RISK CONTROL FOR DISASTER AT THE GEOTHERMAL FIELD

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ABSTRACT

Many electrical power plants by Pacific Ocean side in Tohoku area were visited by 2011 March 11's Great Eastern Japan Earthquake, however, inlying geothermal power plant continued to generate electricity. From this, people looked at geothermal power plants' role in arguments about how national preparation against crisis should be. Geothermal power generation is potential natural resources business, however, its resources lie in the non-visible underground and furthermore the production of high temperature and flowing geothermal vapor has many risks. It is important to recognize these risks and to accumulate vast experience and knowhow. In Yanaizu Nishiyama Geothermal Power Plant, we listed 7 major risks for vapor supply business, and each point is segmentalized. We are studying the countermeasures based on occurrence frequency and severity of each risk in order to be prepared for the worst crisis.

INTRODUCTION

Geothermal electric power generation can be grouped into two in terms of usage purpose: in-house power generation and commercial power generation. It is possible to break down the commercial power generation further into cases in which geothermal vapor production and electric power generation are conducted by different business operators, and cases in which both the production of geothermal vapor and electric power generation are conducted by one business operator. Since many of geothermal power plants in Japan were developed before electricity was partially liberalized due to Electricity Business Act's revision, business models in which they only produced geothermal vapor but did not generate electricity were common. Also Okuaizu Geothermal Co. Ltd., where I belong to, only produces geothermal vapor, and therefore in this paper, I would like to introduce about risk control in geothermal vapor production.

1. YANAIZU NISHIYAMA GEOTHERMAL FIELD AND ELECTRIC POWER STATION

1.1 Location

Yanaizu Nishiyama plant is located in Yanaizu-cho, Fukushima, and is located in 200-km distance from Tokyo to north.

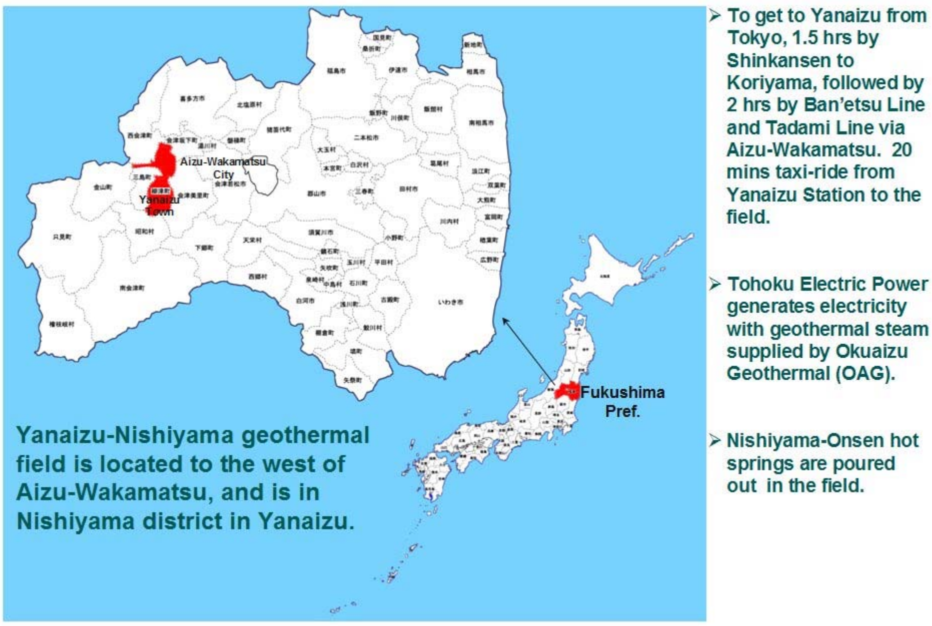


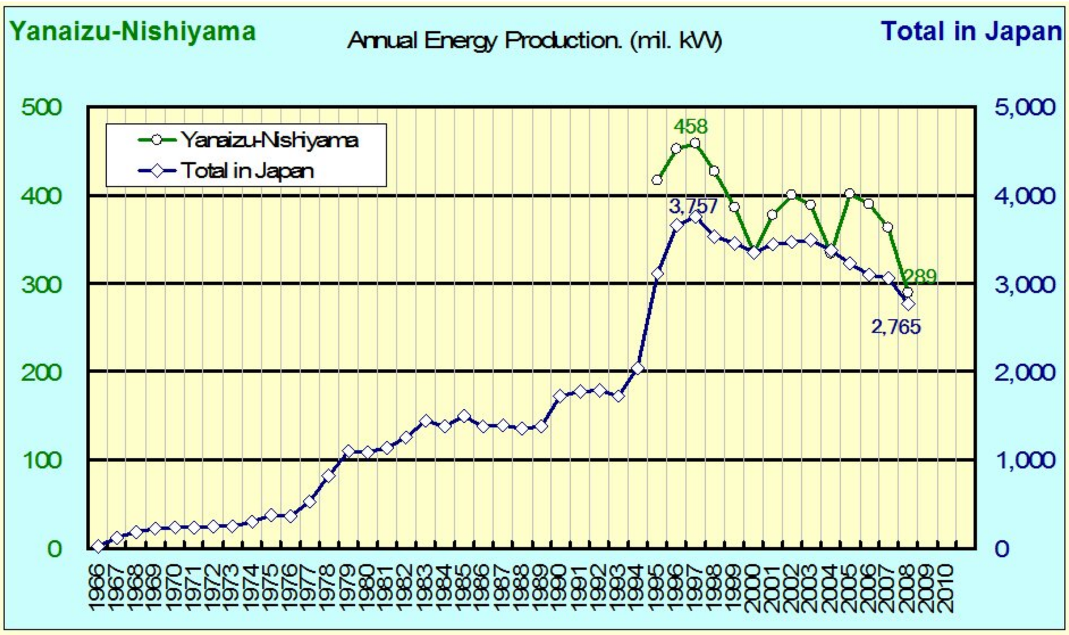
Fig1 Location

1.2 Output

The geothermal power plant in Japan is located at 17 points belonging to eight prefectures, and the steam turbine of 20 units is working. Yanaizu Nishiyama Geothermal Power Plant has permitted output of 65MW and this equals to about 12 % of Japan's permitted output, which is about 540 MW. About 6 billion-kWh electric power was generated for 16 years, i.e. 6000 days, since the operation has begun. The average output of the calendar day is 41.6 MW.

Table1 Geothermal Power Stations in Japan (as of Mar. 31, 2009)

No.	Location	Name of PS	Electricity Producer	Steam Supplier	Capacity (kW)	Output (kW)	Start-up (yy/mm/dd)	Utilization Rate (%)	Energy Production FY2008 (MWh)
1	Hokkaido	Mori	Hokkaido Electric Power	Hokkaido Electric Power	50,000	50,000	82/11/26	25.4	111,321
2	Iwate	Matsukawa	TOHGEC	TOHGEC	23,500	23,500	66/10/08	61.4	126,362
3		Kakkonda (Unit 1)	Tohoku Electric Power	TOHGEC	50,000	50,000	78/05/26	2.4	10,602
4		Kakkonda (Unit 2)	Tohoku Electric Power	TOHGEC	30,000	30,000	96/03/01	14.6	38,487
5	Akita	Onuma	Mitsubishi Materials	Mitsubishi Materials	10,000	9,500	74/06/17	70.7	58,828
6		Sumikawa	Tohoku Electric Power	Mitsubishi Materials	50,000	50,000	95/03/02	71.2	312,071
7		Uenotai	Tohoku Electric Power	TOHGEC	28,800	28,800	94/03/04	80.9	204,059
8	Miyagi	Onikobe	Electric Power Development	Electric Power Development	25,000	12,500	75/03/19	72.8	79,702
9	Fukushima	Yanaizu-Nishiyama	Tohoku Electric Power	Okuaizu Geothermal	65,000	65,000	95/05/25	50.7	288,808
10	Tokyo	Hachijojima	Tokyo Electric Power	Tokyo Electric Power	3,300	3,300	99/03/25	46.1	13,350
11	Oita	Otake	Kyusyu Electric Power	Kyusyu Electric Power	13,000	12,500	67/08/12	75.7	82,850
12		Hacchobaru (Unit 1)	Kyusyu Electric Power	Kyusyu Electric Power	55,000	55,000	77/06/24	83.3	401,332
13		Hacchobaru (Unit 2)	Kyusyu Electric Power	Kyusyu Electric Power	55,000	55,000	90/06/22	90.4	435,501
14		Hacchobaru (Binary)	Kyusyu Electric Power	Kyusyu Electric Power	2,000	2,000	06/04/01	37.2	6,525
15		Takigami	Kyusyu Electric Power	Idemistu-Oita Geothermal	25,000	25,000	96/11/01	91.6	200,622
16		Suginoi	Suginoi Hotel	Suginoi Hotel	1,900	1,900	81/03/06	51.2	9,037
17		Kuju	Kuju-Kanko Hotel	Kuju-Kanko Hotel	2,000	990	98/04/	85.8	7,444
18	Kumamoto	Dakenoyu	Hirose Commercial	Hirose Commercial	200	50	91/10/19	—	—
19	Kagoshima	Kirishi (Binary)	Fuji Electric Systems	Fuji Electric Systems	220	220	06/08/17	45.1	869
20		Ogiri	Kyusyu Electric Power	Nittetsu-Kagoshima Geothermal	30,000	30,000	96/03/01	96.6	253,965
21		Yamagawa	Kyusyu Electric Power	Kyusyu Electric Power	30,000	30,000	95/03/01	46.8	122,865
Total	9	18	11	13	549,920	535,260		60.0	2,764,600



Annual energy production of Yanaizu-Nishiyama GPS hit 458 mil. kWh in FY1997, and bottomed out 289 mil. kWh in FY2008.

Fig2 Anual Energy Production of Yanaizu Nishiyama GPS

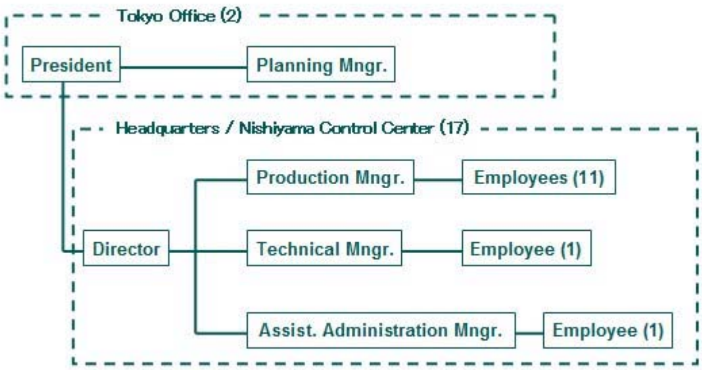
1.3 Corporate structure

The wholly-owned subsidiary of Mitsui Mining and Smelting Co., Ltd., Okuaizu Geothermal Co., Ltd. Conducts vapoer production and Tohoku Electric Power Co., Inc. generates electricity.

Table 2 Company Profile

Name	Okuaizu Geothermal Co., Ltd.
Date Founded	November 12, 1983
Our Business	To supply geothermal steam to Yanaizu-Nishiyama Geothermal Power Station.
Offices	Headquarters : 1034-1 Uenodaira, Sunagohara, Yanaizu, Kawanuma-gun, Fukushima 969-7321, Japan Tel +81-241-41-3001 Fax +81-241-41-3004 Tokyo Office : 1-11-1 Osaki, Shinagawa-ku, Tokyo 141-8584, Japan Tel +81-3-5437-8227 Fax +81-3-5437-8228
Capital	100 mil. yen (as of March 31, 2010) (Wholly owned subsidiary of Mitsui Mining & Smelting)

Company Organization (Number of Employees)



Okuaizu Geothermal Headquarters.

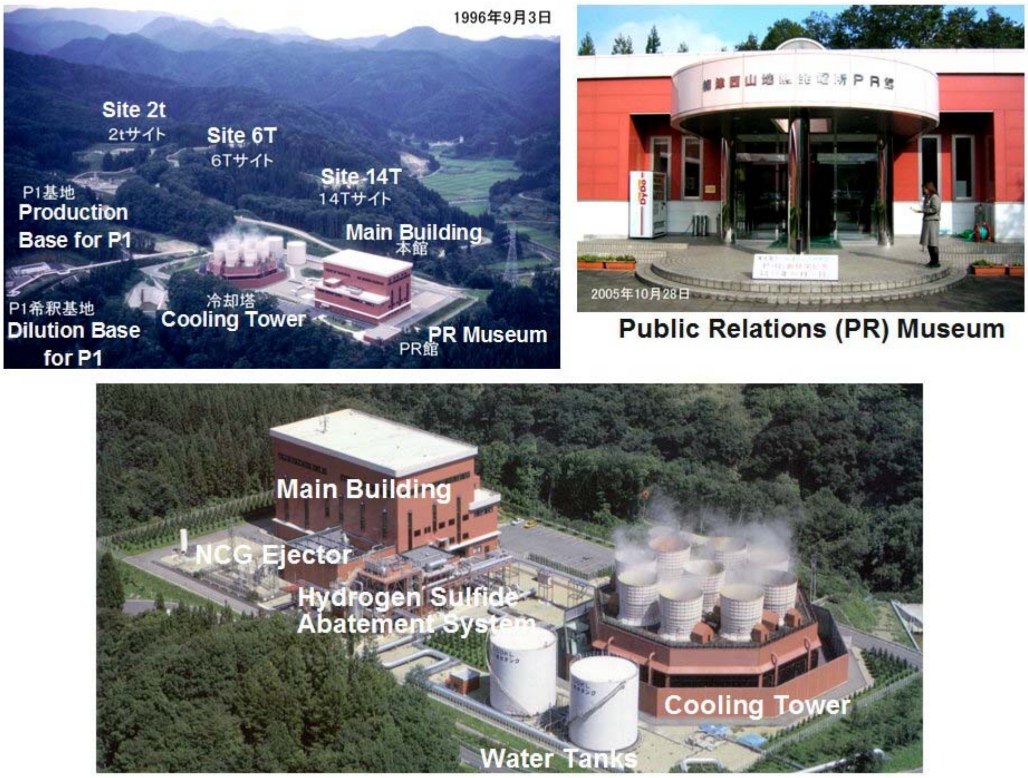


Fig3 Yanaizu Nishiyama GPS

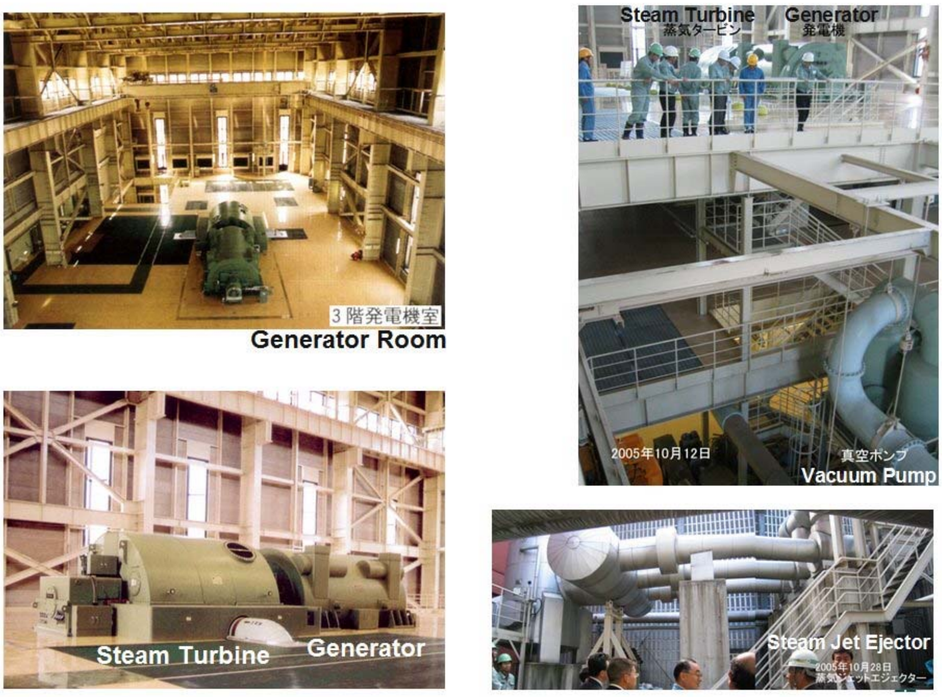


Fig4 Inside of Yanaizu Nishiyama GPS

1.4 Start of Operation

Operation started in 1995, 14 years after Mitsui Mining and Smelting Co., Ltd. started full-scale investigation in 1981.

Table3 History of Exploration and Development

1956	: Prospecting for black ore deposits and perlite in the Aizu area by Mitsui Mining & Smelting (MMS).
1974	: Geothermal exploration launched in the Nishiyama area by MMS.
1977	: Two- year Basic Exploration for Geothermal Development 'the Nishiyama area' by Japan Geothermal Development Center.
1981	: Exploration resumed by MMS on Yanaizu Town's request.
1982	: Two-year Promotion Research for Geothermal Development 'the Okuaizu area' by New Energy Development Organization (NEDO).
1983	: Establishment of Okuaizu Geothermal (OAG) financed by MMS, Mitsui Construction and Toshiba.
1984	: First exploratory well drilled by OAG.
1986	: Joint research undertaken by OAG and Tohoku Electric Power.
Feb. 1990	: Bilateral agreement on promoting geothermal development between OAG and Tohoku Electric Power.
Jan. 1991	: Bilateral basic agreement between OAG and Tohoku Electric Power.
Dec. 1992	: Green light to construct a geothermal power station by the 122nd Electric Development Coordination Council.
Jun. 1993	: Conclusion of environment conservation agreement between OAG, Yanaizu Town and Tohoku Electric Power.
May 1995	: Commercial operation begun.

1.5 Well bore data

Government carried out 14 explorations of wells before 1983, and its total drilling length is 11,333m. The highest temperature confirmed by government's exploration was 266°C, steam flow rate of the exploration well whose diameter of well bottom is 100 mm was 5.7 t/h, and brine flow rate was 5.5 t/h. Okuaizu Geothermal Co., Ltd. has drilled 40 geothermal wells since its establishment in 1983, and the total drilling length is 73,161m. Of these, 8 slim holes and 21 large diameter wells were drilled before the beginning of operation, and among the large diameter wells, 14 were used as production wells and 3 were used as reinjection wells. 11 production wells were drilled after the beginning of operation. Diameter of well bottom of production well is 215.9 mm, and drilling length is 1,500 to 2,610 m. Diameter of well bottom of reinjection well is 311.2 mm, and drilling length is 1,459 to 1,510 m. The highest temperature of production well is 248 to 342°C, and that of reinjection well is 167 to 181°C. At the day of beginning of operation, it started with 64.51 MW power generation output and 632 t/h steam supply to power plant. Brine flow rate at the time of beginning of operation was 148 t/h, and capacity of reinjection well was higher than 638 t/h. There has been marked declination of steam flow, and, under the present circumstances, the production capacity of steam flow rate is 300 to 400 t/h and brine flow rate is about 100 t/h.

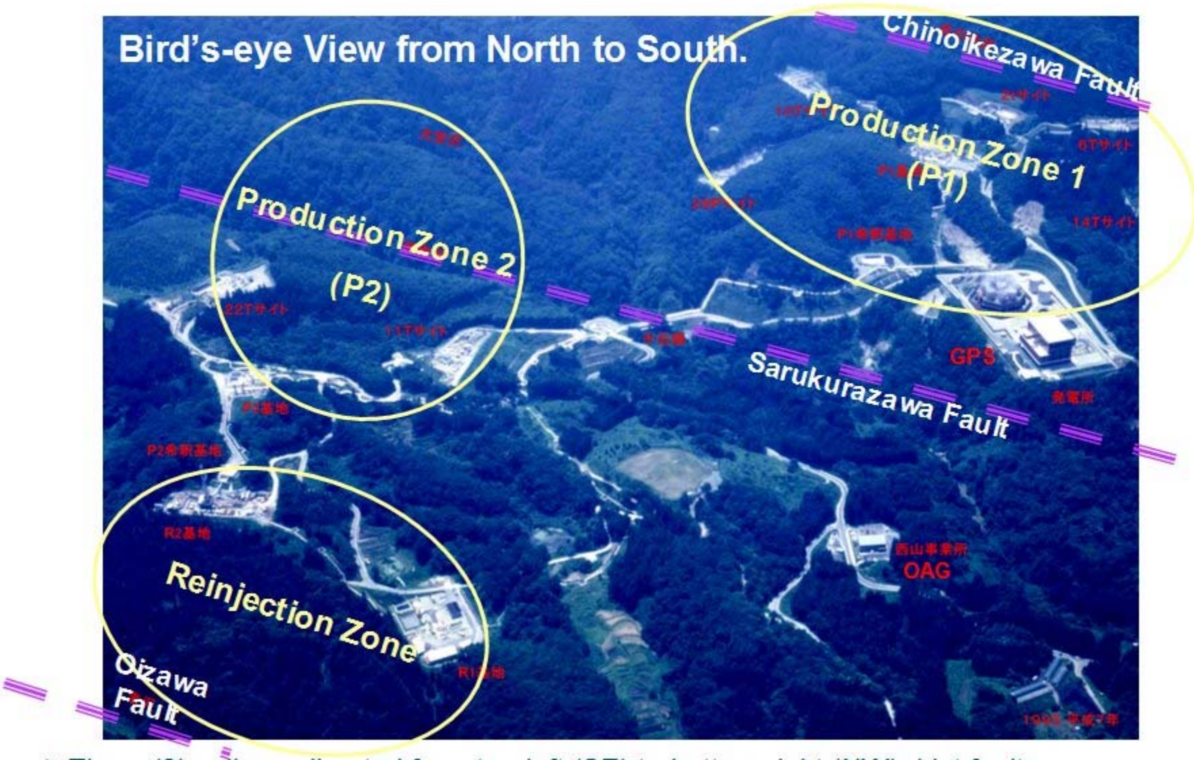
Fig5 Surface Equipment of Steam Production

1.6 Geothermal reservoir

Reservoir of Yanaizu Nishiyama geothermal field is fracture controlled type. Two sets of parallel fracture group inclined at the high angle are used as steam production zone, and a set of fracture group parallel to these is used as brine reinjection zone.

Of these fracture groups that show northwest to southeast strike, the one that is located in the furtest south area is the center of high temperature. The underground temperature distribution of the deep part shows the concentric ellipse that has long axis from northwest to southeast area. The fault of high angle that has strike from north-northeast to south-southwest cuts these three sets of fracture groups and changes to concentric ellipse, which has this fault as a central axis, in the shallow part. Hot spring gushes on the surface of the earth along with this fault,

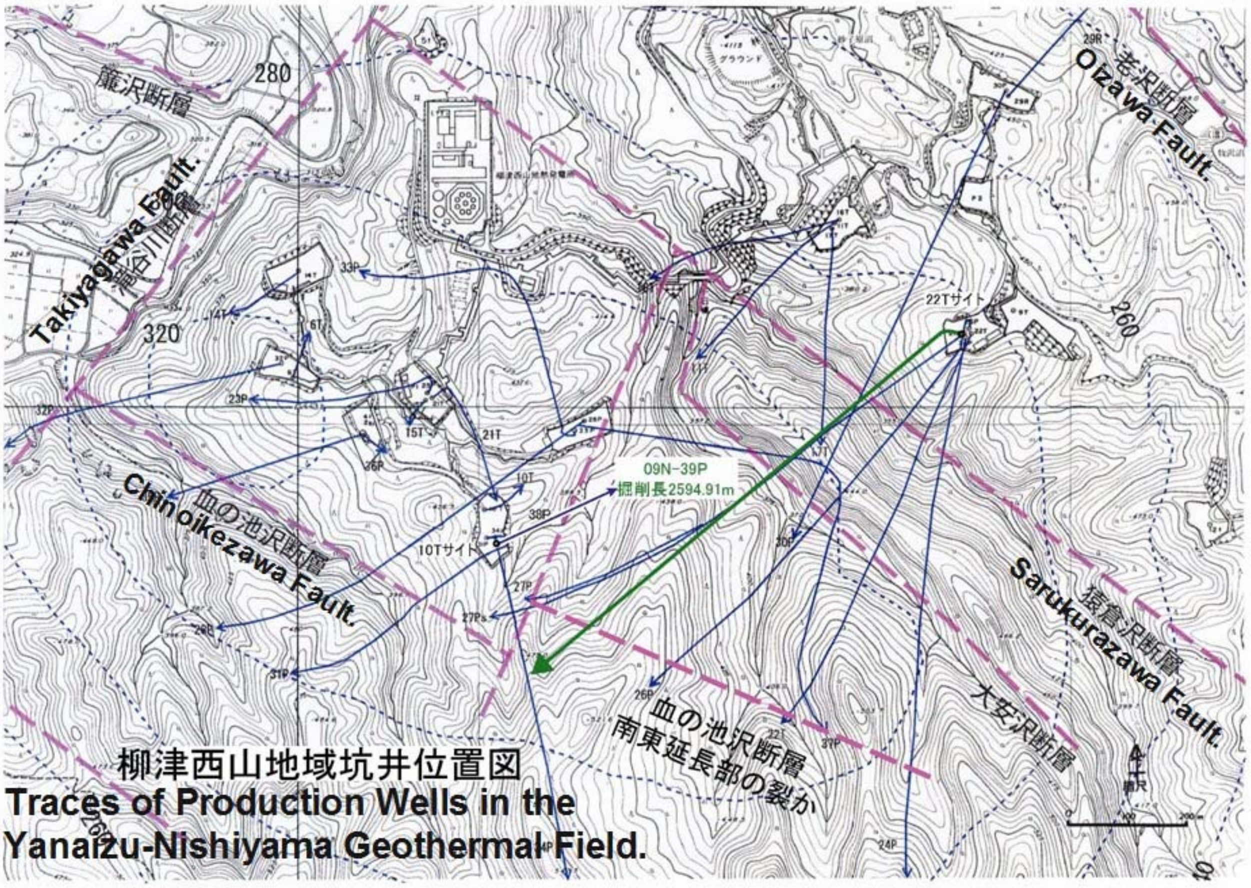
Although permeability of fracture part is high, the supply of brine, which supplements the production volume, is not sufficient because the permeability of the whole reservoir is low. Therefore the reservoir before development was saturated in brine, however, the two phase domain is expanding along with production.



- Three (3) valleys, directed from top left (SE) to bottom right (NW), hint faults. Geothermal steam is produced through wells penetrating Chinoikezawa Fault and Sarukurazawa Fault. Hot water is injected back into the fracture zones of Oizawa Fault.
- Nishiyama-Onsen hot springs are poured out on the bottom-right corner where Oizawa Fault and Takiyagawa Fault (NNE-SSW) intersected.

Fig6 Bird's-eye View of the Yanaizu Nishiyama Geothermal Field

Fig7 Permiable Fracture Samples



Production wells are mainly targeted to Chinoikezawa Fault and Sarukurazawa Fault.

Fig8 Distribution of Geothermal Wells

1.7 Chemical composition

Brine is mainly neutral, however, some of brine that spews from deepest high temperature part show acidity. Moreover, with the drying of reservoir in recent years, chloride acid corrosion problem has been caused due to the generation of hydrogen chlorine gas in some production well.

2. THE EAST JAPAN BIG EARTHQUAKE

On March 11 at the Great East Japan Earthquaku, it measured tremor with intensity of 5 lower in Yanaizu town office located 9km north from Yanaizu Nishiyama Geothermal Power Plant. At Yanaizu Nishiyama Geothermal Power Plant, it measured 4. The accelerometer installed in the Yanaizu Nishiyama Geothermal Power Plant showed 85.6gal, and the plant did not reach automatic-stay conditions. The accelerometer installed in the Yanaizu Nishiyama geothermal power plant showed 85.6gal, and plant did not reach automatic-stay conditions. Three sets (A, B, C) of accelerometers are installed in the Yanaizu Nishiyama geothermal power plant. Any accelerometer's perception of vibration exceeding 8gal will leave automatic record. If any of the accelerometers detects vibration exceeding 25gal, an alarm signal will be emitted, and it will be sent to the power plant staff’s mobile phone, and then the staff will run to the spot for check. If the accelerometer A detects 150 or more gal for more than 2 seconds, and if B or C detects vibration of 190 or more gal, turbine will stop automatically. Moreover, turbine will stop automatically when accelerometer B and C detects vibration of 190 or more gal. Therefore, since the staff that ran to the plant checked that there was no abnormality, the manual shutdown was not performed. There were no abnormalities observed in steam production facility and geothermal well.

Conditions for emergency shutdown of steam turbine are set differently based to each power plant’s anti-earthquake design (foundation strength and structure of building) condition. Since six geothermal power plants in the Tohoku district did not suffer damage from this big earthquake, it contributed to the electric power supply at the time of this large-scale disaster. There were many abnormal changes such as the stopping of some discharges of Tohoku area's hot springs and emergence of new hot spring discharges, there were no abnormal changes seen in the geothermal wells of Tohoku area.

3. RISK CONTROL

Risk management is important in any enterprises. There are seven risks involved in geothermal steam production business: (1) resource risk, (2) facility risk, (3) environmental risk, (4) natural disaster risk, (5) sales risk, (6) location risk, (7) industrial accident risk. If we segmentalize this list further, (1) resource risk includes: (i) declination of steam production capacity, (ii) fall of brine reduction capability, etc. (2) equipment risk includes: (i) blockade in wellbore, (ii) leakage of steam by the perforation of ground piping, (iii) burst of ground piping, etc. (3) environmental risk includes: (i) influence on hot spring, (ii) ground steam emission by steam leakage in underground, (iii) inducement of earthquake, (iv) noise, (v) bad smell, (vi) land subsidence, etc. (4) natural disasters risk includes: (i) landslide, (ii) thunderbolt, etc. (5) sales risk includes: (i) steam production guarantee obligation, (ii) control of steam production in case of power plant stop, (iii) change of steam selling price, etc. (6) location risk includes: (i) claimer complains damage, etc. (7) industrial accident risk includes: (i) hydrogen sulfide poisoning, (ii) fall accident, (iii) burn injury, (iv) traffic accident, etc. Countermeasures for each risk considering occurrence frequency and severity must be prepared anticipating worst situations.

Okuaizu Geothermal Co., Ltd. has conducted hot spring variation investigation to study about the effects on hot springs since 1984 and has reported to hot spring owners and Yanaizu-cho on a regular basis. It has also conducted micro earthquake observation to study about danger of inducement of earthquakes since 1985, and its results have been reported to Yanaizu-cho regularly and presented to local residents at meetings time to time. On October 12, 2009, earthquake of M4.9 occurred in the area of geothermal reservoir and some buildings were damaged as a result. Local residents had a suspicion that this earthquake was caused by geothermal power plant production activities, however, Okuaizu Geothermal Co., Ltd. could gain understanding from them by providing explanation of natural earthquakes and man-induced small earthquakes based on the results from 25 years of micro earthquake observation. Yanaizu-cho requested third party institution to provide research on the relationship between the earthquake and business operation of Okuaizu Geothermal Co., Ltd. to respond to local residents' demands. The institution's conclusion coincided with that of ours: that it was unlikely that these two were related.

CONCLUSION

Geothermal electric power generation is a potential natural resources business, nevertheless, it is crucial to recognize that it carries many risks to produce the high temperature and flowing geothermal vapor that lies in non-visible underground, and thus to accumulate vast experience and practical knowhow.