INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy

Under the auspice of the
Division of Earth Sciences

APPLICATION OF GEOTHERMAL ENERGY IN FOOD INDUSTRY

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Introduction

The heat energy contained in geothermal fluids can be used everywhere where heat is necessary to complete some process. Of course, this is true if the geothermal fluid has sufficiently high temperature and flow, if not than it can be used only for a part of the process or with additional heating to cover all the heat energy needs of the process.

Food industry is a big energy consumer, especially of heat. There is variety of thermal prefabricating processes deal-ing with different kind of food products (fruit, vegetables, grains, sugar, milk, meat, etc.).

1. POSSIBLE FIELD OF USE

Possible field of use of the low-temperature geothermal energy is very wide (Fig.1). Everywhere where low temperatu-re heat is necessary it can be covered with the one extracted from geothermal brines. Depending on the technical organization of concrete industrial process, use of geothermal energy can be independent or in combination with the heat of other origin (fossil fuels, electricity, bio energy, etc.).

The diagram given in figure 1 shows that generally the temperature range of the food processing is from 38°C up to 93°C, with exception of some processes that require higher temperatures.

2. BASIC FOOD INDUSTRY PROCESSES WITH POTENTIAL APPLICATION OF GEOTHERMAL ENERGY

The temperature range being considered here (below 150°C) is used in the basic processes of: preheating, washing, peeling and blanching, evaporation and distilling, sterilizing and drying.

2.1. Preheating and heating

Geothermal energy can be effectively used to preheat boiler and other process-feed water in a wide range of food Industries.

The boiler for feed-water heating has considerable load to pre-heat the feed water coming at typically 10-16 ºC up to the temperature at which it is introduced into the boiler, typically 93-149 ºC, depending on the system.

The geothermal resource can be used to offload the boiler of a part or entire preheating load. A wide variety of industries use water for various processes, large quantities of feed water can be preheated or heated with geothermal energy to the desired temperature.

2.2. Washing

A large amount of low-temperature energy (35-90ºC) is consumed in several food industries for washing and clean-up processes, with major uses in meat processing for scalding; in soft drink production for container and returnable bottle washing (77ºC); in poultry dressing, canning and other food processes.

2.3. Peeling and blanching

In the typical peeling operation, the product is introduced into a hot bath, which may be caustic, than the skin or outer layer, after softening, is mechanically scrubbed or washed off. Peeling equipment is continuous-flow type in which the steam or hot water is applied directly to the product stream or indirectly by heat-ing the product bath. In most instances, product contact time is short.

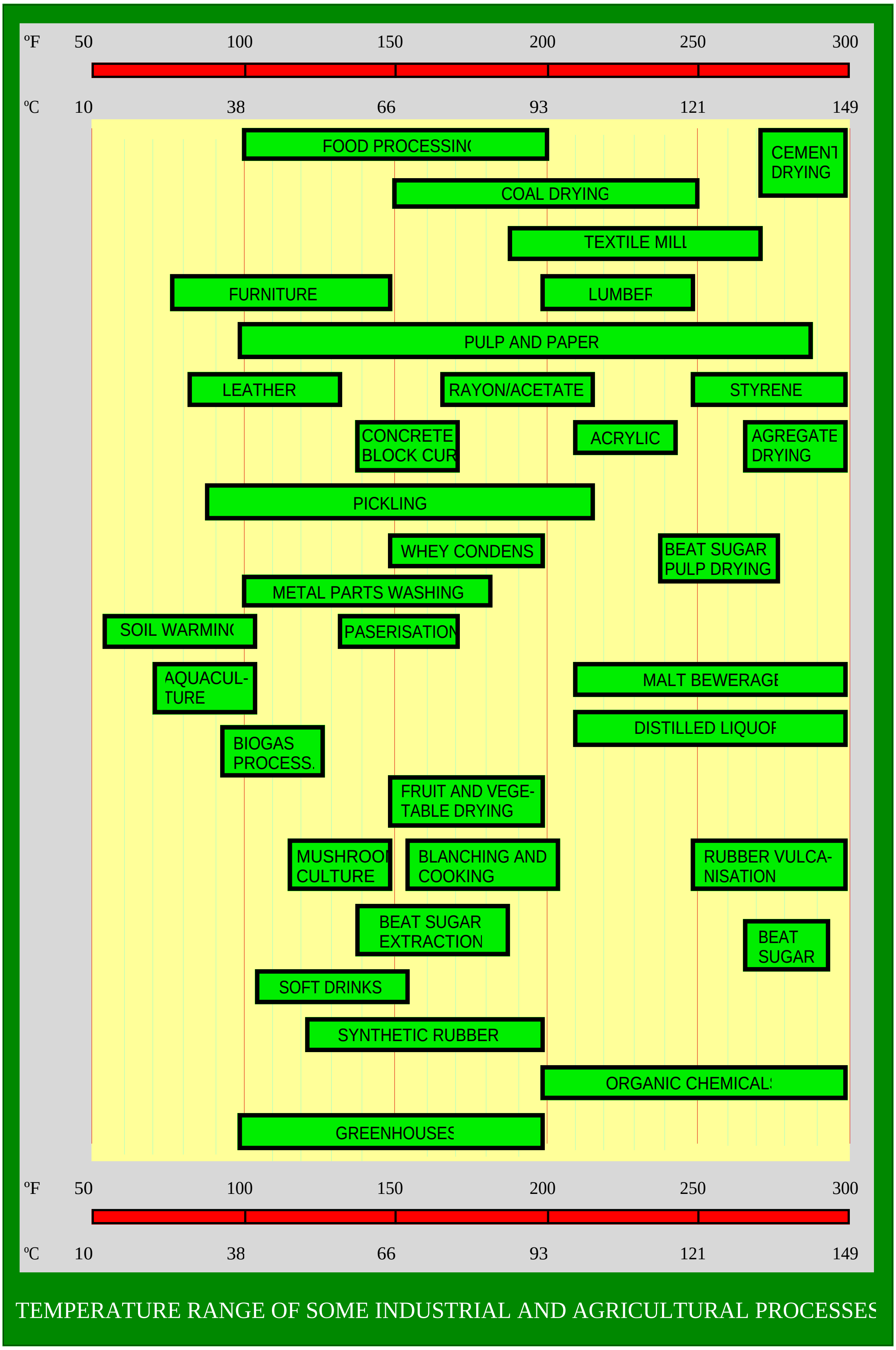

Fig.1 Temperature range of some industrial and agricultural processes

Blanching operations are similar to peeling. Product is usually introduced into a blancher to inhibit enzyme action, provide product coating, or making the product half-ready for cooking. Blanching may be either a continuous or batch operation. Typical blanching fluids require closely controlled properties. Thus, it is unlikely that geothermal fluids could be used directly in blanchers and peelers because of the water quality. Geo-thermal fluids could, however, provide the energy through heat exchangers.

The temperature range for most of the peeling and blanching systems is 77-104 ºC.

2.4. Evaporation and distillation

Evaporation and distillation are basic operations in many processing plants to aid concentrating a product or separating products by distillation. The source temperature requirements vary with the product being evaporated. However, in a majority of agricultural processes, water is being driven off; and in these cases, operating temperatures of 82-120 ºC are typical. In some circumstances, the evaporators operate at reduced pressures that way decreasing temperature needs and improve product quality.

Evaporators are commonly found in sugar processing, mint distilling and organic liquor processes. Evaporators, depending upon temperature and flow rate requirements, can be readily adapted to geothermal energy as the primary heat source. The energy can be transferred trough secondary heat exchangers to the working fluids or, in some instances, used directly in evaporator, depending upon existing plant designs or adaptations to new plant expansions.

2.5. Sterilizing

Sterilizers are used extensively in a wide range of food industries and include applications such as equipment sterilization for the canning and bottling industry. Most sterilizers operate at temperatures of 104-120 ºC and would utilize geothermal energy with the use of heat exchanger potable sterilizer water. Many sterilizers operate in a continuous mode. Equipment wash down and sterilization, however, may occur periodically or at shift changes.

2.6. Drying

Drying of agricultural products, like: rise, vegetables and fruits, grains, sugar and other, are typical food processing applications of the heat in temperature range between 90-150°C (now-a-days there are also low-temperature drying technologies with temperatures up to 50°C).

3. LOCATION OF HEAT CONSUMERS IN TYPICAL FOODINDUSTRY TECHNOLOGY LINES

3.1. Agriculture

Agriculture is given separately from the food industry since it produces row food that should be prepared for further processing – fabricating.

Typical heat consumers in agriculture are drying of animal food, fruits and vegetables. For instance, except to use conventional fuels for a rotary-flame furnace (requireing 1000°C), it is possible to apply a forced-air system using a multi-layer conveyor belt with temperatures of about 135°C. In addition, a newer method introduces field wilting in order to reduce initially the moisture content and then the extraction of the reminded one by warm air stream is taking place (80-120°C).

Significant amount of energy is consumed annually for grains, vegetables and fruit drying. Normally, processes can be adopted for the use of temperature ranges between 40-85°C, which is feasible for most of the geothermal resources. The kiln for grains is typically a large vertical vessel with the grain entering at the top. Hot air is forced through the grain, extracting the moisture before being exhausted. In opposite, the kiln for vegetables and fruits is normally a horizontal line, where the product is moved by means of conveyor through the drying room. Hot air is blown below the product line and dries it by passing the product mass.

3.2. Food processing industry

As already said, the heat consumers in food processing industry can be located in different heat exchangers or consumers for different pre-heating, peeling, blanching, cooking, etc. However, it can be also found that not all of the heat requirements can be covered by the energy of geothermal origin.

For instance, many of the processing methods used by potato processors can utilize energy supplied by 150°C or lower geothermal fluids. Typically, however, a few of the operations, notably the frying operation, will require higher temperatures than can be provided by a majority of the geo-thermal resources.

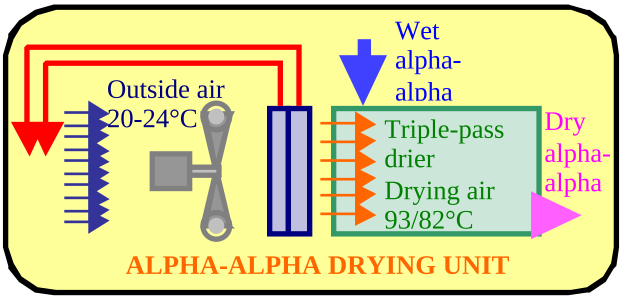

Fig.2 Alpha-apha drying unit

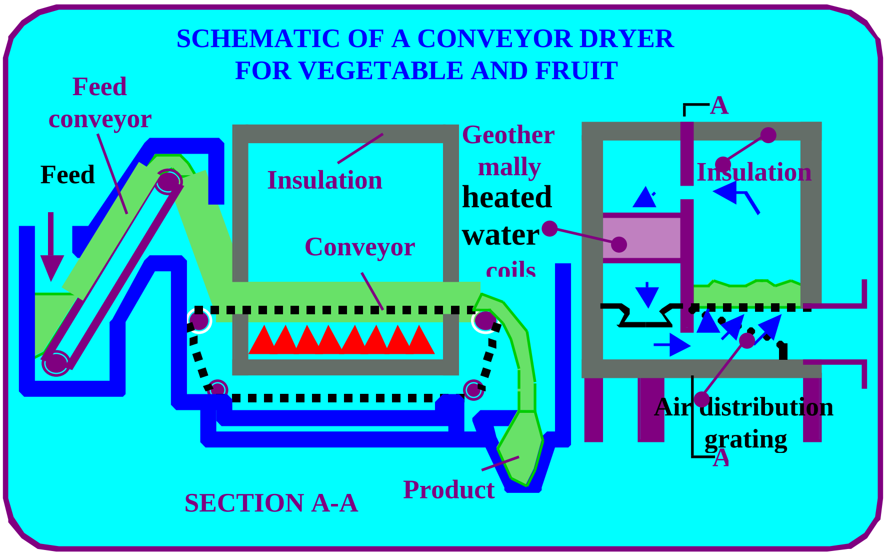

Fig.3 Technology line for drying grains and fruit & vegetables

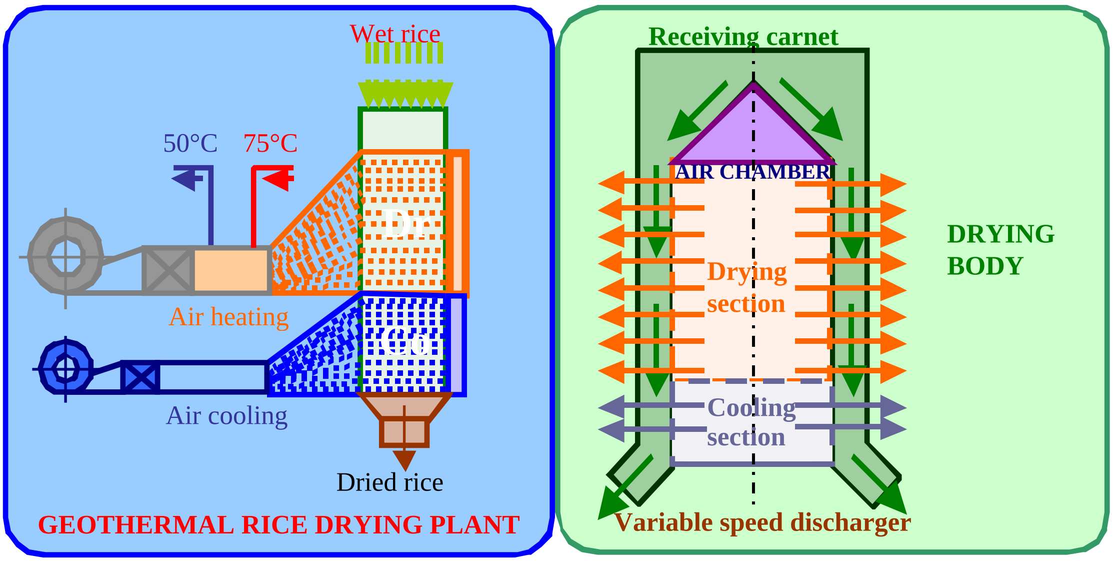

Fig.4 Geothermal rice drying unit

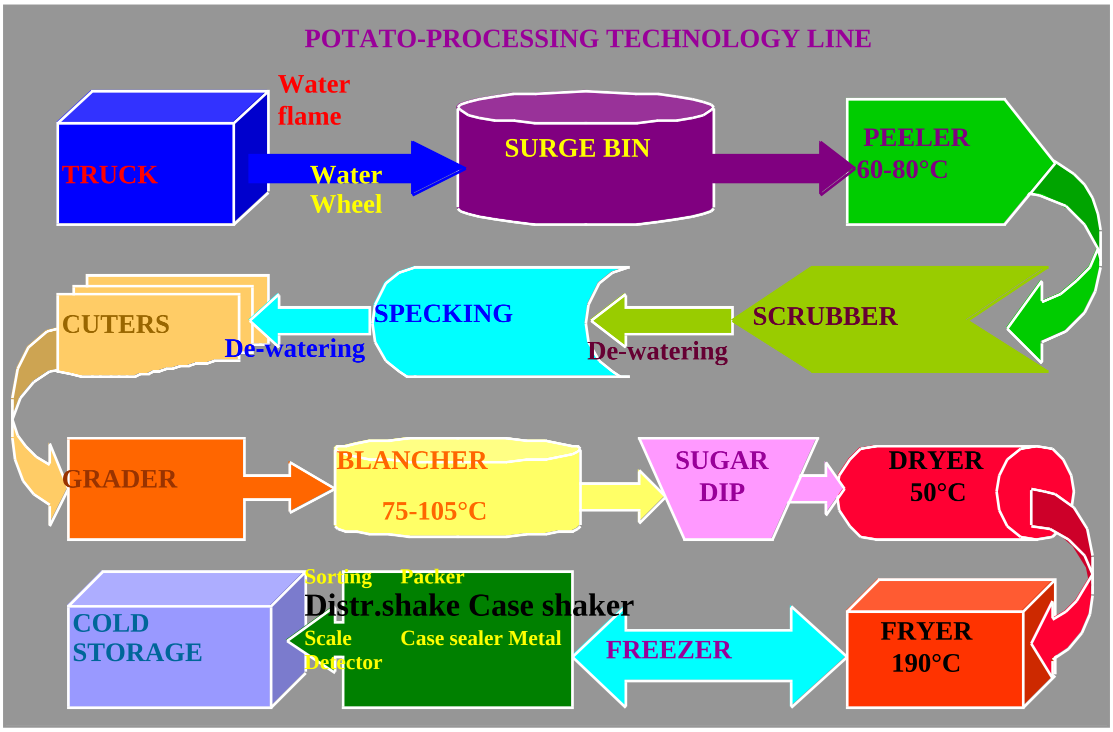

Fig.5 Potato-processing technology line

Usually, in a potato-processing plant there are potato-product lines and several by-product lines. In a french-fried potato-processing line, it can be identified that possible geothermal heat users are the pre-heater, where potatoes are warmed and peel softened, then for preparation of 15% lye solution for chemical peeling of about 60-80°C, for the blanching and frying at temperature of 190°C. It is obvious that for such a line geothermal energy should be used by means of intermediate heat exchangers. To avoid any possible contamination of the product by the geothermal fluid, or the need for separate treatment of the fluid, the geothermal fluid passing through these heat exchangers will transfer energy to a secondary fluid (usually water), which delivers the energy to the process. The secondary fluid, circulating in a closed system, then returns to the intermediate heat exchanger to be reheated. For a geothermal fluid at 120-150°C, all the thermal energy needs for such a line could be met, except for the heating of the fryers.

Sugar processing line is also a typical technology requiring low-grade heat for different parts of the process. For instance, a line for sugar-beet processing, includes the following heat users: diffusion process, juice purification, evaporation, crystallisation and pulp-drying molasses. The diffusers separate the pulp and raw juice from the long thin strips of sliced beet. The requested temperature of the operation is between 70-80°C (the rate of diffusion increases directly with temperature). In order to purify the juice, since it contains non-sugar impurities lime in the form of slurry of calcium saccharine is introduced under a temperature of 65-90°C. After the purification, the juice is introduced under a temperature of 65-90°C. After the purification, the juice is heated to 116°C and transported to the evaporators, where the water is taken from the solution. After the evaporation operation, the juice is going to the crystallisers, where boiling takes place at low steam pressure and thus low temperature in order to avoid the caramelization. After that, following one or two brief washes with pure hot water is coming, before discharging the wet white sugar crystals from the central basket. After that it is sent to pass the dryer or granulator and the cooler. Hot, filtered air is passed through the granulator and cool, also filtered air is passed through the cooler. A sideline of this process is the pulp drying. It is made after the pulp leaves the diffusion process.

The sugar processing from different raw materials principally has the same heat users, with some small differences in temperature levels.

Generally, it can be concluded that geothermal waters of about 120°C can cover all the heat requirements, except for the evaporation phase where higher temperatures are required.

Different food (vegetable and fruit) processing lines have similar composition of heat users, i.e. with the similar limitations for possibilities to cover heat requirements by means of geothermal fluid application.

4. ELEMENTS OF GEOTHERMAL TECHNOLOGY FOR INDUSTRIAL APPLICATIONS

The technology composition for geothermal system function for industrial uses can be divided in two main parts.

The first part includes the general elements of geothermal systems and these are: geothermal well, connector to the geothermal well or a net of distribution, fluid transportation pipes, equipment for chemical treatment of water and apparatus of heat exchangers.

The second part is consisted of elements specific for the industrial application of geothermal energy and they are as follows:

- Steam extraction system,
- System for upgrading geothermal fluids,
- Equipment for adjustment of parameters (pressure, temperature and flow),
- Processing apparatuses for implementation of technological processes.

3.1. General elements of geothermal systems

In this section, the general elements of direct application of geothermal energy (listed above) are discussed, from the aspect of industrial use.

- ***Geothermal well***. There are a variety of methods of providing geothermal fluid to an aboveground system. Artesian wells provide surface water naturally and some non-artesian wells can be induced to flow without pumping.

A mechanism by which a non-artesian well can be induced to flow is to reduce the density of the column of liquid in well. For instance, if the liquid is to be mixed with gas, the combined fluid density may be low enough that the down-hole conditions allow the liquid partially flash to steam; the reservoir maintains the low-density liquid-vapour mixture in the well.

An important advantage of pumping a self-flowing well is that pressure of the liquid is maintained, so down hole flashing and scaling are minimized. Also, not allowing the fluid to flash, the discharge temperature can be much higher than the surface temperature of a self-flowing well. This is an important consideration when high-temperature geothermal applications are desired.

However, several factors, such as depth of the well, fluid chemistry, temperature and pressure of geothermal fluid, should be considered by the designer in choosing a geothermal well pump.

Important part of the connector to the geothermal well, is the apparatus for degassing.

- ***Heat exchangers***. The principal reason to have heat exchanger in geothermal systems is to confine the geothermal waters with their inherent impurities where corrosion or scaling can either be controlled by material selection or where cleaning will be relatively easy and economical.

It must be remembered that there will be a temperature difference between the primary and secondary fluids any time the heat exchanger is used.

Approach temperatures of less then 6 ºC are often uneconomical but depend on heat-exchanger type and particular application.

The principal types of heat exchangers used in geothermal systems are the down-hole heat exchangers; the shell-and tube heat exchanger; the fluidised-bed heat exchanger; the direct-contact heat exchanger, and the plastic-tube heat exchanger.

The down-hole heat exchanger eliminates the problem of disposal of geothermal fluid, since only heat is taken from the well. The exchanger consists of a system of pipes or tubes suspended in the well through which clean secondary water is pumped or allowed to circulate by natural convection.

The interaction between the fluid and aquifer and the one in the well is not fully understood, but it appears that outputs are higher when there is a high degree of mixing, indicating that somewhat permeable formations are preferred.

3.2. Specific elements of geothermal system

In this section, stress is not given to the equipment for adjustment of parameters, and processing apparatuses for implementation of technological processes, because the geothermal system uses the same elements as the convectional one.

- ***Steam extraction system****.* Multiple-temperature steam heating systems are routinely used in industrial process plants. In geothermal technologies, use of the steam flashed from geothermal fluid has many advantages because heat transfer rates with condensing steam are uniformly high, steam is less susceptible to fouling and as very important, any scaling in the flash step can be controlled by proper design of the flash vessels and by the use of scale-suppressant additives.

The design of an extraction system consists of the following parts: Geothermal fluid from each well is pumped individually to the energy extraction system. Here a scale control additive is put into the brine by a positive displacement pump and mixed in a static mixer. The fluid than flows to the first, second and third vessels where the pressure is reduced to the production required temperatures.

After filtration the liquid is routed to the individual re-injection well where high-pressure pumps force the liquid into the receiving strata.

- ***System for upgrading geothermal fluids***. The energy that is available initially from geothermal well is heat, usually in the form of hot water or wet steam. The higher-level heat should first be extracted and a cascade use can then be accomplished to maximize energy utilization. The industries, such as pulp and paper and chemical industries, probably will require steam at varying pressures. In most cases, the heat is extracted for process use by the following means:

1. Geothermal fluid to process fluid heat exchange;
2. Convert to steam for process heating and for electricity generation; and
3. Convert to a secondary fluid vapour (freon, isobutene, etc) for electricity generation or process heating.

Each of these means that heat transport can have some application in specific processes. Taking into account that steam is the universal process heating media, we will concentrate on designing system supply process steam at needed pressures by way of compression.

Mechanical compression, although being capital cost intensive, is used for the high-grade energy upgrading the low heat and pressure.

The basic system for upgrading a geothermal fluid for various industrial process pressures has incorporated a flash vessel for the production of steam; a compressor driven by an isobutene turbine; an isobutene condenser, and a heat exchanger to heat and evaporate the condensed isobutene using the geothermal fluid.

5. PLANTS AND INSTALLATION MATERIALS FOR GEOTHERMAL ENERGY APPLICATION

The change of the technological process in old plants, with application of geothermal energy, excludes discussion on plants and installation materials for the use of this energy, because the only thing necessary to be done to supply the plant with geothermal energy is to prepare the geothermal fluid chemically.

Regarding prospective or new plants projects in which geothermal energy is to be introduced, materials corresponding to the water property must be specified in order to avoid corrosion attacks.

High salinity geothermal fluids will cause high uniform corrosion as well as localized corrosion and will severely limit the use of carbon steels. The application of mild steels to geothermal environments requires that precautions should be taken for de-aeration, flow rate, scaling, galvanic coupling, protection of exterior surfaces and steel specifications.

By taking appropriate precautions, carbon steels can be used for thick-walled applications in contact with most geothermal fluids. Thin-walled applications will be limited by the susceptibility of these materials to localized attack, such as pitting and crevice corrosion.

6. OPTIMISATION OF INDUSTRIAL APPLICATION OF GEOTHERMAL ENERGY

Industrial application of geothermal energy have two directions in development:

1. In utilization of existing plants and equipment, and
2. In building new installation and complex

technologies, adapted to the application of this sort of energy.

In the first case, optimisation should be used as an instrument for examination of economical advantages in application of geothermal energy, over some classical energy resources. This optimisation is determined both temporal and spatial. Optimisation within the system itself has an aim to examine which of the methods used in application of geothermal energy in existing technological equipment is more feasible.

There are two available methods:

1. Direct application of chemically treated geothermal fluid, or
2. The application of heat exchangers using the heat of geothermal fluid for feeding the secondary thermal circuit.

Optimisation plans should include certain changes in the technological process in order to enable the application of geothermal energy, utilization of thermal pumps and determination of the maximal energy level within technological process.

Optimisation on the second level should include mathematical analysis of the great number of factors that are decisive in the development of certain industrial technology. The most important among those factors are: the geothermal fluid parameters chemical structure of the fluid, quality and price of the plant and parameters and regimes of the technological process itself. The equipment for environmental protection is to be mentioned as well.

6. CONCLUSION

In the worldwide practice, the application of geothermal energy, as an alternative energy resource, can be of a great importance. This is especially the case in the countries where exceptional natural geothermal potentials exist.

The major contribution in development of the special technological equipment, required for the utilization of this kind of energy, (e.g. pumps, transportation equipment, chemical treatment of fluid, heat exchangers, etc.), is realized in technologically developed countries, i.e. U.S. and Western European ones.

The industrial application of geothermal energy is at the beginning in Europe. However, the existence of geothermal fields as well as the insufficient resources of conventional energy represents the challenge for further investigations in this field. Quality of geothermal resources that are available in Europe, dictates the use of this type of energy within the low-temperature technological processes. These processes are significantly engaged in different groups of processing industries. Therefore, the expectations for broader engagement of professsional and scientific potentials in various disciplines, is quite legitimate.