4. Shortliffe. E. H. 1976 *Computer-based medical consultation*, MYSIN, New York, American Elsevier

INTERNATIONAL SUMMER SCHOOL on Direct Application of Geothermal Energy
ul. "Dame Gruev" br. 1-3/16 - 91000 Skopje - MACEDONIA
Phone-Fax: + 389 (091) 119 686 - Cellular: + 389 (070) 262 044 - E-mail: isskiri@soros.org.mk
ЗЕМАК

Меѓународно советување за
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ENERGY SOURCE COMPLETION FOR GEOTHERMAL DISTRICT HEATING SYSTEMS

Prof.Dr. Kiril Popovski
International School on Direct
Application of Geothermal Energy
Skopje, Macedonia

SUMMARY

Geothermal district heating systems differs from the others mainly in the part of energy source completion and its connection to the heat distribution systems. Even rather known problematics in the countries where geothermal energy is in wide application, new appearances of mistakes are always present due to the fact that necessary literature is difficult to be found.

Essentials of the geothermal well completion and connection of geotherml source to the district heating distribution system are summarized in the paper and several examples of geothermal projects in flow presented.

1. WELL COMPLETION

1.1. Engineering Background

Well completion is the final phase of the process, initialized by different explorations, investigations, drilling, definition of well characteristics, water sampling, well performances proving, etc. Practically, its target is to finalize all previous work and reached results into completion of a production well, with full guarantees of its conformity and safety conditions.

Before starting the process of well completion design, the engineer has "in hand" the following situation:

- A hole between the formation and surface;
- Results of investigations of physical/chemical conditions of the formation drilled;
- Results of measurements of flow under different influencing conditions, i.e. "capacity" characteristics of the well;
- Results of thermal water analysis;
- Results of measurements of the reservoir behavior under different "exploitation" conditions;
- Material selection guideline; and
- "Know-how" based on the experience of results of different types of well completion for similar reservoirs and wells, own or of the others.

His task is to "unify" inter influences of all the listed factors and to make decision for an optimal compromise, fulfilling the request of a safe production and exploitation with minimally possible capital investment, exploitation and maintenance costs. It is for sure a rather complicated problem if taking into account that some of the project requirements are opposite to each other (maximal economy versus maximal safety and long lasting?).

Detailed elaboration of the problem and explanation of consisting "sub-problems" of different science and technical disciplines is not possible in a short. However, it is possible to make a review of consisted problematics and recommendable solutions, based on the experience of known European low-temperature reservoirs projects.

1.2. Underground completion

The aim of underground completion is to stabilize the well production, i.e. to reduce the risks of instability caused by:
- Low mechanical resistance from the production formation; and
- Return phenomena of solid materials from the production formation.

Both reasons can result with rapid plugging of the well and, in that way, with a consequent loss of its production capacity.

If appears, the problem can be resolved (Bottai, 1992) by using a slotted liner although theoretical production is reduced. Consequently, slotted liners are used only if really and proven necessary. The presence of a slotted liner has sometimes been correlated to a more rapid scaling formation.

1.3. Production casing completion

Type production casing completion should be in accordance with the safety standards appropriate to the characteristics of geothermal fluid in question, mining conditions of concrete well, the aim of production well and corresponding economic parameters.

Physical-chemical characteristics of geothermal fluids are strongly dependent on the production formation characteristics, depth of the reservoir, composition and quality of casing, i.e. prevention of influence of "passed" underground layers of different physical-chemical composition than the one of the production formation (also possible mixing with shallow underground flows).

In general, chemical composition of thermal waters depends on the chemical composition of the production formation, and physical characteristics on the depth of it. Shallow reservoir fluids produce a slight corrosion effect, as they consist mainly of superheated steam or hot water, whereas deep fluid reservoirs are generally characterized by several liquid and gaseous phases.

Fig.1. shows a simple completion of production well originated from a shallow geothermal reservoir. The relative production well-head is shown at Fig.2. Technical solution

fulfills the safety standards and is confirmed in long-year practice of Italy and France. Difference with a completion of a deep well can be noticed by making comparisons with technical solution shown also at Fig.1.

Normally, "integral joint" pipes are chosen for such technical solutions and are able to gua-rantee good conditions for gas sealing and mechanical joint resistance. Also "super EU-CG" ty-pe joints can be considered as suitable because offering very good resistance against the stress corrosion cracking.

The elements of successive casing objectives can be summarized in the following (Bottai, 1992):
- A well completion with a casing in no worn condition because it is not interested by the drilling;
- Possibility of cementing the length of casing in ideal conditions using shoe and/or collar cementing packers;

This objective can be achieved even in cases of wells with strong gaseous emanations with consequent high risks of forming permeability channels in the cement slurry (gas migration) and also in fractured terrains characterized by slurry absorption, typical of productive wells in some European regions (Italy);
- Effects of casing heating (axial compression) during the production phases can be limited due to the possibility of two phase cementing.

This is obtained by keeping the casing in a strong traction (pre-stressing) during the cement hardening. The tensile value usually adopted compensates temperature variations of about 60-80 Deg.C, able to keep the casing in conditions of allowed stress (axial thermal compression) during the production phase.

Taking into account that slurry hardening at high environmental temperatures is influenced by resulting chemical-physical alterations in the slurry it is necessary to pay attention to use the adequate formula for composition of the deep well cement. It should be found through the process of specific laboratory tests.

The minimum diameter of any open hole or casing string should be selected so that fluid velocities at maximum pumping rates are below 1.5 m/s. For wells that flow at the surface, velocity might be lowered by increasing the diameter to obtain larger flows. The additional well costs should be balanced against pumping costs.

The diameter of the inlet portion at the bottom of the well should be chosen to accept the water available from the reservoir. However, it is necessary to take in account that productivity is determined much more by the permeability than by the diameter. For example, for identical conditions of permeability, draw down and radius of influence, doubling the well bore diameter increases production about 10% in an unconfined aquifer and only about 7% in a confined aquifer (Culver, 1989).

1.4. Submerged Pumps

Low-temperature production wells are not artesian very oftenly, which conditions the installation of submerged pumps in the well. As the most reliable in practice following types are confirmed:
- The line shaft pumps with a motor or engine at ground level and a long torque shaft extending down the bore. They requires installation of support of bearings throughout of theirlength. Number of bearings depend on the length. The weak point of this type is the need for special protection from chemical attack of the bearings and adequate (oftenly expensive) lubrication.
- The down-hole electric pump having a submerged electric motor directly coupled to the pump. Taking into account the small diameters of boreholes on disposal, the

motor has a very small torque radius and is consequently very long. Difficulty of sealing a submerged motor and ability of thermal insulation to withstand high temperatures is the weak point of this type of pumps.
The down-hole turbine pump, consisting a submerged down-hole boiler extracting a small fraction of the bore water heat to generate steam that feeds a compact turbine directly coupled to type pump. Fresh water is fed to the boiler through a pipe from the surface, and the turbine exhaust is led up the bore through another pipe to ground level, where can be discharged or recycled to the boiler.

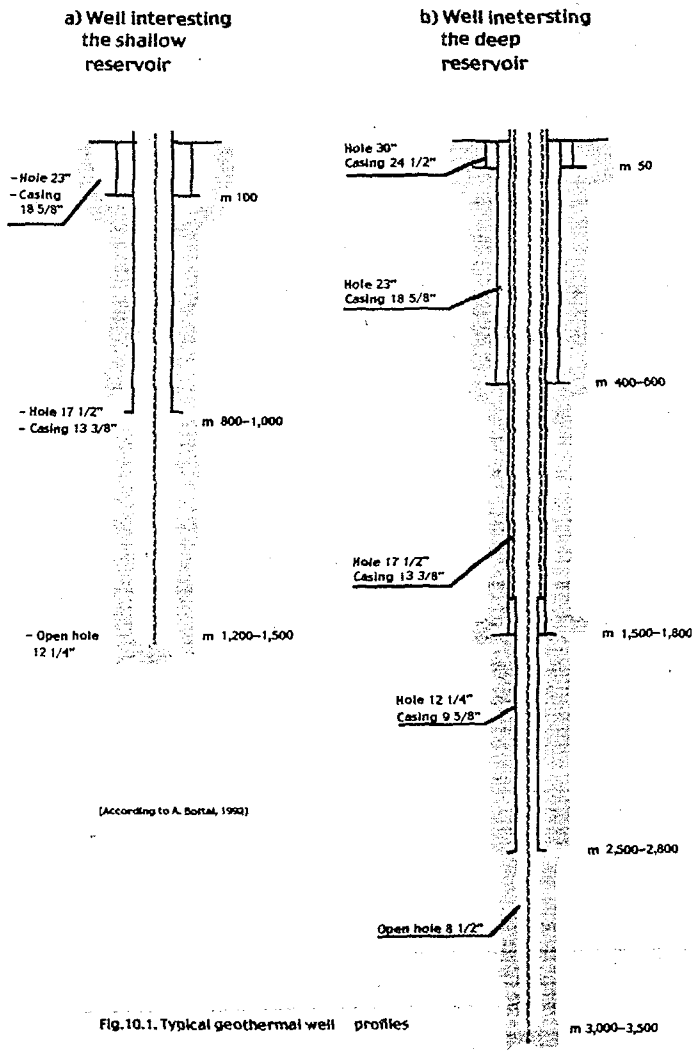

Fig.10.1. Typical geothermal well profiles

Fig.1. Typical geothermal well profiles

Installation of submerged pump conditions installation of surface casing with size accommodated to the pump bowl diameter. Normally it should be two nominal pipe sizes larger than the bowls, to permit easy installation and to allow some well deviation. One nominal size larger diameter is permissible, but not recommended.

The choice of the pump for concrete well depends on its characteristics and requests. However, it is necessary to pay attention not to choose too big units which can over-pump the bore and, in that way, to cause cavitation and perhaps chemical precipitation. It is also recommended not to risk by buying "cheap and good" pumps of new producers. Finally they are coming much more expensive than the ones of the proven producers with long years experience in this problematics.

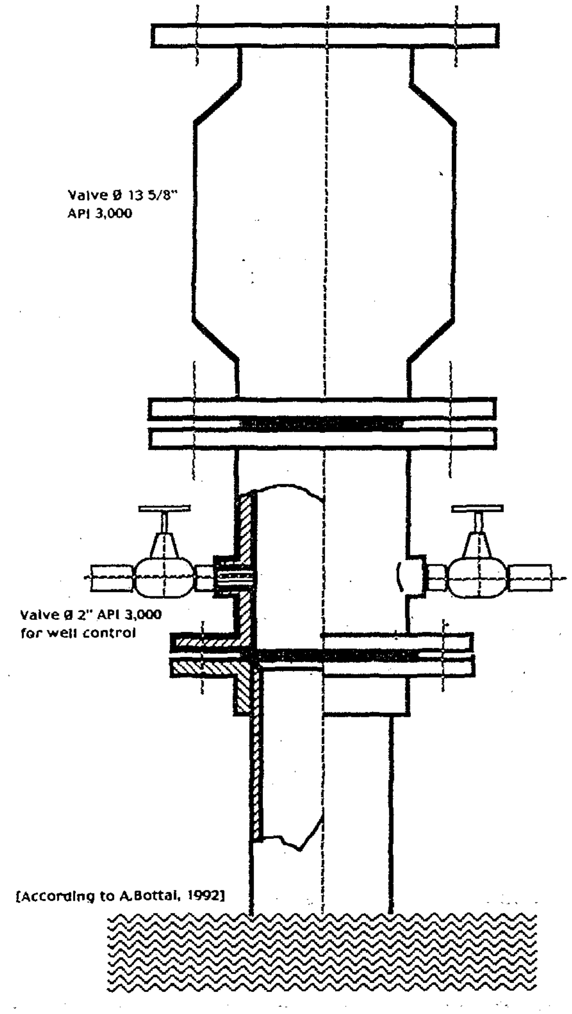

Fig.10.2. Example of production we ll head for wells of the shallow r eservoir

1.5. The Problem of Reinjection

Even not directly connected to the concrete well head completion, reinjection of effluent water of the well influences directly the management of geothermal reservoir and, in that way, also characteristics of the well itself and requests for its completion.

Beside the escorting very high capital investment costs and exploitation costs (electricity for pumping?), main limitations for wider introduction of it are the following ones (Armstead, 1982):

- Need for good information ıbout the real permeability at the base of the reinfection bores in order to be sure that it shall be sufficient to allow the formation to accept large quantities of water without the aid of intolerably high pumping energy;
- Possibility that silica, often present to saturation in bore waters, precipitates on the walls of reinjection bores and within the interstices of the underground formation to an extent that would entail the frequent abandonment of reinjection bores and the sinking of new ones;
- Possibility of rise of dangerous seismic effects caused by the reinfection of relatively cool waters on coming into contact with much hotter rocks; and
- Possible negative effect of introduction of relatively ccol waters on the quantity and quality of production borehole(s).

However, for the water dominated reservoirs listed limitations are practically not valid, according to the rich experience during the last 15 years.

Reinjection is now widely practiced all over the world. Its introduction has been very much "helped" by the environmental protection low restrictions during the recent years, at least in most of developed countries.

2. CONNECTION TO THE WELL(S)

2.1. Classification

Connections of district heating systems (and heating systems in general) to geothermal well(s) may be grouped in two general groups:

- Direct connections; and
- Indirect connections.

Basic difference between the groups is that with direct connections geothermal water is used as heating fluid in the installations of heat users (open loop systems), and with indirect connections it is separated of them by means of a heat exchanger. Water with controlled chemical composition lates through the heating systems of users (closed loop system). The reason is that chemical composition of some geothermal waters or used materials for composition of the heating system allow direct use of it, and of the others do not.

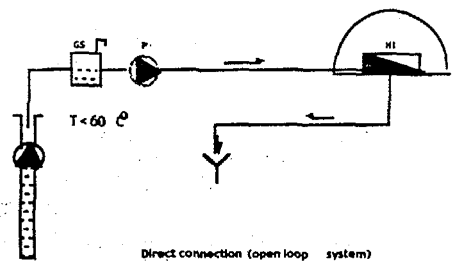

Fig.3. Basic composition of direct connection to geothermal well(s)

Mostly, these are the economical reasons which caused that a typical Mediterranean greenhouse is directly connected to the geothermal well(s) now-a-days. On the opposite very high mineralization and corrosivity of French thermal waters is the reason that indirect connections are normally used there.

2.2. Direct connection to the well(s)

Basic composition of a technical solution for direct connection to geothermal well can be seen at the Fig.3. It consists of a pipe-line between the well and user, a gas separator and circulation pump. The spent fluid is discharged to waste. Sometimes, when artesian pressure is enough high even the pump is avoided. Regulation of the heat supply is made my means of a hand manipulated valve, located at the well head or just before the enter into heat installation of the consumer. Such a design is often for the connection of small greenhouse units, connected as unique consumer to the well.

However, such a technical solution cannot be accepted as a proper one for a serious district heating project. Hand temperature regulation by means of control of thermal water flow doesn't give satisfactory results. It enables "improving" the inside temperature conditions, but not their real control. The system can be recommended only for milder climate regions and for early spring and late autumn proteoted crop cultivation in simple greenhouse constructions. It should be obviously avoided for the winter and all year around production.

Complete technical solutions for direct connection to geothermal well(s) are presented at the Fig.4. In principle, they can be classified as follows:

- Open loop system direct connections (Fig.4.1.a); and
- Semi-open loop system direct connections (Fig.4.1.b).

Open loop system is practically the one of the Fig.4.1. with addition of temperature control by means automatic or semi automatic thermal water flow control (quantitative temperature regulation).

Semi open loop system differs of the open loop one with the incorporation of qualitative temperature regulation, i.e. heating fluid flow in the greenhouse heating installation is constant, only its temperature changes depending on the plant requests and outside climate conditions. However, the thermal water flow is changeable, depending on the part of the return water which is taken back in the installation to mix the fresh one in order to reach needed temperature in the heating installation.

As understandable from previous elaborations, open loop system is practically the single-pipe thermal water distribution, and the semi-open loop the two-pipes distribution system.

Both systems can be combined with the use of heat pump (Fig.4.2. c and d), and back-up boilers (Fig.4.2. a to d).

2.3. Indirect connection to the well(s)

When geothermal water is of very high temperature, corrosive or with high inclination to scaling, in most cases the indirect connection to the well is techno/economically justified solution. Thermal water is, in this case, separated from the heating fluid in greenhouse heating installation(s) by means of heat/exchangers. The purpose of the heat exchangers is to transfer the heat from the geothermal to the heating system medium whilst keeping the two separated. Again, like for the direct connections, technical solution can be arranged for quantitative regulation of heat supply (Fig.5.a), or for the qualitative one

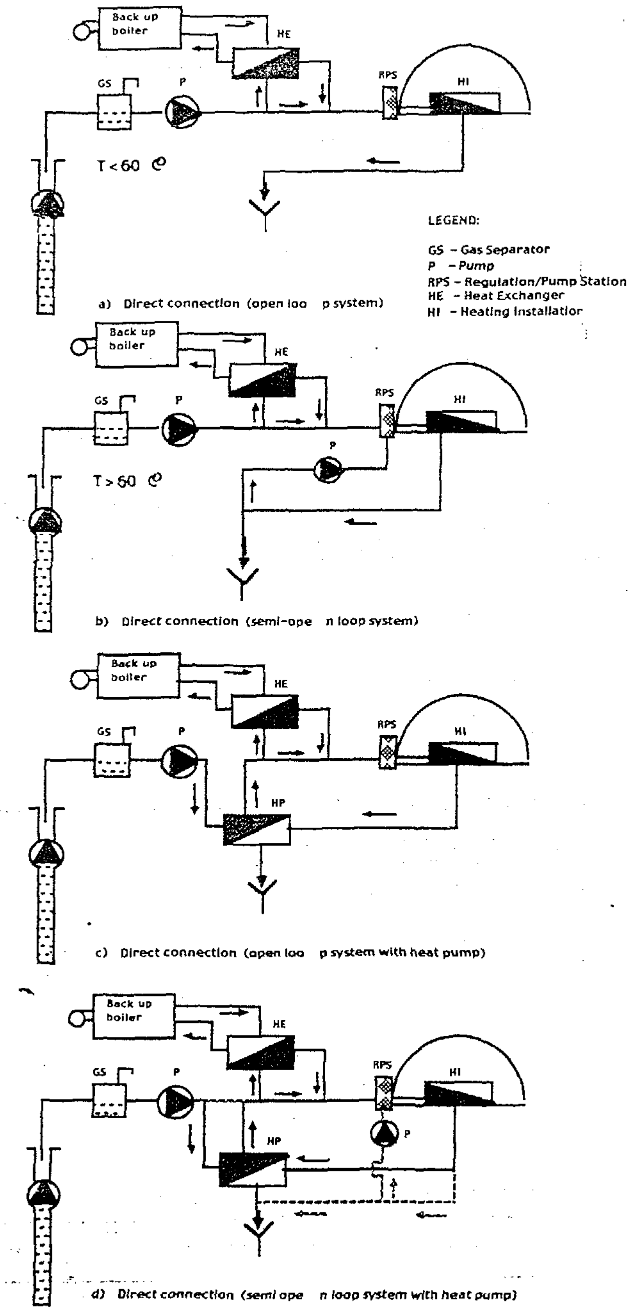

Fig.4. Basic types of direct connection to geothermal well(s)

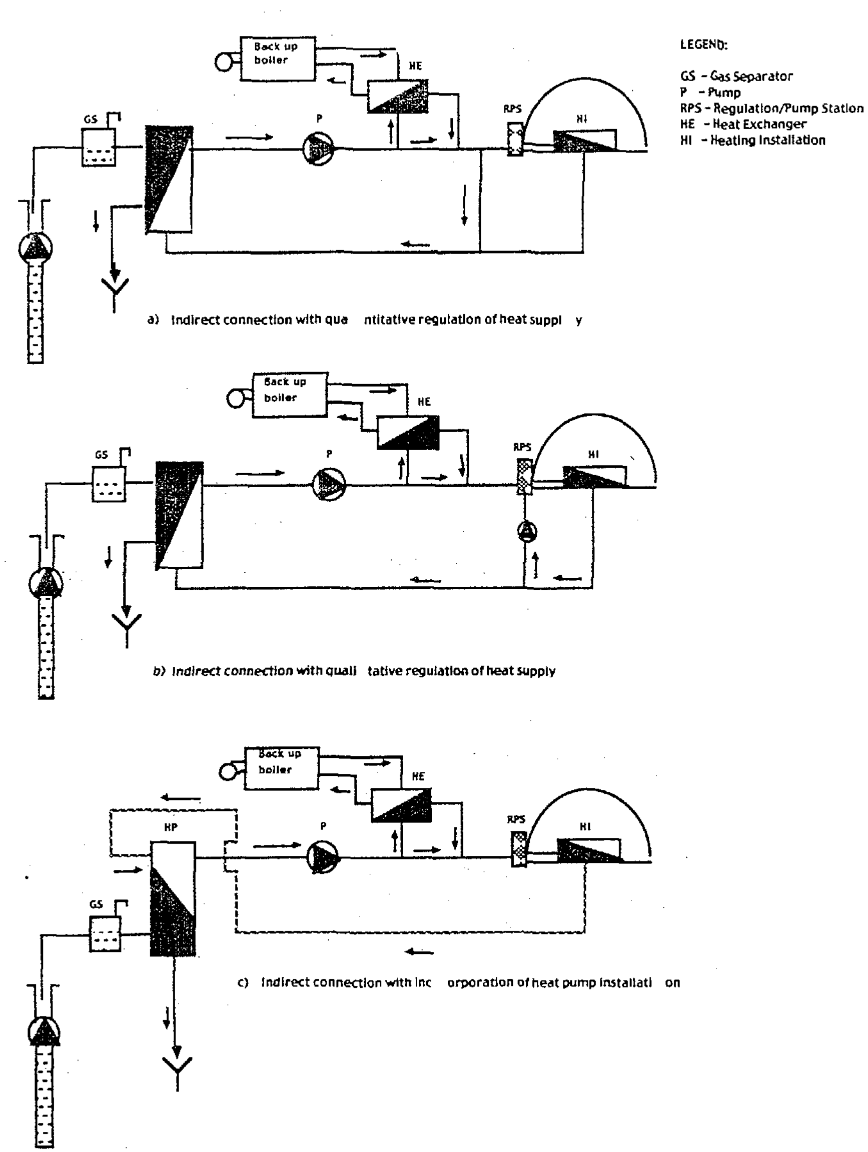

Fig.5. Basic type of indirect connection to geothermal well(s)

temperatures in the greenhouse. The area under the curve (shaded in Fig.6) is proportional to the number of so-called degree days in a year below a given temperatures defined as the accumulated sum of degrees (mean or average temperature) below the given temperature value for the total number of the days in the year.

It is generally found to be more economical to install fossil-fuelled boilers to cover the usually very brief periods of peak demand than to provide geothermal capacity sufficient for all heat loading situation. For example, heat demands over 50% of the maximal one in central European climate conditions participate less than 5-8% of the total annual heat consumption. When putting this information in comparison with the fact that a boiler plant requires a comparatively low capital investment (but is expensive to operate), it makes it typically more economical for heat generation for intermittent peak load applications than would the provision of additional geothermal well(s) and all consisting necessary technical completion. However, it cannot be true when some cases of direct connections are in question. The addition of special heat exchanger plus the capital investment costs for the boiler plant completion can exceed the ones for additional well(s) completion when small systems are in question and when shallow thermal water reservoirs are on disposal.

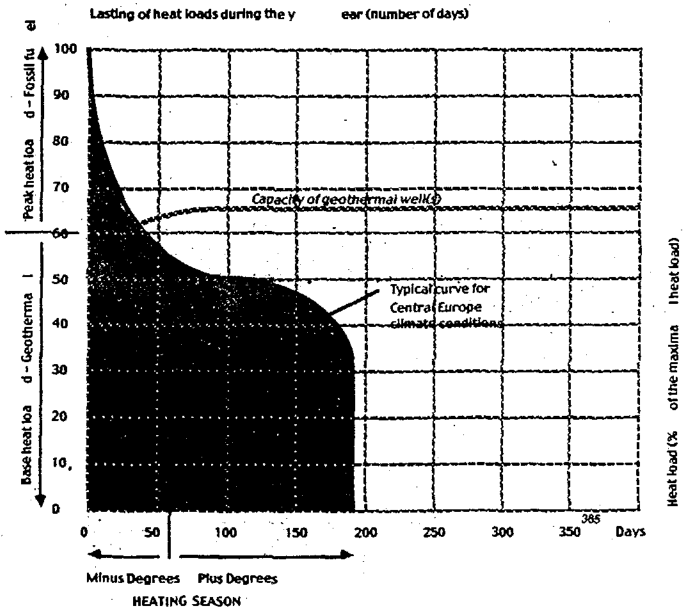

Fig.6. Annual heat loading curve of a central-European geothermal system for heating greenhouses

2.5. Choice of Type of Connection to Geothermal Well(s)

Problem of the choice of type of connection to geothermal well(s) for concrete cases is of complex nature. A feasibility study preparation is obviously necessary before taking the final decision, which should include all the influencing factors, such as are:

- Chemical composition of geothermal water on disposal;
- Geothermal reservoir characteristics, i.e. stability of the heat supply over the year;
- Capital investment costs for technical completion of the well(s) for exploitation; in total and per used heat unit;
- Capital investment costs for technical completion of a boiler plant with the same heat power and for the local most economical fossil fuel on disposal;
- The same for heating systems of the consumer(s);
- Type of heat consumer, i.e. heat load consumption characteristics over a typical climate year;
- Exploitation costs of the geothermal heat supply system per year and per used heat unit;
- The same for a boiler plant with the most economical fossil fuel on disposal;
- The same for maintenance costs;
- The same for amortization costs;
- Influence to the environment;
- Influence of the costs for environmental protection for both technical solutions of heat source completion;
- Recognition and estimation of influence of additional costs, such as can be the support of experts or specialists for resolving untypical exploitation problems;
- Influence of the stability of heat supply over the year (in some countries the supply of fossil fuels is not stabile at the state basis, and sometimes at the regional basis); and
- Possible use of benefits offered by state funds for development of alternative heat sources and their influence to the finally used heat unit.

Generally, except for some demonstration projects, such type of analysis results with an orientation towards the most simple possible technical solutions mainly in order to avoid initial high capital investment costs. Further on, during the project development and exploitation, improvement are incorporated according to the dictate of real situation.

Such an approach has positive and negative sides. Positive is that expensive design mistakes are avoided. They are normally one of the consequences of weak knowledge about the real nature of geothermal reservoir and fluid during the initial period of development. It is also very rare to go directly to development of sophisticated greenhouse complexes for expensive production with geothermal heating of new wells. Normally, beginning is with simple plastic covered greenhouses for cheap production which cannot pay high initial capital costs. Further on, together with the development of the protected crop production quality, also improvement of the quality of technical solution of the connection is incorporated. Meanwhile, the user has time to learn the problematics of direct application of geothermal energy and to come to the real project requests connected to the geothermal energy use in it.

Negative side is that simple technical solutions normally doesn't consist necessary measures for proper reservoir exploitation and environmental protection. Only a small part of available heat energy is used and environment thermally polluted. Sometimes also geothermal reservoirs damaged.

However, due to the multidimensional character of the problem, conditioning engagement of experts of different science and technical disciplines, it is difficult for a greenhouse owner to enable composition of a team of designers enough good to guarantee optimal techno/economic justified technical solutions. State organizational and financial support is necessary for that, at least on the state of "know-how" of today.

2.6. Examples

a) Simple direct connection - Demonstration greenhouse complex at Kralova pri Senci (Slovakia), but also at Eleochoria (Greece), etc.:

The well of 52°C and flow of 45 m^3/h stimulated development of a demonstration greenhouse complex consisting 7 greenhouses heated with different geothermal heating instal-lations and a small open field heating. Geothermal water is of HCO_3 - Cl - SO_4 - Na type, with mineral content of 7.7 gr/l and inclination to crusts deposition. The well FGS-A is artesi-an and available pressure allows to avoid use of water transportation and circulation pumps.

Technical solution of the connection of geothermal project to the well (Fig.7) consists of a steel tank of 15,625 l installed 3.5 m above the ground level and a Ø150 mm PVC pipe with polystyrene thermal insulation for thermal water transmission to the greenhouse complex and Ø100 mm for distribution between greenhouses.3.5 m water pressure is enough to overcome flow resistances in each of the connected heating installations. Heat supply regulation goes manually by use of connection plastic valves installed before the enters of all the greenhouses. Pipe material allows temporal cleaning of crust in installation with HCL solution.

Reasons to make a choice for such a type of connection to geothermal well have been the following:

- Geothermal water is aggressive and with inclination to crust deposition. Use of normal pipe and equipment materials (steel and bronze, or similar) conditions indirect connection of heating installations to the well;
- Complex of greenhouses consists of a very small production surface (about 800 m^2) under very simple constructions, without regulated ventilation and CO_2 concentration;
- Cultivated cultures are mainly vegetables, i.e. cheap it is a cheap production;
- Climate conditions during the production season are rather stabile, i.e. there is no sharp daily changes;
- If intending to introduce indirect connection with the proper material in the primary (geo- thermal circuit) and conditioned pump installation in the second circuit, capital investment costs for that are higher than for the greenhouse constructions and production technology together. Small and cheap production cannot return such an investment in an acceptable time period. Costs of temporal cleaning (during the non-productive period of the year) and changes of damaged part of installations (two heating installations are made of steel pipes) are many times lower than necessary annual repayments under the best possible credit conditions.

b) Direct connection of geothermal heating installations for greenhouses in Srbobran (Yugoslavia)

Geothermal water is rich with O_2 and CO_2 and is sightly aggressive to steel in their presence, i.e. conditioning good de-airaition if intending to use direct connection of the greenhouse heating installation. On the other hand, rather small project cannot pay the costs of necessary expensive plate heat exchanger. Strong regulation for environmental protection conditions low temperature of the effluent water.

Resulting techno/economically feasible technical solution (Fig.7) consists of the following elements:

- Deaeration tank;
- Water tank for compensation of peak loadings;
- Pumps for geothermal water circulation through the heating installations;
- Collection tank for effluent water with regulation of effluent temperature;
- Necessary measuring and regulation equipment.

After dearation geothermal water goes to the collecting tank, where the residual air and gas is removed. The undissolved particles are collected at the bottom of the tank, which is cleaned out from time to time. Tank is enough big to cover 2-3 hours lasting peak demands of consumers. The pipeline is made of carbon steel and insulated with glass-wool wrapped in aluminum foil.

The geothermal water is automatically controlled as a function of water level in the tank, with a control unit, which consists of: the water level sensor, the adapter and water level regulator and the valve operated with a servo motor. The water level is controlled with an on/off switch, commanding the operation of pumps for supplying deaerated water for the users.

The technical design of flow regulation is appropriate for clean fluids, but due to the aggressive features of the thermal water, many operational problems occurred in exploitation. Investigations are in progress for adoption of an anti-corrosive additive in order to protect the most sensitive elements of the control system.

c) Indirect connection of greenhouse's heating installations to geothermal well in Junakovich (Yugoslavia)

The deaerated geothermal water (Fig.8) is pumped from the collecting tank through the three-way valve, directly to the heat exchanger. The surplus water goes back to the tank. The return water of about 40 Deg.C temperature from the heat exchanger flows back to the tank and discharges to a swimming pool.

For heating greenhouses above 2 Deg.C outside temperature, the thermal water of about 45 Deg.C is pumped through the three-way valve by the P2 pump to the collector. The circulating pumps P3 distribute the water from the collector to the heat consumers G1, G2, G3 and G4. The returning water of 37 Deg.C goes back to the return water collector and later to the heat exchanger.

For the heating regime above -5 Deg.C outside air temperature, the thermal water of about 30 Deg.C goes from the heat exchanger through to the three way valve and pumped to the primary cycle of the heat pumps, then returns back with a temperature of about 22 Deg.C to the heat exchanger. In the secondary circle of the heat pumps, the water from the condensers at a temperature of 70 Deg.C, goes to the transportation pump P2. The further circulation of heating fluid is the same as in the previous case, except that the returning water flows to the condenser of the heat pumps and not to the heat exchanger.

For outside temperatures down to -18 Deg.C, the hot water of about 90 Deg.C is pumped with the P2 circulating pumps to the consumers and the returning water of about 70 Deg.C goes back to the boiler plant.

The automatic control system of the geothermal plant consists of the following control devices: temperature sensors for outside and internal temperatures; electronic control unit and servo motors for operation of the three-way mixing valve.

Three regulation circles are applied. The first regulation circle controls the water flow behind the P1 supplying pump, but before the HE heat exchanger. The temperature sensor provides signs for the electronic regulator to control the water mixing process in order to reach the necessary heating fluid temperature of 45 Deg.C. The second regulation circle controls the water flow behind the heat exchanger but before the heat pumps. The main task of the regulator is to select the necessary heating regime. The outside air temperature sensor gives signs to the electronic regulator in order to provide geothermal water for the heating circles of the heat pumps. The third regulation circle controls the mixing of cooled water with thermal water to be discharged into the swimming pool. The heat pump operation is controlled by the temperature sensor of the returning water which switches the heat pump compressors on and off, successively.

This geothermal water supplying system is a rather complex but well designed multi-purpose scheme. It assures a good annual heat loading factor for the geothermal source and an economical use of the whole system including the heat pumps and the peak boiler plant. For large heat requirements, the economy of heat pumps may be questionable because of its high capital investment costs and the fairly high level of electricity prices in the region.

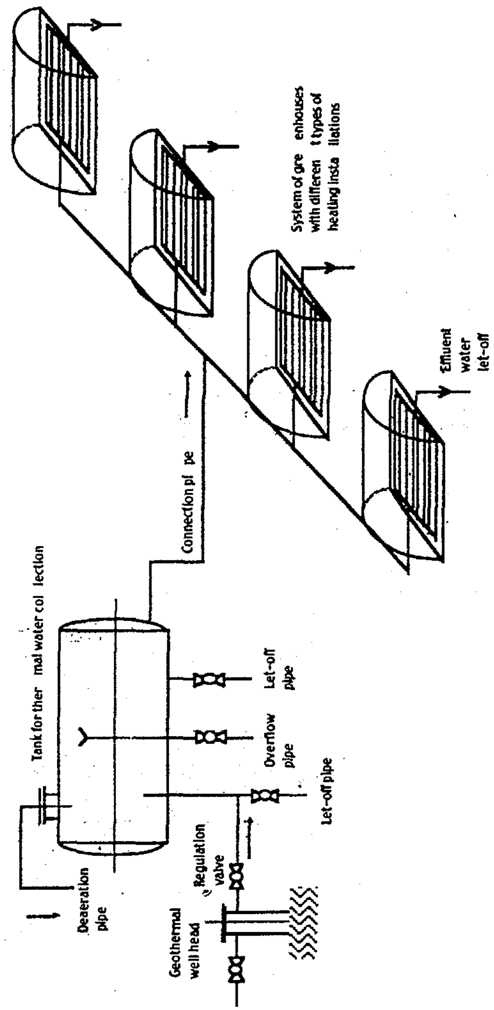

Fig.9.5. Well connection o f the greenho use complex I. n Kralove pri Senci (Slova kia)

4.7. Literature & References

01. Akkus, M.F.: BALÇOVA-IZMIR DISTRIBUTION SYSTEM; First FAO/CNRE Workshop on Geothermal Energy Use in Agriculture, Skopje (Macedonia), March 1987

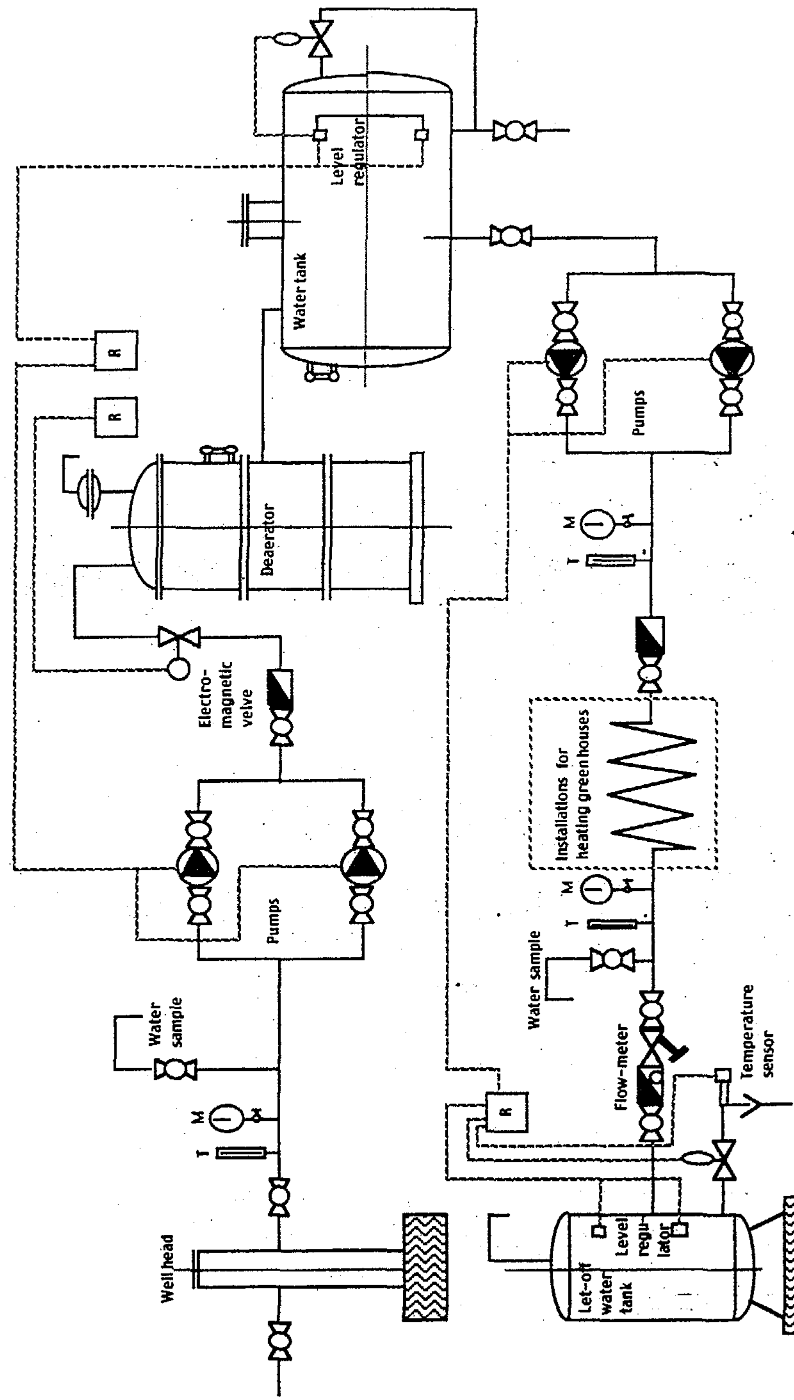

Fig.9.6. Well connection o f the greenho use geotherma l heating ins tallation in Srbobran (Yug oslavia)

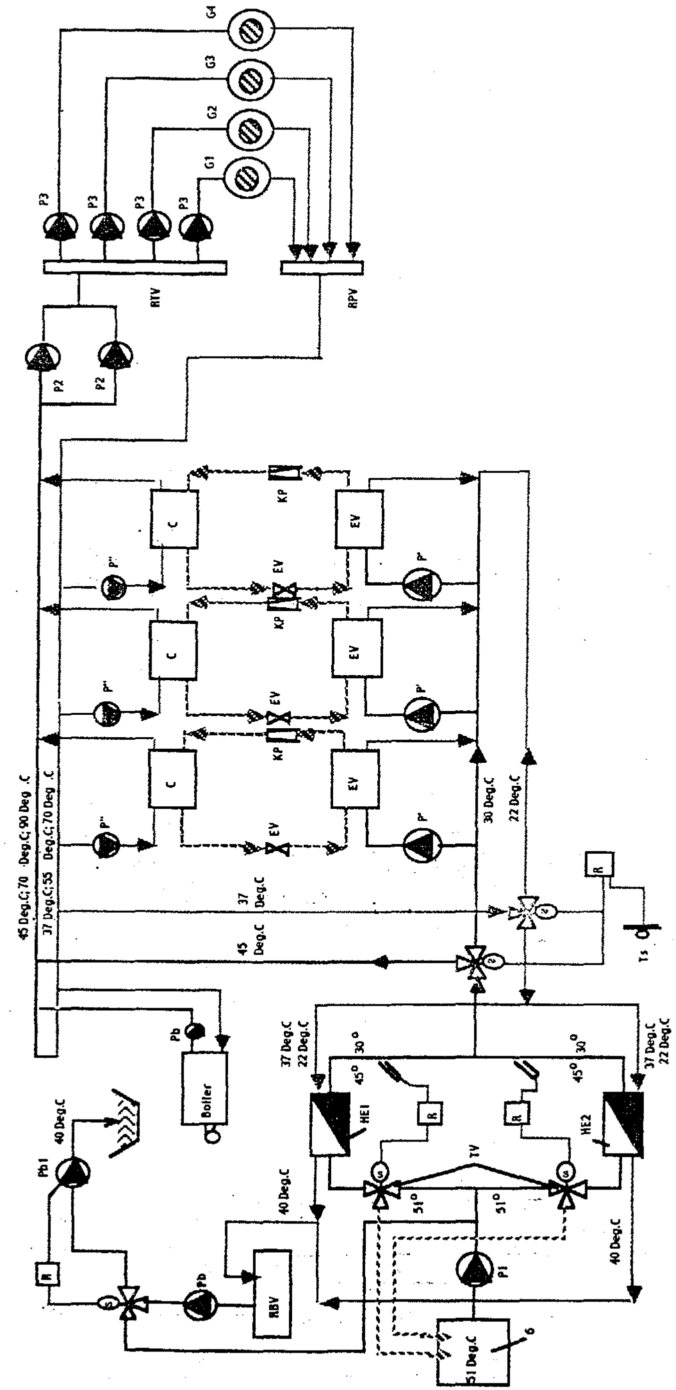

Fig.9.7. Conn ection to the well of gree nhouse comple x Junakovich (Yugoslavia)

02. Aksin, V., Milosavljevic, S., Ceman, L., Jovanovic, M.: NEKI VIDOVI KORISCENJA GEOTERMALNE ENERGIJE U SAP VOJVODINI; Personal contribution, Novi Sad (Yugoslavia), 1987

03. Campbell, M.D., Lehr, J.H.: WATER WELL TECHNOLOGY; McGrow Hill Book Co., New York 1973

04. Cigny, U., Bottai, A.: COMPLETION TECHNIQUES OF DEEP GEOTHERMAL DRILLING; Seminar on the Utilization of Geothermal Energy for Electric Power Production and Space Heating, Florence 1984

05. Duda, M., Danko, V.: DESIGN SOLUTIONS OF HOT WATER DISTRIBUTION IN CULTIVATION AND UTILIZATION; Paper presented at FAO/CNRE Workshop on Use of Geothermal Energy in Agriculture, Skopje 1987

06. Eliasson, E.T. et al.: SPACE AND DISTRICT HEATING; Chapter 4.2. of the SMALL GEOTHERMAL RESOURCES (Dickson, M. & Fanelli, M. - Editors); UNITAR/UNDP, Rome 1990

07. Einarsson, S.S., Vides, R.A., Cuellar, G.: DISPOSAL OF GEOTHERMAL WASTE WATER BY REINJECTION; Proc. U.N. Geothermal Symposium, Vol.2, San Francisco 1975

08. Gringarten, A.C., Sauty, J.P.: A THEORETICAL STUDY OF HEAT EXTRACTION FROM AQUIFERS WITH UNIFORM REGIONAL FLOW; Journal Geophysics Res., Vol.80

09. Culver, G.: DRILLING AND WELL CONSTRUCTION; Geothermal Direct Use Engineering and Design Guidebook (Lineau, P.J. & Lunis, B.C. - Editors), Chapter 7, Geo-Heat Center of the Oregon Institute of Technology, Klamath Falls 1989

10. Menjoz, A., Lambert, M.: THE DOUBLET SCHEME: A CONVENIENT SYSTEM FOR THE GEOTHERMAL EXPLOITATION OF LOW ENTHALPY RESERVOIRS; Text-book of the International Summer School on Direct Application of Geothermal Energy: ENGINEERING ASPECTS OF GEOTHERMAL ENERGY USE IN AGRICULTRURE (K.Popovski - Editor), Skopje,1992