LONG TERM USE OF ACIDIC RESERVOIR AT ONIKOBE GEOTHERMAL POWER PLANT

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Summary

Onikobe Geothermal Power Plant is a single flash type geothermal plant. It has been operated for 18 years since march 1975.

At present, Onikobe Geothermal Power Plant has 9 production wells and 6 reinjection wells. 5 of production wells are used, and the hot water after steam–water separation of three of these wells exhibit acidity which is 3 or a fraction more in pH values. The steam production from these acid wells accounts for approximately 70% of the total steam.

Based on our long experience on the hydrochloric acidic reservoir at Onikobe Geothermal Power Plant, it has been verified that a life of production well more than 8 years can be maintained without using special materials (8 years means the average of a life of production well in Onikobe), if the pH of hot water is 3.4 or so. The stainless steel material has to be used for the well–mouth equipment down to the separator, but this does not pose an economic problem.

It is recommended that the use of acidic reservoir is studied with positive attitude in other geothermal regions.

1. Outline of Onikobe Geothermal Power Plant and History of Its Development

Onikobe Geothermal Power Plant is a single flash type geothermal plant which has been constructed by the Electric Power Development Co., Ltd. (EPDC) at Narugo Town in Miyagi Prefecture. The power plant was commissioned in March, 1975 with an output of 9,000 kW, and it was authorized at 12,500 kW in April 1976. It has been operated for 18 years since march 1975.

The major design parameters of Onikobe Geothermal Power Plant are as follows.

Authorized output, 125,000 kW, steam conditions (turbine inlet); 138.2℃, 2.5kg/cm², 141.7 to/h, 12 production wells (6 wells in operation, 6 wells used and exhausted, depth 228m¯500m), reinjection wells; 5 (depth 550m¯800m).

The operating performance of Onikobe Geothermal Power Plant is presented in the table below. (Table 1)

Table 1

figical year	approval capacity kV	generated hours Hı	generated power MwHr	svailability factor %	capacity factor %	auxiliary power ratio %
1974	9,000	312	2,888	100.0	102.8	9.4
1975	11,000	8.247	77,818	95.4	95.0	13.2
1976	12,500	8,420	92,749	97.0	84.7	11.8
1977	12,500	8,263	85,449	95.1	78.1	13.0
1978	12,500	8,306	71,186	95.6	65.0	15.3
1979	12,500	8,244	59.268	94.8	54.0	18.4
1980	12,500	8,251	52,007	95.3	47.5	21.2
1981	12.500	8,252	45,646	95.3	41.7	23.2
1982	12,500	8,293	60.214	95.6	55.0	17.2
1983	12,500	8,197	70,455	94.5	64.2	14.6
1984	12.500	8,465	58,349	97.3	53.3	17.9
1985	12,500	8,417	51,423	96.7	47.0	19.9
1986	12,500	8,454	61,112	97.0	55.8	18.0
1987	12,500	8.259	63,149	94.8	57.5	17.4
1988	12,500	8,448	97.787	97.0	89.3	11.8
1989	12,500	8,401	100,054	95.9	91.4	10.0
1990	12.500	8,411	98.393	96.0	89.9	12.0
1991	12.500	7.558	87.430	86.0	79.6	10.7
1992	12,500	8,407	71,628	96.0	65.4	15.4

availability factor = $\frac{\text{working days}}{\text{calender days}} \times 100\%$, capacity factor = $\frac{\text{generated power}}{\text{capacity} \times \text{cal.days}} \times 100\%$

Exploration wells from GO-1 Well to GO-12 Well have been drilled, and the electrical explorations (Schlumberger method), seismic explorations(refraction method, reflection method), gravity explorations, geochemical explorations, etc. have been performed.

Based on the result of these surveys, it was found out that there are three layers of reservoirs, each at different depth, exist at Onikobe. These reservoirs lies at depth of 300 m or so, near 800 m and near 1000 m, respectively.

Naturally, these reservoirs do not exist on a horizontal layer, but geothermal reservoirs are formed along the fracture systems near their depths.

High quality, enough temperature steam was recovered from a shallow layer near a depth of 300 m. While this hot water was neutral, the steams obtained at flow rates of 30 to 40 t/hr from 2 deep wells, which are 1,350 m and 1,300 m respectively, had hot water of high acidity (2.6 to 3.3 in pH value), which are considered to be unsuitable for power generation. After this, the drilling of the deep well was terminated, and shallow wells were drilled to construct the power plant.

After the power plant was commissioned, the decline of shallow wells was substantial, and additional drilling of shallow wells was not effective in preventing the decrease of the power plant output.

2. Degree of Acidity and Consideration on Cause of Acidity

At this moment, the wells having acid hot water was GO–10, GO–11 and GO–105.

The hot water of these wells exhibited acidity of hydrochloric acid with pH values of 2.6 to 3.4.

Since the shallow wells could not be counted on, all documents were studied in order to identify the new production area, and it was suggested that a neutral geothermal fluid may be obtained if distance was kept from the center of the active source of hot water alteration that happened to exist at Onikobe. In this discussion, the opinions of Dr. Takejiro Ozawa (Professor Emeritus of Saitama University) and Dr. Isao Takashima (Professor of Akita University) were taken into consideration.

Dr. Takashima conducted X–ray refraction analysis on 102 pieces of samples collected from the ground surface of Katayama Geothermal area on which Onikobe Geothermal Power Plant was situated, and 250 pieces of samples obtained from the exploration wells of EPDC. The result was presented to the presentation meeting of Geothermal Survey Institute held in January, 1978. According to this presentation, many minerals containing zeolite were found, and the alteration zones were classified to heulandite zone, laumontite zone, wairakite zone and pyrophyllite zone. These alteration zones distribute in lamination, but reversals of lamination, and formation of mordenite and stilbite zone and pyrophyllite, which were produced in the high temperature mineral zones (wairakite zone) when subjected to low temperature, were found in some locations. From this fact, it was inferred that the geology at Katayama has been subjected to alteration action twice in the past. In some measurement data of the transition temperature of quartz in the samples of deep underground layer, two peaks were indicated, and this could also be regarded as the evidence of the two alterations. In addition, when the chemical campositions of altered rocks was examined, they were rich in SiO_2 and extraordinarily poor in Na, K, etc. at deep location.

Summarizing above features, it was considered that, at Katayama, Ogama and Menuma in Onikobe Region, there were substantial alteration activities, accompanied by leaching, in the past, and the activities extended in the NW–SW direction. As a result, an alteration zone, which was almost exclusively composed of SiO_2 and Al_2O_3, was formed, and the neutralization action could not affect the current hot water activity of hydrochloric nature that was produced later on.

It was concluded that, if the above inference was correct, the development sites should not be placed at the center at Katayama, but they must be separated from the center, if the above inference was correct.

3. Background on Which It was decided to Use Acid Reservoirs

In order to validate this working hypothesis, #U–1 was drilled as exploration well which inclined at an angle of 40" against vertical line, running from the premises of EPDC toward west (with the drilling length of 1160m and horizontal length of 575 m). This well was almost neutral, with 6.2 to 7 pH value, and it is still used now as a production well #127. Later, wells #128 and #129 were drilled, and their hot water was neutral with pH value of 8.1.

However, the productivity of these wells was not good, except well #128, and it was found out that the wells producing acidic hot water had higher permeability. The pH value of these wells was around **3.4,** which was similar to the hot water of shallow well #105. It was found that the wells having this value had been used for 8 years had no abnormal condition when these wells were abandoned. In addition, it was clarified that the internals of these acidic wells were coated with PbS, and no corrosion occurred. The hot water of well #130, which was drilled later, had the characteristics similar to well #105, and it was estimated that this well could be used. For these reasons, it was attempted to drill production wells in the acidic regions.

At present, Onikobe Geothermal Power Plant has 9 production wells and 6 reinjection wells. (See Fig. 1) 5 of production wells are used, and the hot water after steam–water separation of three of these wells exhibit acidity which is 3 or a fraction more in pH values. The steam production from these acid wells accounts for approximately 70% of the total steam. The hot water of the remaining 2 production wells, which was first neutral, changed its pH value to less than 5.

The steam after steam–water separation does not contain special gas. It has steam content of more than 99%, and there is no problem in steam transfer tube, turbine and condenser.

Various measures, which have been devised based on our experiences, have been applied to the finishing work of production wells, well–mouth facilities, separators and hot water pipe line. The acidic reservoirs have been utilized without serious troubles up to the present time. This performance is reported below.

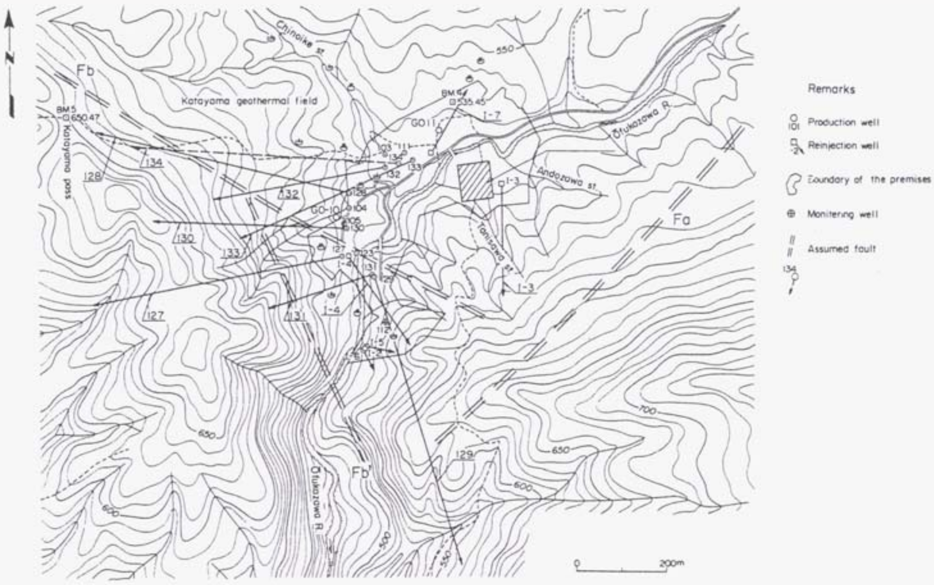

Fig.1 Onikobe Geothermal Power Plant Location map of Wells.

4. Operating Conditions

4.1 Characteristics of Each Production Well

The table of chemical components of the hot water after steam–water separation at each production well, at the stage of commencement of production and at the present time, are presented.(Table 2, Table 3)

Table 2 Chemical composition of hot water from production wells after separation in the Onikobe geothermal field..(Initial State)

10 Aug. 1993
EPDC M.Abe

well no.		103	111	127	128	129	132	130	131	133	105	GO–10	GO–11
length(m)		228	320	1160	1255	1461	1300	1500	1000	1300	375	1350	1300
comp	unit												
pH		7.3	**8.0**	**5.6**	8.1	8.1	7.6	3.4	3.4	3.0	3.34	3.30	**2.60**
Cl	mg/l	2780	2780	**3630**	1990	3490	**2600**	4910	4480	4600	**5630**	**5286**	9570
SO,	mg/l	75	77	13	**33**	17	*23*	19	19	**33**	31.0	**55.2**	201
HCO,	mg/l	25	49	**<6**	31	61		**<6**	**<6**	**<6**	28		
CO,	mg/l	<6	**<6**	**<6**	**<6**	**<6**	**<6**	**<6**	**<6**	**<6**	(002)		
Na	mg/l	1400	**1300**	1700	1300	**1900**	930	1900	1400	**2000**	**1950**	1787.5	3120
K	mg/l	250	210	**340**	**230**	310	130	440	**360**	430	439	503.5	810
Ca	mg/l	290	320	340	83	310	160	450	470	**650**	408	408.4	1460
Mg	mg/l	2.7	4.6	**2.6**	0.42	0.81	0.22	33	**34**	63	48.4	137.1	270
T–Fe	mg/l	1.1	0.59	**0.25**	<0.01	0.02	0.03	150	110	130	220	323	648
As	mg/l	0.24	0.53	**1.2**	1.1	0.76	1.3	1.3	**1.5**	1.3	4.62		
Hg	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.0006**		
Al	mg/l	**0.12**	0.03	0.05	<0.02	<0.02	<0.01	0.53	**0.22**	0.27	4.32	3.83	
B	mg/l	59	**54**	58	32	***66***	47	61	75	73			
Li	mg/l	1.9	1.6	3.7	**2.8**	2.8	**3.1**	3.9	**2.8**	**2.58**	1.91		
T–Cr	mg/l	<0.02	<0.02	<0.02	<0.02	**<0.02**	<0.01	<0.02	**<0.02**		0.14		
Cd	mg/l	**<0.005**	<0.005	<0.005	<0.005	<0.005	**<0.005**	**<0.005**	0.010	0.02	0.07		
CN	mg/l	**<0.05**	**<0.05**	<0.05	**<0.05**	**<0.05**	<0.1	**<0.05**	<0.1				
I	mg/l	1.2	1.1	1.4	0.8	1.5	0.6	**2.8**	3.3				
Pb	mg/l	**<0.05**	**<0.05**	**<0.05**	<0.05	**<0.05**	<0.02	0.97	0.77	3.41			
Zn	mg/l	**<0.01**	**<0.01**	0.04	0.01	**<0.01**		3.0		6.16	2.33		
Mn	mg/l	**2.5**	**1.5**	**1.5**	0.02	0.55	**0.2**	7.4	9.3	14.3	9.75		
Br	mg/l	5.4	4.8	6.0	3.5	6.0	**4.6**	7.8	7.1				
SiO_2	mg/l	**360**	**380**	720	680	650	690	690	660	610	**515**	**510**	**144**

sampling data well 103, 111. 127. 128, 129. 130
(except T–Fe. Hg, Al, B. Li, T–Cr. I, **Zn**, Br, Mn) 1987.Dec.
well 103, 111. 127. 128, 129, 130
(T–Fe. Hg. Al, B. Li. T–Cr. I. Zn. Br. Mn) 1987.Jun.
well 131 1988.Jun.
well 132 1990.Jun.
well 133 1993.May
well 105 1979.Dec.
GO–IO 1969.Nov.
GO–11 1970.Dec.

Table 3 Chemical composition of hot water from production wells after sepatation in the Onikobe geothermal field (recent).

10 Aug. 1933
EPDC M. Abe

well no.		103	111	127	128	129	132	130	131	133	105	GO–10	GO–11
length(m)		228	320	1160	1255	1461	1300	1500	1000	1300	375	1350	1300
comp	unit												
pH		8.2	8.4	4.6	4.7	7.9	7.3	3.1	3.3	3.0	3.34	3.30	2.60
Cl	mg/l	2200	2200	4190	2990	4000	3000	4090	4520	5000	5630	5286	9570
SO,	mg/l	78	69	18.6	**26.5**	25	21	16.4	27.9	40.0	31.0	55.2	201
CO,	mg/l	27	**34** / **19**	15	8	0	0 / 0	10	5	<5	28 (002)		
Na	mg/l	1300	1200	1990	1450	1800	1400	1730	1980	2020	1950	1787.5	3120
K	mg/l	150	**160**	**350**	288	270	260	355	363	410	439	503.5	810
Ca	mg/l	150	150	459	**248**	360	260	434	558	643	408	408.4	1460
Mg	mg/l	1.20	1.3	4.72	18.9	1.5	**2.0**	34.4	34.5	61.4	48.4	137.1	270
T–Fe	mg/l	0.35	0.0	0.64	3.85	0.12	0.57	144	82.0	134	220	323	648
As	mg/l	0.28	0.20	0.97	**2.38**	0.13	1.30	1.24	1.01	1.28	4.62		
Hg	mg/l	**0.000**	**0.000**			**0.000**							
Al	mg/l	0.13	0.23	0.32	0.27	0.02	0.00	0.27	0.13	0.27	4.32	3.83	
B	mg/l	**36**	44	60.2	46.7	60	29	55.3	61.9	67.2			
Li	mg/l	1.2	1.1	3.15	2.67	2.9	3.7	2.45	2.29	**2.58**	1.91		
T–Cr	mg/l	0.02	0.02			0.00	0.00						
Cd	mg/l	0.00	**0.00**			0.00	0.00				0.07		
CN	mg/l	0.0	0.0			0.0	0.0						
I	mg/l	**0.7**	0.3			1.2	1.8						
Pb	mg/l	0.00	0.00	<0.01	0.11	0.00	0.00	1.84	0.89	3.41			
Zn	mg/l			<0.01	0.10			3.48	1.33	6.16			
Mn	mg/l	0.44	0.55	3.15	8.02	1.4	0.94	8.80	6.08	14.3			
Br	mg/l	3.4	2.8			5.2	4.5						
SiO_2	mg/l	**360**	**300**	**665**	768	360	640	738	618	618	515	510	144

well 132 1991. **Nov.**
well 129 1992. **Nov.**
well **103**, 111 1993. May
well 127, 128, 131, 133 1993. **July**
well 105 1979. **Dec.**
GO–10 1969. **Nov**
GO–11 1970. Dec.

4.2 Characteristics of Reservoirs, **Result** of Tracer Test, Relation between Acidic Hot Water and Power Generation

(1) Characteristics of Reservoirs

The shallow wells, which had been drilled at the early stage of development, can be classified into 3 categories according to the nature of hot water.

The first category includes wells in which the concentration of C1 ion is extremely low, such as 8102, #112 and 8117. In #112 and #117 wells, the SO_4^{--} concentration exceeds 700 ppm. pH value of 8108 well is slightly alkaline, with pH value of 7.9. 8105 well exhibits acidity of pH 3.2, similarly to exploration wells; #GO–10 and #GO11. These wells are shallow, but it is inferred that they are located near the fracture system leading to the depth.

Inclined wells #127, 8128, 8129 and 8132 are all neutral, with pH values ranging from 7.2 to 8.9. #130, #131, and #133 wells are fairly acidic, with pH ranging around **3.3.** Cores and cuttings collected from wells were sampled and altered minerals were classified by X–ray refraction and microscopic observation.. The samples from locations where acidic hot water is produced are characterized by the presence of pyrophyllite. The areas where neutral hot water is produced exhibit chlorites, and these areas are sericite zones, where calcite is present. This situation is schematically illustrated in Fig. 2.

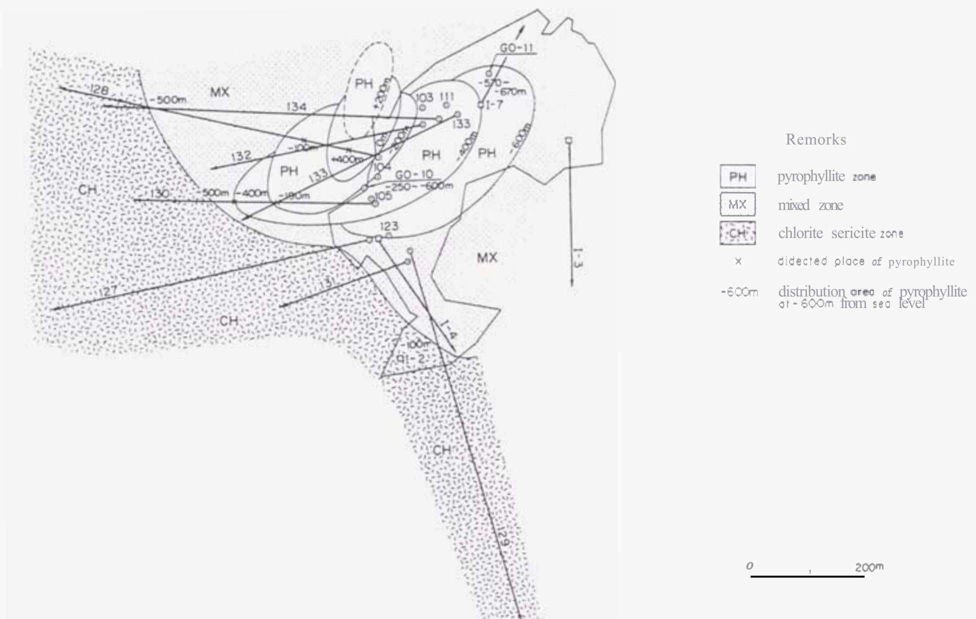

Fig.2 Distribution of alteration zone.

Up to #130 well, there was a distinctive correlation between the hot water and the altered minerals of the location, which support the above description.

However, this correlation has changed from #131 well. $131 well was drilled at a location where the production of neutral water was expected according to its distribution of altered minerals. The cuttings thereby obtained did not contain pyrophyllite, and despite the presence of calcite, acidic hot water of 3.3 pH value has been produced.

Although the hot water of

8132 well is separated from #131 well only by 110 m in terms of horizontal distance and 150 m in vertical distance, it is neutral with pH value of 7.6. There is a distinctive boundary between the acidic hot water chamber and neutral hot water chamber in the distance of only a little over 100 m.

(2) Result of Tracer Test

In this region, the tracer test has been conducted at appropriate occasions, such as when a new reinjection well was drilled, or a set of production wells started production in a specific area. From April, 1988 to March, 1990, a systematic pressure observation and tracer test program has been implemented as a field test related to the research of reinjection mechanism which was sponsored by NEDO. The tracer was mainly potassium iodide (KI), and potassium bromide (Br) was added when the test was conducted simultaneously at two locations. The amount of injection in one test was 1000 kg for KI, and 2000 kg for BrI.

According to these tests, the tracer, which was injected to reinjection well.

#I−3, located in the southeast of the premises, reached shallow wells #103, #111 and #130. The tracer from #104, which is an old production well now used for reinjection, appeared in #130.

The southwestern area, which is the main reinjection area of this region, different injection performance was obtained depending on the reinjection depth. That is, when reinjection is implemented at a depth shallower than 500 m, a trivial recirculation was observed to shallow wells. When reinjection is done to a depth deeper than 600 m, very small recirculation was observed in #127 and #130 wells. These results were simulated in a fluid flow simulation analysis, and the future prediction was made. The simulation result indicated that the cold front would not arrive for more than 30 years in the future, and there would be no impediment against power generation.

However, it is desirable to disperse the reinjection area, and a new reinjection well, #I−7, has been drilled in the northeast area.

(3) Relation between Acidic Hot Water and Power Generation

The well−mouth of each production well at Onikobe Geothermal Power Plant is equipped with a separator, which separate steam and water. The characteristics of the steam after separation is not related to the pH of hot water, and its characteristics is constant. Therefore, no problem has been experienced. The characteristics of the steam at the inlet of the turbine, for the period from 1988 to 1992, are presented in Table 4. To look at the water−gas ratio of the steam, the water content is 99.63

Table 4 Change of the main steam characetristics

	Item	Data	1988		1989		1990		1991		1992		1993		Ave.	St.dev
			7 Jun.	25 Oct.	15 May	16 Oct	18 Jun	7 Nov	20 May	11 Nov	19 May	17 Nov	27 May			
Steam Condition	Flow Late	t/h	114	111	124	125	131	125	124	125	8 86	79	115		114	16
	Temp.	℃	138	138	140	135	133	134	141	132	134	136	136		136	3
	Press	atg	1.95	2.08	1.98	2.20	2.10	2.10	2.10	2.00	1.51	1.60	1.79		1.95	0.21
Ratio of water/gas		Vol%														
	Water	%	99.71	97.79	99.76	99.79	99.74	99.75	99.70	99.65	99.66	99.71	99.47		99.52	0.55
	Gas	%	0.29	2.21	0.24	0.21	0.26	0.25	0.30	0.35	0.34	0.29	0.53		0.48	0.55
Compo-nent of gas	CO_2	%	60.3	62.5	58.2	58.7	63.8	60.0	61.0	60.2	59.3	59.4	56.3		60.0	1.9
	H_2S	%	24.0	26.0	22.5	25.4	25.9	25.7	25.1	20.1	22.4	22.8	24.7		24.1	1.8
	R	%	15.7	11.5	19.3	15.9	10.3	14.3	13.9	19.7	18.3	17.8	19.0		16.0	3.0
Compornent of Residual gas		Vol%														
	H_2	%	25.20	32.27	9.14	25.62	22.85	23.38	18.86	12.85	20.90	20.90	20.60		21.14	5.93
	N_2	%	73.16	65.80	90.19	72.80	75.31	74.95	79.84	86.00	77.60	78.05	78.50		77.47	6.25
	CH_4	%	1.64	1.93	0.67	1.58	1.84	1.67	1.30	1.15	1.50	1.05	0.90		1.38	0.38
Composition of Condensed water	pH	−	4.1	4.1	3.9	4.2	4.2	4.3	4.1	4.6	4.4	4.1	4.2		4.2	0.2
	EC	μs/cm	29	28	34	27	28	25	43	18	20	39	26		29	7
	Cl	mg/l	0.3	0.3	0.4	1.0									0.5	0.3
	Na	mg/l	0.78	0.25	0.23		0.28	0.29	0.15	0.16	1.30	0.05	0.23		0.37	0.36
	K	mg/l	0.0	0.0	0.0		0.0	0.2	0.3	0.0	0.2	0.0	0.0		0.1	0.1
	Ca	mg/l	0.2	0.0	0.0		0.0	0.0	0.0	0.0	0.4	0.0	0.3		0.1	0.1
	Mg	mg/l	0.02	0.00	0.00		0.03	0.02	0.00	0.00	0.05	0.00	0.02		0.01	0.02
	T−Fe	mg/l			0.03		0.03	0.03	0.05	0.06	0.10	0.06	0.03		0.05	0.02

vol% in the average, where the gas content is only 0.47 vol%. No significant change in steam was observed during this period, despite the fact that acidic hot water wells, #131 and $133, have been deployed during this period. However, in the early period of operation, including the test operation in 1975, some turbine blade failures have been experienced, apparently caused by the scaling on the stator blades and nozzles of the turbine's first stage.

This scale was mainly composed of NaCl and FeS, and it was inferred that the carry−over of hot water from separators and subsequent ingress of hot water to the steam line had caused this scaling.

Later, an electric conductivity meter, equipped with a steam line alarm, was installed, and the situation has been dealt with by conducting continuous monitoring and automatic recording of data.

When acidic hot water is used, the carry−over of hot water from the separator is hazardous to the turbine, and the production wells must be managed carefully and meticulously.

4.3 Total Production from Each Well

The total steam production, from the commissioning of the power plant in March 13, 1975 to May 31, 1993, was 13,906,669 tons. The total hot water production was 39,303,668 tons. The total production of geothermal fluid was 53,210,337.7 tons.

The production performance of each well at Onikobe Geothermal Power Plant is illustrated in the table below.

Table

well	length	period	steam vol.	water vol.	total vol.	S/W	pH	total Kcal
GO-	m		S tol	W ton	T ton	S:W/S		Kcal
101	233	'75/3 −'82/4	683095	933675	1616770	1:1.37	4.5	572232
102	301	'7513 −'82/6	237468	318857	556325	1:1.34	5.7	197760
103	228	'75/3 −'93/5	1565586	3234852	4800438	1:2.07	7.3	1474441
104	366	'75/3 −'84/5	528645	946273	472943	1:1.79		472943
105	375	'75/3 −'83/8	646128	1285013	1931141	1:1.99	3.3	630274
106	351	'75/3 −'82/5	351413	501556	852969	1:1.43		296725
108	243	'7513 −'82/10	375070	101894	476964	1:0.27	7.6	258061
111	320	'81/8 −'93/5	875369	3969204	4844573	1:4.53	8.0	1119439
117	170	'75/3 −'82/10	546955	135729	682684	1:0.25	8.4	3752246
118	112	'75/8 −'83/11	424265	128596	552861	1:0.30	8.6	283289
120	383	'7518 −'78/5	158803	161783	174982	1:1.02		105838
123	153	'79/10−'80/7	30238	40977	71156	1:1.36		25122
127	1155	'8216 −'83/2	12322	85785	98107	1:6.96		19395
128	1255	'80/9 −'93/5	1382705	4171985	5554688	1:3.02	5.6	1499634
129	1451	'8217 −'93/5	2154163	8365236	10520399	1:3.88	8.1	2677040
130	1500	'83/5 −'92/12	570824	2725812	3396636	1:4.06	8.1	851111
131	1000	'85/10−'93/5	1013482	2962220	3975702	1:2.92	3.4	1144639
132	1300	'8814 −'93/5	1674041	7489286	9163327	1:4.47	3.4	2263629
133	1300	'90/6 −'92/1	514505	1719718	2234223	1:3.34	7.6	600019
		'93/3 −'93/5	61594	169013	230607	1:2.74	3.1	65826
total vol.			13906669t	39303669t	63210338t			

5. Countermeasures against Acidic Hot Water

5.1 Well Finishing Works

Facilities on the ground surface can be sufficiently monitored, and their materials can be fully examined before use.

However, for underground facilities, their replacement is impossible, and there is nothing to do but to use them with careful attention for their safety.

In the past, experience has been gained on the successful operation of #105 well having the pH value of 3.4 for 8 years, and wells producing hot water of similar acidity have been operated. No particular difficulty has been experienced while #130 well has been operated for 7 years and 10 months and #131 well for 5 years and 4 months.

However, special attention has been given on the sequencing program in order to assure the safety of operation. As an example, the casing program of #134 well which is now being drilled, are presented (Fig.3).

In the drilling area of Onikobe Geothermal Power Plant, alteration has progressed to the ground surface. The ground from depth of 20 m to 50 m are soft clay layer, and the guard casing is set down to cover this depth. The ground from 100 m to 150 m in depth is constituted by impermeable layer which is made of the stratum altered to clay. This layer constituted the caprock in the early stage of development, and there was a steam dominant geothermal fluid which could be termed the steam cap. The second stage casing is set down to this depth. The production casing is set down to depth of 550 m to 1100 m depending on the situation. The material is C−75, 40LB of API Standard, but CR−25, 40LB which contains 25%chromium, is used from the well−mouth to the depth of 200 m for wells #132 and #133. The galvanic action is a problem because different metals are combined. Therefore, the ceramics is plasma sprayed on the coupling section, to provide insulation between two different metals. A stainless steel pipe cost roughly 10 times the conventional pipe, and it can not be used easily. Stainless steel pipes are used only at locations where production of acidic hot water is anticipated.

The difference from conventional geothermal production well is the insertion of the third stage casing for depth from 350 m to 600 m. This is provided based on the concept that, even if damage is inflicted on the production casing at depth of 300 m or less by corrosion or erosion of acidic hot water, there are double and triple casing, so that the well life can extended by replacing the well−mouth equipment to the outer casing.

In addition, the CR−25 stainless steel casing is provided, which provides additional safety in reference to its resistance against geothermal hot water of 3.3 pH or so, as proven by the operating experience as surface piping. Then, one more stage of casing is provided at depth shallower than 150 m. This provision is to prevent, at least for some time, the eruption of geothermal fluid through the well wall to the ground surface, even if the casing is damaged from inside.

5.2 Surface Facilities

Well #105, which has been used for approximately 9 years from 1975 to 1983, had exhibited hydrochloric acidity of 3.1 to 3.34 in pH value. This characteristics is roughly similar to exploration wells #GO−10 and #GO−11, and this was interpreted as the rise of hot water through the hot water fracture at the depth which was directly produced from well #105. In employing #105 well, it has been known that the lower flow rate is desirable based on the result of the erosion/corrosion test conducted on exploration wells #GO−10 and GO−11, and the well was operated by reducing the flow speed down to 100 m/s or less by throttling the well−mouth valve (secondary valve) of well #105.

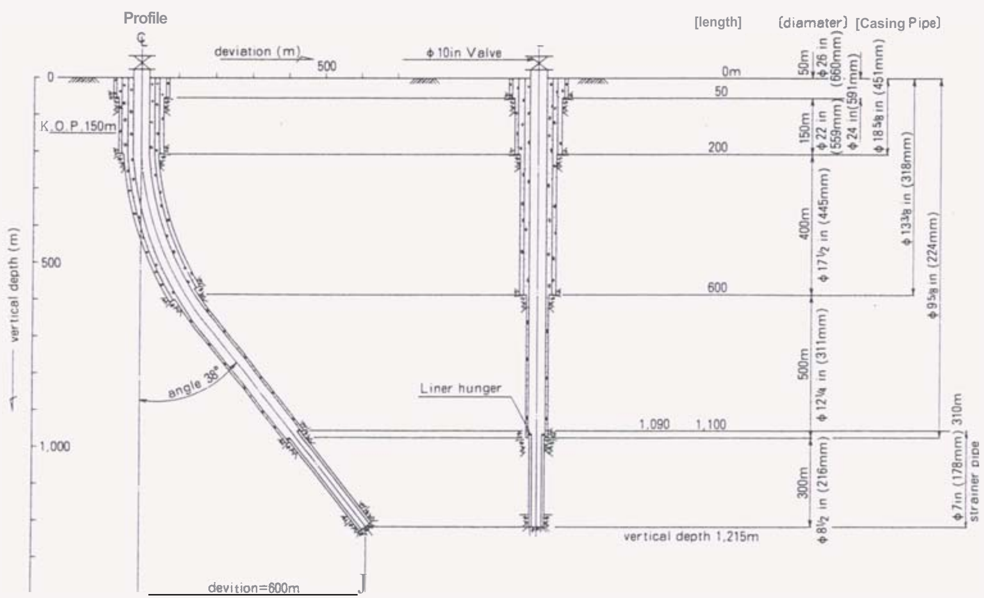

Fig.3 Casing Program of GO−134.

The well has been operated without damaging accident owing to this consideration. As the enthalpy was reduced, the steam flow was reduced. When the well #105 was abandoned, the well–mouth equipment, separator, etc. were subjected to scrutinizing inspections. The liner of the well–mouth separator and other equipment was thinned, but the surfaces were all covered with lead–colored gray scale. Analyses were conducted by X–ray refraction, SEM, EMPA, etc., and it was found out that most of the scale is lead sulfides (PbS). By this, it was found that erosion may be caused by discharge of slime, etc. at the initial production, the internals of these equipment are coated with lead sulfide when a stable operation is established, and corrosion and other damages are not inflicted.

Based on this finding, the hot water of hydrochloric acidity up to 3.4 in pH value can be used for power generation. There is no problem if attention is paid on the two–phase section down to the separator. The problem of the hot water piping has been successfully resolved by using the fiberglass reinforced plastic pipes (FRPs) which are light weighted and strong against corrosion.

Although #130 well has exhibited similar acidity, the use of the secondary valve for flow control was stopped, and a stationary orifice plate was used, to realize the normal operation of the well.

#131 well is operated with a well–mouth pressure of 11 kg/cm^2 in order to reduce the flow speed. At the initial phase of operation, the position of the throttle valve was not adequate. The cavitation by turbid flow and vibration were created, and the valve was penetrated in one month, and it was forced to replace the valve.

An elbow in the section from the well–mouth to the separator, where a turbid, 2–phase flow is created, was penetrated in approximately 2 moths.

Therefore, the secondary valve was replaced with an orifice, and the configuration was modified by providing a straight section on the downstream of the orifice as long as possible, and by installing an elbow, and the piping materials were replaced. As a result, the system has been successfully operated for 5 years afterwards up to the present time. Speaking o fmaterials, the stainless steel for 2–phase system, for which development has progressed in manufacturers, is superior in erosion and corrosion resistance, and this material has been effective for locations such as elbows where erosion is likely to occur. An austenitic stainless steel containing Mo is used for the orifice, and so far there has been no damage. However, our experience is not rich concerning the geothermal materials, and researches in this area must be pursued in future.

5.3 Reinjection of Acidic Hot Water

The hot water from shallow wells is generally acidic only with pH of less than 5.0, and there has been no problem with reinjection. After deep wells have been developed to produce hot water of 7.6 to 8.9 pH values, silica scale presented a problem. A research was conducted with the objective of preventing deposit of silica scale by blending the acidic hot water from deep wells. The polymerization of silica is accelerated to accelerate the scale deposition, when alkaline hot water is mixed with a small amount of acidic hot water, due to the metallic ions contained in large amount in acidic hot water. However, it was found out that, when the pH of the mixed hot water is kept below 5, the deposition of scale is substantially suppressed.

6. Operating Performance and Problems

Wells producing acidic hot water can be maintained without particular problem if care is exercised on the life extension of casing section and safety of surface facilities, and the hot water carry–over is prevented by installing the well–mouth separator. Problems are rather encountered in wells that produce neutral hot water that passes the acidic hot water area. The problem is the damage of casing, etc. due to the aging of well, which invites ingress of acidic hot water. This turns the hot water acidic, and at the same time deposits smectite scale in the production well, thereby clogging the well and interrupting the production. This occurred in 8128 well. Although the well was cleaned, it did not recover completely. #132 well, which has produced more than 80 t/h of steam and performed as an excellent well, clogged in 2 years as it had 2 feed zones and acidic hot water was mixed.

Therefore, this point must be taken into consideration in formulating the sequencing program of wells from which production of neutral hot water is expected. In addition, production of geothermal hot water relying only on the acidic reservoir may produce recirculation of the reinjected hot water, which may acidify the whole system. It is required to drill the neutral hot water producing wells at a certain percentage.

7. Future Development

#134 well currently drilled is the replacement of #128 well, and a neutral hot water is expected. In future,+ another neutral hot water well is expected near #132 well, to balance the whole system.

8. Conclusion

Based on our long experience on the hydrochloric acidic reservoir at Onikobe Geothermal Power Plant, it has been verified that a life of more than 8 years can be maintained without using special materials, if the pH of hot water is 3.4 or so. The stainless steel material has to be used for the well–mouth equipment down to the separator, but this does not pose an economic problem. It is recommended that the use of acidic reservoir is studied with positive attitude in other geothermal regions.

893 words

9. References

Abe, M. (1985) Geothermal model of the Katayama field, Onikobe area. Jour. Geoth. Res. Soc. Japan, 7, 283–309 (in Japanese).

Takashima, I. (1988) Rock alteration and hydrothermal systems in the Onikobe geothermal area, Northeast Japan. Rep. Geol. Sur. Japan, 268, 229–244.

Yamada, E. (1988) Results of researches in the Kurikoma geothermal area, Northeast Japan: an overview. Rep. Geol. Soc. Japan, 268, 7–18.

Abe, M., Nakanishi, S., Mishima, A. and Fujita, Y. (1989) Operation and Reservoir Management of Onikobe Geothermal Power Plant. Jour. of Japan Geothermal Energy Assoc., Vol. 26, No.3 (Ser. 108)