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Reducing Flat Time in Geothermal Drilling: Surface-Landed Threaded Wellhead Installation

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ABSTRACT

Reducing non-productive time is critical in geothermal drilling, where complex formations and high costs demand operational efficiency. The field-proven, wellhead installation method presented eliminates waiting on cement cure time by landing each casing string at the surface. The method leverages redesigned wellhead equipment (WHE), which allows the wellhead to be landed directly on the previous casing string and uses threaded connections manufactured to American Petroleum Institute (API) wellhead specifications. This configuration enables immediate blowout preventer (BOP) installation without waiting for cement to cure.

In conventional wellhead installation, the BOP stack cannot be reinstalled until the cement achieves sufficient compressive strength to support the casing, often resulting in extended flat time. The new design eliminates the need for welding and associated heat-treatment time by employing threaded interfaces between the casing strings and the wellhead housing. This configuration enables BOP-related work to begin immediately after cement placement. Operational experience has verified that an 8-hour time savings per string is achievable, which can eliminate approximately one full day of rig time in a multi-string geothermal well.

The incremental cost of modifying the WHE is minimal, typically involving only machining threaded connections rather than weld preparation. Overall, this method is estimated to reduce well construction costs by tens of thousands of dollars per well.

Safe implementation of the new approach relies on appropriate engineering design, defined operational procedures, and disciplined risk mitigation strategies. The results demonstrate that targeted equipment redesign and procedural innovation can reduce flat time without compromising well integrity or safety, thus offering a method for improved efficiency in geothermal well delivery.

1 INTRODUCTION

Geothermal wells are expensive to drill and complete, with a significant part of the cost tied directly to rig time. For every hour the drilling crew is not advancing the hole, the end cost increases. Operators conscious of this drawback strive to limit the non-productive time (NPT), typically defined as unplanned rig time that does not directly advance the planned operation.

Generally, boosting drilling program efficiency is primarily attempted by reducing NPT. However, significant time is also spent on routine activities, such as waiting on cement (WOC), welding on wellheads that do not directly contribute to the bit-on-bottom drilling portion of the well activities. In a multi-string geothermal well, these pauses add up to form a predictable flat segment when plotted on a time-versus-depth curve, in which the well's depth remains unchanged and the hole is not advanced.

In a conventional installation sequence, the casing is run through the blowout preventer (BOP) stack, cemented in place, and allowed to cure with the casing in tension before the casing is landed for wellhead equipment (WHE) and BOP installation. Once the specified cement strength has been reached, the BOP is lifted to allow access to cut the casing off. The next wellhead is installed on the new casing, and the BOP stack is then reinstalled on the completed wellhead profile and pressure tested before drilling resumes into the next hole section.

Waiting for the cement slurry to cure is an accepted step in conventional casing-installation methods; however, WOC adds time to the process that could be used more productively. In this paper, a wellhead design and installation method used in recent geothermal drilling projects to address that specific block of flat time is highlighted. The approach lands each casing string at surface and uses modified WHE that can be installed directly onto the previous casing head, which keeps the casing in tension and stable while removing the BOP and installing a wellhead with threaded connections manufactured to American Petroleum Institute (API) wellhead specifications. In this configuration, the BOP can be reinstalled and pressure tested without an extended WOC period before surface equipment changes.

The following sections of this paper define the conventional wellhead operations, explain how the new design and installation method differs from traditional means, and discuss the engineering and risk considerations. The wellhead design was applied in separate operations, which will be briefly addressed herein.

2 BACKGROUND AND CONVENTIONAL WELLHEAD INSTALLATION OPERATIONS

Currently, no globally accepted standards are established specifically for geothermal wellheads. Deep geothermal projects use surface pressure-control equipment designed and manufactured in accordance with API Specification 6A, *Wellhead and Tree Equipment*. The wellhead and christmas tree equipment are selected with project-specific adjustments for temperature, casing size, and structural loads.

In practice, a typical geothermal wellhead is an API-style casing head with gate valves at the surface. In numerous high-enthalpy steam and flashed steam wells, produced fluid flows up the production casing and the production tree is installed directly on top of the expansion spool (Williams 1991). When the completion includes a dedicated production or injection tubing string, a conventional tubing head and tubing hanger (within the same API 6A equipment classification) are added above the wellhead.

2.1 Conventional Casing and Wellhead Installation Sequence

In the conventional configuration referenced herein, the surface wellhead uses conventional API casing with a slip-on-weld (SOW) casing head installed on the surface casing after the cementing operation. The interval of interest is from the end of the surface casing cementing operation until drilling resumes below the casing shoe because this duration is when the wellhead is tied into the casing and the BOP is returned to service. During the standard operations sequence, the cement level is confirmed to be at the surface after the casing is run and cemented. Until the cement at the casing shoe and within the shallow annulus reaches the specified compressive strength, the casing is left undisturbed and kept in tension to lower the risk of damaging the cement slurry while it develops sufficient compressive strength. Once cement strength is confirmed, the surface casing is cut to a predetermined elevation and the SOW casing head is installed. The head is slipped over the casing, aligned, and welded in place. The weld is then allowed to cool and is pressure tested before the connection is used as a load-supporting structure.

After preparation is complete, the BOP stack is hoisted, installed on the casing head flange, secured, and pressure tested against the surface casing; drilling below the surface casing shoe can only resume after a successful BOP test. Subsequent casing strings are run through the existing sections, with the same sequence of operations performed before the next section of drilling can commence.

2.2 Flat Time and Operational Impact of the Conventional Wellhead System

In the referenced configuration, all activity between the end of the surface casing cementing operation and the restart of drilling below the shoe is considered flat time. The rig must first wait until the surface cement reaches the specified strength before the crew can cut the surface casing, install and weld the SOW casing head, allow the weld to cool, and inspect and accept the connection. Afterward, the wellhead bowl is prepared, the BOP is hoisted and installed on the casing head flange, and a full BOP pressure test is conducted against the surface casing. These steps cannot be overlapped with the drilling because a welded and accepted SOW head and a tested BOP stack are prerequisites for drilling the next hole section.

Although subsequent casing strings are installed relatively quicker than the initial effort, they still introduce additional flat time. After each section is drilled, cased, and cemented, the BOP is nippled down and lifted so that the next wellhead section can be installed. After the appropriate WOC, the new casing string is landed and cut to the required length, and the wellhead is installed and pressure tested. The BOP is then reinstalled and tested before drilling resumes. Across a multi-string geothermal well, these repeated sequences account for a material share of total rig time. The alternative method described in the next section focuses on this interval and aims to reduce the time needed for wellhead work.

3 INNOVATIVE WELLHEAD EQUIPMENT AND INSTALLATION PROCEDURE

The redesigned wellhead system described in this paper is a surface-landed, screw-on wellhead arrangement in which each casing string is supported at the surface and the associated casing head is installed on a threaded landing mandrel. The goal of this system is to eliminate the time spent on waiting for cement to cure, remove welding time where applicable, and proceed directly to BOP installation and pressure testing.

Once the casing is landed, the cementing operation can be accomplished with a stab-in stinger attached to an inner string. This process works well with the cementing practices used in geothermal wells, where lost circulation events are common and casings need to be cemented to the surface with no free-water pockets in the inter-casing annulus.

3.1 Typical Constituents of the Wellhead

In a typical configuration, the system is built upward from the base (landed on the conductor) to a compact stack of screw-on casing heads installed on mandrels, all of which pass through the blowout preventer equipment (BOPE).

For the surface casing, a fabricated landing plate is used. This plate is designed to run through the rotary table and be sturdy enough to support the axial load generated by the weight of the surface casing. The ring is landed on top of the conductor in the cellar to support the vertical load of the surface casing during installation and cementing operations. After the cement cures, the cemented annulus provides long-term load support. In some instances, the landing ring must be a split C-plate because of the limited opening of the rotary table.

After landing and cementing the surface casing, the first casing head is installed on the surface casing. This head provides the primary bore for subsequent drilling once the BOP is installed and tested.

As drilling progresses, additional casing heads are added at the surface. Each casing string is run, and a mandrel is landed onto the previous casing head. Once the cementing operation is completed, the landing joint and BOP stack are removed, and the next wellhead is placed on top of the casing hanger mandrel.

Side outlets are arranged at various elevations on the stack and used for cementing and annulus management. Upper outlets are typically configured for high-pressure service and feature flanged connections, whereas lower outlets are used for low-pressure functions and are generally coupled with threaded connections to the wellhead.

At the top of the stack, a standard drilling spool or studded connection provides the interface to the BOP stack during drilling and to a master valve or tree in later operations. The overall setup remains compatible with conventional surface equipment while replacing weld-on casing heads with controlled threaded construction at each stage.

3.2 Installation Sequence of the Wellhead

This subsection describes the operational line-up of the wellhead installation, focusing on the operations directly related to the wellhead. The initial casing head can be installed with the following available methods:

- The surface casing is cut after being landed, and an SOW casing head is placed and welded on top of the surface casing.
- The surface casing's top joint is threaded to the bottom of the first casing head, and the casing head is landed on the conductor via a landing flange. A split landing plate can also be used.
- A landing ring is welded onto the surface casing, and the casing is landed with a running tool. The casing head is run in a consecutive step and screwed to the top of the mandrel hanger.

Once the surface casing is landed on the conductor using one of these methods, the inner string stringer is run and latched to the float collar. Cement is then pumped, and the surface casing is cemented to the surface.

While the cement is curing, the drilling wellhead preparation immediately commences with the installation of the BOPE. The wellhead and BOP are pressure tested, the flowline is constructed, and the drill-out assembly is run to the bottom of the casing. These operations generally provide enough time for cement to cure; therefore, when the drill-out assembly reaches the float collar, the cement has developed sufficient strength to be drilled.

Drilling operations continue until the next casing point is reached. The casing is again run to the bottom and then dressed with a casing mandrel. The casing is lowered into the previous casing, and the mandrel is landed onto the inside of the previous casing head. Note that the mandrel can be fitted with seals to prevent hydraulic communication of the annulus with the wellbore.

The casing is then circulated and cemented conventionally, in reverse, or through an inner string. The return flow is received through the side outlets of the previous casing head in forward-circulated cementing operations. If cementing is unsuccessful in bringing high-quality cement to the surface, the same side outlets are used for a top-squeeze procedure, similar to a reverse cementing operation, to ensure the casing is thoroughly cemented with no void spaces (Finger et al. 2010).

Because the casing is landed in tension, BOP and wellhead operations can begin immediately after the primary cement job is finished. Remedial cementing can also be performed as efficiently and practically as possible during wellhead installation and nipple-up operations.

After the primary cementing operation has been completed, the BOP is nippled down and lifted out of the way. The casing head is threaded and torqued onto the landed casing. The height of the BOP stack is adjusted by removing a spacer spool. The BOP stack is then installed on the new wellhead, allowing pressure testing of the BOP to commence.

As previously mentioned, this design eliminates the time spent waiting for cement to cure and develop sufficient strength, thus providing time savings by immediately proceeding to the wellhead installation after cementing.

4 ENGINEERING AND DESIGN CONSIDERATIONS

From an engineering standpoint, this wellhead system is treated as a properly rated assembly that must fit within an existing well design. The main considerations are simple; the published ratings and referenced standards must cover the expected pressures, temperatures, and loads. The interfaces need to match the planned conductor, casing program, and cement design, and the BOP must stack up without creating undesirable load paths or clearance issues. Each installation then requires a defined fit-up and pressure-test sequence that confirms integrity and establishes a clear operating envelope and limits of use.

Functionally, this system does not differ from a conventional wellhead system because the governing specifications are the same, such as pressure rating, temperature classification, and material designations. The same principles used in selecting a conventional wellhead apply.

4.1 Load and Support at the Surface

The axial loads related to the drilling operation are dictated by the weight of the casing suspended by the wellhead. Because the casing is landed on the wellhead before the cementing operation, the entire weight of the string needs to be supported mechanically by the previous casing head before cement provides structural support. The load of the next casing string is distributed to the existing cemented casing and the wellhead.

Production-related loads also need to be considered, particularly the axial movement and loads generated by high-temperature produced fluids. Geothermal strings are allowed to expand during heat-up and, conversely, shrink when cooled, thus any seal in the wellhead assembly is ineffective after the first heat-up (Putri et al. 2020). This thermal growth and shrinkage over the life of the well is the main reason slips are not used when landing the casing. After the casing's length increases during heat-up, the slips reset and prevent any decrease in length during subsequent cooling. Over time and after multiple cycles, this process can place tension on the casing that exceeds its tensile strength, leading to casing failure.

4.2 Geometry, Stack Up, and Physical Constraints

Using this system places practical constraints on the physical surface layout. Like conventional wellheads, this system also requires careful planning regarding the height and other dimensions of the wellhead. Generally, large BOP stacks provide a satisfactory margin for expected surface pressures, which allows them to be used throughout the entire well drilling. However, large BOPE constrain the available real estate under the drilling rig's floor. The height and dimensions of the wellhead should be planned carefully before committing to the design.

The conductor size, cellar dimensions, and rotary opening must also be considered to allow the landing plate and casing head to be installed safely. The final stack height must be compatible with the rig floor elevation and the BOP configuration, with clear access for stabbing and torquing connections.

5 LIMITATIONS OF THE DESIGN, OPERATIONAL RISKS

Wellhead installation without WOC is not universally applicable and has different constraints than conventional welded or spool-type wellheads. Its use depends on the well design envelope, expected loads, and operator's tolerance for changing long-standing practices. This section summarizes the main limitations, associated risks, and typical mitigation measures.

5.1 Load Capacity of the Conductor

The structural loading capacity of the conductor and its contact area with shallow formations are primary limitations for installing without WOC. The conductor carries most of the wellhead load before the surface casing cement has cured sufficiently to support the load. Landing the casing strings and wellhead at the surface imposes greater axial and bending loads onto the conductor than some conventional arrangements. Shallow conductors set into weak or disturbed near-surface formations, coupled with a heavy surface casing combination, increase the risk of conductor instability, movement, or permanent wellhead tilt. Large-diameter conductors set at sufficient depths with a competent cement job are generally able to handle these loads; however, when load capacity is uncertain, the structural strength of the conductor and shallow formation should be assessed explicitly. Each casing head installation needs an individual structural load capacity evaluation.

In practice, this effort means treating the conductor and surface casing as structural elements during the design. The depth, size, and cement must be confirmed as adequate for the combined weight of the surface casing, wellhead, BOP, and anticipated pressure loads. Simple acceptance criteria also need to be established for allowable wellhead movement. If the shallow support is clearly marginal, installation without WOC should be considered outside the design envelope and a more conventional wellhead arrangement needs to be retained.

5.2 Integrity of the Wellhead Connections and Seals

The installation relies on threaded and gasketed connections that are assembled once and then left in place beneath the BOP. Incorrect torque, misalignment, contamination on sealing surfaces, or damage to seals during handling can cause leaks during pressure testing or early operations. Mitigation is procedural; critical sealing surfaces must be cleaned and inspected before assembly. The manufacturer's installation procedure and torque values are adhered to using calibrated equipment, and the torque values are recorded. A functional pressure test of the assembled wellhead is conducted before drilling resumes. Any sign of leakage or movement at this stage is treated as a trigger for controlled disassembly and reinstallation instead of field modification.

5.3 Cement Design and Quality

The wellhead design assumes that all casing strings are cemented to the surface with a competent, continuous cement sheath. Although the wellhead support path is structurally independent of cement initially, full-height cement is still required to lock the casing in place and limit uncontrolled thermal expansion. Note that the cement has a coefficient of linear thermal expansion that is lower but of the same magnitude as the coefficient of linear thermal expansion for the steel casing. The change in casing head elevation is limited by the expansion of cement in the inter-casing annulus, where the mechanical bond of the cement to the external casing is comparatively weak.

This requirement is consistent with the general need for high-quality cement (i.e., no voids or free-water pockets) to prevent trapped pressure in the inter-casing annular space and inhibit casing collapse (Hole 2008). Wells where cement cannot be reliably brought to the surface, or when severe losses make full-height cement unlikely, should have contingent top-fill and top-squeeze cementing operations planned (Rickard et al. 2013).

6 ECONOMIC ADVANTAGES OF THE NEW WELLHEAD DESIGN

The design's cost advantage is generally realized by the following two factors:

- The wellhead design uses standard API 6A qualified flanges and designs, and the cost of a conventional casing hanger spool, coupled with a mandrel hanger, is similar to the new casing head setup. The primary cost difference is associated with modifying the wellhead to accept a threaded connection, which is achieved by cutting an appropriate thread profile on the casing head.

- The new design prevents time spent waiting for the cement to develop sufficient strength before the wellhead work at the surface can begin. The cure time, in which the cement should be left undisturbed, is generally dependent on the cement blend, additives, and downhole conditions. For lightweight cement blends that are used in severe loss-circulation wells, this setting time can be significant.

Situations with the cement-setting time must be delayed to accommodate high formation temperatures at the casing shoe are common. Additives that optimize the setting time of the cement at the shoe also delay the setting time of the slurry at the surface, which cures at a much lower temperature.

By eliminating the time spent waiting for the cement to reach sufficient strength and progress the well construction, each well can save 6 to 8 hours per cementing operation. In the domain of deep geothermal well drilling, where large drilling rigs and multiple service providers are needed, bypassing WOC could reduce the well's cost by $3,000 to $5,000 per hour.

7 FIELD IMPLEMENTATION AND CASE EXAMPLES

As a demonstrative example, two wells in which this wellhead system was used are described herein.. Well A is a high-temperature well, where the flow can be supported at high rates with the well flowing. Well B is a lower temperature well than Well A, with high deliverability under pumped conditions. The depths have been rounded to preserve the anonymity of the wells.

7.1 Well A: Case 1: 28-Inch Surface Casing

Well A was drilled in an area with known high bottom hole temperatures of approximately 500 to 600 degrees Fahrenheit (°F). Considering the expected temperature at the bottom hole and the known high productivity of the area's reservoir, the well was designed to be produced from inside the casing without artificial lifting; the well was planned to be drilled to a total depth of 8,000 feet (ft). A 36-inch conductor was installed to a depth of approximately 80 ft before the rig was brought on site. After mobilizing and setting up the 1,500-horsepower drilling rig, the well was spudded with a 34-inch bit. The construction sequence of the well is explained as follows:

1. 34-Inch Surface Section: The 34-inch hole was drilled to 300 ft. The last joint of the 28-inch casing was furnished with a 37-inch landing ring, and the casing was landed on the conductor, as shown in Figure 1. Once landed, the top of the surface casing was cut above the landing ring and prepared for a slip-on weld to a 26¾-inch casing head. The casing was cemented with a stab-in adapter after the rough cut was made, as depicted in Figure 2. Wellhead operations continued immediately after cement pumping was completed, and the top of the cement was confirmed to be at the surface.

2. 26-Inch Intermediate Section: The next hole section was drilled with a 26-inch bit to approximately 1,300 ft after testing the casing and BOPE. The 20-inch casing was run and landed in the 26¾-inch casing head on a casing hanger. Cementing was performed with an inner string, and cement returns were received in the cellar through the side outlets. Immediately after cementing, the landing joint was removed, and a 20¾-inch casing head was screwed into the casing hanger, followed by the installation of BOPE. This section skipped waiting for the cement to set or the casing head to be welded, saving approximately 12 to 16 hours compared with a conventional sequence.

3. 17½-Inch Production Section: After pressure testing, the 17½-inch hole was drilled to more than 4,000 ft; the hole was then underreamed to 20 inches. The 16-inch casing was run and landed in the 20¾-inch casing head. Cementing and wellhead installation for the 16-inch casing used the same approach used for the 20-inch casing. The 20¾-inch BOPE was removed and hung off, then reinstalled in one piece onto the 16-inch valve installed on the 16-inch casing head. In this section, the operator saved 12 to 16 hours by eliminating WOC and welding time, plus at least 4 hours by reusing the BOPE stack, which was simply unbolted, hung off under the substructure, and then reinstalled.

4. Reservoir Section: After pressure testing the BOP, drilling operations continued to 8,000 ft, which included running and cementing an intermediate liner. A 7-inch hang-down string was then installed for testing purposes. The 7-inch string was landed in the 16-inch casing head using a profile that can also be used to install a cemented 13⅜-inch completion string when the well is converted to production. The ability to hang the completion casing in the same profile is expected to save at least 4 to 8 hours of WOC time when the future operation is conducted.



Figure 1. 28-inch surface casing with the manufactured landing ring, being run in the hole in Well A.



Figure 2. 5½-inch drill pipe equipped with a stinger, being run in the hole to cement the surface casing after landing on the conductor in Well A.

The wellhead stack up for Well A is demonstrated in Figure 3.

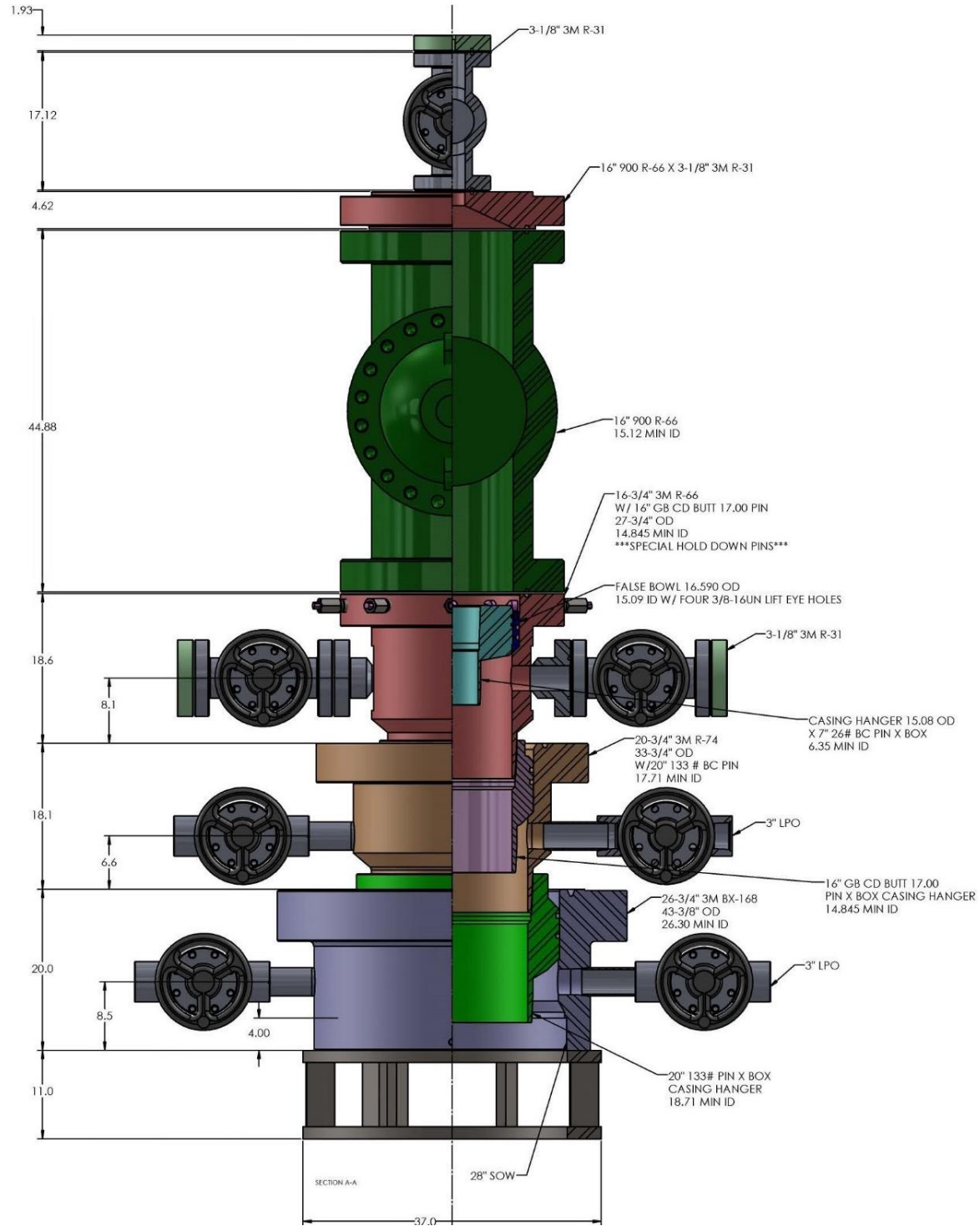


Figure 3. Stack up of the wellhead of Well A depicted in its final form (courtesy of EPI Valves Texas, LLC).

7.2 Case 2: 20-Inch Surface Casing Well B

Well B was drilled in an area with an expected bottom hole temperature of approximately 350°F. Considering the relatively low expected temperature at the bottom hole and the known high productivity of the reservoir, the well was designed to be produced using an artificial lift method. With an expected target of 9,000 ft, the well was planned with two full-length casings and two liners. A 30-inch conductor was installed to a depth of approximately 80 ft before the rig was brought on site. After mobilizing and setting up the 1,500-horsepower drilling rig, the well was spudded with a 26-inch bit. The construction sequence of the well is explained as follows:

1. 26-Inch Surface Section: The surface hole was drilled through the conductor with a 26-inch bit to a depth of slightly more than 500 ft. A 20-inch surface casing string was then run, and a 20¾-inch, 3M casing head was constructed on the rig floor, as depicted in Figure 4. Using a landing flange and drill pipe, the casing was landed on a C-plate set on the cut-off conductor and cemented in place. BOPE installation began immediately after cement placement, avoiding WOC strength and saving an estimated 4 to 8 hours of rig time.

2. 18½-Inch Intermediate Section: After casing and BOPE pressure tests, an 18½-inch intermediate hole was drilled to more than 4,500 ft and cased with a 16-inch casing string landed in the 20¾-inch casing head on a mandrel-style hanger with O-ring seals. The casing was cemented using inner string cementing, with returns received in the cellar through the side outlets on the casing head. Once cement was brought to the surface, a 16¾-inch casing head was screwed onto the casing hanger mandrel, and the BOPE was reinstalled. Because the hanger and threaded casing head system did not require welding or dedicated WOC before nippling up, the intermediate-section wellhead work saved an estimated 12 to 16 hours of rig time compared with a conventional weld-on head installation.

3. 14¾-Inch Section: This section was covered with a 13⅜-inch liner and 12¼-inch open hole without further hanging casing at the surface. After a flow test, the well was capped with a 3⅛-inch valve.



Figure 4. Installation of 20¾-inch casing head using a drill pipe conveyed landing flange (also known as potato masher) at Well B.

The wellhead stack up for Well B is demonstrated in Figure 5.

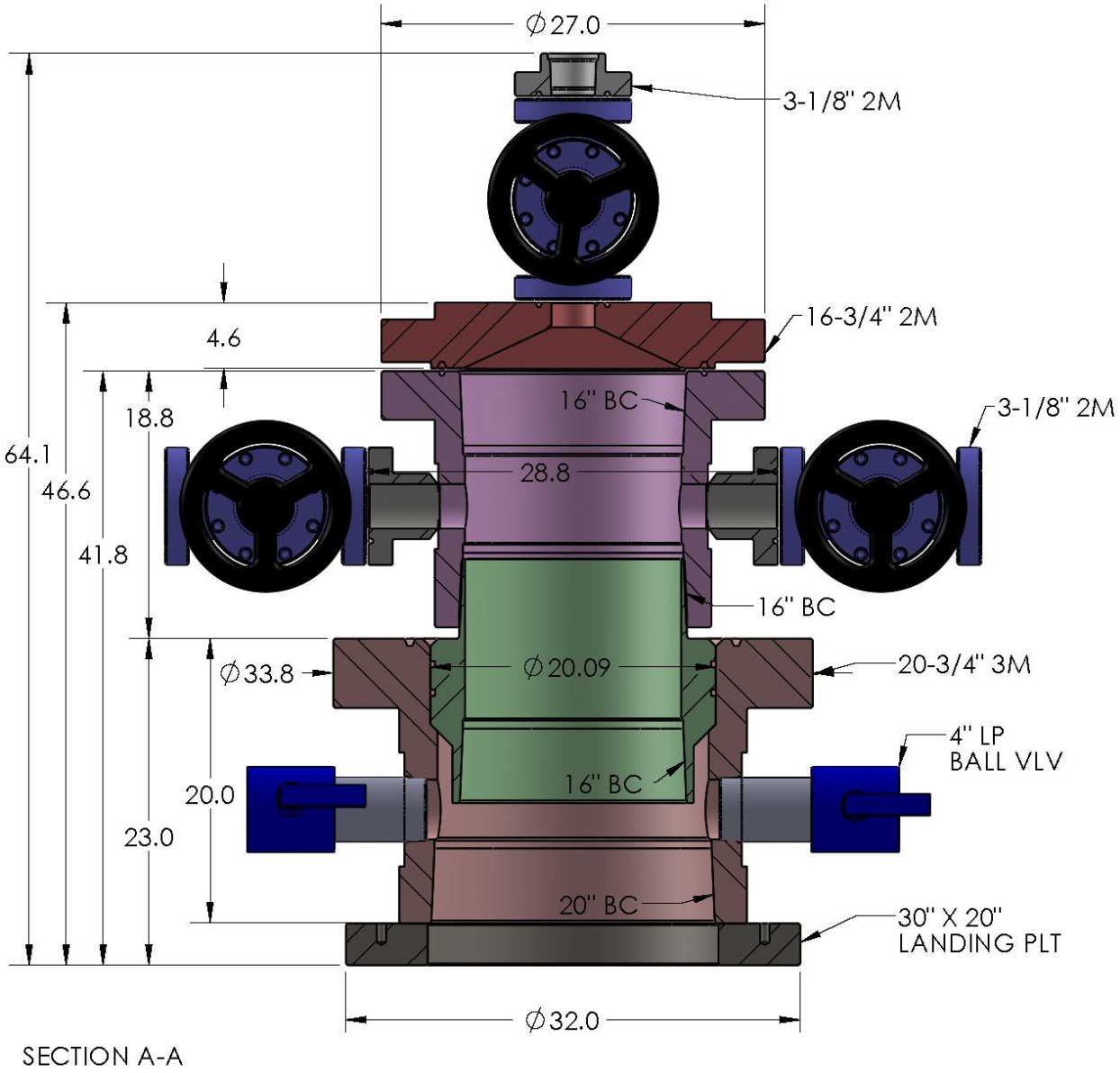


Figure 5. Stack up of the wellhead of Well B depicted in its final form (courtesy of EPI Valves Texas, LLC).

8 CONCLUSIONS

Considering the recent, successful developments that have significantly increased the rate of penetration, geothermal well drilling projects are more sensitive to flat time associated with cementing and wellhead work. Several hours of NPT are embedded, but not always apparent, in each casing string installation under the conventional sequence: waiting on cement to build strength, BOP removal, surface wellhead assembly, and subsequent BOP reinstallation and testing. The field-proven approach described in this paper shows that this sequence is not invariable. By landing each casing string at the surface and using a wellhead system that can be installed directly onto the previous casing with threaded connections, operators can remove WOC from the critical path. Minimizing the casing head installation time for BOP operations, while preserving the mechanical and pressure integrity of the well, is expected of modern geothermal wells.

The case examples demonstrate that this method consistently recovers meaningful flat time per casing string, typically several hours, without introducing additional risk to well control or long-term wellhead performance. In every application described, BOP nippling up and pressure testing proceeded immediately after cement placement, and subsequent integrity tests confirmed that casing support and cement quality met or exceeded project requirements. The engineering considerations and operating guidelines outlined in the paper, including attention to the conductor, surface casing load paths and subsequent load transfer, cement to surface, thermal expansion considerations, and disciplined testing practices, provide a practical design and execution basis for applying the system in other geothermal programs.

This approach is not universal; therefore, it requires appropriate wellhead hardware, a conductor and surface casing scheme that can safely carry early loads, and a rig crew that can be trained in the revised sequence. The approach also does not replace the need for sound cementing practices or careful geomechanical design. Within these limits, however, the method offers a straightforward way to reduce NPT in a cost environment in which even fractional days matter. As geothermal drilling programs move toward multi-well campaigns and standardized designs, integrating this style of wellhead installation into planning, equipment selection, and contracting has the potential to deliver cumulative schedule gains over an entire field, not just a single well.

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