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Federal Department of the Environment, Transport, Energy and Communications DETEC

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Bohrlochverrohrung aus glasfaserverstärktem Kunststoff für geothermische Anwendungen (GRE-GEO)

Glass Fiber Reinforced Epoxy Casing for Geothermal Application (GRE-GEO)

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Zusammenfassung

Die meisten geothermischen Ressourcen enthalten Reservoirflüssigkeiten, die stark korrosiv gegenüber Standardgehäusematerialien sind. Die Korrosion ist so stark, dass lange vor dem erwarteten Lebenszyklus des Bohrlochverrohrung die Integrität des Bohrlochs unterdurchschnittlich ist, was zu Undichtigkeiten des Bohrlochverrohrung führt. Neben diesen möglichen Umweltauswirkungen wirkt sich dies negativ auf die finanzielle Durchführbarkeit des prognostizierten Projekts aus. Bestehende Alternativen zu nicht korrosiven Bohrlochverrohrungsystemen bestehen aus Glasfaser. Diese Bohrlochverrohrungalternative wurde jedoch speziell für die Öl- und Gasförderindustrie entwickelt und ist aufgrund ihrer geringeren Abmessungen (Durchmesser und Größe), Handhabung und Installationsmethode nicht für die Erdwärme geeignet. Hauptziel des Projektes ist es daher, ein kostengünstiges, glasfaserverstärktes Epoxid-Bohrlochverrohrungsystem mit großem Durchmesser zu entwickeln, das speziell für geothermischen Bohrungen entwickelt wurde und auch geeignet ist, die korrodierenden Stahlverrohrung bestehender geothermischen Bohrungen zu ersetzen.

Summary

Most geothermal resources contain reservoir fluids that have are strongly corrosive to standard well casing materials. The corrosion is so severe that long before the expected lifecycle of the well casing the well integrity is underperforming causing well casing to leak, and next to this potential environmental impact, it negatively impacts the forecasted project’s financial feasibility. Existing alternative of non-corrosive well casing systems are composed of fiber glas. However, this well casing alternative is specifically designed for the oil and gas exploitation industry and is not suitable for geothermal because of its smaller dimensions (diameter and size), handling and installation methodology. Therefore the main objective of this project it to develop a cost-efficient, large-diameter, glass-fiber reinforced epoxy casing system that is especially designed for geothermal wells and is also suitable to replace the corroding carbon-steel casing of existing geothermal wells.

Contents

1 Introduction

Background information and current situation

Most geothermal resources contain reservoir fluids that have are strongly corrosive to standard well casing materials. The corrosion is so severe that long before the expected lifecycle of the well casing the well integrity is underperforming causing well casing to leak, and next to this potential environmental impact, it negatively impacts the forecasted project's financial feasibility. Existing alternative of non-corrosive well casing systems are composed of fiber glas. However, this well casing alternative is specifically designed for the oil and gas exploitation industry and is not suitable for geothermal because of its smaller dimensions (diameter and size), handling and installation methodology. Therefore the main objective of this project it to develop a cost-efficient, large-diameter, glass-fiber reinforced epoxy casing system that is especially designed for geothermal wells and is also suitable to replace the corroding carbon-steel casing of existing geothermal wells.

Purpose of the project

The fluid composition of geothermal projects contains multiple elements that accelerate corrosion and induce scaling. This reduces the lifespan of the steel casing systems and forces workover procedures earlier than expected, becoming a significant financial burden. On the other hand glass fiber casings (GRE) now used to substitute steel have a small inner diameter and their sizing, handling and installation is regulated by oil/gas standards, which were originally developed for steel. This restriction leads to reduced flow rates or increases in own power consumption, which even further jeopardizes the profitability of each geothermal project facing massive corrosion.
Therefore, the main objective of the project is to develop a cost-reducing, large diameter, glass-fiber reinforced epoxy casing system that is especially designed for geothermal well application (GRE-GEO) and is suitable for workover of the old wells.

Objectives

The project is focusing its efforts on the geothermal production piping so that its resources are used efficiently in the boundaries of the GEOTHERMICA framework. The aim is to increase the inner diameter of an already existing piping class and to limit the outer diameter of pipe and fitted connecter in the given stress envelope. Thereby, the project aims to rely as much as possible on existing in-house developments.
Furthermore, the project will also include the much-needed guidelines and tools for installation of the GRE casing. This will integrate the end product into the market. The improvement in the field of casing system technology and materials are a major advantage in comparison to the steel-based casing systems. High corrosion resistance significantly prolongs the overall lifespan of the wellbore compared to conventional steel casing designs.
The GRE-GEO (glass fiber reinforced epoxy casing for geothermal application) project will develop a new well completion strategy that aims to establish a corrosion-resistant alternative to decrease the development and production costs of geothermal energy while avoiding extra investments. Lower costs also improve the competitiveness of the participating companies in Europe. Reduced costs, shorter maintenance time, and mitigation of risks connected to health, safety, and the environment will increase the social acceptance.

At the moment, GRE pipes are used worldwide together with steel casings in double barrier well schemes for oil/gas as well as for geothermal projects. But a specific large diameter GRE production casing is currently nonexistent due to standardization limitations imposed by the oil/gas industry. In general, geothermal projects are forced earlier than expected to do workover or to retrofit steel wells with economic unsuitable small diameter GRE tubing.
Glass fiber reinforced epoxy piping has very different physical properties when compared with steel. These include different stress behavior, different relation between axial stress, internal yield pressure, collapse pressure and a lower wear susceptibility. All these properties need to be investigated and its potential weaknesses must be addressed to ensure that GRE will comply with the highest international standards on well integrity. Moreover, because of the high influence of temperature in yielding strength of glass-fiber epoxy, the temperature needs to be taken into account too (e.g. for use in district heating systems therefore the maximum allowed temperature is limited to be 120°C). Also, the handling of GRE needs special care with the development of the tooling.

2 Procedures and methodology

The work program for GRE-GEO consists of 8 work packages in total. Work packages 1 to 5 build upon each other. Work packages 6 to 8 are almost independent and can be developed in parallel.

A short description of the objectives of each work package (the results per each completed work packages is described in chapter 3):

Work Package 1: Definition of requirements (Month 1 to Month 6)

- The objective of Work Package 1 is to develop together with legal authorities and end-users an extended catalog of requirements which will gives a clear and up to date picture on the basic conditions as well as quality and functional needs for the end-product. The catalog shall update and include requirements for future geothermal wells and existing wells which are facing severe corrosion problems. The focus will be but not limited to the Netherlands, Germany and Switzerland. The work performed in this WP will be used as input for the development and specification of the following R&D work program.First dialogue with mining authorities, other stakeholders and end user
- Differentiate the scope of application
- Life cycle assessment
- Requirements engineering for GRE casing system
- Requirements engineering for pipe handling and installation tooling

Work Package 2: Research and development R&D

In Working Package 2 the main R&D work will be performed with the main goal of demonstration in the field.

- Design and manufacturing integrity verification
- R&D on well design
- R&D of new future GRE compositions, pipe, and connector system
- R&D on installation process and product qualification
- R&D on pipe handling and installation equipment incl. casing running procedure, handling tools and make-up and break-up unit
- Manufacturing of Makeup/Breakout unit, adaptation of handling tools if required

Work Package 3: System test and verification

In this working package the developed casing class is tested and verified for application according to the defined use-cases and protocols.

- Development of test and qualification program
- Test set-up and running tests according to test program
- Technical integrity verification

Work Package 4: Design review

- Evaluation of the gathered data and results
- Final modification and/or corrective actions

Work Package 5: Operating and Demonstration

- Development of demonstration program
- Crew training
- Demonstration
- Operating manual

Work Package 6: Standardization and code development

- develop a framework and the starting point for the next generation of standards suitable for GRE and geothermal application.

Work Package 7: Development of contractor certification program

- Develop a training and certification program to implement GRE piping systems.

Work Package 8: Communication and acceptance

- Establishment of three-year communication concept (messages, receiver, channels, and activities)
- Web page
- Presentations and participation in exhibitions, congresses
- Public relations by applicants through coordination of main applicant

In the first step, the partners, led by gec-co, define the requirements in dialog with the regulatory body and the end-users. This process will be completed in about six months. The next work package contains the main R&D work for well design, tubing, tooling, and installation process. The R&D will be done in parallel to WP3 with testing and verification. The work will be iterative and will be finalized with the WP4 design review. WP5 with demonstration follows in the last step whereas the implementation carefully planned and executed. Standardization and code development, development of a contractor certification program and communication and acceptance run parallel to work packages 1 to 5. The following list contains the details of the individual work packages and estimated person months per partner.

3 Activities, Results and Evaluation of Results to-date

The most important scientific and technical results:

1) **Work Package 1**

   All objectives of work package 1 were successfully achieved. Reports were created and submitted to Geothermica. Work package 1 is considered as completed.

   Outcome of:

   - Work package 1.1: Requirements catalogue, use case description, scope definition with specification but not limited to maximum temperature and diameter range.
   - Work package 1.2: Updated scope of application and create short-list of use-cases.
   - Work package 1.3: Developed concept on the integrity life cycle of the GRE casing, from its design, to abandonment.
     Mitigation strategies for design, construction, and operation. Concepts for intervention and abandonment.
   - Work package 1.4: Specification of R&D work program on well design as well as future GRE composition, pipe and connector system.
   - Work package 1.5: Research Program. Specification of R&D work program on well design ensuring safe casing installation process, product qualification in terms of handling and installation requirements, pipe handling, and installation equipment.

   In the Appendix of this report the final reports of Work package 1 (the ones that are not confidential) are included.

2) **Work Package 2**

   Work package 2 is not yet completed. A description of the planned outcome and progress so far with work package 2:

   - Work package 2.1

     Planned outcome: Specifications for test protocols

     Progress: The short-term material test and the preparation of the long-term material tests. The short-terms tests are performed and are partially completed. The long-term tests are designed and prepared, and execution of these long-term tests will be undertaken as a part of work package 3. Tests were performed with GRE-pipe samples to analyze its behavior. Also the material loss of the GRE-pipe during drilling (wear test) was tested, the collapse and bursting (short-term) behavior at high pressure difference between the pipe and the annulus. These test results are checked and evaluated with the consortium partners. The findings from analyzing the test results will be used in the further development of the test procedure and the product itself.

   - Work package 2.2 and 2.3 were merged.

     Planned outcome:

     - According to previously defined requirements and determined scope of application, different well design variants per use-case are developed in

conjunction with WP 2.3, which is the development of the GRE casing and tubing itself.

  - GRE casing and tubing class for geothermal application

The most important result of work package 2.2 is the development of a single well design. This well design is the starting point for further development by GRE GEO.

- Work package 2.4 is work in progress.

  Planned outcome:

  - Installation process certification protocol and product qualification certification protocol

- Work package 2.5 is work in progress.

  Planned outcome:

  - casing and tubing handling equipment design ready for manufacturing

3) HAZID Study

In parallel with multiple work packages, workshops were held for the further development of the hazard identification (HAZID) study.

4) Involvement of a well casing cementing expert

Contact was made with the company Fangmann Energy Services who is a well casing cementing expert. Currently a non-disclosure agreement is being agreed on.

5) Work Package 6

The work of Work package 6 already commenced because the development of standards for the large-scale use of GRE piping is of importance. By starting early with working on the standards the compatibility and acceptance within the existing well casing standards can be increased significantly.

6) Assimilation of geochemical database

A database with geochemical data of various geothermal plays was assimilated. This database will be used for the modeling work to evaluate the scaling and corrosion potential.

7) Work package 8: Marketing

List of dissemination activities:

- ***Social media***
  - *Project hashtag use: Not available yet*
  - *Facebook, Twitter or other accounts: Not available yet*
  - *Project website:* ***Under Construction at the moment.***

- Holding a seminar together with Dr. Schneider, https://www.thinkgeoenergy.com/webinar-reinforced-epoxy-casing-systems-for-geothermal-march-12-2021/
- Preparation of an abstract for the Call for Papers of the European Congress for Geothermal 2022
- Lecture on GRE GEO project at the Geothermal Congress in Essen, 30 November to December 2, 2021.
- ***Website***
  - *GRE GEO Website has been completed Link .*

- *The Website is currently being updated accommodating latest discoveries*

- ***WGC October 24-27***
  - *GRE GEO has participated by providing a short Poster*
  - *Flyer describing the latest progresses of the project*

- ***DGK Erfurt November 25***
  - *Personal presentation about GRE GEO project and product advantages*
  - *An Article about the latest project advancements.*

- Swiss dissemination via direct contact with:
  - SIG
  - Geo Energie Suisse

4 Next steps

The project is planned for 36 months. The next steps are outlined by the work packages presented in Chapter 2.

5 National and international cooperation

The following consortium of seven applicants from three countries including one research institution, consists of experienced companies and established market leaders in their respective fields:

- gec-co Global Engineering & Consulting – Company GmbH, Germany
- Future Pipe Industries B.V., The Netherlands (FPI)
- Clausthal University of Technology, Institute of Petroleum Engineering, Germany (ITE)
- DrillTec GUT GmbH Großbohr- und Umwelttechnik, Germany (GUT)
- Dynaflow Research Group B.V., The Netherlands (DRG)
- Eartha AG, Switzerland (Eartha)
- Nuclear Research and Consultancy Group, The Netherlands (NRG)

Additionally, the cosortium has invited end-users from Germany, the Netherlands and Switzerland to consult the development of the end product. Moreover, an end-user from Switzerland, Sercices Industriels de Genève, decleared very strong interest and joint the team as a cooperation partner, this will improve its position in the future geothermal market.

Each project partner brings competence and represents essential parts of the complete lifecycle for designing, planning and installation of GRE in a geothermal well.
In particular, the framework development and supply of the casing will be led by FPI, casing testing and verification incl. cementation by ITE, project development and planning of the geothermal cycle as well as services around running the casing and completion by gec-co, drilling the well and running the casing incl. tools by DrillTec, geochemical characterization of geothermal fluids and gases as well as their interaction with GRE and environmental impact by Eartha and NRG, technical due diligence of

the casing by DRG and gec-co. Additionally, the analysis of the radioactive scaling influence on the material and development of GRE-Steel comparison model will be performed by NRG.
The experts at FPI and Dynaflow will be in charge for development of the new framework because of their decades of experience in preparation of standards for glass-fiber epoxy pipes. TU Clausthal will deliver the critical link to steel casing and testing. DrillTec, due to it's well-known and strong foothold in the European geothermal market, gives the project the possibility to adapt rig and tooling for running the casing and on-site demonstration in the field. Eartha together with NRG have a wide knowledge about European reservoir structure and fluid composition. They will evaluate the physical and chemical interaction of the developed product with reservoirs and geothermal fluids of different countries (especially the Netherlands, Germany and Switzerland). The connection between all the interdisciplinary tasks will be coordinated by gec-co with its experience in research and development in the drilling technology and geothermal field.

The Netherlands
The group of companies from the Netherlands lead by FPI has a primary goal of development of the GRE piping and its subsequent optimisation for the demonstration and preparation of a commercial design. The production of the prototype for testing as well as preparation of the products for the demonstration will be carried out by FPI. The Dynaflow Research Group (DRG) will take over the task of carrying out the numerical modelling of the new system. NRG is responsible for studying the interaction of the material with radioactive particles that are often present in deep geothermal reservoirs.

Germany
The consortium partners from Germany is led by gec-co and include ITE and DrillTec. The main work carried out by national companies could be represented as follows: ITE will take over the prototype testing close to real subsurface environment conditions. Its objective would be determination of the piping properties, determination of its limitations and verification. They will also assist and play a major role in the cross-country development which is targeting the connector. gec-co on the other hand takes over the role of the coordinator and product owner in the definition of requirement, moreover, providing engineering of the surface and downhole equipment and its integration to the existing or newly erected geothermal plants. DrillTec will have a primary focus on development of proper GRE handling tools and practices as well as actual setting the tubing during the demonstration phase.

Switzerland
Switzerland is represented by Eartha, which has a vast experience in reservoir engineering. Its priority would be study and determination the interaction between GRE casing and piping system and reservoir to determine consequences thereof. Additionally, due to the vast hands-on experience in preparing and managing field operations such as geothermal well drilling and well testing, Eartha will also support the organization of the Demonstration phase.

6 Communication

A website about the GRE-GEO project is developed and can be accessed via the following website address: https://www.gre-geo.org/

7 Appendix

Results of Work Package 1:

WP 1.1 First Dialog with End Users and Mining Authorities

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Federal Department of the Environment, Transport, Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Stakeholder	Category	Priority	Country	Lead	First Name	Last Name	URL	Role	E-Mail Adress	Mobile
SoDM	official authority		the Netherlands	FPI	Ron	Leichsenring			R.A.Leichsenring@sodm.nl	
EBN	public company	high	the Netherlands	FPI	**Isabelle**	**Goulay**	www.ebn.nl	Well Engineering	isabelle.goulay@ebn.nl	+31 640902668
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HVC	public company		the Netherlands	FPI	Gerrit	Schurink	www.hvc-group.nl		g.schurink@hvcgroep.nl	+31 683151577
DAGO	association		the Netherlands	FPI			www.dago.nu	Secretary Operations	dio.verbiest@dago.nu	+31 (0)6 2503 6104
Hydreco Geomec	end user	high	the Netherlands	gec-co	Eric	van Bennekom	https://www.hydrecogeomec.nl	Project Management	eric.van.bennekom@hydrecogeomec.nl	
Ennaturlijk	end user	medium	the Netherlands	gec-co	Harald	Droog	MR	Project Management	Harald.Droog@ennatuurlijk.nl	
ECW	end user	high	the Netherlands	FPI	Wim	Bos	www.ecwnetwerk.nl	Manager Geosystemen Sub-Surface	w.bos@ecwnetwerk.nl	+31 6 22 328 917
Well Engineering Partners (WEP)	engineering	high	the Netherlands	FPI	Alexander	Nagelhout	https://wellengineeringpartners.com	CFO	alexander.nagelhout@we-p.nl	
Engie	end user	medium	the Netherlands	gec-co	Horst	Kreuter				
Vermillion	end user	on hold	the Netherlands	DrillTec						
Shell	end user	medium	the Netherlands	DrillTec	**Laurens**	**van der Sluijs**			Laurens.vandersluijs@shell.com	
Shell	end user	medium	the Netherlands							
Veegeo	consultant	high	the Netherlands	DrillTec	Floris	Veeger	www.veegeo.nl		Floris.veeger@veegeo.nl	+31 614818818
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Vito	public company	high	Belgium	gec-co	Matsen	Broothaers		Engineering	matsen.broothaers@vito.be	
Stichting Geothermal Groep Nederland	end user	high	the Netherlands	DrillTec	Andre	Mol			voorzitter@stichting-geothermiegroep.nl	+31-6-52625436
Internationales Geothermiezentrum Bochum	research institute	high	Germany	gec-co	Rolf	Bracke				
Geoforschungszentrum Potzdarm	research institute	medium	Germany	gec-co	Ernst	Huenges				
Landesamt für Bergbau, Energie und Geologie (Niedersachsen)	official authority	medium	Germany	ITE	Faissal	Boulakhrif			faissal.boulakhrif@lbeg.niedersachsen.de	
BVeG	official authority	?	Germany	DrillTec						
Sächsisches Oberbergamt			Germany							
EnBW			Germany							
SWM	end user	high	Germany	DrillTec	Christian	Pletl			pletl.christian@swm.de	
Stadtwerke Waldkraiburg			Germany							
ENTEGA AG			Germany							
Deutsche Erdwärme (DEW)	end user	medium	Germany	gec-co	Lutz	Stahl				
Erdwärme Neustadt-Glewe GmbH	end user	high	Germany	gec-co	Norbert	Schröder				
Geothermie Neubrandenburg (GTN)	engineering	high	Germany	gec-co	*Peter*	*Seibt*				
Stadtwerke Waren	end user	medium	Germany	gec-co	*Peter*	*Seibt*				
Stadtwerke Schwerin	end user	medium	Germany	gec-co	*Peter*	*Seibt*				
Bergamt Stralsund (Meklenburg)	official authority	medium	Germany	gec-co	*Horst*	*Kreuter*				

Geothermie Straubing	end user	medium	Germany	gec-co						
Geothermie Erding	end user	medium	Germany	gec-co						
Steag (Geothermie Erding/Pullach)	end user	high	Germany	gec-co	Markus	Wolf				
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GeoT	engineering	high	Germany	gec-co	Horst	Kreuter				
Services Industriels de Genève (SIG)	end user	high	Switzerland	gec-co	Frederic	Mirjolet			frederic.mirjolet@sig-ge.ch	
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Company Francaise de Geothermy	engineering	high	France	FPI	Louis	Hirsinger	www.cfgservices.fr	Drilling engineer	l.hirsinger@cfg.brgm.fr	+ 33 (0)6 12 82 36 89
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Tullip Energy Exploration & Development	engineering	medium	the Netherlands	FPI	Nico	Kuipers	www.tullipenergy.com	CEO	nico@tullipenergy.com	+31 (0) 612481154
Stadtwerke München	end user	high	Germany	gec-co						
Vulcan	end user	medium	Germany	gec-co	Weiman	Thorsten				

WP 1.2 Differentiate the Scope of Application:

Confidential - omitted

Work Package 1.3: GRE Pipe Life Cycle Assessment

Confidential - omitted

Work Package 1.4: Requirement engineering for GRE casing system

In progress

Work Package 1.5: Requirement engineering for pipe handling and installation tooling

Confidential - omitted

Work Package 2

In progress