Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

THE PRESENT STATUS OF KOREAN GEOTHERMAL RESEARCH AND INVESTIGATIONS

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Key Words: Korea, geothermal research, bathing

ABSTRACT

Geothermal uses in Korea have been primarily and traditionally provided in public baths, which are recently the most economic way. In Korea no geothermal energy has been yet utilized for electric power generation, nor will such plans be made in the near future. KIGAM (Korea Institute of Geology, Mining & Materials) not only plays a major role in geothermal investigations and research, but also is currently the unique governmental institute to continue geothermal studies and hot spring assessments. From 1992 to 1998, KIGAM conducted the analysis of U, Th, and K, mainly in granites and partially in sedimentary rocks from more than 200 outcrops, and measured about 149 thermal conductivities from fresh outcrops and drilling cores. Additionally, continuous temperature logs have been taken from over 350 boreholes nationwide (depth ranges from 150 to 1,500 meters). Heat flow rates can be estimated from the thermal gradients of the temperature logs and the neighboring heat production rates. The geothermal resources in Korea are mainly distributed in areas of granitic rocks, and the granite contribution is the major source of geothermal phenomena. The temperature measurements and isotopic analyses mentioned above are focused in these granitic areas, and its average value is somewhat higher than the average in nation-wide geothermal properties. Heat production rates in granites generally do not coincide with high geothermal potential areas. The high geothermal gradients, however, indicate the high geothermal potentials, and are mainly dependent on the local convective ground waters. Geological evidence shows that the geothermal waters in Korea should be considered as local convective ground waters without direct conduction of volcanism and tectonism. The deeply circulated ground waters in granites show higher temperatures near the surface, especially along and near the fractures—such as extention faults—than those showing normal geothermal gradients.

1. INTRODUCTION

Geothermal waters in Korea have been provided to the people, who love to bathe in them. Using natural waters is an old national tradition and people believe that bathing in natural hot water is the only—and a powerful—way to reduce their fatigue and stress. Other facilities around hot spring areas have been developed and would be good investments.

From 1982 till 1997, geothermal studies in Korea have been executed by KIGAM, and they continue to publish the preliminary reports of high geothermal potential areas. KIGAM played a role to assess geothermal wells and determine the optimal pumping rates and the temperatures. Recently, KIGAM performed applied research of heat flow and heat production in granitic rocks. Three other institutes also participated in the assessment of geothermal resources since 1997.

Investments into and development of the geothermal resources in Korea mainly give attention to the spa and bathing industries. We don't have any research and plans for geothermal electric power plants.

15 "Old Geothermal Areas" with temperatures ranging from 25 to 75°C have 233 geothermal wells and 452 hot spring facilities, and their annual users exceeded 24 million in 1994. About 100 "New Geothermal Areas," ranging from 25 to 50°C, have 42 spas and facilities (areas) constructed up to 1997, and the annual users estimate is about 5 million. The applications of geothermal waters to green houses, district heating and industrial uses are locally conducted near geothermal areas, but no statistics exist.

2. GEOTHERMAL RESEARCH IN KOREA

Yum (2000, in this proceeding) mentioned overall reviews of geothermal resources in Korea and its geochemistry. Historical aspects of Korean geothermal uses are considered by Yum (1999).

Geothermal phenomena in Korea are closely related to granite distribution, and the research of geothermal potentials is focused on radiogenic elements, thermal conductivities and thermal gradients in granite. Granite stocks and batholiths are considered one by one: half of the granite distributions are covered by KIGAM. Thermal conductivities are measured by QTM (Quick Thermal conductivity Meter) in the rock slabs of granite, and heat flow densities are calculated with thermal gradients. The average thermal conductivity in granite is 2.61 W/mK. Heat flow determinations in Korea were reviewed by Lim and Kim (1997): the average heat flow in granite is calculated at 67 mW/m^2, but the highest value exceeds 100 mW/m^2 on the southeastern part of the Korean peninsula.

Heat production in granite can be calculated by measurements of U, Th, and K using γ–ray spectrometry, NAA (neutron activation analyses), and wet analyses. A total of 550 sets of data were already analyzed and collected (Jin et al., 1992 and Jin et al., 1998).

The areas showing high geothermal potential in Korea coincide with the regions of high ground water temperature, and thermal gradient from boreholes. Conductive ground waters contribute to high geothermal potential, in addition to the heat production of granite itself.

3. STATISTICS

A country update of Korean geothermal resources and research is illustrated in this section, and it is convenient to explain the same table as used in all the other country updates.

3.1 Table 1. Present and planned production of electricity

In Korea, production of electricity is mainly focused on fossil fuels and nuclear energy, and no future plan exists for electrical generation using geothermal resources.

3.2 Table 3. Utilization of geothermal energy for direct heat as of Dec. 1999

Utilization of geothermal resources in Korea is almost concentrated in bathing. 15 “Old Geothermal Areas” yield hot waters from boreholes that flows directly to public bathing facilities and rooms, even after cooling. “New Geothermal Areas” and recently developed areas are pumping waters of temperatures below 42°C, and they dispose of these waters after heating. Blanks in the outlet temperatures and calculated values indicate that these waters are not used directly.

3.3 Table 5. Summary table of geothermal direct heat uses as of Dec. 1999

Statistics of geothermal uses in Korea are relatively simple, but it is hard to collect them all because developers and investors of geothermal hot springs explore and develop privately.

3.4 Table 6. Wells drilled for electrical, direct and combined uses of geothermal resources from Jan. 1, 1995 to Dec. 31, 1999

Numbers of wells in Table 6 are restricted in the data of KIGAM, which was proceeding the assessment programs. It is estimated that the numbers and total depth would be twice as shown in Table 6.

3.5 Table 7. Allocation of professional personnel to geothermal activities (restricted to personnel with university degrees)

Till 1997, around 10 researchers in KIGAM had executed geothermal assessment projects simultaneously with ground water projects. Recently, funds on these projects are decreasing after the economic crisis of 1997, and KIGAM shares the projects to assess geothermal resources with three other institutes. Overall numbers of researchers have increased, but some are moving to ground water projects in KIGAM. Very few professors in universities are interested in geothermal phenomena.

3.6 Table 8. Total investments in geothermal in (1999) US$

Investments in field developments and utilization are assumed from the data of assessing programs. Public funding has increased recently because district governments are interested in investing in hot spring facilities.

4. DISCUSSION AND CONCLUSIONS

The potential of geothermal resources in Korea is considered to be very low, and some locations—showing local hot or warm ground waters upcoming through deeply connected fractures—are treated as geothermal springs. Their origin is meteoric, and evidence affecting from volcanism and tectonism was not found.

Geothermal uses in Korea are focused on bathing, and the statistics are poor. Future plans for a geothermal electrical power plant do not exist, and KIGAM is now planning a central data center to collect all available geothermal data, such as drawdown, pumping yields, and water quality. Governmental and international fund supporting are required for this project.

ACKNOWLEDGEMENTS

The author is indebted to Dr. Kim, Y. J. and anonymous editors for their effort to review.

REFERENCES

Jin, M. S., J. S. Lee, S. J. Jee, H. J. Seo, S. Y. Kim, S. J. Kim, and S. C. Shin (1992). Petrological and Geochemical Studies on the Geothermal Energy of the Hot Dry Rock in South Korea (III). KIGAM. KR-92(T)-23, p.172 (in Korean: abstracts in English)

Jin, M. S., H. C. Kim, and B. W. Yum (1998). Preliminary Study for the Geothermal Resources in the Northwestern part of the Jeonra Province. KIGAM. KR-98(C)-07, p.71 (in Korean: abstracts in English)

Lim, J. U. and H. C. Kim (1997). Heat Flow in South Korea. *CCOP Technical Bulletin*, Vol.26, pp.85-91.

Yum, B. W. (1999). Historical Review of Hot Spring Waters in the Republic of Korea. In: *Stories from a Heated Earth, Our Geothermal Heritage*, Geothermal Resources Council International Geothermal Association, Sacramento, California pp.379-392.

Yum, B. W. (2000). Geochemistry of Geothermal Waters and Deep Ground Waters in Korea. Proceedings of WGC2000 (in this volume)

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Rewables (specifiy)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-Ity Mwe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000				141863		4770		100315				246948
Under construction in January 2000												
Funds committed, but not yet under construction in January 2000												
Total projected use by 2005				201745		4330		123091		19		329185

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

1) I = Industrial process heat; H = Space heating & district heating (other than heat pumps); C = Air conditioning (cooling); B = Bathing and swimming (including balneology); A = Agricultural drying (grain, fruit, vegetables); G = Greenhouse and soil heating; F = Fish and animal farming; O = Other (please specify by footnote); S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt)
Note: The capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow rate	Temp (^oC)		Enthalpy[2)] (kJ/kg)			Ave. flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outllet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Yusong	B	69.45	53	42			3.20	46.3	67.2	0.67
Deoksan	B	43.35	42	40			0.36	28.9	7.6	
Onyang	B	78.15	54	42			3.92	52.1	82.5	0.67
Donglae	B	69.45	64	42			6.39	46.3	134.4	0.67
Haeundae	B	26.1	62	42			2.18	17.4	45.9	0.67
Icheon	B	52.05	31.5					34.7		
Cheoksan(Sokcho)	B	86.85	54	42			4.36	57.9	91.6	0.67
Osaek	B	26.1	35.5					17.4		
Suanbo	B	43.35	53	42			2.00	28.9	41.9	0.67
Dogo	B	34.65	31.7					23.1		
Baekam	B	43.35	53	42			2.00	28.9	41.9	0.67
Deokgoo	B	43.35	41	40			0.18	28.9	3.8	0.67
Bukok	B	69.45	76	42			9.88	46.3	207.6	0.67
Mageumsan	B	34.65	48	42			0.87	23.1	18.3	0.67
Pocheon	B	52.05	46	42			0.87	34.7	18.3	0.67
Hwasoon	B	43.35	26					28.9		
Jirisan	B	43.35	26.5					28.9		
Sangdae	B	34.65	29					23.1		
Neungam	B	34.65	27.3					23.1		
Kyongjoo	B	60.75	31.5					40.5		
Dogok	B	43.35	29					28.9		
Byunsan	B	52.05	29					34.7		
Pohang	B	60.75	40					40.5		
Asan	B	43.35	34					28.9		
Ulsan	B	43.35	31.8					28.9		
Yakam	B	34.65	28.4					23.1		
Gochang	B	34.65	25.4					23.1		
Wanjoo	B	43.35	26.7					28.9		
Hwasung	B	43.35	25.9					28.9		
Wanggung	B	26.1	25.7					17.4		
Wolchulsan	B	26.1	25.8					17.4		
Hongsung	B	26.1	34.1					17.4		
Yongam	B	34.65	26					23.1		
Yaksan	B	34.65	29					23.1		
Moonkyung	B	34.65	31.1					23.1		
Eusung	B	43.35	32.6					28.9		
Seoul	B	34.65	26.1					23.1		
							36.2		761	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalphy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW=10^6 W)
Note: The capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Space Heating[4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish and Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	35.8	753	0.67
Other Uses (specify)			
Subtotal	36.2	761	0.67
Geothermal Heat Pumps			
TOTAL			

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

1) Include thermal gradient wells, but not ones under 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C					
	150-100° C					
	<100° C		164			111.3
Injection	(all)					
Total			164			111.3

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degress)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributied Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	5		1			
1996	5		1			
1997	5		1			
1998	10		2			
1999	12		2			
Total	37		7			

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989	0.1	71	142		99.9	0.1
1990-1994	0.27	139	278		99.9	0.1
1995-1999	0.15	92	184		99.9	0.1