GEORG

GEOTHERMAL RESEARCH GROUP

FINAL REPORT

Deep roots of geothermal systems

Mechanics of materials for deep root equipment, failure analysis and improvements in design.

Part 3.2

Project ID: Magnús Þór Jónsson

Coordinator: Magnús Þór Jónsson

Start date: 01.09.2013

Duration: Three years

Partners: Guðrún Sævarsdóttir, HR; Sigrún Nanna Karlsdóttir, HÍ; Kristinn Ingason, Mannvit; Geir Þórólfsson, HS; Kristján Einarsson, LV; Ingólfur Ö. Þorbjörnsson

1 Project summary

Energy of deep geothermal heat sources is extracted from geothermal reservoirs through geothermal wells. The energy rich water turns to steam as the pressure drops while it flows up the well. High temperature geothermal wells are often constructed of three concentric casings; a surface casing, an anchor casing and a production casing where the geothermal fluid flows. The casing components that form the casing are either connected with threaded couplings or welded together. Each casing is cemented externally all the way to the top for structural support and leakage prevention. The purpose of the casings is to prevent collapse of the borehole, to prevent flow from unwanted aquifers, for blow out prevention during drilling and to be a conductor for the geothermal fluid to flow up the well. The anchor casing is connected to an expansion spool below the master valve, allowing for axial displacement for the production casing inside the wellhead when it expands thermally. In the project DRG Part 3.2 the main objective is to analyze then mechanics of casing materials for deep root geothermal wells.

Numerous casing load cases arise during different stages of geothermal wells, as shown in Figure 1, the main ones being; casing weight (A), differential pressure between outer and inner surface of the casing (B) and temperature changes (C and D).

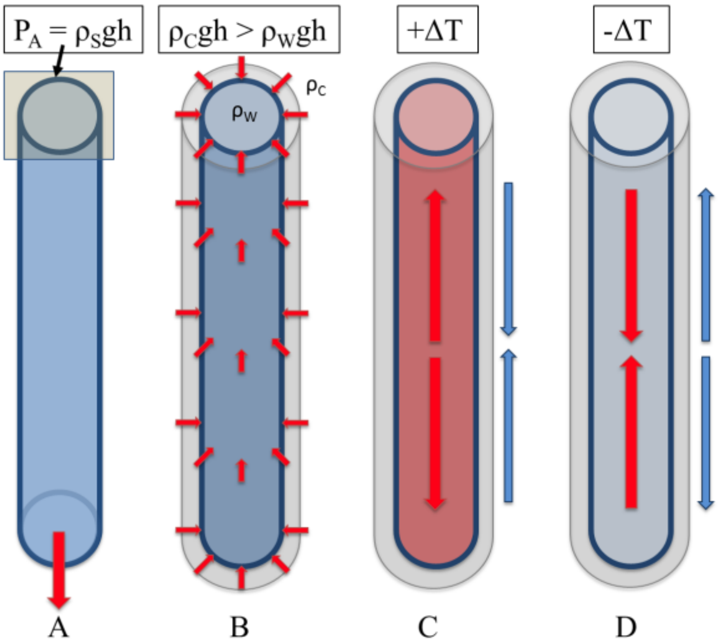


Figure 1: Main load cases of casings; (A) Self weight, (B) Differential pressure and (C and D) Temperature changes.

In general, casing strength is calculated in terms of axial tensile strength, collapse and burst pressures. The most important design loads for oil and gas are casing weight, tensile loading and fluid pressure, in geothermal wells however, high temperature loading is the most severe. The temperature change from the cementing temperature conditions to production temperature conditions can be around 300-350°C uppermost in the well, but the temperature distribution of the casings during cementing provides the initial conditions for thermal stress calculations. Thermal expansion generates thermal stress in the casings and concrete because of the thermal gradient in between the layers. Assuming completely constrained casing, the thermal stress is about 2.5 MPa/°C, which means that a K55 steel casing reaches its yield point (fym = 379 MPa) at a temperature change of approximately 150°C. Fortunately, K55 casing steel is very ductile and can therefore generate large strain before problems occur. A well composed of concentric steel casings, concrete and surrounding rock formation forms a structural system which involves a number of structural components, e.g. friction between contacting surfaces, tensile and compressive properties of materials and diminished material properties at elevated temperatures, all of which add nonlinear characteristics to the structure. The load subjected on the structure, the cased well, consists of transient wellbore pressure and temperature changes. The temperature rise while the well is initially discharged can lead to stresses reaching the yield strength of the casing which results in formation of plastic strain. The plastic strain is permanent so if the well cools down again, the plastic strain leads to tensile forces in the casing.

During the discharge of high temperature wells, the temperature difference in the well from non-flowing to flowing conditions is large. The large temperature change generates thermal stress in the casing which is partially constrained by the concrete. Casing failures can lead to a reduced energy output from the well, render it inoperative and in worst cases cause unsafe conditions above the surface. Thus the structural integrity of well casings is essential for the utilization of geothermal wells. The casings and the wellhead form a structural system which is unpractical to solve analytically mainly due to the nonlinear behavior of the contacting surfaces. Therefore, the structural system has been analyzed numerically with the use of the nonlinear finite element method (FEM). A thermal and nonlinear structural model of the cased well has been constructed where nonlinearities, e.g. friction, plasticity and large non-uniform deformations are accounted for [1].

The nonlinear finite element method (FEM) was used to construct three models of the cased well providing a tool which can be used to assess casing failure risks by modeling various possible load scenarios that could lead to casing problems. A specific failure mode, such as a local casing failure, does not necessarily require a full 3D modeling of the whole well a section of the well could be sufficient to explain the failure mode. As shown in Figure 2, three models are essentially used to analyze different aspects of the structural system of the high temperature geothermal well; (i) a 2D axisymmetric model of the whole cased well used to model temperature, displacements, stress and strain distributions down the well, (ii) a 2D axisymmetric model of a detailed coupling surrounded by concrete used to further model coupling strength and concrete damage near couplings, and (iii) a 3D model of a section of the well which can be used to model non-symmetric phenomena such as collapse. Casing failure modes and the corresponding FEM models that are used to analyze them are listed in Table 1.

Eight-node quadrilateral-shaped elements and six-node triangle-shaped elements are used in the 2D analyses, and 20-node structural solid elements are used in the 3D analysis. Contact element pairs are used between contacting surfaces with the main purpose of preventing intersection of surfaces, while still allowing gap formation and frictional displacement between casing and concrete surfaces. The Coulomb friction model is used to describe friction between contacting surfaces. The largest of the three models, the (i) 2D axisymmetric model of the whole cased well is used to analyze the structural response of wells to wellbore temperature and pressure changes, see Figure 2. The geometrical sizes and material properties of a particular well and a load history of the well can be read into the model with specific input files. Temperature, displacements, stresses and strains of the casings and concrete at any depth is the output of the model.

Table 1: Casing failure modes and corresponding FEM model used for analysis.

Failure mode	**Description**	**FEM model**
Axial tearing	Tearing at couplings due to high tensile stress.	(i) 2D axisymmetric model of the whole cased well. (ii) 2D axisymmetric model of a detailed coupling surrounded by concrete.
Collapse	Collapse due to pressure difference between the outer and inner pipe wall.	(iii) 3D model of a section of the well, includes impurities and geometrical defects, i.e. manufacturing tolerance, off center casing, external defect, eccentricity and ovality of the casing.
Burst	Rupture due to high internal pressure and low external pressure.	Not specifically modeled.
Concrete damage	Concrete braking because of stress reaching beyond the strength of the concrete.	(i) 2D axisymmetric model of the whole cased well. (ii) 2D axisymmetric model of a coupling surrounded by concrete. (iii) 3D model of a section of the well.
Wellhead displacement	Wellhead displacement due to wellhead pressure and wellbore temperature change.	(i) 2D axisymmetric model of the whole cased well.

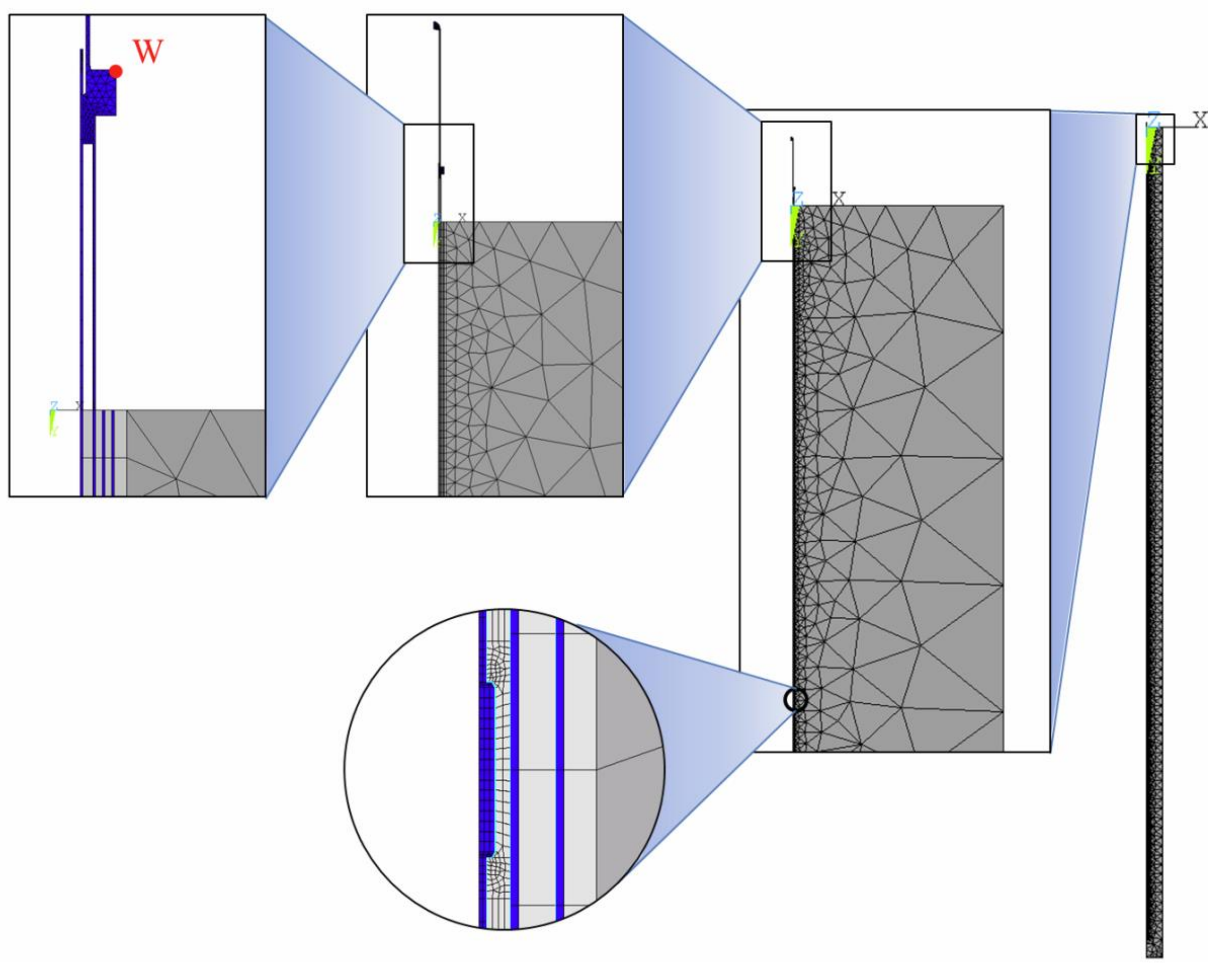


Figure 2: Model i, 2D axisymmetric model of the whole cased well used to model temperature, displacements, stress and strain distributions down the well.

The structural response of geothermal wells to various load cases can therefore be analyzed. Wellhead displacement due to wellbore temperature changes and wellhead pressure can also be modeled with the model and the model shows correlation with measured wellhead displacement.

Probabilistic Analysis was used to quantify uncertainties of the model. As opposed to deterministic analysis, where input parameters are treated as constants which results in a one possible solution, a probabilistic approach is used, where the input parameters are assumed to contain a reasonable amount of scatter, which then gives an estimate of the model uncertainties [2]. Scatter plots of the input parameters versus the output results reveal which input parameters are significant to the results of the FEM model. A cumulative distribution function of the wellhead movement and the maximum von Mises stress in the casings and surrounding concrete is obtained here and will be used to review the uncertainty of the model.

The nonlinear structural finite-element model of the cased section of a high temperature geothermal well was validated with wellhead displacement data [3]. The validation of the model was essential for further stress and strain analysis of geothermal well casings. The main conclusion of the analysis was that high stress was seen in the production casing where thickness changes of the anchor casing were located. The analysis showed that stress in the production casing could be reduced by using uniform thickness in the anchor casing.

Flow testing of IDDP-1, the first Icelandic Deep Drilling Project (IDDP) well drilled in the Krafla geothermal field in Iceland, demonstrated promising results by producing superheated steam. During an unavoidable quenching of the well the innermost casing failed presumably due to tensile stresses caused by thermal contraction. Since the structural integrity of casings is essential for utilization of high temperature geothermal wells, the well has not been discharged again. The casings of the well are analyzed structurally with a nonlinear finite-element model [4]. The load history of the casings is followed from installation and through several thermal cycles, but the well was discharged at least six times before it was quenched with cold water. The results show that changes in stiffness due to the presence of casing shoes and changes in casing thickness has an effect on the stress and strain formations in neighboring casings. The results illustrate that the production casing is thermally shocked during each thermal cycle and that the external casings are somewhat protected, provided that cementing in between is adequate. Such modeling also provides evaluation prospects of different materials that could be used in future wells. The main conclusion of the analysis was that high stress was seen in the production casing where thickness changes of the anchor casing were located. The analysis showed that stress in the production casing could be reduced by using uniform thickness in the anchor casing.

Geothermal wells are subjected to various types of loads and deformations arising from service requirements that may range from standard to extreme values during the construction, operation or discharging process. The objective is to design a casing and a wellhead that can withstand such demands throughout its expected lifetime.

In the traditional allowable stress design, the design is based on the criteria that the stresses resulting from the design loads are lower than the allowable stresses based on material strength and safety factors. The limit state design is based on explicit consideration of various conditions where the structure may not fulfill its intended function. For these conditions, the strength is estimated and used as a limit for such behavior. The emphasis in structural design is moving from the allowable stress design to the limit state design because that approach makes it possible to design a rigorous and economical structure considering directly the various relevant modes of failure.

A limit state of a geothermal well is defined by the characterization of conditions for which a part or an entire well fails to perform the function that is expected of it. For a structural design, four types of limit states are presented: serviceability limit state, ultimate limit state, fatigue limit state and accidental limit state.

In the project, the limit state design methodology was considered as a part of the design procedure for high temperature geothermal wells. Only two limit states are studied, ultimate limit state and accidental limit state. The load-carrying capacity of the well is evaluated using nonlinear elastic–plastic large-deformation finite element analyses related to geometry, material properties, initial imperfections, boundary condition, and load applications for discharging and quenching.

In the case of an accident to a geothermal well the primary concern of the accident limit state design is to keep the control and the integrity of the well. In this presentation, different methodologies to analyze the resistance of the well are discussed.

For the ultimate limit state design, the temperature dependent yield conditions are considered for ultimate stresses and strains including the Bauschinger effect for cyclic loading. At high temperatures, the stiffness and the strength of steel are reduced. That is, however, usually not the only reason of a rupture failure which occurs by a combination of expansion, material degradation and geometrical discontinuity.

The decision process was tested in a MS-project, Structural Analysis of Casings in Well ÞG-14. At well ÞG-14, in the high temperature geothermal field at Þeistareykir in Iceland owned by Landsvirkjun, the cementing of the production casing was problematic which led to large segments of the casing being uncemented. Since the cementing was unsuccessful, there is a risk of casing failures due to trapped water between the production casing and the anchor casing or the rock. The trapped water will expand when the well warns up and can cause the production casing to collapse. There is also the possibility of Euler buckling where casings are uncemented at large areas. There were three different load steps with three different temperature profiles which were applied to the structure which represents when the well was being drilled, cooled and when it warms up. The results in this project are twofold, firstly, severe Euler buckling occurs in the production casing due to axial forces when the well warms up and secondly the production casing will most likely collapse due to pressure from expansion of trapped water. From these results the possibility of putting an extra casing inside the production casing was studied. A loose 7" casing was placed within the production casing and it was analysed whether it would be better to cement it within the production casing or not. The results imply that cementing the 7" casing does not increase the structures resistance to Euler buckling due to large axial forces. Cementing the 7" casing increases the risk of Euler buckling but increases the collapse resistance. In order to cause the minimum damage to the structure it is critical to control the temperature increment and let it warm up as slowly as possible.

[1] Gunnar Skúlason Kaldal, Magnús Þ. Jónsson, Halldór Pálsson, Sigrún Nanna Karlsdóttir, „Structural Analysis of Casings in High Temperature Geothermal Wells in Iceland“, Proceedings World Geothermal Congress 2015 Melbourne, Australia, 19-25, April 2015

[2] Gunnar Skulason Kaldal, Magnus T. Jonsson, Halldor Palsson, and Sigrun N. Karlsdottir, ,,Using Probabilistic Analysis with Finite Element Modeling of High Temperature Geothermal Well Casings” SIMS 54th conference Bergen University College, Norway October 16-18, 2013

[3] Kaldal, G.S., Jonsson, M.T., Palsson, H., Karlsdottir, S.N., „Structural modeling of the casings in high temperature geothermal wells“, Geothermics 55 (2015), 126 – 137, 2015

[4] Gunnar Skulason Kaldala, Magnus T. Jonsson, Halldor Palsson, Sigrun N. Karlsdottir, „Structural Modeling of the Casings in the IDDP-1 Well: Load History Analysis“, Geothermics 62 (2016), 1 – 11, 2016

[5]Gunnar Skúlason Kaldal, Magnús Þ. Jónsson, Halldór Pálsson, Sigrún Nanna Karlsdóttir,“Structural Analysis of the Casings in Deep Geothermal Wells“, SIMS2017, 58th International Conference of Scandinavian Simulation Society, Sept. 25-27, Reykjavik Iceland, 2017

[6] Aron Singh Helgason and Þórir Bjarni Traustason, „Structural Analysis of Casings in well ÞG-14“, Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, School of Engineering and Natural Sciences, University of Iceland, Reykjavik, June 2017

Milestones:	**Planned date:**	**Confirmed date:**
Project stated:	01.09.2013	01.01.2014
Progress Statement #1	31.01.2014	05.02.2014
Annual Report #1	30.06.2014	08.11.2014
Progress Statement #2	31.01.2015	01.04.2015
Annual Report #2	30.06.2015	09.11.2015
GEORG open conference	18.02.2016	18.02.2016
GGW2016	24.11.2016	24.11.2016

Schedule of the project:

1. **Introduction, collection of data and information**

Collect information about the problems that have occurred both in this country and abroad when producing from corrosive and high-energy wells.

Process	Planned	Confirmed
Starts:	01.09.2013	01.09.2013
End:	31.12.2015	31.05.2017
Man-month:	Postdoc: 4 MM MSc: 2 MM	PD: 4/4 MS: 2/2

2. **Materials research**

Study the condition of materials in geothermal well equipment where problems have occurred. Evaluate the corrosion resistance of different materials for different conditions, identify their strengths for different temperatures and check the thermal expansion. Map the choice of materials for different temperatures and chemical composition of steam and equipment.

Process	Planned	Confirmed
Starts:	01.06.2014	01.06.2014
End:	31.12.2015	31.08.2016
Man-month:	Postdoc: 7 MM MSc: 0 MM	PhD: 7/7 MSc: 0/0

3. Model development and verification

Develop, verify and use models to analyze cases where problems have occurred. Find ways to verify the results.

Process	Planned	Confirmed
Starts:	01.09.2013	01.11.2013
End:	30.04.2016	31.05.2017
Man-month:	Postdoc: 9 MM MSc: 3 MM	PhD: 9/9 MSc: 3/3

4. Root cause analysis

Analyze the key elements in assessing the root causes of the failure of mechanical components in deep drilling projects, IDDP-1 and ÞG-14.

Process	Planned	Confirmed
Starts:	01.01.2015	01.01.2016
End:	30.04.2016	31.05.2017
Man-month:	Postdoc: 6 MM MSc: 2 MM	PhD: 6/6 MSc: 2/2

5. Develop a decision process

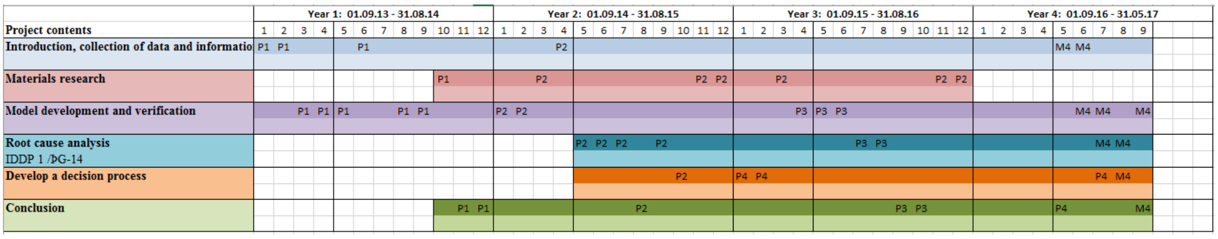
Collect data, analyze and find ways to make decisions that seek to reduce the risk of wear and damage when well is opened to flow or during production and cooling of wells and other production equipment.

Process	Planned	Confirmed
Starts:	01.01.2015	01.01.2016.
End:	30.06.2016	31.05.2017
Man-month:	Postdoc: 4 MM MSc: 1 MM	PhD: 4/4 MSc: 1/1

6. Conclusion

Conference and Journal papers, MSc thesis and PhD thesis.

Process	Planned	Confirmed
Starts:	01.06.2014	01.07.2014
End:	31.08.2016	31.05.2017
Man-month:	Postdoc: 6 MM MSc: 1 MM	PhD: 6/6 MSc: 1/1



	Year 1: 01.09.13 - 31.08.14											
Project contents	1	2	3	4	5	6	7	8	9	10	11	12
Introduction, collection of data and informatio	P1	P1				P1						
Materials research										P1		
Model development and verification			P1	P1	P1			P1	P1			
Root cause analysis IDDP 1 /ÞG-14												
Develop a decision process												
Conclusion											P1	P1

	Year 2: 01.09.14 - 31.08.15											
Project contents	1	2	3	4	5	6	7	8	9	10	11	12
Introduction, collection of data and informatio				P2								
Materials research			P2								P2	P2
Model development and verification	P2	P2										
Root cause analysis IDDP 1 /ÞG-14					P2	P2	P2		P2			
Develop a decision process										P2		
Conclusion								P2				

	Year 3: 01.09.15 - 31.08.16											
Project contents	1	2	3	4	5	6	7	8	9	10	11	12
Introduction, collection of data and informatio												
Materials research			P2								P2	P2
Model development and verification				P3	P3	P3						
Root cause analysis IDDP 1 /ÞG-14							P3	P3				
Develop a decision process	P4	P4										
Conclusion									P3	P3		

	Year 4: 01.09.16 - 31.05.17								
Project contents	1	2	3	4	5	6	7	8	9
Introduction, collection of data and informatio					M4	M4			
Materials research									
Model development and verification						M4	M4		M4
Root cause analysis IDDP 1 /ÞG-14							M4	M4	
Develop a decision process							P4	M4	
Conclusion					P4				M4

2 Project Management

Each week the following group, discuss the status of the project and plan the next week.
The steering group of the project at UI is composed of:
Prof. Magnús Þór Jónsson ,
Assoc. Prof. Sigrun N. Karlsdottir,
Assoc. Prof. Halldor Palsson,
Lector Asdis Helgadottir,
Department of Mechanical Engineering at the University of Iceland.

Also involved in project management:
Ólafur Sverrisson, LV, Kristján Einarsson, LV, Sigurður H. Markússon, LV, Kristinn Ingason, Mannvit, Geir Þorhallsson, HS, and Ásbjörn Einarsson.

3 Student involvement

Students involved in the project 01.09.2013 – 31.05.2017:

Gunnar Skúlason Kaldal, PhD student at Dept. of Mech. Engineering, University of Iceland

Aron Shing Helgason, MSc student at Dept. of Mech. Engineering, University of Iceland

Þórir Bjarni Traustason, MSc student at Dept. of Mech. Engineering, University of Iceland

4 Publications and disseminations

Abstracts and Presentations:

Magnús Þór Jónsson, "Numerical Analysis of High Temperature Wells – Geothermal Power Production in Iceland", Invited speaker, College of Construction Engineering, Jilin University, China, 26. Sept. 2013.

Magnús Þór Jónsson, "Introduction, Well and plant design", The Deep Roots of Geothermal Systems, Open Conference, Reykjavik Energy Headquarter, 18-19 Feb. 2016.

Gunnar Skúlason Kaldal, "Structural analysis of casings in high temperature geothermal wells", The Deep Roots of Geothermal Systems, Open Conference, Reykjavik Energy Headquarter, 18-19 Feb. 2016.

Magnús Þór Jónsson, "Principles of limit state design for geothermal wells", GGW2016, Georg Geothermal Workshop, Nov. 24-25, 2016

Gunnar Skúlason Kaldal, " Structural modeling of casings in high temperature geothermal wells, GGW2016, Georg Geothermal Workshop, Nov. 24-25, 2016

Conference papers:

Gunnar Skulason Kaldal, Magnus T. Jonsson, Halldor Palsson, and Sigrun N. Karlsdottir, ,,Using Probabilistic Analysis with Finite Element Modeling of High Temperature Geothermal Well Casings" SIMS 54th conference Bergen University College, Norway October 16-18, 2013

Gunnar Skúlason Kaldal, Magnús Þ. Jónsson, Halldór Pálsson, Sigrún Nanna Karlsdóttir, „Structural Analysis of Casings in High Temperature Geothermal Wells in Iceland“, Proceedings World Geothermal Congress 2015 Melbourne, Australia, 19-25, April 2015

Gunnar Skúlason Kaldal, Magnús Þ. Jónsson, Halldór Pálsson, Sigrún Nanna Karlsdóttir,“Structural Analysis of the Casings in Deep Geothermal Wells“, Submitted and under review, SIMS2017, 58th International Conference of Scandinavian Simulation Society, Sept. 25-27, Reykjavik Iceland, 2017

Aron Singh Helgason, Þórir Bjarni Traustason, Gunnar Skúlason Kaldal, Magnús Þ. Jónsson, „Structural Analysis of Casings in well ÞG-14“, Submitted and under review, SIMS2017, 58th International Conference of Scandinavian Simulation Society, Sept. 25-27, Reykjavik Iceland, 2017

Journal papers:

Kaldal, G.S., Jonsson, M.T., Palsson, H., Karlsdottir, S.N., „Structural modeling of the casings in high temperature geothermal wells“, Geothermics 55 (2015), 126 – 137, 2015

Gunnar Skulason Kaldala, Magnus T. Jonsson, Halldor Palsson, Sigrun N. Karlsdottir, „Structural Modeling of the Casings in the IDDP-1 Well: Load History Analysis“, Geothermics 62 (2016), 1 – 11, 2016

MSc thesis:

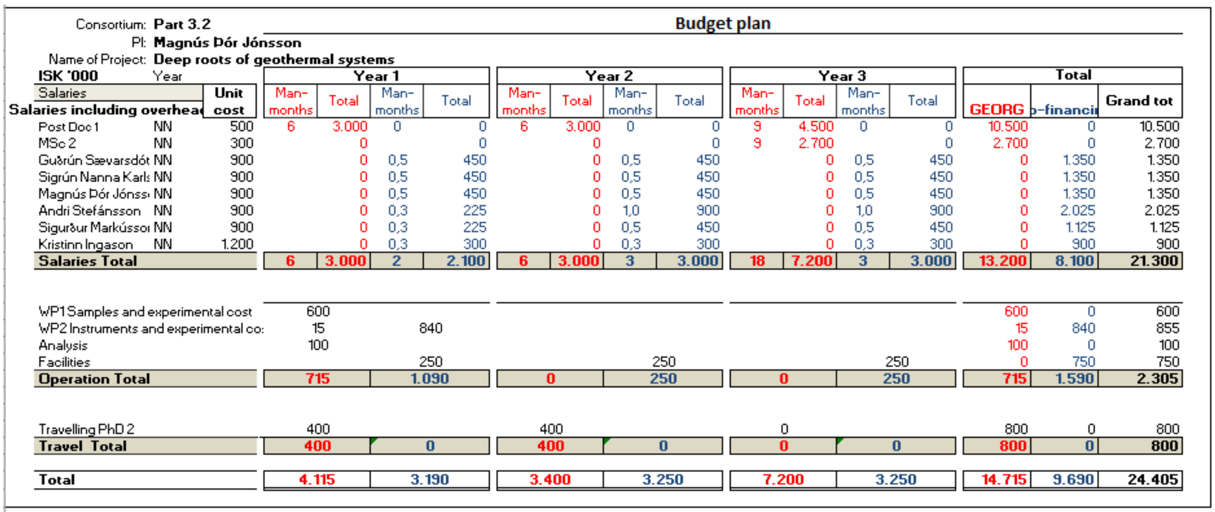
Aron Singh Helgason and Þórir Bjarni Traustason, „Structural Analysis of Casings in well ÞG-14“, Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, School of Engineering and Natural Sciences, University of Iceland, Reykjavik, June 2017

PhD thesis:

Gunnar Skúlason Kaldal, “Nonlinear Finite Element Analysis of Casings in High Temperature Geothermal Wells, Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, School of Engineering and Natural Sciences, University of Iceland, Reykjavik, Partly submitted and under review, December 2017

5 Cost statement

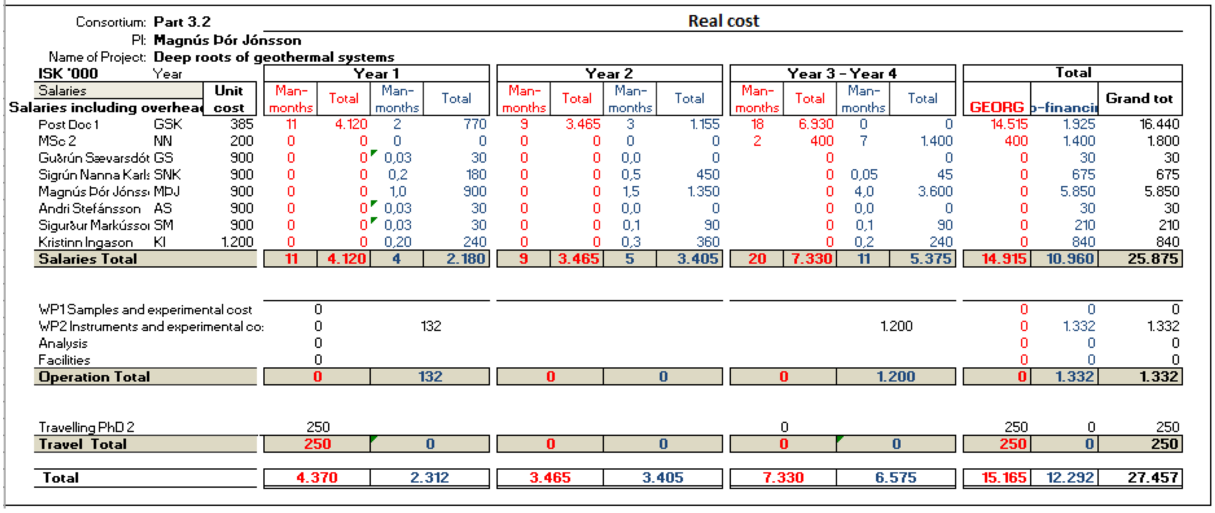
Gunnar Skulason Kaldal has worked at the project as a PhD researcher with monthly salary including overhead cost at 385 þ.ikr until 1st of January 2015. For this calendar year the monthly cost is 400 þ.ikr. He has been working fulltime, 12 months of the year from the start until 31st of May 2016 and the University of Iceland has paid three months of this period and the difference in cost. The MSc students, Aron Shing Helgason and Þórir Bjarni Traustason was supported by Landsvirkjun 1100 þ.ikr.



Consortium: **Part 3.2**
PI: **Magnús Þór Jónsson**
Name of Project: **Deep roots of geothermal systems**

Budget plan

ISK '000	Year		**Year 1**				**Year 2**				**Year 3**				**Total**		
Salaries **Salaries including overhea**		**Unit cost**	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	**GEORG**	**þ-financi**	**Grand tot**
Post Doc 1	NN	500	6	3.000	0	0	6	3.000	0	0	9	4.500	0	0	10.500	0	10.500
MSc 2	NN	300		0		0		0		0	9	2.700		0	2.700	0	2.700
Guðrún Sævarsdót	NN	900		0	0,5	450		0	0,5	450		0	0,5	450	0	1.350	1.350
Sigrún Nanna Karl	NN	900		0	0,5	450		0	0,5	450		0	0,5	450	0	1.350	1.350
Magnús Þór Jónss	NN	900		0	0,5	450		0	0,5	450		0	0,5	450	0	1.350	1.350
Andri Stefánsson	NN	900		0	0,3	225		0	1,0	900		0	1,0	900	0	2.025	2.025
Sigurður Markússo	NN	900		0	0,3	225		0	0,5	450		0	0,5	450	0	1.125	1.125
Kristinn Ingason	NN	1.200		0	0,3	300		0	0,3	300		0	0,3	300	0	900	900
Salaries Total			**6**	**3.000**	**2**	**2.100**	**6**	**3.000**	**3**	**3.000**	**18**	**7.200**	**3**	**3.000**	**13.200**	**8.100**	**21.300**
WP1 Samples and experimental cost				600											600	0	600
WP2 Instruments and experimental co:				15		840									15	840	855
Analysis				100											100	0	100
Facilities						250				250				250	0	750	750
Operation Total				**715**		**1.090**		**0**		**250**		**0**		**250**	**715**	**1.590**	**2.305**
Travelling PhD 2				400				400				0			800	0	800
Travel Total				**400**		**0**		**400**		**0**		**0**		**0**	**800**	**0**	**800**
Total				**4.115**		**3.190**		**3.400**		**3.250**		**7.200**		**3.250**	**14.715**	**9.690**	**24.405**



Consortium: **Part 3.2**
PI: **Magnús Þór Jónsson**
Name of Project: **Deep roots of geothermal systems**

Real cost

ISK '000	Year		**Year 1**				**Year 2**				**Year 3 - Year 4**				**Total**		
Salaries **Salaries including overhea**		**Unit cost**	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	Man-months	Total	**GEORG**	**þ-financi**	**Grand tot**
Post Doc 1	GSK	385	11	4.120	2	770	9	3.465	3	1.155	18	6.930	0	0	14.515	1.925	16.440
MSc 2	NN	200	0	0	0	0	0	0	0	0	2	400	7	1.400	400	1.400	1.800
Guðrún Sævarsdót	GS	900	0	0	0,03	30	0	0	0,0	0		0		0	0	30	30
Sigrún Nanna Karl	SNK	900	0	0	0,2	180	0	0	0,5	450		0	0,05	45	0	675	675
Magnús Þór Jónss	MÞJ	900	0	0	1,0	900	0	0	1,5	1.350		0	4,0	3.600	0	5.850	5.850
Andri Stefánsson	AS	900	0	0	0,03	30	0	0	0,0	0		0	0,0	0	0	30	30
Sigurður Markússo	SM	900	0	0	0,03	30	0	0	0,1	90		0	0,1	90	0	210	210
Kristinn Ingason	KI	1.200	0	0	0,20	240	0	0	0,3	360		0	0,2	240	0	840	840
Salaries Total			**11**	**4.120**	**4**	**2.180**	**9**	**3.465**	**5**	**3.405**	**20**	**7.330**	**11**	**5.375**	**14.915**	**10.960**	**25.875**
WP1 Samples and experimental cost				0											0	0	0
WP2 Instruments and experimental co:				0		132								1.200	0	1.332	1.332
Analysis				0											0	0	0
Facilities				0											0	0	0
Operation Total				**0**		**132**		**0**		**0**		**0**		**1.200**	**0**	**1.332**	**1.332**
Travelling PhD 2				250								0			250	0	250
Travel Total				**250**		**0**		**0**		**0**		**0**		**0**	**250**	**0**	**250**
Total				**4.370**		**2.312**		**3.465**		**3.405**		**7.330**		**6.575**	**15.165**	**12.292**	**27.457**

Magnús Þ Jónsson