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STEAM PRODUCTION ACTIVITIES OF STAGE I AND FUTURE PROSPECT IN THE KIRISHIMA GEOTHERMAL FIELD,JAPAN

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ABSTRACT

The Ogiri Geothermal Power Plant commenced the commercial operation on March 1, 1996. It is the joint project between the Kyushu Electric Power Co., Inc. and the Nittetsu Kagoshima Geothermal Co., Ltd., which are responsible for the power generation and the steam production, respectively.
Concerning the cost reduction of geothermal power generation as one of the most important factors for the geothermal development, attention should be paid to the drilling costs of the steam wells and the improvement in utilization factor of geothermal power plant facilities. While the author submitted a report titled 'Improvement of Success Ratio of Drilling Wells' to the WGC 1995, the present report is to make a supplementary statement from a point of view of the cost reduction of drilling.
The Ogiri Geothermal Power Plant has been enjoying a satisfactory and stable work with the cumulative utilization factor of 94.84 % (against the national average of 76.1 % in 1989) for 39 months (as of the end of May 1999) since the beginning of the commercial operation.
The report will not only give an outline of the situation of operation mainly of the steam producing division, the improvement in utilization factor of the plant facilities, and the cost reduction, but mention the future prospect.

1. INTRODUCTION

The Kirishima geothermal field is located in a hill country in the northern part of Kagoshima Prefecture, which ranges between 700 m and 900 m high in altitude and borders on Miyazaki Prefecture, has the hot-spring resort of Kirishima in the neighborhood, and forms part of the scenic Kirishima-Yaku National Park (Fig. 1). The Ogiri Geothermal Power Plant is the fourth one for commercial use in Kyushu and started the commercial operation on March 1, 1996, which has enabled the rated capacity of geothermal power plants in Japan to exceed 500 MW. The plant generates 30 MW of electricity. The Kyushu Electric Power Co., Inc. and the Nittetsu Kagoshima Geothermal Co., Ltd. are responsible for the power generation and the steam production, respectively. The plant is operated and monitored by remote control from the Sendai power plant 60 km away and has kept an extremely smooth run since the beginning of the commercial operation.

The cost reduction of geothermal power generation is one of the most important factors for the further development of geothermal development in Japan. Out of various factors such as the shortening of development period and the cost reduction for preliminary surveys and plant facilities, a great deal of technical attention should be paid to the following two factors : the cost reduction for drilling before and after the development works by raising the success ratio and the improvement in utilization factor of the plant facilities.

In addition to the previous report titled 'Improvement of Achievement Ratio of Drilling Wells' , the present report gives an outline of the relationship between the improvement in achievement ratio of drilling wells and the cost reduction, the situation of operation mainly of the steam producing division, and the improvement in utilization factor of the plant facilities, which contributes to the stable operation and the reduction in power generation cost. At the same time, part of the future prospect of the project will be mentioned here.

2. DEVELOPMENT OF THE KIRISHIMA GEOTHERMAL FIELD AND THE ACHIEVMENT RATIO OF DRILLING WELLS

2.1 Details of development

The Kirishima geothermal field was identified as a promising area for the geothermal development by 'surface surveys by private companies' and 'Basic surveys for geothermal development by the government', which started in 1973 and 1974 respectively, and 'Detailed surveys for geothermal development' initiated in 1975. The process of a full-scale of survey and development since 1979 is divided into the following four stages:

1) 1979~1981 Stage of surveys
A joint survey by the Nippon Steel co., Ltd. and the Nittetsu Mining Co., Ltd. identified a gush of steam out of three small diameter exploration wells. In particular, the well KE1-2 that penetrated the Ginyu fault in shallow part spouted out a lot of geothermal fluid, getting a start on the development of the Ogiri geothermal field including the Ginyu reservoir.

2) 1982~1984 Surveys and early stage of development
Both of the companies continuously conducted not only drilling of four small diameter wells and seven large diameter wells but also borehole electric prospecting in Ginyu and Shiramizugoe districts. Eight small diameter exploration wells were drilled in the 'Promotion survey of geothermal development in the Kurino-Tearai district' by NEDO (New Energy and Industrial Technology Development Organization).Three of the exploration wells drilled in the Shiramizugoe district recorded the bottom temperature of some 300ºC, indicating prospects of the district. However, they are partially associated with acidic thermal water, so that the geothermal development of the district has been transferred to the stageⅡ. Exploration wells in the Ginyu district not only showed a strong outflow of thermal fluid around the Ginyu fault as expected but ascertained the southeastern extension of the fault as well.

3) 1985~1987 Middle stage of development - Verification survey of potentiality of the Ginyu district
Out of five large diameter exploration wells drilled in the Ginyu

district, the eastern borehole (KE1-19S), the central one (KE1-17: NT-A1) and the western one (KE1-22: NT-C2) showed an outflow of thermal water. Combined with the data of surface surveys and borehole electric prospecting, the Ginyu fault has been identified as a highly permeable geothermal reservoir with a strike extension of 1,200 m.
A simultaneous outflow-reinjection test equivalent to 125t/hr and 14 MW, which was subsequently carried out for three months, verified a stable quantity and quality of geothermal fluid. The 'Estimation Committee of the Geothermal Project in the Ogiri District' of the Kyushu Electric Power Co., Inc. Identified the reservoir as a resource with a feasible potentiality of 30 MW.

4) Stage of development
The Nittetsu Kagoshima Geothermal Co., Ltd. was founded for the smooth and efficient promotion of the geothermal development in the Kirishima district, and drilled seven production wells and seven reinjection wells. The subsequent simultaneous outflow-reinjection test for ten production wells including wells for diverted use and nine reinjection wells completed the production system. After a short-term assessment survey on environmental effects, the construction of steam supply facilities and a power plant, and a trial run, the plant started the commercial operation on March 1, 1996.

2.2 Achievement ratios of drilling wells in the stages ranging from survey to development

Achievement ratios of drilling wells in the stages ranging from survey to development estimated by Kodama (1995) and Maki et al. (1996) are summarized in Table 1.

3. OGIRI POWER PLANT AND UTILIZATION FACTOR OF THE FACILITIES

3.1 Outline of the facilities

The Ogiri power plant is located in the center of the site measuring 500 m wide and 1,500 m long on the slope of a gentle hill ranging from 700 m to 900 m high above sea level. Production wells are drilled in the eastern and central parts of the Ginyu fault with higher altitudes, while reinjection wells are arranged in lower parts. This arrangement enables the steam-water separation in the site and the reinjection by natural flow. The layout of facilities related to the steam supply is shown in Fig. 2, whilst Tables 2 and 3 summarize an outline of facilities of the power plant and resources' characteristics in the Kirishima district, respectively.

3.2 Utilization factor of geothermal power plants

In Japan are working 19 geothermal power plants with a total generation capacity of 533 (544) MW. Table 4 shows the utilization factors of plant facilities and others.

3.3 Utilization factors of plant facilities and stoppage factors

The operational style and environmental problems ask geothermal power plants for a higher utilization factor of plant facilities. The Ogiri power plant has maintained a highly stable work with acumulative utilization factor amounting to as high as 94.84 % for 39 months (as of the end of May, 1999) since it started the commercial operation on March 1, 1996. The breakdown of the stoppage measuring as small as 5.16 % is listed in Table 5.

Inadequate parts in the steam supply facilities were remedied in the first operational year without any change of the basic design. Doubling of level control valve and changes to geothermal specifications were applied to some parts of the facilities for the safety improvement. Through an accumulation of regular repairing and daily checking, a legal program best-suited to the resources characteristics is expected to be devised under the collaboration with the power generation division.

3.4 Main factors controlling utilization factor of plant facilities

The geothermal power generation is a (joint) project of resource-environment-facilities-type. Main factors controlling the utilization factor of plant facilities are classified as shown in Table 6. The facilities factors and the common factors are previously mentioned in the section 3.3 in connection with the utilization factor of facilities of the Ogiri power plant. While no phenomenon has required any change in the basic model of geothermal structure and the resource estimation at the programming stage in the initial three years equivalent to one fifth of the project life with reference to the resource factors, they will be given a full account in a separate report after a satisfactory understanding of the actual performance.

4. ACHIEVMENT RATIO OF DRILLING WELLS, UTILIZATION FACTOR OF PLANT FACILITIES, AND GEOTHERMAL POWER GENERATION COST

4.1 Achievement ratio and success ratio of drilling wells and cost analysis

The steam production ranges from 64 % to 70 % of the power generation cost in Japan , averaging some 65 %. Further, some 50 % of the power generation cost is spent as the initial cost of steam production. The drilling cost ranges from 24 % to 31 % of the power generation cost with an average of about 30 %. The running cost occupies 27 % of the power generation cost, of which 14 % and 13 % are spent for steam production and power generation, respectively. According to a cost analysis of power generation (Matsuda,1991) based on a cost model, the improvement from 50 % to 70 % and from 80 % to 90 % in success ratio of exploration wells and development wells, respectively, leads to 7.1 % of the reduction in power generation cost. In short, a 10 % increment of the success ratio of development wells contributes to a 5 % reduction in power generation cost. In the stage I of the Ogiri district, the achievement ratio of drilling wells attained to as high as 88 % to 92 % (equivalent to 100 % in success ratio) instead of the planned ratio of 80 %, which contributed to a great reduction in power generation cost.

4.2 Utilization factor of plant facilities and power generation cost

According to a sensitivity analysis by Maki et al. (1996) and Matsuda (1991), a 5 % improvement in utilization factor of plant facilities reduces the power generation cost by 5 to 6 % under the condition that the utilization factor of plant facilities is raised from 80 % to 90 % at the auxiliary power ratio of 7 %. Since an improvement in utilization factor of plant facilities makes a great deal of contribution to a reduction in power generation cost, not only an improvement in utilization factor of the existing facilities but also a high utilization factor for additional facilities should be secured through a full consideration of cost versus effect. The utilization factor of plant facilities is an important index for operation and management of geothermal power generation. Our company, which fully satisfies the planned value of 90 % in utilization factor of plant facilities as a steam supplier for the Ogiri power plant at the moment, will try to maintain a stable supply in the future, too.

5. DISCUSSIONS AND CONCLUSIONS

While the existing geothermal power plants might have fewer advantages than the other power sources just after the construction, they have some advantages for reinvigoration of local economies and as a countermeasure against environmental problems.

Geothermal power plants maintaining a high utilization factor of plant facilities never compare unfavorably with the other sources in an economic point of view when the life-cycle is taken into account. Such long-term problems as a rise in oil price, earth warming, and utilization of domestic energy are expected to necessitate a long-range plan for the geothermal development.
Various measures to reduce drilling-related costs and improve the utilization factor of plant facilities should be taken for the steam supply in the long-term geothermal development, including the stages of survey and development, initial operation, and continuous full operation. For that, it will be required to keep technologies for improving the achievement ratio of drilling wells and facilities and technologies for securing a high utilization factor of plant facilities at a suitable level.

In the Stage I representing the first development period of the Kirishima geothermal field, the supply of steam to the Ogiri power plant has been maintained at an appropriate level, while insufficient experience in management and estimation of the resource reserves has compelled us to operate at a common technical level in the geothermal industry. Taking the geothermal development in the Shiramizugoe district representing the stage II into consideration, we would like to build up a high level of our own technologies suitable for the Kirishima district, including countermeasures against acidic geothermal resources and improvement in well productivity.

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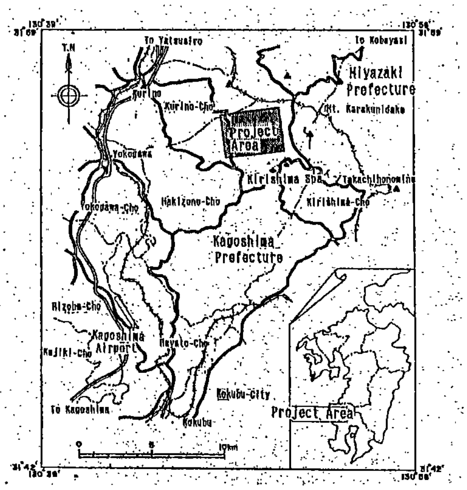

Figure 1 Location of the project area

Table 1 A.W. & S. R. in each step

Area / District / Step	Kirishima Geothermal Area A. W. *1				Japan Total S. R. or H. R.*2	
	Production Well			Reinj, W.		
	Kirishima	Ogiri	Ginyu	Kirishima		
1. research	67%	100	100	-	9 (10)	
2. Initial Dev.	43	40	61	60	47 (50)	Total Aver-age 62%
3. Middle Dev.	59 (Plan 80)	88 (80)	59 (80)	80 (80)	76 (80)	
4.Development	88 (80)	88 (80)	88 (80)	92 (80)	93 (90)	

*1 A.W. means [Achievement ratio of drilling wells]

A.W. = Number of successful wells / Number of drilled wells × 100%

Factor [Standard capacity, A. I. 70, Permeability 5dm., pH, Side truck]

*2 S.R. or H.R. means [Successful wells Ratio or Hitting Ratio]

S.R. = Number of success wells / Number of drilled wells × 100%

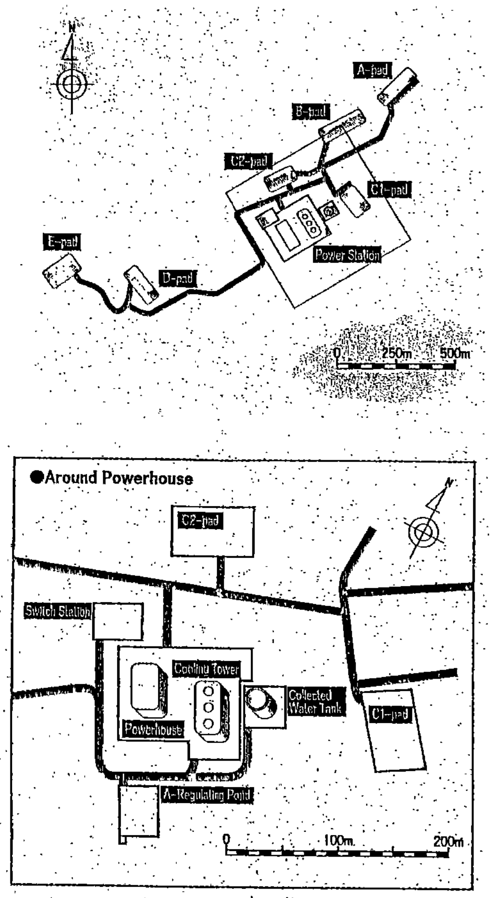

Figure 2 Ogiri Geothermal Power Plant general layout

Table 2 Major plant facilities of the Ogiri Geothermal Power Plant

(Outline of power plant)

Output	30.0 MW			
Land Area	29.8 ha			
Power Station Facilities	Turbine	Steam Pressure	2.0	kg/cm^3
		Steam Temperature	129.9	°C
		Steam Flow Rat	290	t/h
		Single cylinder, single flow, impulse, reaction condensing type		
	Generator	Capacity	34,000	kVA
		Voltage	11	kV
		Horizontal, cylindrical revolving field type		
	Cooling Tour	No. of cells	3	cells
		Capacity	9,800	m^3
		Mechanical draft, counter flow double suction type		
	Condenser	Vacuum	679	mm Hg
		Spray jet type + Tray type gas cooler		
Steam Production Facilities	Production Well	Total No. of wells	10	
		Depth 1,000 - 1,500 m	A-pad	4
			B-pad	4
			C1-pad	1
			C2-pad	1
	Reinjection Well	Total No. of wells	9	
		Depth 800 - 1,300 m	D-pad	5
			E-pad	4
	Separator	Capacity	370	t/h
		No. of unit	3	
		Vertical, cylindrical cyclone separator		
	Pipe line	Total length	4,000	m
		2phase line	600	m
		Steam line	1.100	m
		Hot water line	2.300	m

Table 3 Chemical composition of separated liquid of the Kirishima geothermal field

Well	Flow rate(t/h)			Chemical composition of separated liquid (mg/l)													
	Sampling date	Water	Steam	pH	Na	K	Ca	Mg	Al	Fe	Cl	SO4	HCO3	B	SiO2	CO2	H2S
N55-KT-5	1982/3/10	1.7	6.1	8.2	560	240.0	12.4			9.70	1200	90	191.0	87.70	745		2.7
N56-KT-8	1983/2/24	33.0	18.0	2.9	772	161.0	3.9	2.40	0.70	16.80	1190	404	<0.1	83.80	1008		4.3
KE1-1	1980/10/3	5.0	0.8	8.3	510	44.0	30.0	0.01	0.50	<0.01	940	132	13.0	38.00	309	9.6	
KE1-2	1981/8/6	2.2	2.0	9.2	200	17.0	0.3	0.01	0.07	1.10	32	194	244.0	1.60	422	191.4	13.5
KE1-2(P)	1981/12/18	5.0	8.4	9.4	85	13.2	5.6	2.50	1.71	4.40	38	104	42.9	0.25	283	35.6	13.6
KE1-3	1981/8/13	16.0	5.0	8.5	420	55.6	8.3	0.01	0.59	<0.01	660	145	31.5	75.00	567	23.3	3.8
KE1-4	1983/11/6	20.0	7.1	8.8	417	61.0	9.7	0.01	1.00	<0.01	571	156	4.0	36.10	574	3.0	3.6
KE1-5	1983/5/17	19.7	7.3	8.4	394	61.7	7.0	0.01	1.70	<0.01	660	143	5.4	43.60	627	4.0	<0.01
KE1-6	1983/7/6	6.6	2.3	8.3	653	78.3	19.5	0.01	0.69	0.14	1075	80	2.5	53.70	508	1.9	18.7
KE1-9	1984/6/26	45.8	24.2	2.8	842	196.0	10.8	2.10	0.41	25.30	1205	375	0.0	85.00	1023	2.6	
KE1-11	1984/5/27	47.6	19.7	2.4	765	167.0	17.4	4.80	0.09	39.70	980	697	0.0	83.70	1036	1.8	
KE1-19S	1986/8/28	65.5	20.4	8.7	456	76.3	16.0	0.01	1.30	<0.01	594	190	7.0	42.90	609	5.0	2.9
KE1-21	1986/2/22	5.0	8.9	7.9	702	77.9	40.7	0.01	8.70	1.90	1198	188	7.0	65.10	602	6.0	3.9
KE1-23	1986/9/2	19.8	12.3	8.3	439	53.4	19.9	0.01	1.10	<0.01	582	228	14.0	36.50	544	10.0	3.1
NT-A1	1986/4/11	161.2	50.6	8.7	441	53.4	11.0	0.01	1.20	<0.01	596	198	16.0	38.80	628	10.0	2.6
NT-A2	1990/11/24	167.9	55.1	8.8	452	63.0	10.0	0.01	<0.1	<0.5	640	194	12.0	40.00	603	9.0	3.1
NT-A3	1991/2/8	158.1	53.6	8.8	478	64.6	9.7	0.01	<0.1	<0.05	633	195	16.0	40.00	614	11.0	2.6
NT-A4	1991/5/25	159.9	50.6	8.7	478	61.3	11.5	0.01	<0.1	<0.05	635	201	9.0	36.00	571	7.0	2.5
NT-B1	1990/12/12	169.6	52.0	8.8	466	64.8	9.7	0.01	<0.1	<0.05	654	194	13.0	39.00	615	10.0	3.0
NT-B2	1991/3/2	173.9	54.5	8.8	483	64.9	10.1	0.01	<0.1	<0.05	633	193	12.0	36.00	611	9.0	2.8
NT-B3	1991/5/12	157.1	50.7	8.7	475	64.3	9.9	0.01	<0.1	<0.05	626	194	12.0	34.00	602	9.0	3.1
NT-B4	1991/7/1	150.3	52.3	8.6	466	64.0	9.4	0.01	<0.1	<0.05	633	194	10.0	37.00	611	8.0	2.6
NT-C1	1983/5/26	62.3	19.9	8.5	478	69.4	8.3	0.01	0.90	<0.01	660	194	2.1	40.20	647	1.5	2.8
NT-C2	1987/2/18	120.9	39.1	8.7	448	69.6	15.5	0.01	1.50	<0.01	583	188	9.0	40.00	612	7.0	2.4

Collected at atmospheric pressure. pH:measured at room temperature. Data for wells N55-KT-5, N56-KT-8 are from NEDO(1983).
Wells KE1-2(P), 19S, NT-A1～A4 intersect the Ginyu fault.

Table 4 The Utilization Factor* of geothermal power plants in Japan

As of end of May, 1999

Year / Item	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Ogiri power plant					'96 Mar. 1: Operation start '97 May 6-June 6: 1st. Periodical maintenance '99 Apr. 5-27: 2nd Periodical maintenance					
Utilization factor Yearly %					99.65	98.25	91.25	99.91		
Utilization factor Accumulated %						98.36	94.95	96.96	94.84	
Japan Total U.F. Yearly %	74.5	75.6	70.4	72.3	70.3	78.7	80.9	76.1		
New in Operation	'91 Oct. Takenoyu 0.1 MW			'94 Mar. Uenotai 27.5	'95 Mar. Yamagata 30.0 '95 May. Yanaizu-Nishiyama 65.0	'96 Mar. KakkondaII Ogiri 30.0, 30.0	'97 Mar. Takigami 25.0		'99 Mar. Hachijyojima 3.3	
Capacity (MW)	283.8			392.3	517.3		543.6	546.9		
Rated Output	270.0				503.7				533.3	

* Utilization Factor is equivalent to: Average Power through the year / Rated Output × 100%

Table 5. Factor of facility stoppage in Ogiri Power Plant

As of end of May, 1999

Stoppage hr & % / Item	Stoppage hr	Stoppage %	Component %
1. Initial facility maintenance	32.8	0.44	8.5
2. Lightning influence & uncertain accident	1.0	0.03	0.6
3. Periodical (yearly) & usually (daily) maintenance	327.2	4.69	90.9
Total	361.0	5.16	100.0

Table 6 General factor of facility stoppage

Main factors	Main Contents	Power generation	Steam generation
A. resource factors	1. Quantity and quality of resource Scale of facilities and absolute quantity of resource Changes in qualitative and environmental estimation of resource	—	◎
	Estimation of reduction including initial fall		○
	2. Shortage of resource by accidental factor	△	
	Sudden change in supply ability by natural disaster	○	○
B. facilities factors	1. Design ability of facilities Correspondence to the lack or breakdown of facilities Correspondence to the changes of resource characters		◎
	2. Suitable repair maintenance	◎	
	Legal periodical maintenance plan	△	
	Proper prevention for preservation - cost performance	○	○
C. Combined and common factors	1. Early (Short time) recovery to the stoppage of facilities by natural disaster		
	2. Proper running by Man-Machine system and suitability for preservation and facilities test	○	△

◎: Main Correspondence part, ○: Correspondence part, △: Sub-correspondence part, —: No relation