

Summary of Drilling Fluids Additives and Waste

1.1 Introduction

The tables below are issued as indicative estimates to describe the drilling fluid chemicals and casing cementing chemicals required to drill and complete one geothermal well. To the extent it is practically possible, the drilling fluid will be reused between each hole section and between multiple wells.

All drilling fluids will be in a closed circulating system consisting of tanks at surface and the wellbore. As part of the continuous circulating system the drilling fluid that is circulated out of the wellbore will undergo mechanical treatment (shakers and centrifuges as applicable) as well as occasional chemical treatments before returned to the surface tanks.

Drill cuttings as well as drilling fluid which is deemed unfit for reuse will be disposed of at approved waste treatment plants.

Actual required concentrations of each chemical will depend on hole conditions and geological formations encountered while drilling. Similarly, the actual required volumes will also be determined while drilling based on conditions of the wellbore (geological formation tops, formation washouts, casing design etc.). As the provider (contractor) of drilling fluid chemicals is only identified at a later stage, the product names might change with contractor, however, it is expected that additives will largely remain the same.

1.2 Drilling Fluid Concepts

The aquifers will be isolated with either a conductor or a drilled using a simple environmentally friendly Bentonite/Polymer system.

Drilling activities from below identified aquifer to base chalk at +/-1800 m measured depth will be conducted in one or more sections depending on reservoir conditions and final casing design. The section is planned drilled through use of a simple environmentally friendly Bentonite/Polymer system with weighing agents added if higher mud weights are required.

It is estimated that a total circulating system of 1000 – 1500 m³ is required (reused from previous well if possible) to drill the sections.

Drilling of the section(s) below the base chalk (from +/- 1800 m measured depth to total final depth of +/- 2500 m measured depth) is drilled with a water based system which is designed to fulfil several objectives such as stabilizing reactive and swelling shales/clay, minimize volume of filtrate that enters reservoir formation, minimize seepage losses in sand formations.

It is estimated that a total circulating system of 500 - 1000 m³ is required (reused from previous well or hole section if possible) to drill the section(s).

1.3 Cementing Fluid Concepts

Each of the drilling sections as described in the "Projektbeskrivelse" will be cemented in place such that whole or part of each casing is sealed on the outside according to applicable regulations and best practice. The specific cement fluid recipe and volume will be tailored according to specific encountered wellbore conditions such as temperature, formations encountered, hole conditions etc.

1.4 Expected used volumes, used chemical associated waste generation per well

The summary tables below indicate the estimated consumptions based on experience from drilling of three previous wells in Århus area (Skejbyvej and Sumatravej).

All chemicals used are diluted and forming part of the drilling fluid system in a closed circulating system. Generally, the chemicals used, are posing no or minor risk to the environment even in undiluted form. One exception is biocide which in case of exposure to environment in concentrated form is considered hazardous. Biocide is therefore used at minimum volumes and only in case of deemed absolutely required to mitigate bacterial degradation of the drilling fluids in the closed circulating system.

The list of chemicals will be verified once the final contractors are selected and prior to operation.

Drilling Fluid Chemicals

Additive - Primary	Function	Composition	CAS	Total [kg]
Aluminium Sulfate	Dewatering/removal of fines	Aluminium Sulfate	CAS: 16828-12-9	100
Amine	Shale Inhibitor	Complex compound of Amines	CAS: 68411-90-5	20,000
Barite	Weighting Agent	Barite	CAS 7727-43-7	50,000
Bentonite	Viscosifier	Bentonite	CAS: 1302-78-9	13,000
Biocide	Biocide	Hexahydrotriazine	CAS: 4719-04-4, CAS: 141-43-5	1,000
Calcium Carbonate	Weighting Agent	Calcium Carbonate	CAS: 1317-65-3	110,000
Caustic Soda	Ph Control	Sodium Hydroxide	CAS: 1310-73-2	2,500
Citric Acid	Treat cement contamination	Citric acid anhydrous	CAS: 77-92-9	500
Corrosion inhibitor	Corrosion Inhibitor	Fatty Acids Derivative	CAS: 68909-77-3	2,500
Defoamer	Defoamer	Aqueous polydimethylsiloxane	N/a	200
Encapsulator	Shale Inhibitor	Natural Polymer Derivative	N/a	4,000
Flocculant	Dewatering/removal of fines	Floc Cationic	CAS: 77-92-9	1,000
KCl	Shale Inhibitor/ ionic balance	Potassium Chloride	CAS: 7447-40-7	30,000
Lubricator	Reduce high torque friction	Triglycride / Ester based	CAS: 64742-47-8	20,000
Na-Bicarbonate	Treat cement contamination	Sodium Bicarbonate	CAS: 144-55-8	1,500
NaCl	Weighting Agent	Sodium Chloride	CAS 7647-14-5	65,000
Oxygen scavenger	Oxygen Scavenger	Sodium Sulfite	CAS: 7757-83-7	500
PAC	Viscosity/Fluid Loss	Polyanionic Cellulose	CAS: 9004-32-4	12,000
Polymer	Viscosity	Natural Polymer	N/a	2,000
ROP Enhancer	Improve ROP	Surfactants	CAS: 934242-87-2, 111-76-2	10,000
Sodium Carbonate	Ph Control	Sodium Carbonate	CAS: 497-19-8	1,500
Starch	Fluid loss	Starch	CAS 9049-76-7	4,000
Wellbore Stabilizer	Stabilizing weak formations	Fines	CAS: 9005-25-8	10,000

Additive - Standby	Function	Composition	CAS	Total [kg]
Biostabiliser		Hop Extract	N/a	Contingency
Fibers	Fluid loss	Mineral Fibres	N/a	Contingency
Polyglycol	Shale Inhibitor	Polyglycol	CAS: 143-22-6, 1559-34-8, 112-34-5	Contingency
Silicate	Shale Inhibitor/ ionic balance	Na-Silicate	CAS: 1344-09-8	Contingency
Silicate	Shale Inhibitor/ ionic balance	K-Silicate	CAS: 1312-76-1	Contingency
Sodium Bromide		Sodium Bromide	CAS: 7647-15-6	Contingency

Cementing Chemicals (awaiting input from cementing contractor)

Additive - Primary	Function	Composition	CAS	Total [kg]
Antifoam	Prevent foaming	N/A	N/A	250
Barite	Weight	Barite	13462-86-7	20,000
Calcium Carbonate	Weight	Calcium Carbonate	14808-60-7	6,000
Cement Class C	Cement	Portland Cement Clinker	65997-15-1	40,000
Cement Class G	Cement	Portland Cement Clinker	65997-15-1	110,000
Cement Class HOZ	Cement	Cement, lime, salt, flue ash	65997-15-1;1317-65-3;68475-76-3;7778-18-9	10,000
Dispersant	Dispersant	N/A	N/A	10,000
Expanding Agent	Tight slurry	Calcium magnesium oxide	37247-91-9	500
Extender	Filler	Fly ash; Silica	68131-74-8; 14808-60-7	3,000
Fluid Loss	Minimize dehydration	N/A	N/A	1,500
Polymer	Viscosity	N/A	N/A	200
Retarder	Increase pumping time	N/A	N/A	1,000
Sodium Chloride	Weight	Sodium Chloride	7647-14-5	5,000

Waste stream

	Volume [m3]	Weight [MT]
Drill cuttings (wet) per well	600 - 800	1300 - 1800
Waste fluids per well	800 - 1000	900 -1200