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2.5.
DIRECT APPLICATION TECHNOLOGIES AND PROJECT DEVELOPMENT

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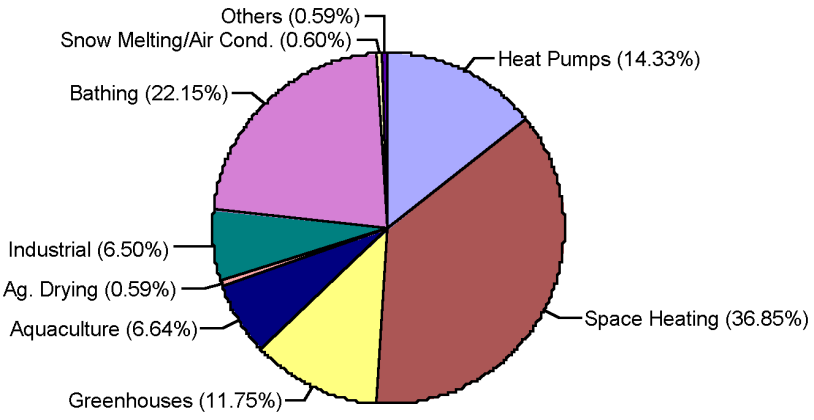
Summary: Normal uses of low enthalpy geothermal energy are related with heating purposes as are (Fig.1):

- Space heating and domestic hot water.
- Agricultural applications of heat;
- Aquaculture.
- Industrial applications of heat, like hot water, drying etc.
- Desalination of sea or brackish water.
- Combination of some or all listed consumers (district heating systems).
- Some other non characteristic uses (snow melting, etc.).

However, there is not only one technology for extracting the heat from the geothermal resource and its supply to concrete user. Each one of listed purposes uses particular sets of already developed technology(ies) in order to meet the concrete users' requests.

Some of the particularities connected to the composition of optimal technology chains for geothermal energy use for concrete uses but also with a concrete resource on disposal are discussed in this paper.



(Lund, Freeston, 2000)

Fig.1. Different direct uses of geothermal energy in the world

INTRODUCTION

Direct application of geothermal energy became the main line of development of geothermal energy use during the recent decade. Different application technologies have been developed or the existing ones for classic fuels use have been accommodated, enabling very wide field of possible use (Fig.1). However, still, it is not possible (and it shall not be) to speak about some kind of common technology for the use heat from the earth because also a list of local particularities influence the composition of a concrete project and economy of its application.

The factors that must be considered when assessing the economic viability of a geothermal project vary from project to project, from conversion technology to conversion technology, and especially from electrical generation to direct use. There

are, however, a number of factors common to all projects, although actual cost and impact on project economics will be, to a large extent, dependent upon resource characteristics and national or even local political and economic circumstances.

Therefore, when speaking about the technology of direct application of geothermal energy, we are dealing more with chains, composed of different technologies, than for one technology. Elements of such chains are:

- Technologies of extraction the heat from the earth, i.e. its production for the needs of consumer(s);
- Technologies of transportation the heat from the source(s) to the consumer(s);
- Technologies for monitoring and regulation of heat supply to different users;
- Technologies for monitoring and regulation of the heat use by concrete user(s);
- Technologies for protecting the environment of possible negative impacts of geothermal energy use.

Final quality of a technology chain depends on the local possibilities, used "know-how" for its composition and economical factors.

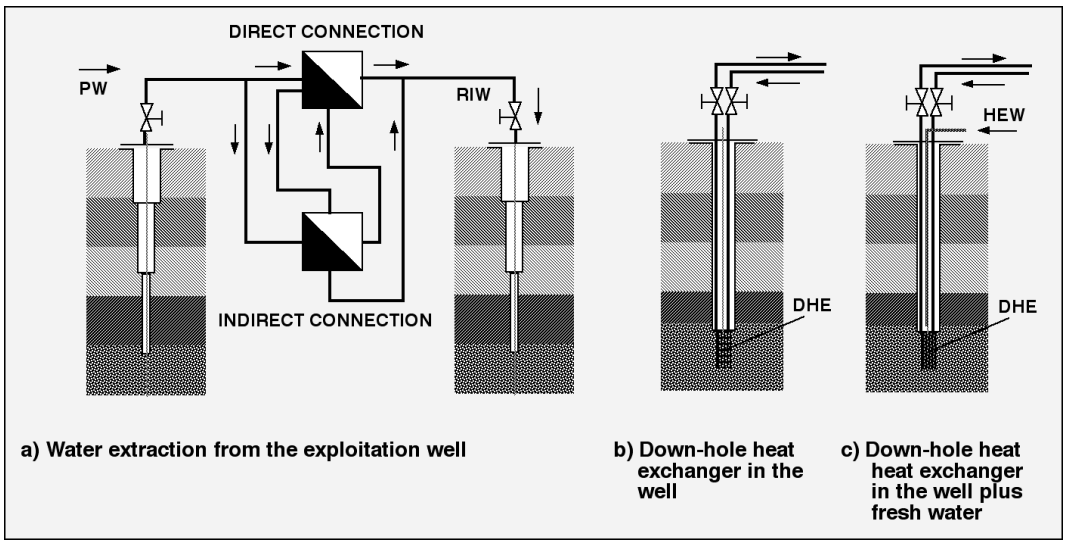
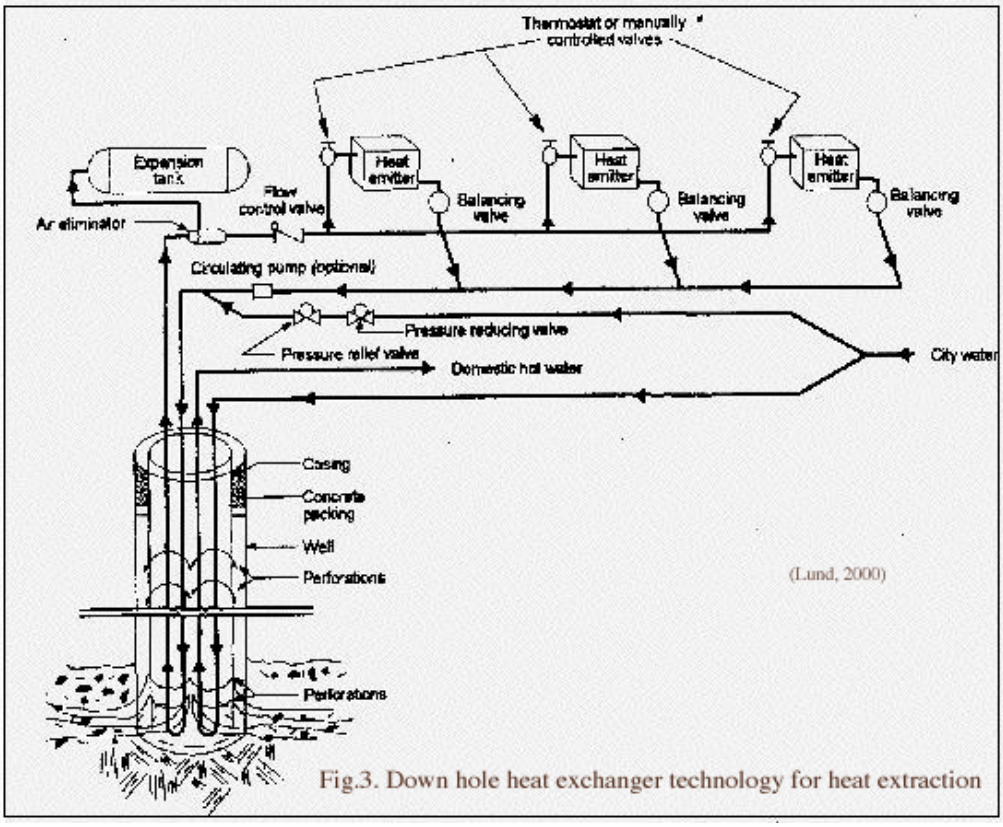
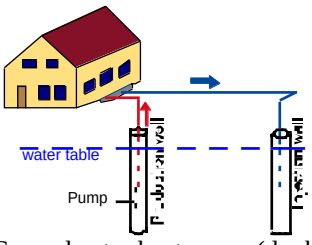
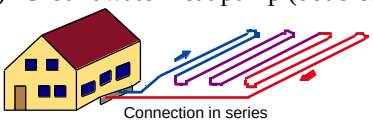


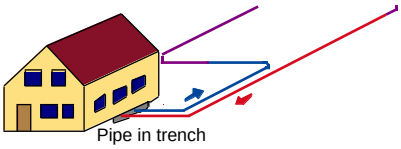
Fig.2. Technologies for heat extraction from the earth (hydro-convective systems)



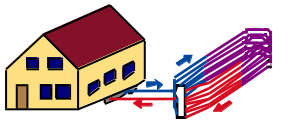


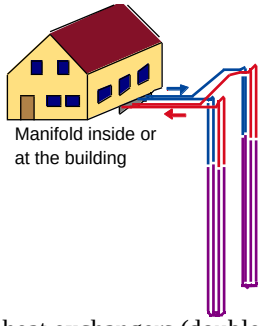
a) Groundwater heat pump (doublette





b) Horizontal ground heat exchanger types





c) Borehole heat exchangers (double-U-pipe)

(Sanner, 2004)

Fig.4. Principles of GHP heat extraction

1. TECHNOLOGIES FOR HEAT EXTRACTION

Presently, three groups of heat extraction technologies are in use, i.e.:

- Hydro-convective systems;
- Geo Heat pumps; and
- Systems for effluent heat of power generation use.

Elements of the listed technologies are:

a) Hydro-convective systems

Three main technologies are in use, i.e.:

- Thermal water extraction from geothermal wells (Fig.2-a);
- Down-hole heat extraction from geothermal wells (Fig.2-b and Fig.3);
- Hot-dry rock system (Fig.2-c), i.e. heat extraction from dry subsurface heat sources by addition of surface water as heat transfer fluid and its direct or indirect (with down-hole HE) use

b) Heat pump systems

Three main technologies for heat extraction are in use:

- Ground coupled heat pumps (Fig.4-1) with horizontal vertical or spiral pipe heat exchanger use;
- Ground water heat pumps (Fig.4-2) with or without reinjection of effluent water; and
- Surface water heat pumps (Fig.4.3) with closed or open loop system.

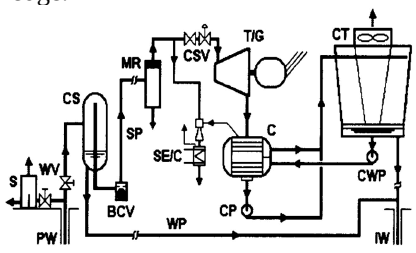
c) Effluent heat of geothermal power generation (Fig.4 and 5)

Two main technologies for heat extraction are in use:

- Closed loop system with heat extraction by the use of heat exchanger put at the effluent hot fluid flow.
- Open loop system with the use of effluent fluid as heating fluid (possible only with convenient chemistry of the fluid).

It's necessary to underline that most of the technologies in question (except the ones with the use of down hole or ground coupled heat exchangers, condition careful handling of the geo-thermal reservoir in order to preserve it from the overloading, i.e. water or heat extraction over its natural capacity. Re-injection of effluent water for hydro-convective geothermal resources is a part of the reservoir engineering (returning back the water to the reservoir from which is extracted) and play role preserving the reservoir water level but also in the environmental protection of possible negative impact of high mineralized (and often hot) waters.

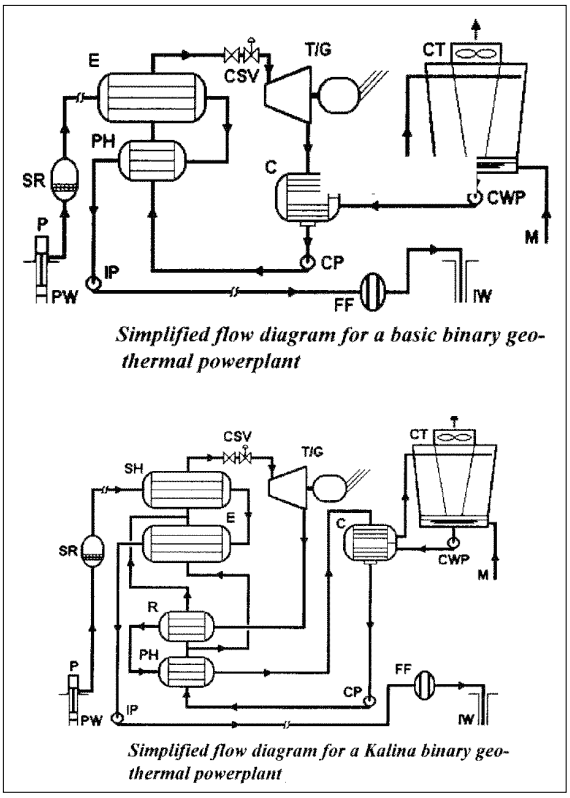
This part of the whole technology chain for geothermal energy use is the most risky and complicated one. Its proper composition, completion and exploitation conditions a multi disciplinal knowledge.



Single Flash Geothermal Plant

(Bloomquist, 2003)

Fig.5. Scheme of a single flash geothermal power production plant



(Bloomquist, 2003)

Fig.5. Schemes of the binary and Kalina geothermal power production plants

2. TECHNOLOGIES FOR TRANSPORTATION OF HEAT FROM THE HEAT SOURCE TO THE HEAT USERS

Normally, heat is transported by the use of:
- Thermal water as transportation fluid (conditioning low mineralized or chemically treated water in order to preserve the transportation pipes from scaling or corrosion); and
- Soft water as transportation fluid, i.e. before transport, heat is extracted from the thermal water with the use of heat exchanger.
- In both cases, a pump station is necessary in order to enable movement of the transportation fluid from the source to the user.

Transportation of the water is going through pipe-lines (Fig.6) positioned directly in the ground (Fig.6.a), or in beton channels below (Fig.6.b) or above (Fig.6.c) the ground surface. The use of pipelines above the ground surface without beton channels is not recommended because being vulnerable to the unprofessional handling or stilling of its parts.

In principle, when low temperature direct application is in question, transportation of heat to longer distances is not economically viable, i.e. distance between the source and users should be as shorter as possible in order to decrease the pumping costs.

3. TECHNOLOGIES FOR MONITORING AND REGULATION OF HEAT SUPPLY TO DIFFERENT USERS

The problem is connected to the daily and seasonal changes of heat consumption, due to the climate changes (different heatings) or seasonal character of use (drying agricultural products). In order to follow the changes of heat needs, it is necessary to change the flow of the heating fluid.

When a geothermal system is in question, monitoring and regulation of heat supply to the users consists three main problematics, i.e.:
- Monitoring and regulation of heat extraction from the geothermal field in order to enable proper use of it and proper following of changeable heat needs. That is particularly important for the hydroconvective systems where overpumping results with decrease of the water level in the reservoir. Regulation itself is connected to the work of pumps in the well(s) and the water distribution pumps.

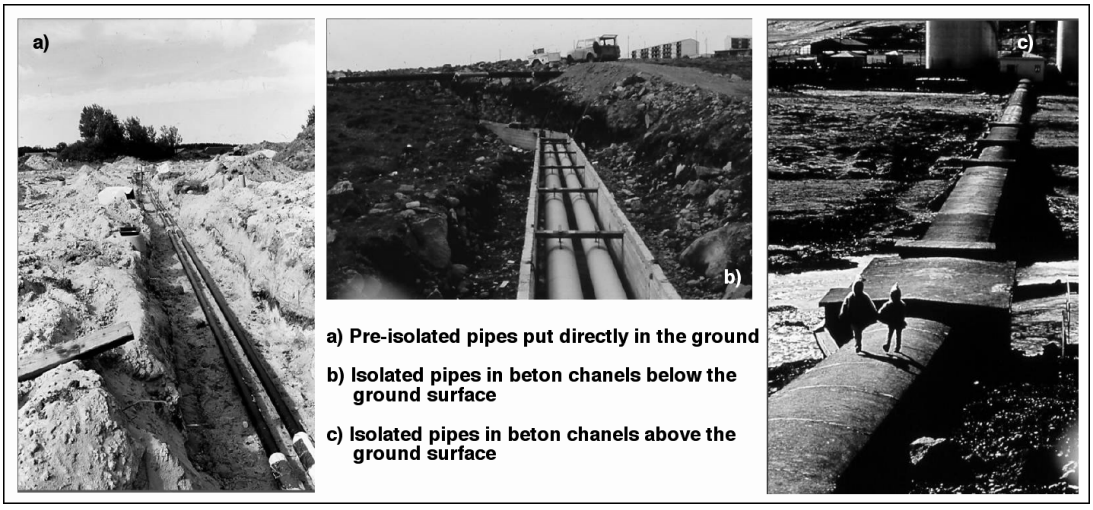


Fig.6. Pipe-lines for transportation of geothermal heat (Bloomquist, 2003)

- Proper completion of the heat source in order to enable proper maintenance of the requested parameters of the user(s) but also economical use of geothermal heat. Normally, at least when different central heatings are in question, daily and seasonal climate changes result with short lasting of maximal loadings of the system (Fig.7). Peak loadings above 50% of the maximal heat power participate with less then 5% of the total annual heat consumption.

Therefore, high investments in completion of the geothermal resource for covering this part of annual heat consumption shall not be economically justified and shall result with production of expensive heat. Normally, short morning peak loadings can be covered by introduction of a hot water accumulator (Fig.8 and Fig.9). It is filled during the lasting of low heat consumption and emptied during the peak loadings. However, for some users (greenhouses) that is not enough and additional hot water boiler using fossil fuels should be incorporated (Fig.8) in order to meet longer peak loadings during the winter season. Capacity of the heat accumulator, type and power of the boiler are matter of technical and economical calculations.

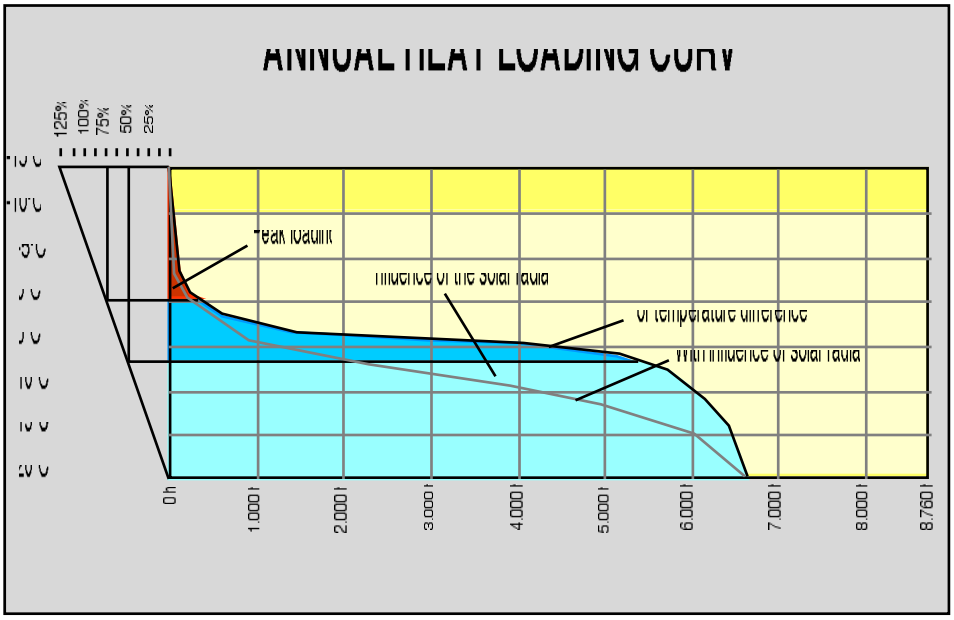


Fig.7. Annual heat loading curve of a greenhouse in middle European climate conditions

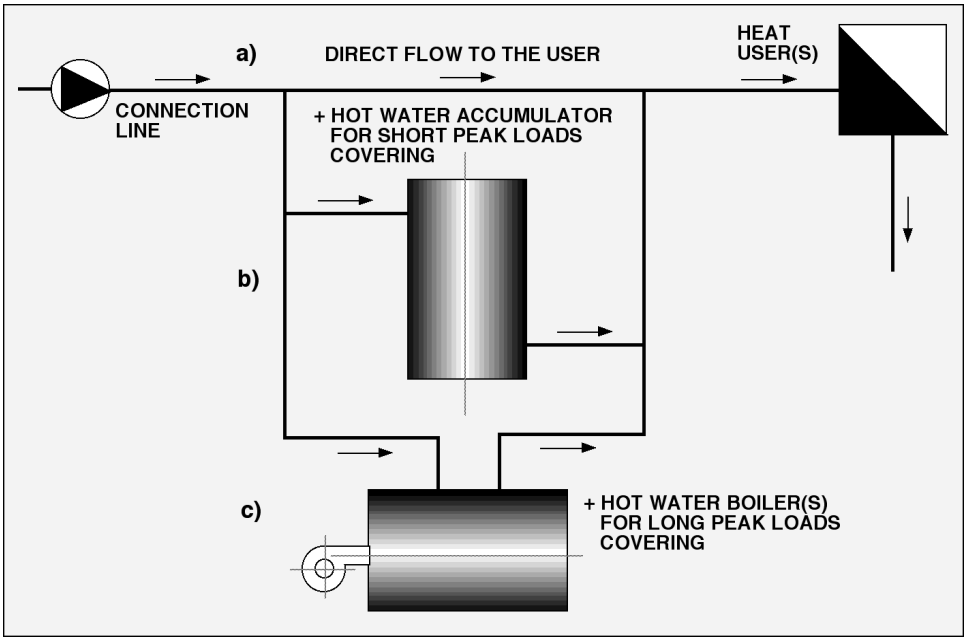


Fig.8. Economical composition of the heat source

Fig.9. Heat accumulation reservoirs of the district heating system in Reykjavik (Iceland)

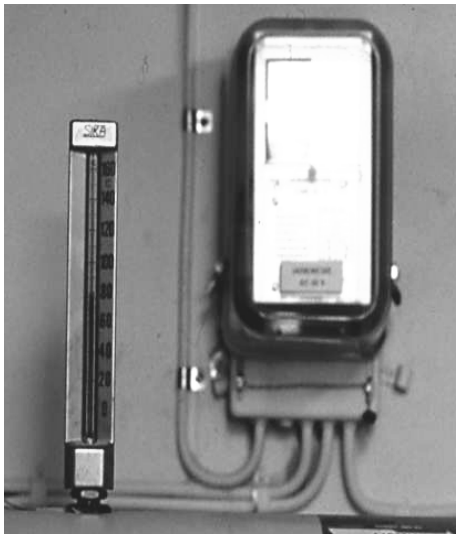


Fig.10. Measurement of heat consumption

Fig.11. Geothermal plate heat exchanger

Connected to this part of the system is also measurement of the heat supply and the use of open or closed loop system by the user.

Normally, so called “calorimeters” should be applied (Fig.10), using multiplication of the water flow and temperature difference for determination of the “heat flow”. However, mostly, only measurement of water flow is in use because enabling to the supplier to “press” the user to use also the lower parts of temperature difference on disposal. It is recommended to install the measurement of the thermal water flow even in the cases when it doesn’t serve for payment purposes because enabling orientation about short and long term thermal water consumption, i.e. necessary data for setting the regulation.

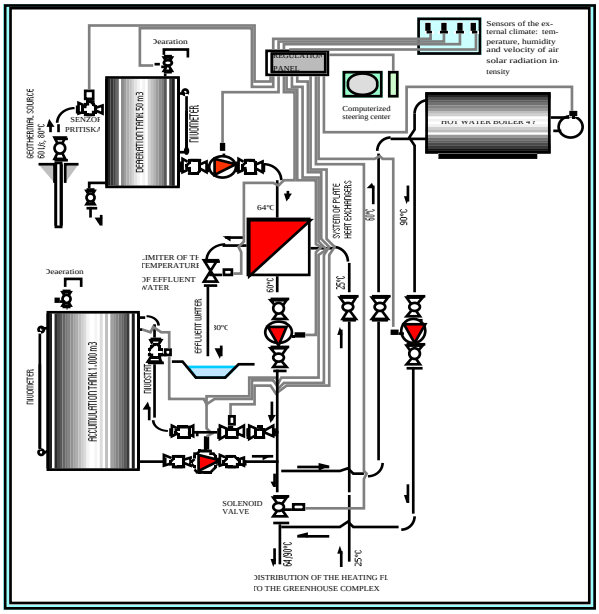


Fig.12. Composition of the central connection station of a large greenhouse complex

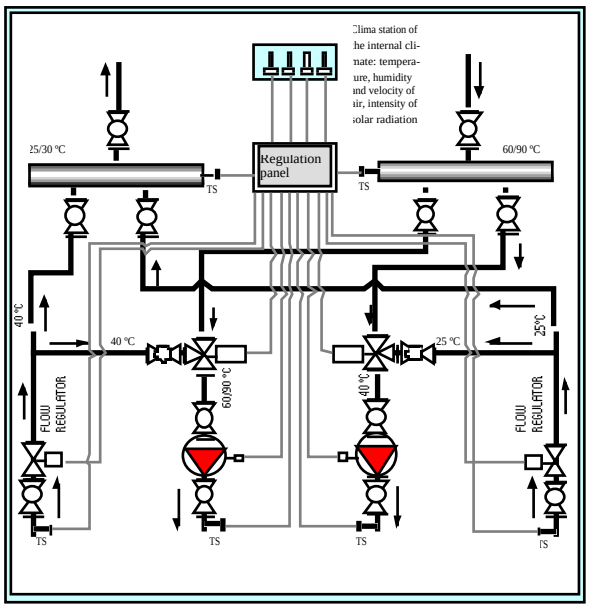


Fig.13. Composition of connection station of a consumer to the distribution network

The question of application of open or closed loop system by the heat users is a quite important

decision to be taken before the project completion. Closed loop system conditions installation of expensive heat exchangers and escorting equipment but enable protection of the installations from scaling and corrosion. Plate heat exchangers (Fig.11) enable easy maintenance and cleaning of the geothermal water side. Also re-injection of the effluent water is much easier and cheaper. On the other hand, open loop system is much simpler and can be used even without any control equipment. It is much cheaper and in wide use by the small consumers. Both systems enable the use of hand or automatic regulation of thermal water supply. The choice depends on results of economy analysis, i.e. requests of the heat user. At Fig.12 and 13 examples of completion of connection stations with automatic regulation for a larger greenhouse complex composed of several users are given.

4. TECHNOLOGIES FOR MONITORING AND REGULATION OF THE HEAT CONSUMPTION BY CONCRETE USER(S)

Heat requests and consumption of concrete consumer depend on the changes of climate conditions, when central heating is in question, or changeable technological requests of the processes using geothermal heat. In both cases, a continual control of reached parameters is necessary and regulation of the heat supply according to their changes. Normally, hand regulation cannot fulfill successfully such requests and the automatic one should be mostly applied (Fig.13). However, the economy reasons are the background of a very wide use of the hand regulation, particularly between small consumers.

Practically, this part of the technology chain is the crucial point of the geothermal energy direct use in comparison with the fossil fuels. When a heat consumer is making decision for technical solution to cover his needs, most important elements are the necessary investments, quality of heat supply, simple handling and maintenance and cheap exploitation. If fossil fuels are in question, he has on disposal excellent technologies enabling fulfilling of all the requests, except the last one. He has nothing to do with complicated technologies enabling the use of some of renewable energies and, if the cost of energy is not a crucial factor for his work, he shall hardly make the decision to go to them. Or, when small users are in question, he shall try to avoid all the complications by simplifying maximally the technical solutions and, at the end, shall get a heat supply with weak quality. Therefore, a real development cannot be expected without offering a solution which shall "divide" the consumer from the problems of heat "production". His problems should finish at the border of the connection station, where to take the energy and pay for it according to the measured consumption. That is possible only with development of larger district heating systems and is the background of their success everywhere where properly completed. However, that also means incorporation of a another and rather complicated technology in the geothermal energy technology chain.

5. TECHNOLOGIES FOR THE HEAT USE BY CONSUMERS

At the end of the chain come technologies for the heat use by consumers. In principle, that should not be a "special" case, differing from the technologies where fossil fuels are used, because when being on disposal heat is heat, doesn't matter from what origin. However, there are differences due to the fact that the heat source "offers" the heat with continual characteristics, i.e. temperature and flow are not changeable according to the needs of the consumer. In addition, temperatures on disposal are normally lower than the ones conditioned by the classical technologies base on the fossil fuels use.

The above listed resulted with development of so called "low-temperature" technologies for heating the rooms, drying agricultural products, industrial applications, etc. Some of them brought improvements of the quality (heating of greenhouses, drying of agricultural products) and later on have been accepted also by the fossil fuels users. However, common characteristic of all these technologies is that being more expensive than the classical ones.

6. ENVIRONMENTAL PROTECTION

In addition to the technologies for production and consumption of the heat, final and obligatory part of the chain is the environmental protection. If not incorporating it, geothermal energy utilization shall have negative impact(s) to the environment, mainly thermal, chemical or with scaling of consisted minerals, plus the destroyed balance of geothermal reservoir. Different technologies for protection can be applied, depending on the characteristics of concrete resource and type of application.

Some of them are incorporated by the applied technology of heat extraction itself (down hole heat exchangers). However, for most of the others it is the most complicated part of the technology of application.

First problem, which often appears, is the scaling. Immediately after disturbing the pressure and temperature balance of thermal water by its extraction from the reservoir, a list of consisted minerals begin to scale on the internal pipes surface.

Second problem is the corrosion, resulting from the presence of corrosive minerals in many thermal waters, particularly when coming in touch with the oxygen from the atmosphere.

Technological solutions on disposal for both problems are quite complicated and expensive. They can be physical (taking measures not to disturb the pressure balance of the water) or chemical (by addition of neutralization agences). First ones condition expensive investments and the second expensive exploitation.

Additional problem is the re-injection of effluent water back to the reservoir. It should not be with a chemical composition which is very much different of the original one because can damage the reservoir, Therefore, many times additional measures are necessary in order to fulfill its requests, and that can increase significantly the exploitation costs.

If the water is not re-injected back to the reservoir, which is an often case when small users are in question, negative thermal or chemical impact to the environment is immediately visible and causes a negative reaction of local people to further development of the source or application.

7. COMPOSITION OF VIABLE TECHNOLOGY CHAIN(S)

Summary of the consisted problematics, made in 1-6, illustrates the complicate character of composition, application and development of direct application geothermal projects. As already said, that is not a question of completion of one, good or bad, technology for application but composition of a accommodated chain of a list of technologies for different parts of it. By intention it is not said an optimal but an accommodated chain because economy reasons normally do not allow application of the best solutions on disposal, particularly not for smaller projects with only one user.

Composition of the technology chain is normally dictated by:

- Nature of the geothermal resource which should produce the heat for the project;
- Characteristics of the heat consumption which should be covered;
- Existence or not of combination of users with different heat consumption characteristics;
- Distance between the heat source and heat consumer(s);
- Particularities of the technology(ies) of the heat use by the consumer(s);
- Financial funds on disposal for investments in the technology chain completion; and
- Final prize of used heat which can be competitive for the user(s).

It's obvious that it is a quite complicated multi-disciplinal task. Normally, first comes the definition of "minimal" limits of completion of each one of technologies in question and definition of negative technical and economy consequences of application of such "minimal" solutions. Then, it comes the evaluation and estimation of resulting negative consequences and positive implications of introduction of possible improvements. These ones are compared afterwards in combination with the necessary investments for their incorporation, influence to the final price of used heat and financial funds on disposal for completion for project completion. Finally, not optimal but the viable combination is chosen, enabling a successful start with the new energy source use. That is the reason why a geothermal project is never finished, i.e. based on the experiences of running it, there are always possibilities (and need?) for improvements and development. That is also the reason why the technology chain applied for one project cannot be applied for some other one.

In that way, we localized the weakest point of the direct application of geothermal energy and possibilities for its further development. Very complicated character of the application technology chains conditions an expensive initial engagement of multi-disciplinal teams of experts in order to guarantee success of accepted solutions. Numerous trials for simplification of small owners regularly finish with negative results and, in that way, stopping of initiatives for development of direct application of geothermal energy in many locations.

It's quite clear now-a-days that a real wider development is possible only with application of bigger district heating schemes. They justify the engagement of expensive experts for definition of concrete elements of the technology chain(s) and team of professionals, able to perform a proper exploitation and maintenance of the project. As bigger it is and as better is the combination of heat users, better are possibilities to reach a higher annual heat loading factor of the system and better final economy results.

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