

Table of Contents

Abstract	7
From the Editor.....	8
Introduction.....	9
Chapter 1	
Heat pumps	11
1.1. Principles of heat pump operation.....	12
1.2. Construction of heat pumps.....	14
1.3. Working agents.....	15
1.4. Low-temperature heat sources	17
1.4.1. Rock mass	18
1.4.2. Confined groundwater	18
1.4.3. Surface water.....	19
1.4.4. Solar energy.....	19
1.4.5. Technological processes	19
1.4.6. Waste.....	19
1.4.7. Infrastructure.....	20
1.5. Heating, cooling and heating-and-cooling systems based on low-temperature heat.....	20
1.6. Energetic and economic efficiency of heat pumps	21
Chapter 2	
BHE structure.....	26
2.1. BHE parameters.....	27
2.2. Classical BHEs.....	28

2.3. Deep BHEs.....	29
2.3.1. Turaszówka	30
2.3.2. Prenzlau (Germany).....	32
2.4. BHE with direct evaporation	33
2.5. Slant BHEs - geothermal radial drilling (GRD)	35
2.6. Energy piles.....	39
2.6.1. Advantages and disadvantages of using energy piles	42
2.6.2. Requirements of cement slurries for bearing piles.....	42
 Chapter 3	
Energetic efficiency of BHEs	46
3.1. Literature values (from the lithological profile)	46
3.2. Temperature profiling	47
3.3. TRT	54
3.3.1. TRT device components	55
3.3.2. Stages of a Thermal Response Test	56
3.3.3. Duration of a Thermal Response Test	57
3.3.4. Calculation methodology	57
3.3.5. Exemplary interpretation of TRT	62
3.4. Heating power of a larger amount of exchangers.....	65
 Chapter 4	
Mathematical model of heat transfer in a BHE.....	66
4.1. Numerical model of heat transfer in a BHE.....	73
4.2. Results of calculations of heat transfer in a BHE.....	74
4.3. Lithological variability.....	75
4.4. Earth's internal heat flow	78
4.5. Heating power for different lithological formations	81

4.6. Coaxial BHE	82
Chapter 5	
Pressure loss in BHEs	88
5.1. Assumptions	89
5.2. Pressure losses	93
5.3. Deep BHE in Poland	101
5.4. Analysis of the diameter of BHE production pipes in the view of the heat carrier flow rate.....	104
Chapter 6	
BHE drilling and construction	112
6.1. Rotary drilling	113
6.2. Rotary drilling using a mud motor and coiled-tubing	120
6.3. Rotary-percussion method	123
6.4. Double head rotary drilling.....	130
6.5. GeothermalRadialDrilling (GRD).....	132
6.6. Augering.....	134
Chapter 7	
Sealing slurries used in BHEs	135
7.1. Selection criteria for sealing slurries in BHEs	135
7.2Laboratory tests on fresh sealing slurries	136
7.3. Laboratory tests on hardened sealing slurries	142
7.4. Materials increasing thermal conductivity applied in sealing slurries	145
7.5. Specialized mixes used for sealing BHEs	146
7.6. Technique and technology of sealing BHEs.....	148

Chapter 8

The Laboratory of Geoenergetics at Faculty of Drilling, Oil and Gas at AGH UST in Krakow, Poland.....	150
8.1. Test posts at the Laboratory.....	157
8.2. Description of test posts.....	157
8.3. Functions of the Laboratory of Geoenergetics	165

Chapter 9

Using the thermal potential of rock masses with BHEs	169
9.1. Origins of heat accumulated in the rock mass	169
9.2. Technical methods of exchanging heat with the rock mass	170
9.3 Possible application of BHEs.....	173
Conclusions.....	181
Acknowledgements	181
Bibliography.....	182