Proc. 10th New Zealand Geothermal Workshop 1988

COMPUTER AIDED DESIGN OF GEOTHERMAL WELL HEAD EQUIPMENTS

-- A Preliminary Study

Pan Hesong, Zhu jialing, Zhang Taiping, Qi Jinsheng

Tianjin Geothermal Research and Training Center
Tianjin University
Tianjin, P. R. China

ABSTRACT

Different well head equipments are required for geothermal wells with different fluid parameters and different utilization systems. Appropriate choice and reasonable design of well head equipments are of importance because the geothermal well is the key to the overall utilization system. The authors began the research project of geothermal well head equipments in 1983 and the equipments include well pumps, separators, heat exchangers, downhole heat exchangers, sand removers and pipes. Beginning from this year (1988) we started trying computer aided design of the well head equipments. This paper summarized our effort on this work.

FORWORD

Included in the well head design are logical reasoning, judgement, choice of equipments, calculation for design and output of designing results as blueprings. All these work are being carried but by computers with the deepening research and development of artificial intelligence and computer systems. Our final aim is to simulate the working process of human experts in the design of well head equipments, the core of utilization system, and to complete a expert system for the design of well head equipments, since the artificial intelligence of the expert system is the closest to the practical application. The artificial intelligence was limited only in laboratories in the past time, but now it is widely used in a variety of pratical areas, and it is applied even in the irregular organization of knowledge, which used to be thought most inappropriate, (Liu, 1987) But, unlike common computer softwares, the expert system is a system of intelligence, which requires bases of knowledge, structure of intelligence and databases, etc.. We have not obtained this perfect goal up till now and further effort is required, therefore, we describe our present work as computer aided design of well head equipments. This paper is devoted mainly to the compilation of a computer program for the well head equipments and this program should be capable of design of each piece of the above mentioned equipment. Therefore this work must be based on the complishment of design of various types of well head equipments. A program has been writen in the BASICA language and debugged on the IBM-XT computer. We will replace the BASICA language with the C language in order to improve the efficiency of the program and make it transplantable. (Plum, 1983) Discussed first in this paper is the basic ideas and steps for the design of the well head equipments and, then a concise description is made of designing principles of typical equipments and consideration of computer aided design.

CLASSIFICATION OF WELL HEAD EQUIPMENTS

According to the wells to which they are applied, well head equipments are divided into high-medium temperature type and low temperature type. In high-medium temperature (above 100 deg. C) geothermal fields, the fluid at the well head may be a mixture of vapor and liquid, therefore, in applied engineering systems, the well head equipments can be calssified as direct liquid transmission, two-phase flow transmission, single-staged separation, multi-staged separation, downhole separation and downhole heat exchanger. (Pan and Qi, 1986)

The direct liquid transmission type and the two-phase flow transmission are consisted of valve group and expanders. In the mills of the Tasman Pulp & Paper Co. at Kawerau, New Zealand, the two-phase flow tranmission type is adopted, and the geothermal fluid is delivered to a place adjacent to the mills and separated for use. For power generators on liquid-dominated geothermal fields, dry vapor is required and there must be a separator at the well head to separate the vapor and liquid. High-temperatured and high-pressured geothermal fields may need separators of more than two stages and be equipped with water collector, safty valve, controlling orifice plate and such and such matching systems. Equipments of this type are under use in high-temperature and liquid-dominated geothermal fields in many countries, e.g., Wairakei, New Zealand. (Armstead, 1978) Study of the downhole separator type well head equipments was initiated in the Geothermal Institute, the University of Auckland in New Zealand in 1982, and the first paper on this study was published in November, 1984, (Kanyua, 1984) but no report on practical use has been found up till now. As for the downhole heat exchanger type, it does not need to pump the geothermal fluid uphole. The well head is the inlet and outlet of a downhole heat exchanger and the clean water is circulating in the heat exchanger to absorb the heat downhole. More than 600 sets of equipments of this type are under use in America, New Zealand and other countries. (Pan, 1983)

Well head equipments for low-temperature geothermal fields (less than 100 deg C.) are classified as those for artesian wells and those for non-artesian wells, and downhole heat exchangers may be used likewise. The one for the artesian well, that is the well with an automatic outflow, is relatively simple and only the valve bundle and pipes at the well head need to be designed. To increase the flow of an artesian well the well head equipments should be modified both artesian and capable of being pumped. This poses quite a problem. This kind of equipments need all the matching components for the proper operation of the pump, and when the pump stops working, the artesian flow may not be decreased. At the same time the eauir>ments must be well spalprf to prevent the leakage of the artesian flow. There is, for instance, a geothermal well on the Lizigu Farm, Tianjin,. with a well head temperature of 96.5 deg C. and an artesian flow rate of 30 or pumping flow rate of 60 cubic meter per hour supplying heat for the chichenhouses, greenhouses, fishponds, etc.. (Pan and Qi, 1984) In summer (May-October) the well is closed as there is no need for heat. In spring (March-May) and autumn (October-December), the artesian flow is enough to meet the needs. In winter (December-March), a flow of 40-58 cubic meter per hour is required. This can be achieved by switching on the pump which was equipped four years ago and has been working perfectly ever since. There is a set of similar equipments on the geothermal farm in Tuanbo, Tianjin, which have been working for two continuous years. For non-artesian wells, pumps and matching components are required. It is easier to realize as there is no special technical difficulties.

STRUCTURE OF THE PROGRAM

We are intending to establish, with the computer aided designing programs, a program system with a wealth of knowledge and experiences of geothermal experts, in a bid to simulate the working processes of experts like reasoning, judging and calculation, and the technology of artificial intelligence and the knowledge in some special areas provided be experts are employed during the process. In another word, the system is able to emulate experts in such complicated and meticulaous designing jobs.

Using the above mentioned classification as the stem of the program structure and adopting the block structure to make it clear and logical and easy to be understood and validated, the program looks like a tree with nodes of program segments. The most abstract node is the root of the tree and corresponding to it is the main program segment. The other nodes are distributed at different parts hierarchically according to their affinity to the root node. There are definate constrainments between higher and lower levels and, the higher levels may recall the lower levels while the lower levels serve as the base of the whole hierarchy. Each node is relatively independent and shares clear and certain responsibility. The excution of the program begins from the root node which reflects the systematic structure of the problem, and the abstract operation is realized through hierarchical recallings.

The design of the geothermal well head equipments depend on the natural conditions of the well and the need of the user, e.g., well head parameters like pressure/water level, flow rate, temperature and utilization coefficients like heat load, water quality and/or temperature requirement, etc.. The differences of these parameters and coefficients make the designs different. We are working on a design of a set of satisfactory equipments through reasoning, judgement and choices of equipments according to these parameters and coefficients and classification. Therefore, by a thorough understanding of the well head design knowledge, we divided the design job into several parts and found out the relationships and restrictions between them, and finally, worked out the flow chart of the program. (Fig.l)

We considered the following points in the program design:

1. design downward from the top, gradually perfect the program according to the system configuration and the desired quality of the software.

2. the program and the data are processed separately, the program structure and the data structure correspond to each other. Flexible controlling and convenient check are thus realized.

3. a module body is compiled for each piece of equipments, which has a strong independence. These will be expanded later.

DESIGN OF TYPICAL EQUIPMENTS

Fig.l shows that the main program has designs of several typical equipments. We compiled a module, or a subroutine for each typical equipment design, which is relatively independent and has relatively perfect functions. These modules may be recalled during the excution of the program. The design principles of these modules are briefly described as follows.

1. <u>pump choice and its matching components design:</u> The submerged pump should be preferably used as it is cheap and easy to be installed. The working temperature of the pump cannot be higher than 50 deg C, therefore the pump should be the first choice when the downhole temperature is less than 50 deg. C. The number of stages and the pump model should be determined according to the well diameter, the possible flow rate and the required lift. Since the geothermal water is generaly higher than 50 deg. C, the lineshaft pump is very often applied to the geothermal well. We have finished a series of designs of pump beds and pump houses for different pump models. (Pan and Qi, 1986) Once the pump model is chosen, the construction drawings for the pump bed, pump house, supplementary pipes and working guide and technical desire may be finished by the computer aided design system on the plotter.

2. <u>design of the surface heat exchanger:</u> We chose the most widely used shell and pipe heat exchangers and the plate heat exchangers as the surface heat exchangers. The concerned mathematical formulae and design steps were quoted from the existing literature. (Kern, 1970; Xu Zhongquan, 1987) The heat exchanger may be selected by the user according to his own financial circumstances and field conditions. The computer aided design can output the coefficients of the heat exchanger and its installation diagram.

3. <u>design of the downhole heat exchanger:</u> The downhole heat exchanger may be employed when the heat load is small, the permeability and temperature of the geothermal reservoir are high enough. It has the advantage that it does not need to pump the geothermal fluid and has no harmful effect on the environment and the geothermal reservoir. The program for the downhole heat exchanger design was adapted from a previously completed optimization program, (Pan et. al., 1987) and it can automatically optimize 15 geometric and performance parameters for the downhole heat exchanger and, at the same time, it can design coaxial pipe (annular type) heat exchanger and 'U' type heat exchanger according to the known parameters of the geothermal well and the need of the user. A perforated casing or a convective promoter pipe should be used to increase the convective flow in the geothermal well.

4. design of the sand remover: Through careful and repetitive comparison we selected rotational flow remover as the well head sand removing equipment. For wells with defferent flow rates we designed sand removers of defferent sizes. The wall thickness of the remover was designed according to the well head pressure. Different materials were selected for different water qualities. Thermal insulation was also considered. It should be noted that the sand remover is not necessary when the geothermal water is clean enough.

5. design of the two-phase flow transmission pipeline: The two-phase flow theories employed in the design were from Perry and Chilton (1973) and minimum annual cost method from Pan et. al. (1986). Pipelines may be laid overhead or subsurface according to the interest of the users, and the expander and supporter of the pipeline were automatically designed by the computer according to the pipeline parameters and the design drawing was finished by the computer controlled plotter.

6.design of the separator: There are many types of separators from which we chose the most economical and most efficient Weber Type according to the suggestions of Armstead (1978). The pipe diameter, which ranges from 76 to 137 cm, was determined interms of the mass flow at the well head, and its geothermal parameters were calculated according to the pipelines of Bagma (1961). Finally the strength and wall thickness of the separator and matching components like water collector, safty valve, silencer and controlling orifice plate were designed. More than two stages of the separator, if necessary, will be designed for high temperature and high pressured geothermal well. The plotter is capable of the final design drawing.

7. design of the water distribution tank: The number of the diversion outlets were determined according to the need of the user, and the geometric parameter and materials were determined by the mass flow rate at the well head and water quality. The wall thickness and the insulating thickness were designed according to the pressure and internal-external temperature difference. Finally, the tank supporter was selected according to its geometrical parameters and the installation diagram was plotted after validation of its compression strength by the computer.

Above was only a brief account of the modules of the program. Factually we designed 11 modules in all. (Tab. 1)

Tab.l. List of the Modules

1. lineshaft pump choice and matching components design,
2. submerged pump choice and matching components design,
3. design of shell and pipe heat exchanger,
4. design of plate heat exchanger,
5. design of downhole heat exchanger,
6. design of sand remover,
7. pipeline design (including two-phase flow pipe),
8. design of separator and matching components,
9. design of water distribution tank,
10. pumpless artesian well head design,
11. design of the dual functioned well head equipments (the equipments do not reduce the artesian flow when the pump is at leisure and the valve is open).

MEASURES TAKEN IN THE PROGRAM DESIGN

Considering the practicability and reliability of the program, we took the following measures:

1. design of the man-machine interface: In order that the user may comander the software in a short period of time, we emphasized the friendliness of the man-machine interface. A hierarchically strucuted menu was designed and each frame was elaboratively worked out. All the information concerning the geothermal well and the interest of the user are to be input by the user. An ojptimum design is then accomplished by the computer through strict calculation and optimization.

2. security: By means of the trap method, the operative errors of the users may be tolerable and the excution of the program connot be inerrupted because of the casual carelessness of the user. The best cooperation is thus achieved between the designer and the computer.

3. automatic drawing: In order to perfect the designing process, we used the computer controlled plotter of the CAD system to accomplish the design drawing. (Tong, 1987) Modification, manification and reduction, transtational movement and rotation of the drawing may be realized at the will of the user. The drawing include those of technical processing, overall installation and components. This can not only replace the routine work of many engineers, but help the designers with their creative works.

4. optimization calculation: In the above mentioned design of surface and downhole heat exchanger, pump and matching components, sand remover, pipeline and separator, optimization calculation was employed, the objective function were usually the lowest cost, the best performance, the most reasonable structure, etc.. During the process of optimization, a number of variables that are directly or indirectly related to the objective function are selected and, while these variables affect each other, the computer, in terms of the optimization principles, searches many times the parameters multi-dimensionally to get a set of optimum parameters. These parameters ensure the optimum design.

5. database: The designing calculation require tables of steam, thermal properties of air, parameters of steels and insulating materials, models of pump, etc.. A database containing these information is being presently established, which will be an independent module of the program and may be recalled whenever necessary. Some data can only exist in the form of tables, while others, e.g., tables of vapor, thermal properties of air, may be expressed in analytical formulae to save the space of the internal storage of the computer.

Tab.2. List of the Sub-Bases of the Database

1.) table of compressed water,
2.) table of steam and saturated water,
3.) table of thermal properties of air,
4.) table of models of deep well pumps,
5.) table of models of submerged pumps,
6.) table of anti-corrosion properties of metals,
7.) table of strengths and prices of metals,
8.) table of models of pipes,
9.) table of insulating materials and their thermal properties,

10.) table of pipe auxiliary components,
11.) table of friction resistances of fluids.

6. artificial intelligence: We shall design "intelligence consulting model" to realize the "consulting dialogue" between the man and machine. The ways in which the answers are give should be diversified to support the need of the user, we shall do our best to make full use of the natural human intelligence in the expert system.

CONCLUSION

Our present program is already capable of designs of separator, sand remover, water diversion tank, water transmission pipeline and choice of models of pump, but the results are not yet of satisfaction and further improvements are required. Our final aim is to establish an expert system for the design of geothermal well head equipments and our work is only a preliminary study hitherto.

BIBLIOGRAPHY

ARMSTEAD, H. C. H. (1978) Geothermal Energy— Its past, Present and Future Contributions to the Energy Needs of Man E & F. N. SPON LTD, London

BANGMA, P. (1961) The Development and Performance of A Steam-Water Separator for Use on Geothermal Bores. Paper G/13, Rome 3, 60.

FU, K., CAI Z., XU G. (1978) Artificial Intelligence And Its Applications, Qing Hua Univ. Pub. House (in Chinese)

KAYUA, J. K. & Grant-Taylor, D. F. (1984) A Downhole Gas Separator for Geothermal Fluids-- Conceptual Design And Performance, Proc. of 6th NZ Geotherm Workshop

KERN, D. Q. (1970) Process Heat Transfer McGRAW-HILL KOGAKUSHA, LTD

LIU, L. (1978) Policy Support & Expert System Computer Engineering & Design No. 2 1987 (in Chinese)

PAN, H (1983) Geothermal Downhole Heat Exchangers. ME Thesis, Univ. of Auckland, NZ

PAN, H. & Qi, J. (1984) Geothermal Wellhead Equipments Design in Lizigu Farm, Tianjin. Design Report, Tianjin Univ. (in Chinese)

PAN, H. & Qi, J. (1986) The Design of Low Temperature Geothermal Well Head Devices UNDP Project Rep. TRTC Tianjin, PRC

PAN, H., CAI, Y., WANG, X. (1986) The Design of Geothermal Water Transmission Systems. Proc Geotherm Util. & Res. GRTC. No. 2-2 (in Chinese)

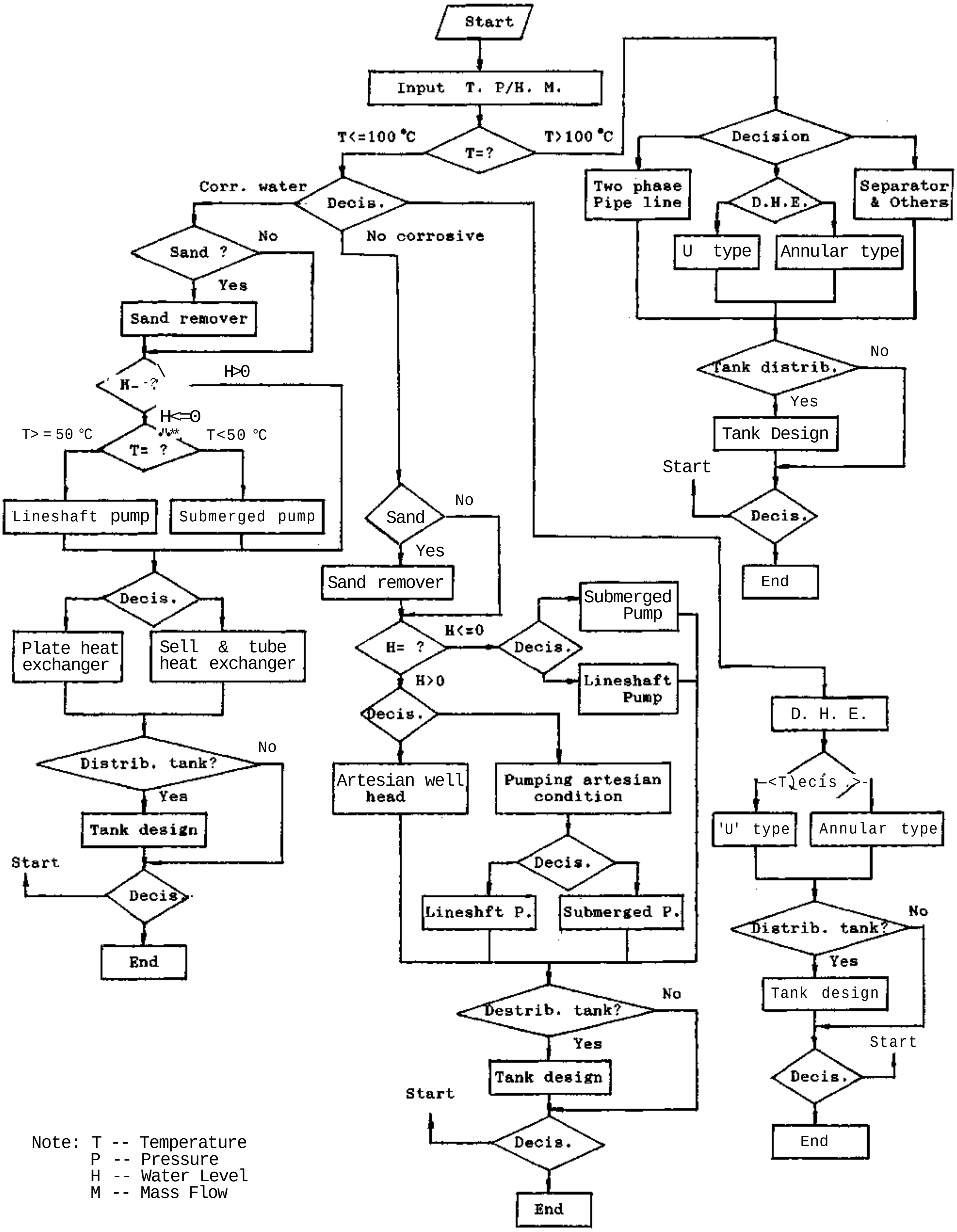
PAN, H., YANG, L., FANG, Z. (1987) A Model Study And Optimum Design of Geothermal Downhole Heat Exchangers, Proc. of GRC Annual meeting

PERRY, R. H. & CHILTON, C. H. (1973) Chemical Engineers Handbook 15th ed. McGraw-Hill Kogakusha, Ltd.

PLUM, T. (1983) Learning to Program in C Prentice-Hall, Inc.

TONG, L (1987) Auto CAD Drawing System, Kehai Training Center, Beijing (in Chinese)

XU, Z., (1987) Heat Exchangers Design Handbook, Light Industry Publ House (in Chinese)



Note: T -- Temperature
P -- Pressure
H -- Water Level
M -- Mass Flow

Fig. 1. Flow Chart of the Computer Aided Design of Geothermal Well Head Equipments