Chapter 5

BALNEOLOGY

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Introduction

The word “balneology” has Latin origin, and is connected to “taking baths”, or “bathing”. More precisely, it relates to warm baths for healing purposes with natural thermal waters, with different temperatures, chemical composition or viscosity (pure liquid or mud). It is directly connected to the word “spa”, i.e. place where such “bathing” and curing is on disposal. However, now-a-days, the meaning of the word became wider, i.e. that’s not only the use of thermal water for medical treatments but also for recreation, sports (“water centers”), etc., plus the use of contained energy for heating the spa facilities.

In any case, people have used geothermal water and mineral waters for bathing and their health for many thousands of years. Many hot springs have been used in connection with religious rites in Egypt and by the Jews of the Middle East. In Europe, the Greeks, Turks and Romans were famous for their spa development and use from Persia to England. The same is with Indians in America, Maoris in New Zealand and in Japan.

Now-a-days, spas for medical and recreation purposes are widely accepted in Europe. The former Soviet Union had 3500 spas and some 5000 reconditioning centers all administered and run by the state. In the former Czechoslovakia, there are 52 mineral water health spas and more than 1900 mineral springs, where every year about 220.000 citizens are granted free spa treat-

Fig.5.1. Ruins of a Roman Spa in Bansko, Macedonia

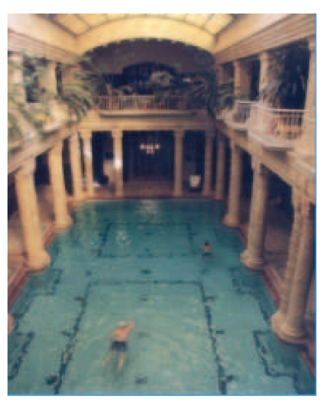

Fig.5.2. Gellert Spa in Budapest, Hungary

Fig.5.3. Topolsica spa in Slovenia

ment for three weeks, paid by the national health insurance program. The more famous ones are Karlbad in the present Czech Republic and Piestany in Slovakia. Similar is the situation in Hungary, Bulgaria, France, Germany, Italy, Macedonia, Romania, but also in Greece, Turkey, and many other European countries (Lund, 2005).

By the middle of eighties of last century, a movement that can be defined as a "return to nature" began at global level. It positively affected also the development of balneology all over the world. At the beginning and middle of nineties, "thermalism", as part of this movement, started to gain impulse and adepts by the means of reopening, recovering and modernization of old fashion thermal spas and creation of new thermal centers that respected natural environment in which they were hosted. That resulted with a growing interest for the exploitation of thermal waters not only for medical purposes but also as a tourist attraction. Soon, "thermal recreational centers" appeared, offering different contents, interesting also for the healthy middle age and younger generation. At least in Europe, that is now, probably, the fastest development tourist sector. It's main advantage is that working all-year-around and, in that way being more profitable than the seaside or mountain tourism.

On the other hand, recent development of geothermal energy usage technologies in combination with the international wide orientation towards environmentally friendly energy technologies, stimulated introduction of the use of heat contained in thermal waters for central heating, sanitary warm water preparation, air-conditioning, swimming pools heating, etc. That made spas and recreational centers more attractive and more profitable, which was an additional "push" for wider development of this new tourist sector.

5.1. What is Spa or Thermal Recreational Center?

The word "spa" is normally understood as the place where different medical treatments with thermal waters are made, comprising full lodgment and medical services. medical treatment normally by special therapies using baths or pools with thermal water. Also, drinking the waters with particular mineral composition is in practice. is a series of treatments over time including baths, taking (drinking) water, massage, exercise, mud baths, etc.

Now-a-days, the meaning of the word "balneology" became wider, i.e. that's not only the use of thermal water for medical treatments but also for recreation, sports ("water centers"), etc., plus the use of contained energy for heating the spa facilities. If, at least in Europe of nineteen century, spas were the most popular destination of the aristocracy and rich people for holidays and personal contacts, it looks that the situation is becoming similar at the end of the twentieth and beginning of the twenty first century. However, this time for much wider circle of users. The introduction of so called "water centers" in spa locations made them interesting also for the young people, looking for the year around possibilities for taking joy in warm water. They consists of possibilities for swimming, water sports practicing all year around, athletic programs for improving the body condition, courses for learning swimming, wide offer of facilities for play of children, etc. The middle age people is also offered with a list of convenient services, emphasizing certain medical treatments but also recreation and refreshment, like it is intensive fitness, rejuvenation, weight-loss, "magic mud", etc., in combination with healthy food and restful accommodation and walks in beautiful environment.

New meaning of the word "balneology" practically illustrates the change of the initially monden and medical life sector into a wide spread and quickly developing tourist sector.

Classical approach in many spa centers is still kept. Excellent medical services and improved conditions for stay increased their popularity not only in the European countries with long tradition behind but also in a great number of new ones all over the world. Popular are medical spas with healing possibilities, offering good conditions for taking rest in a quite and beautiful surrounding nature. Their main characteristic is that didn't take the new way of introducing active recreation, interesting for healthy younger people, i.e. market of interest is mainly between middle age and old people.

The new “market sector”, i.e. recreational water centers, is mainly orientated towards the young and early middle age population.

Improving the health and healing particular diseases is still underlined as principal task of such centers but connected to the active recreational approach of improving the wellbeing of guests. Attractive programs of special courses, programs and treatments make the stay interesting and pleasant, enabling development of other profitable activities, like restaurants, tourist agencies connected with the ones of near locations offering different attractions, sports centers for improving condition of active sportsmen, etc., etc. That all enabled introduction of the use of thermal waters not only for medical but also for energy purposes. Geothermal energy is regularly used in new balneology centers everywhere, where possible and economically justified.

5.2. Thermal Waters Use

First pre-condition for developing a spa or recreation center is to have on disposal thermo-mineral water, to know its chemical composition and temperature, and to find what are possible medical and energetic benefits of it’s use.

Mineral waters, when analyzed, are found to contain a great many substances; although, some of them occur only in very minute quantities. The principal constituents found in mineral waters are sodium, magnesium, calcium and iron, in combination with the acids to form chlorides, sulphates, sulphides and carbonates. Other substances occasionally present in sufficient quantity to exert a therapeutic influence are arsenic, lithium, potassium, manganese, bromine, iodine, &c. The most important ones, from a therapeutic point of view, are sodium, magnesium and iron, carbonic acid, sulphur, and perhaps sulphuric acid. Their different combinations determine possibilities for healing concrete diseases or combination of diseases by using different therapies.

The chief gases in solution are oxygen, nitrogen, carbonic acid and sulphuretted hydrogen. Argon and helium occur in some of the "simple thermal" and "thermal sulphur waters."

Most known are the programmed baths in bathtubs under medical control (Fig.5.4) or in pools (fig.5.5). The first ones are orientated towards thermal treatment of the body and absorption of minerals through the skin surface, and the second ones for the after operational rehabilitation treatments and re-mobilization of moving organs of the body.

Fig.5.4. Baths in hot thermal water

Fig.5.5. Baths in small pools for rehabilitation

Second way of use is by drinking the thermal water. Therapeutically, drinking large quantities of water tends to provide a general washing out of the organs. This produces a temporary increase in certain excretions, augmented diuresis, and a quantitative increase of urea, of sodium chloride, and of phosphoric and sulphuric acids in the urine.

Fig.5.6. Drinking the thermal waters

On the other hand, warm water is better absorbed by the stomach and has a higher therapeutic action than cold water.

Fig.5.6. Threatment with mineral mud

Associated with most spas is the use of muds (peloids) that are either found at the site or imported from special locations. These are so-called "aromatic" or "medicated" baths, in which substances are mixed to exert a special influence on the skin and peripheral nerves. The volatile ethereal constituents are supposed to penetrate the skin and to stimulate the cutaneous circulation and peripheral nerves, being eliminated later by the ordinary channels. They act like a large poultice applied to the surface of the body, and in addition to the influence of the temperature, exert a considerable mechanical effect. They have very great value in gouty and rheumatic conditions and in some of the special troubles of women.

The skin effects of mud are:

1. Increasing the body temperature
2. Lowering the blood pressure
3. Influencing the mineral metabolism and blood chemistry.

From the recreational point of view, thermal water can be used for recreational swimming in open air (Fig.5.7) or indoor swimming pools (Fig.5.8).

Fig.5.7. Outdoor thermal swimming pool (Albena, Bulgaria)

Depending on the thermal water temperature on disposal, it can be also used for

Fig.5.8. Indoor swimming pool (Bansko Spa, Macedonia)

energy purposes, i.e. heating the floor around the baths and pools, rooms, for air-conditioning purposes and heating the sanitary warm water.

Due to the high mineral contain in thermal waters, their medical and energetic use should be treated separately, i.e. needed measures for protection against corrosion or scaling for the heating systems are not aloud to be applied in the systems for medical purposes.

5.3. Typical Spa Design

There are many types of designs for spas, depending upon the local culture, the unique character of the location, and what the developer is trying to achieve in terms of atmosphere, service and type of clientele.

Two basic types exist, with an emphasis on targeted market and the type of use of geothermal water:

- "Clean" medical spa, orientated towards treatment of particular diseases, and
- Composition of a combined project, consisting the medical treatment and recreation or other types of use of the thermal water.

The second consists the same elements of the first one, however with different, more "open" arrangement.

It's necessary to underline that design of "purely" recreational projects, based on thermal water use doesn't exist.

Furthermore, it's necessary to take into account that three main "spa philosophies" exists, influencing very much the design, completion and exploitation of the spa in question. Classical European approach consists of highly sophisticated medical treatment. American or New Zealand approach is more flexible and orientated more to pleasure than to medical use, or better said it involves tourist elements in the medical use of the spa. The Japan one is based to the long local tradition and is composed of highly sophisticated medical treatment but in combination with a combination of religious and elements of traditional culture.

In any case, each spa project is a "challenge" for itself because it is very important to reach an individual and fully recognizable "image" of it. Future market depends very much on that.

Developing a spa, either only for medical or for recreational purposes is quite expensive. The first purpose conditions completion of rooms and facilities for performing medical investigations, treatments, rehabilitation, accommodation of patients, kitchen and restaurants, plus arranged nature around to create restful atmosphere. The second purpose conditions completion of high quality accommodations, restaurants and other hotel facilities, big thermal pools (indoor and outdoor) for recreation, facilities for rehabilitation with thermal water and other treatments, facilities for different outdoor and indoor rehabilitation and sports practiceing, etc. plus small shops, dancing and night clubs, casinos, etc

Therefore, designing a spa is a complex multidisciplinal problematic, where the use of thermal water for healing, rehabilitation or recreation should be the tool to reach general goals, defined in advance.

The categories and dimensions that are part of a spa and should, for the most, be incorporated into its design and development are (Lund, 2005):

1. Natural, environmental, ecological
2. Medical, psychological, therapeutic
3. Scientific, technical, research
4. Economical, financial, managerial
5. Planning, architectural, building
6. Social, fashionable, gastronomical
7. Artful, historical, literal
8. Spiritual, mystical, religious

Listed factors are mainly neither medical nor technical but anyhow they are of crucial importance for development of the necessary "image" of the future spa and, with that, to the composition of future customers.

In addition, the design must be accommodated to the possibilities for financing the development in accordance with the possibilities and development of the market and defined strategic approach, in order to enable development process suiting well the finance and market possibilities.

Composition of the medical part of the spa is dictated by the planned therapies, and the full service normally consists of:

* Medical examinations (diagnosis, therapyes determining, necessary corrections during the treatments control of therapies results, post therapies treatments determination)
* Balneo Therapy
* Physiotherapy
* Occupational Therapy

* Electro Therapy
* Magnetic field with laser Therapy
* Thermo Therapy
* Hyperbaric Therapy
* Measurement and traction
* Massage
* Rehabilitation
* Other specific therapies.

Staying facilities are composed of:

* Stationary, i.e. accommodation
* Restaurant
* Free time facilities (walks in nature, library, free time club room, etc.).

If "open" type of the spa is in question, additional facilities are necessary, as are:

* Recreational indoor pools
* Open type restaurant(s)
* Facilities for particular short programs performance
* Additional commodities (special apartments, shops, beauty treatments, etc.).

Finally, if the recreational project is in question, it must consist:

* Recreational (indoor and outdoor) pool with open character, and accommodated to the needs of younger population and children
* Facilities for different sports practicing
* Open bars and "quick food" restaurants
* Higher class restaurants of open type
* Dancing clubs and bars
* Other locally specific tourist offer.

Normally, as told before, a good "European" completion results with a large complexes of buildings and facilities located in beautiful natural environment (Fig.5.9).

Fig.5.9. A classical medical spa in Czech Republic

Normally, also the interior of such spas is accommodated to the still of main building and orientation towards the particular clientele (Fig.5.10).

Modern spas differs in style but the ap-

Fig.5.10. Interior of a classic Czech spa

Fig.5.11. A modern recreational center in Czech Republic

Fig.5.12. Indoor pool in Patience, Slovakia

Typpically, when recreational complexes are in question, also the indoor and outdoor facilities are of quite large dimensions, accommodated to bigger amount of guests.

Fig.5.13. “Aquapark” in Poprad, Slovakia

Still, difference exists depending on the type of clientele targeted. More luxurious are more orientated towards comfortable accommodations and leisure (Fig.5.11 and

Fig.5.14. Public aquapark in Senec, Slovakia

5.12), and the real aquaparks towards active recreation (Fig.5.13 and 5.14).

In opposite, New Zealand or American project is of smaller dimensions and concentrated to smaller locations, with the spa contents in front of the building (Fig.5.15) or surrounded with rooms and facilities (Fig.5.16).

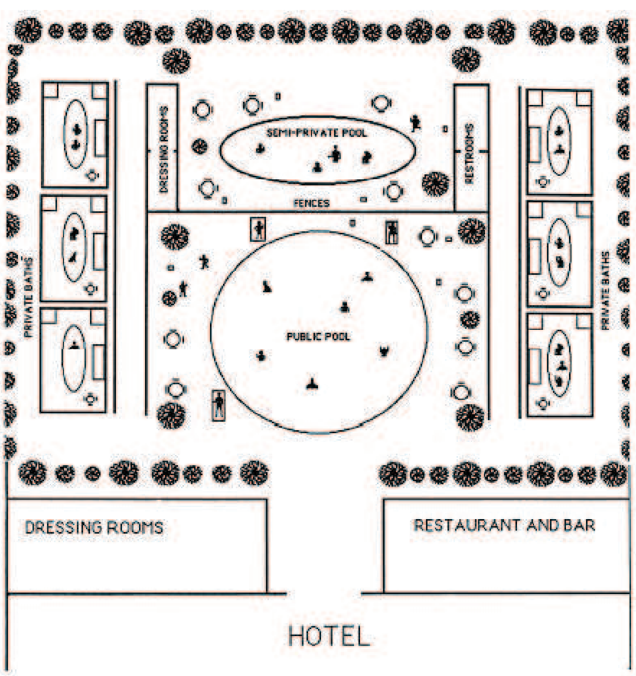

Fig.5.15. Design for a geothermal spa offering private, semi-private, and public bathing facilities (Woodruff and Takahashi,1990).

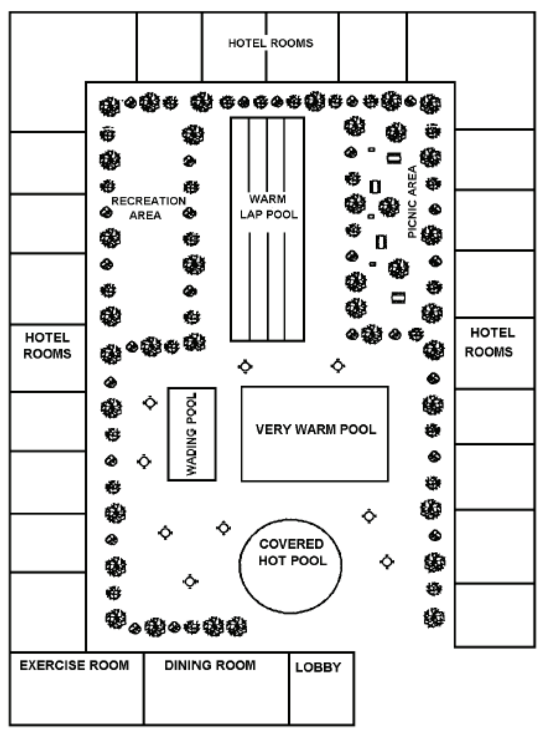

Fig.5.16. General scheme of a modern geothermal spa located in California (Woodruff and Takahashi, 1990).

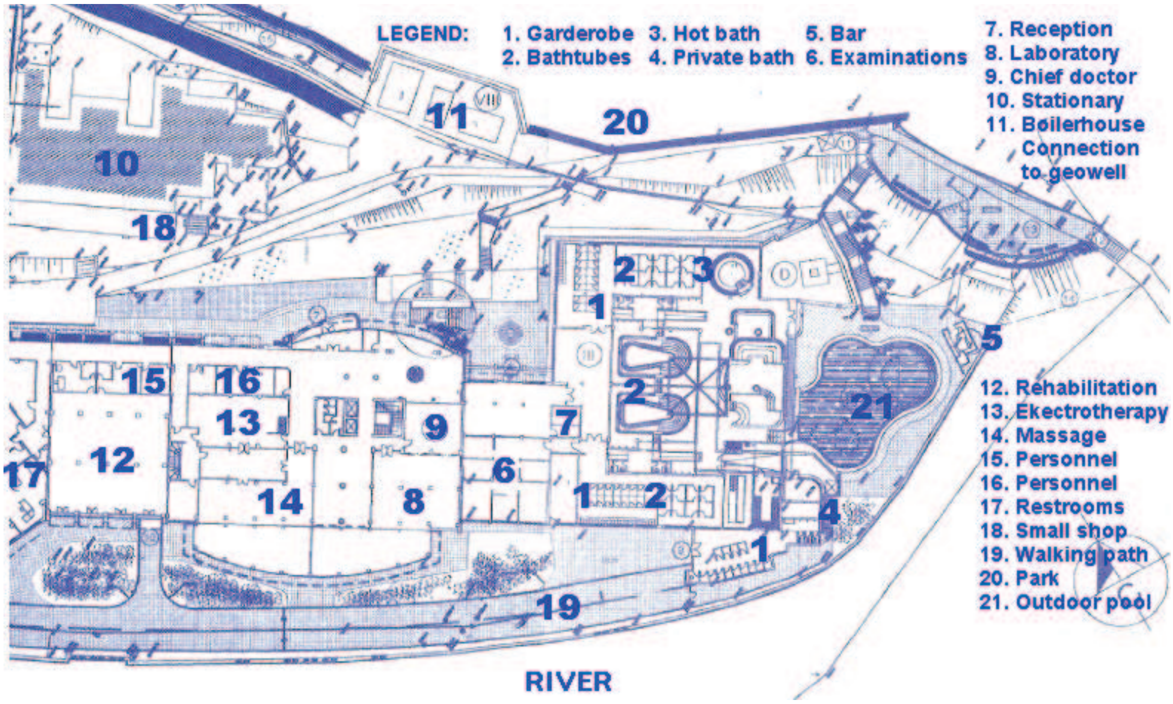

Fig.5.17. Concept of the active part of Katlanovo Spa, Macedonia

The difference in approach can be noticed if comparing them to the concept of a small medical spa in Europe (Fig.5.17).

5.4. Spa's Energetics

Thermal water for long has not been treated as an energy source for covering the heat needs of spas. It was all the time treated as a particular raw material for medical purposes only and all the investigations connected to it's characteristics have been directionned towards finding better methods for healing uses and resolving problems with scaling and corrosion of pipes and equipment where flowing. However, and particularly when taking into account that spas "sell" the health, new environmental protection issues just pushed the development in finding possibilities to use it for heat supply purposes, too.

Generally, problematic should be the same, as elaborated in the chapter for direct heat application, i.e. for geothermal central heating of buildings, air-conditioning, sanitary warm water preparation, etc. However, there are some particularities which need to be elaborated.

First particularity is that it is not possible to treat both types of use together.

Thermal water for medical purposes should go directly to the users as it is, i.e. without possibility to get changes of its chemical and gas composition. On the other hand, each heating use conditions maximal protection against scaling and corrosion and normally consists of measures and techniques for protection against their appearance. Therefore, their common flow from the source (or well) is not aloud. Separate circuits should be designed.

Normally, for the medical purposes, thermal water is transported through non-metal or stainless steel pipes. It is one way flow, i.e. after the use it is thrown out in canalization. Mostly, that is not a big problem, if taking into account that quite small flows are in question and that don't impact the nature in different way than before being used in the spa.

However, the thermal water flow for energy purposes can be wither one or two way flow. One way flow is with it's direct use in circulating pipes and heating equipment, and the second one is with two separate loops connected via a heat exchanger system. Geothermal water goes to the heat exchanger, transfer the heat to second loop, and is returned to the source, i.e. re-injected into the aquifer. Second loop uses "soft wa-

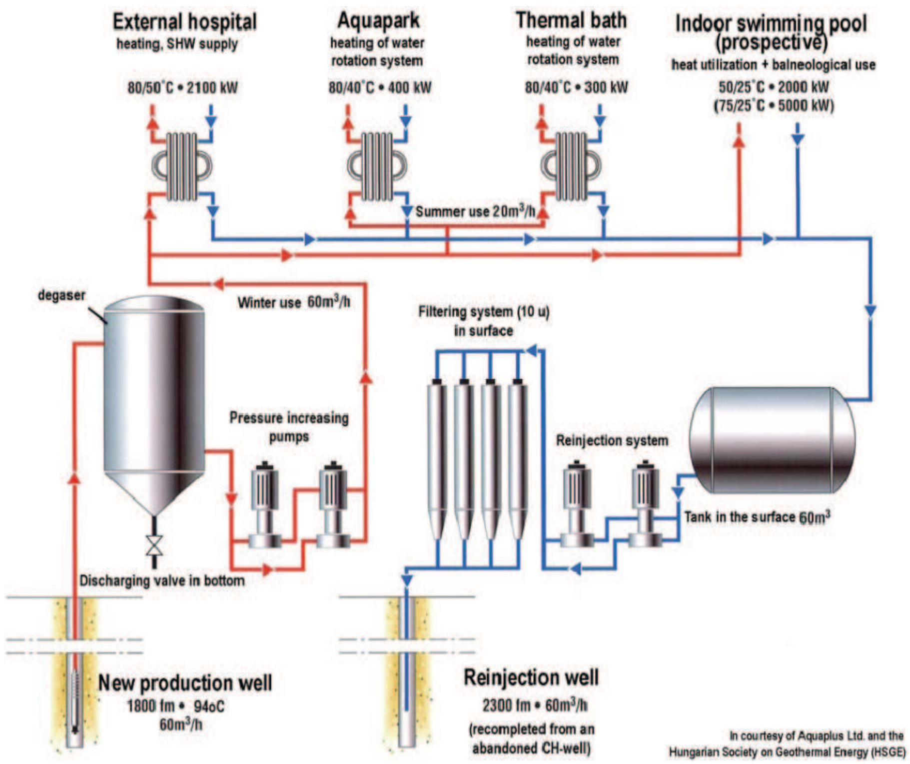

Fig.5.17. Concept for a new geothermal spa heating system in Hungary (Szita, 2002)

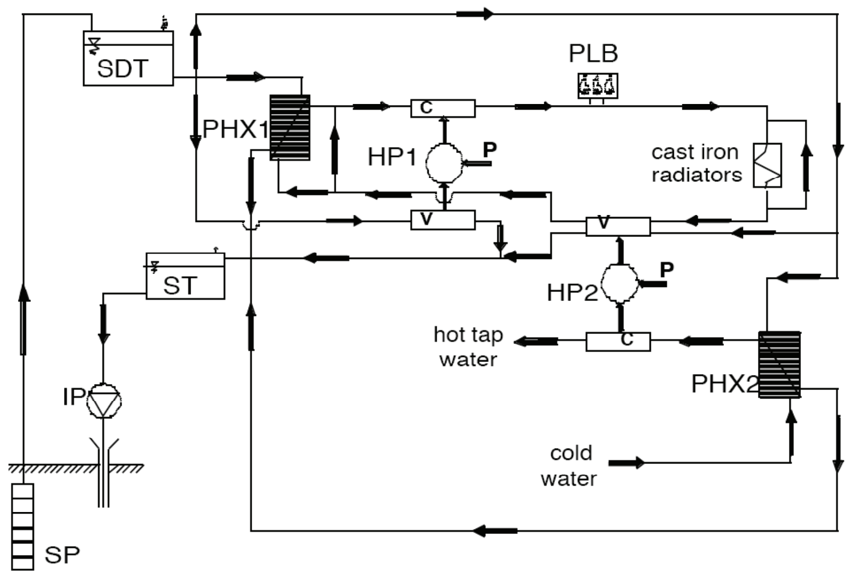

Fig.5.18. Concept of an indirect system in Romania (Rosca, 2001)

ter" as heat carrier. It takes the heat from geothermal water in the heat exchanger, and then transport it to the heating systems. First type of use is possible only if thermal water is with low mineralization and without intention for scaling or corrosion. When that is not the case, i.e. when the water is corrosive or with intention for scaling, particular measures should be applied, like addition of chemical additives for neutralization of negative effects of thermal water flow through metal pipes and equipment. It's necessary to underline that such a solution makes the exploitation complicate and expensive and that result with difficulties with re-injection of used water to the aquifer. Separated loops are a much more secure system and without complications in exploitation.

Second typical problematic is the design of energy installations for medical and swimming pools. Several characteristic situations appear, depending on the type of pool in question, i.e.:

- Indoor pools for medical purposes;
- Indoor recreational pools;
- Indoor swimming pools;
- Outdoor recreational pools;
- Outdoor swimming pools.

Difference in their heat requirements are due to the differences in water temperature and surrounding conditions, i.e.:

Temperature in the medical pools can be different, depending on the therapy in question. If the rehabilitation exercises are in question, normally 27-28ºC is applied. If the leisure small pools are in question, temperature can be increased up to 35ºC. For the indoor recreational pools temperature can vary significantly, depending on the local habits, i.e. from 25-35ºC. For outdoor recreational pools temperature varies depending on the season, i.e. it's lower during the summer (24-27ºC) and higher during the winter (28-35ºC). In Japan, they are significantly higher and can go up to 40ºC. Finally, for indoor and out-door swimming pools, temperatures between 25-28ºC are recommended.

When heat requirements are in question, situation is quite complex because consisting particular demands and influence of surrounding conditions, i.e.:

- Temperature of the water is different of the temperatures of the air above it but also of the soil around. That results with conductive, convective and radiation heat losses.
- Temperature and air humidity of the air above the pool provoke evaporation of water from the pool surface.
- When indoor pools are in question, keeping defined temperature and humidity of surrounding air is necessary. Particularly keeping the humidity at certain level is difficult due to the intensive evaporation of the pool surface and limitations of allowed velocity of air movement in the room.
- Not only the air temperature around the pool should be kept at certain level. Also the floor surface around should be warm, and
- Sometimes, even the surface of seating places should be kept at certain level.

Main problem to fulfill all listed requirements is that the influence of the water temperature in the pool and it's evaporation result with opposite situations even during the colder seasons of the year, i.e. sometimes is necessary to heat and sometimes to cool the air inside. Cooling is regularly needed during the summer months. That, in combination with necessary drying of the air requires air-conditioning installations application.

Second problem, when covering the heat requirements is in question, is the type of water used in the pool, i.e. is it the thermal water itself or normal water heated by the thermal one. In the first case, additional heating of the water is normally not necessary but in the second one heat exchanger system is needed.

When direct use of thermal water is applied, needed temperature is kept by regular flow of it through the pool. Its intensity depends on the heat losses. When the indirect use is in question, pool water must be treated with clorine, which dictate the use of resistant materials in the heat exchanger. In such a question, temporal change of the whole water content in the pool is necessary, and when that is realized the peak loading of the heating system appear. Normally, 6-8 night hours are taken for a complete change of the water.

Calculation of heat requirements for keeping the needed air, water and floor surface temperatures, and humidity of the inside air involves all the types of heat transfer, i.e.:

- Conduction through the pool walls, walls and ceiling of the room and floor surface;
- Convection from the pool surface, pool walls, walls and ceiling of the room and floor surface;
- Radiation from the pool surface, pool walls, walls and ceiling of the room and floor surface; and
- Evaporation from the pool surface.

When the pool is in question, conduction is generally the least significant unless the pool is above ground or in contact with cold groundwater.

Convection losses depend on the temperature difference between the pool water and the surrounding air, and the wind velocity, when the outdoor ones are in question. This is substantially reduced for indoor pools and ones with wind breaks.

Radiation losses are significant for outdoor pools and are greater at night, however during the daytime there will be solar gains which may offset each other. A floating pool cover can reduce both radiation and evaporation losses. For the indoor pools they are neglectable.

Evaporation losses normally constitute the greatest heat loss from pools, i.e. they are 50 to 60%of the total ones. The rate at which evaporation occurs is a function of air velocity and pressure difference between the pool water and the water vapor in the air (vapor pressure difference). As the temperature of the pool water is increased or the relative humidity of the air is decreased, evaporation rate increases. It's necessary to underline the multiple influence of the evaporation to the temperature of the water in the pool, temperature and humidity of the inside air. High humidity is unpleasant for the users but also results with condensation on the walls and particularly the ceiling of the pool room.

Heat requirements of the pool consist of two components, i.e. q_1 – that is the pool heat-up rate (W) and q_2 – that is the heat loss from pool surface (W). Calculation is quite simple:

$$q_1 = r.c_p.V.(t_w - t_i)/q \qquad [5.1]$$

where:

q_1 = pool heat-up rate, W
r = density of water = 1,000 kg/m^3
c_p = specific heat of water = 4.184 kJ/kgK
V = pool volume, m^3
t_w = desired temperature of the water, K
t_i = initial temperature of pool, K
q = pool heat-up time (usually 24 hours)

and

$$q_2 = U.A.(t_p - t_a) \qquad [5.2]$$

where:

q_2 = heat loss from pool surface, W
U = surface heat transfer coefficient = 214.4 (W/m^2K)
A = pool surface area, m^2
t_p = pool temperature, K (°C)
t_a = ambient temperature, K (°C)

then:

$$q_t = q_1 + q_2 \qquad [5.3]$$

If there is no heat-up time (for pools using flowing geothermal water) then equation [1] will be zero and only equation [2] will apply. Heat loss equation [2] assumes a wind velocity of 1,5 to 2,2 m/s. For indoor pools, and average wind velocity of less than 1,5 m/s, the second equation (q_2) can be reduced to 75%. For wind velocity above 8 m/s, it's necessary to multiply the heat transfer coefficient by 1,25; and for wind velocity of 16 m/s, by 2,0.

When the calculation of heat gains of the pool room is in question, it's necessary to underline that spas require year-round humidity levels between 40 and 60% due to the needed comfort, energy consumption, and building protection. That means the need of humidity control by ventilation (exchange the inside with outside air), drying of inside air before its re-distribution in the room, etc. Calculation of whole heat requirements/gains due to the evaporation and air exchange should take into account all the listed factors but also the economy of exploitation, i.e. to find the balance between the number of air exchanges and needed additional drying of the inside air.

Convenient air relative humidity for humans is between 40 to 60%. Outside of this range increase levels of bacteria, viruses and fungi can be noticed, plus the other factors that reduce the air quality. Lower part of the range is for elder people and for people in movement and swimmers 50 to 60% relative humidity is most comfortable.

On the other hand, high relative humidity levels are destructive to building components. Mold and mildew can attack wall, floor, and ceiling coverings; and condensation can degrade many building materials. In the worst case, the roof could collapse due to corrosion from water, condensing on the structure. Therefore, limit conditions for condensation appearance should be determined and air distribution system designed in that way that continually streaming the ceiling surface.

Heat loads for a spa include building heat gains and losses from outdoor air, lighting, walls, roof, and glass, with internal latent heat loads coming generally from people and evaporation. The evaporation loads are large compared to other factors and are dependent on the pool characteristics, such as the surface area of the pool, air movement velocity, wet decks, water temperature and the activity level in the pool.

The evaporation rate (w_p in kg/s) can be calculated for pools of normal activity levels with the use of relation:

$$w_p = A.(p_w - p_a).(0.089 + 0.0782\ V) / Y \qquad [4]$$

where

A = area of pool surface, m^2
p_w = saturation vapor pressure taken at the surface water temperature, kPa
p_a = saturation pressure at room air dew point, kPa
V = air velocity over water surface, m/s
Y = latent heat required to change water to vapor at surface water temperature, kJ/kg

For Y values of about 2.330 kJ/kg and V value of 0.10 m/s, and multiplying by an activity factor F_a to alter the estimate of evaporation rate based on the level of activity supported, equation [4] can be reduced to:

$$w_p = 4.16.10^{-5}.A.(p_w - p_a).F_a \qquad [5]$$

p_w values are:
at 15ºC water, pw = 1.70 kPa
at 20ºC water, pw = 2.34 kPa
at 25ºC water, pw = 3.17 kPa
at 30ºC water, pw = 4.25 kPa
at 35ºC water, pw = 5.63 kPa
at 40ºC water, pw = 7.38 kPa

For outdoor locations with a design dry bulb air temperature below 0ºC, p_a can be taken as 0.61 kPa. For indoor locations with a design humidity from 40 and 60%, the following values of p_a can be used:

Air Temperature	Relative humidity 40%	Relative humidity 50%	Relative humidity 60%
ºC	kPa	kPa	kPa
20	0.94	1.17	1.40
25	1.27	1.58	1.90
30	1.70	2.12	2.55

The activity factor depends on the type of pool in question and should be applied to the area of specific features, and not to the entire wetted area:

Type of Pool	Typical Activity Factor (Fa)
• Residential pool	0.5
• Condominium	0.65
• Therapy	0.65
• Hotel	0.8
• Public, schools	1.0
• Whirlpools, spas	1.0
• Wavepools, water slides	1.5 (min)

Importance of application of the correct correct activity factor for calculation of the water evaporation rate can be noticed by the difference in peak evaporation rates between residential and active public pools of the same size. It may be more than 100%.

When the design operating temperatures conditions are in question, higher operating temperatures are preferred by the elderly and lower for younger users. Air temperatures in public and institutional pools should be maintained 1 to 2ºC above the water temperatures (but not above the comfort threshold of 30ºC) in order to reduce the evaporation rate and avoid the chill effect on swimmers. The maximum water temperature that can be tolerated by the human body (for short periods of time) is 43ºC. The recommendations are shown in the table given afterward.

Typical Temperature/Humidity Relations

Type of pool	Air Temp. ºC	Water Temp. ºC	Humidity %
Recreational	24 to 29	24 to 29	50 to 60
Therapeutic	27 to 29	29 to 35	50 to 60
Competition	26 to 29	24 to 28	50 to 60
Diving	27 to 29	27 to 32	50 to 60
Whirlpool/spa	27 to 29	36 to 40	50 to 60

It is recommended not to maintain the relative humidity below recommended levels because of the evaporated cooling effect on a person emerging from the pool and because of the increased rate of evaporation from the pool, which increases pool heating requirements. Humidity higher than recommended encourage corrosion and condensation problems as well as occupant discomfort.

When ventilation/aircondidion systems are in question, recommended air velocities should not exceed 0.13 m/s at a point 2.4 m above the walking deck of the pool, however they can be higher below the ceiling in order to prevent from the condensation appearance.

Pool areas should have a light negative pressure and automatic door closers to prevent the humid and contaminated air (laden with moisture and chloramines evaporated from the water in the pool, when indirect heating is applied) from migrating into adjacent areas of the building. Most normative codes require a minimum of six air changes per hour, except where mechanical cooling is applied. In such a case, recommended rate is four to six air changes per hour for therapeutic pools.

At last but not least, it's necessary to underline natatoriums can be a major energy burden on a facility, thus energy conservation should be considered. This includes evaluating the primary heating and cooling systems, fan motors, backup water heaters (in the case of geothermal energy use) and pumps. Natatoriums with fixed outdoor air ventilation rates without dehumidification generally have seasonally fluctuating space temperature and humidity level.

Taking into account that very sophisticated powerful air-conditioning systems are a very expensive as investment but also in exploitation, normally economical optimizations are applied, resulting with application of less powerful ones. Since these systems usually cannot maintain constant humidity conditions, mold and mildew growth and poor indoor air quality is often present in the indoor pools area. In addition, varying activity level during the day also causes variable humidity level and thus change of the demand on ventilation air.

The minimum air quantity to remove the evaporated water can be calculated from the following relation:

$$Q = w_p/[r.(W_i - W_o)] \qquad [6]$$

where:

Q = quantity of air (m^3/s)

r = standard air density = 1.204 kg/m^3

W_i = humidity ratio of pool air at design criteria (kg/kg) (from psychrometric chart)

W_o = humidity ratio of outside air at design criteria (kg/kg)(from psychrometric chart).

The number of air changes per hour (n) to remove the quantity of moist air (Q) is:

$$n = (V/Q)/3600 \qquad [7]$$

where:

V = volume of the building in m^3

Normally, the air changes calculated from the above expression are smaller than the minimum recommended before, i.e. four to six per hour.

Finally, some comments should be given for the heating systems to be applied in spas or recreation centers. Normally, the use of classical heat exchangers should be avoided in order to avoid problems with corrosion and possibilities of strikes of young active users, or old un-secure walking old people. Maximally possible application of low-temperature panel heatings (Fig.5.19), incorporated in the material of the floor and walls is recommended. They create more pleasant feeling of warm floor below the naked legs and warm walls around, even for lower air temperature than if heated with classical convective heat exchangers. When the later ones are applied, use of plastic pipes and armature is recommended, and cast non corrosive heat exchangers.

5.5. Conclusion

Using the heat of thermal waters for healing and rehabilitation purposes, in combination with their chemical composition, has been the first energy use of them. Slowly, during the recent years, also the use for heating purposes has been introduced and became a "normal" part of spa and recreational centers design. When taking into account that it is already one of the most developed sector using geothermal energy (Fig.5.20) and that a significant development is in flow, it's easy to understand that balneology is one of the important markets for further development of geothermal energy use. Two main benefits of that should be

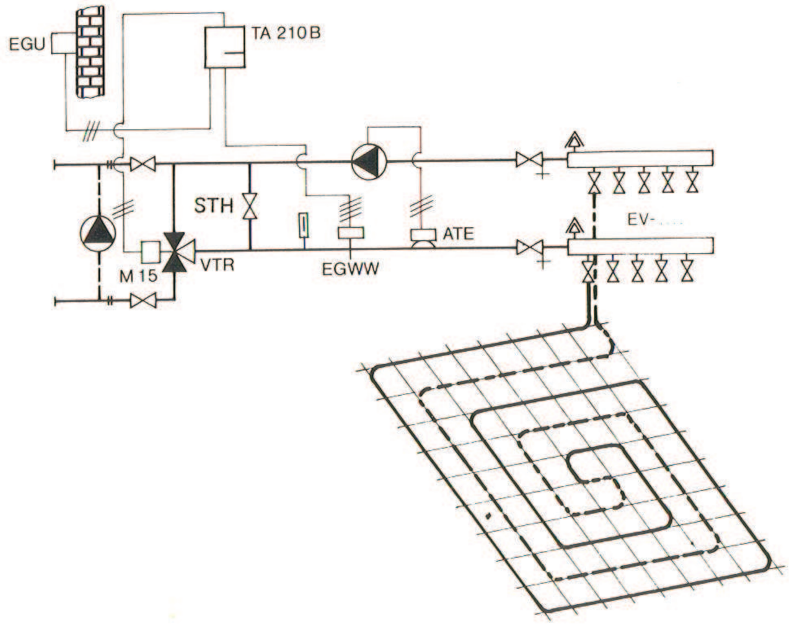

Fig.5.19. Low-temperature floor heating system

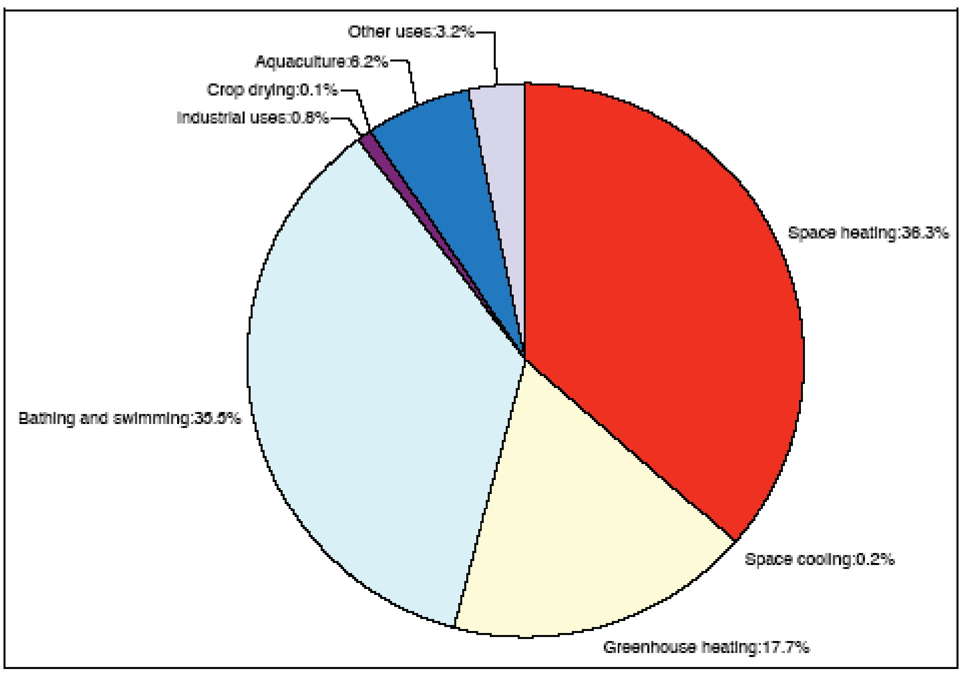

Fig.5.20. Distribution of geothermal energy direct use in Europe 2007

underlined:

- It is confirmed as technically feasible and economically justified energy source in a very important life sector with very high quality requirements, i.e. the health protection and healing. That can have significant positive influence for propagation of further development of this environmentally benign renewable energy source; and
- It's an application field where also more expensive sophisticated technical solutions can be applied, which can have positive influence to the scientific investigations and new technologies for application development.

The above listed enable to take a general conclusion that balneology is an important field for geothermal energy use and deserve full attention and work to support it's further development.

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