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ENERGY, ECONOMIC AND ENVIRONMENTAL ANALYSIS OF BALNEOTHERAPY

ENERGY, ECONOMIC AND ENVIRONMENTAL ANALYSIS OF BALNEOTHERAPY

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DIPLOMA THESIS

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PODKLADY A LITERATURA

Applicable laws, ordinances, regulations and standards related to the solving theme of diploma thesis.
Domestic, European and world literature, proceedings of scientific conferences and professional events in the field of HVAC.
Sources on the Internet.
Data from solved building.
Detailed information and further clarification of diploma thesis provides supervisor during consultation.

ZÁSADY PRO VYPRACOVÁNÍ

The thesis will be processed in accordance with applicable regulations (laws and regulations, standards).
A. Analysis of the theme, objectives and methods of solution
The analysis of a given topic, normative and legislative requirements
The aim, the chosen methods of solution
Relevant technical solutions in practice
Theoretical solutions (using the physical phenomena of processes)
Experimental solutions (description of methods and instrumentation)
B. Application of the topic at the solved building - conceptual design
Design of technical solution in given specialization (including documented calculations) in basic drawings and diagrams, technical report.
Evaluation of the current state of solutions, analysis of potential efficiency measures, space requirements, economy of operation, etc .
C. Experimental solutions and processing of results
Experimental measurements carried out in real operation involving a subset of a given topic.

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doc. Ing. Jiří Hirš, CSc.
Vedoucí diplomové práce

ABSTRACT

The aim of this diploma thesis is to point out European Union´s goals such as low carbon economy, mainly future increasing the use of renewable sources as a potential source of energy. Slovak republic has due to its position in central Europe, rich in natural healing sources of water, which are considered as the most perspective sources of renewable energy in this country.

The problem was solved as energy, economic and environmental analysis of Balneotherapy at Slovak Heath Spa Piešťany a.s. This analyzation was provided by real experimental measurement of temperature and flow rate and computational simulation of technological devices in opened natural healing water system. Experimentally measured data were afterwards use for elaboration conceptual design of new technological devices in order to increase efficiency of collection energy from potential renewable source of energy.

The research shows that with help of new design technological devices connected to existing ones will be possible to cool down temperature of hot natural healing water from 67 °C to 21 °C, which decrease operation costs of Balneotherapy for more than 1 414 € per day.

By Slovak republic entering to European Union it was necessary to accept global goals of low carbon economy. This diploma thesis provides an attention on potential energy in natural healing sources of water as renewable source of energy and helps Slovak Health Spa Piešťany to decrease amount of green-house gases released to atmosphere by efficient increasing the use of energy potential in natural healing source of water.

KEYWORDS:

natural healing source of water, heat exchanger, Low-carbon economy, Balneotherapy, renewable source of energy,

ABSTRAKT

Cieľom diplomovej práce je vyzdvihnúť nízko-uhlíkovú ekonómiu Európskej Únie, hlavne budúce zvýšenie využiteľnosti obnoviteľných zdrojov ako potenciálny zdroj energie. Slovenská republika je vďaka je pozícií v strednej Európe, bohatá na prírodné liečive zdroje vody, ktoré sa považujú za najperspektívnejšie obnoviteľné zdroje energie v tejto krajne.

Zadanie bolo riešené ako energetická, ekonomická a environmentálna analýza Balneoterapie v Slovenských Liečebných Kúpeľoch a.s. v Piešťanoch. Analýza bola uskutočnená experimentálnym meraním teploty a prietoku a počítačovou simuláciou technologických zariadení otvoreného systému prírodne liečivej vody. Experimentálne namerané dáta boli nasledovne využité pri koncepčnom návrhu nových technologických zariadení za účelom zvýšenia účinnosti získavania energie z potenciálneho obnoviteľného zdroja energie.

Výskum ukázal, že za pomoci novo navrhnutých technologických zariadení pripojených k existujúcim bude možné schladiť horúcu prírodne liečivú vodu z 67 °C na 21 °C, čo zníži náklady na prevádzku Balneoterapie o 1 434 € za deň.

Vstupom Slovenskej republiky do Európskej Únie bolo nutné prijať všeobecné ciele nízko-uhlíkovej ekonómie. Táto diplomová práca poukazuje na energetický potenciál v prírodne liečivých zdrojoch vody ako obnoviteľných zdrojov energie a napomáha Slovenských Liečebných Kúpeľoch a.s. v Piešťanoch znížiť množstvo vypúšťaných skleníkových plynov do atmosféry účinným zvýšením využívania energetického potenciálu prírodne liečivej vody.

KLÚČOVÉ SLOVÁ:

prírodne liečivý zdroj vody, tepelný výmenník, nízko-uhlíková ekonómia, Balneoterapia, obnoviteľný zdroj energie,

BIBLIOGRAFICKÁ CITACE VŠKP

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Declaration:

I declare that, diploma thesis was written individually by myself and I stated all used information sources.

In Brno 12.1.2018

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In Brno 12.1.2018

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Signature of author

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CONTENT

1. INTRODUCTION

“Unity in diversity”, the motto of the European Union, first came into use in the year 2000. It signifies how the European have come together, in the form of the EU, to work for peace and prosperity, while at the same time being enriched by the continent’s many different cultures, traditions and languages. [10]

According to the referendum listed in 2003 by the president of Slovak republic Rudolf Schuster, 92, 46 % of native citizens accepted entering of the Slovak republic into the European Union. This milestones means not only promise of using local requirements and laws but although to fulfill general goals and ideas of the EU. [11]

The low-carbon economy belongs to the one of the biggest EU goal´s which the European commission is looking at. The roadmap suggest that, by 2050, the EU should cut its emissions to 80 % below the year 1990 levels through domestic reductions alone (i.e. rather than relying on international credits). This is in line with EU leader´s commitment to reducing emission by 80 – 95 % by 2050 in the context of similar reductions to be taken by developed countries as a group. To reach this goal, the EU must make continued progress towards a low-carbon society. Clean technologies play an important role. [16]

The Slovak Republic has due to its position in the Central Europe, environment and climate condition from global point of view rich in the natural healing sources of water. The natural healing sources of water are primary used for healing procedures at spas and are protected from the law against using them as commercial source of energy.

The Slovak Health Spa in Piešťany, Slovakia worldwide belongs to the most well knowns spas, due to its results in healing procedures. Behind this success stands complicated systems of accumulating and transporting of NHS water into individual departments of spa, which after certain time needs to be modernized and analyzed from the economic, environmental, energy point of view.

This diploma thesis aims on current state analyzation of accumulation station which is the main transporting the NHS water system component and developing innovations in technological processes to effectively fulfill the European Union´s goal concerning the low-carbon economy.

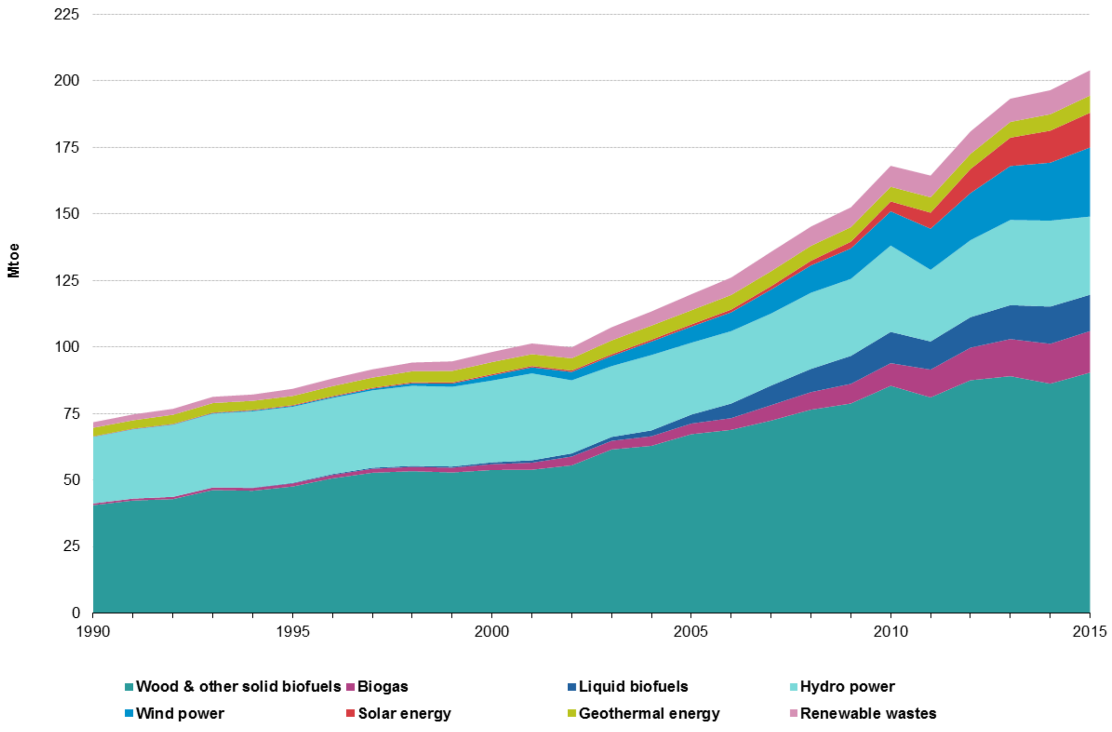
2. ANALYSIS OF THE THEME , OBJECTIVES AND METHODS OF SOLUTION

The subject of this chapter is to provide general theoretical information about the aim of this diploma thesis, concerning analysis of the given topic, normative and legislative requirements, the aim, the chosen methods of solution, relevant technical solutions (using physical phenomena of processes), experimental solutions (description of methods and instrumentation).

2.1. POLITICS OF EUROPEAN UNION CONCERNING RENEWABLE SOURCES OF ENERGY

The use of renewable energy has many potential benefits, including a reduction in greenhouse gasses emissions, the diversification of energy supplies and a reduced dependency on the fossil fuel markets (in particular, oil and gas). The growth of renewable energy sources may also have the potential to stimulate employment in the EU, through the creation of jobs in new "green" technologies. [12]

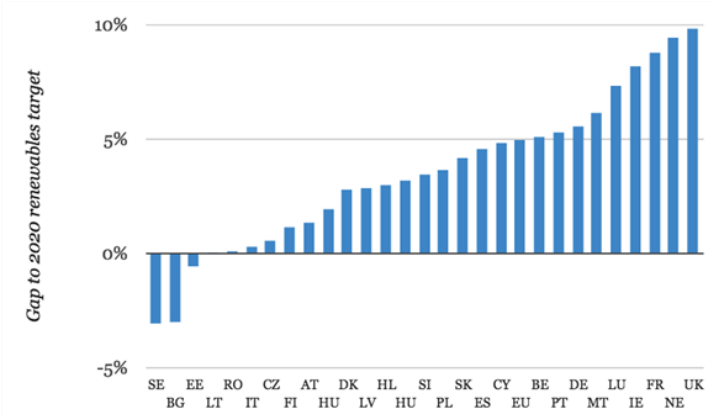
The Renewable Energy Directive establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20 % of its total energy needs with renewable by 2020 – to be achieved through the attainments of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020 (Picture 2.1.). [12]



Picture 2.1. – Primary production of energy from renewable sources [12]

2.1.1. European Union: 2020, 2050 goals

The aim of Slovak politics is to use renewable sources of energy in ratio to gross final consumption of energy from 6, 7 % in 2005 to 14% till the year 2020. The essential document in relationship with reaching this goal is National action plan for energy from renewable sources of energy, which government granted at 6th of October 2010, government resolution SR c. 677/2010. The goal of this resolution is to reach 15,3 % from use of renewable sources of energy in ratio to gross final consumption of energy. Energetic politics of SR is influenced by European Union, which wants to decrease the number of greenhouse gases by 20 %, increase the energetic efficiency up to 20 % and use of renewable sources by 20 % till the year 2020 – Picture 2.2. and Table 2.1. [17]

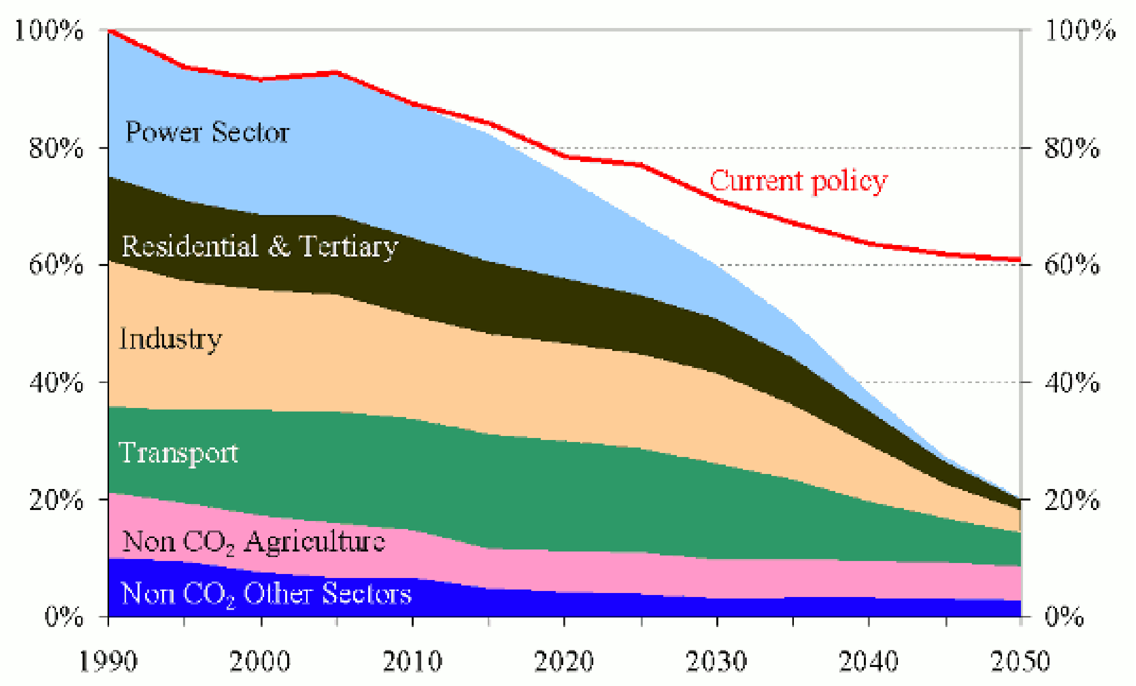


Picture 2.2. - Graph of 2020 goals [13]

Table 2.1. - Estimation of using renewable sources of energy till the year 2020 [15]

Renewable source of energy	Production in year 2002	Production in year 2010	Production in year 2020
	GWh	GWh	GWh
Geothermal energy	**0**	**1**	**40**
Wind energy	0	100	550
Solar energy	0	0	10
Small water power stations	245	350	600
Biomass	153	350	1300
Biological fuels	6	52	500
Sum of energy:	404	853	3000
Water power stations	4924	5000	5300
Sum of energy:	5328	5853	8300

According to the European low-carbon economy roadmap it is suggested that, by the year 2050, the EU should cut emissions to 80 % below 1990 levels. Milestones to achieve this are 40 % emissions cut by 2030 and 60 % by 2040. All sectors need to contribute. The low-carbon transition is feasible and affordable – Picture 2.3.. [7]



Picture 2.3. – Possible 80 % cut in greenhouse gas emissions in the EU (100% =1990) [7]

2.2. NATURAL HEALING SOURCE AS RENEWABLE SOURCE OF ENERGY IN SLOVAK REPUBLIC

Currently the NHS energy is used at almost 40 locations and next 26 are considered to be new source of renewable energy.

At the depth 1000 m under the therian level, should has the natural healing water temperature around θ = 40 °C, this fact influence the surface temperature. The water is getting into this depth primary by curtain from mountain ridges after rainfall. In Liptovský Mikuláš region reach the limestone mountains the depth around two kilometers and the water is naturally heated to the temperature θ = 60 – 70 °C. [26]

2.2.1. Potential natural healing source of water at Slovak republic

A Spa area is declared town territory or the part of town territory, on which are located the natural healing water sources, the natural healing spa, the healing spa and other devices necessary for providing healing procedures. [19]

A Spa territory is comprehensive territory at the spa area, which size is defined in the statute of the spa area. At the spa area is applied protection of a spa regime. [19]

The regulation No. 446/2006 Z.z. issued by the Slovak government were assigned statutes of the spa area, which can be seen in Table 2.2. with the resolution number of the Slovak government. At the Slovak Republic only this places are allowed to provide healing procedures by using natural healing sources. [19]

Table 2.2. - Overview of license holders for the operation of natural healing spa and spa treatment [4]

Overview of license holders for the operation of natural healing spa and spa treatment			
No.	**License holder**	**No. of resolution**	**Type of using**
1.	Bardejovské kúpele a.s	13.12.2006	PLK-PLZ
2.	Kúpeľno.liečebný ústav MV SR Družba, Bardejovské Kúpele	6247-147/2008/ŠKK, 23.01.2008	KL-PLZ
3.	Kúpeľe Bojnice a.s.	19.12.2006	PLK-PLZ
4.	Kúpele Brusno a.s.	09.06.2005	PLK-PLZ
5.	Prírodné jódové kúpele Číž, a.s.	06.09.2005	PLK-PLZ
6.	Kúpele Dudince a.s., Dudince	164/2008/ŠKK,	PLK-PLZ
7.	SLOVTHERMAE, Kúpele Diamant Dudince š.p.	28242-73/2006/ŠKK, 13.12.2006	KL-PLZ
8.	Kúpele Horný Smokovec s.r.o.	07.12.2006	PLK-KPVL
9.	Kúpele Nový Smokovec a.s.	20.12.2006	PLK-KPVL
10.	Tatrasan, s.r.o., Nový Smokovec	02.02.2007	KL-KPVL
11.	Wellness Kováčová s.r.o.	20.06.2006	PLK-PLZ
12.	Špecializovaný liečebný ústav Marina š.p. , Kováčová	28104-65/2006/ŠKK, 11.12.2006	KL-PLZ
13.	Kúpele Lučivná a.s.	13.02.2008	PLK-KPVL
14.	Kúpeľno-rehabilitačný ústav MV SR BYSTRÁ, Liptovský Ján	27856-92/2006/ŠKK, 21.12.2006	KL-KPVL
15.	Liptovské liečebné kúpele a.s., Lúčky	235/2008/ŠKK,	PLK-PLZ
16.	Kúpele Nimnica a.s.	27.08.2007	PLK-PLZ
17.	**Slovenské liečebné kúpele Piešťany a.s.**	**12068-168/2008/ŠKK,**	**PLK-PLZ**
18.	Slovenské liečebné kúpele Piešťany a.s. - prevádzka Smrdáky	168/2008/ŠKK, 14.04.2008	PLK-PLZ
19.	Vojenské zdravotnícke zariadenia a.s. Piešťany	27284-79/2006/ŠKK, 13.12.2006	KL-PLZ
20.	Slovenské liečebné kúpele Rajecké Teplica a.s.	16785-2/2005, 02.06.2005	PLK-PLZ
21.	Kúpele Sliač a.s.	23.11.2006	PLK-PLZ
22.	Liečebné termílne kúpele a.s., Sklene Teplice	6531-1/2007/ŠKK, 17.01.2007	PLK-PLZ
23.	Kúpele Štós, a.s.	09.01.2007	PLK-KPVL
24.	Sanatórium Tatranská Kotlina n.o.	14.04.2005	KL-KPVL
25.	Sanatórium Dr. Guhra n.o., Tatranská Polianka	6378-3/2007/ŠKK, 18. 01.2007	KL-KPVL
26.	Vojenské zdravotnícke zariadenia a.s. Piešťany, prevádzka Tatranské Matliare	29068-88/2006/ŠKK, 20.12.2006	PLK-KPVL
27.	Kúpele Trenčianské Teplice a.s.	17.03.2008	PLK-PLZ
28.	Kúpeľno-liečebný ústav MV SR ARCO, Trenčianské Teplice	28241-67/2006/ŠKK, 18.12.2006	KL-PLZ
29.	Slovenské liečebné kúpele Turčianské Teplice, a.s.	06367/2006-SP, 12.05.2006	PLK-PLZ
30.	Kúpele Vyšné Ružbachy, a.s., Vyšné Ružbachy	07054/2006-SP, 13.02.2006	PLK-PLZ

LEGEND:

PLK Natural healing spa
KL Spa treatment
PLZ Natural healing sources

KPVL Climatic conditions beneficiant for healing

2.2.1.1. Mineral water

According to the law 538/2005 Z. z. mineral water is underground water which is originally accumulated in a natural environment and pouring out of the ground by the one or more natural or artificial exit drills, which differs from other underground water by [18]:

- its origin
- the content of trace elements
- the content and character of total diluted solid particles exceeding 1000 $mg.l^{-1}$ or by the content of dissolved gas particles exceeding 1000 $mg.l^{-1}$ of Carbon Dioxide, or at least 1 $mg.l^{-1}$ of Sulfur
- minimal temperature 20 °C [18]

2.2.1.2. Natural Healing water

According to law 538/2005 Z. z. the natural healing water is mineral water, which was due to its composition sufficient for healing procedures recognized by the State Spa commission of the Ministry of Health of the Slovak republic [18]:

2.2.1.3. Natural healing source of water

The natural healing source of water is source of the mineral water, from which was water recognized by the State Spa commission of the Ministry of Health of the Slovak republic as a natural healing water according to the law 538/2005 Z. z. [18]:

According to the conception of geological research and investigation at the territory of Slovak republic from the year 2011, Slovakia has a great energetic potential of the NHS. These renewable sources are split over the whole country and its using has economic and ecological benefits.

A technical exploitable potential of the individual renewable sources is shown at Table 2.3., where is although shown the energetic potential of the unused renewable sources, which could be used after the introduction of available technologies, breaking administration and ecological barriers. Nowadays we can say, that the most energetic potential has biomass (over 44 %), then the geothermal energy (16, 6%), the solar energy (13, 7%), the waste management (9, 3%), the biological fuels (6, 6%) and the wind energy (1, 6%). [25]

The division of the geothermal sources at Slovakia is: [25]

- Sources with low temperature from 20 °C to 100 °C
- Sources with medium temperature from 100 °C to 150 °C
- Sources with high temperature more than 150 °C

For the better understanding at Table 2.4. is shown the division of geothermal sources of the water according to individual authors and their categorization of the temperature of the geothermal sources. [25]

The substantiality is given in ls^{-1} or m^3h^{-1}. According to this we divide the sources: [25]

- With slight substantiality – less than 1,0 ls^{-1}
- With very low substantiality – from 1,0 ls^{-1} to 5,0 ls^{-1}
- With low substantiality – from 5,0 ls^{-1} to 10,0 ls^{-1}
- With medium substantiality – from 10,0 ls^{-1} to 25,0 ls^{-1}
- With large substantiality – from 25,0 ls^{-1} to 50,0 ls^{-1}
- With very large substantiality – more than 50,0 ls^{-1}

Table 2.3. - Technical exploitable potential of individual renewable sources [25]

Name of renewable source	Technical exploitable potential		Present using of source		Unused energetic potential	
	TJ/r	GWh/r	TJ/r	GWh/r	TJ/r	GWh/r
Geothermal energy	**22 680**	**6 300**	**1 224**	**240**	**24 456**	**5 960**
Wind energy	2 178	605	0	0	2 178	605
Solar energy	18 720	5 200	25	7	18 695	5 193
Small water power stations	3 722	1 034	727	202	2 995	832
Biomass	60 458	16 794	11 491	3 192	48 967	13 602
Waste management	12 726	3 535	4 504	1 251	8 222	2 284
Biological fuels	9 000	2 500	1 188	330	7 812	2 170
Sum of energy:	129 484	35 968	19 159	5 222	113 325	30 646
Water power stations	23 785	6 607	18 335	5 093	5 450	1 514
Sum of energy:	153 269	42 575	37 494	10 315	118 775	32 160

Table 2.4. - Division of geothermal sources of water according to individual author [21]

Author / **Classification of source**	**Muffler Cataldi (1978)**	**Hochstein (1990)**	**Benderriter Corny (1990)**	**Mavrickij et. al. (1977)**	**Haenel et al. (1988)**
low temperature	< 90 °C	< 125 °C	< 100 °C	< 70 °C	< 150 °C
medium temperature	90 - 150 °C	125 - 225 °C	100 - 200 °C	70 - 100 °C	-
high temperature	> 150 °C	> 225 °C	> 200 °C	> 100 °C	> 150 °C

2.3. MONITORING OF NATURAL HEALING SOURCES OF WATER AT SLOVAK REPUBLIC

The monitoring system of the natural healing sources and the natural mineral water sources is independent part of environment monitoring system.

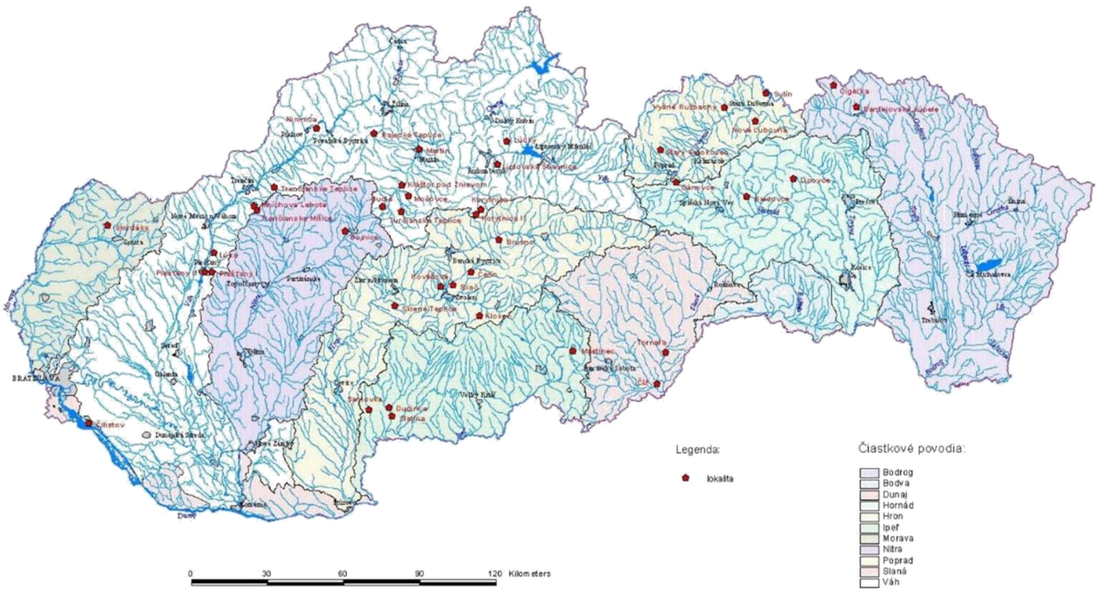
2.3.1. Definition and requirements

The Monitoring system of the NHS and the natural mineral water sources is system, through which the regime monitoring of hydrogeological, chemical, physical, microbiological and biological parameters of natural healing sources, natural mineral water sources, observation wells, observation objects and meteoroidal parameters of given area to the extent specified in the permit to use natural healing source is providing.

The user of source is obligated to ensure and provide the monitoring system of the natural healing source or the natural mineral water source and the observation wells connected to the national monitoring system of Slovak Ministry of health, according to the conditions of using sources, continuously send data to the database of the Slovak Ministry of Health and provide local information system. [20]

2.3.2. The aim of monitoring system

The aim of monitoring system is to ensure qualitative and quantitative parameters of the natural healing sources and the natural mineral water sources and their rational using on the base of relevant data from the observation of given qualitative and quantitative parameters, the hydrological and climatic data of local sources. (Picture 2.4.)



Picture 2.4. – Map of Natural healing sources at Slovakia [19]

2.4. HEAT EXCHANGERS

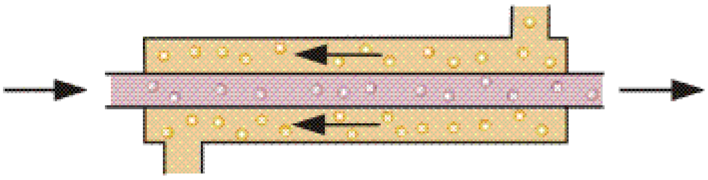
Heat exchanger is a device used to transfer heat between two or more fluids. The fluids can be single or two phase and depending on the exchanger type, may be separated or in direct contact. Devices involving energy sources such as a nuclear fuel pins or a fired heater are not normally regarded as the heat exchanger although many of principles involved in their design are the same. [27]

In order to discuss the heat exchanger it is necessary to provide some form of categorization. There are two approaches that are normally taken. The first considers the flow configuration within the heat exchanger, while the second is based on the classification of equipment type primarily by construction. Both are considered below:

The classification of heat exchanger by four basic flow configuration [27]:

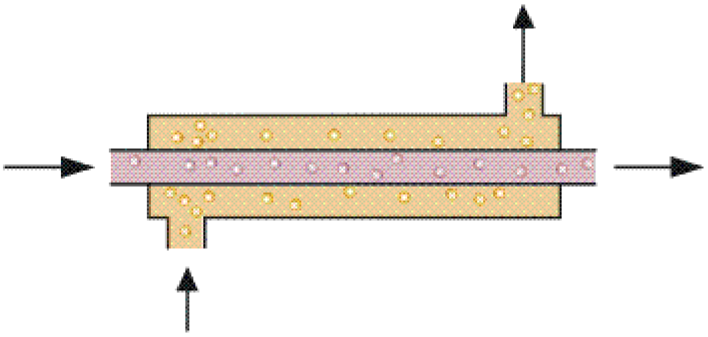
- Counter flow
- Concurrent flow
- Crossflow
- Hybrids such as Cross Counter flow and Multi Pass Flow

Picture 2.5. illustrates an idealized counterflow exchanger in which the two fluids flow parallel to each other but in opposite directions. This type of flow arrangement allows the largest change in temperature of both fluids and is therefore most efficient (where efficiency is the amount of actual heat transferred compared with the theoretical maximum amount of heat that can be transferred). [27]



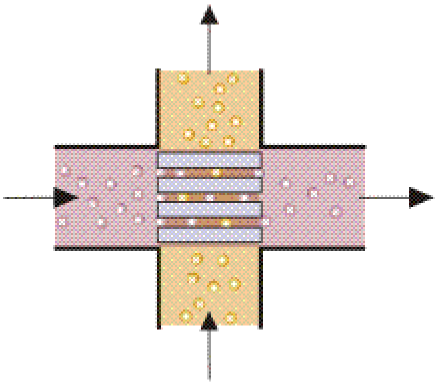
Picture 2.5. – Counter current flow [27]

In cocurrent flow heat exchanger, the streams flow parallel to each other and in the same direction as shown in Picture 2.6.. This is less efficient than counter current flow but does provide more uniform wall temperatures. [27]



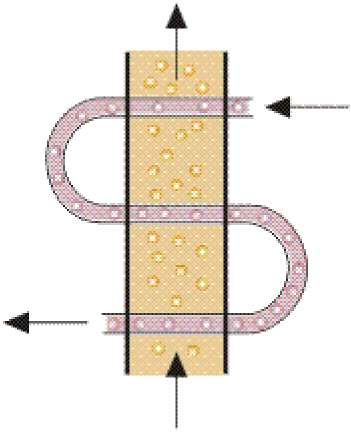
Picture 2.6. – Cocurrent flow [27]

Crossflow heat exchanger are intermediate in efficiency between counter current flow and parallel flow exchangers. In these units, the streams flow at right angles to each other as shown on Picture 2.7.. [27]



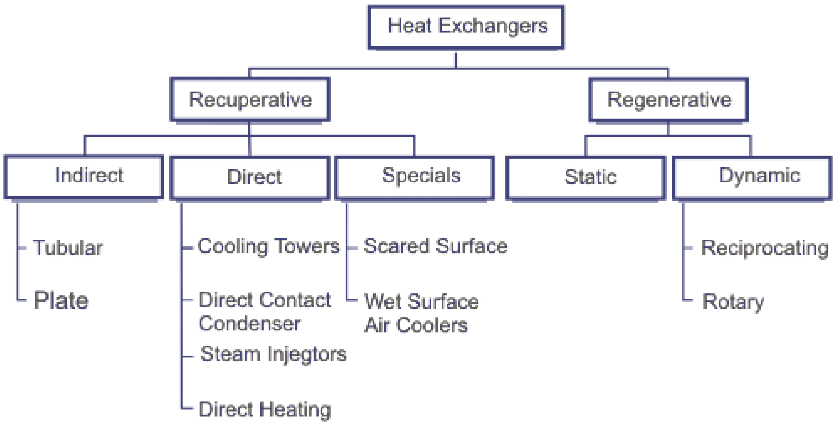
Picture 2.7. – Crossflow [27]

In industrial heat exchanger, hybrids of the above flow types are often found. Example of these are combined crossflow/counter flow heat exchangers and multi pass flow heat exchangers (Picture 2.8.). [27]



Picture 2.8. – Cross/counter flow [27]

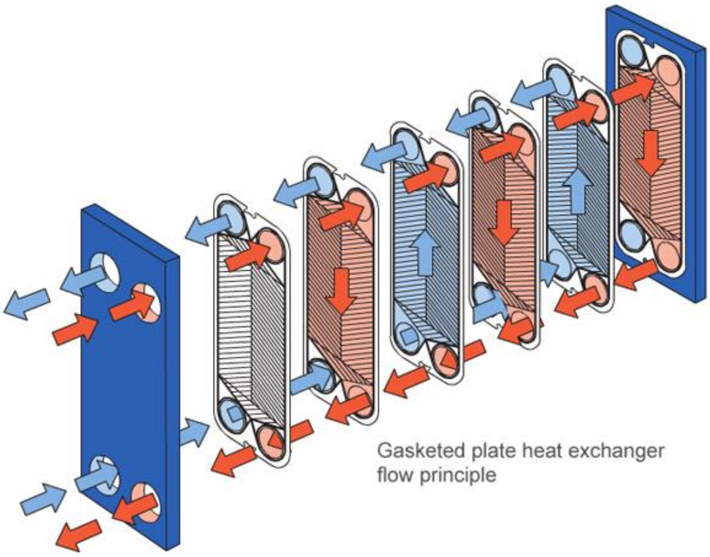
Classification of heat exchangers according to the construction is shown on Scheme 1.1.



Scheme 2.1. – Classification according to construction [27]

2.4.1. Plate heat exchanger

The plate heat exchangers are constructed on the base of the building kit principles (Picture 2.9.) – the surface of heat transfer area could be resized by adding or subtracting plates. Fluids are flowing through slots between the plates, which are profiled in the way to be the heat transfer maximal and simultaneously sediment occurs minimally. Sedimentation is occurring less in the plate heat exchangers in comparison with the tubular heat exchangers. The typical plate of heat exchanger is pressed, made of stainless steel and has four openings, for each chamber are two openings function and two openings are separated from flow chamber by sealing liner. The design way of sealing liner, shape of plates are subject of systematic development. [3]



Picture 2.9. – Scheme of plate heat exchanger [22]

Advantages [3]:

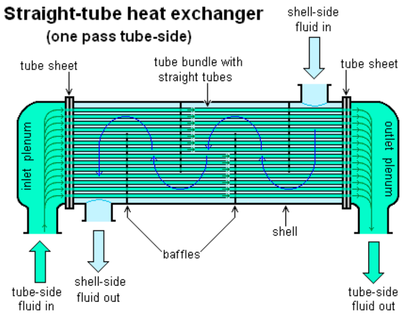
- Possibility to changer heat transfer area according to requirements
- Profiling of plates caused turbulent flow at small flow rates
- Short rest periods
- High possibility for cleaning
- Hygienic

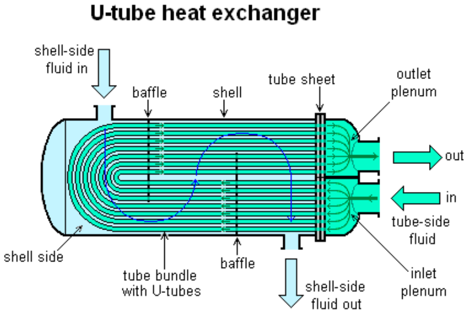
Disadvantages [3]:

- Limited scope of temperatures and pressures (given by material of sealing liner and stiffness of plates)
- Sealing liner (long sealing areas)

2.4.2. Shell and tube heat exchanger

It is the most common type of the heat exchanger in the oil refineries, other large chemical processes and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consist of the shell (a large pressure vessel) with a bundle of the tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of the tubes is called a tube bundle, and may be composed of several types of the tubes, plain, longitudinally finned, etc. The tubes may be straight or bent in the shape of a U, called U-tubes (Picture 2.10., Picture 2.11.). [3]





Picture 2.10.- Straight-tube heat exchanger [28] Picture 2.11. – U-tube heat exchanger [28]

The simple design of a shell and a tube heat exchanger makes it ideal cooling solution for a wide variety of the applications. One of the most common application is the cooling of the hydraulic fluid and the oil in engines, transmissions and hydraulic power packs. With the right choice of the material they can also be used to cool or heat other mediums, such as swimming pool water. [3]

Advantages [3]:

- Possibility to use wide range of materials – stainless steel, glass, plastic lath
- Good design of flow rate sections
- Can be used in wide range of temperature and pressures
- Possibility of mechanical cleaning
- Easy for production

Disadvantages [3]:

- Relatively high pressure lost, mainly at multi-flow exchangers
- Higher weight of shell and tube heat exchanger, according to heat transfer area

2.5. DESCRIPTION OF MEASURING DEVICES AND SIMULATION SOFTWARE

For the analyzation of given object we have to use proper measuring devices. In next chapters are described the basic information about the devices used during the elaboration of this diploma thesis.

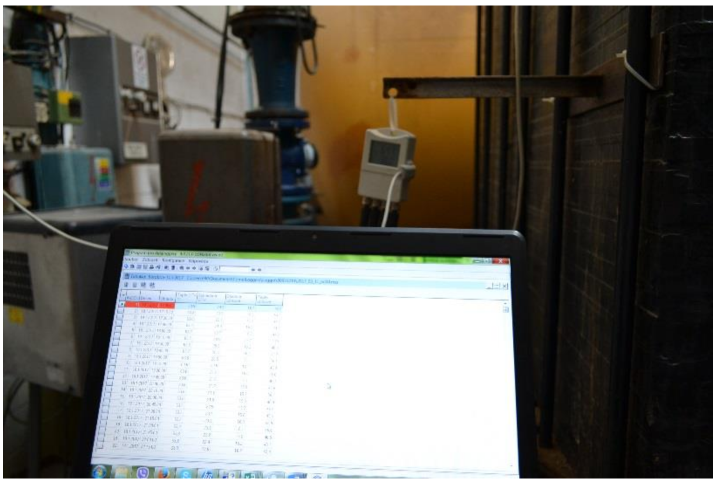
2.5.1. Temperature measuring

The Temperature (sometimes called thermodynamic temperature) is a measure of the average kinetic energy of the particles in a system. Adding heat to a system causes its temperature to rise. While there is no maximum theoretically reachable temperature, there is a minimum temperature, known as absolute zero, at which all molecular motion stops. Temperature is commonly measured in the Kelvin or Celsius scales, (Fahrenheit scale in the USA). [30]

For measurement of temperature at solved object described in next chapter I used Data logger and thermography described below.

2.5.1.1. <u>Data logger Comet</u>

The logger is designed for measurement and record of temperature from four temperature probes connected via connectors. Measured values are displayed on the two-line LCD display and are stored in selectable time interval to internal nonvolatile memory. All logger control and setting are performed from PC. Minimum and maximum measured values can be displayed (display switches to actual measured values and min/max values automatically). Stored values can be transferred from logger memory to the PC by means of communication adapter. (Picture 2.12 and 2.13).



Picture 2.12. – Data logger S0141 Picture 2.13. - Downloading measured data

Technical parameters:

- Measuring range: - 90 °C to 260 °C (RTD Pt1000/3850 ppm probes)
- Measuring range: - 50 °C to 150 °C (RTD Ni1000/6180 ppm probes)
- Resolution: 0,1 °C
- Accuracy of the inputs without probes:
  - ± 0,2 °C from -50 °C to 100 °C
  - ± 0,2 % from reading from 100 °C to 260 °C
  - ± 0,4 % from reading from -50 °C to – 90 °C
- Logging interval to memory: 10 s to 24 h
- Dimensions: 93 x 64 x 29 mm

2.5.1.2. Portable thermometer 1832 DEGREE

The temperature measurement of the heat transfer medium in pipelines by the portable thermometer 1832 DEGREE (Picture 2.14. – 2.15.).

Picture 2.14. – Portable thermometer

Picture 2.15. – Measurement of temperature

Technical parameters:

- Measuring unit: Celsius (°C)
- Resolution: ± 0,01 °C
- Accuracy: ± 0,01 °C
- Dimensions: 300 x 80 x 15 mm

2.5.1.3. Thermography Flir

The temperature measurement of the collective natural healing water from source by thermography – Thermography camera Flir I7 (Picture 2.16.).

Picture 2.16. – Thermography camera Flir i7.

Technical parameters:

- Display temperature curve of measuring surface
- Thermography picture can be downloaded to PC
- Measuring range: -20 °C to 250 °C
- Detection of thermal bridges
- Detection of thermal irregularity caused by insulation malfunction, humidity and air intersection.

2.5.1.4. Portable digital thermometer Greisinger GTH 175/Pt

The measurement of the temperature of the thermal transfer fluid by portable digital thermometer Greisinger GTH 175/Pt (Picture 2.17. and 2.18).

Picture 2.17. – Digital thermometer GTH 175/Pt

Picture 2.18. – Measuring of temperature

Technical parameters:

- Measuring range: - 199,9 °C to 199,9 °C
- Resolution: 0,1 °C
- Accuracy: 0,1%
- Dimensions: 106 x 67 x 30 mm

2.5.2. Flow rate measuring

The flow measurement is quantification of the bulk fluid movement. Flow can be measured in a variety of ways. Positive displacement flow meter accumulate a fixed volume of the fluid and then count the number of times the volume is filled to measure the flow. Other flow measurement methods rely on the forces produce by the following stream as it overcomes a known constriction, to indirectly calculate the flow. Flow may be measured by measuring the velocity of the fluid over a known area.

2.5.2.1. Flow meter Krohne

The flow rate measurement of the collected natural healing water by the portable ultrasonic flow meter UFM 610P Krohne (Picture 2.19.).

Picture 2.19. – Portable ultrasonic flow meter UFM 610P Krohne

Technical parameters:

- Measuring unit: l/s; kg/h
- Resolution: 0,001 l/s
- Accuracy: ± 0,001 l/s
- Dimensions: 230 x 120 x 45 mm

2.5.2.2. Flow meter Omega

The flow rate measurement of the collected natural healing water by the portable ultrasonic flow meter FDT-21 Omega (Picture 2.20.).

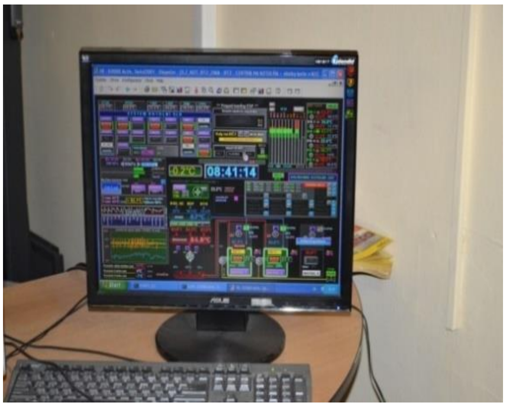
Picture 2.20. – Left ultrasonic flow meter FDT-21, right flow meter case

Technical parameters:

- Temperature range: 0 °C to 70 °C or 0 °C to 160 °C
- Velocity: ± 0,01 to 30 m/s
- Pipe size: DN 19 to DN 6000
- Accuracy: ± 1%
- Dimensions: 100 x 66 x 20 mm

2.5.3. Dispatching of measurement and regulation

Working place of the MaR dispatching at the SLKP a.s. (Picture 2.21.) is equipted with six monitoring stations, where the software was developed by the IPSOFT Žilina company, the system Actis D 2000, version 7.01.010.



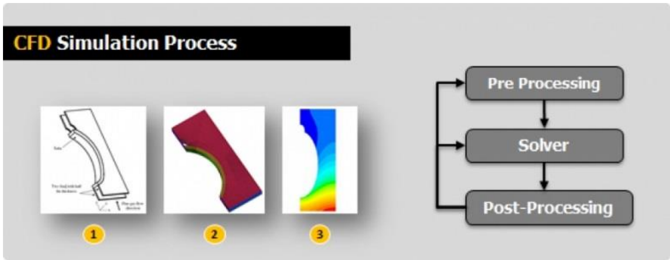
Picture 2.21. – Dispatching MaR at SLKP a.s.

2.5.4. Simulation software ANSYS Fluent

ANSYS, Inc. is an American Computer-aided engineering software developer headquartered south of Pittsburg in Cecil Township, Pennsylvania, and United States. ANSYS publishes engineering analysis software across a range of disciplines including finite element analysis, structural analysis, computation fluid dynamics, explicit and implicit methods and heat transfer. [1]

Software ANSYS Fluent is a tool for performing 2D/3D computational fluid dynamics (CFD). Its characteristic feature is an universal using possibility from basic to the physically complicated applications. As it is working with the real shape of analyzing object (2D or 3D analyzation) it is possible to monitor the spatial distribution of solved variables such as speed, temperature, pressure, composition, etc. This analysis allows us to better understand the effects, which are occurring during the flow motion and give us chance for the optimization of given product, operating state or whole process. Within this analyzation it is possible to evaluate the pressure lost, the resistance of obturator, distribution of temperatures in the fluid or solid particles, abrasion speed of the construction during the transport of a material, etc. [2]

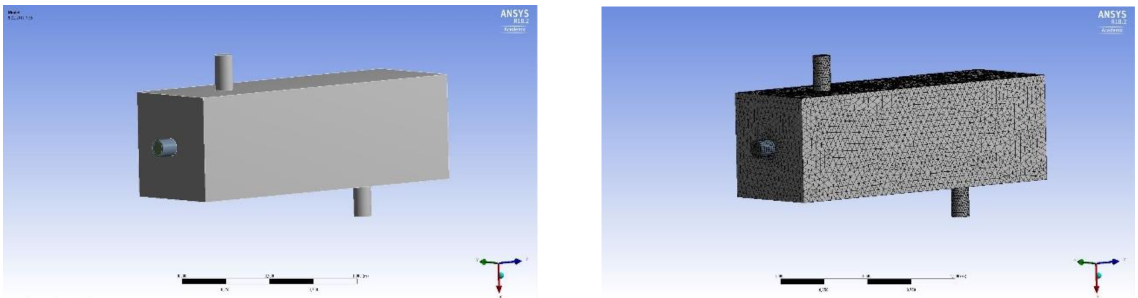
Every CFD simulation must be performed in the three step procedure (Picture 2.22.):



Picture 2.22. – CFD simulation process [2]

I. First step so called “Pre Processing”:

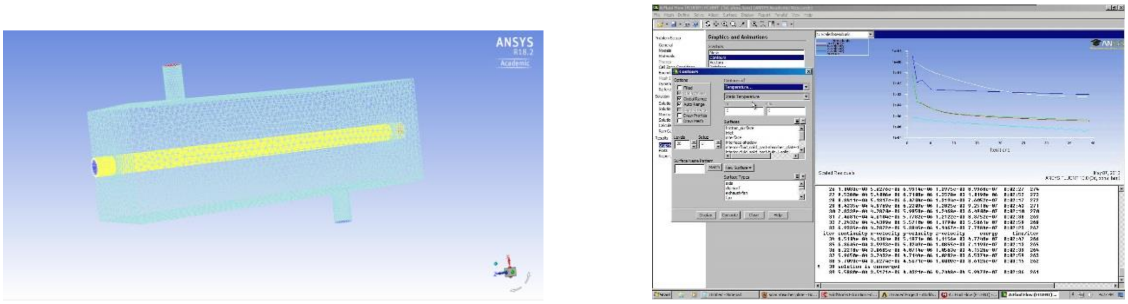
This step consist of defining a geometry to define our domain of interest. The domain of interest is then divided into segments, called as mesh generation step and the problem is set-up defining the boundary conditions. Gridgen, CFD-GEOM, or ANSYS Workbench Environment & Modules, ANSYS ICEM CFD, TGRID etc. are some of the popular pre-processing software (Picture 2.23.). [2]



Picture 2.23. – Left example of geometry in ANSYS Workbench, right example of geometry mesh in ANSYS Workbench

II. Second step so called “solver”:

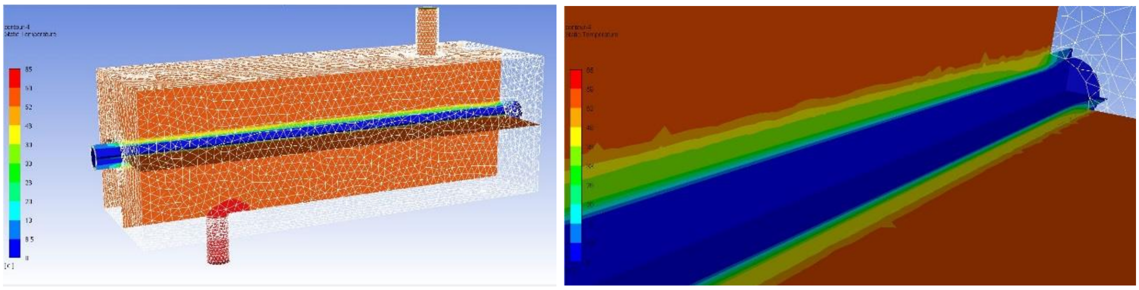
Once the problem is set-up defining the boundary condition we solve it with the software on computer, (can also be done by hand-calculations, but would take long time). ANSYS Fluent software is capable of solving the equations at every probe-point defined during the mesh generation step and also we can include additional models as required by the physics. The numerical methods are also defined at this stage and we solve the whole problem Picture (2.24.). [2]



Picture 2.24. – Left mesh in ANSYS fluent solver, right Ansys Fluent solver

III. Third step so called “Post Processing”:

Once we get the results as values at our probe points we analyse them by means of color plots, contour plots, appropriate graphical representation and can generate reports. Tecplot 360, EnSight, FieldView, ParaView, ANSYS CFD-Post, etc. are some of the popular post processing softwares (Picture 2.25.). [2]



Picture 2.25. – Left, right example of post processing solution through color plots.

2.6. MULTIPLE-CRITERIA DECISION

Multiple-criteria analyzation belongs to methods of the complex evaluation, which helps to minimalize degree of a subjection in the way of choosing the optimal alternative. The responsibility of this analyzation is to describe an objective reality during the evaluation of optimal variant, by standardized progression and thus given choosing problem formalized i.e. translate it to the mathematical model of the multiple-criteria decision situation. The method of the multiple-criteria decision has the same goal – analyzed several variants of given problem solution according to a defined criteria and determination of their order. A general procedure for evaluation task with the multiple-criteria decision has to follow steps below: [14]

- Definition of criteria on which will be variants evaluated
- Determination of individual criteria strengths (standardized or non-standardized)
- Calculation of overall usefulness of individual variants
- Determination of optimal variant, efficiency

2.6.1. Multiple-criteria methods

The issue of task solution by multiple-criteria evaluation is solved by several authors, who describe possibilities of a determination strengths for the individual criteria and the method for a calculation overall usefulness of individual variants. The methods are different in the way of a criteria strengths calculation (Table 2.5.). [14]

Frist task is to define the criteria, under which will the variants be evaluated and its ability to fulfill defined criterion is described by the cardinal rank. The cardinal rank i.e. range of the evaluation, defined sensibility of the method. The more alternatives and factors we have, the bigger range is and the bigger the cardinal rank is. [14]

The degree of compliance or failure to comply of individual criterion is possible to evaluate in two ways [14]:

- Minimizing – the less points from cardinal rank variant obtained, the better fulfill defined criteria
- Maximizing – the more point from cardinal rank variant obtained, the better fulfill defined criteria

Strengths of individual the criterion is possible to determine in two ways [14]:

- Direct method – according to this method one person evaluate and define the strengths of individual criterion. They are so called “biased strengths” – very big impact of subjectivity
- Indirect methods – are more complicated methods, where the strengths of individual criterion are defined by comparing each criterion with others to obtain the less possible impact of subjectivity. They are so called “objective strengths”.

Table 2.5. – Strengths criterion determination and overall usefulness of variants [14]

Determination of individual criterion strenghts	Direct methods	Metfesell´s allocation
		Calsifictaion of criteria into groups
		Assign points to criteria from the specidied score scale
		Rating scale
		Preferential order of criteria
	Indirect methods	Pair comparison- Fuller Triangle
		Saaty´s method
Calcutaion of overall usefulness of individual variants	Direct methods	The weighted sum method - the ratio index method
		Method of multiplying awards
		Qudartic chart method
	Indirect methods	Pair comparison method
		Saaty´s method - AHP method
		Distance from fictional variant

2.7. MATHEMATICALY-PHYSICAL MODEL OF OPENED NATURAL HEALING SOURCE OF ENERGY SYSTEM

- Physical equations:

I. Continuity equation:

Explains the law of conservation of mass for flowing liquid. The equation we can be described in the way that, liquid is during its flowing divided into separated particles, which are moving with the speed c. During the movement of particles at observed endless small time interval is particle made of same molecules and has to respect the law of fluid compressibility $\rho = \rho_{(\rho,\, s)}$. Particle of liquid could during the time change its volume (density). The equation of continuity can be explain in derivative or integral form.

Integral form: (2.1)

$$\iiint_V \frac{\partial \rho}{\partial t} dV + \iint_S \rho(\vec{c}.d\vec{S}) = 0$$

Derivative form: (2.2)

$$\frac{\partial \rho}{\partial t} + div\ \rho\vec{c} = 0$$

II. Equation of motion :

Equation of motion of flowing liquid are derived from Newton´s laws of motion. According to this law is time change of motion of moving liquid particle equals to a sum of all outer forces acting on particle. For description of time change we use the difference of liquid movement.

Integral form: (2.3)

$$\iiint_V \frac{\partial \rho\vec{c}}{\partial t} dV + \iint_S \rho\vec{c}(\vec{c}.d\vec{S}) = \sum_i \vec{F}_i$$

Derivative form: (2.4)

$$\frac{\partial \rho\vec{c}}{\partial t} + div\rho\vec{c}\,\vec{c} = \rho\sum_i \frac{\vec{F}_i}{m} = \rho\sum_i \vec{f}_i$$

III. Energy equation

Energy equation is specific form of axiom conversation of mass, while we consider heat, kinetic energy, geopotential energy and mechanical work.

Integral form: (2.5)

$$\iiint_V \frac{\partial \rho e}{\partial t} dV + \iint_S \rho e \left(\vec{c}.d\vec{S}\right) = \dot{Q} - \dot{W}$$

Derivative from: (2.6)

$$\frac{\partial \rho e}{\partial t} + div\ \rho e \vec{c} = \frac{\rho\,(\dot{Q} - \dot{W})}{m}$$

IV. Calorimetry equation:

The calorimetry equation is describing heat transport through the laws of motion. On its base is possible to determine specific heat capacity, amount of heat, which is necessary to add or remove, in order to obtain temperature change or to gain the total heat transport.

$$Q = m.c.(\theta_2 - \theta_1) \tag{2.7}$$

$$Q_{handover} = Q_{obtained} \tag{2.8}$$

$$c_1.m_1.\Delta\theta_1 = c_2.m_2.\Delta\theta_2 \tag{2.9}$$

- Economical equations:

V. Annual savings (2.10)

$$B = S\ .\ E - \Delta P\&\acute{U}$$

(Currency/year)

Where:

S	-saving of energy per year (kWh/r)
E	-price of energy
ΔP&Ú	-difference of cost of operation and maintains (+ or -) (Currency/year)

VI. Method of gross return – Payback (2.11)

$$PB = \frac{I_0}{B} (roky)$$

Where:

I_o - total initially investment (currency)
B - annual savings (currency/year)

VII. Net present value method (2.12)

If the result is positive the investment is profited.

$$NPV = B.\frac{1-(1+r)^{-n}}{r} - I_0 (-)$$

Where:

r - real interest rate
I_o - total initially investment (currency)
B - annual savings (currency/year)

VIII. Coefficient of net present value (2.13)

$$NPVQ = \frac{NPV}{I_0} (-)$$

Where:

I_o - total initially investment (currency)
NPV - net present value

IX. Net return method – Pay-OFF (PO) (2.14)

- Annuity factor

$$f = D^{-1} = \frac{r}{1-(1+r)^n}$$

Where:

r - real interest rate
n - net return

3. APPLICATION OF THE TOPIC AT SOLVED BUILDING

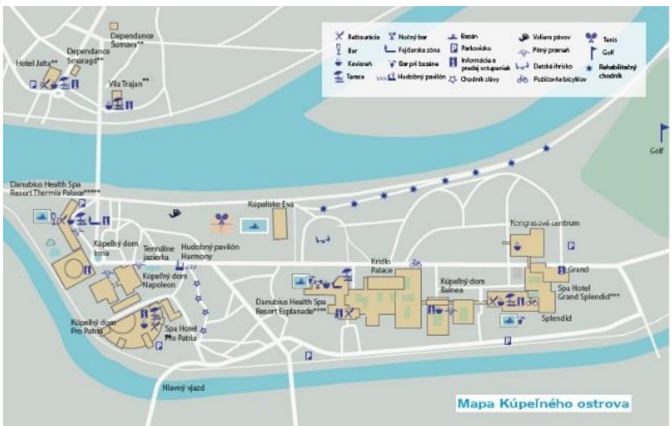
The subject of this chapter is to develop conceptual design, design of technical solution in given specialization (including documented calculations) in basic drawings and diagrams, technical report, evaluation of the current state of solution, analysis of potential efficiency measures, space requirements, economy of operation.

3.1. PIEŠŤANY SLKP a.s. - LOCATION OF SOLVED BUILDING

For the purpose of elaborating this diploma thesis, was chosen a small spa town Piešťany, located at the west side of Slovakia, 80 km from the capital city Bratislava (Picture 3.1). Because of its good position from the Vienna International airport Schwechat– road distance 160 km and from Bratislava International airport – road distance 80 km, is visiting yearly by thousands of visitors and people willing to be curate.

Picture 3.1. – Location of spa town Piešťany

Piešťany are well known because of its Spa Island (Picture 1.1), which is situated on a river Váh at east side of town Piešťany. Thank to springs with the natural healing water the world famous spa was established here. Besides the spa resort, spa buildings and hotels people can as well enjoy a public swimming pool EVA and play golf on a Golf curt located at the east side of the Spa island. The island is connect with the city center with pedestrian Colonnade Bridge (Picture 3.2.), and next three bridges were built as a transport connection to village Banka.



Picture 3.2. – Map of Spa Island

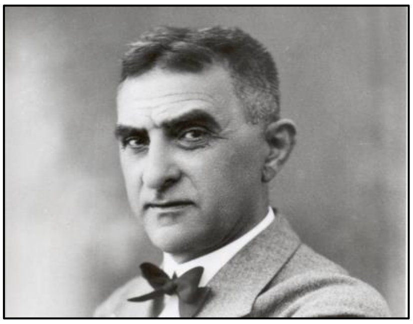
3.1.1. History of spa town Piešťany

Piešťany is interesting for foreigners simply because of its name. Etymologists see the origin of the name Pescan in the word “sand”. The first settlements originated near sandy soils around the River Váh. Archeologists have found here and in surrounding locations incredibly interesting discoveries, such as bones of prehistoric animals and traces of some settlements by prehistoric humans that give evidence of the attraction of the hot springs in this fertile valley. [23]

People say that the curative effects of Piešťany´s springs were first discovered by Roman legions. Roman horses were so tired after their long journey that they could not continue without rest. Soldiers then decided to relax for several days next to a muddy meadow near the River Váh. They supposedly continued their journey after this stay unusually refreshed. [23]

The beginning of progressive rational changes in Piešťany´s curative healing methods meant the arrival of Dr. František E.Scherer, M.D., pioneer of the modern balneal therapy, who worked in Piešťany Spa from 1829 to 1837. He advocated an individual approach for the prescription of curative cures based on advance defined diagnosis, and on the phase of the advanced state of disease of the patient. [23]

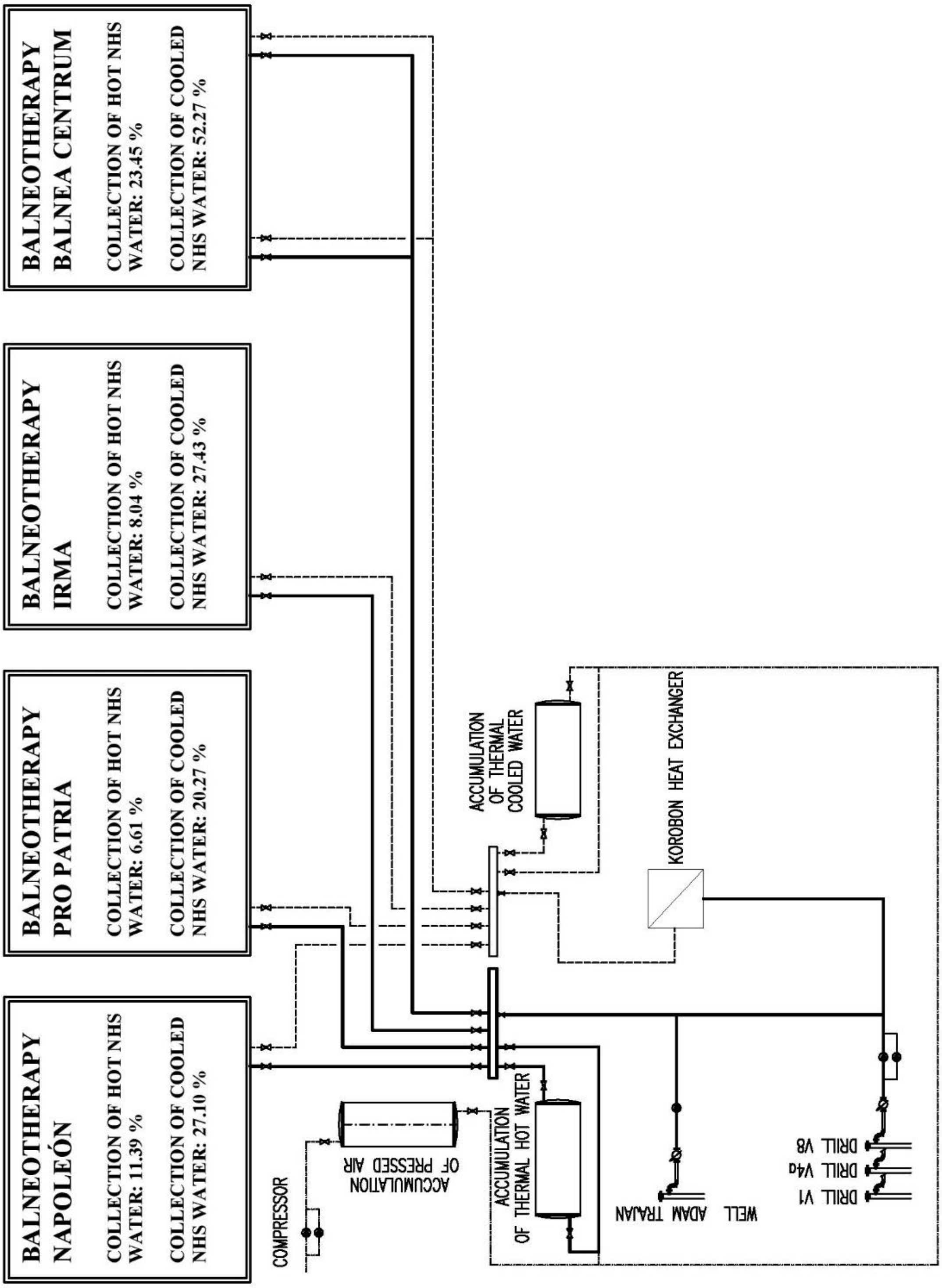
A crucial era in the development of the spas of Piešťany is wedded to the name of the family Winter. At the beginning of the 20th century, the spa hotel Thermia Palace was created along with the balneal therapy building Irma (1912), the spa hotel Pro Patria (1916) and the Hotel Excelsior in the thirties in the functional style (now known as Jalta). Father Alexander and later his sons, especially Ľudovít and Imrich, served and managed the development of the cultural and social life in Piešťany. During the era managed by the Winters, the roads and transportation system improved dramatically. Many schools were built as well as a new post office, the pedestrian Colonnade Bridge with its symbol of the Spa – a bronze statue of man, Crutch Breaker. (Picture 3.3). [23]



Picture 3.3. – Left: Colonnade Bridge, Right: Ľudovít Winter [8]

3.2. ANALYSIS OF CURRENT STATE AT SLOVAK HEALTH SPA PIEŠŤANY

Objective analysis of current state at the Slovak Health Spa a.s Piešťany, is provided by individual analyzation of the partial objects located the Spa Island. This analyzation provide initial data for design elaboration, which will help Slovak Health Spa Piešťany a.s. to fulfill emission and energy goals of European Union stated in Chapter 1..



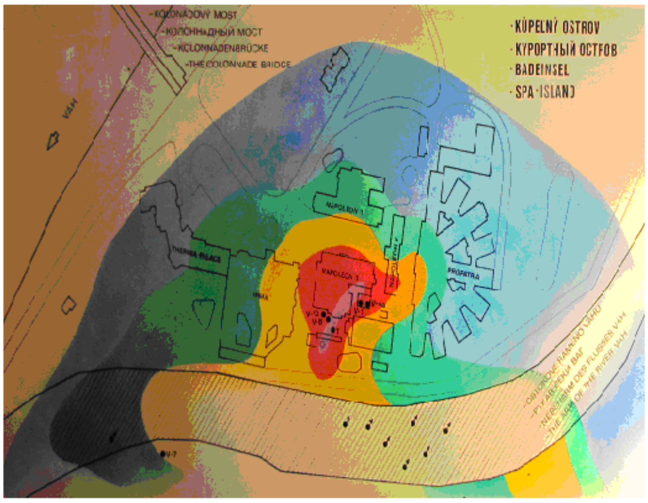
Scheme 3.1. – Slovak Health Spa Piešťany a.s. balneotherapy

Scheme 3.1. shows full operation of the SLKP a.s.. All technological processes start by the collecting water from drills and well shown in left bottom corner. After collection is the natural healing water process with the help of technological devices in the accumulation station distributed to all Balneotherapy departments.

3.2.1. Collection of natural healing sources of water at SLKP a.s. Piešťany

Collection of the natural healing water for the Balneotherapy departments is located at observed from historical point of view significant locations, where were by the long-term analysis detected the healing effects on a human organism. Mostly they are the natural seepage of the natural healing water source, which are collected and by the technological equipment transported to the Balneotherapy departments (Picture 3.4. and 3.5.).

Picture 3.4.– Image representation of natural healing water sources springing into the balneotherapy departments from the left side Thermia Palace, Irma, Napoleon spa and on the left side Pro Pátria (Source: Wall painting at Irma)



Picture 3.5. – Image representation of natural healing water source spread at alluvial layers (Source: Presentation material at drinking pavilion in Piešťany)

3.2.1.1. Situation of natural healing sources of water

Picture 3.6. – Situation of wells and dills of NHS at Spa Island.

3.2.1.2. Natural healing source of water – drills V1, V4a, V8 and well Adam Trajan

The result of the complex geological structure of the natural healing sources of water and the hydrogeological factors is, that nowadays the Balneotherapy departments in the SLKP a.s. are supplied from drills V1, V4a (Picture 3.8.), V8 (Picture 3.9.) and supplement well Adam Trajan signed as drill V5, V5a (Picture 3.7.). [24]

Picture 3.7. – Well Adam Trajan V5 (Left picture view before reconstruction, right picture view after reconstruction)

Picture 3.8. – Left picture drill V-1, right picture drill V-4a

Picture 3.9. – Drill V8

3.2.1.3. Analyzation of natural healing sources of water

Analyzation of the natural healing sources at the Slovak Health Spa a.s. Piešťany has geological character, which describes the existing natural healing water system. This section is including in this diploma thesis as it is considered to be initial data for the elaboration complex analysis of the Balneotherapy. The analyzation provide information about the temperature and the flow rate of individual natural healing water source, which is affected by the level of recipient and its flow rate regulation (Table 3.1. – 3.2.).

Table 3.1. – Information about well and drills at Spa Island. [24]

Source of NHS water		Max. enabled collection of NHS water	Temperature of NHS from long-term point of view	Depth
		[l/s]	[°C]	[m]
Drills	V1	4,1	62,6 - 66,7	54,3
	V4a	8,0	64,4 - 66,5	54,0
	V8	6,2	62,2 - 67,0	55,0
Wells	Adam Trajan	13,5	60,8 - 62,5	16,0
Total		31,8		

Table 3.2. - Temperatures and dimensions of drills according to geological works [24]

Drill	Ground	Depth of drill	Max. temperature	Collection from depth	Q	H_2S	Notes
	[m /m]	[m]	[°C]	[m]	[l/s]	[mg/l]	
V-1	159.84	55.20	67.5	55.20		11,00	Dressing 159,96 mn/m; 23,5 l/s
V-2		231.80	56.60	60.3	6,60		
V-3		125.00	59.4	26.00	16,00		
V-4a	159.84	54,00	68,00		24,00	8,90	Cavern 15 m; dressing 24 l/s
V-5		11,20	66.5	11,20	2,70		Drill V-5 and V-5a in Adam Trajan well 11m
V-5a		11,00	66.5	11.0	2,00		
V-6		57.8	67.1	24,00	10,00		
V-7	159.84	66.5	69.0	66.5	5,21	5,92	According to G-10, dressing 5.21 l/s
V-8	159.84	55,00	68.2	54.4	7,50	7,50	
V-9 teraz	159.84 159.65	81.7	69.6	81.7		8,60	Bearing temperature = 71.5 °C.
V-10	159.99						Situated near V-8, depth 16 m
V-11	160.87	70,00					
V-12	158.93	58,00					

Analyzation of the natural healing sources of water shows that currently the Slovak Health Spa a.s. Piešťany is for operation of the Balneotherapy using drills V1, V4a, V8 and well Adam Trajan, whose temperature and flow rate as well as amount of H_2S will be initial data for a design elaboration to make improvement in the opened natural healing water source system.

The detailed information about the composition of the natural healing water from source is available in ANNEX 8.6..

3.2.2. Balneotherapy departments

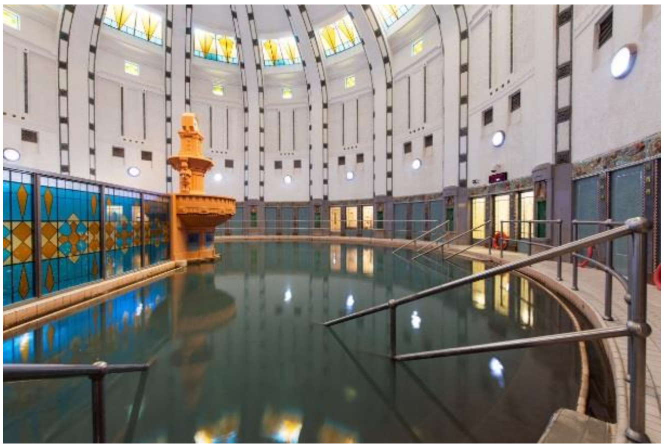
Healing treatments at the Slovak Health Spa Piešťany a.s. are currently provided at four Balnotherapy departments, situated on the Spa island (Picture 3.10.).

Picture 3.10. – Map of Balneotherapy departments

3.2.2.1. Balneotherapy departments – collection of natural healing water

From collection of natural healing water source point of view, the Balneotherapy departments use relatively same technological devices for ensuring healing procedures.

The historically most well know is a mud pool "*Bahnisko*" (Picture 3.11.). The Mud pool is a flow-through rehabilitation pool with the natural bottom, always situated on existing natural seepage of the natural healing source water. The pool bottom is made of a natural peloid. The depth of the pool is from 1,0 m to 1,2 m – reason of small depth is because all pool must be designed for sitting. There are two ways of collecting water, directly from the source of the natural healing water and secondly pouring the cooled thermal water to secure temperature 40 °C in the pool.



Picture 3.11. – Mud pool "Bahnisko"

Another Balneotherapy equipment is a Mirror pool "*Zrkadlisko*" (Picture 3.12.). The Mirror pool is a flow-through ceramic rehabilitation pool with the temperature of the natural healing water 39 °C. The depth of pool is 1,2 m – designed for sitting. Supplying of the pool with the natural healing water is provided by mixing armatures on the base of mixing the hot natural healing water with the cooled natural healing water, where must be secured the minimum flow rate and the temperature from hygienic point of view.

The mirror pools are daily poured out and filled with fresh natural healing water.

Picture 3.12. – Mirror pool "Zrkadlisko"

The water treatment – is provided by the water treatment bathtubs, which are situated in the bath departments. The bathtubs are special Balneotherapy devices, which allow user to set up several water treatments setting (bead bath, underwater massages …) and resisting aggressive the natural healing water (Picture 3.13.).

Picture 3.13. – Bathtub for water treatment

3.2.2.2. Balneotherapy departments – developing simplified schemes

As concern that the Balneotherapy departments do not have recordings about consumption of the natural healing water, accounting in the field of company is based on expert decision of a real consumption of the natural healing water from source and the amount of sold Balneotherapy treatments.

For the purpose of elaboration this diploma thesis, the scheme of each Balneotherapy department was developed, based on the individual measurement and analysis of given object. All schemes were consulted with the project manager of Slovak Health Spa a.s. Piešťany, to declare its accuracy and possibility to use for the further evaluation of the opened natural healing source of energy system (Scheme 3.2. – 3.5.).

Each scheme contains the fluid temperature and the flow rate based on long term analyzation, simplified distribution scheme of the natural healing source of water, the number and connection of the technological devices located in each Balneotherapy department.

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Scheme 3.2. – Scheme of Balneotherapy Pro Pátria

Scheme 3.3. – Scheme of Balneotherapy Balnea Centrum

Scheme 3.4. – Scheme of Balneotherapy Napoleón

Scheme 3.5. – Scheme of Balneotherapy Irma

3.2.2.3. <u>Balneotherapy departments – collection of NHS water analyzation</u>

The analyzation of individual Balneotherapy departments based on schemes was elaborate in the Microsoft office - Excel and for the further analyzation exported into a graphical solution.

Table 3.3. – Balance sheet of natural healing sources of water - Balneotherapy Irma

Table 3.3. shows in upper part the collection places list of the natural healing source of water, the time of its operation, basic technical properties, average daily temperature of the hot, cooled and mixed natural healing water including its daily average collection based on the expert decision from long-term analyzation. For energy evaluation the most important values are:

- Temperature of NHS water at object: 65,8 °C
- Amount of hot NHS water at object: 1,16 l/s = 100,16 m^3/day
- Amount of cooled NHS water at object: 1,56 l/s = 134,21 m^3/day

Middle part of table shows the balance of the waste NHS water at the cooling sedimentary tank with the division into a balance at operation time and a balance out of operation time. For energy evaluation determined the amount of NHS water is 2,71 l/s = 234,37 m^3/day, based on expectation this amount of the NHS water collected in the Balneotherapy Irma is equal to the amount of water poured into sedimentary cooling tank. Average temperature was measured by the portable thermometer equals to 38,2 °C.

Bottom part of table shows a balance of collective hot and cooled NHS water at the Balneotherapy, divided into two parts: during the operation time and out of the operation time.

Table 3.4. – Balance sheet of natural healing sources of water - Balneotherapy Napoleón

	[hours]	[m²]	[m³]	[°C]	[°C]	[°C]	[l/s]	[m³/day]	[l/s]	[m³/day]	[l/s]	[m³/day]
Minor pool man – water filling	1,5	27,185	32,6	41,20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minor pool man – water adding	10,5			43,10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minor pool woman – water filling	1,5	27,185	32,6	41,20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minor pool woman – water adding	10,5			43,10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minor pool 1 sick cave – water filling	1,5	29,593	35,15	41,20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minor pool 1 sick cave – water adding	0,5			43,10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BT hot tube 1 sauna	4	1,22	1,37		[illegible]	[illegible]			[illegible]	[illegible]		
Water treatment 120 proc./day	1,5											
15 x bathtubs			2,7	37,00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mud pool	12	31,883	38,26			[illegible]			[illegible]	[illegible]		
Amount of waste natural healing source water – during the operation of balneotherapy										[illegible]		[illegible]
Amount of waste natural healing source water – during the out of the time operation of balneotherapy										[illegible]		[illegible]
Amount of collection hot NHS water during the operation of balneotherapy									[illegible]	[illegible]	[illegible]	[illegible]
Amount of collection hot NHS water out of the operation of balneotherapy									[illegible]	[illegible]	[illegible]	[illegible]
Amount of collection cooled NHS water out of the operation of balneotherapy									[illegible]	[illegible]	[illegible]	[illegible]
Amount of collection cooled NHS water during the operation of balneotherapy									[illegible]	[illegible]	[illegible]	[illegible]

Table 3.4. shows in upper part the collection places list of the natural healing source of water, time of its operation, basic technical properties, average daily temperature of the hot, cooled and mixed natural healing water including its daily average collection based on the expert decision from long-term analyzation. For energy evaluation the most important values are:

- Temperature of NHS water at object: 67,4 °C
- Amount of hot NHS water at object: 1,64 l/s = 141,99 m^3/day
- Amount of cooled NHS water at object: 1,53 l/s = 132,58 m^3/day

Middle part of table shows a balance of the waste NHS water at the cooling sedimentary tank with the division into a balance at operation time and a balance out of operation time. For energy evaluation determined the amount of NHS water is 3,18 l/s = 274,57 m^3/day, based on the expectation that the amount of the NHS water collected in the Balneotherapy Napoleón is equal to the amount of water poured into the sedimentary cooling tank.

Bottom part of table shows a balance of collective hot and cooled NHS water at the Balneotherapy, divided into two parts: during the operation time and out of operation time.

- Amount of collection hot NHS water out of the operation: 0,72 l/s
- Amount of collection hot NHS water during the operation: 0,92 l/s
- Amount of collection cooled NHS water during the operation: 0,14 l/s
- Amount of collection cooled NHS water out of the operation: 1,39 l/s

Table 3.5. – Balance sheet of natural healing sources of water - Balneotherapy Pro Patria

Table 3.5. shows in the upper part collection places list of the natural healing source of water, time of its operation, basic technical properties, average daily temperature of the hot, cooled and mixed natural healing water including its daily average collection based on the expert decision from long-term analyzation. For energy evaluation the most important values are:

- Temperature of NHS water at object: 67,1 °C
- Amount of hot NHS water at object: 0,95 l/s = 82,3 m^3/day
- Amount of cooled NHS water at object: 1,15 l/s = 99,17 m^3/day

Middle part of table shows a balance of the waste NHS water at the cooling sedimentary tank with the division into a balance at operation time and a balance out of operation time. For energy evaluation determined the amount of NHS water is 2,10 l/s = 181,56 m^3/day, based on expectation that the amount of the NHS water collected in the Balneotherapy Pro Patria is equal to the amount of water poured into sedimentary cooling tank.

Bottom part of table shows a balance of collective hot and cooled NHS water at the Balneotherapy, divided into two parts: during the operation time and out of operation time.

- Amount of collection hot NHS water out of the operation: 0,21 l/s
- Amount of collection hot NHS water during the operation: 0,74 l/s
- Amount of collection cooled NHS water during the operation: 0,33 l/s
- Amount of collection cooled NHS water out of the operation: 0,82 l/s

Table 3.6. – Balance sheet of natural healing sources of water - Balneotherapy Balnea Centrum

Table 3.6. shows in the upper part collection places list of the natural healing source of water, time of its operation, basic technical properties, average daily temperature of hot, cooled and mixed natural healing water including its daily average collection based on the expert decision from long-term analyzation. For energy evaluation the most important values are:

- Temperature of NHS water at object: 54,5 °C
- Amount of hot NHS water at object: 4,71 l/s = 407,09 m^3/day
- Amount of cooled NHS water at object: 2,96 l/s = 255,74 m^3/day

Middle part of table shows a balance of the waste NHS water at the cooling sedimentary tank with the division into a balance at operation time and a balance out of operation time. For energy evaluation determined the amount of NHS water is 7,67 l/s = 662,83 m^3/day, based on expectation that amount of the NHS water collected in the Balneotherapy Balnea Centrum is equal to the amount of water poured into sedimentary cooling tank.

Bottom part of table showsbalance of collective hot and cooled NHS water at the Balneotherapy, divided into two parts: during the operation time and out of operation.

- Amount of collection hot NHS water out of the operation: 1,95 l/s
- Amount of collection hot NHS water during the operation: 2,76 l/s
- Amount of collection cooled NHS water during the operation: 1,59 l/s
- Amount of collection cooled NHS water out of the operation: 1,37 l/s

3.2.2.4. Balneotherapy departments – energy evaluation

Table 3.7. – Total energy balance of Balneotherapy Irma

Theoretical energy losses	244,14	[kWh/day]
Theoretical energy usable	3 050,64	[kWh/day]
Theoretical energy waste	1 541,60	[kWh/day]
Theoretical energy	4 836,39	[kWh/day]
Theoretical efficiency energy losses	**5,05**	[%]
Theoretical efficiency energy usable	**63,08**	[%]
Theoretical efficiency energy waste	**31,88**	[%]

Table 3.7. shows current using ratio of energy heat losses at Balneotherapy Irma based on average values, which were obtained by experimental measurement and consultation with Slovak Health Spa a.s. Piešťany.

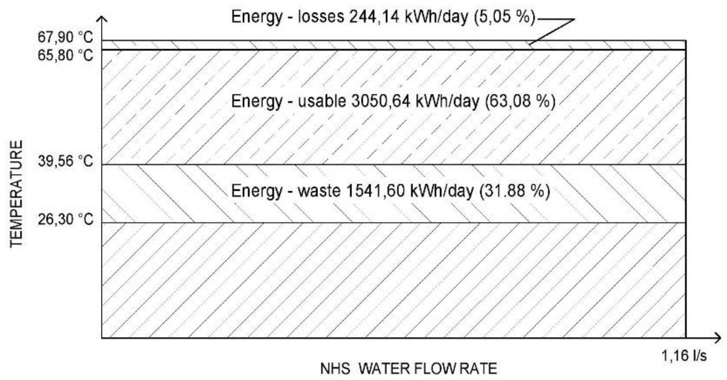


Chart 3.1. – Energetic balance of Balneotherapy Irma

Chart 3.1. shows the energetic balance of the Balneotherapy Irma, where first part refers to an energetic losses at the distributive the natural healing water – 5,05 % from a theoretical energetic usage, second part refers to the consumption of the energy during the operation of Balneotherapy – 63,08 %, third part refers to a energy, which is lost at the sedimentary cooling tank – 31,88 %.

Table 3.8. – Total energy balance of Balneotherapy Napoleón

Theoretical energy losses	82,26	[kWh/day]
Theoretical energy usable	4 134,51	[kWh/day]
Theoretical energy waste	2 479,39	[kWh/day]
Theoretical energy	6 696,16	[kWh/day]
Theoretical efficiency energy losses	**1,23**	[%]
Theoretical efficiency energy usable	**61,74**	[%]
Theoretical efficiency energy waste	**37,03**	[%]

Table 3.8. shows current using ratio of the energy heat losses at the Balneotherapy Napoleón based on average values, which were obtained by the experimental measurement and consultation with the Slovak Health Spa a.s. Piešťany.

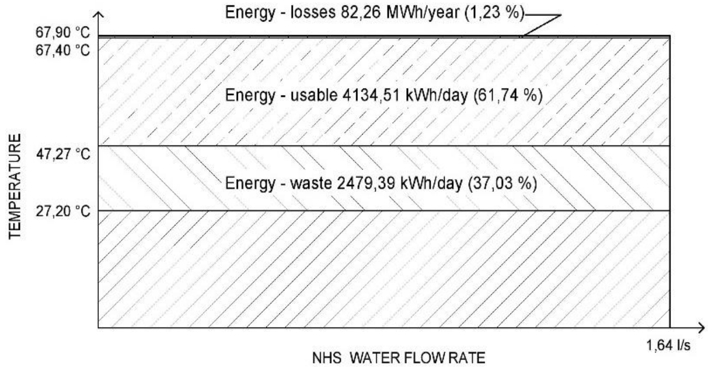


Chart 3.2. – Energetic balance of Balneotherapy Napoleón

Chart 1.1. shows an energetic balance of the Balneotherapy Napoleón, where first part refers to an energetic losses at the distributive natural healing water – 1,23 % from the theoretical energetic usage, second part refers to the consumption of an energy during the operation of Balneotherapy – 61,74 %, third part refers to a energy, which is lost at the sedimentary cooling tank – 37,03 %.

Table 3.9. – Total energy balance of Balneotherapy Pro Patria

Theoretical energy losses	76,51	[kWh/day]
Theoretical energy usable	2 476,90	[kWh/day]
Theoretical energy waste	1 424,93	[kWh/day]
Theoretical energy	3 978,34	[kWh/day]
Theoretical efficiency energy losses	**1,92**	[%]
Theoretical efficiency energy usable	**62,26**	[%]
Theoretical efficiency energy waste	**35,82**	[%]

Table 3.9. shows current using ratio of the energy heat losses at the Balneotherapy Pro Patria based on average values, which were obtained by the experimental measurement and consultation with the Slovak Health Spa a.s. Piešťany.

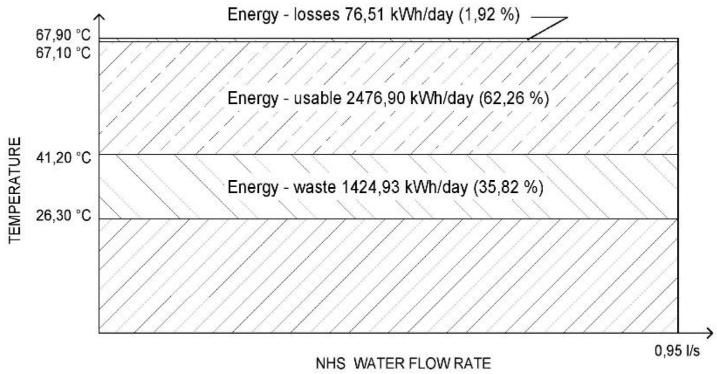


Chart 3.3. – Energetic balance of Balneotherapy Pro Patria

Chart 3.3. shows an energetic balance of Balneotherapy Pro Patria, where first part refers to the energetic losses at the distributive natural healing water – 1,92 % from theoretical energetic usage, second part refers to the consumption of an energy during the operation of Balneotherapy – 62,26 %, third part refers to an energy, which is lost at the sedimentary cooling tank – 35,82 %.

Table 3.10. – Total energy balance of Balneotherapy Balnea Centrum

Theoretical energy losses	6 331,68	[kWh/day]
Theoretical energy usable	6 969,57	[kWh/day]
Theoretical energy waste	6 591,56	[kWh/day]
Theoretical energy	19 892,81	[kWh/day]
Theoretical efficiency energy losses	**31,83**	[%]
Theoretical efficiency energy usable	**35,04**	[%]
Theoretical efficiency energy waste	**33,14**	[%]

Table 3.10. shows current using ratio of the energy heat losses at the Balneotherapy Balnea Centrum based on average values, which were obtained by the experimental measurement and consultation with the Slovak Health Spa a.s. Piešťany.

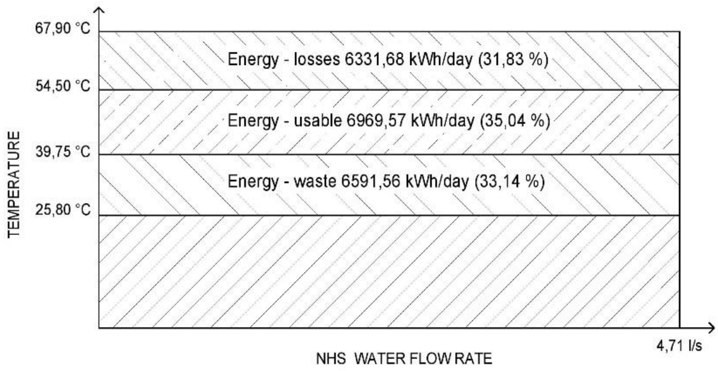


Chart 3.4. – Energetic balance of Balneotherapy Balnea Centrum

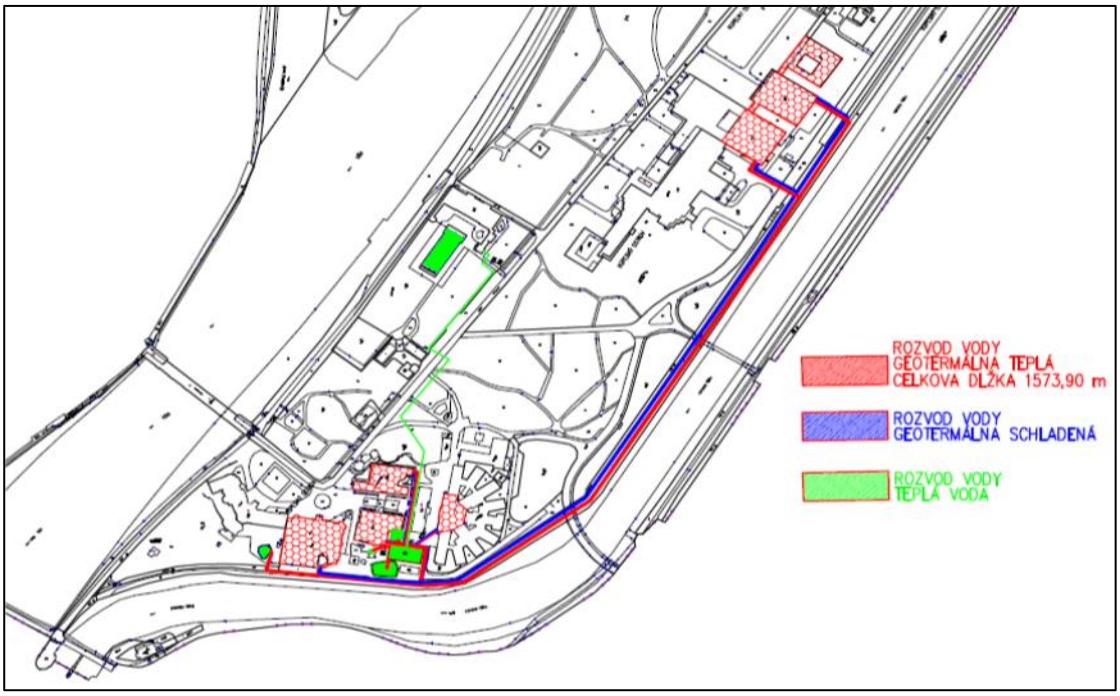
Chart 3.4. shows an energetic balance of the Balneotherapy Balnea Centrum, where first part refers to an energetic losses at the distributive natural healing water – 31,83 % from theoretical an energetic usage, second part refers to a consumption of energy during the operation of Balneotherapy – 35,04 %, third part refers to an energy, which is lost at the sedimentary cooling tank – 33,14 %.

3.2.3. Distribution of NHS across the Spa Island

Historical solution of the Balneotherapy grouped all departments near the source of the natural healing water – Balneotherapy Irma, Balneotherapy Napoleón, Balneotherapy Pro Pátria. As new technology in transport of medium were developed, modern age allows the Slovak Health Spa Piešťany a.s. to build the Balneotherapy departments far away from the source of the natural healing water – Balneotherapy Balnea Centrum, which has impact in distribution of natural healing water. Currently this technology change is concerning distribution of the NHS water to the Balneotherapy Balnea Centrum with the length of the pipelines 1 573, 90 m concerning distribution of hot and cooled natural healing water. In past collectors at which this pipelines are situated, were solved as common collectors for the distribution of the NHS water and the steam pipelines which allows the Slovak Health Spa Piešťany a.s to provide heating in the hotel complexes – heat losses at NHS hot and cooled pipelines was negotiated. By the reconstruction of energetic, the steam pipelines were canceled and due to that the heating system of collectors was canceled as well, as an impact of this solution was increasing the thermal losses at distribution of the NHS water.

Thanks to the cancelation of distribution steam pipelines in collectors an energetic paradox appears, that higher thermal losses at the NHS hot pipelines has an impact at mixing armature in the Balneotherapy Balnea Centrum, were the collection of cooled NHS water decrease, which is from the energetic and ecologic point of view wasting of the natural healing source energy.

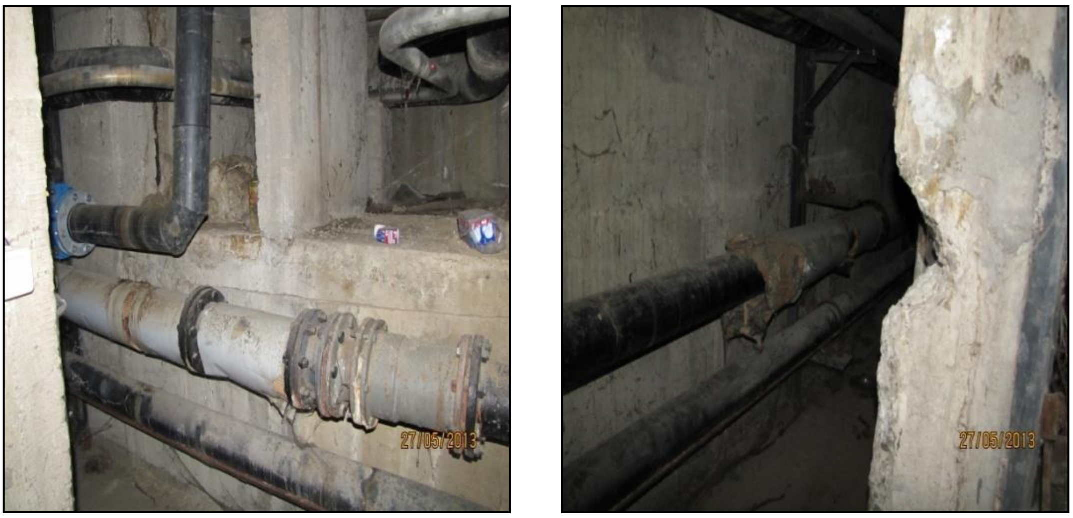
Distribution of the natural healing water across the Spa Island is shown on cadastral map at Picture 3.14..



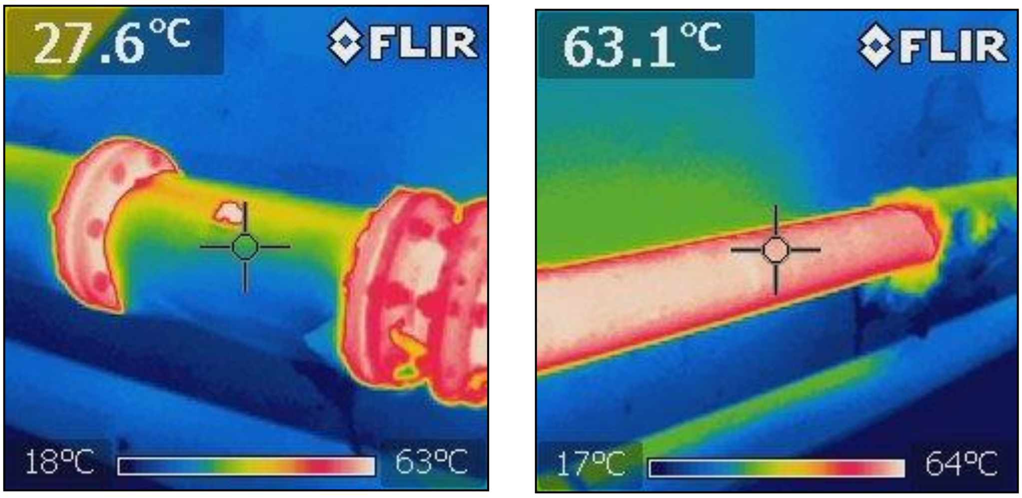
Picture 3.14. - Cadastral map of Spa Island with marked distribution of NHS water.

3.2.3.1. Partial analyzation of NHS water distribution current state

The pipelines for distribution of the NHS water are made of a cast iron DN 150 at an over-ground concrete collector. After partial analyzation of current state it is possible to say, that part of the pipelines is insulated by a basalt insulation and part of the pipelines is without any insulation. Partial analyzation shows although that in year 2008 were canceled the distribution of the steam and condensation pipelines, which had provided the heating system at the whole Spa Island areal. Concurrence of the pipelines and high thermal losses at the steam pipelines has an impact on temperature of air at collector which was 45 °C (statement of energetic engineer of Slovak Health Spa Piešťany Ing. Pavol Mikláš). By the cancelation of the steam distribution, distribution of the NHS water at parts of pipelines without any insulation becomes source of the energy losses – analyzation is provided below (Picture 3.15. and 3.16.).



Picture 3.15. – Current state of NHS water distribution at collector.



Picture 3.16. – Thermography analyzation of current state of NHS water distribution at collector.

The experimental measurement of the current state shows that the biggest energetic potential is at the NHS distribution to the Balneotherapy Balnea Palace, where the basic parameters of this distribution are shown below:

• Dimension of pipelines:	DN 150
• Pipeline material:	Cast iron
- Density:	7220 $kg.m^{-3}$
- Thermal conductivity λ:	198 $W.m^{-1}.K^{-1}$
- Thermal diffusivity α:	17,4 x 106 $m^2.s^{-1}$
- Specific heat capacity c:	500 $J.kg^{-1}.K^{-1}$
• Thickness of thermal insulation:	30 mm
- Density:	105 $kg.m^{-3}$
- Thermal conductivity λ:	0,038 $W.m^{-1}.K^{-1}$
- Thermal diffusivity α:	0,548 x 106 $m^2.s^{-1}$
- Specific heat capacity c:	660 $J.kg^{-1}.K^{-1}$
• Fluid temperature in pipelines:	65 °C
• Surface temperature of pipelines:	
- With insulation:	57 °C
- Without insulation:	61 °C
• Air temperature at collector:	21,2 °C
• Outside air temperature:	9,6 °C
• Length of distribution:	1573,90 m

The aim of this diploma thesis is not to provide detailed analyzation of distribution NHS water at Spa Island. As concern the big potential in thermal losses at distribution pipelines, separate study must be provided. For general purpose the evaluation of the thermal losses is calculated below.

Calculation of thermal losses at pipelines with insulation th. = 10 mm.

$Q_{str} = m.c_v.(\Theta_z - \Theta_k)$

Where:

m – amount of NHS distributed water [l/s]

c_v – specific heat capacity [kJ/kg.K]

Θ_z – temperature of NHS water at the beginning of distribution [°C]

Θ_k – temperature of NHS water at the end of distribution [°C]

Q_{str} = 4,71 x 4,186 x (67,9 – 54,5) = $\underline{\underline{264,19\ kW}}$

3.2.4. Other NHS water collection places at Spa Island

From the NHS water collection point of view, there are next collection places necessary for operation of the Balneotherapy.

The ripening pools of the peloid (Picture 3.17.) are two hydraulically separate pools design for ripening of the peloid mined from recipient of the river Váh – "Teplé rameno". A mined mud is storing at the ripening pools for one year and with the help of systematic filling with the NHS water is mineralizing and regulated to desired temperature. After one year ripening is the peloid distributed to the Balneotherapy departments. Distribution of the NHS water into ripening pool is solved by several inlets at the perimeter of pool. Inlet flow rate of the NHS water is 5,23 l/s. Stated collection of the NHS water is disturbed only four days a year when new peloid is added to pool or taken out for distribution to the Balneotherapy departments.

The ripening pools must be all year uncovered due to influences of the sun at mineralizing process in the peloid.

Picture 3.17 – Ripening pool with peloid

Next collection places of the NHS water are exterior and interior drinking fountains (Picture 3.18.)

Picture 3.18. – Exterior NHS water drinking fountains (Left: located at facade of Balneotherapy Napoleón, Right: located near the thermal lakes at Spa Island)

3.2.5. Accumulation station – location

Accumulation station is situated at west side of the Spa Island (Picture 3.19.) and was constructed in the year 1985. The purpose of this building is to group technological devices for operation of the Balneotherapy departments and the hotel complexes. The location was designed near the natural healing sources of water, because of technical means of that age, which do not allow company to transport the natural healing water to far away from source.

Picture 3.19. – Location of accumulation station

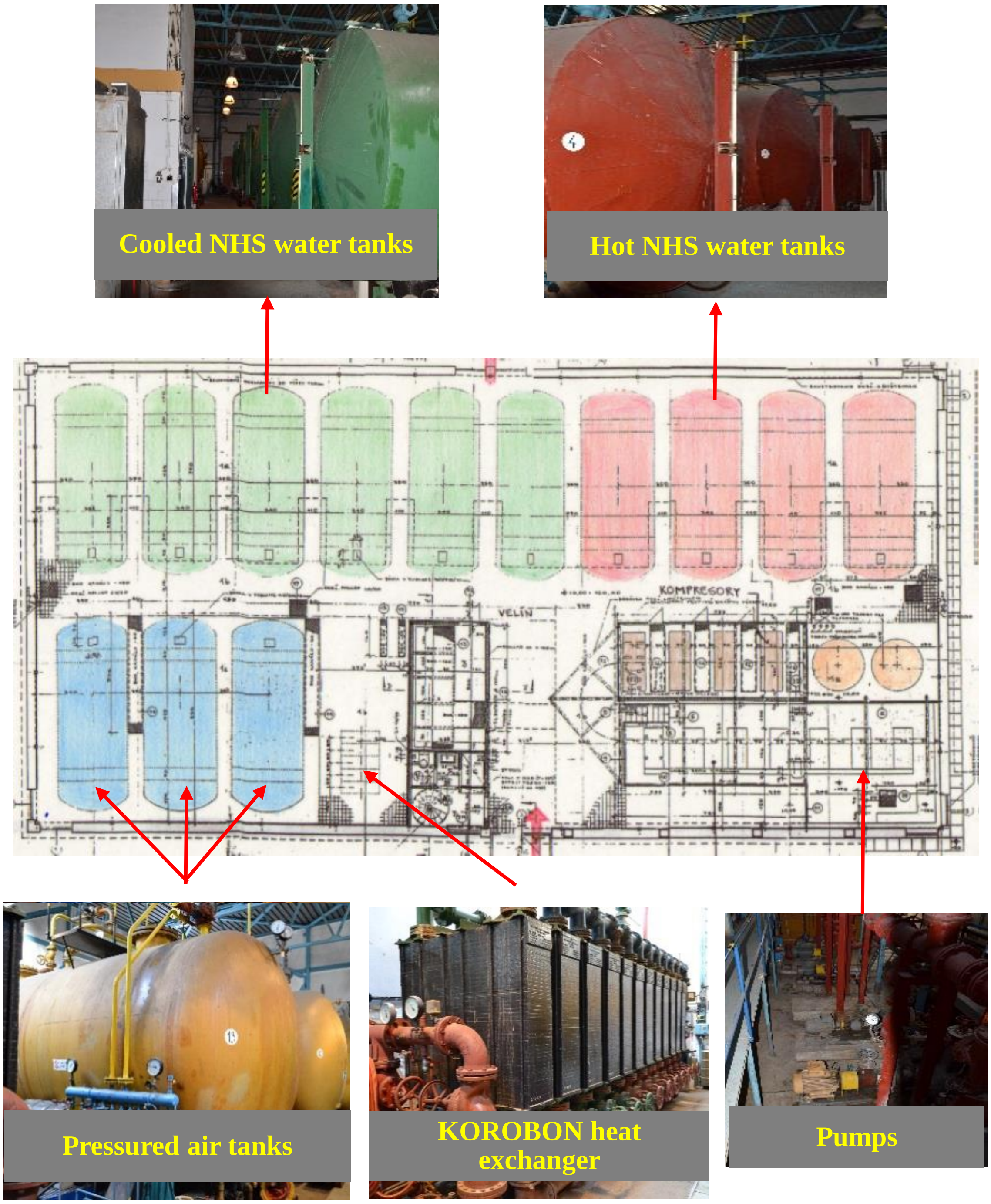
3.2.5.1. <u>Accumulation station basic information</u>

Due to the fact that the natural healing water has temperature cca. 65 °C at source, is useless for the healing procedures at the Balneotherapy departments and it is necessary to mixed it with the cooled NHS water. Mixing of the NHS water with another water e.g. from common well is not possible due to its mineral composition which will discard healing proposition of this water and cause its coloring. For this reason it is necessary to cooled down the NHS water collected from the natural healing water source.

From the source is the NHS water flow-through gravitationally collected at lower part of the accumulation station - Picture 1.1, where with the help of a pumps is pressed into the opened distribution system.

At the accumulation station is collected the NHS water from the flow-through well and drills with the help of pumps pressed and distributed into individual departments. To secure required amount of the NHS in consideration of nonlinear requirement, there are situated horizontal tanks for the accumulation of at NHS at accumulation station. Nowadays Spa Piešťany owned 4pc. of an horizontal tanks for hot NHS and 6 pc. for cold NHS – Picture 3.20..

Accumulation station is grouping technological devices necessary for cooling down the NHS water and its distribution (Picture 1.1.).



Picture 3.20 – Accumulation station – technological solution of accumulated NHS water

3.2.5.2. Accumulation station analysis

The accumulation station has the biggest impact as concerning energetic, environmental and ecological point of view. Analysis of this object is the most important part of this diploma thesis, because all the Balneotherapy departments are supplied and depended on its operation. Analysis is divided into two parts, first part is concerning analyzation of accumulation station as a whole object – disposition, space requirements, basic and detailed calculations, drawings and second part is concerning analyzation of the graphite heat exchanger Korobon – which provide the cooling down of the natural healing water from source.

3.2.5.3. Analyzation of accumulation station

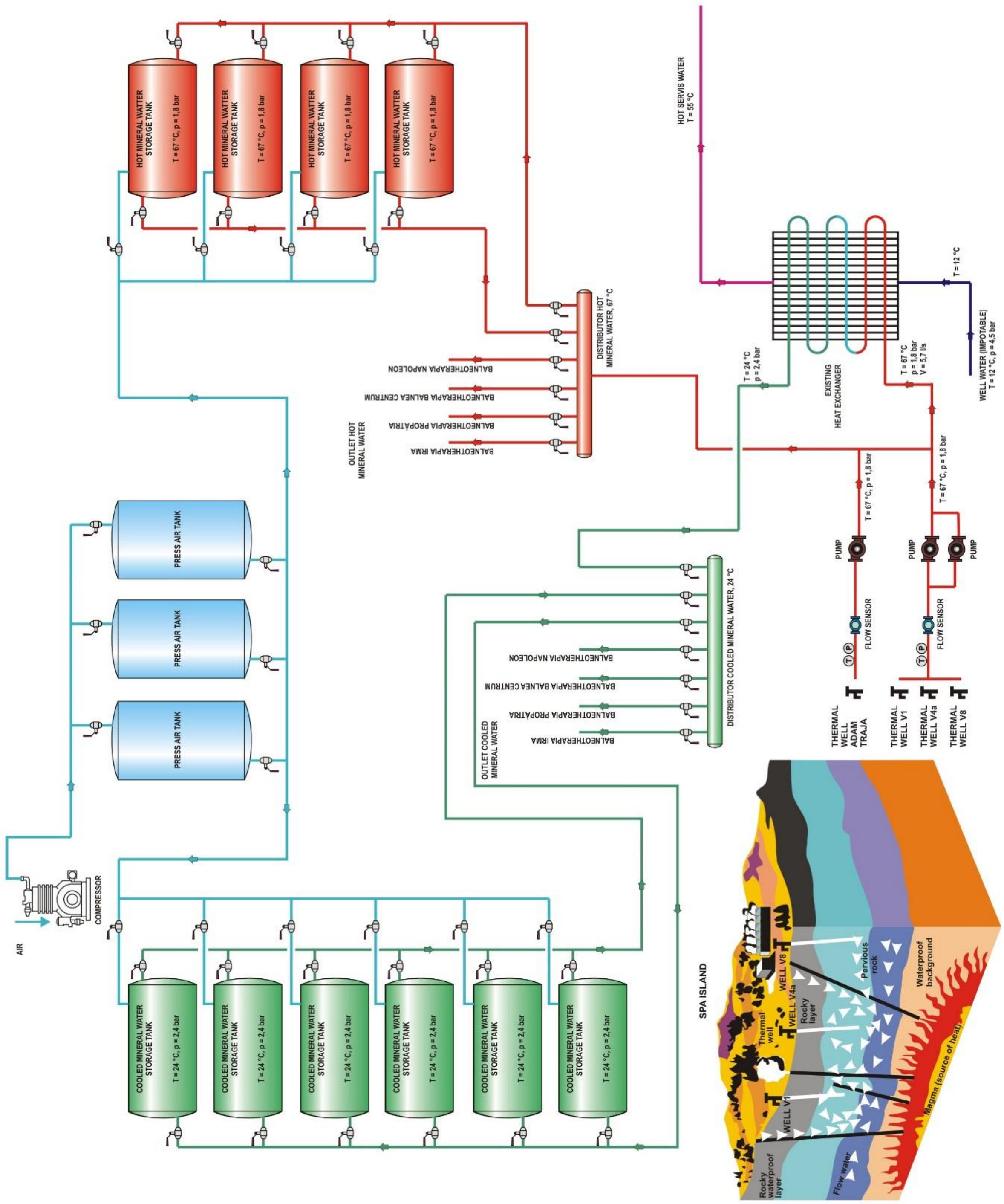
For the purpose of analyzation the Slovak Health Spa Piešťany a.s. provided original project documentation of the station (Picture 3.21., Picture 3.22.). During the years of operation small improvement and reconstructions mainly at pipelines were made. For this reason it was necessary to map current state of the accumulation station, by individual measurement directly in the accumulation station concerning disposition, space requirements, types of armatures, dimensions which validate original project documentation. This project documentation, was redraw into electronical by using project design software Autocad and redesign to respond the reality. The output of first part of this analyzation is the project documentation of current state stated in attachment.

Picture 3.21. – Section of accumulation station provided by SLKP a.s. Piešťany

Picture 3.22. – Accumulation station floor plan provided by SLKP a.s.Piešťany

3.2.5.4. Accumulation station – design simplified schemes

For the purpose of analyzation, it was necessary to develop scheme of current pipelines involvement (Scheme 3.6.).

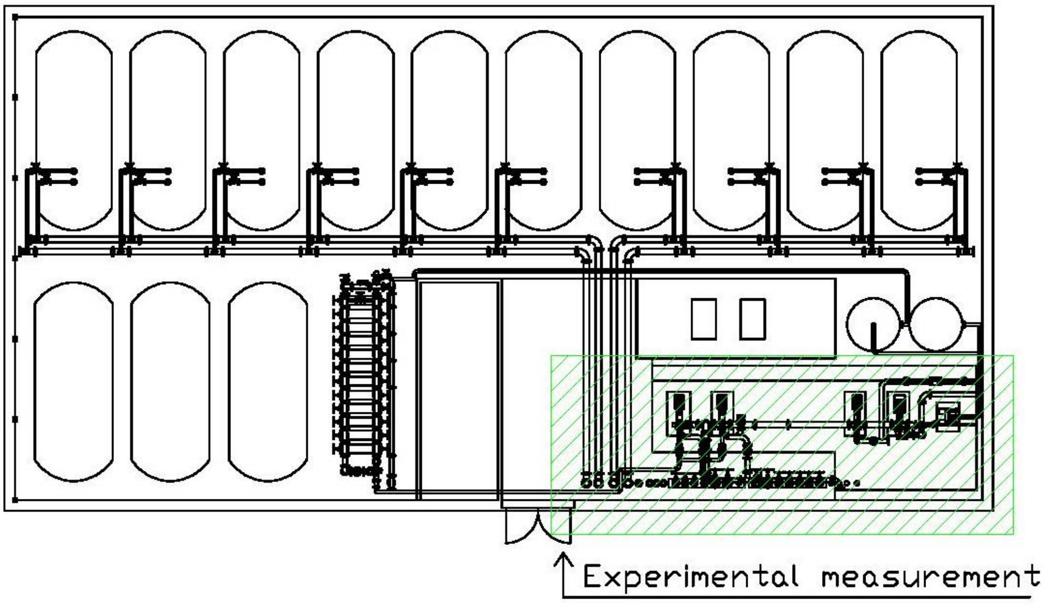


Scheme 3.6. – Scheme of current accumulation station state

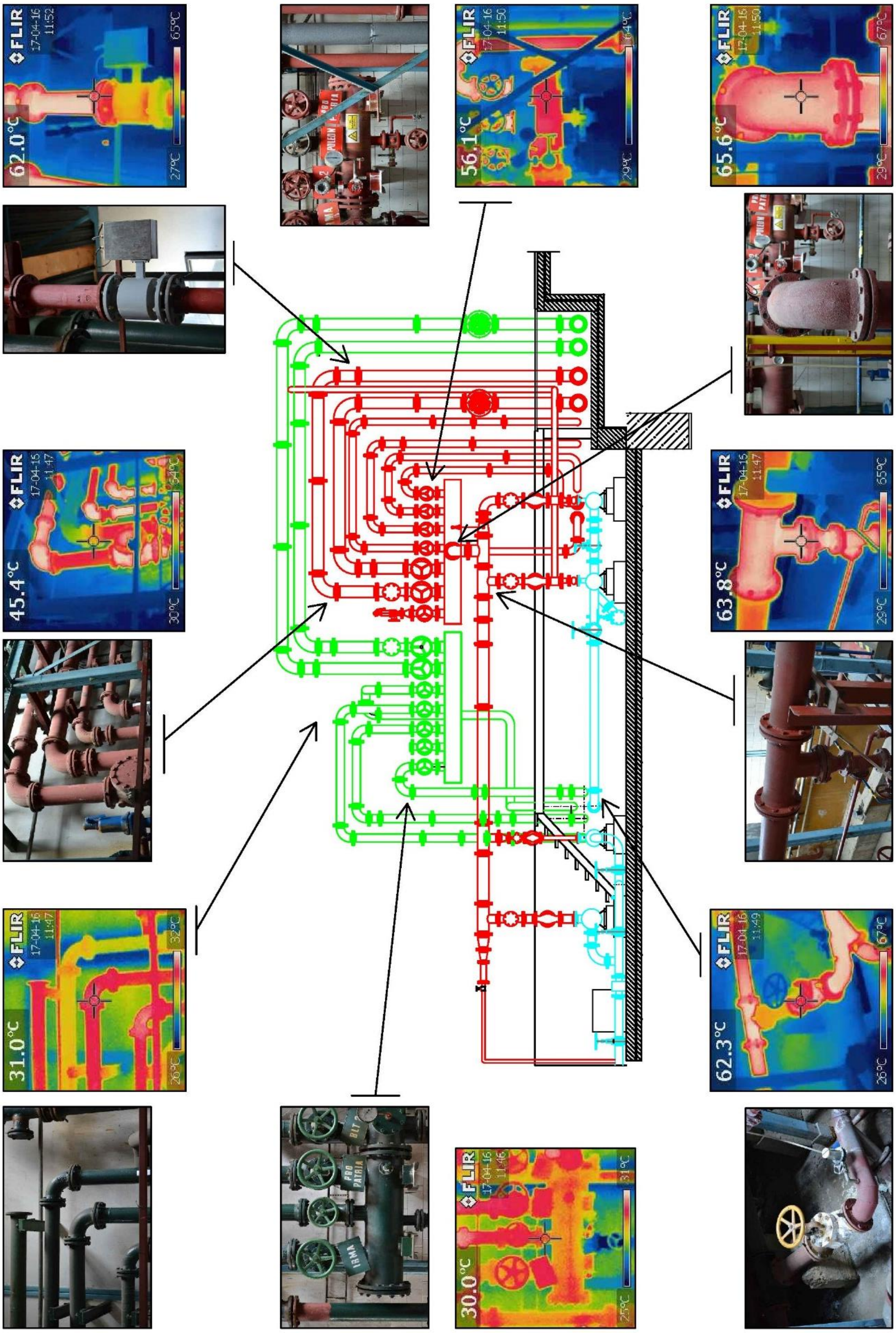
Scheme 3.6. shows distribution of the natural healing water from drills V1,V4a,V8 and well Adam Trajan in bottom right corner at the accumulation station. The amount of water is on the base of the monitoring system of the Slovak Ministry of Health monitored and recorded. Average temperature of the natural healing water which is pumped into the water distribution system is 67 °C, which was obtained from long-term measurement. Part of the NHS water is flowing directly to the hot water distributor (marked with red color), from where is flowing into the Balneotherapy departments, second part is flowing into the block graphite heat exchanger Korobon, where is cooled down to temperature ccs. 24 °C and flowing to the cooled water distributor (marked with green color), from where is flowing to the Balneotherapy departments. Analysis of block graphite heat exchanger is evaluated in next section. The distributor of hot NHS water separate partially amount of NHS hot water for the hot NHS water storage tanks, where is stored at temperature cca. 67 °C and pressure 1,8 bar. The cold NHS distributor separate partially amount of the NHS cooled water for the cooled NHS water storage tanks, where is stored at temperature cca. 24 °C and pressure 2,4 bar. The pressure in the storage tanks is provided with the help of air collected from the compressor at the pressure air tanks (marked with blue color). In the case of high demand of water it is possible to use this stored water in the distribution system.

3.2.5.5. Accumulation station - Thermography evaluation

Thermography evaluation was provided with the help of thermo camera FLIR at the selected part of accumulation station – distributors of hot and cooled natural healing water (Picture 3.23.).

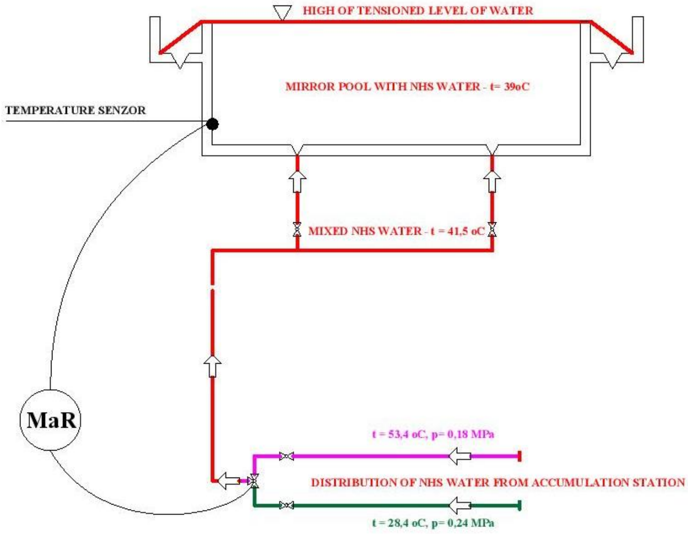


Picture 3.23. – Location of experimental thermography measurement



Scheme 3.7. – Experimental thermography measurement

The experimental measurement (Scheme 3.7.) was elaborated on 28.03.2017 during the operation of the Balneotherapy with thermography camera Flir – basic parameters stated in the Chapter 2. From thermography pictures it is possible to say, that at the time of measurement hot natural healing water distributed to the Balneotherapy departments was 62,0 – 65,6 °C and temperature of cooled natural healing water distributed to the Balneotherapy was 30 – 31 °C which depends on the temperature sensor at bottom of technological devices and its current using (Scheme 3.8.). It is although possible to say that temperature of fluid distributed from accumulation station is higher than temperature at mixing armature due to distribution losses stated in previous section.



Scheme 3.8. – mixing armature and temperature sensor at balneotherapy technological devices

3.2.5.6. Distributors of NHS - Temperature measurement

Experimental measurement of NHS water distributor temperature was provided by Comet data logger – basic parameters are stated in previous chapter. Table 3.11. shows example of experimentally measured values, which were process into charts stated below.

Table 3.11. – Example of experimentally measured values at distributor of NHS water

Date and time	Hot NHS water	Cooled NHS water
	[°C]	[°C]
13.3.17 3:45	64,20	31,20
13.3.17 4:00	65,40	31,40
13.3.17 4:15	65,40	31,30
13.3.17 4:30	65,40	31,00
13.3.17 4:45	65,40	30,80
13.3.17 5:00	63,60	30,70
13.3.17 5:15	63,90	30,60
13.3.17 5:30	64,10	30,80
13.3.17 5:45	64,10	31,10
13.3.17 6:00	64,10	31,30

Chart 3.5. – Experimental measurement of time and temperature dependence of hot NHS water from distributor

Chart 3.6. – Experimental measurement of time on temperature dependence of cooled NHS water from distributor

After chart review, it is possible to say that, during the experimental measurement hot the NHS water distributed to the Balneotherapy departments is in range 63 – 65,7 °C (Chart 3.5.) and the cooled NHS water distributed to the Balneotherapy departments is in range 20,0 – 35,0 °C (Chart 3.6.). Obtained values will be input data for design of actions which will help to the SLKP a.s. to fulfill the European Union´s goals.

3.2.6. Korobon – graphite heat exchanger

For ensuring the operation of the Balnotherapy in the SLKP a.s., the opened natural healing water system is complete with the distribution of cooled NHS water, which is prepared at the Korobon graphite block heat exchanger (see Scheme 3.10.). The Korobon heat exchangers is special atypical heat exchanger situated at the accumulation station. It was constructed in 1965 in the Germany Democratic republic by company VEB ELEKTROCHEMISCHES KOMBINAT BITTERFIELD under the name KAMMER – WÄRMEUBERTRAGER K20/20 – KOROBON 10302 (Picture 3.24.).

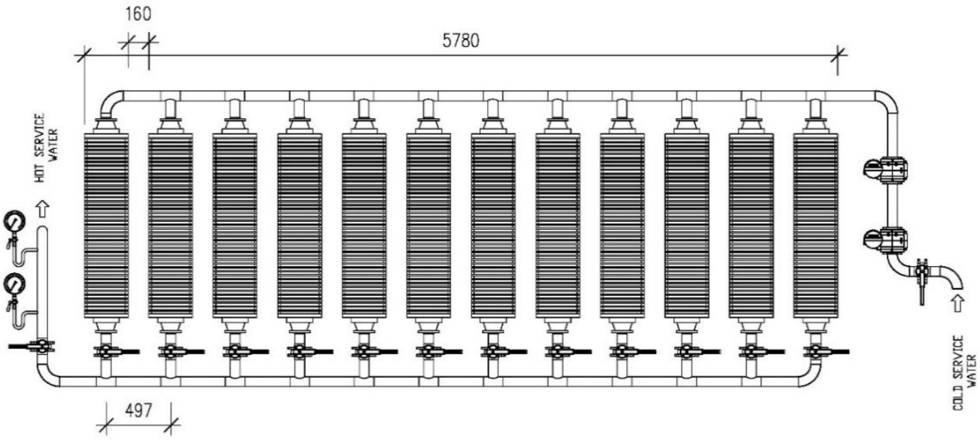
Basic parameters:

- Number of units: 12
- Heat transfer surface area: 22 m^2 / unit
- Height: 1,63 m
- Length: 1,565 m
- Width: 0,440 m
- Power of one unit: 112 kW
- Power of heat exchanger: 1 344 kW

Picture 3.24. – Korobon block graphite heat exchanger

3.2.6.1. Developing simplified schemes – Korobon

Due to the fact that Korobon block graphite heat exchanger is the most important part of opened natural healing water system for further evaluation it is necessary to develop simplified schemes with the basic dimensions of the heat exchanger (Scheme3.9.).



Scheme 3.9. – Korobon: side view

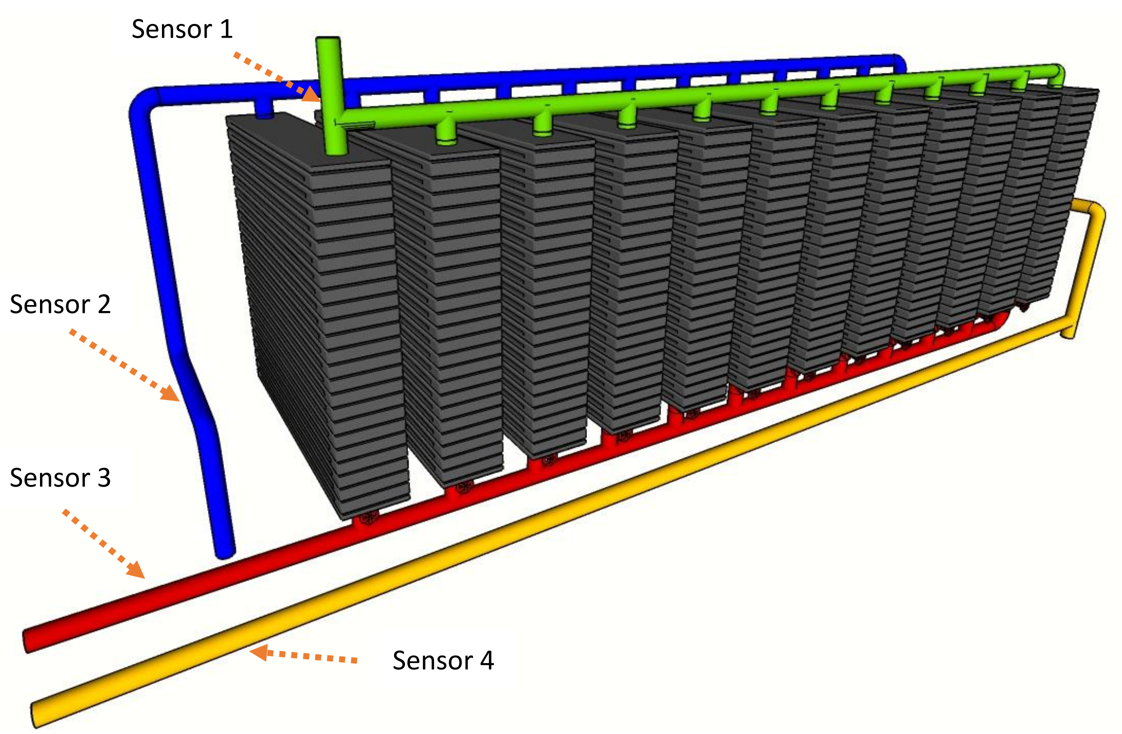
3.2.6.2. Temperature and flow rate measurement – Korobon

The experimental measurement of the NHS water at the Korobon graphite block heat exchanger was provided by the Comet data logger from 20.11.2016 to 11.03.2017 and was hold on the pipelines of the hot natural healing water (red color in scheme), the cooled natural healing water (green color in scheme), the hot service water (yellow color in scheme), the cold service water (blue color in the scheme) (Scheme 3.10.).

After an consultation and technical decision there were four temperature sensors placed, one on each pipelines (see scheme 3.10.). All sensors were insulated from outer influences with polystyrene th. = 40 mm, and the heat transfer area was increased with the help of aluminum foil in shape of U (Picture 3.25.and 3.26.).

Picture 3.25. – Left: Temperature sensor at cooled natural healing water (green pipeline), right: Temperature sensor at cold service water (blue pipeline)

Picture 3.26. – Left: Temperature sensor at hot service water (yellow pipeline), right: Temperature sensor at hot natural healing water (red pipeline)



Scheme 3.10. – Position of senors at Korobon heat exchanger

The temperature data obtained from data logger were recorded into a table and after wise analyzed with the help of graphic solution. Due to the fact that measurement contains more than 10000 records table below is only for illustration purpose (Table 3.12.)

Table 3.12. – Korobon – recorded values from Comet data logger

TIME AND DATE	HOT THERMAL WATER	COOLED THERMAL WATER	COLD SERVICE WATER	HOT SERVICE WATER
	[°C]	[°C]	[°C]	[°C]
20.11.16 12:00	64,00	26,20	18,30	44,00
20.11.16 12:15	64,10	26,30	18,20	43,80
20.11.16 12:30	64,00	25,90	18,30	43,60
20.11.16 12:45	64,10	26,50	18,20	44,70

Measurement of the flow rate was elaborated in two variants. First variant was measured by the Ultrasonic Flow Meter Krohne – basic details are available in Chapter 2. Analyzation by this flow meter was unsuccessful, due to the sedimentation incrust with thickness more than 30 mm on the inner pipeline perimeter (Picture 3.27.) Second variant was elaborated on the base of the recorded data by specialized workers in the accumulation station. This data are archived for global archive of the Slovak Ministry of Health - Spa monitoring system (Picture 3.28.).

Picture 3.27. – Sedimentation incrust at inner pipeline perimeter

Picture 3.28. – Flow rate data recorded by specialized workers at SLKP a.s. [32]

Data recordation is provided every two hours from the water-gauges situated at the hot natural healing water pipeline and cold service water pipeline. This data were processed into an excel table (Table 3.13) and edited with the help of mathematical spline algorithm from the flow rate m^3/2hours to m^3/15min to be compatible with the temperature measurement – table has only informative purpose, due to the total amount of recorded data more than 10 000 values. Mathematical spline algorithm was developed with the help of Microsoft Visual Basic. (see ANNEX 8.2.).

Table 3.13. – Experimental flow rate measurement

TIME AND DATE	WATER-GAUGE		AMOUNT OF WATER		FLOW RATE - 15 min	
	SERVICE WATER	NHS WATER	SERVICE WATER	NHS WATER	SERVICE WATER	NHS WATER
	[m^3]	[m^3]	[m^3]	[m^3]	[m^3 /15min]	[m^3 /15min]
	93645,000	434277,000	0,000	0,000		
20.11.16 12:00	93708,000	434312,000	63,000	35,000	7,875	4,375
20.11.16 12:15	93712,915	434316,575	67,915	39,575	7,408	4,407
20.11.16 12:30	93717,790	434321,107	72,790	44,107	6,944	4,433
20.11.16 12:45	93722,586	434325,554	77,586	48,554	6,490	4,446
20.11.16 13:00	93727,263	434329,871	82,263	52,871	6,049	4,442
20.11.16 13:15	93731,783	434334,018	86,783	57,018	5,625	4,414
20.11.16 13:30	93736,105	434337,950	91,105	60,950	5,222	4,356

Validation of the mathematical spline algorithm was elaborated on the base of comparison of the area under the chart polylines. Chart 3.7. shows original obtained data from specialized workers at spa Piešťany (orange polyline) and data calculated with the help of algorithm (blue polyline). Area under the orange polyline (original data) is 2185,39 units and area under the blue polyline (calculated data) is 2204,64 units. From the analyzation of areas it is possible to stated, that ratio is 99,12 % which is less than 5 % error in transformation and from the technical point of view is satisfied.

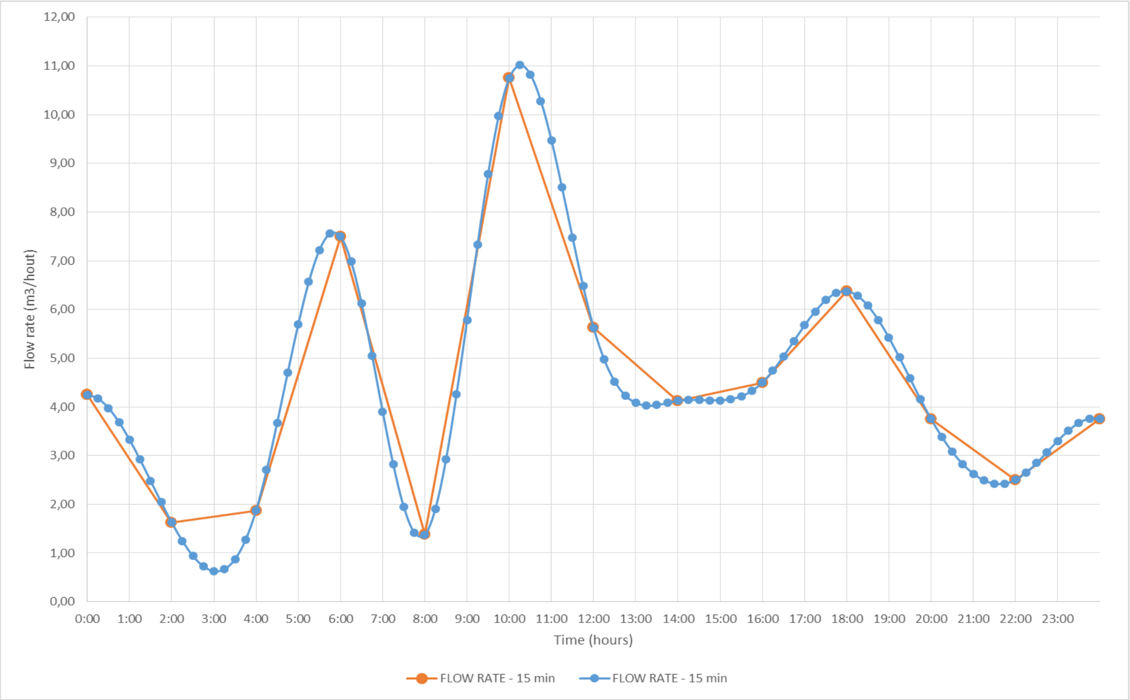


Chart 3.7. – Edited flow rate by mathematical spline algorithm

Chart 3.8. – Senor 1: dependence of time on temperature and flow rate of cooled natural healing water (green pipeline)

Chart 3.9. – Sensor 2: dependence of time on temperature and flow rate of cold service water (blue pipeline)

Chart 3.10. – Sensor 3: dependence of time on temperature and flow rate of hot natural healing water (red pipeline)

Chart 3.11. – Sensor 4: dependence of time on temperature and flow rate of hot service water (yellow pipeline)

After revision of Charts 3.7. – 3.11. it is possible to state that, for the analyzation from the temperature point of view it is necessary to find the average temperature interval of the Korobon heat exchanger operation. For this purpose was developed charts., which shows the temperature values in dependence on the number of values.

From Chart 3.12. – Temperature measurement of the hot natural healing water, is clear that more than 99 % of operation time is the temperature interval (63,0 °C – 64,6 °C), which will be input data for the experimental solution. The temperature interval (62,3 °C – 63,0 °C) is less than 1 % of operation time and could be considerate as an error in measurement caused by outer influences, such as manual control of sensor.

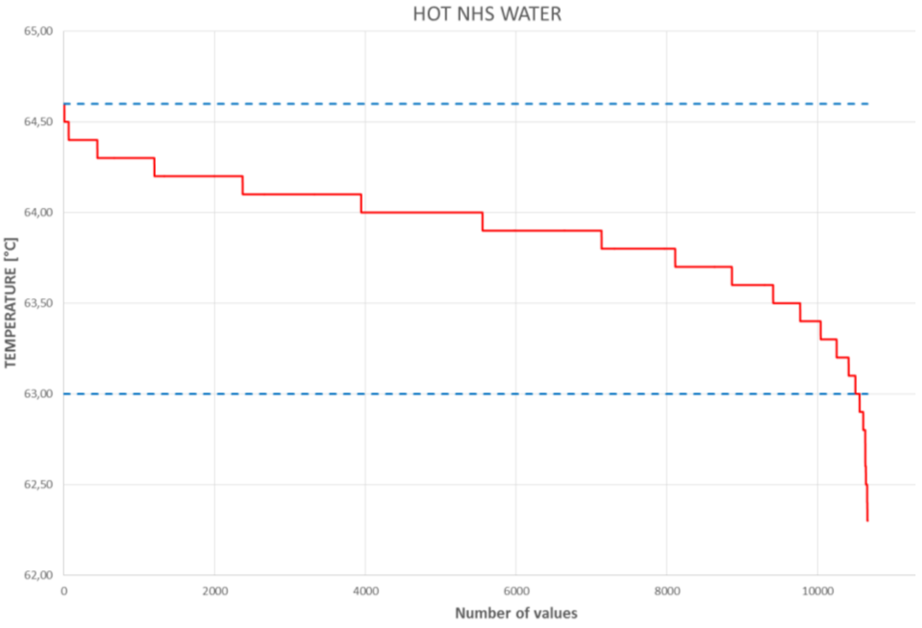


Chart 3.12. – Dependence of temperature and number of values – hot NHS water

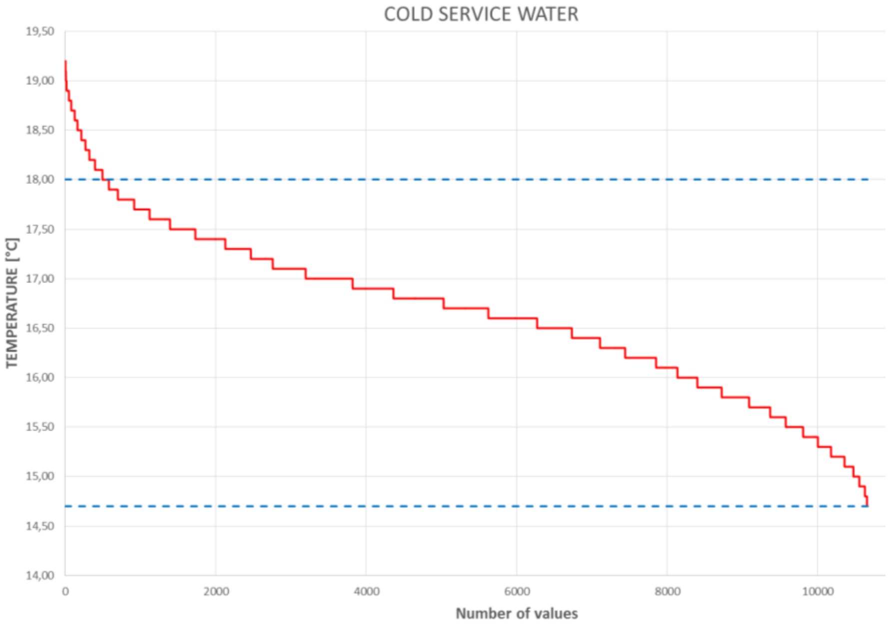


Chart 3.13. – Dependence of temperature and number of values – cold service water

Analyzation of Chart 3.13. – Temperature measurement of the cold service water, shows that more than 95 % of operation time is the temperature interval of cold service water (14,7 °C – 18,0 °C) and will be input data for the experimental solution. Temperature data from interval (18,0 °C – 19,3 °C) is less than 5 % of the operation time and could be considered as an error in measurement, caused by outer influences, such as manual control of sensors.

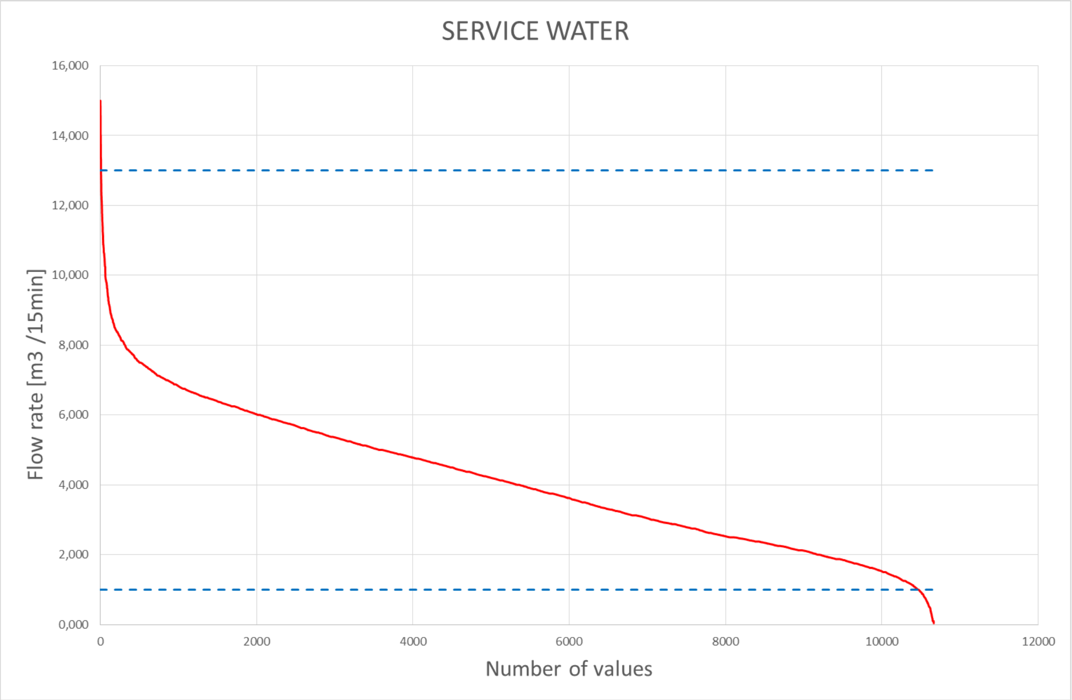


Chart 3.14. – Service water flow rate measurement dependent on number of values

Chart 3.14. – shows dependence of the service water measured values and the number of data, analyzation of the flow rate was consulted with the project manager of SLKP a.s., and after technical revision it could be stated that the flow rate during the operation of the Balneotherapy is in interval (1 m^3/15 min – 13 m^3/15 min), which is 95,2 % of the operation time. Values outside interval are impossible to obtain and could be considered as an error in measurement, caused by human factor. This error is 4,8 % of operation time, which is from technical point of view acceptable.

Chart 3.15. – shows dependence of the hot natural healing water measured values and the number of data, analyzation of the flow rate was consulted with the project manager of SLKP a.s., and after technical revision it could be stated that the flow rate during the operation of Balneotherapy is in interval (1 m^3/15 min – 13 m^3/15 min), which is 96,85 % of operation time. Values outside interval are impossible to obtain and could be considered as an error in measurement, caused by human factor. This error is 3,14 % of operation time, which is from technical point of view acceptable.

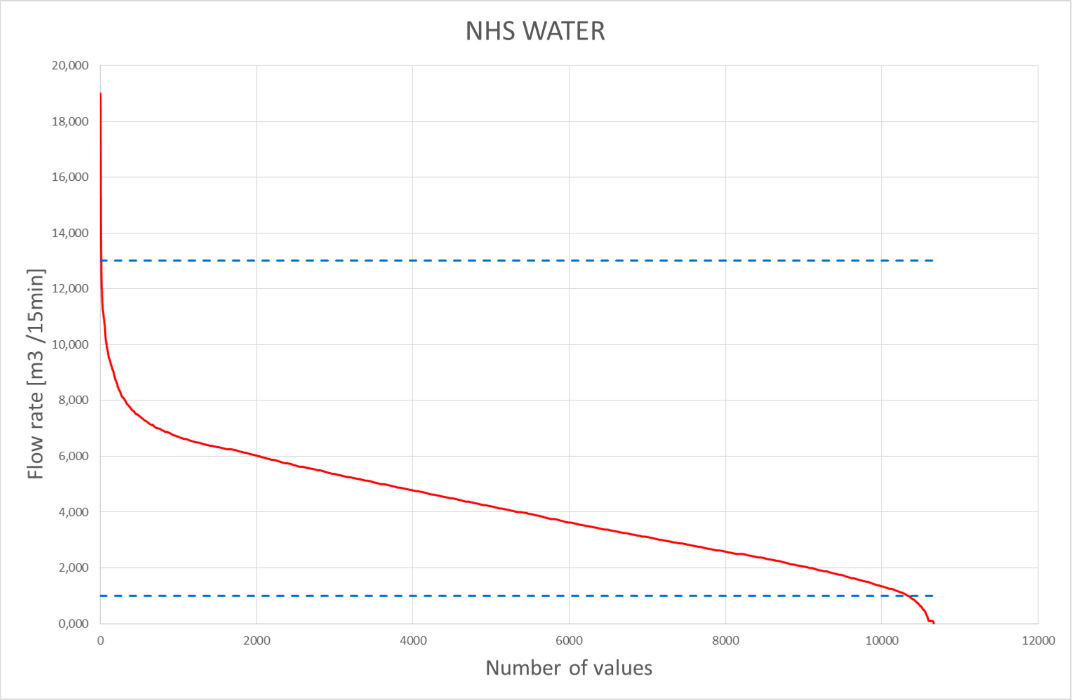


Chart 3.15. – NHS water flow rate measurement dependent on number of values

Chart 3.16. – Service water flow rate week analyzation

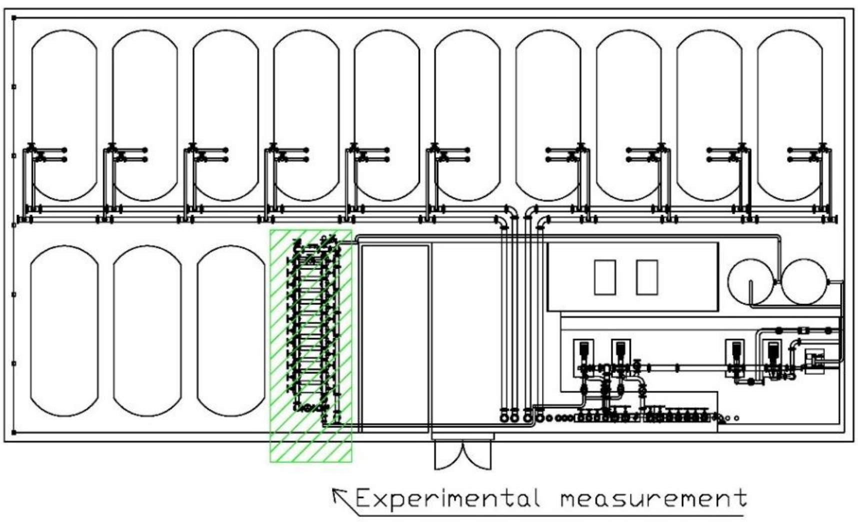
A service water week analyzation (Chart 3.16.) shows the maximum (red line), the average (green line) and the minimum flow rates (blue line) during the measurement at the certain time. From week analyzation it is possible to state that service water system is working with daily periodicity, where the maximum flow rates are reaching during the operation of Balneotherapy and lowest during the night – out of Balneotherapy operation.

Chart 3.17. – Hot natural healing water flow rate week analyzation

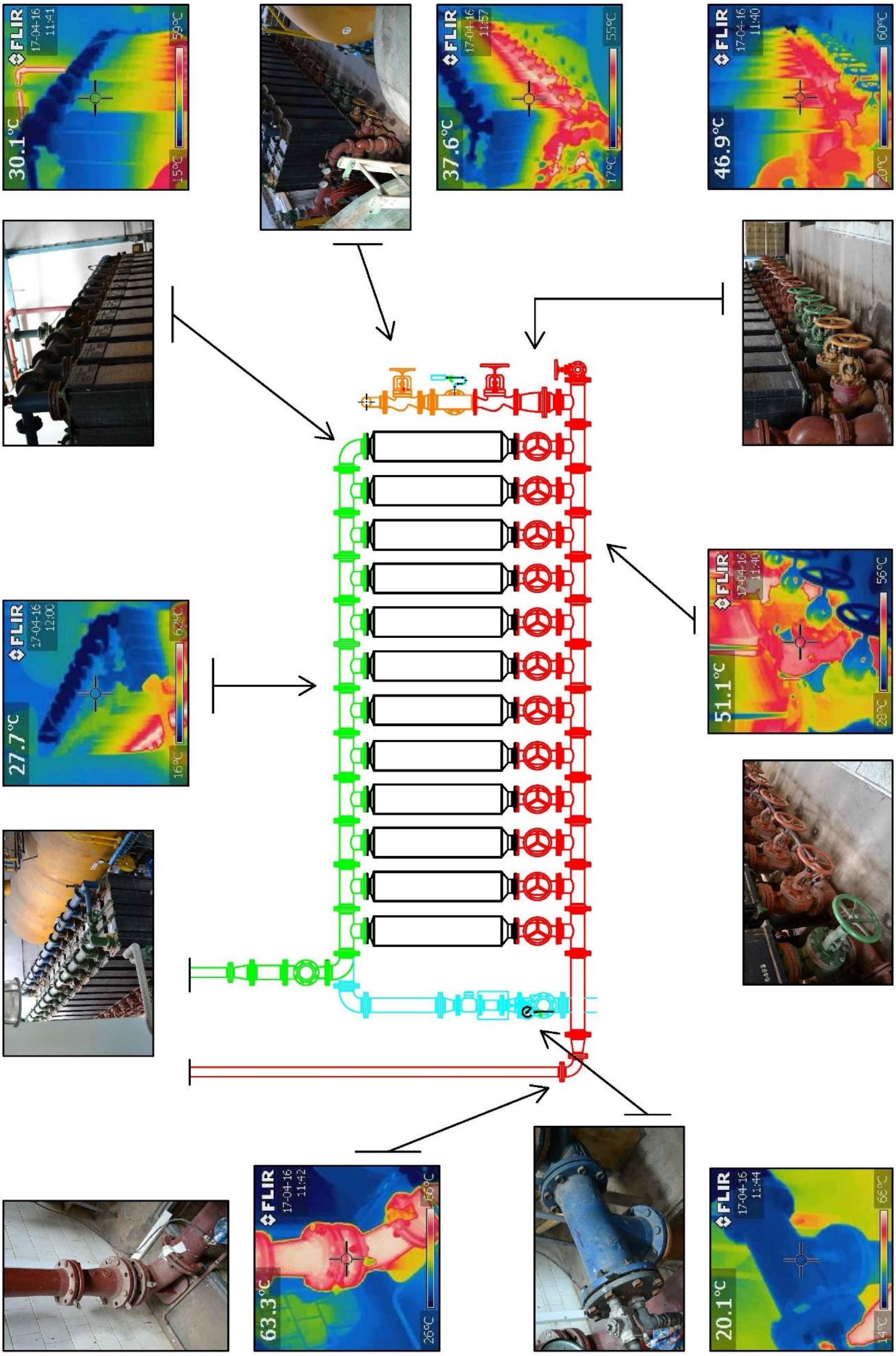
The hot natural healing water flow rate week analyzation (Chart 3.17.) shows the maximum (red line), the average (green line) and the minimum flow rates (blue line) during the measurement at the certain time. From week analyzation it is possible to state that service water system is working with daily periodicity, where the maximum flow rates are reaching during the day – operation of Balneotherapy and lowest during the night – out of Balneotherapy operation.

3.2.6.3. Korobon – thermography analyzation

The thermography analyzation was provided with by thermo camera FLIR (parameters are stated in previous chapter), at the selected part of the Korobon heat exchanger (Picture 3.29.).



Picture 3.29. – Experimental measurement location in accumulation station



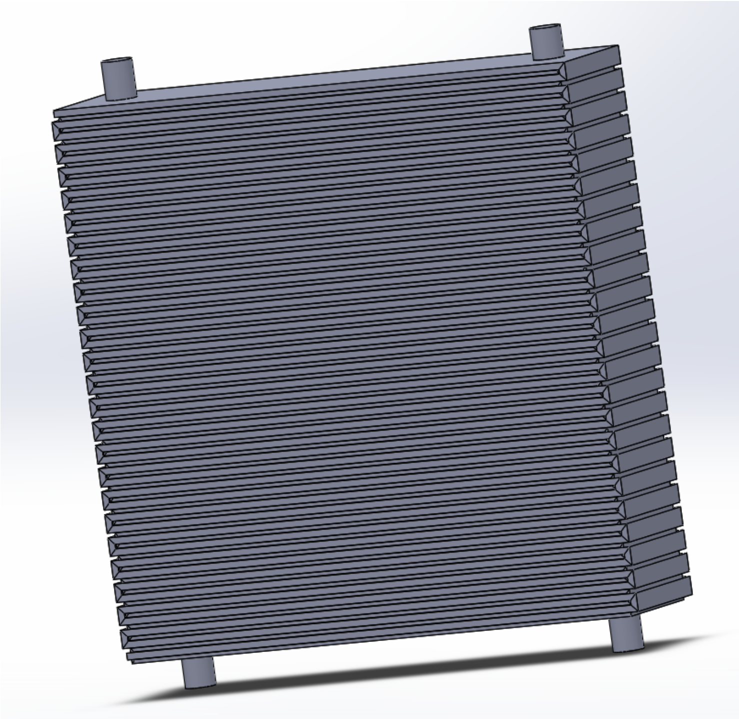
Scheme 3.11. – Korobon heat exchanger thermography analyzation

The eExperimental measurement was elaborated on 28.03.2017 during the operation of Balneotherapy. Thermography analyzation shows that, inlet temperature of the hot natural healing water is 63,3 °C, inlet temperature of the cold service water is 20,1 °C. From thermography pictures is clearly visible that, the Korobon heat exchanger is counter-flow, where from lower part is flowing hot natural healing water, which is cooled down with the cold service water from upper part (Scheme 3.11).

3.2.7. Simplified computer simulation of Korobon in ANSYS software

The computational analysis is provided on one unit of the Korobon heat exchanger, which was due to the academic license of the ANSYS Fluent software restriction in the amount of the computational ceils simplified. Simplified analysis is provided in three steps described in Chapter 2..

First step was to develop the simplified geometry of the existing Korobon heat exchanger unit, based on the real documentation. The geometry was developed with the help of the SOLIDWORKS 2017 academic. (Picture 1.1.).



Picture 3.30. – Simplified geometry of Korobon unit in SOLIDWORKS 2017

Secondly, the mesh (Picture 3.31.) was generated from the developed geometry and in the way that fulfill the minimum quality requirements (Table 3.14. and 3.15).

Table 3.14. – Skewness requirements

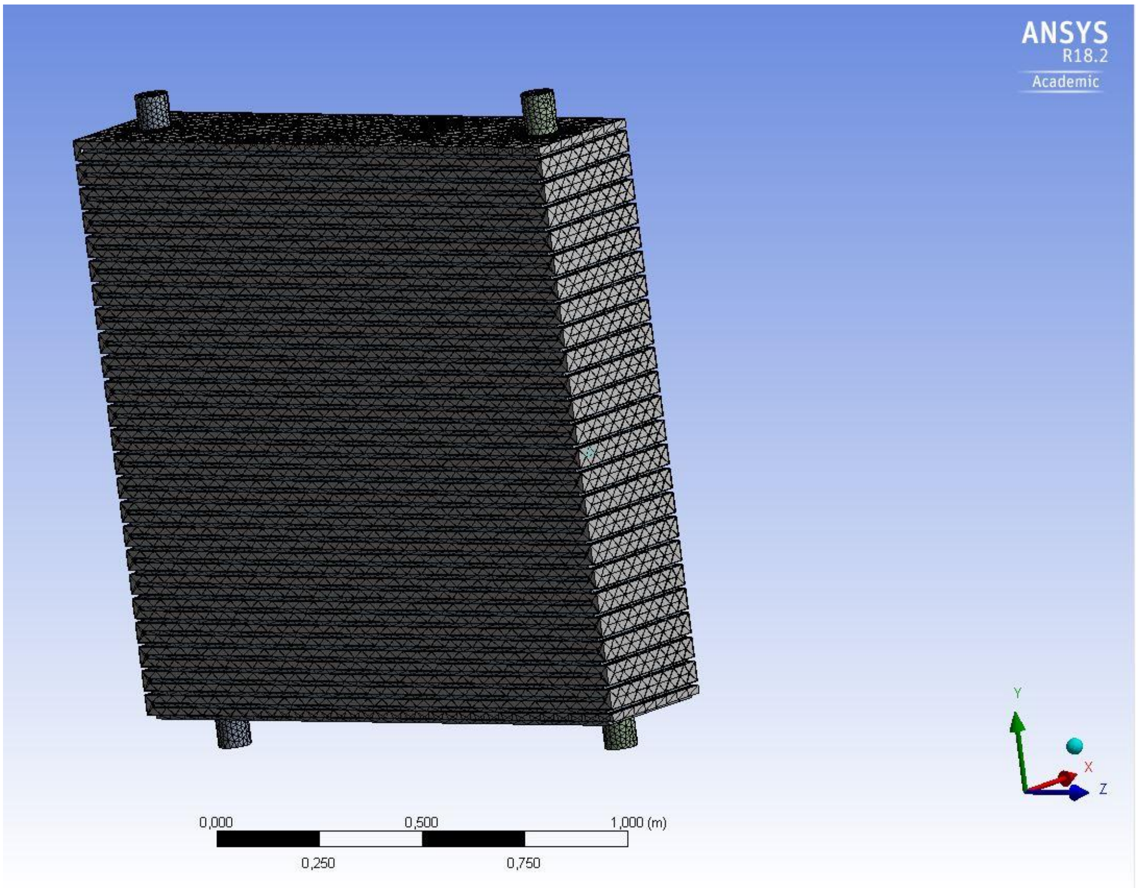
Skewness mesh metrics spectrum:

Excellent	Very good	Good	Acceptable	Bad	Unacceptable
0-0.25	0.25-0.50	0.50-0.80	0.80-0.94	0.95-0.97	0.98-1.00

Table 3.15. – Orthogonal quality requirements

Orthogonal Quality mesh metrics spectrum:

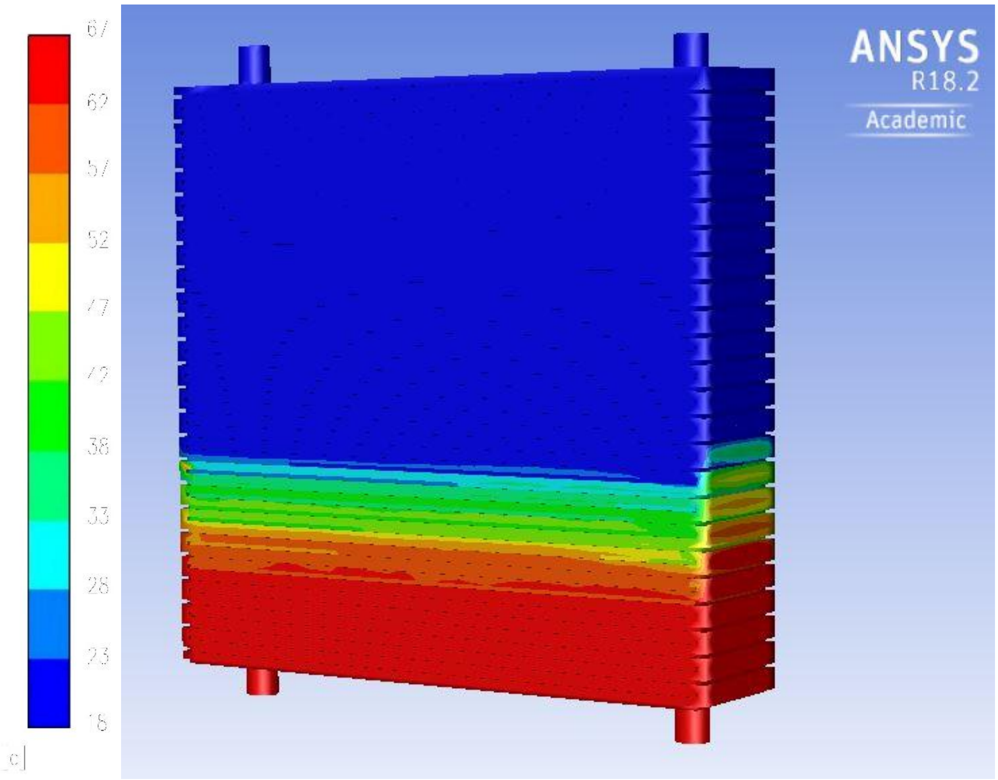
Unacceptable	Bad	Acceptable	Good	Very good	Excellent
0-0.001	0.001-0.14	0.15-0.20	0.20-0.69	0.70-0.95	0.95-1.00



Picture 3.31. – Mesh of Korobon unit generated in ANSYS software

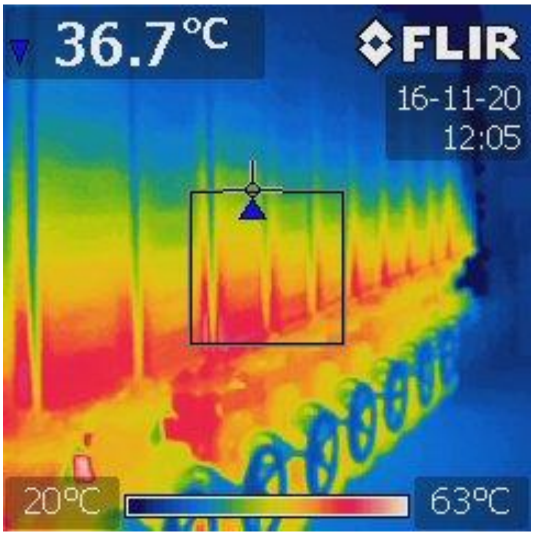
Thirdly the solution was evaluated in the ANSYS Fluent software with the boundary condition, which were obtained from the real operation of the Korobon heat exchanger:

- Hot inlet temperature: 67 °C
- Cold inlet temperature: 18 °C
- Hot water flow rate: 13,03 l/s
- Cold water flow rate: 13,3 l/s



Picture 3.32. – Solution of thermal field in Korobon unit evaluate in ANSYS Fluent

The graphical solution gives us view on the process at the Korbon heat exchanger unit during the operation and future possibility to determine critical states. A validation of calculated data is provided by thermography picture of the Korobon heat exchanger generated at the time of the boundary conditions (Picture 3.33.).



Picture 3.33. – Thermography picture of Korobon heat exchanger.

The main goal of this diploma thesis is to analyses whole opened natural healing system and for the more precise evaluation and the computational calculation is necessary to obtain higher quality of the mesh, which is not possible with the ANSYS Fluent academic license.

3.2.8. Slovak Health Spa Piešťany a.s. – energy overall evaluation

Operation of the Balneotherapy in the SLKP a.s is complicated accumulation and distribution system. For this purpose was elaborated the current state overall analyzation. Table 3.16. concerns all partial analyzation stated before and provide results of measurements.

Table 3.16. – Overall analyzation of SLKP a.s.

Based on the measured data and analyzation it is possible to say that for operation of the Balnotherapy and other collection places, is necessary to accumulate 731,64 m^3/day of the hot NHS water and 621,69 m^3/day of the cooled NHS water. Current accumulation system – the Korobon heat exchanger is able to accumulate 489,26 m3/day of the cooled NHS water, which is less than total amount of the cooled NHS water daily used in operation of the Balneotherapy. This water amount difference is currently solved by the accumulation of cooled and hot NHS water in the accumulation tanks from where is transporting to the Balneotherapy in case of higher water amount demand.

3.3. PARTIAL CONCLUSION

The Balneotherapy departments and technological devices belongs to oldest equipment, which use the natural healing water. The balneotherapy of the Slovak Health Spa Piešťany is one of them. For all years of the operation people were considering them as an equipment which heals their organism. Energetic and ecologic point of view was secondary, respectively any.

Elaborated analysis gives us a comprehensive view of the Balneotherapy operation of the opened natural healing source water system in the SLKP a.s..

The Balneotherapy departments, are operating on the base of manual NHS water collection regulation (experiences of accumulation station employees). For the further operation it is necessary to design new electronic system of monitoring and regulation.

Treatment temperature at the Balneotherapy departments is required to be 40 °C, which ensured by the mixing armatures of cold and hot NSH water at each object entrance. From experimental measurement was discovered that deficit of the cooled NHS water during the operation is problem and nowadays is solved by adding water from accumulation tanks to the opened NHS water system. This solution is inappropriate and for future operation it is necessary to design new technological devices which will be more efficiency cooling down hot NHS water.

4. EXPERIMENTAL SOLUTION AND PROCCESING OF RESULTS

The subject of this chapter is to process analysis result and design technological processes and devices, which will help Slovak Health Spa Piešťany a.s. to increase energy, economic and environmental operation of Balneotherapy departments and fulfill European Union goals.

4.1. AIM OF EXPERIMENTAL SOLUTION

The experimental solution solved reconstruction of the accumulation station in the Slovak Health Spa Piešťany a.s., within which the safety operation of the Balneotherapy should be increased, with the maximum usage of the NHS water and the hot service water energetic potential at the same time. This solution will leads to energy costs savings at operation of the Balneotherapy.

Realization documentation (see ANNEX 8.7.) was elaborated on the base of material stated below:

- Project documentation: Tursnov, Žurkin, Hronček, Menkyna, accumulation station of NHS water in Piešťany – reconstruction and extension, April 1995
- Cadastral map of Spa Island
- Individual observation of given object
- Practical experiences of SLKP a.s. employees
- Technical material of technological devices manufacturers
- Previous analysis of opened NHS water system - Chapter 3

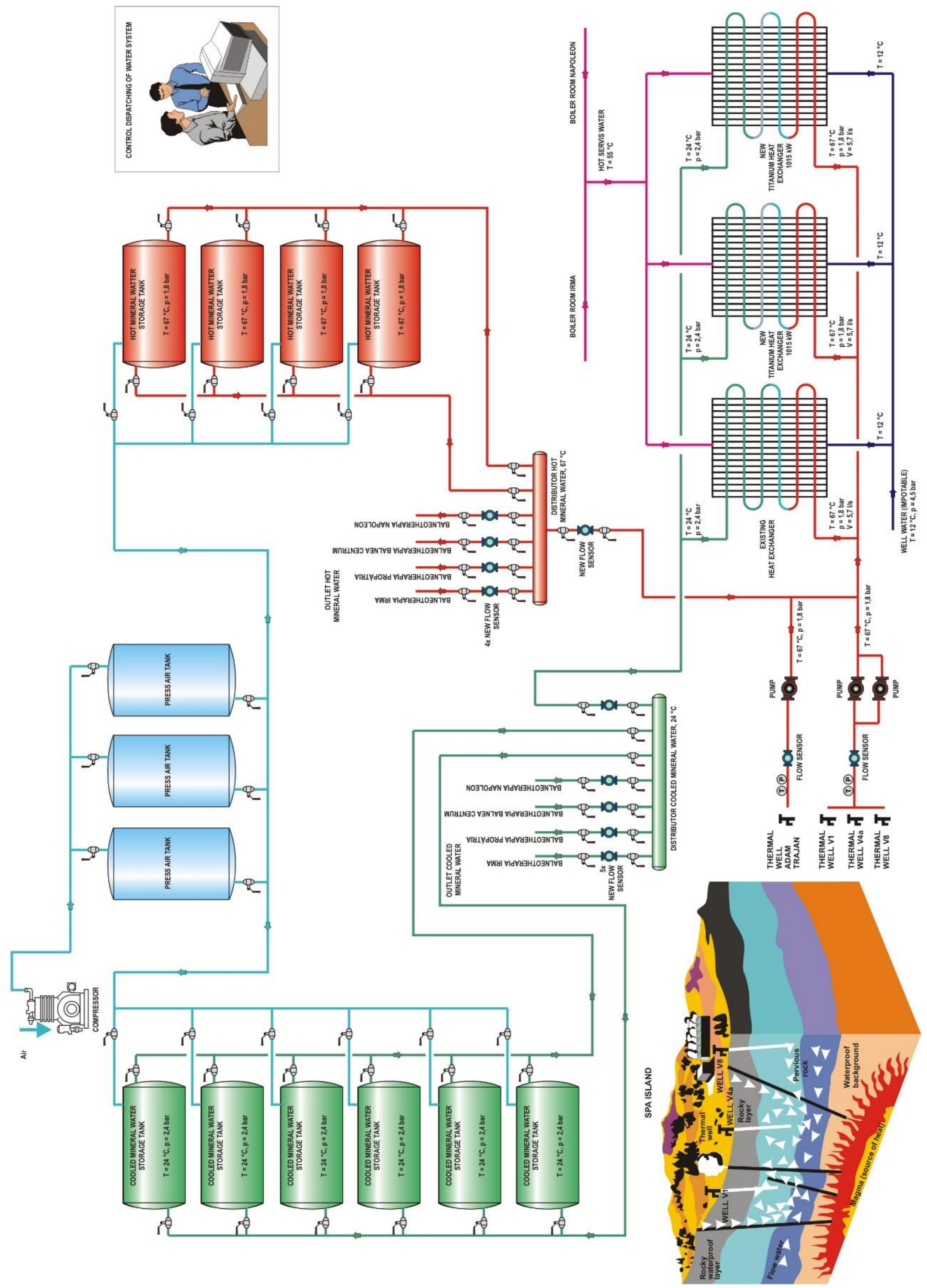
The natural healing water is basic and at the same time the most important element for healing procedures at the Balneotherapy departments. The SLKP a.s. has available seven sources of the natural healing water, while currently it is used only four of them. The NHS water is collecting from depth cca. 50 m and is not pumped. Collection is based on overflow of drills V1, V4a and V8 in combination with pumped well Adam Trajan. The temperature of the NHS water from overflow is cca. 67 °C – 69 °C and at the wells is secured from mixing with over ground water, which ensure constant chemical compound and temperature.

From overflows the NHS water is distributed to the accumulation station, where first part of the natural healing water is stored at the accumulation tanks, second part directly distributed to the Balneotherapy departments and third part cooled down to the temperature cca. 24 °C.

Operation of the Balneotherapy:

- has from long-term point of view deficit of the cooled NHS water, which has impact on individual departments operation and ensuring the healing treatments.
- has not immediate monitoring consumption system of individual Balneotherapy departments, which influence the economy efficiency of the cooled NHS water.

4.2. DESCRIPTION OF TECHNOLOGICAL SOLUTION



Scheme 4.1. – Scheme of accumulation station – designed solution

For increasing the NHS cooled water amount with the temperature cca. 24 °C, will be flanged next heat exchangers at accumulation station. The number of heat exchanger will depend on the type of heat exchanger and expert decision of manufacturers (Scheme 4.1.). New heat exchangers will be situated at lower part of the accumulation station on concrete pads, on which are currently situated pumps (see ANNEX 8.7.) and will be in parallel connection with the existing Korobon heat exchanger. Due to the fact of sedimentation the design of new heat exchanger is based on the assumption to be 100 % backup of the existing Korobon heat exchanger.

The technological solution was elaborated in four variants based on the type and the material of heat exchanger:

- Variant A – Plate heat exchanger (Stainless steel)
- Variant B – Plate heat exchanger (Titanium steel)
- Variant C – Plate heat exchanger (Carbon fibers steel)
- Variant D – Graphite block heat exchanger (Carbon fibers steel)

4.2.2. Variant A – Plate heat exchanger (Stainless steel)

Cooled NHS water will be prepared at one plate heat exchanger from SWEP Company B649HTx206/1P-SC-S (/ 4xDN150C PN40 - ASME FORGED) made of stainless steel parallel connected to existing Korobon heat exchanger with total heat exchange 2155 kW.

SWEP technical specification (Picture 4.1.):

A DOVER COMPANY

SWEP International AB
Box 105, Hjalmar Brantings väg 5
SE-261 22 Landskrona, Sweden
www.swep.net

JEDNOFÁZOVÉ - NABÍDKA
VÝMĚNÍK TEPLA : B649HTx206/1P-SC-S (/ 4xDN150C PN40 - ASME FORGED)

SSP G7 - (v 7.0.3.76)
Datum : 2017-11-10

Art No : 17215-206

Acc. No.	**Denomination**
28388	B649 COMPLETE OPTION SUPPORT LEGS + HANGERS

Informace o připojení	P1 -	FLANGE DN150C PN40AISI 304- ASME/PED(54)
	P2 -	FLANGE DN150C PN40AISI 304- ASME/PED(54)
	P3 -	FLANGE DN150C PN40AISI 304- ASME/PED(54)
	P4 -	FLANGE DN150C PN40AISI 304- ASME/PED(54)
Umístění připojení	Strana 1:	P2/P4 (Uvnitř / Ven)
	Strana 2:	P3/P1 (Uvnitř / Ven)
Médium strana 1 :	Water	
Médium strana 2 :	Water	
Strana 1 :	Vnitřní okruh	
Strana 2 :	Vnější okruh	

Typ toku : Protiproud
SSP Alias : B649HT

TECHNICKÉ ZADÁNÍ		**Strana 1**		**Strana 2**
Výkon	kW		2155	
Vstupní teplota	°C	61,00		14,00
Výstupní teplota	°C	21,00		58,00
Průtočné množství	l/s	13,00		11,80
Maximální tlaková ztráta	kPa	50,0		50,0
Termická délka		8,473		9,32

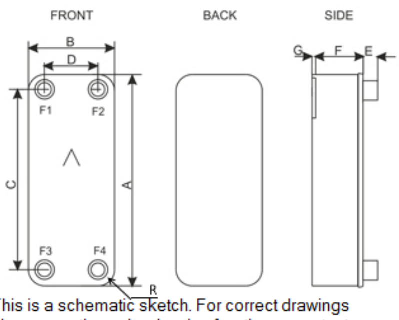
DESKOVÝ VÝMĚNÍK TEPLA		**Strana 1**		**Strana 2**
Teplosměnná plocha	m²		134	
Tepelný tok	kW/m²		16,1	
Střední teplotní rozdíl	K		4,72	
Koeficient prostupu tepla (dostupný/žádaný)	W/m²,°C		4120/3420	
Tlaková ztráta - celková*	kPa	52,1		44,3
- v připojení	kPa	0,254		0,209
Průměr připojení	mm	150/150 (hore/dolu)		150/150 (hore/dolu)
Počet kanálů na průchod		103HT		102HT
Počet desek			206	
Plošná rezerva	%		21	
Faktor znečištění	m²,°C/kW		0,050	
Reynoldsovo číslo		728,1		607,5
Rychlost v připojení	m/s	0,736/0,736 (hore/dolu)		0,668/0,668 (hore/dolu)

FYZIKÁLNÍ VLASTNOSTI		**Strana 1**		**Strana 2**
Referenční teplota	°C	41,00		36,00
Dynamická viskozita	cP	0,641		0,706
Dynamická viskozita – u stěny	cP	0,669		0,674
Hustota	kg/m³	991,9		993,7
Měrná tepelná kapacita	kJ/kg,°C	4,179		4,178
Tepelná vodivost	W/m,°C	0,6320		0,6248
Max. tepelný rozdíl u steny	K		0,55	
Min. teplota média na stěně	°C	17,90		17,35
Max. teplota média na stěně	°C	59,67		59,43
Koeficient přestupu tepla	W/m²,°C	9300		8630
Průměrná teplota stěny	°C	38,79		38,41
Rychlost v kanálech	m/s	0,168		0,154
Smykové napětí v mezní vrstvě	Pa	35,6		30,2

ÚHRNÉ HODNOTY		**Strana 1**		**Strana 2**
Celková hmotnost prázdny	kg		481	
Celková hmotnost plný	kg		668	
Hold-up objem, vnitří obvod	dm³		93,6	
Hold-up objem, vnější obvod	dm³		94,6	
Velikost připojení F1/P1	mm		150	
Velikost připojení F2/P2	mm		150	
Velikost připojení F3/P3	mm		150	
Velikost připojení F4/P4	mm		150	
NND F1/P1	mm		158	
NND F2/P2	mm		158	
NND F3/P3	mm		158	
NND F4/P4	mm		158	

Uhlíková stopa	kg	3200
Materiál desek		316 Nerezavějící ocel
Materiál pájky		Měď
Max. provozní tlak	bar	25/22
Testovací tlak	bar	43
Max provozní teplota	°C	135/225

Rozměry



This is a schematic sketch. For correct drawings please use the order drawing function or contact your SWEP representative.

A	mm	1230 +/-2
B	mm	537 +/-2
C	mm	995 +/-2
D	mm	300 +/-2
E (F-Strana)	mm	0,000
E (P-Strana)	mm	54,0
F	mm	376
G	mm	0,000 +/-1
R	mm	118

Picture 4.1. – Plate heat exchanger – technical specification SWEP Company

4.2.3. Variant B – Plate heat exchanger (Titanium)

The cooled NHS water will be prepared at two plate heat exchangers AQ4LP, from Alfa-laval Company with the total heat exchange 2000 kW. This plate heat exchanger is certified with the AHRI certifying program for the heat exchanger liquid-liquid according to the standard AHRI 400. The heat exchanger certified with the AHRI are subject of strict and uninterrupted control. These plate heat exchanger will be connected parallel to the existing Korobon heat exchanger.

Alfa – laval technical specification (Picture 4.2.):

Cas 2000-5.59
/11. 4. 2016/ 7:36:15
PPL PHE EUR 16.1
Lund OM-SEI 16.1
Application: AHRI 400 Version 15.1
Automatic 1-Phase

AHRI CERTIFIED™ www.ahridirectory.org

ALFA LAVAL

Alfa Laval Plate Heat Exchanger Specification

Model : AQ4LP 181 PL Titanium
Item : AHRI 10kPa Date : 11. 4. 2016

		Hot side	Cold side
Fluid		Water	Water
Density	kg/m3	989.8	992.8
Specific heat capacity	kJ/(kg*K)	4.18	4.18
Thermal conductivity	W/(m*K)	0.633	0.623

Viscosity inlet	cP	0.420	1.17
Viscosity outlet	cP	0.983	0.480
Volume flow rate	l/s	13.0	13.3
Inlet temperature	°C	67.0	14.0
Outlet temperature	°C	21.0	58.0
Pressure drop	kPa	9.41	10.3
Fouling resistance * 10000	m2*K/W	0.26	
Duty margin	%	9.9	
Heat exchanged	kW	2445	
L.M.T.D.	K	8.0	
Heat transfer coefficient	W/(m2*K)	3422	
Heat transfer area	m2	89.5	
Rel. directions of fluids		Countercurrent	
Number of plates		181	
Plate material / thickness		TI / 0.50 mm	
Channel arrangements		1*90H	1*90H
Number of passes		1	1
Extension capacity		6 plates	
Connection diameter	mm	100	100
Design pressure	bar	10.0	10.0
Design temperature	°C	80.0	80.0
Overall length x width x height	mm	1740 x 480 x 1885	
Net weight, empty / operating	kg	790 / 1020	
Nominal A-Dimension	mm	637.1	

Picture 4.2. - Plate heat exchanger – technical specification Alfa-laval

4.2.4. Variant C – Plate heat exchanger (Carbon fibers)

The cooled NHS water will be prepared at two plate HCGP-GXD-042-L-5-NR-61 heat exchangers, from Hennlich Company with total heat exchange 2477 kW. These plate heat exchangers will be connected parallel to the existing Korobon heat exchanger.

Hennlich company technical specification (Picture 4.3.):

HENNLICH

Výpočet výměníku

Zákazník:	Miček Denis	Datum:	13.11.2017
		Nabídka č.:	
Email:		Výpočet č.:	2302763
Reference zákazníka:	Lázně Piešťany	Pozice č.:	
		Technik:	
Typ:	**HCGP-GXD-042-L-5-NR-61**	Počet výměníků:	2 (v sérii!)

		Teplá Strana		***Studená Strana***		
Médium		Voda		Voda		
PROVOZNÍ ÚDAJE		***Vstup***	***Výstup***	***Vstup***	***Výstup***	
Průtok - kapalina	kg/s	12,88	12,88	13,21	13,21	kg/s
Provozní teplota	°C	67,00	21,00	14,00	58,85	°C
Tlak.ztráta (Dov./Skut.)	kPa	50,00 / 44,56		50,00 / 47,16		kPa

Provozní tlak	MPa(g)	0,25	0,21	0,43	0,38	MPa(g)
Výkon	kW		2 477			
K (čistý)	W/(m²·°C)		7 176			
K (provozní)	W/(m²·°C)		6 311			
Celková teplosměnná plocha (vým	m²		51,92			
LMTD	°C		7,56			
Plošná rezerva	%		12			
FYZIKÁLNÍ VLASTNOSTI		***Vstup***	***Výstup***	***Vstup***	***Výstup***	
Měrná hmotnost	-	0,98	1,00	1,00	0,99	
Specifické teplo	kJ/(kg·°C)	4,19	4,18	4,18	4,19	
Tepelná vodivost	W/(m·°C)	0,66	0,60	0,59	0,65	
Viskozita (prům.)	cP	0,42	0,97	1,17	0,48	
PŘIPOJENÍ						
Pozice		S1	S3	S2	S4	
Typ		STUDDED	STUDDED	STUDDED	STUDDED	
Velikost		DN100	DN100	DN100	DN100	
Jm.tlak		DIN2501 PN10	DIN2501 PN10	DIN2501 PN10	DIN2501 PN10	
Materiál		S355J2 Carbon Steel		S355J2 Carbon Steel		
KONSTRUKCE						
Počet cest		1		1		
Uspořádání kanálů		30LS+0LD		30LS+0LD		
No. of units in series		2				
Rozměr-A / Rozměr-C	mm	231,8 / 1036				
Materiál desek (Materiál / tloušťka)		1.4401 / 0.5 mm				
Materiál těsnění (Teplá/Studená Strana)		NBR		NBR		
Počet desek		61				
Materiál rámu/Nátěr/Odstín		S355J2 Carbon Steel / Enamel / RAL 5012 (Royal Blue)				
Stahovací šrouby / matice Materiál / Povrchová		8.8 / 8 / FZB				
Tlak (Návrhový / Zkušební)	MPa(g)	1,00 / 1,43		1,00 / 1,43		
Teplota (Min. / Max. Návrhová)	°C	-10,00 / 80,00		-10,00 / 80,00		
Hmotnost prázdný/plný	kg	476 / 556				
Norma		PED				

Picture 4.3. - Plate heat exchanger – technical specification Hennlich.

4.2.5. Variant D – Graphite block heat exchanger

This variant was elaborated with the help of SGL Group Company, which is designer of the original placed block graphite heat exchanger Korobon. Technical specification is designed in the way of adding next 12 DIABON graphite groove heat exchangers parallel to the existing Korobon heat exchanger.

Technic specification from SGL Group Company (Picture 4.4.):

Customer:	**Slovenske Liecebne Piestany**	SGL GROUP THE CARBON COMPANY Prozess Technology
Project:	**12 units in parallel**	
Date:	**21.12.2017**	

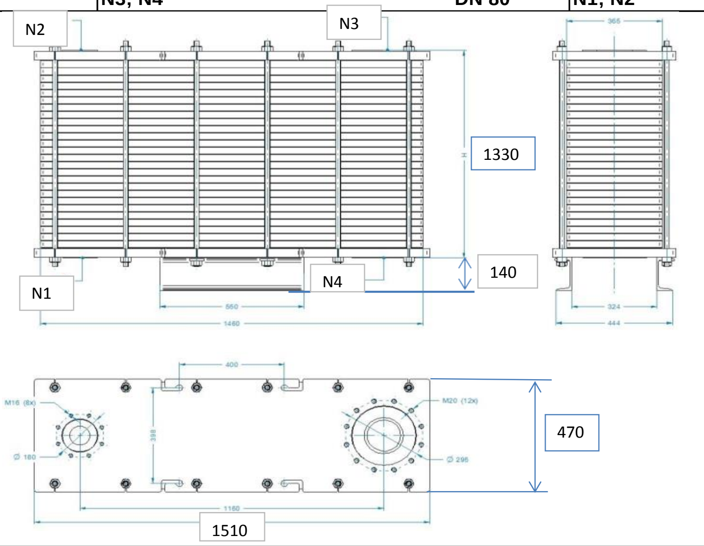
Media:	**System 1** **Media 1:** **Water**	**System 2** **Media 2:** **Water**

Process Data	**Symbol**	**Steam In**	**Liquid out**	**Unit**	**Symbol**		**Unit**
Mass flow per unit	m_1	**0**	**3900**	**kg/h**	m_2	**3990**	**kg/h**
Volume flow	V_1	**0**	**3,91**	**m³/h**	V_2	**4,0**	**m³/h**
Temperature IN	T_{E1}	**67**		**°C**	T_{E2}	**14**	**°C**
Temperature OUT	T_{A1}	**21**		**°C**	T_{A2}	**58**	**°C**
Pressure (abs.)	p_1	**2,5**		**bar**	p_2	**4,3**	**bar**
Max. allowed pressure drop	Δp_{1zul}	**0,5**		**bar**	Δp_{2zul}	**0,5**	**bar**

Calc. pressure drop	Δp_1	0,07	bar	Δp_2	0,087	bar
Fouling factor	R_1	0	m^2K/W	R_2	0	m^2K/W

Physical properties		Steam	Liquid				
Density	ζ_1 (Rho$_1$)	0	998	kg/m^3	ζ_2 (Rho$_2$)	998	kg/m^3
Spec. heat capacity	c_{p1}	0	4180	J/kgK	c_{p2}	4180	J/kgK
Heat conductivity	λ_1 (Lambda$_1$)	0	0,643	W/mK	λ_2 (Lambda$_2$)	0,643	W/mK
Viscosity	η_1	0,000554	0,000554	kg/ms	η_2	0,00055	kg/ms

Heat Duty	208,3 kW				
MTD	8 K				
Required Area	42,2 m2				
Actual Area	21,5 m2				
Overdesign	-49%				
Choosen apparatus	GHX-H-40-1.1				
Dimensions	1510 x 470 x 1330 mm				
Weight	ca.1164 kg				
Process Volume	System 1	136	l	System 2	114 l
Nozzle Diameter	N3; N4		DN 80	N1; N2	DN 80



Picture 4.4. – Graphite block heat exchanger – SGL Group

4.3. MULTIPLE-CRITERIA DECISION ANALYSIS OF VARIANTS

The multiple-criteria decision analysis is provided according to the step defined in Chapter 2. Firstly, it was necessary to define the criteria for evaluation of individual variants. Secondly, with the help of chosen method was defined the strength of individual criteria. Afterwards the calculation of overall variants usefulness was elaborated. From results the most efficient variant was chosen for given boundary conditions, by the full pair comparison method.

Variant input:

- Variant A – plate heat exchanger (Stainless steel)
- Variant B – plate heat exchanger (Titanium steel)
- Variant C – plate heat exchanger (Carbon steel)
- Variant D – graphite block heat exchanger (Carbon steel)

4.3.1. Criteria definition for multi-criteria decision analysis

For the evaluation and comparison of individual variants was defined 16 criteria to obtain the best possible choice. Analysis will be solved as a maximizing – the more points the criterion from the cardinal state obtain, the more important for choosing the best variant is.

Defined criteria:

A. Material (chosen because each material has different durability in NHS water)
B. Estimated price (total costs for purchasing)
C. Experience in operation (SLKP a.s. experience in operation of heat exchanger from long-term point of view)
D. Possibility of cleaning
E. Ability and ease of future expansion
F. Width
G. Length
H. Height
I. Heat transfer area
J. Maximum design temperature
K. Minimum design temperature
L. Maximum working pressure
M. Maximum flow rate
N. Minimum flow rate
O. Calcium sedimentation (Aggressive water in SLKP a.s. and its sedimentation at given material according to boundary conditions)
P. Sulfur sedimentation (Aggressive water in SLKP a.s. and its sedimentation at given material according to boundary conditions)

4.3.2. Calculation of normative strength of criteria

It is necessary to compare defined criteria between each other, analyze its importance, chose not standardized criteria strengths and translate them into the standardized forms. [14]

For strength determination of individual criteria was chosen the indirect method – full pair comparison (with restricted equality of criteria strengths). The determination was elaborated on the base of following steps:

I. Development of criteria matrix (Table 4.1.), where in the first row are enrolled defined criteria
II. Into upper triangular matrix is written that criterion, which in comparison with other has bigger strength – is more important
III. Into column k_i – number of criterion occurrence is written occurrence amount of individual criterion at whole upper triangular matrix. If the situation that two criterion has same occurrence following formula must be used $k_i = n + 1 - p_i$, where n is number of criteria and pi is criterion rank from best to worst

IV. Translation from non-standardized form to standardized form is provided with following formula: [14]

$$\alpha_i = \frac{k_i}{\sum_{i=1}^{n} k_i}$$

Table 4.1. – Criteria matrix with defined standardized strengths

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	k_i	$k_i = n + 1 - p_i$	α_i
A	-	A	C	A	E	F	G	H	I	J	K	L	M	N	O	P	2	3	0,0221
B	-	-	C	B	E	F	G	H	I	J	K	L	M	N	O	P	1	1	0,0074
C	-	-	-	C	C	C	C	C	I	C	C	C	C	C	O	P	12	14	0,1029
D	-	-	-	-	D	F	G	H	D	J	K	L	M	N	O	P	2	2	0,0147
E	-	-	-	-	-	E	E	E	I	J	K	L	M	N	O	P	5	7	0,0515
F	-	-	-	-	-	-	F	F	I	J	K	L	M	N	O	P	5	6	0,0441
G	-	-	-	-	-	-	-	G	I	J	K	L	M	N	O	P	4	5	0,0368
H	-	-	-	-	-	-	-	-	I	J	K	L	M	N	O	P	3	4	0,0294
I	-	-	-	-	-	-	-	-	-	J	I	I	I	I	O	P	11	12	0,0882
J	-	-	-	-	-	-	-	-	-	-	J	L	M	J	O	P	10	11	0,0809
K	-	-	-	-	-	-	-	-	-	-	-	L	M	N	O	P	7	8	0,0588
L	-	-	-	-	-	-	-	-	-	-	-	-	M	L	O	P	10	10	0,0735
M	-	-	-	-	-	-	-	-	-	-	-	-	-	M	O	P	11	13	0,0956
N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	O	P	8	9	0,0662
O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	14	15	0,1103
P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	16	0,1176
																		∑ = 136	∑ = 1

4.3.3. Calculation of overall individual criterion usefulness

The full pair comparison method is used for the calculation of overall individual criterion usefulness. [14]

Table 4.2. (See attachment) provide pair comparison according to partial usefulness of individual variants and criteria. Procedure has to undergo following steps:

I. Partial usefulness of individual variants is based on the calculation of u_{ij} – ratio between individual occurrence of the variant and the total occurrence of variants in dependence on the criterion. The individual occurrence of variant is based on comparison variants between each other and recording which variants is better according to the criterion

II. Usefulness of the individual variant Uj is calculated at Table 1.1. with help of following formula: [14]

$$U_j = \sum_{i=1}^{n} \alpha_i \times u_{ij} \,;\, j = 1,2,3,\dots,m$$

Table 4.2. – Calculation of overall variants usefulness

	Criteria	α_i	Variant A		Variant B		Variant C		Variant D	
			u_{ij}	$\alpha_i . u_{ij}$	u_{ij}	$\alpha_i . u_{ij}$	u_{ij}	$\alpha_i . u_{ij}$	u_{ij}	$\alpha_i . u_{ij}$
A	Material	0,0221	0	0	0,1670	0,0037	0,3330	0,0073	0,5000	0,0110
B	Estimated price	0,0074	0,3330	0,0024	0,1670	0,0012	0,5000	0,0037	0	0
C	Experience in operation	0,1029	0	0	0,3330	0,0343	0,1670	0,0172	0,5000	0,0515
D	Possibility of cleaning	0,0147	0	0	0,3330	0,0049	0,1670	0,0025	0,5000	0,0074
E	Ability and ease of future expansion	0,0515	0	0	0,3330	0,0171	0,1670	0,0086	0,5000	0,0257
F	Width	0,0441	0	0	0,1670	0,0074	0,3330	0,0147	0,5000	0,0221
G	Lenght	0,0368	0,5000	0,0184	0,1670	0,0061	0,3330	0,0122	0	0
H	Height	0,0294	0,5000	0,0147	0	0	0,1670	0,0049	0,3330	0,0098
I	Heat transfer area	0,0882	0,1670	0,0147	0,3330	0,0294	0	0	0,5000	0,0441
J	Maximum design temperature	0,0809	0,3330	0,0269	0,1670	0,0135	0	0	0,5000	0,0404
K	Minimum design tempearture	0,0588	0	0	0,3330	0,0196	0,1670	0,0098	0,5000	0,0294
L	Maximum working pressure	0,0735	0,5000	0,0368	0,1670	0,0123	0,3330	0,0245	0	0
M	Maximum flow rate	0,0956	0,1670	0,0160	0,3330	0,0318	0	0	0,5000	0,0478
N	Minimum flow rate	0,0662	0	0	0,3330	0,0220	0,1670	0,0111	0,5000	0,0331
O	Calcium sedimetation	0,1103	0	0	0,1670	0,0184	0,3330	0,0367	0,5000	0,0551
P	Sulfur sedimentation	0,1176	0	0	0,1670	0,0196	0,3330	0,0392	0,5000	0,0588
	Total sum $\sum$ =	1,0000		0,1299		0,2414		0,1924		0,4363

The multiple-criteria decision analysis is elaborated as a maximizing, variant with the highest overall usefulness value is the most efficient solution. For the purpose of increasing efficiency from energy, economic and environmental point of view is chosen the Variant D –graphite block heat exchanger from SGL Group Company. The results are although based on consultation with SLKP a.s..

It is although possible to evaluate the variants according to chart review – Chart 4.1. graphical displaying partial variants usefulness values u_{ij} . It can be clearly seen that the Variant D – graphite block heat exchanger is dominant from all the variants and this visualization validate data obtained from the calculation at Table 4.2..

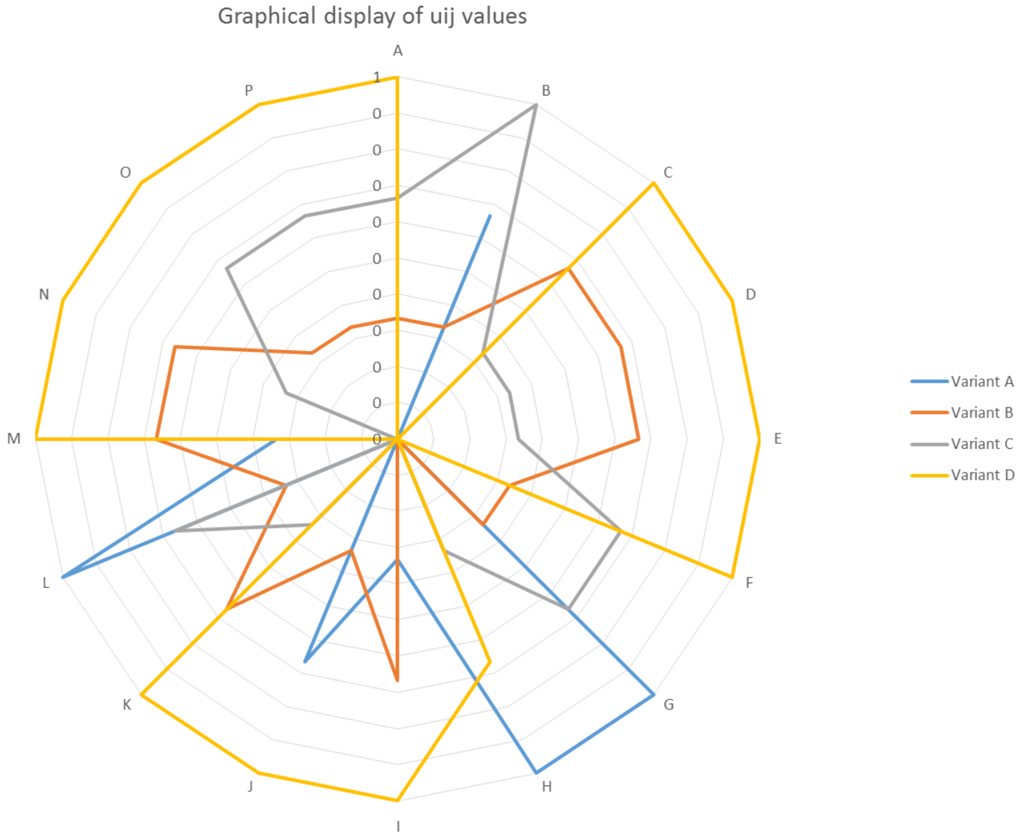


Chart 4.1. – Graphical displaying partial variants usefulness values u_{ij}.

4.4. ENERGY, ECONOMIC AND ENVIRONMENTAL EVALUATION OF EXPERIMENTAL SOLUTION

The energy point of view is the base solution of describing any NHS water system and its using. For the overall evaluation it is necessary to evaluate partially the NHS water system at collection places – the Balneotherapy departments and secondly evaluate whole system using data obtained from experimental solution. Evaluation is based on comparison efficiency of the current NHS water system and the new experimentally designed NHS water system.

4.4.1. Energy evaluation

The Variant D - Diabon graphite block heat exchanger allowed the Slovak Health Spa Piešťany a.s. not only to cover deficit of the cooled NHS water, but to generate its surplus, which will be used for the current Balneotherapy extension. Ability to cool down the hot NHS water to the temperature 21 °C, caused that by this new technological devices will consumption of the cooled NHS water decrease and consumption of the hot NHS water increase. Table 4.3. shows the total amount of NHS cooled and hot water calculation from overall opened geothermal system point of view.

Table 4.3. – overall analyzation of SLKP a.s. with new technological device

[illegible]	During the operation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Out of the operation				[illegible]	[illegible]					[illegible]	[illegible]	
[illegible]	During the operation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Out of the operation				[illegible]	[illegible]					[illegible]	[illegible]	
[illegible]	During the operation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Out of the operation				[illegible]	[illegible]					[illegible]	[illegible]	
[illegible]	During the operation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Out of the operation				[illegible]	[illegible]					[illegible]	[illegible]	
Other collection places	[illegible]	[illegible]	[illegible]	[illegible]									[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]									
	Accumulation tanks		[illegible]	[illegible]									
	Swimming pool EVA		[illegible]	[illegible]									
	[illegible]		[illegible]	[illegible]									

The parallel connection of the existing Korobon graphite block heat exchanger and the designed Diabon block graphite heat exchanger, in consideration of the fact that new designed heat exchanger will work on 100 %, cover existing deficit 132,43 m^3/day and create surplus 529,07 m^3/day, which will be used in future extension of the Balneotherapy departments.

4.4.1.1. Energetic balance of system with new heat exchanger

The energetic balance of the new Diabon block graphite heat exchanger, which will be parallel connected to the existing Korobon heat exchanger is described below.

Primary side of new heat exchanger:

- Inlet temperature: $T_1 = 67$ °C
- Outlet temperature: $T_2 = 21$ °C
- Average temperature: $T_{12} = 44$ °C
- Density of water: $\rho = 998$ kg/m^3
- Flow rate: $V_{gv2} = 13{,}03$ l/s = 46,92 m^3/h
- Mass flow: $M_{gv2} = 46{,}92 \times 998 = 46826{,}16$ kg/h = 13,01 kg/s

From calorimetric equation it is possible to obtain heat power:

$$Q_1 = M_{gv2} \times c \times (T_1 - T_2) = 13{,}01 \times 4180 \times (67 - 21) = 2\ 501\ 562\ W\ = 2{,}5\ MW$$

Where:

c - specific heat capacity (J.kg^{-1}.k^{-1})

This heat power has to be transfer to secondary side

Secondary side of new heat exchanger:

- Inlet temperature: $T_1 = 14$ °C
- Outlet temperature: $T_2 = 58$ °C
- Average temperature: $T_{12} = 36$ °C
- Density of water: $\rho = 998$ kg/m^3

From calorimetric equation it is possible to obtain mas flow rate at secondary side:

$$M_{sv} = \frac{Q_1}{c \times (T_1 - T_2)} = \frac{2501562}{4180 \times (58 - 14)} = 13{,}601\frac{kg}{s}\ \times 3600 = 48964\frac{kg}{h}$$

Where:

c - specific heat capacity (J.kg^{-1}.k^{-1})

Hot service water flow rate:

$$V_{sv} = \frac{M_{sv}}{\rho} = \frac{48964}{998} = 49{,}06\ m^3/h$$

4.4.1.2. Outputs from energetic balance of system with new heat exchanger

- At 100 % utilization of the new Diabon heat exchanger will be possible from the opened NHS water system obtain 46,92 m^3/h which is equal to 1126,32 m^3/day of the cooled NHS water with the temperature 21 °C for healing procedures.
- At the same time it is possible to obtain at 100 % utilization of the new Diabon heat exchanger 49,06 m^3/h which is equal to 1177,32 m^3/day of the hot service water with the temperature 58 °C.
- Due to the fact that hot service water will be used during the operation and out of the operation of the Balneotherapy, mainly for a pools heating at wellness centrum, an outer pooled heating, a water heating for showers at the Balneotherapy or equivalent showers at the accommodation units, it is possible to calculate with utilization of whole capacity obtained from the cooling down of hot NHS water.

4.4.1.3. Theoretical savings from waste heat in SLKP a.s.

The theoretical savings of gas is calculated from assumed utilization of the waste heat, which will be obtained from 1126,08 m3/day of the NHS water from temperature 67°C to temperature 21 °C.

- Assumed amount of cooled NHS water: $V_o = 1126{,}08\ m^3$
- Density of water: $\rho = 998\ kg/m^3$
- Specific heat capacity of water: $c = 4180\ J.kg^{-1}.K^{-1}$
- Coefficient of energy losses at system: $z = 0{,}9$

Daily transferred heat for cooling NHS water:

$$Q_{o,d} = 10^{-3} \times \frac{z \times \rho \times c \times V_o \times (T_2 - T_1)}{3600}$$

$$Q_{o,d} = 10^{-3} \times \frac{0{,}9 \times 998 \times 4180 \times 1126{,}08 \times (67 - 21)}{3600}$$

$$Q_{o,d} = 54\ 022{,}404\ kWh$$

By cooling down 1126,08 m^3 of hot NHS water will SLKP a.s. daily generate cca. 1177,44 m^3 with the temperature 58 °C. If this hot service water will be used for energy purpose of SLKP a.s., than it is possible to obtain:

$$Q_T = Q_{O,d} \times d = 54022{,}404 \times 365 = 19\ 718\ 177\ kWh$$

The amount of energy obtained by cooling down assumed amount of the hot NHS water is 19 718 177 kWh = 70985,437 GJ. It is necessary to take into account heat losses at distribution and in heat exchanger – 15 %, it is possible to calculate with the generated heat from hot NHS water 60337,621 GJ/year.

4.4.2. Economic and ecologic evaluation

The economic evaluation is based on compartment of the heat boiler room Balnea Centre with performance 9,98 MWh and the designed opened NHS water system – Table 4.4. and Table 4.5..

Table 4.4. – Economic evaluation of the heat boiler room in Balnea Centre

Measured amount of consumed gas in July 2015	m^3	[illegible]
Average amount of consumed gas per one day	m^3	[illegible]
Costs of gas in July 2015	€	[illegible]
Price for m^3	€/m^3	[illegible]
Calorific value of gas in July 2015	kWh/m^3	[illegible]
Measured amount of energy in July 2015	kWh	[illegible]
Measured amount of energy per one day	kWh	[illegible]
Measured amount of consumed gas per year 2015	m^3	[illegible]

Table 4.5. – Total savings per one day

Amount of green house gases	The heat boiler Balnea Centre	Korobon	Diabon	Korobon + Diabon
	kg/day	kg/day	kg/day	kg/day
TZL	0,10031515	0,00640270	0,00727227	0,01367497
SO2 / SOx	0,01203772	0,00076832	0,00087267	0,00164098
CO	1,95614453	0,12485264	0,14180917	0,26666181
TOC	0,78998157	0,05042127	0,05726910	0,10769036
Amount of used NHS water per one day	kWh	**25293,61**	**28728,79**	**54022,40**
Amount of saved gas	m3	2612	2966	5578
Total savings per one day	€	1262	1434	2696

Calculation of payback time:

- Theoretical savings per one day: 1 434 €
- Theoretical savings per one year: 523 410 €
- Total investments: 1 250 000 €

$$T_s = \frac{IN}{CF} = \frac{1\ 250\ 000}{523\ 410} = 2{,}38\ year = 2\ years\ 140\ days$$

Where:

IN - investments, one-off costs to realize savings

CF - annual cash flow

4.5. EXPERIMENTAL SOLUTION - PROPOSED RECOMENDATIONS

Due the fact that the monitoring, measuring and regulation is currently provided manually by the specialized workers at the SLKP a.s., it is necessary for fully make use of the new experimentally designed opened NHS water system to design new ways of monitoring, measuring and regulation to enhance new system.

The operation of the accumulation station must be fully automatic, which will be supported by the dispatching of measurement and regulation.

4.5.1. On-line monitoring of consumption NHS water at Balneotherapy departments

Fully online monitoring should be provided at:

- Measurement of NHS water temperature
- Measurement of NHS water high level at accumulation tanks
- Measurement of pressure at accumulation tanks filled with air
- Measurement of flow rate, temperature and water level of NHS water at drills and well
- Measurement of flow rate and amount of NHS water distributed to Balneotherapy departments
- Fault states of accumulation station (maximum water level at accumulation tanks, flooding of accumulation station, power failure)
- Possibility to control power of pumps, start/stop, operation and failure signalization of frequency converter at drills, well and booster pumps

4.5.2. Data server and working stations at dispatching – AQUA dispatching

Measurement and regulation dispatching – AQUA dispatching should have possibility to:

- Monitor all actual temperatures of NHS water distributed from distributors of hot and cooled NHS water
- Monitor all actual flow rates of NHS water distributed from distributors of hot and cooled NHS water
- Monitor all system failures at accumulation station and water distribution from AQUA dispatching and its evaluation
- Archive measured data of flow rates and temperatures
- Regulate individual collection places on the base of measured data
- Optimize energy efficiency of individual regulated circuits

5. CONCLUSION

Life environment is source of the all living species on the Earth. To ensure its quality and protection against the human factor the European Union accept several goals, such as the low-carbon economy, which should decrease amount of the Green House gases in the Europe by increasing the use of renewable sources.

From applicability point of view the most uncommon renewable source in the Slovak republic is the natural healing source energy, which currently we are using only for healing purposes. Energy stored in the NHS systems due to its relatively high temperature has big energy potential, which can beneficially influence the economic and environmental situation in the Slovak republic.

Diploma thesis *Energy, economic and environmental analysis of Balneotherapy* provides an attention on energy potential of the natural healing water source at the Slovak Health Spa Piešťany. To be able to fully understand the opened NHS system it was necessary to elaborate the overall analyzation of its current state. This analyzation was provided by the experimental measurements and simplify computer simulations. After research it is possible to state that currently SLKP a.s. is using for healing procedures at the Balneotherapy hot NHS water, which is transported directly from the water source and the cooled NHS water, which is cooled down with the help of the Korobon graphite block heat exchanger. It was discovered that for current operation of the Balneotherapy and its future expansion, the amount of the cooled NSH water is not satisfactory.

The main goal of this diploma thesis is to design the new technological devices to increase generation of the cooled NHS water, which will cover current insufficiency and allow the SLKP a.s. to provide expansion of the Balneotherapy. For this purpose were elaborated four variants and with the help of multiple-criteria decision chosen the one which will from energy, economic and environmental point of view be the most efficient.

The overall result is in form of the recommendation, the project documentation and the experimental calculation of the new technological devices connected to the existing opened NHS system. Firstly, it was proven, that decreasing the temperature of the cooled NHS water will leads to increasing the amount of used hot NHS water distributed directly from water source in the Balneotherapy departments. Secondly, new design technological devices will increase the amount of the saved gas necessary to heat water in the Balneotherapy departments and therefore help to the SLKP a.s. to fulfil the European Union low-carbon economy.

During the elaboration and analyzation of opened NHS system potential were discovered next several possibilities that can enlarge energy potential of the NHS water in the SLKP a.s. Firstly, the monitoring, measurement and regulation dispatching has not possibility to obtain actual data from the opened NHS system, such as flow rate, pressure and temperatures – automate collection of data from sensors through server. Secondly, improvement of insulation at the distribution pipelines of the NHS water, which is from energy and economic point of view unacceptable.

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7. LIST OF ABBREVIATIONS AND SYMBOLS

Q	Flow rate	[l/s]
H2S	Hydrogen Sulfid	[mg/l]
t	Temperature	[°C]
p	Pressure	[MPa]
m	Flow rate	[l/s]
λ	Thermal conductivity	[$W.m^{-1}.K^{-1}$]
α	Thermal diffusivity	[$m^2.s^{-1}$]
c	Specific heat capacity	[$J.kg^{-1}.K^{-1}$]
Q_{str}	Thermal losses	[kW]
Th.	Thickness	[mm]
α_i	Standardized strengths of criterion	[%]
U_j	Usefulness of individual variant	[%]
Q_1	Heat power	[MW]
Qo,d	Daily transferred heat	[kWh]
Q_T	Yearly transferred heat	[kWh]
T_s	Payback time	[year]
ρ	Specific density	[kg/m^3]
m_o	Substantiality of NHS source	[l/s]
η	Efficiency of NHS system	[%]
Pc.	Number of pieces	[pc.]

CHAPTER 7 – LIST OF ABBREVIATIONS AND SYMBOLS

EU	European Union
NHS	Natural healing source
SR	Slovak Republic
No.	Number
LCD	Liquid crystal display
PC	Portable computer
MaR	Measurement and Regulation
SLKP a.s.	Slovak Health Spa Piešťany a.s.
2D	Two dimensional
3D	Three dimensional
CFD	Computational Fluid Dynamics
PLK	Natural healing spa
KL	Spa treatment
PLZ	Natural healing sources
KVPL	Climatic conditions beneficent for healing

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