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KLAIPEDA GEOTHERMAL DEMONSTRATION PROJECT

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ABSTRACT

In 1996 a new project for the use of geothermal energy was initiated. The proposed project consists of a pilot "demonstration" plant representing the first phase in the development of geothermal resources for space heating in Klaipeda city and other urban areas of Lithuania. Four geothermal wells were drilled, completed and tested during the two years and will be used for heating purposes. The above-ground facilities are under construction. Geothermal water will be extracted from production wells and returned with reduced temperature to the same depth through two injection wells to maintain formation pressure and to avoid causing water pollution problems. Geothermal heat will be transferred to the district heating network of Klaipeda by four LiBr absorption heat pumps which are driven by hot water (175 ^{0}C, 10 bar) from boilers. The driving heat for the absorption heat pumps will be supplied to the district-heating network together with geothermal heat.

The technology required for utilisation of the available low-temperature geothermal heat in existing district heating networks is well developed and is being employed in several European towns and cities. The plant shall extract up to 20 MW heat with absorption heat pumps from up to 700 m^3/h of 38 ^{0}C, 14 % salinity geothermal water. The proposed project will have only positive environmental impacts as no emissions will be generated, and it will also significantly reduce the use of fossil fuels. The geothermal plant will result in annual reductions of emissions of CO_2 and NO_x by 52 000 and 270 tons respectively.

1. INTRODUCTION

Preliminary geoscientific evaluations with regard to the geothermal energy potential, together with initial assessments of the economics and technical conditions related to geothermal development within Lithuania were carried out during 1992. The project was initiated with the purpose of determining the size and quality of geothermal resources in Latvia and Lithuania and assessing the potential for utilising geothermal energy to replace currently used fossil fuel for heat generation. With the temperature of the geothermal water resources being between 30 – 95 ^{0}C, the energy could only be utilised economically for heating by requiring access to a district heating system. The project confirmed that substantial geothermal aquifers occur within the Devonian and Cambrian strata, and it identified a number of cities where the use of geothermal energy could substitute for fossil fuel for up to 30% of energy consumption, dependent on the actual aquifer temperature.

Geologically the general Klaipeda area is part of the Baltic Basin, occupying the major Baltic Sea as well as the Estonian, Latvian and Lithuanian land areas. The main objective geological section comprises the Lower Devonian D_1 km (Kemeri) formation located at 963 m MSL within the project area.

For possible extraction of heat from geothermal water, eight potential locations including Klaipeda, Silute, ŠSilale, Siauliai and Radviliskis were analysed. After evaluation of data received in the course of investigations, Klaipeda City was selected as the optimal location for the construction of the geothermal demonstration plant which extracts heat from geothermal water pumped out of the Devonian aquifer.

Economic sources of geothermal energy in Klaipeda region are evaluated as 1460x10^{15} J, but only 30% of the energy, i.e. only 440x10^{15} J are available for space heating purposes. However, this energy is sufficient for Klaipeda City demands for 100 years if the current 4420 TJ/year utilisation is maintained. The population of Klaipeda city is 206,000. 88% of the population is provided with heat by a district heating system. The geothermal plant shall be erected next to the Eastern Boiler House owned by SPAB "Klaipedos energija". Prospective production of heat in the geothermal plant shall cover only about 25% of the yearly Klaipeda City heat demands. Net geothermal energy shall amount to 598 TJ/year.

2. KLAIPEDA GEOTHERMAL DEMONSTRATION PROJECT

2.1. Objectives of the Project

The proposed Klaipeda Geothermal Demonstration Project which shall provide heat to the district heating system shall be the first project in the Baltic states which conforms with the objectives of the demonstration project.

The main objectives of Klaipeda Geothermal Demonstration Project are:

a) to demonstrate the feasibility and value of using *low temperature geothermal water* as a renewable indigenous energy resource in district heating systems;
b) to improve the technological use of geothermal energy and the promotion of this kind of energy in the country;
c) to reduce emission of greenhouse gasses and sulphur dioxide by replacing heavy fuel oil with a sulphur content of 3,5 %;
d) to promote sustainable management and the development of environmentally sound and non-polluting geothermal resources from both a national and regional perspective.

2.2. Preliminary results.

Two geothermal production wells and one injection well (required to return the used geothermal water to the same depth) were drilled.

Based on the test evaluation the following main conclusions were made:

a) it seems reasonable that the two production wells will be capable of providing up to 800 m^3/hour, which is far above the expected value - 600 m^3/hour, of gethermal water;
b) there exists effective communication between the production wells and injector well KGDP – 1I.

c) the injection capacity in well KGDP –1I is conclusively insufficient for the injection of 700 m^3/hour of geothermal water. The test results from well KGDP –1I conclusively demonstrated considerable aquifer formation damage combined with reduced aquifer quality as compared to the predictions.
d) the reservoir evaluation revealed a lower than predicted geothermal water temperature. Hence producing wellhead water temperature was monitored at 38 ^{0}C rather than at the 42 ^{0}C as expected.

In order to achieve an annual heat production at 500 TJ p.a. therefore requires an increased water production and injection rate from 600 m^3/hour to 700 m^3/hour. This required the construction of an additional geothermal injection well. The present productivity and flow efficiency of the wells is shown in the table 1.

The corrosion properties of the geothermal water were investigated. The corrosion rate of the geothermal water has been measured to be 0.1 – 0.2 mm per year in carbon steel. The primary agent of corrosion seems to be carbon dioxide and the corrosion rates should be taken as indicative of actual corrosion in the system depending on the pressure and temperature of the system and deposits formed on the pipe walls. However, the present conclusion is that normal steel can be used with 5 mm corrosion allowance and the moving parts such as balls in ball valves can, for example, be AISI 316. The carbon steel should, however not contain more than 0.02 % of S. Special consideration must be taken to welds, which can be corroded by the carbon dioxide. Corrosion is avoided by using special materials and special gas. Precipitation problems are not expected; however, the down-hole sample was not analysed due to the lack of pressure on the testing bottle.

With the help of petrophysical research it is able characterises the Devonian (Kemery) sandstone as follows:

- Net sand thickness 50-60 M
- Reservoir permeability 1.2-2.7 Darcy
- Reservoir porosity 23-27%
- Well productivity 14-47 M^3/h/bar

Water with a high mineral content has more than 96 % NaCl and CaCl. The pH-value is up to 6.3. One litre of geothermal water contains 160 ml of dissolved gas. Approximately 94 % of this gas is N_2. The static water level reaches to over 20 m.

The completions of the production and injection wells were carried out with a gravel-pack installation screen at the depth interval 975 – 1118 m. The geothermal water will be pumped out by submersible pumps with the flow rate of 300 to 400 m^3/h and a pressure head 245 m. Injection pumps will pump the cooled geothermal water back into the aquifer.

2.3. Project technology

The Klaipeda Geothermal Demonstration Project involves the circulation of 700 m^3/h of 38 ^{0}C geothermal water from about 1100 metres depth via a closed geothermal loop (figure 1), utilising heat pumps for the retrieval and subsequent supply of heat into the existing district heating network in Klaipeda. The geothermal water would be extracted from two production wells and returned with reduced temperature through two injection wells to the same depth to maintain formation pressure and to avoid creating water pollution problems. The loop is designed based on the same concept used at the Thisted geothermal plant in Denmark, which has been in operation since 1984. This design has been chosen because of the close similarities of aquifer parameters at Klaipeda and Thisted.

The geothermal loop is designed using corrosion-resistant materials for piping, welding and valves. The piping material is made of diffusion-proof carbon steel and the valves are air proof. The geothermal water circulated into the system will be pre-filtered to avoid deposition of scale. The loop will be operated at over pressure to eliminate the entry of oxygen from the air into the system; over pressure in the loop will be maintained during stoppage using pressured nitrogen cylinders.

Heat is extracted from geothermal water using an absorption heat pump. The configuration of the heat absorption pump comprises an evaporator, an absorber, a condenser and a working fluid generator. The pump uses lithium bromide (LiBr) solution as the heat absorbent working fluid. Water-lithium bromide absorption uses the principle of water vapour affinity for an aqueous solution of lithium bromide. When water vapour at temperature T comes in contact with a concentrated solution of LiBr (concentration about 62 %), it is absorbed in this solution by condensation of LiBr. To allow the water vapour to condense, the corresponding amount of heat is extracted in an exchanger called absorber.

The absorption heat pump is driven by 175 ^{0}C hot water from the boiler, which is part of the Klaipeda Geothermal Demonstration Plant. The heat supplied by the boiler to operate the pump would then be transferred to the district heating network together with the extracted geothermal heat. The single-effect absorption heat pumps for Klaipeda Geothermal Demonstration Plant are tailor-made equipment in order to obtain optimum performance. The pumps are designed for the required operating conditions, as well as to have the best cooling effect with high COP while guaranteeing the reliability of the equipment. The design of the heat pumps is based on horizontal-tube falling film exchangers.

Absorber and evaporator tube bundles are installed in one shell mounted on a skid, whereas the generator and the condenser will be installed in a separate shell which will then be installed on top of the lower skid. Each heat pump is completely mounted on the skid with all auxiliary equipment. 4 identical units will be installed in Klaipeda Geothermal Demonstration Plant. Each unit consists of a serial connection of 2 groups of heat pumps, each group including 2 heat pumps connected in parallel. The district heating water is heated in the group 1 absorbers. It then enters the group 2 absorbers, goes into the group 1 condensers and exits through the group 2 condensers. The geothermal water is first cooled in the group 2 evaporators and then cooled to the exit temperature in the group 1 evaporators (Figure 1).

The design procedures and material selection are made in order to provide a lifetime of at least 25 years.

2.4. Project management and financing.

For the purposes of the construction and operation of the Klaipeda Geothermal Demonstration plant, a company (UAB "Geoterma") was founded with the Following shareholders:

- Ministry of Economy of the Republic of Lithuania,
- AB "Lietuvos energija".

UAB "Geoterma" is responsible for the project leadership and management of the geothermal and heating systems of the whole geothermal plant.

The construction of the geothermal heating plant consists of:
- establishment of two production and two injection wells;
- above-ground facilities including buildings and necessary equipment such as absorption heat pumps, water boilers, and auxilary equipment for control and regulation of the plant and the heat transfer to the Klaipeda district heating system; and
- piping between production wells and geothermal plant, as well as piping from the geothermal plant to the injection wells, and piping between the geothermal plant and the district heating network.

The Klaipeda Geothermal Demonstration Project is the first project to be financed through the World Bank in which the geothermal energy transferred to the district heating system uses heat pump technology. The Project is included in the National Energy Strategy Programme. The project adds to the obligations of Lithuania to develop renewable energy sources and follows requirements of both the Montreal Protocol (Convention) and the 1992 United Nations General Climate Change Convention ratified by Seimas of the Republic of Lithuania. These obligations include reduction of environmental pollution and support of advanced technologies. The Global Environmental Facility Trust Fund and Danish Environmental Protection Agency through the World Bank included input of the Klaipeda Geothermal Demonstration Project into overall environmental protection (decrease in emission of particulates, CO_2, SO_2 and NO_X gases which produce the "greenhouse effect"). In order to support technologies which cut down emission of gases producing the "greenhouse effect", the Global Environmental Facility Trust Fund and Danish Environmental Protection Agency provided subsidies for the project.

Table 1. Productivity and flow efficiency of the wells.

Well	Productivity[1], $m^3/h/bar$	Flow efficiency[2], %
KGDP – 1I	14	56
KGDP – 2P	26	52
KBDP – 3P	47	94
KGDP – 4I[3]	49.2	76

[1] Productivity and flow efficiency have been evaluated for a 12 hours production time and at reservoir level, i.e. the fiction loss from top of screen to surface is not included.
[2] Flow efficiency = (actual productivity)*100/(ideal productivity). The ideal productivity is the undamaged producing capacity, i. e. with skin factor = 0.
[3] After completion and gravel packing a short-term airlift test was performed.

Investments and Financing Sources for Klaipeda Geothermal Demonstration Project [4]

- Global Environmental Fund (GEF) 27.60 LTL
- The Government of Danmark 12.00 LTL
- The Government of Lithuania 14.28 LTL
- The World Bank 23.60 LTL
- **Total 77.48** LTL

The plant will come on stream in the spring of 2000.

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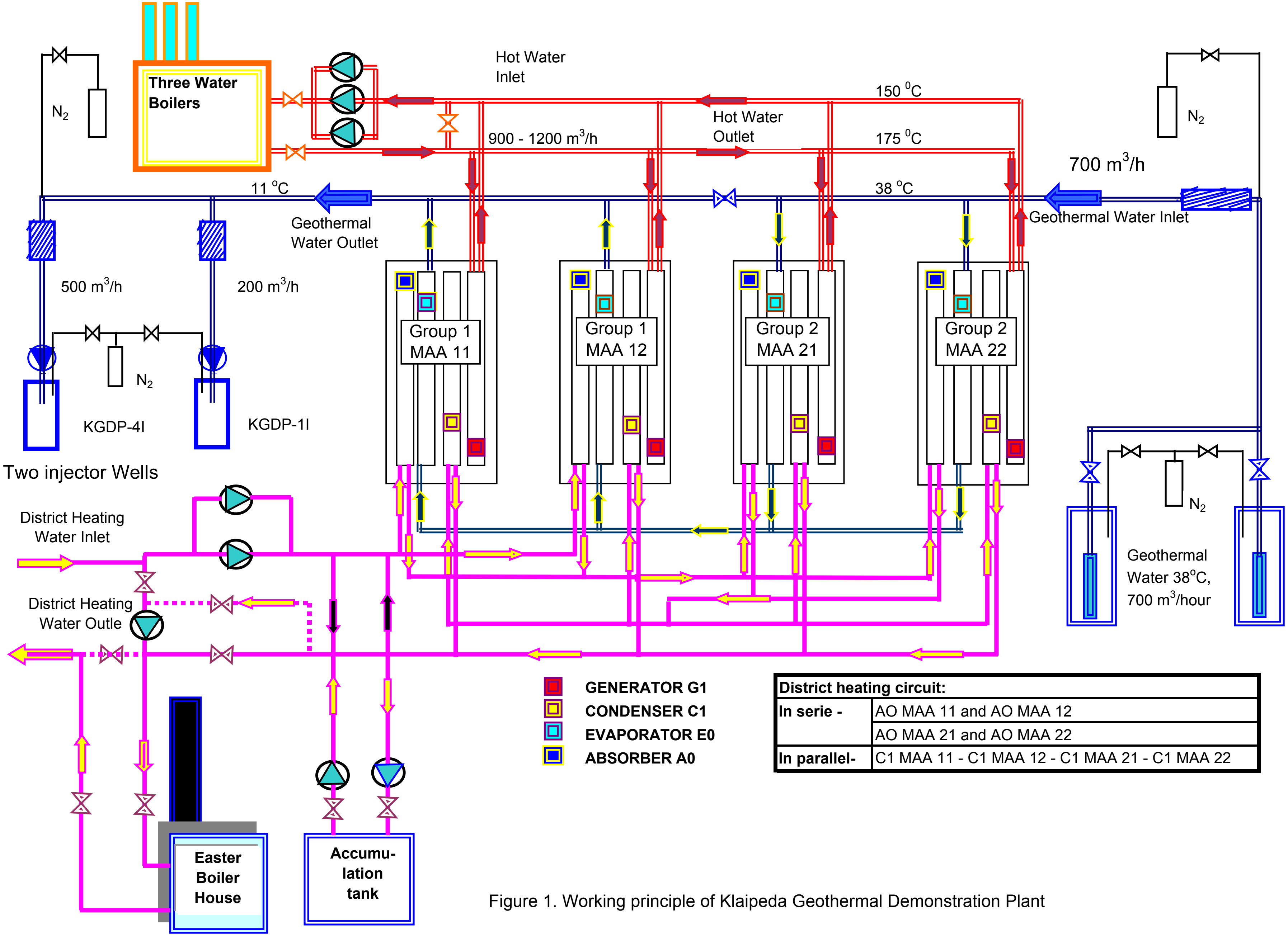

District heating circuit:	
In serie -	AO MAA 11 and AO MAA 12
	AO MAA 21 and AO MAA 22
In parallel-	C1 MAA 11 - C1 MAA 12 - C1 MAA 21 - C1 MAA 22

Figure 1. Working principle of Klaipeda Geothermal Demonstration Plant