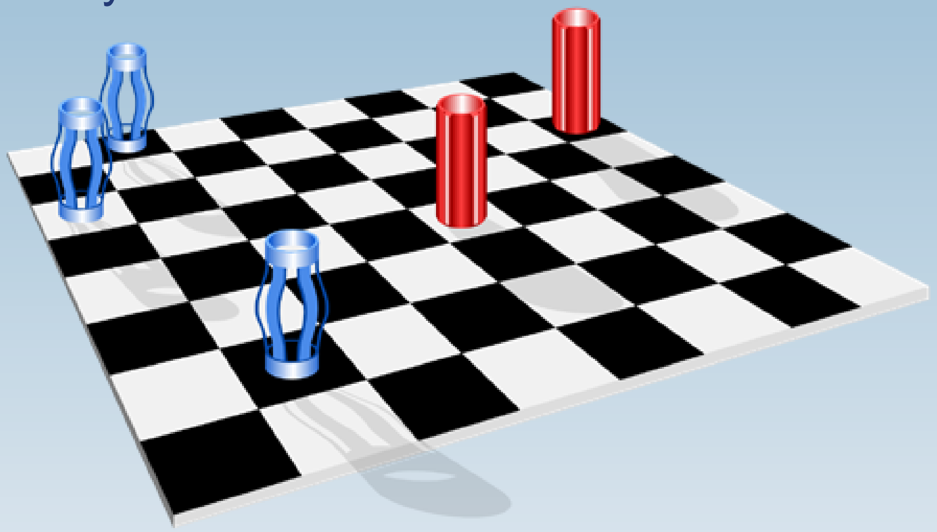
Pegasus Vertex, Inc.

Drilling Software | Sophisticated Yet Simple

WHITE PAPER

Casing Centralizers:

Are We Using Too Many or Too Few?



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I. Challenges

A casing centralizer is a mechanical device secured around the casing at various locations to keep it 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 in ensuring 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, with an estimated 10 million centralizers manufactured and used globally every year.

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 challenge faced by both operators and service companies 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: bow-spring, rigid, semi-rigid, and mold-on, each with its pros and cons.

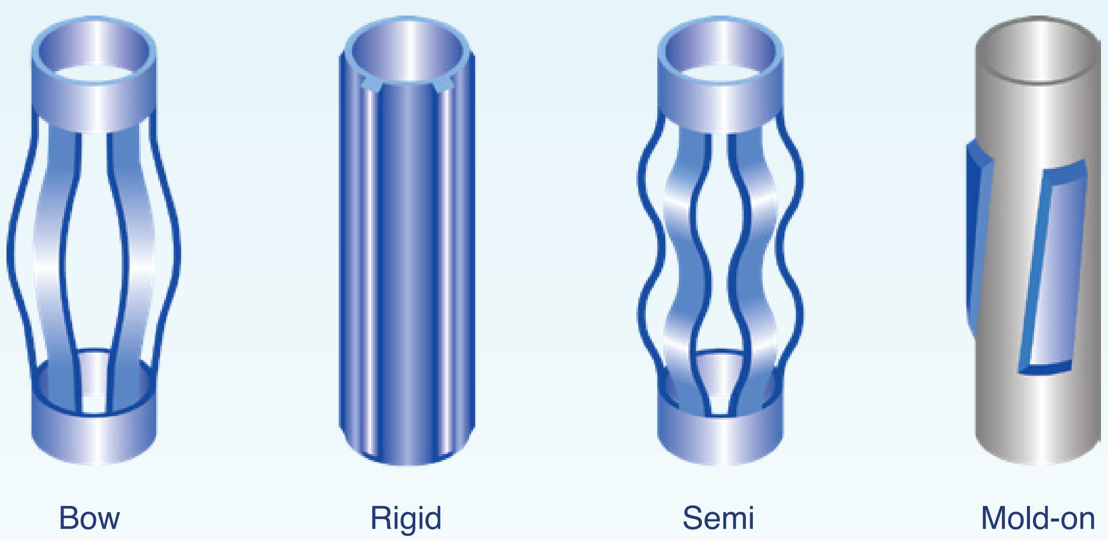


Fig. 1. Types of centralizers

1. Bow-Spring

Bow springs, slightly larger than the wellbore, 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 location.

The shape and stiffness of bows determine the restoring force, which is defined as the resistance force when a bow is compressed 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, the helically buckled casing could create a side force of 50,000 to 100,000 lbf [222 to 445 kN], well beyond the capabilities of a bow-spring centralizer. A solid centralizer would be able to meet the requirements.

2. Rigid

Rigid centralizers, made of solid steel bar or cast iron, have a fixed blade height and are sized to fit a specific casing or hole size. They work well even in deviated wellbores, regardless of the side force, providing guaranteed standoff and functioning as bearings during pipe rotation. However, they do not provide as good centralization as bow-spring types in vertical wells due to their smaller size.

3. Semi-Rigid

Semi-rigid centralizers, made of double-crested bows, combine features of both bow-spring and rigid centralizers. The spring characteristic of the bows allows the semi-rigid centralizers to compress to pass through tight spots and severe doglegs while providing restoring forces exceeding API standards.

4. Mold-On

Mold-on centralizer blades, made of carbon fiber ceramic material, can be applied directly to the casing surface. The blade length, angle, and spacing can be designed to fit specific well applications, especially for close tolerance annuli. 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 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.

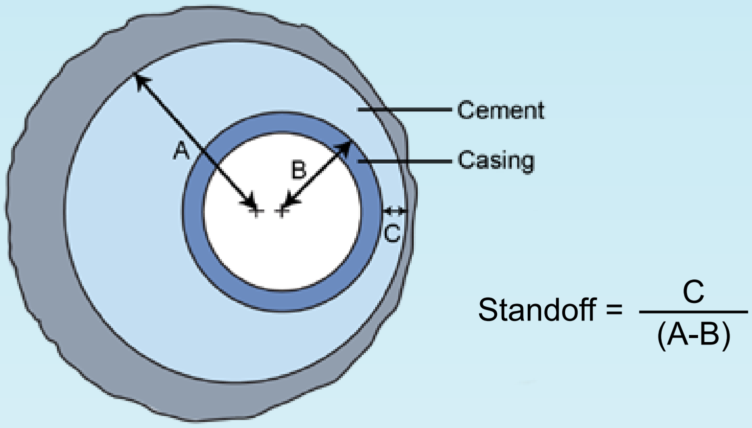


Fig. 2. Definition of standoff

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

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 (buoyancy)

IV. Casing Deflection

Between centralizers, the casing string sags or deflects. Studying casing deflection involves analyzing the force balance (Fig. 3) for a pipe segment.

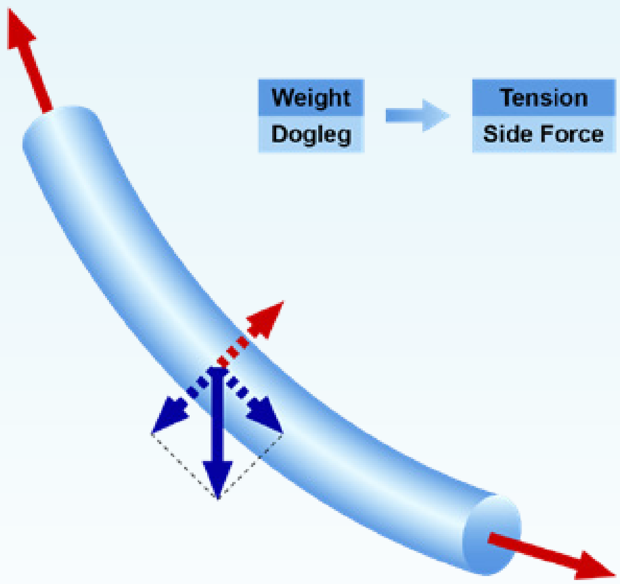


Fig. 3. Force balance

Two 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 side force, the analysis starts from the bottom and calculates for each element. Step by step, we move upward and obtain the side force profile, as shown below (Fig. 4).

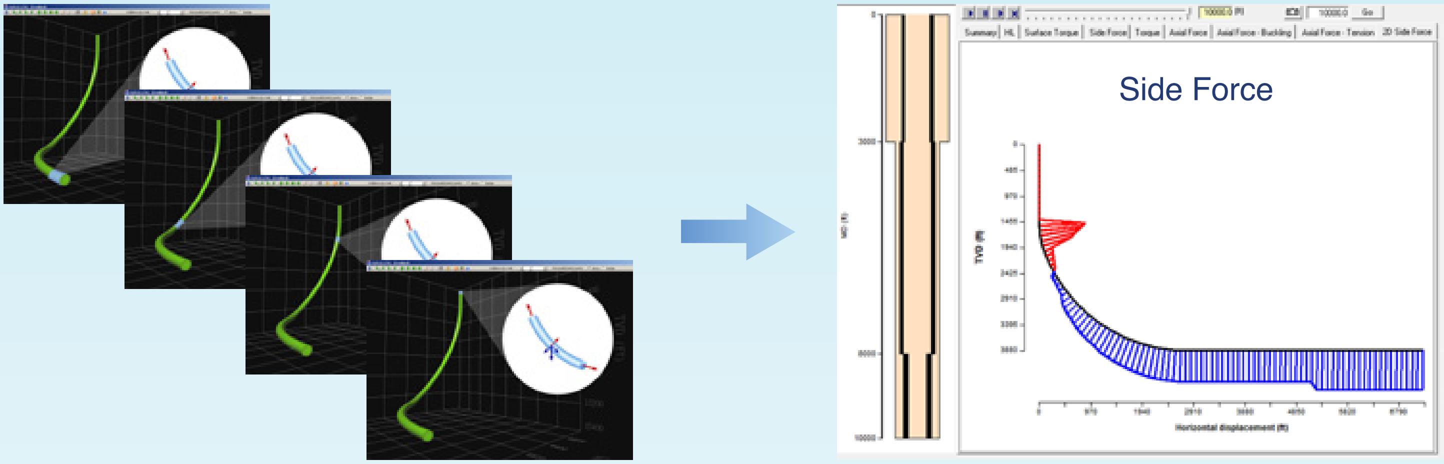


Fig. 4. Side force calculation and profile

In the above profile, red lines indicate that the side force is acting upward and that the casing touches the upper side of the well. 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 casing without centralizers exhibits variations in standoff along the length of the casing (Fig. 5).

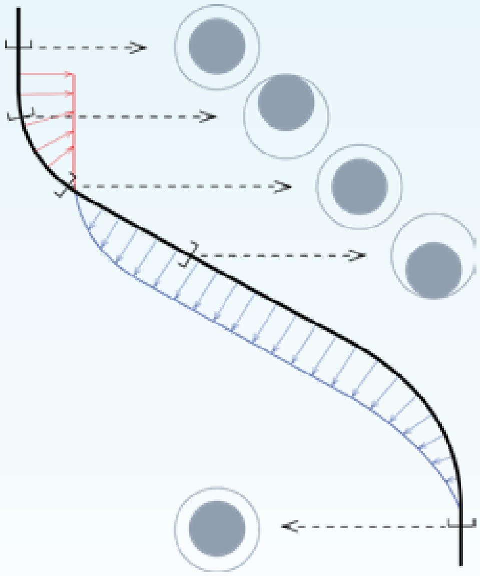


Fig. 5. Standoff profile without centralizers

V. Buoyancy

Any fluids present in the wellbore create an uplifting force (buoyancy) on the casing, reducing the force acting on the wellbore. During a cementing job, as heavy cement slurry is inside the casing and drilling mud is outside, the casing is at its heavies". As cement slurry turns a corner and light displacement fluid occupies 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 cementing job.

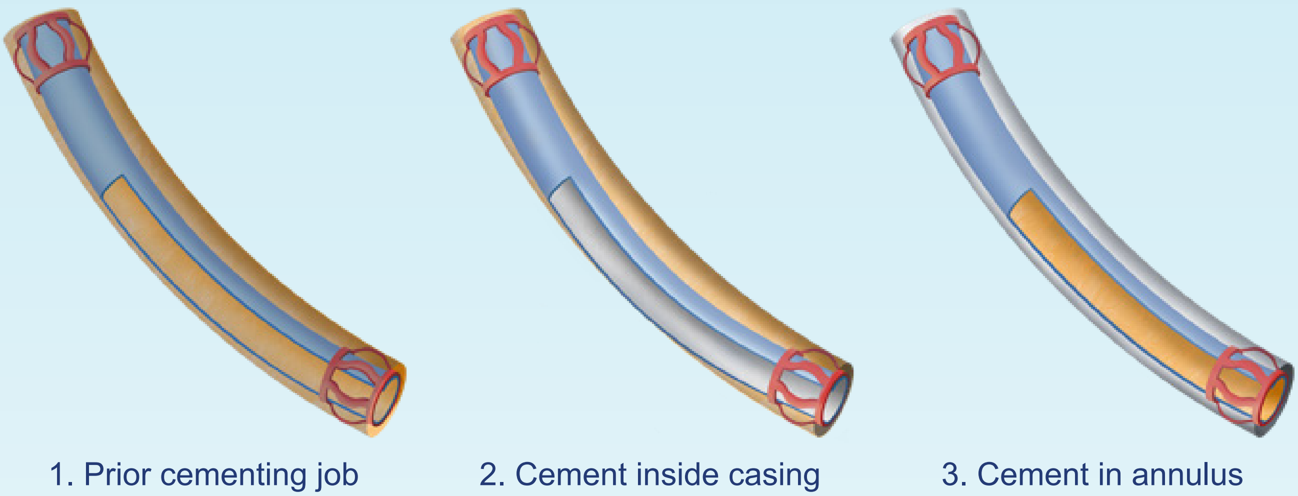


Fig. 6. Casing deflection between centralizers

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

IV. Modeling

Theory

Centralizer selection and placement can be solved using computer models. Over the past 24 years, various models have been developed, from simple Excel spreadsheets to integrated cementing software. These models help engineers understand the importance of casing centralizers and their placement.

Pegasus Vertex, Inc. (PVI) has been working with both operators and centralizer manufacturers and developing CentraDesign, an advanced engineering software geared toward centralizer placement analysis, since 2000.

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

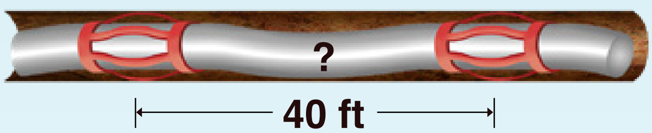
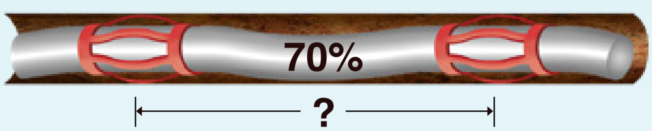
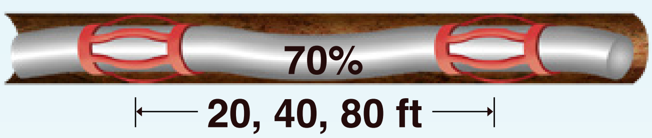
The hinged-ends model assumes that a casing string transmits no bending moment across centralizers, resulting in excessively high casing deflection. Therefore, the hinged-ends model was replaced by the more advanced fixed-ends model, which is used to calculate the deflection between the centralizers.

In this more sophisticated model, the casing deflection between 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 two 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 two deflections, caused by the axial tension and the casing weight.

CentraDesign utilizes the fixed-ends model to predict casing deflection in a 3D well, considering changes in azimuth angle and compression of bow-spring centralizers.

Calculation Modes

Three methods are used to design centralizer placement:

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

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

For users without significant experience, or who prefer the software to calculate the spacing, the second approach - specify standoff - can be used. Users simply specify the required standoff at the middle span, and the program uses a numerical method to obtain the centralizer placing, ensuring that the standoff at the middle point between centralizers meets the specified value. The "specify standoff" mode ensures the minimum standoff of casing between centralizers while yielding a difficult-to-follow placement program.

To benefit from the best elements of both approaches, PVI has developed an optimum placement solution, the third method in the diagram. In this approach, users specify the standoff with an incremental spacing requirement. This ensures the standoff requirements are met while resulting in a not-difficult-to-follow placement program. For high-impact operations such as deep water and the 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, 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.

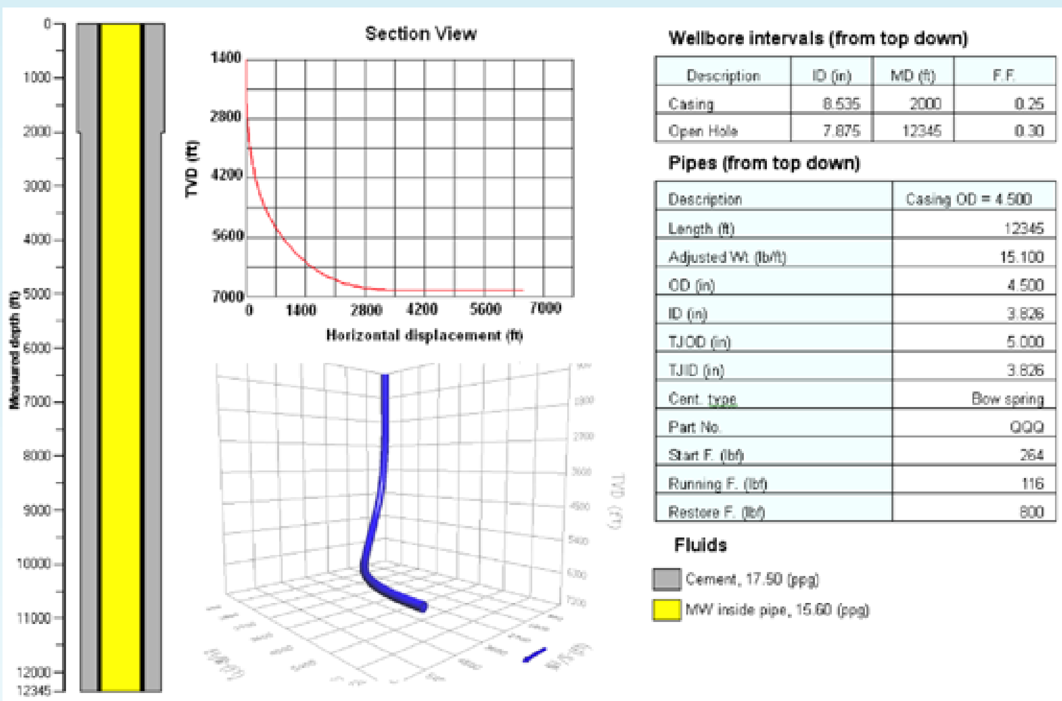


Fig. 7. Example well

The example well shown in Figure 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 4 1/2” casing, deviating from 0o to 90o. The centralizer considered is a bow-spring type with a restoring force of 800 lbf.

Specify Spacing

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

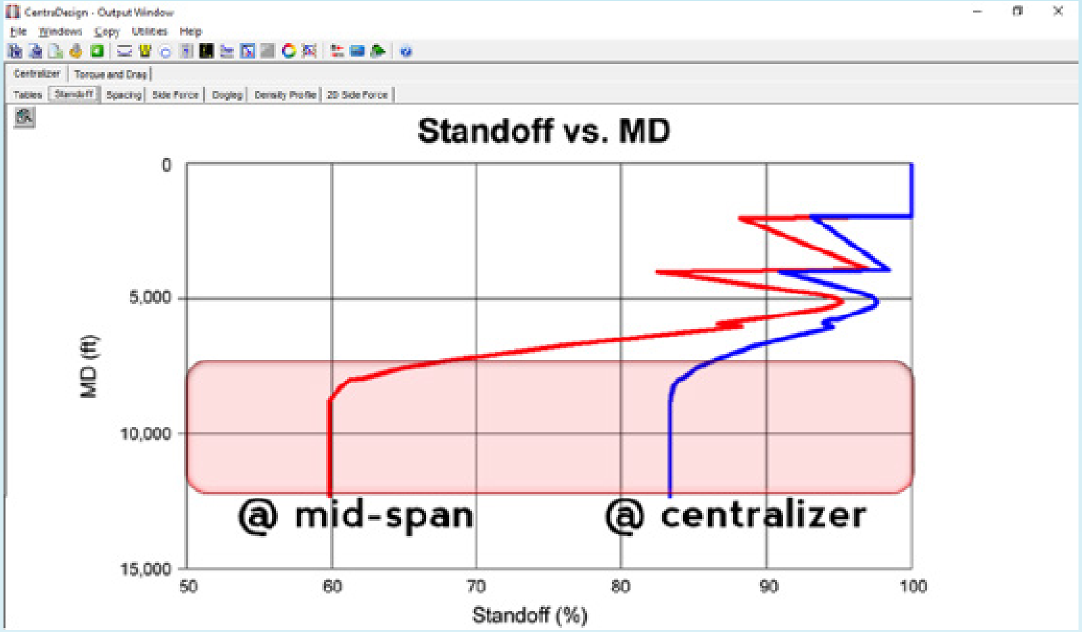


Fig. 8. Standoff profile (specified spacing = 40 ft)

From 2,000ft to 7,000 ft (inclination from 0o to 30o), the standoff at mid-span is between 100% and 70%, meeting the industry standard of 67%. From 7,000ft to 12,345 ft (inclination from 30o to 90o), the standoff drops from 60%, which is problematic: poor standoff profile at this section may cause potential cementing problems.

Now let's try two centralizers per joint (spacing of 20 ft). Figure 9 shows the resulting standoff profile. The number of centralizers needed is 617.

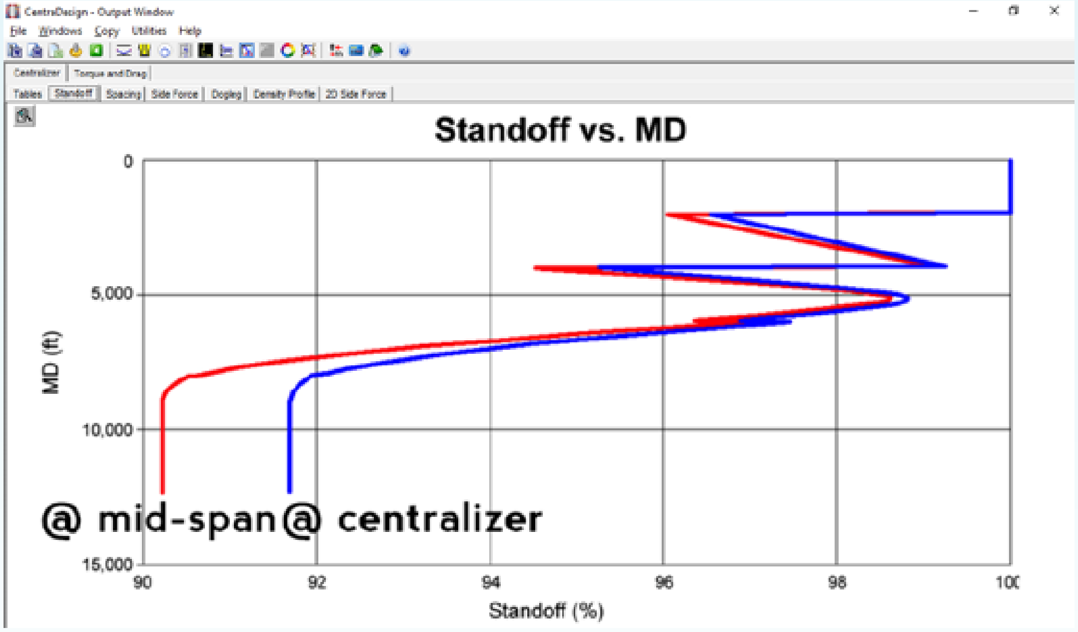


Fig. 9. Standoff profile (specified spacing = 20 ft)

The standoff at the mid-span is very good, at more than 90%. This new placement may be too conservative, leaving doubts in the engineer's mind: "Am I 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 centralizers. With the required 70% standoff throughout the 4 1/2" casing, CentraDesign displays the necessary spacing to achieve the specified standoff. The total number of centralizers used is 230, a significant reduction from previous approaches.

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

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

Optimum Placement

To get the best elements from both approaches, PVI has designed the optimum placement solution, which specifies a standoff (70%) with an incremental spacing requirement (20 ft). The resulting standoff profile and spacing required are displaced in Fig. 11 and Fig. 12, respectively.

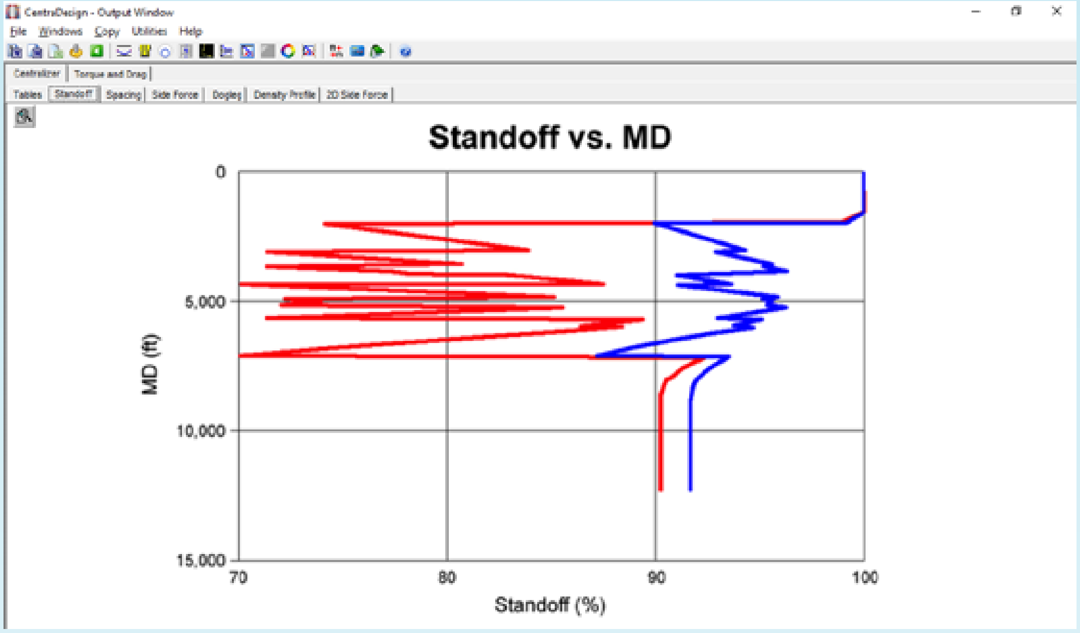


Fig. 11. Optimum placement - Standoff profile

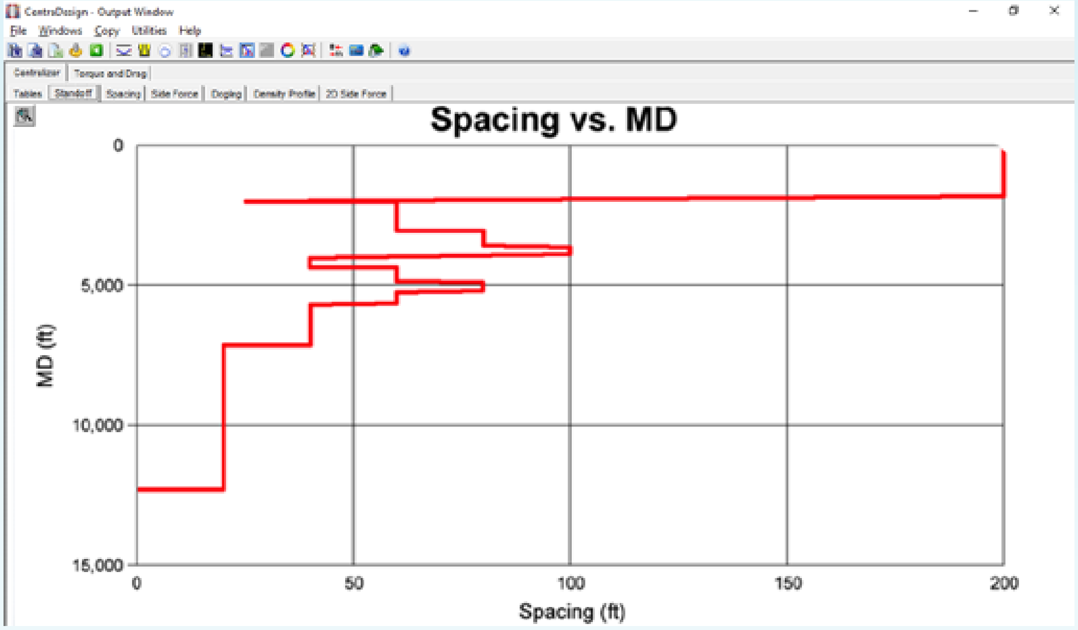


Fig. 12. Optimum placement - Spacing

This method meets the standoff requirement and provides easy-to-follow spacing. The total number of centralizers resulted is 360.

The results of the three placement modes illustrated above are summarized in Table 1. The optimum placement provides satisfactory standoff, ease of field installation, and good economics.
total number of centralizer is 360.

	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 top-quality products.

It is critical that we maximize engineering potential while selecting the proper type of centralizer and placement. Software like CentraDesign should be an integral part of the total approach of centralizer placement optimization.

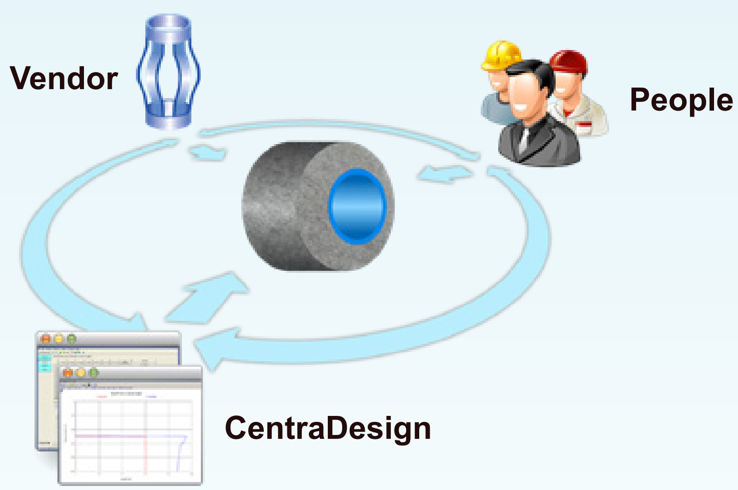


Fig. 13. Total approach of casing centralization

When optimizing 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 fewer centralizers.
- Centralizer vendors similarly aim to obtain satisfactory standoff and hopefully sell more units.
- CentraDesign optimizes centralizer placement and usage, reducing risk and cost.

For more information on CentraDesign, please contact PVI at www.pvisoftware.com. You are invited to join our complimentary webinar (check our schedule on the website) and explore other related free resources available on our website.

VIII. References

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