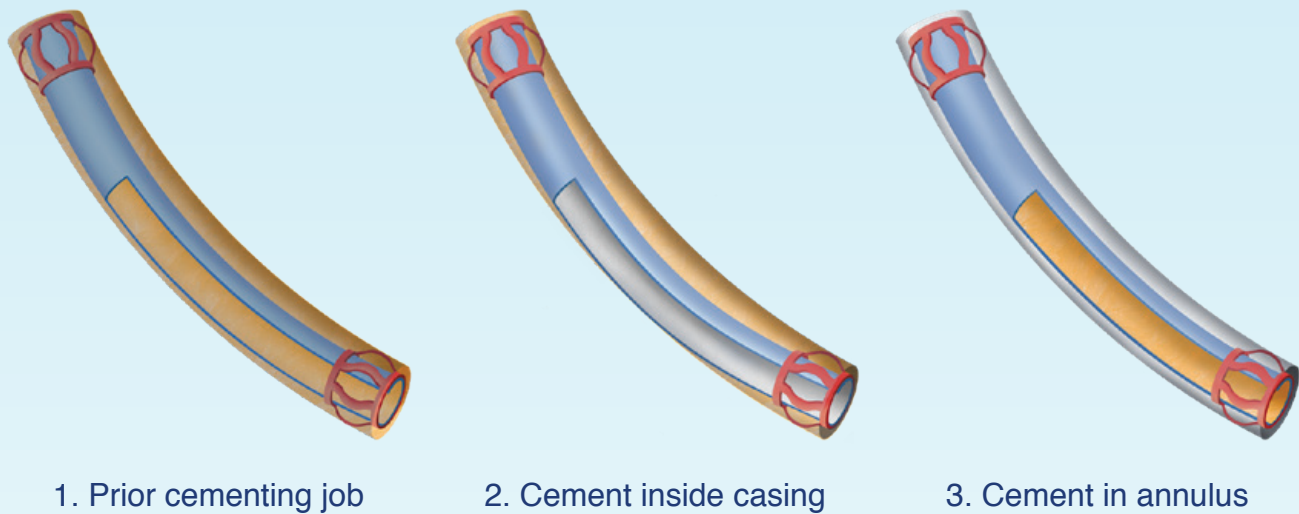


Fig. 6. Casing deflection between centralizers

A good centralizer design requires top of cement (TOC), cement slurry densities, and mud weight, etc. Larger density difference between cement slurry and mud would improve the stand-off profile.

## IV. Modeling

### Theory

The puzzle of the centralizer selection and the centralizer placement can be best solved by using computer models. Over the past 20 years, a variety of models have been developed—some simply utilizing Microsoft Excel® spreadsheets, others implementing it as part of the cementing software. These efforts help engineers to understand the importance of casing centralizers and placement.

Since 2000, PVI has been working with both operators and centralizer manufacturers and have been developing [CentraDesign](#), the advanced engineering software that geared towards the centralizer placement analysis.




There are 2 methods to model the casing deflection between centralizers: the hinged-ends model (Lee, Smith and Tighe) and the fixed-ends model (Juvkam-wold and Jiang Wu).

Hinged-ends model assumes that a casing string transmits no bending moment across centralizers. This assumption results in the excessively high casing deflection. The hinged-ends model was replaced by the more advanced fixed-ends model, which is used to calculate the deflection between the centralizers. Anyway, casing string is a continuous beam in the wellbore. In this more sophisticated model, the casing deflection between the centralizers in a 3D wellbore no longer occurs solely in the vertical plane or in the dogleg plane; instead it occurs as a spatial deflection in 2 planes: one in the dogleg plane and the other in the plane perpendicular to the dogleg plane. The resulting deflection is the vector summation of these 2 deflections, caused by the axial tension and the casing weight.

CentraDesign uses this latest model to predict the casing deflection in a 3D well, which also considers the contribution from changes of the azimuth angle's. For bow spring centralizers, the compression of the bows themselves caused by the side force must be considered as well in the standoff calculation.

## Calculation Modes

3 methods are used to design the placement of centralizers.

Specify Spacing		Users specify the spacing. Software checks the standoff.
Specify Standoff		Users specify the standoff at the mid-span, between the centralizers. Software calculates the spacing.
Optimum Spacing		Users specify the standoff and the spacing increments. Software calculates the spacing.

In the first approach, the spacing is specified utilizing the users' experience; the software then checks for the satisfactory standoff at the centralizers and at the middle of the span. This mode offers the simple-to-install centralizer placement because of its constant spacing. This method, however, may compromise the quality of the standoff or the quantity of the centralizers, because the side force changes as the wellbore deviates.

For users without significant experience, or who prefer that the software calculates the spacing, the second approach (specify standoff) can be used. Simply specify the required standoff at the middle span, and the program uses a numerical method to obtain the centralizer placement, so that the standoff at the middle point between the centralizers is as specified. The "specify standoff" mode ensures the minimum standoff of the casing between the centralizers, while yielding a difficult-to-follow placement program.

To benefit from the best elements of these approaches, we have developed an optimum placement solution, the third method in the diagram. In this approach, users can specify the standoff with an incremental spacing requirement. This ensures the standoff requirements, yet results in a not-difficult-to-follow placement program. For high impact operations such as deep water and use of inline bow spring centralizers, these methods can be used once a casing schematic is available to optimize the exact placement of each centralizer.

## Case Study

With the help of computer modeling, the centralizer placement optimization becomes easy to perform for all types of wells. Ideally, this kind of optimization should be done before each casing job. Here is an example of optimization. (Fig. 7)

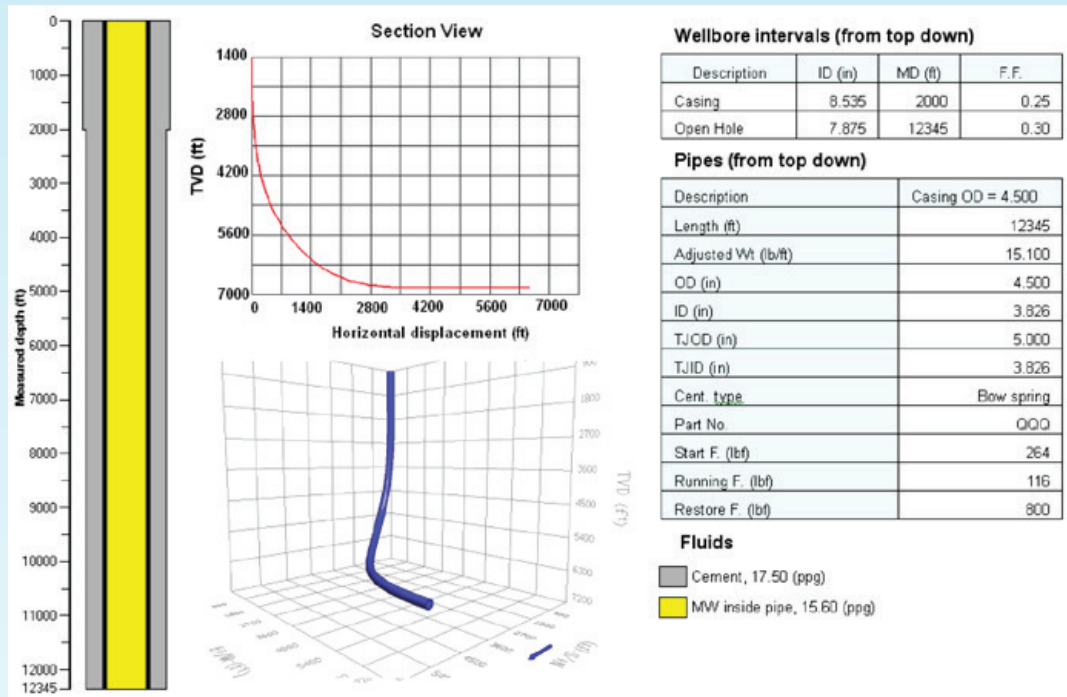


Fig. 7. Example well

The example shown in Fig. 7 has a kick-off point of 2,000 ft. The previous casing (ID = 8.535") was set at the same depth. Our goal is to centralize the 12,345 ft of a 4 1/2" casing, deviated from 0° to 90°. The centralizer considered in the picture is the bow spring type with a restoring force of 800 lbf.

## Specify Spacing

40 feet are used for the centralizer spacing (1 centralizer per joint). Fig. 8 shows the resulting stand-off profile. The blue line is the stand-off at the centralizer, while the red line is the stand-off at the middle point between the centralizers, which is always lower than that at the centralizers. Because bow spring centralizers are used here, the stand-off at the middle point between centralizers is the summation of the casing sagging between the centralizers and the bow spring compression at the centralizers. For this approach, the required number of centralizers is 309.

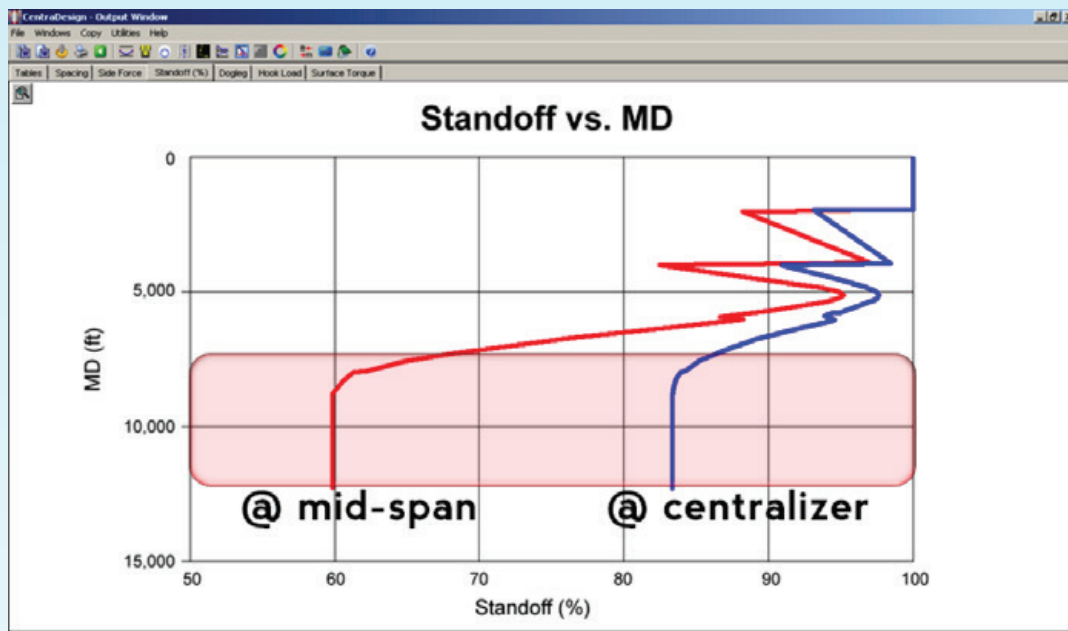


Fig. 8. Standoff profile (specified spacing = 40 ft)

From 2,000 ft to 7,000 ft (inclination from 0° to 30°), the stand-off at mid-span is between 100% and 70%, which meets the industry standard of 67%. From 7,000 ft to 12,345 ft (inclination from 30° to 90°), the stand-off drops from 60%, which is risky, because a poor stand-off profile at this section may cause potential cementing problems.

Now try 2 centralizers per joint (spacing of 20 ft). Fig. 9 shows the resulting standoff profile. The number of centralizers needed is 617.

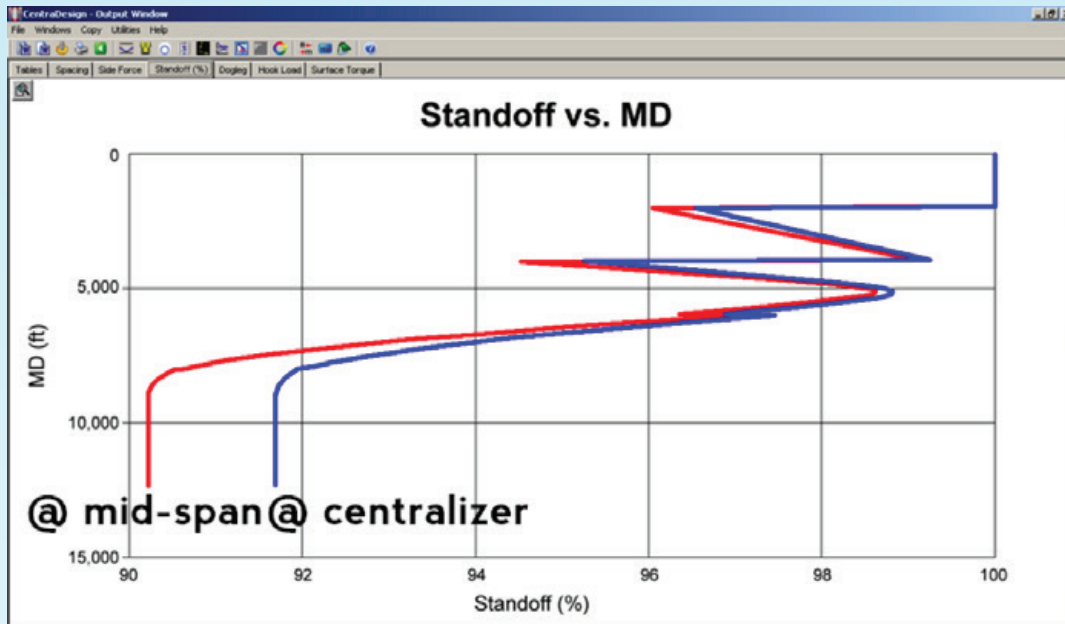


Fig. 9. Standoff profile (specified spacing = 20 ft)

The standoff at the mid-span is very good, at more than 90%. This new placement may be too conservative and can leave engineers wondering: “Are we using too many centralizers?”

## Specify Standoff

Alternatively, the required standoff can be specified by the user, while the software instructs the user on how to space the centralizers.

With the required 70% standoff throughout a 4 1/2" casing, CentraDesign displays the following spacing necessary to achieve the specified standoff. The total number of centralizers used here is 230, a significant reduction from previous approaches.

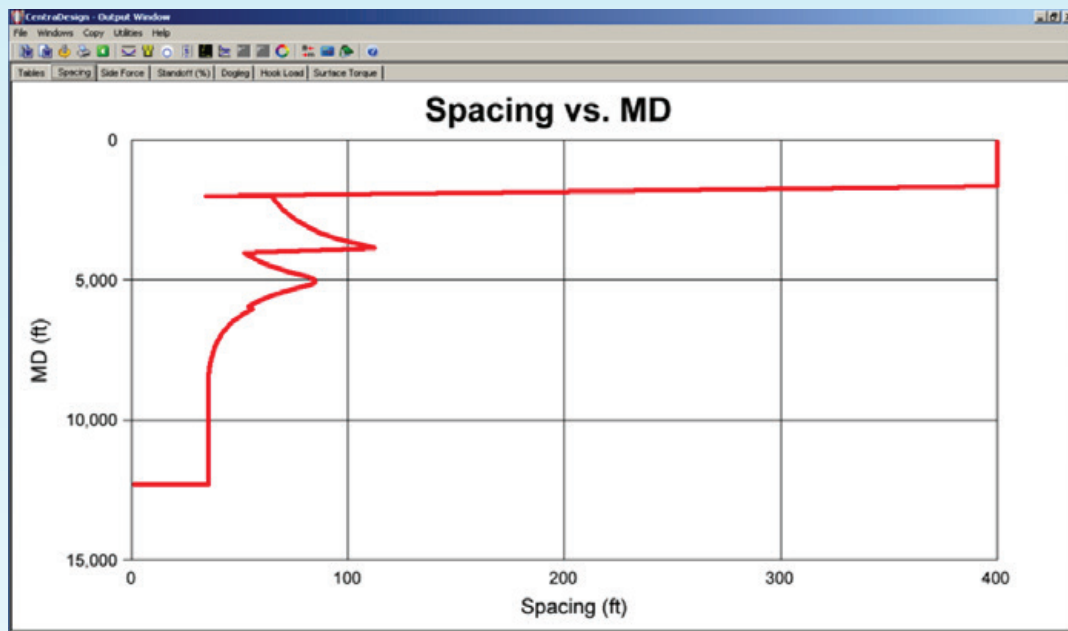


Fig. 10. Calculated spacing required to achieve 70% standoff

Logically, as the well builds up from 0° to 90° the inclination angle, the spacing decreases: the casing needs more support in the deviated or horizontal sections, but putting centralizers strictly following the placement required by Fig. 10 is somewhat impractical.

## Optimum Placement

To get the best elements from both approaches, we have designed the optimum placement solution, which is specifying the standoff (70%) with the incremental spacing requirements (20 ft). The resulting standoff profile and spacing required are displaced in Fig. 11 and Fig. 12, respectively.

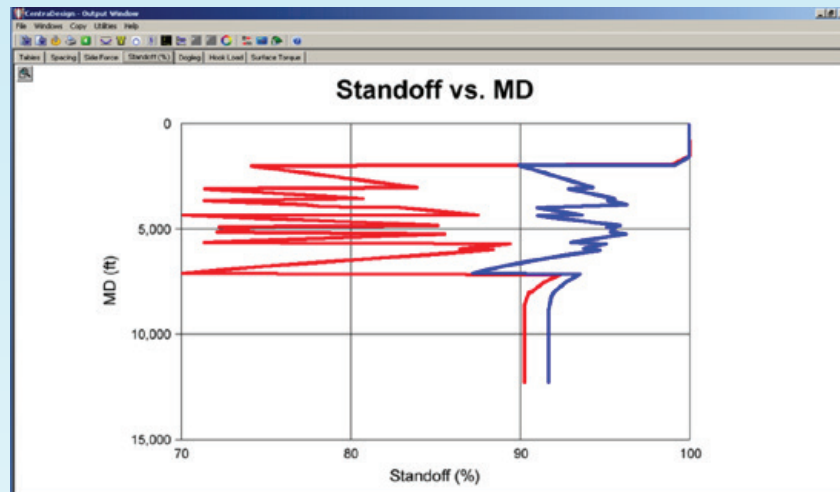


Fig. 11. Optimum placement - Standoff profile

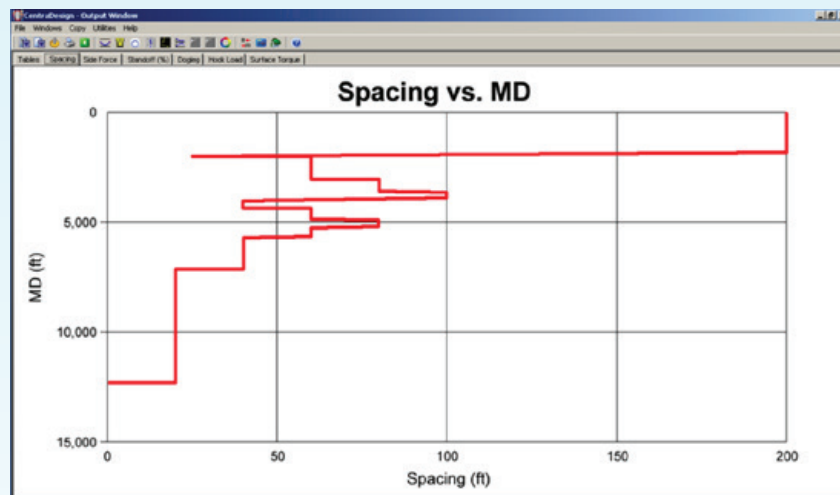


Fig. 12. Optimum placement - Spacing

This method meets the standoff requirements and gives an easy-to-follow spacing. The result of the total number of centralizer is 360.



The results of the three placement modes previously illustrated are summarized in Table 1. The optimum placement gives a satisfactory standoff, an ease of field installation, and good economics.













	Spacing 40 ft	Spacing 20 ft	Standoff 70%	Optimum
Centralizers	309	617	230	360
Standoff				
Installation				
Economics				

Table 1. Centralizer placement comparison

## VII. Conclusion

Our industry is blessed with many talented and experienced engineers. We also have centralizer vendors producing the very best and top quality products.

It is critical that we maximize the engineering potential while selecting the proper types of centralizers, and placements. A software like CentraDesign should be an integral part of the total approach of the centralizer placement optimization.

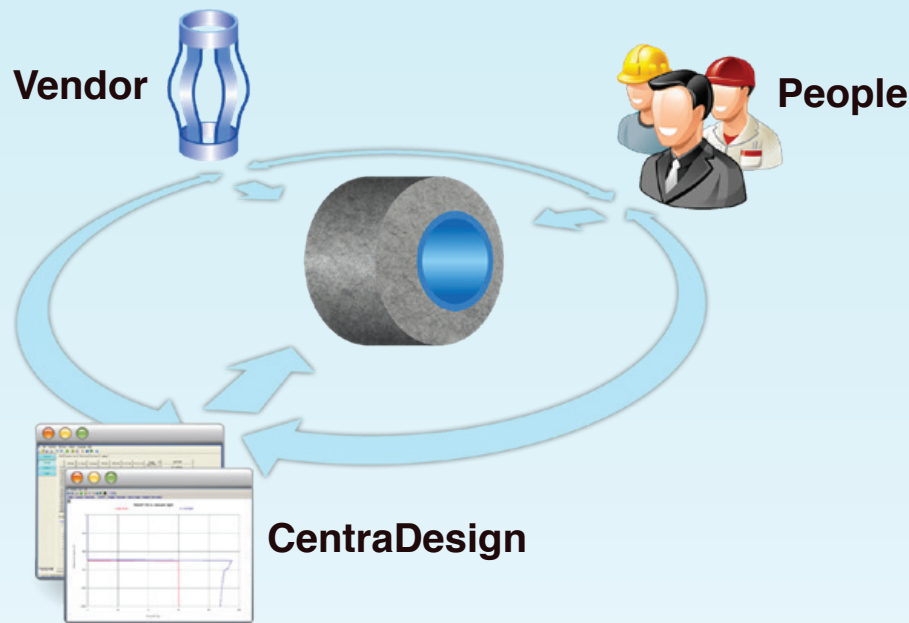


Fig. 13. Total approach of casing centralization

When optimizing the centralizer placement, consider the following:

- Each well is different. Our past experience may not apply to the next well.
- Operators aim to obtain a satisfactory standoff with less centralizers.
- Centralizer vendors similarly aim to obtain a satisfactory standoff to sell more units.
- CentraDesign optimizes the centralizer placement and usage, and reduces risks and costs.

For more information on [CentraDesign](#), please contact PVI at:

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## VIII. References

1. Gefei Liu, Lawrence Weber, “Centralizer Selection and Placement Optimization” (SPE 150345), SPE Deep-water Drilling Conference and Exhibition, Galveston, Texas, June 2012.
2. Erik B. Nelson and Dominique Guillot, Well Cementing, 2nd Edition, published by Schlumberger, 2006.
3. API Specification 10D, 2002: “Casing Centralizers”, Sixth Edition
4. Juvkam-Word, H.C. and Wu, Jiang 1992: “Casing Deflection and Centralizer Spacing Calculations,” SPE Drilling Engineering, P. 268 – 274, December.
5. Lee, H. K., Smith, R. C., and Tighe, R. E., 1986: “Optimal Spacing for Casing Centralizers”, SPE Drilling Engineering, P. 122 – 130, April.
6. Wu, Jiang, Chen, P., and Juvkam – Word H. C., 1991: “Casing Centralization in Horizontal Wells”, Popular Horizontal, P. 14 – 21, April/June.
7. C.A. Johancsik, et al, Torque and Drag in Directional Wells – Prediction and Measurement, SPE Reprint Series, No. 30, Directional Drilling, 1990, P. 130.