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GEOTHERMAL DIRECT USE ENGINEERING AND DESIGN GUIDEBOOK AVAILABLE FOR AN EXPANDING MARKET

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ABSTRACT

The Geothermal direct use industry potential, growth trends, needs, and how they are being met, are addressed. The high potential for industry growth, coupled with a rapidly expanding use of geothermal energy for direct use, and concerns over the greenhouse effect is the setting in which a new engineering and design guidebook is being issued to support the growth of the geothermal direct use industry. Recent investigations about the current status of the industry and the identification of technical needs of current operating district heating systems provide the basis upon which this paper and the guidebook is presented. The guidebook, prepared under the auspices of the U.S. Department of Energy, attempts to impart a comprehensive understanding of information important to the development of geothermal direct use projects. The text is aimed toward the engineer or technical person responsible for project design and development. The practical and technical nature of the guidebook answers questions most commonly asked in a wide range of topics including geology, exploration, well drilling, reservoir engineering, mechanical engineering, cost analysis, regulations, and environmental aspects.

INTRODUCTION

The use of low- and moderate- temperature (10 to 150°C) geothermal resources for direct use applications has increased significantly since the late 1970's. As a result of this growth, and recognizing the need to document available state-of-the-art information for geothermal direct use project development, a guidebook was prepared and published in March, 1989 (Lienau, 1989). The Oregon Institute of Technology (OIT) and the Idaho National Engineering Laboratory (INEL), both involved in direct use research and development since the mid 1970's, initiated the creation of the Geothermal Direct Use Engineering and Design Guidebook (Guidebook). The U.S. Department of Energy provided funding, guidance and the technical support of the INEL to OIT to prepare and publish the Guidebook under grant number DE-FG07-87ID 12693. The INEL work was performed under the auspices of the U.S. Department of Energy, DOE Contract No. DE-AC07-76ID01570.

DIRECT USE INSTALLATIONS

Direct heat use of geothermal energy in the United States is recognized as one of the alternative energy resources that has proven itself technically and economically, and is commercially available. Developments include space conditioning of buildings, district heating, groundwater heat pumps, greenhouse heating, industrial processing, aquaculture, and swimming pool heating. Forty-four states have experienced significant geothermal direct use development in the last ten years. The total installed capacity is 5.8 billion Btu/h (1,700 MW_t), with an annual energy use of nearly 18,000 billion Btu/y (4.5 million barrels of oil energy equivalent). These data are based on an extensive site data gathering effort by the Geo-Heat Center in the spring of 1988, under contract to the U.S. Department of Energy (Lienau, 1988). Based on the 1988 study, Table 1 shows best estimates of the years that different types of geothermal direct use projects went on line for the 1940 to 1985 period, their estimated annual energy use, and the anticipated 1990 quantities.

These energy use values are graphically displayed in Figure 1, showing the significant increase in the use of geothermal energy for direct use, especially after 1970. Historically, direct uses of geothermal energy in the United States were by small resorts and limited space and district heating systems. The oil price shocks of the 1970's revived interest in the use of geothermal resources as an alternative energy source. Beginning in 1977, the United States Department of Energy initiated numerous programs that caused significant growth in this industry. These programs involved technical assistance to developers, the preparation of project feasibility studies for potential users, cost sharing of demonstration projects (space and district heating, industrial, agricultural, and aquaculture), resource assessments, loan guarantees, support of state resource assessment and commercialization activities, and others. Also adding to the growth were various federal and state tax credit programs (Lunis, 1988).

Table 1. GEOTHERMAL DIRECT USE PROJECTS ENERGY ON-LINE IN 10^9 BTU/Y AND APPROXIMATE NUMBER OF PROJECTS (each)

Year	Resorts & Pools	Space Heating	Dist. Heating	Green Houses	Aqua-culture	Indust. Proc.	Heat Pumps	Total Energy
1940	1019(80)	15(100)	30(1)	-0-	-0-	-0-	-0-	1064
1950	1083(85)	22(150)	30(1)	-0-	-0-	-0-	?	1135
1960	1146(90)	38(250)	68(2)	39(3)	-0-	-0-	?	1297
1970	1400(110)	53(350)	68(2)	85(7)	202(1)	408(1)	109(2000)	2352
1975	1426(112)	508(600)	68(2)	187(16)	376(3)	1142(2)	272(3000)	3979
1980	1452(114)	592(700)	183(6)	324(28)	673(8)	3104(6)	545(10000)	6873
1985	1452(114)	677(800)	609(20)	381(33)	808(15)	8322(14)	1641(30000)	13890
1990	1452(114)	744(829)	700(23)	852(35)	970(18)	8625(16)	4357(80000)	17700

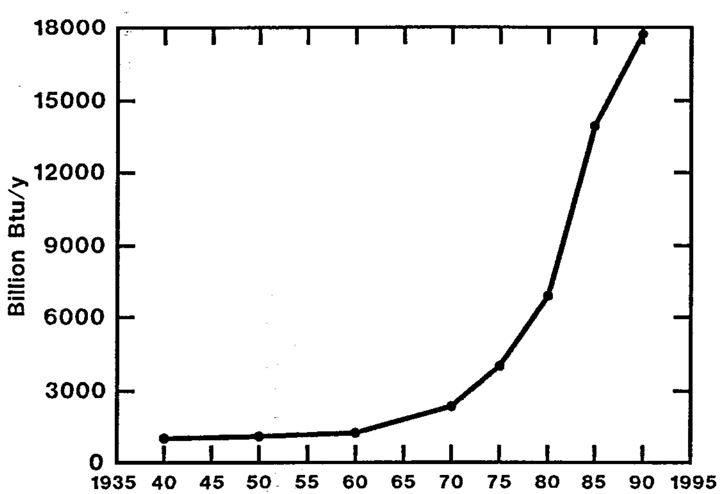

FIGURE 1
Geothermal direct use energy on-line from 1940 to 1990

Table 2 gives the distribution of use according to application, which includes the largest single application, the secondary oil recovery operations in Montana, North Dakota, South Dakota and Wyoming.

Figure 2 shows the projects on line, separating heat pump installations from the other direct use applications. Most people think of geothermal energy as a western states resource; however, there are significant numbers of projects developing this resource for space conditioning and district heating where low temperature (7 to 20°C) ground water aquifers exist in the central and eastern states. Ground water and earth coupled (vertical configuration) heat pump systems depend upon the average ground water temperature. The temperature of the ground and aquifers below varying depths are controlled by the geothermal gradient and thus are considered geothermal. The recent phenomena of heat pump installations expects a growth rate of about 50

Table 2 UNITED STATES GEOTHERMAL USE BY APPLICATION IN 1988

Application	Quantity (Each)	Capacity (10^9 Btu/h	Annual Energy (10^9 Btu/yr)
Industrial	16	1,246	8,625
Heat pumps	66,135	3,202	3,602
Resorts/pools	114	234	1,452
Aquaculture	180	180	970
Greenhouses	35	297	852
Space heating	829	231	744
District heating	23	283	700
	67,170	5,673	16,945

percent per year through 1990, according to the heat pump industry. Approximately 66,100 groundwater heat pump installations are presently installed.

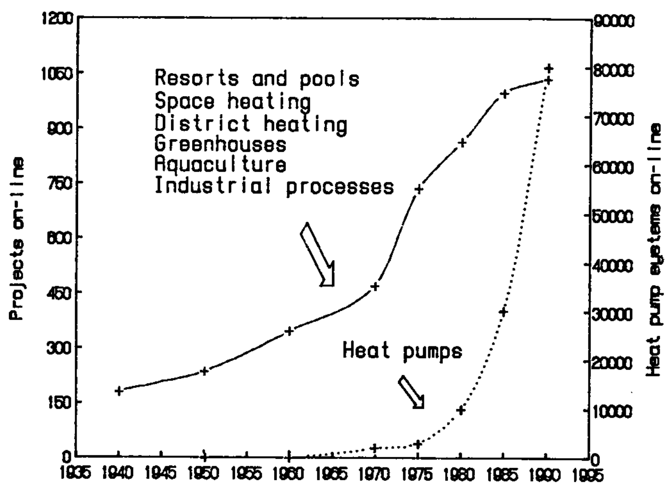

FIGURE 2

Geothermal direct use projects on-line between 1940 and 1990

DIRECT USE POTENTIAL

Studies by the U.S. Geological Survey state that the resource base for geothermal energy is very large (Muffler, 1978 and Reed, 1982). There are 1,324 identified hydrothermal and conduction dominated geothermal systems. The estimated wellhead energy for low-to-moderate-temperature (<90 to 150°C) resources, assuming a recovery factor of 0.25, is 249.5 quadrillion Btu (quads). (The total annual energy consumption of the United States is ~80 quads.) The estimates include resource temperatures <10°C above the mean annual air temperature at the surface and, therefore exclude an enormous amount of shallow groundwater in the United States. Industry recognizes that such shallow waters may be useful as a source of energy for heat pumps.

GLOBAL WARMING MITIGATION

Numerous bills have been and are being introduced into the congress because of concerns over global warming due to the use of chlorofluorocarbons and the generation of carbon dioxide and other gases. Emphasized within these bills are conservation and the use of renewable energies. Geothermal energy, because of its environmentally benign nature, is an ideal source whose use will help mitigate the causes of potential global warming. As knowledge and concern increases about the effects of global warming, the need, and desire, to use geothermal energy for direct uses (and power production) is expected to increase significantly.

GUIDEBOOK CONTENTS

It is in this setting of increasing use of geothermal energy for direct applications, a significant identified resource base, and concerns about global warming, that a Geothermal Direct Use Engineering and Design Guidebook is issued.

Direct Utilization of Geothermal Energy: A Technical Handbook (Anderson, 1979) was published several years ago to help meet the industry's needs. Since that time, a great deal of information has been gained from the development and operation of many projects. That experience is incorporated in the Guidebook to provide current, state-of-the-art technical and institutional information.

Lessons learned from various heating, agribusiness, aquaculture and industrial projects, including those developed as a result of the U.S. Department of Energy's Program Opportunity Notices, provide the background for the Guidebook.

The Guidebook contains 20 chapters prepared by numerous contributors with extensive experience in the use of geothermal energy for direct use applications. Table 3 lists the chapters and their respective authors. Considerable support efforts were also needed, and the various contributors are identified in Table 4.

Table 3 GUIDEBOOK CHAPTERS AND AUTHORS

Chapter	Title	Author
1	INTRODUCTION	P. J. Lienau, OIT[1]
2	DEMONSTRATION PROJECTS LESSONS LEARNED	B. C. Lunis, INEL[2]
3	NATURE OF GEOTHERMAL RESOURCES	Dr. P. M. Wright, UURI[3]
4	EXPLORATION FOR DIRECT HEAT RESOURCES	Dr. P. M. Wright, UURI[1]
5	GEOTHERMAL FLUID SAMPLING TECHNIQUES	C. Kindle, BPNL[4]
6	DRILLING AND WELL CONSTRUCTION	G. Culver, OIT
7	WELL TESTING AND RESERVOIR EVALUATION	S. Stiger/J. Renner, INEL, and G. Culver, OIT
8	MATERIALS SELECTION GUIDELINES	P. F. Ellis, Radian[5]
9	WELL PUMPS	G. Culver/K. Rafferty, P.E., OIT
10	PIPING GEOTHERMAL FLUIDS	K. Rafferty, OIT
11	HEAT EXCHANGERS	K. Rafferty, OIT
12	SPACE HEATING EQUIPMENT	K. Rafferty, OIT
13	HEAT PUMPS	K. Rafferty, OIT
14	ABSORPTION REFRIGERATION	K. Rafferty, OIT
15	GREENHOUSES	K. Rafferty, OIT
16	AQUACULTURE	K. Rafferty, OIT
17	INDUSTRIAL APPLICATIONS	P. J. Lienau, OIT
18	ENGINEERING COST ANALYSIS	C. Higbee, OIT
19	REGULATORY AND COMMERCIAL ASPECTS	Dr. R. G. Bloomquist, WSEO[6]
20	ENVIRONMENTAL CONSIDERATIONS	B. C. Lunis, INEL

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The Guidebook addresses all aspects of a geothermal direct use project from initial planning to final operation. Because each project is unique, it should be approached in phases to minimize risk and costs. The first phase, which generally involves securing rights to the resource, is presented in Chapter 19. This chapter provides an overview of the various regulatory and commercial aspects that affect the development of geothermal direct use projects. Information is provided on pertinent geothermal definitions, ownership, leasing, agencies involved, injection requirements, etc. for the federal government and 13 western states.

The second phase of development could involve the interdisciplinary activities of geology, geochemistry, geophysics, drilling, and reservoir engineering. In Chapter 3, the nature of geothermal resources is discussed including; geological processes, resource classifications, description of low- to moderate- temperature geothermal resources and the potential for geothermal development. Chapter 4 discusses exploration strategies where the main objective is to site wells that intersect the resource. Geothermal fluid sampling techniques, Chapter 5, suggests sample treatment (stabilization) and field analysis techniques appropriate for minimizing errors that may result from changes in water samples between time of collection and time of analysis. Chapter 6 provides information on the basics of equipment and methods used for drilling and completion of geothermal wells. It provides data needed by engineers and consultants to assist them in specification writing, selection of contractors, drilling, and completion inspection. The purpose of Chapter 7, Well Testing and Reservoir Evaluation, is to acquaint the direct use project engineer or developer with interpretation of the analytical information provided by a hydrologist on well testing, reservoir assessment, and reservoir management. It provides guidance in a practical sense for setting up testing and monitoring programs, what to specify and how to evaluate the resource with regard to system design and project life.

The preliminary design of a direct use project could take place concurrently with reservoir testing and evaluation. Special consideration should be given to design of equipment such as well pumps (Chapter 9), piping (Chapter 10), heat exchangers (Chapter 11), and space heating equipment (Chapter 12). Direct use systems requires careful corrosion engineering if the most cost effective material selections are to be made. Chapter 8 provides guidelines on material selection for low-temperature geothermal systems (50 to 105°C), as well as guidance in materials design of heat pump systems for very low-temperature geothermal resources (>50°C).

The Guidebook should prove useful for understanding important factors in the conceptual and final design of space heating and cooling systems (Chapters 12 and 14), commercial heat pump systems (Chapter 13), greenhouse heating systems (Chapter 15), aquaculture (Chapter 16), and selected industrial applications (Chapter 17). Engineering cost analysis, Chapter 18, is designed to provide an understanding of the skills necessary to complete a life cycle cost analysis of a proposed project. Regulatory statutes, commercial and environment aspects, Chapter 19 and 20, are important considerations in any direct use project. Since these aspects are unique in each state, statutes and state agencies are identified for the developers convenience.

TECHNOLOGY NEEDS

As the geothermal direct use industry experienced growth over the past decade, a number of areas have been identified where applied research and development could improve the efficiency, performance, and operation of these systems. Identified areas include: the performance of materials and equipment in geothermal fluids, economical piping systems to replace epoxy lined asbestos cement pipe, open cycle heat pumps, more efficient utilization of fluids for greenhouses and aquaculture projects, marketing techniques for district heating systems, and in general, a better understanding of low-temperature geothermal systems and their definitive locations near population centers.

Based on the evaluation of the performance of 13 geothermal district heating systems, the Geo-Heat Center has identified problems which could hinder geothermal direct use development. These include the cause of repeated downwell production pump failures, evaluation of apparent hardening of elastomer seat seals from resilient butterfly valves, and evaluation of the thermal and geofluid compatibility limitations of commercially available piping systems being considered as the most cost effective alternative to asbestos cement (AC). AC pipe, which has been the most popular type of piping for geothermal district heating systems, is either being eliminated or severely curtailed by many manufacturers. Effective marketing techniques need to be identified to encourage customers to participate in geothermal district heating projects.

Open cycle heat pumps are capable of producing steam, utilizing waste effluent water at temperatures typical of geothermal district heating effluents. These heat pumps could provide steam to industrial process areas or buildings with steam heating systems, thus greatly increasing the load factor of the district heating systems. Engineering and economic feasibility of utilizing open cycle heat pumps needs to be investigated.

Aquaculture of fresh water species and geothermal heated green houses are two of the fastest growing direct uses as shown by the rapid increase in the number of projects on-line and currently under investigation. There is a need to determine which system designs have proven successful and most efficient in the utilization of fluids in different settings, and why. There is also a need to investigate the possibility of cascading from geothermal power plants effluents that could be used for greenhouses, aquaculture and industrial processes. This information could be made available to potential users.

Most geothermal direct use projects have been able to surface discharge spent geothermal fluids in the past. However, especially in areas where multiple users draw fluids from a common reservoir, the drawdown of geothermal fluids may necessitate varying degrees of reservoir analysis and the use of injection wells to maintain aquifer stability. There is a need to provide guidance to developers on reservoir engineering programs that can identify the placement of injection wells and the design of monitoring networks to determine their definitive locations with respect to population centers. These are areas where the State Cooperative Reservoir Assessment Program and the U.S. Geological Survey could make a significant contribution.

CONCLUSIONS

The United States direct use industry is and will continue to experience a significant growth rate with a qualified infrastructure of developers and users. The purpose of the Guidebook is to provide an integrated information source to assist in the successful development of direct use projects that in turn will contribute to the mitigation of global warming.

Resolution of the concerns identified will result in greater system reliability, reduced maintenance costs, and greater user confidence. Most direct utilization systems are designed and installed by private enterprises or municipalities, which lack the monetary and scientific resources to solve geothermal engineering problems. The opportunity exists for government and industry to enhance and increase the use of an energy form that will provide the benefits available from geothermal systems.

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