

Geothermal Well Construction Products



**Completion &
Production Solutions**

Handling the heat to provide your clean energy needs

At NOV, we are proud to be part of the ongoing, highly innovative energy transition. We have specialized in geothermal technologies for more than a decade, with experience in completing the wellbore in hundreds of geothermal installations for projects ranging from heating villages in small communities, to highly prolific electrical generation and heating projects for farming communities, regional governments, and major international companies. We approach each job—no matter how big or small—with enthusiasm, knowing these developments are vital in paving the way to a greener future for generations to come.

Our extensive portfolio, experienced staff, and specialized solutions, customized to your needs, are readily available to meet this growing market's demands. We provide complete well construction and completion solutions that solve your most complex geothermal well challenges.

We're invested in your success and provide high-quality products, superior customer service, and innovative technical solutions for the geothermal market.

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Introduction



Our people and experience

Our staff and their dedicated engineering experience have proven to be our greatest asset. Since 2008, we have extensively supported the geothermal industry, particularly in Central and Western Europe. We provide complete support from initiation of the well planning and construction process through installation and production. We also offer detailed applications, metallurgist consultations, project management, and installation services for our valued customers.

Our highly technical sales teams are always looking to add value for their customers, and our talented personnel consistently deliver critical cost-savings solutions. We have demonstrated our ability to save our customers time and money on their projects. Whether it's a novel use for our current products or a willingness to utilize our products in new applications, we save our customers rig time and get their wells fully operational faster.



Dedicated support for every challenge

Completion Tools proudly supports our global customers in the energy transition and particularly in geothermal liner system applications. We actively support many projects ranging from the smallest district heating projects to high-profile power generation projects. We listen to our customers and work through their challenges with them, jointly solving their problems. Our engineering team uses a balance of creativity and experience to challenge the status quo while developing new solutions and techniques for the completions market. Whatever your challenge or wherever your operations, we have the solutions.



Service capabilities

We have excellent partners in both the oil and gas and geothermal industries, starting at home with our colleagues within NOV. We strive to be the first call for our customers and offer them fully integrated solutions from large-bore liner hanger systems with TK™-Liner technology to advanced screen solutions and annulus casing packers (ACP). Working closely with Fiber Glass Systems and Tuboscope, along with third-party partners, gives us the ability to provide unique solutions to customer challenges.



Run history

With more than 300 successful geothermal-specific installations for more than 50 customers in eleven countries, we have proven that we understand the unique conditions and challenges for geothermal applications and regularly provide solutions to meet these needs. We have installed systems ranging from 16 in. x 20 in. large-bore systems to smaller 2.875 in. x 5 in. systems.



Partners

We have the unique benefit of designing, manufacturing, and installing our equipment in Central Europe from our hub in Vechta, Germany. Our machine shop has been active since 1997 and is both ISO 9001:2015 and API Q1 accredited. We also have several additional capabilities and licenses to support our ability to provide high-end products and services with exceptional quality. Our integrated, full-fledged machine shop coupled with our vertically integrated sales, design engineering, applications engineering, and field engineering teams allow us to provide turnkey solutions for our customer challenges with exceptionally competitive lead times.



Downhole corrosion solutions

The world's first cemented 9⁵/₈-in. x 13³/₈-in. production liner hanger system with fiberglass-reinforced casing in a deep geothermal well in the Netherlands

Sustaining the integrity of geothermal wells is a big concern in the industry. It is well-known that corrosion will quickly degrade standard steel (traditionally used in geothermal installations), the result is potentially expensive remediation costs for the operator. While corrosion-resistant alloys (CRA) could be used as a remedy, CRA casing brings about other technical challenges, including the potential for galvanic corrosion and very high costs combined with very long lead times for tubing and casing. Other alternatives have also been attempted, such as injecting corrosion inhibitors into the injection/production fluid to slow down corrosion; however, this may be unreliable and expensive. This method also raises environmental risks/concerns.

NOV provided complete, packaged liner hanger system solution featuring TK-Liner technology installed into the carbon-steel pipes for corrosion **prevention** in a geothermal well. The fiberglass liner system installed using a **proprietary cement blend provides exceptional** corrosion protection and maximum coverage of the injection/production pipe annulus. The TK-Liner system incorporates an end-flange design that provides an internally centralized flush connection which is compatible with most existing oilfield tubular connections on the market, without the need for any modification, including virtually all proprietary premium connections.

Combining TK-Liner technology with our suite of field-proven well construction products, we were able to provide an economical solution to corrosion challenges with our cemented liner. Through excellent internal and external collaboration, testing, and engineering, we jointly managed to deliver the solution on time and complete the installation successfully.



Addressing casing collapse issues

Unique rupture disc design eliminates temperature-induced casing collapse issues

We used our existing field-proven liner hanger technologies, combined with various sizes and custom solutions, to execute successful installations for a geothermal application. Our liner hanger systems represented a crucial aspect of the well design due to the need to limit weight on the wellhead and improve the cement job quality by avoiding a long string well design.

Based on lessons learned from previous installations and job requirements, the project required a system that mitigated casing collapse. The customer had noticed that in previous geothermal operations, when the temperature increased, it caused pressure to rise behind the casing. The trapped pressure from the liner top packer caused the casing to collapse, resulting in costly workover operations.

After detailed studies and findings, the customer requested incorporating a burst disc to provide relief should the pressure in the annulus exceed the mechanical collapse rating of the casing. A two-stage liner cementing job utilizing our duo wiper plug with a stage tool was recommended to reduce losses while cementing the 9⁵/₈-in. liner hanger.



Longest and Heaviest Geothermal Liner

Successful installation of the longest and heaviest 13⁵/₈-in. large-bore liner hanger in a European geothermal well

Compared to conventional surface casing, a liner system provides reduced material cost, simplified wellhead design, reduced installation drag, and reduced hook weight. Running a longer casing string consequently allows the use of smaller drilling rigs and increased annular flow area, resulting in better cement job quality. Our integrated design and applications engineering team is vital to designing the full system solutions required to handle these kinds of challenges and set new records in geothermal installations.

A robust setting tool is required to carry and deploy the load of the long large-bore liner. Our MRS mechanical setting tool has a proven track record of deploying heavy, large-bore liners. Consequently, to set and hang such a heavy liner, we used our reliable GSP hydraulic multi-cone liner hanger, combined with the HFS ball seat, to suspend the 13⁵/₈-in. liner. The HFS ball seat was selected to minimize piston forces while accommodating the heavy liner. The cement job was performed with the duo wiper plug system, which improved cement displacement and reduced contamination between mud and slurry.

To optimize the annular flow rate for removing drilling cuttings to surface during the following drilling sections, we provided the customer with a temporary 13⁵/₈-in. tieback stem and casing to surface, which can be retrieved once the drilling has been completed. This allowed the customer to regain the larger flow area in the upper part of the well, which is crucial for geothermal production requirements.



Cost-effective gravel pack systems

Over twenty installations to date with operators in Poland, providing significant rig-time savings

Single-trip liner-conveyed gravel pack systems are generally synonymous with high-profile wells and technology often not considered for geothermal operations due to prohibitively high cost. Available low-cost alternatives are commonly associated with failures, and consequences could include setting tools not being retrieved back to surface, resulting in a large amount of non-productive time (NPT) and costs.

We were approached by a customer in Poland to develop a solution to run a gravel-packing operation of a 6⁵/₈-in. screen to total depth (TD), complete setting the hanger, release tools, and pull out of hole in one run. After working with the customer and understanding their previous challenges, we discussed the job with them and improved the system. We designed and developed a complete system solution to meet all operational objectives, stay within budget, and ultimately save the customer an entire trip.

Leveraging our expertise, we utilized our existing field-proven liner hanger technologies and combined them with a bespoke gravel pack solution to perform the liner run and gravel pack in one combined trip. We developed a dedicated system to complete their operation successfully and reduce and eliminate failures and NPT related to stuck pipe. The addition of selective circulating subs and improved liner top packer functionality increased the system's reliability and significantly improved upon all predecessors. We provided a customer-focused solution comprised of premium technology at a feasible price point for their geothermal-specific applications.

Large-bore Liner Hanger System Designed for Geothermal Applications



Tieback string

VXP liner top packer

GSP hydraulic liner hanger

PureFlow stage cementing tool

TK Coating and TK-Liner

SURESET liner hanger packer

Casing accessories



Geothermal Well Construction Solution

Large-bore liner hanger system

Commonly used in geothermal well designs because they provide a larger internal flow area required to improve the overall output of the geothermal system, our large-bore liner hangers are ideal for many geothermal applications. We offer industry-leading liner top packers tailored for geothermal applications from 9½ to 16-in. with the flexibility to be set in a large range of host casings.

Large-bore liner systems provide many benefits in geothermal well design and construction when compared to conventional surface casing, including:

- Reduced material cost due to not needing to install casing to surface
- Simplified design and reduced load on wellhead due to tapered string
- Improved chances of reaching TD due to ability to rotate liner casing and reduced overall weight
- Reduced hook weight, allowing you to run a deeper casing string (especially on smaller drilling rigs)
- Improved cement bond through rotation and increased flow area

SURESET Integrated Liner Hanger Packer

Key features:

- Integrated hold-down slips keep the liner string in position after cementation and prevent it from floating. Various elastomer options are available for multiple downhole conditions.
- The multi-cone recessed slip design activates hydraulically and allows for higher hanging capacity, which enables running longer liners
- The integrated liner top packer ensures that well integrity is not compromised and forms a barrier between the liner and host casing at the liner top. Together with the cement, these barriers mitigate gas migration.

Tieback solutions

We offer tieback solutions ranging in sizes up to 16-in. for geothermal applications that may be used temporarily during drilling or permanently as part of the production string to provide a monobore ID to the surface, thereby optimizing the annular flow rate and increasing flow velocity for curing removal or production requirements. The tieback string may optionally be coated to enhance corrosion-resistance capabilities.

Additionally, we have successfully utilized HPHT tieback seals applications in excess of 600° F and 30 ft. PBRs to allow for extreme tubing movement for enhanced geothermal system (EGS) applications.



Non-cemented tieback seal stem

Geothermal one-trip gravel pack

We utilize our existing field-proven liner hanger technologies and combine them with a bespoke gravel pack solution to perform the liner run and gravel pack in one combined trip.

A dedicated system was developed that allowed the operations to be completed successfully and reduced and eliminated the occurrence of failures and NPT related to stuck pipe. The addition of selective circulating subs and improved liner top packer functionality increase the system's reliability and significantly improve existing geothermal gravel packing solutions.



Excellence

We are committed to delivering quality and customer satisfaction. As a certified specialist company, we offer the highest precision during the manufacturing process using our qualified personnel, the latest machines, and network-based planning.

Services

Our substantial offerings include:

- Dedicated project management, field service, and manufacturing teams
- State-of-the-art pressure testing facilities capable of more than 15,000 psi
- Bucking services for tools up to 20-in. OD and 160,000-ft/lb torque
- Manufacturing centers of excellence located around the globe, including in Europe, the USA, Canada, and the Middle East
- Extremely competitive standard lead times with options available for expedited delivery

Quality Management System

Our quality management system (QMS) permits our staff to manage projects together in a homogenous method, driving efficiency. Our system also permits us to:

- Manage traceability of products, including inspection information and material certificates
- Manage communications and tasks to ensure high-quality products are delivered on time
- Handle client-specific quality control plans (QCPs) and third-party inspections
- Control non-conformities
- Conduct risk management tasks

Production

Our production group contains:

- Over 20 CNC milling and turning machines in Vechta, Germany dedicated to our geothermal portfolio
- State-of-the-art measurement technology
- Dedicated quality management team

Certification & Licenses

With continual improvement front and center, we bring top-class products and services to our clients. We are certified to:

- ISO 9001:2015
- API Q1
- API 11D1
- API 5CT
- API 7-1

We are also proud to be a VAM Licensee.

Tuboscope™ TK™ – Corrosion Control Liner hanger applications

TK-Liner is a high-performance protective lining system for production, injection, and disposal applications. In addition to providing exceptional corrosion protection, the glass-reinforced epoxy (GRE) lining system offers insulation properties that improve thermal efficiency in geothermal and other energy applications.

TK-Liner is installed using a proprietary blend of cement that is injected into the annulus between the host-pipe ID and the lining-system OD and can take the full mechanical loadings of the pipe, up to pipe-body yield (in combined loading). Compatible with most threaded and coupled premium connections, TK-Liner's TK-Ring and TK-Ring II require no modification to the original host connection.

The TK-Ring II system has successfully been deployed into geothermal producers in the Netherlands, the world's first application of these types of products in geothermal production wells. Our engineered system is proven to prevent corrosion, reduce heat loss by providing thermal insulation properties, and minimize friction, thus maximizing flow.

Tube-Kote™ (TK) Coatings are used across a wide range of harsh environments in geothermal liner applications including flow-wetted liner hanger system components as well as the customer liner.

Recognized worldwide as the industry leader in corrosion control, TK Coatings have been used in geothermal projects throughout the Netherlands, Germany, and France since 2003. The proprietary suite of coatings provides unmatched corrosion protection, thermal insulation, deposit mitigation, and flow assurance across a broad range of temperatures in energy applications.

XLF connector

Our XLF connector has successfully been used in geothermal applications in New Zealand, California, and Latin America. XLF's flush OD and ID, metal-to-metal seal, and full pipe body pressure ratings make it ideal for geothermal slim well applications.



Engineering and modeling capabilities

Engineering

Our engineering group is based locally and designs and develops our tailor-made client solutions. The team also conducts dedicated API 19LH or API 11D1 testing on our products. Our engineering group has completed API 19LH and/or API 11D1 testing up to 15,000 psi with gas-tight requirements over an extensive range of sizes. Our metallurgists work closely with our design engineering team to confirm that our designs will meet customer requirements as per API standards.

Modeling capabilities

Increasingly complex well designs solve customer challenges, but often create similarly increased complexities for their engineering groups. To aid the implementation of these well designs, we can run and model torque and drag simulations, swab and surge analyses, centralizer placement simulations, hydraulic simulations, tube move simulations, and more.

Torque and drag simulations

Torque and drag simulations are used to plan drilling and completion operations and assess the predicted torque and drag loading conditions on planned operations based on well design. The primary outputs considered are tension, torque, and fatigue loads, along with buckling conditions along the length of the string from the top-down over a range of friction factor conditions. Using torque and drag simulations helps ensure the drill string is set up to handle all potential contingency operations properly and that the liner can be run to depth on the first attempt.

Swab and surge analyses

Swab and surge analyses are useful when there is a narrow pore pressure/frac gradient window, a tight clearance completion string that may unexpectedly surge the formation and require slow run-in-hole times, or concerns of a ball seat or other shear pressure event that could fracture or otherwise disrupt a weak formation at the toe. It is essential to control the run-in-hole speed for tight-clearance completions and other factors such as position, and set shear pressure for shear events to avoid inducing formation damage due to excessive swab or surge pressures.

Centralizer, standoff, and placement simulations

Proper centralization of the casing and liner is crucial to ensuring the quality of a cement job by preventing mud channeling and poor zonal isolation. Centralizer placement simulations assist with optimization of centralizer type, placement position, and quantity used, all of which allow operators to achieve a good standoff profile. Our centralizer placement simulations predict casing standoff and torque and drag for ERD or deviated wellbores.

Hydraulic simulations

Hydraulic simulations allow us to calculate fluid pressure losses during liner installations, providing an accurate hydraulic liner equipment activation plan. The effects of changing mud weights and temperature effects may be modeled.

Tube move simulations

Tube move simulations are often used to determine the net forces on an installed and set packer, or to determine the movement of a tieback string to estimate the recommended tieback receptacle length, as well as for other useful scenarios. The tube move simulations consider the net combined results of the piston, buckling, ballooning, and temperature effects to determine the overall impact to relevant completion tools and assist with optimization of the overall well design.

Partners

NOV Fiber Glass Systems

Fiber Glass Systems is focused on geothermal wells and associated distribution lines. To date, we have installed over 3,000 km of piping in geothermal environments using this lightweight, easy to install, maintenance-free, corrosion-resistant solution. These tailored offerings also offer solutions related to flow efficiency, thermal conductivity, and various system temperature ranges as required.

NOV XL Systems

XL Systems provides the geothermal industry with robust and reliable products for large OD conductor and casing programs. We have been supplying the industry since 1985 and have launched several innovations such as:

- Weld-on connections from 16-in. to 38-ft OD
- Metal-to-metal and elastomeric primary pressure seal options with 100% of pipe ID
- Full-scale fatigue testing
- Gas-tight options

Tuboscope / NOV Germany

We have helped customers protect and get the most out of their tubular assets since 1938. Tuboscope/VETCO has continued to raise the global standard with a comprehensive and integrated suite of value-added solutions that maximize the lifecycle of your assets. As the pioneer of tubular inspection and internal corrosion control technologies, we continue to provide innovative solutions that maximize performance and asset life. Our corrosion control solutions that are used widely in the geothermal environment include:

- TK internal and custom coating technology for drill pipe, OCTG, line pipe & accessories
- TK-Liner technology, state-of-the-art GRE liner technology for OCTG

Additionally, we support the geothermal industry with a wide array of services, including:

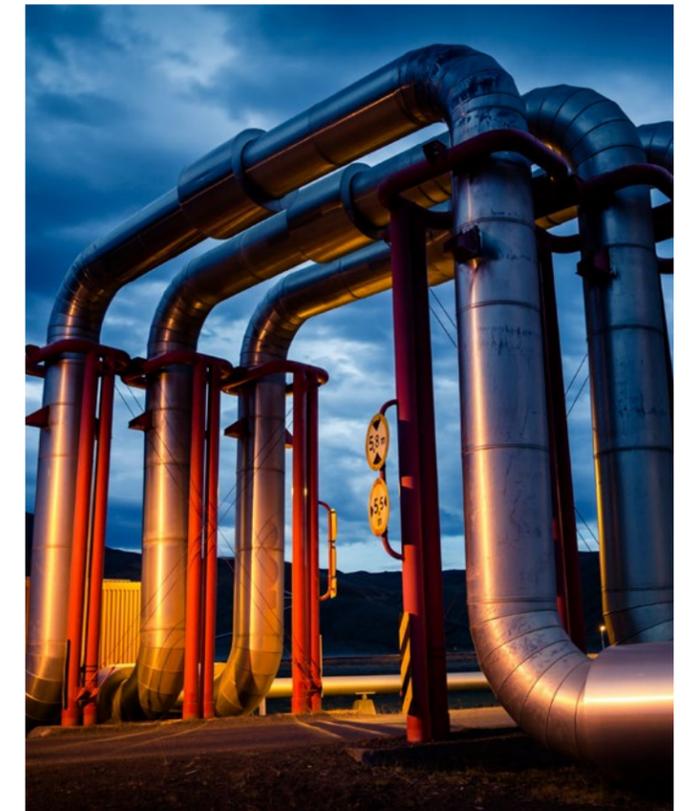
- Threading and machining services
- Inspection services, including on-site inspections
- Hardbanding
- Asset management for drilling tubulars, OCTG and accessories

HP Well Screen BV

Based in Wierden, The Netherlands close to our German facility, HP Well Screen BV (HPWS) has been providing screen solutions for the global geothermal industry for more than 30 years. NOV partners with HP to offer various customizable options ranging from wire-wrapped screens (WWS) and premium metal mesh screens (MMS) to simplified slotted and perforated liner solutions that are fit-for-purpose for geothermal applications.

TAM International

TAM International is headquartered in Houston, Texas, with offices in Europe and worldwide, providing inflatable packers, swellable packers, and associated products. Particularly beneficial to the geothermal industry is TAM's FREECAP GT™ swellable packer for geothermal and steam-assisted gravity drainage (SAGD) applications, which complements their existing swellable packer line. The FREECAP GT elastomer technology features a superior elastomer base compound that can handle downhole temperatures up to 575°F (302°C).



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