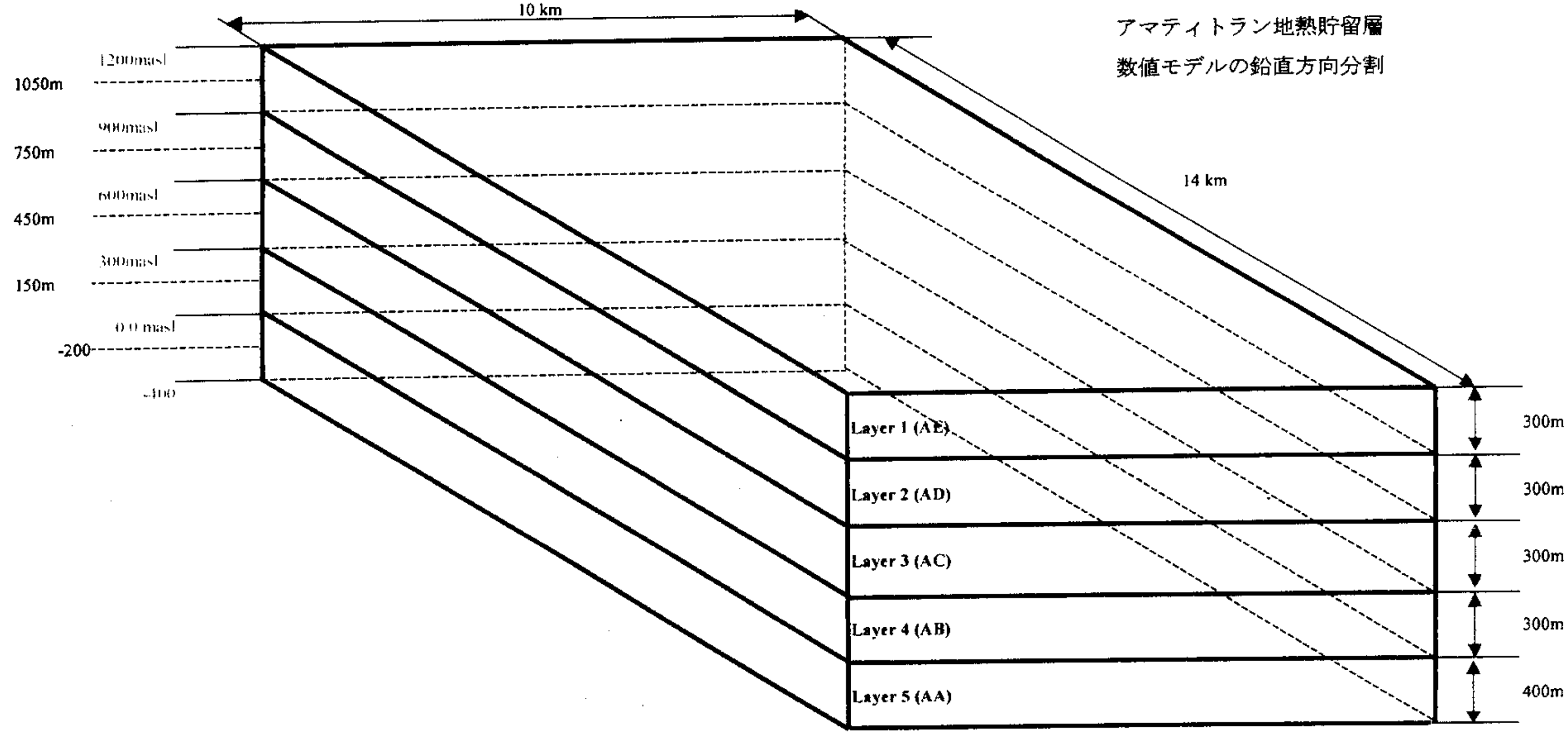
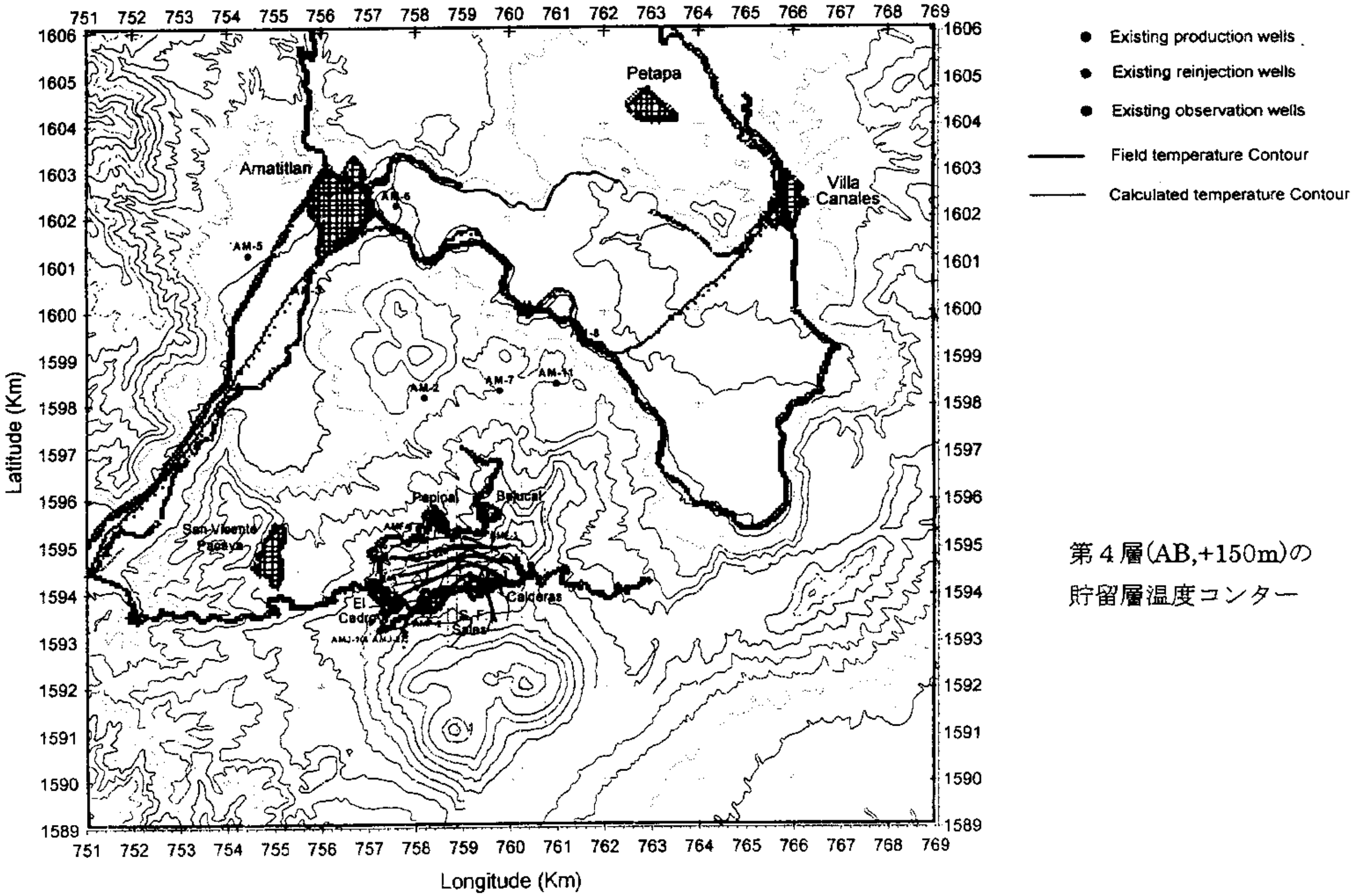
Fig. 3-1-3 Layers of the control volume



Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-4 **Contour map of field and calculated temperatures, layer 4 (AB, +150 m)**



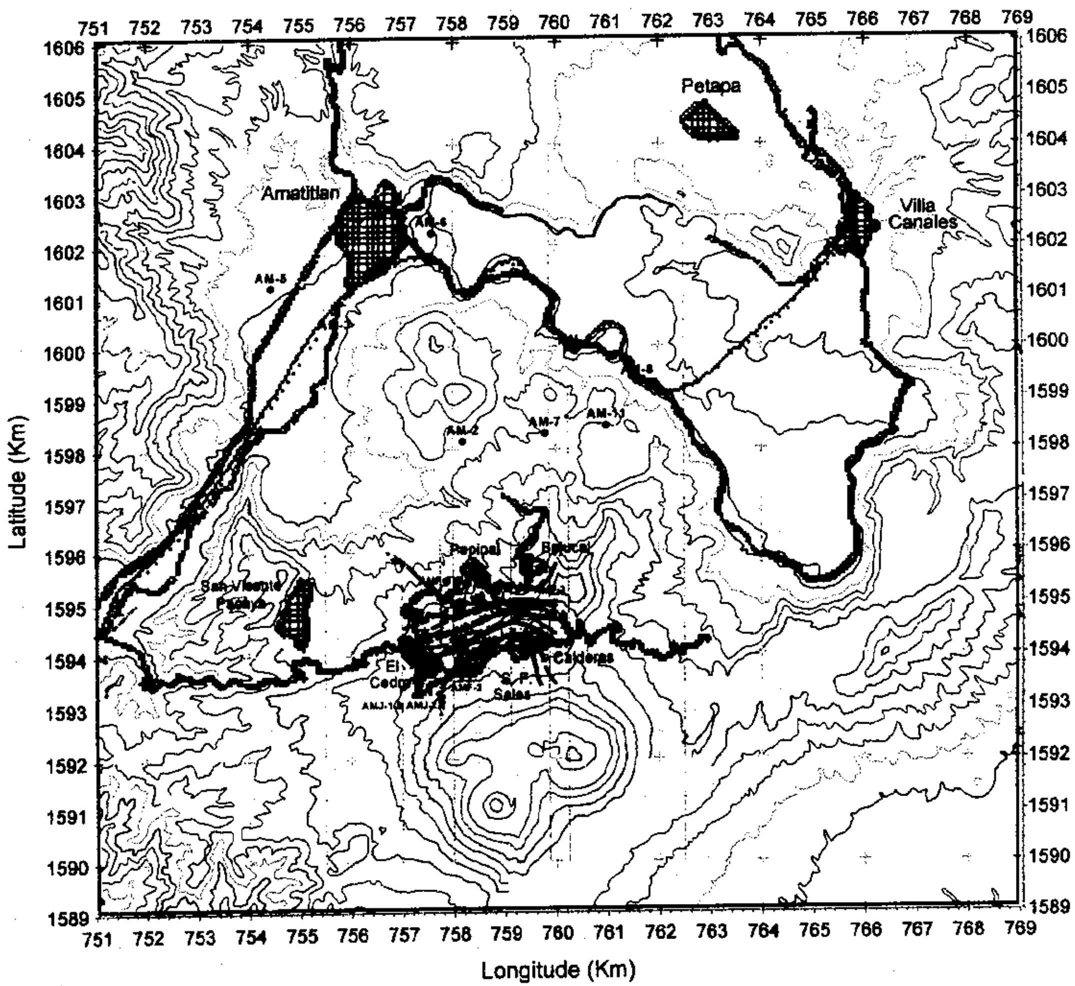
第４層(AB,+150m)の
貯留層温度コンター

Amati_Wells-NS_Temp_150.srf

JICA/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-5 Contour map of field and calculated temperatures, layer 3 (AC, +450 m)



● Existing production wells
● Existing reinjection wells
● Existing observation wells
—— Field temperature Contour
—— Calculated temperature Contour

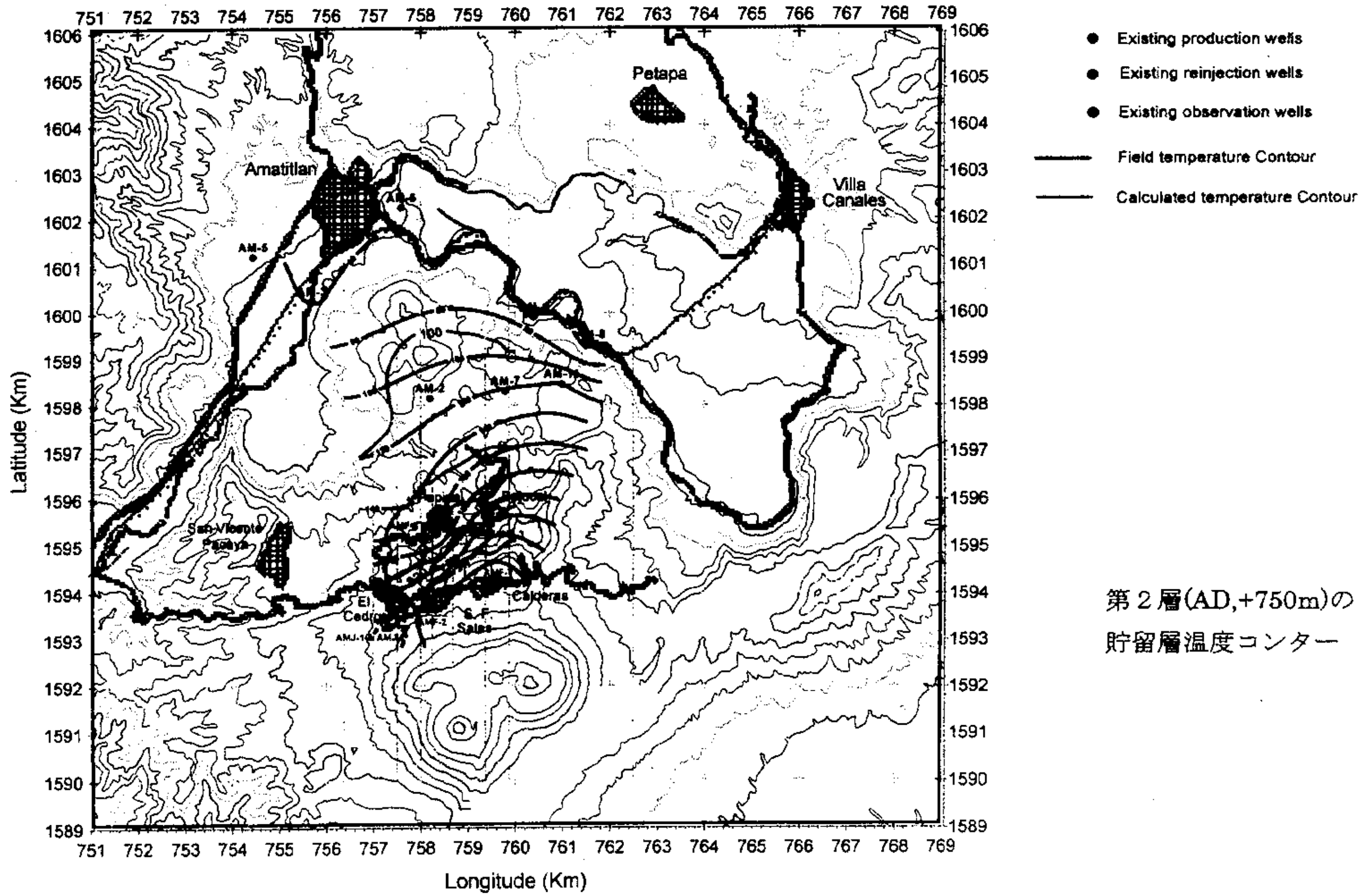
第３層(AC,+450m)の
貯留層温度コンター

JICA/West Jec

Amab_Wells-N8_Temp_450.surf

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-6 Contour map of field and calculated temperatures, layer 2 (AD, +750 m)



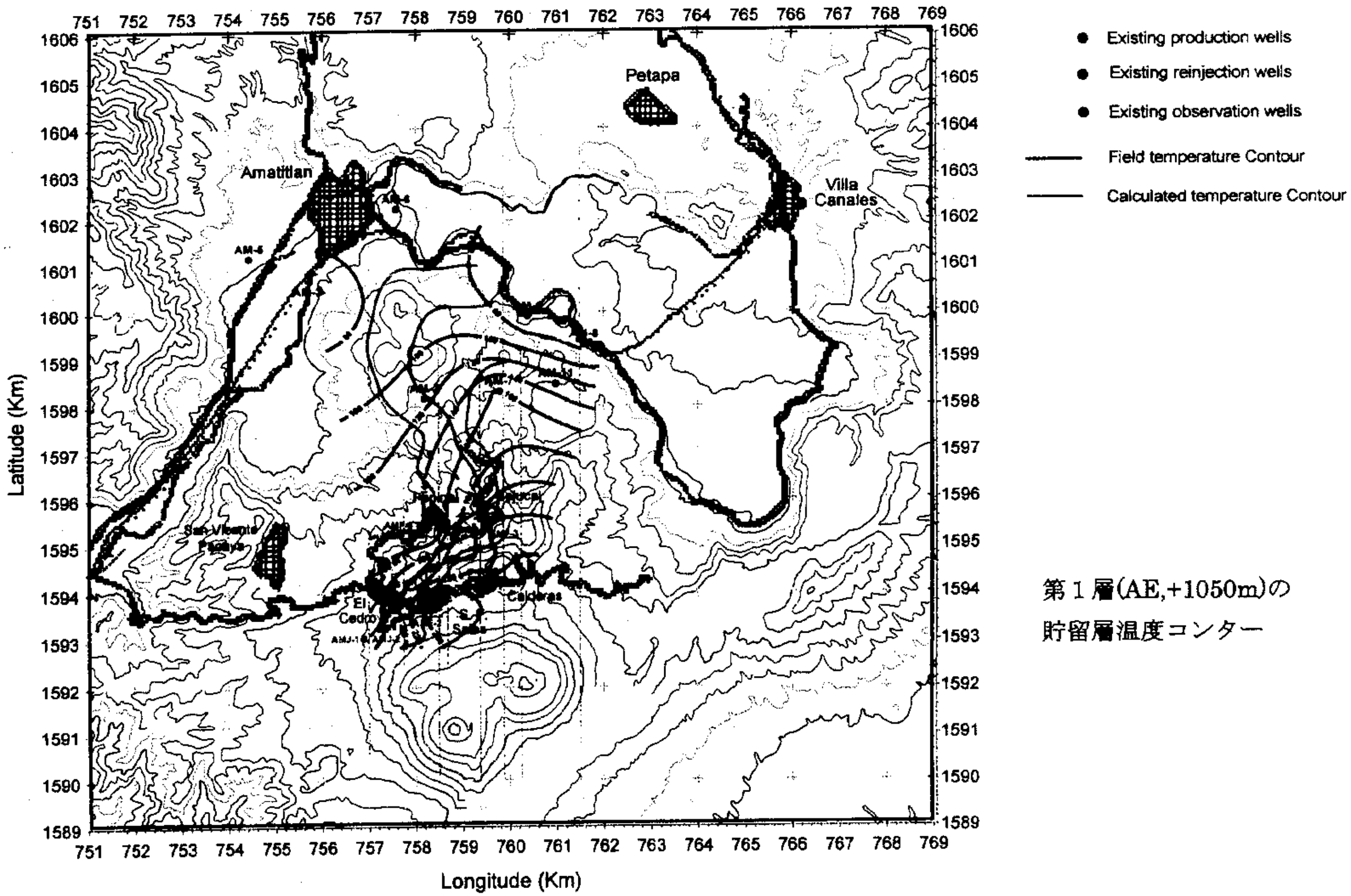
第２層(AD,+750m)の
貯留層温度コンター

Amati_Wells-NS_Temp_750.surf

JICA/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-7 Contour map of field and calculated temperatures, layer 1 (AE, +1050 m)



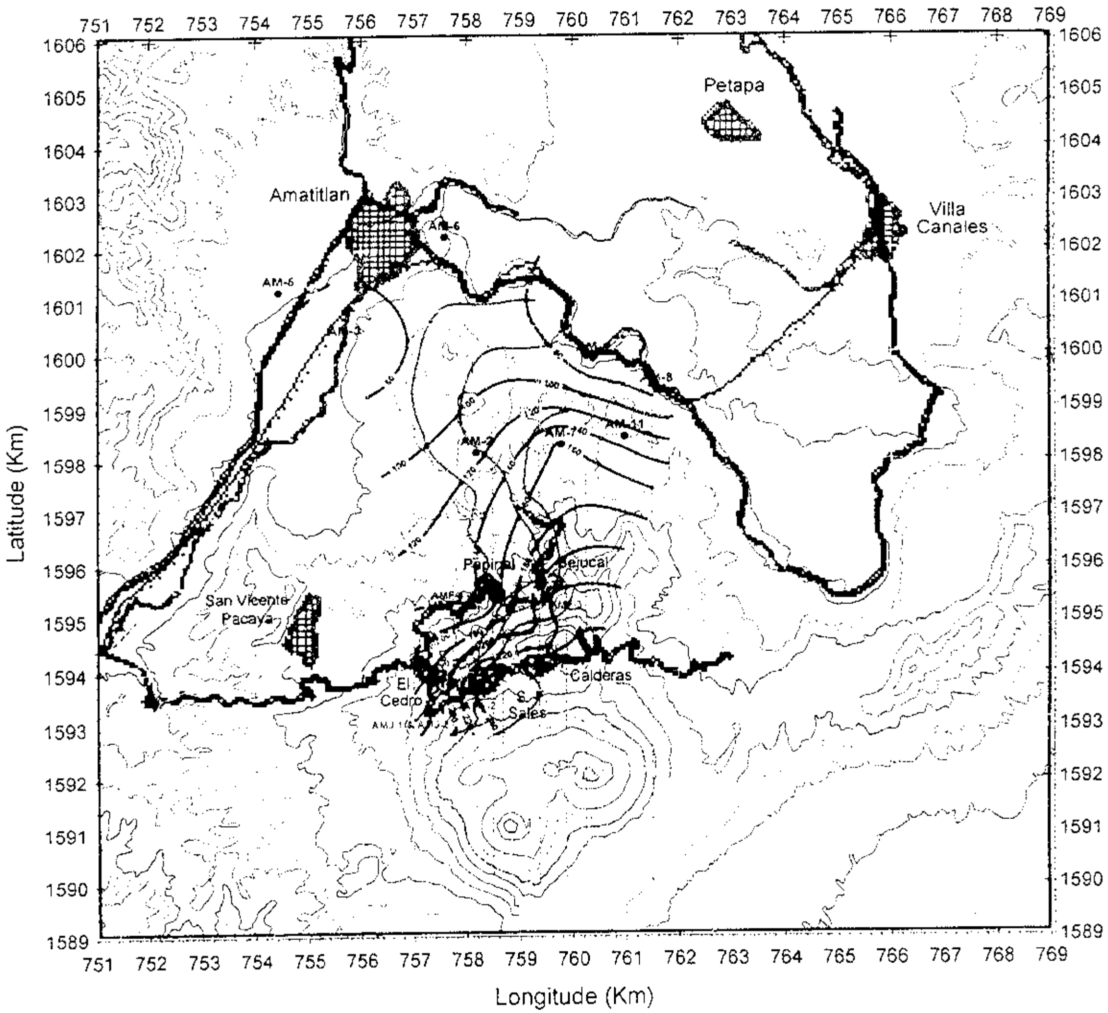
第１層(AE,+1050m)の
貯留層温度コンター

Amat_Wells-NS_Temp_1050.surf

JICA/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-7 Contour map of field and calculated temperatures, layer 1 (AE, +1050 m)



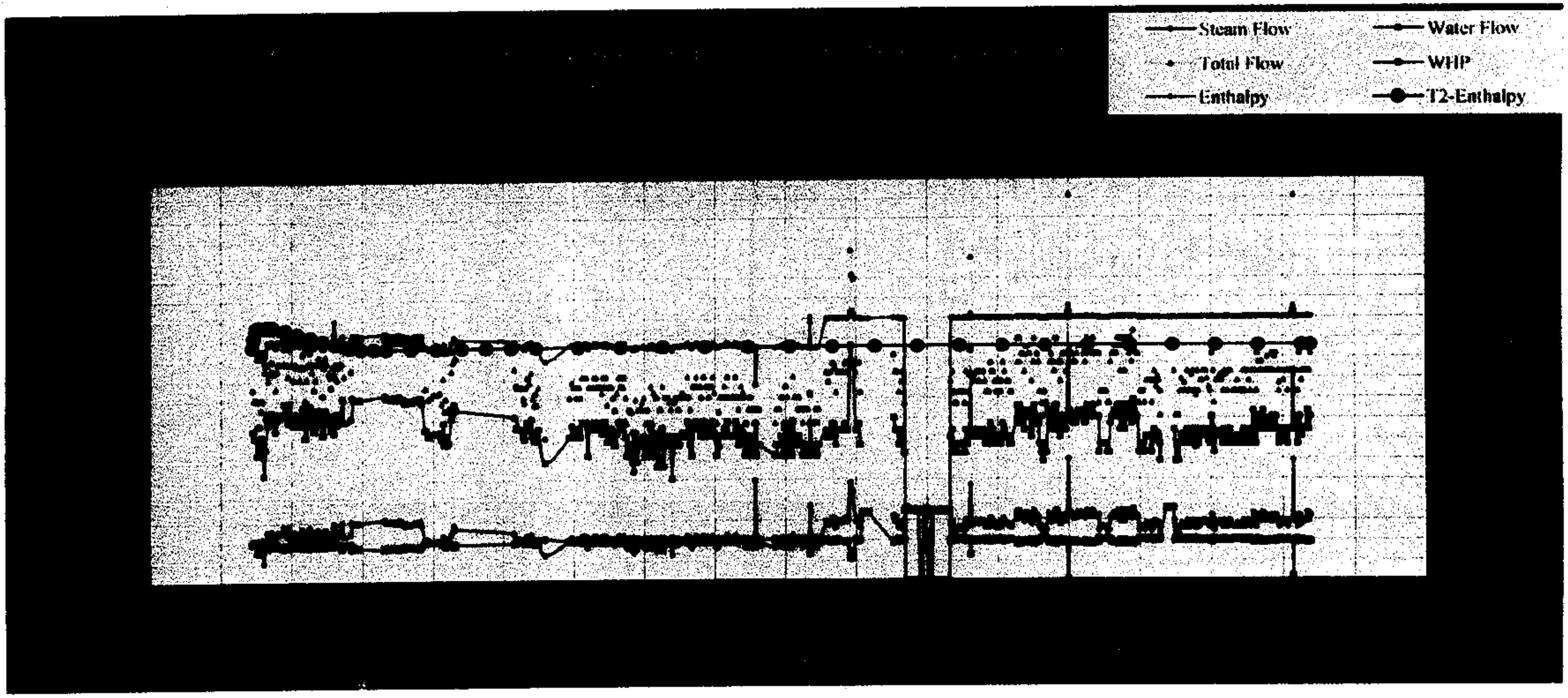
Existing production wells
Existing reinjection wells
Existing observation wells
Field temperature Contour
Calculated temperature Contour

第１層(AE,+1050m)の
貯留層温度コンター

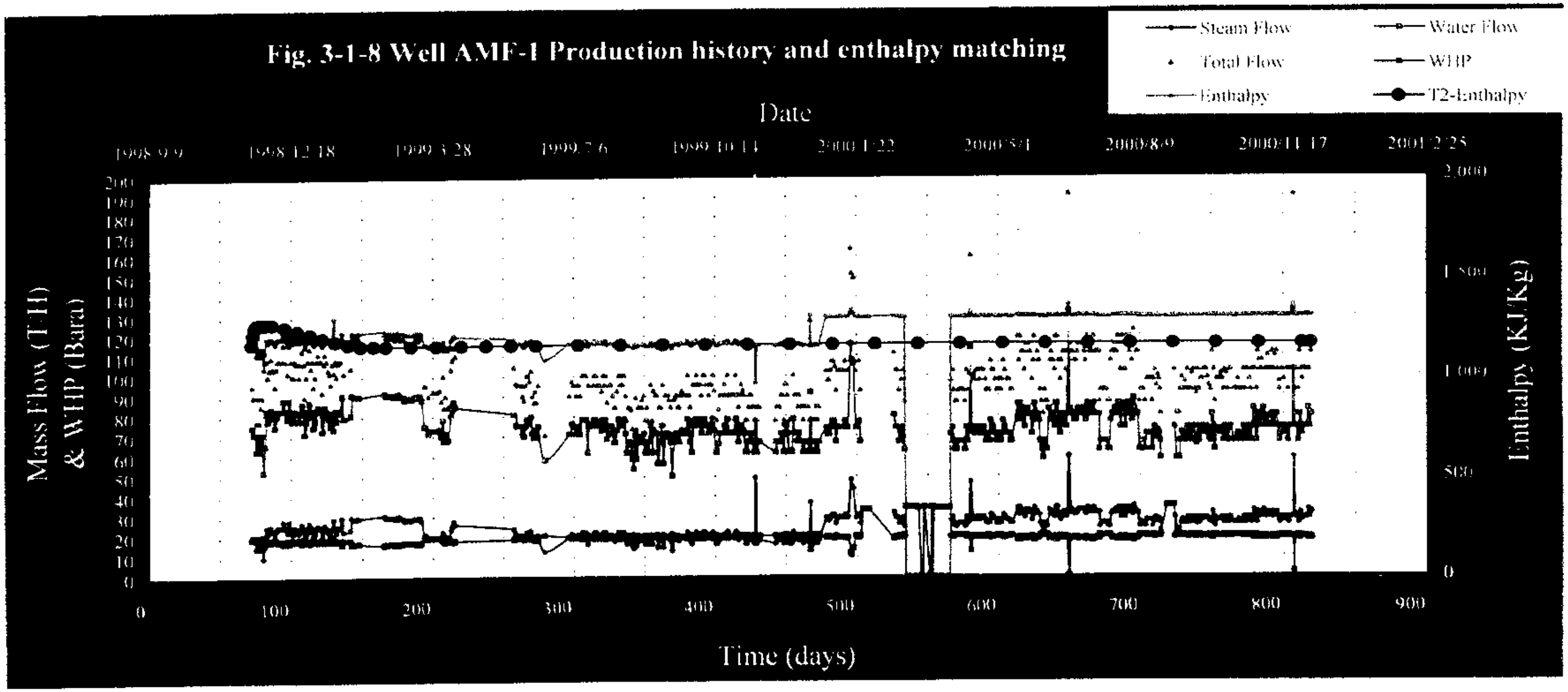
Amatı_Wells-NS_Temp_1050.surf

JICA/West Jec

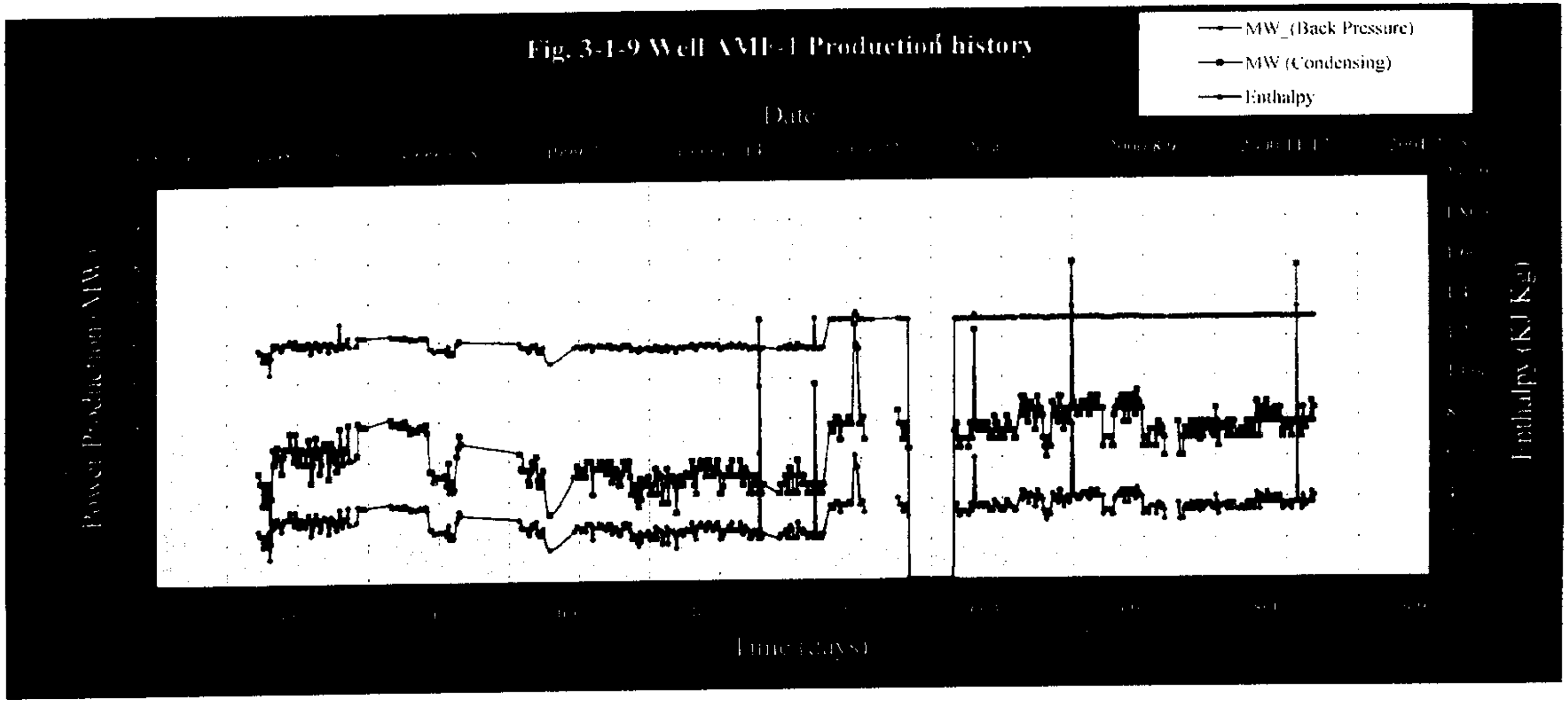
生産井 AMF-1 の噴出量変化とエンタルピーマッチング



生産井 AMF-1 の噴出量変化とエンタルピーマッチング



生産井 AMF-1 の出力変化



生産井 AMF-1 の出力変化

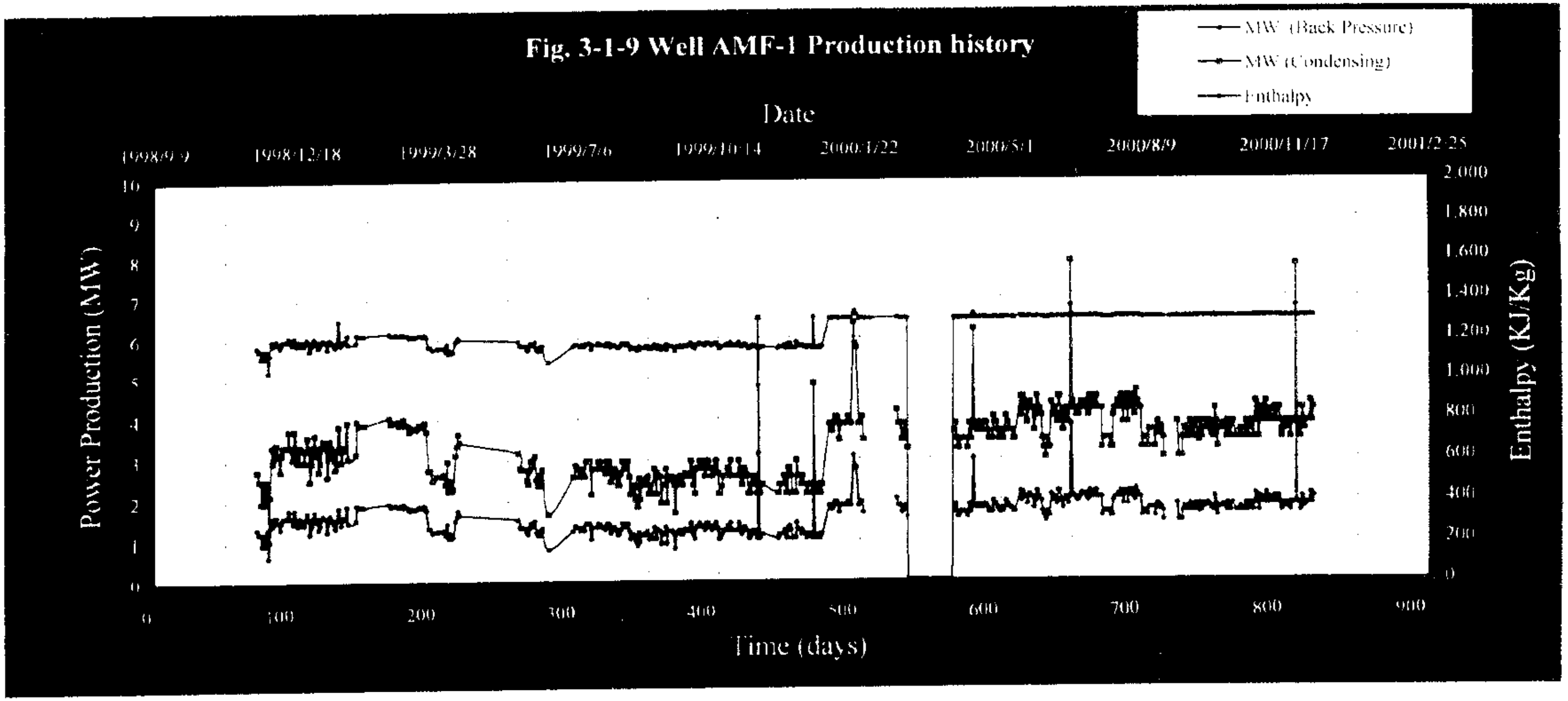


Fig. 3-1-9 Well AMF-1 Production history

生産井 AMF-2 の噴出量変化とエンタルピーマッチング

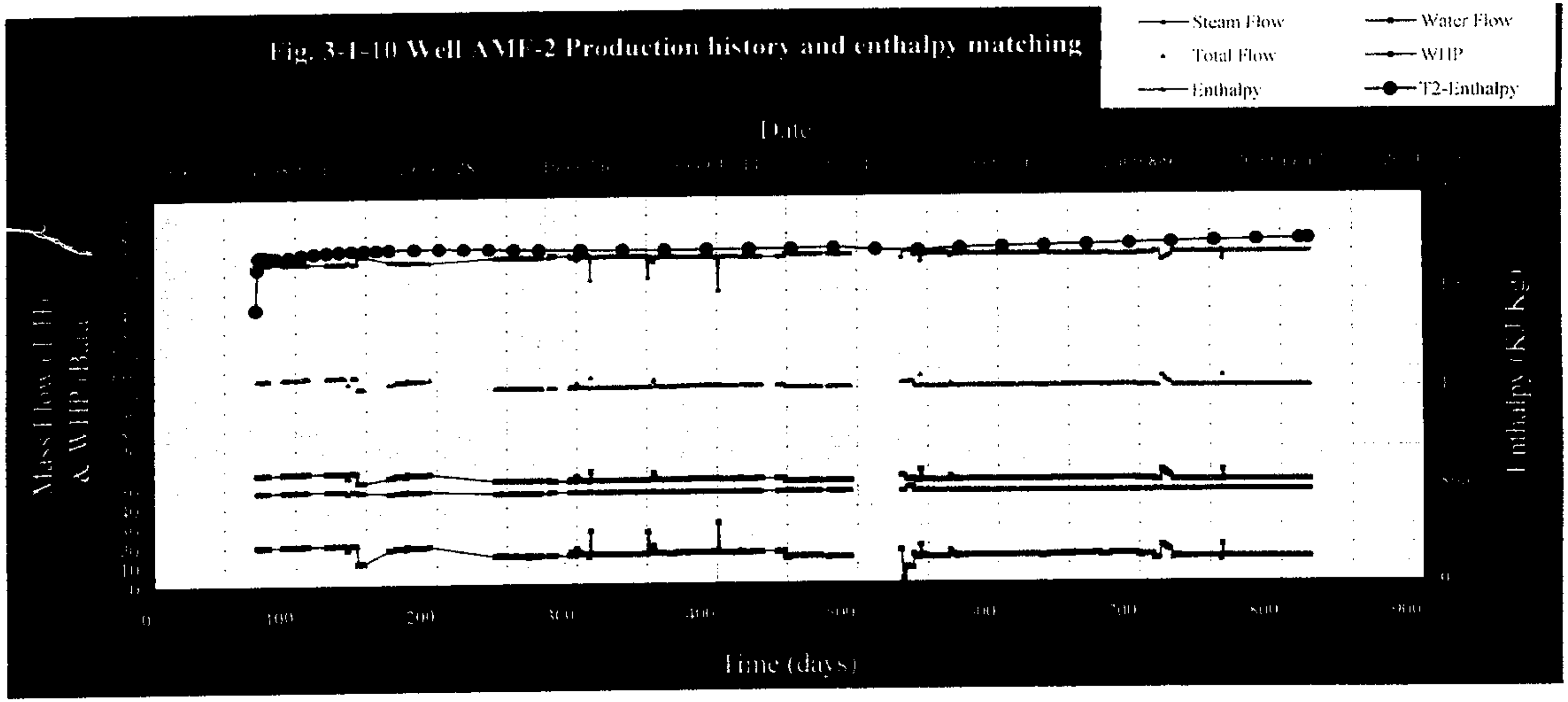


Fig. 3-1-10 Well AMF-2 Production history and enthalpy matching

生産井 AMF-2 の噴出量変化とエンタルピーマッチング

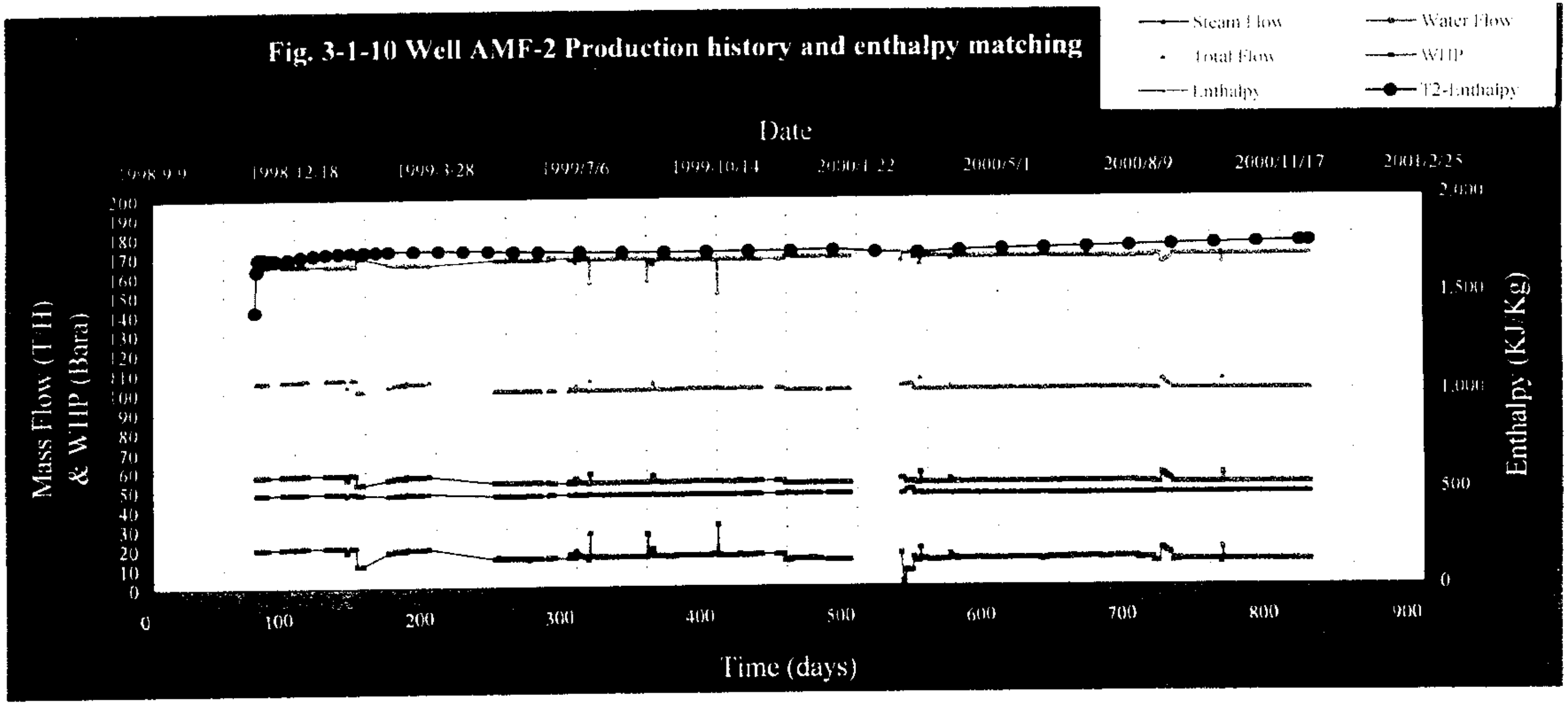
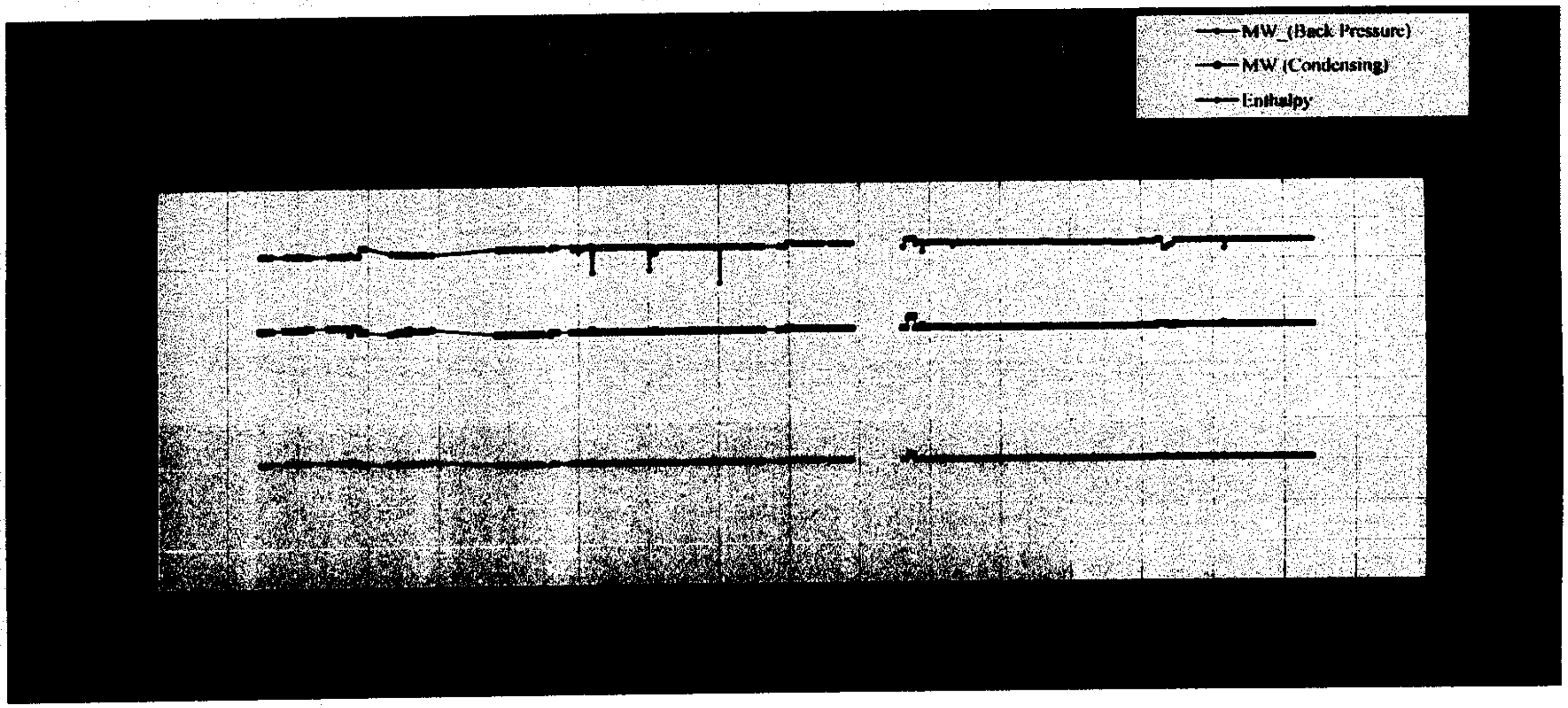


Fig. 3-1-10 Well AMF-2 Production history and enthalpy matching

生産井 AMF-2 の出力変化



生産井 AMF-2 の出力変化

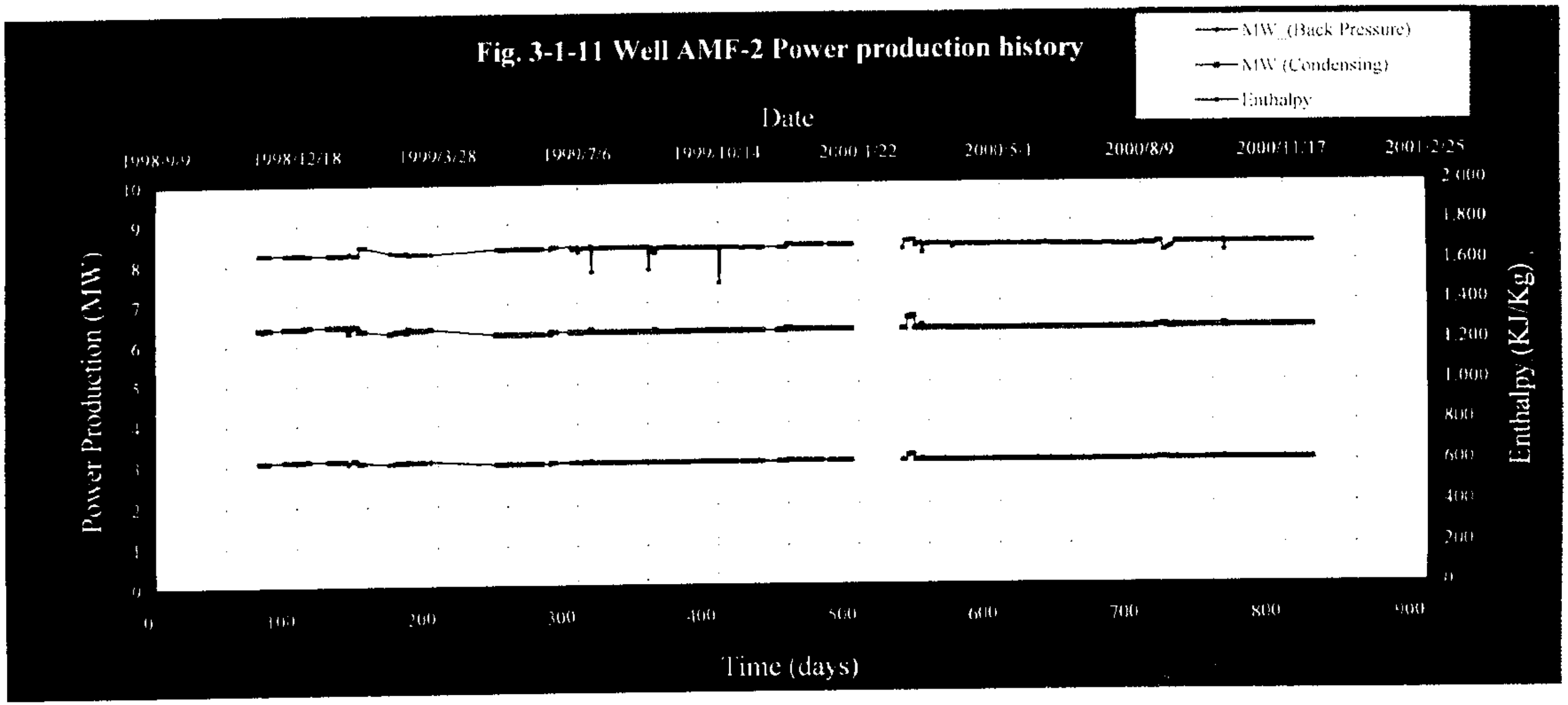
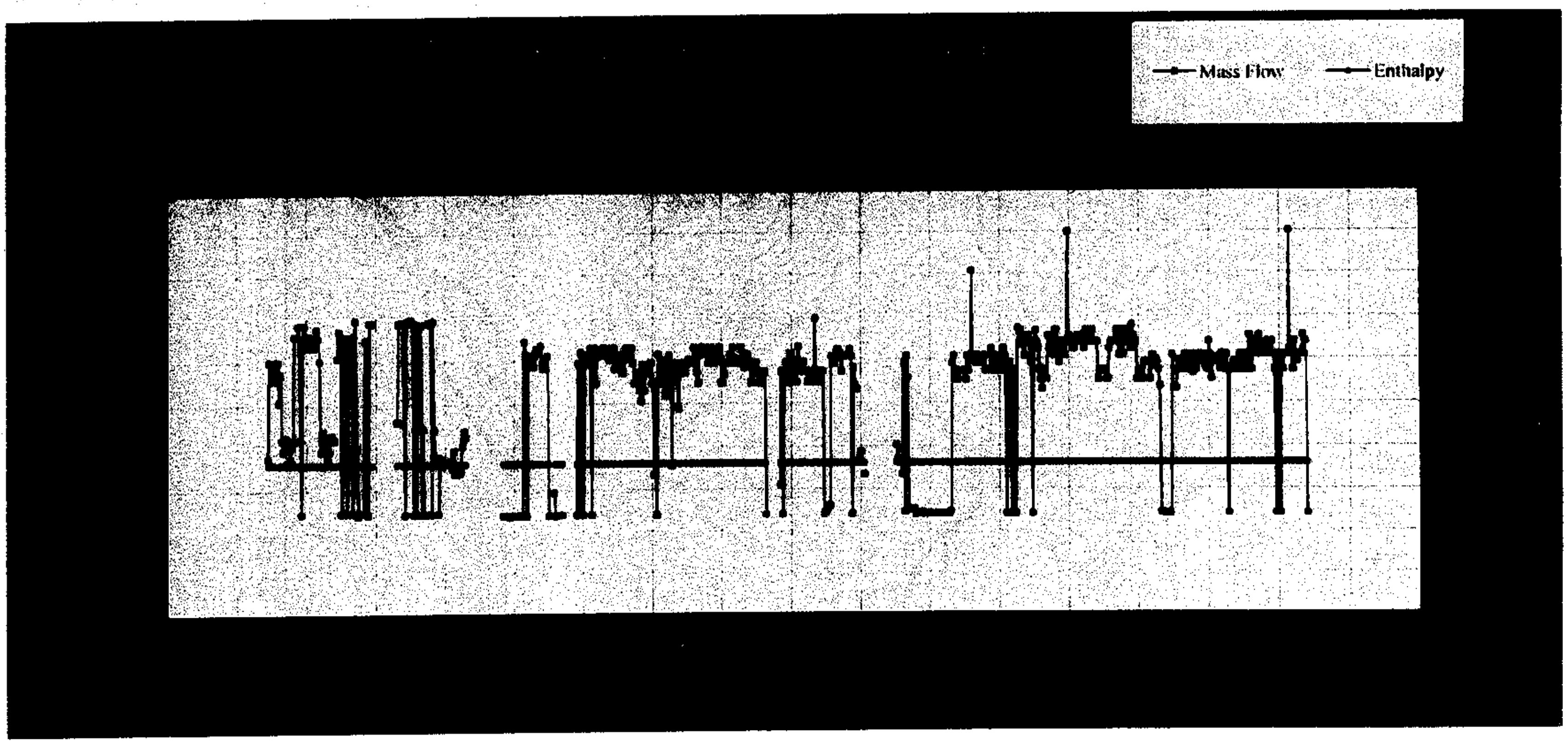


Fig. 3-1-11 Well AMF-2 Power production history

還元井 AMF-3 の還元量変化



還元井 AMF-3 の還元量変化

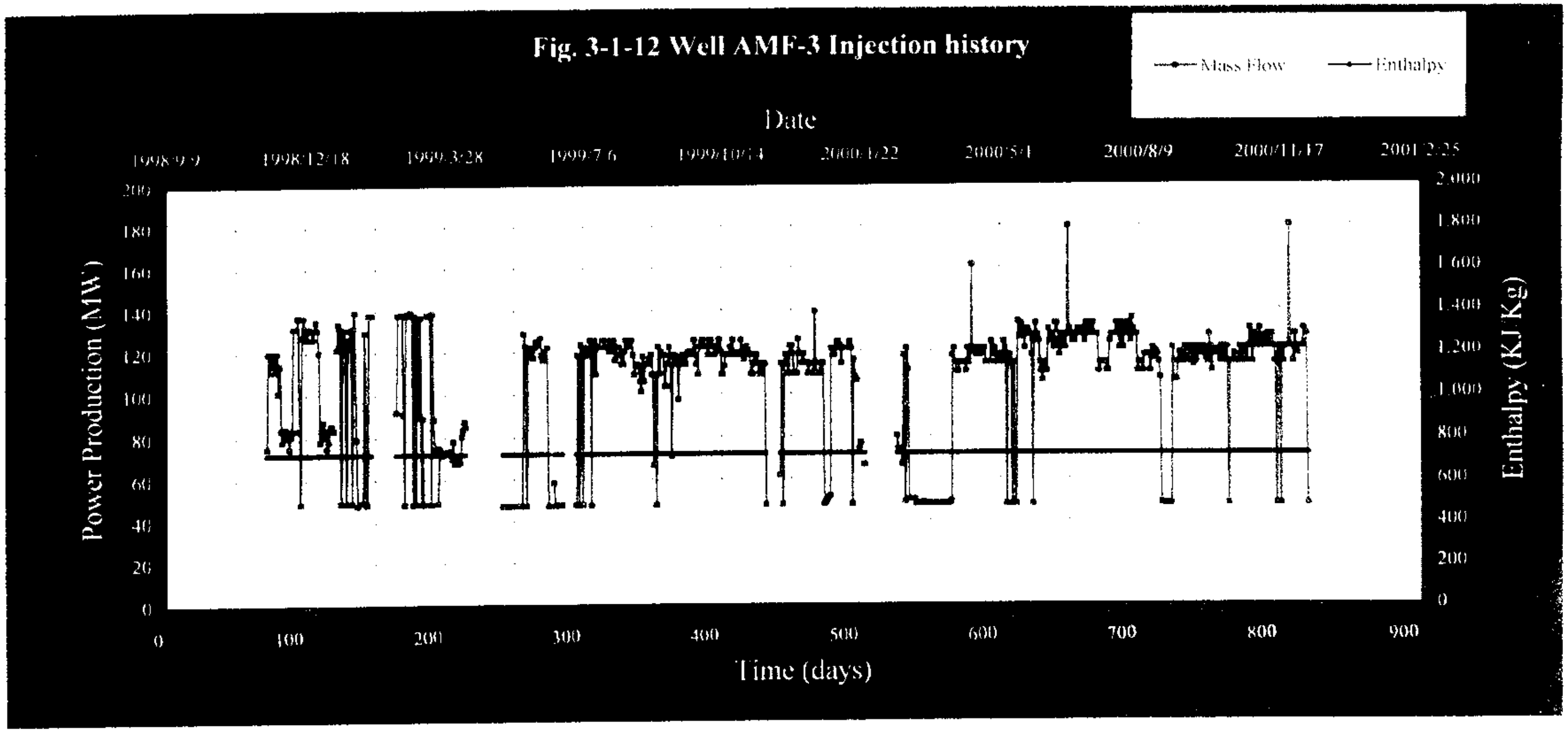
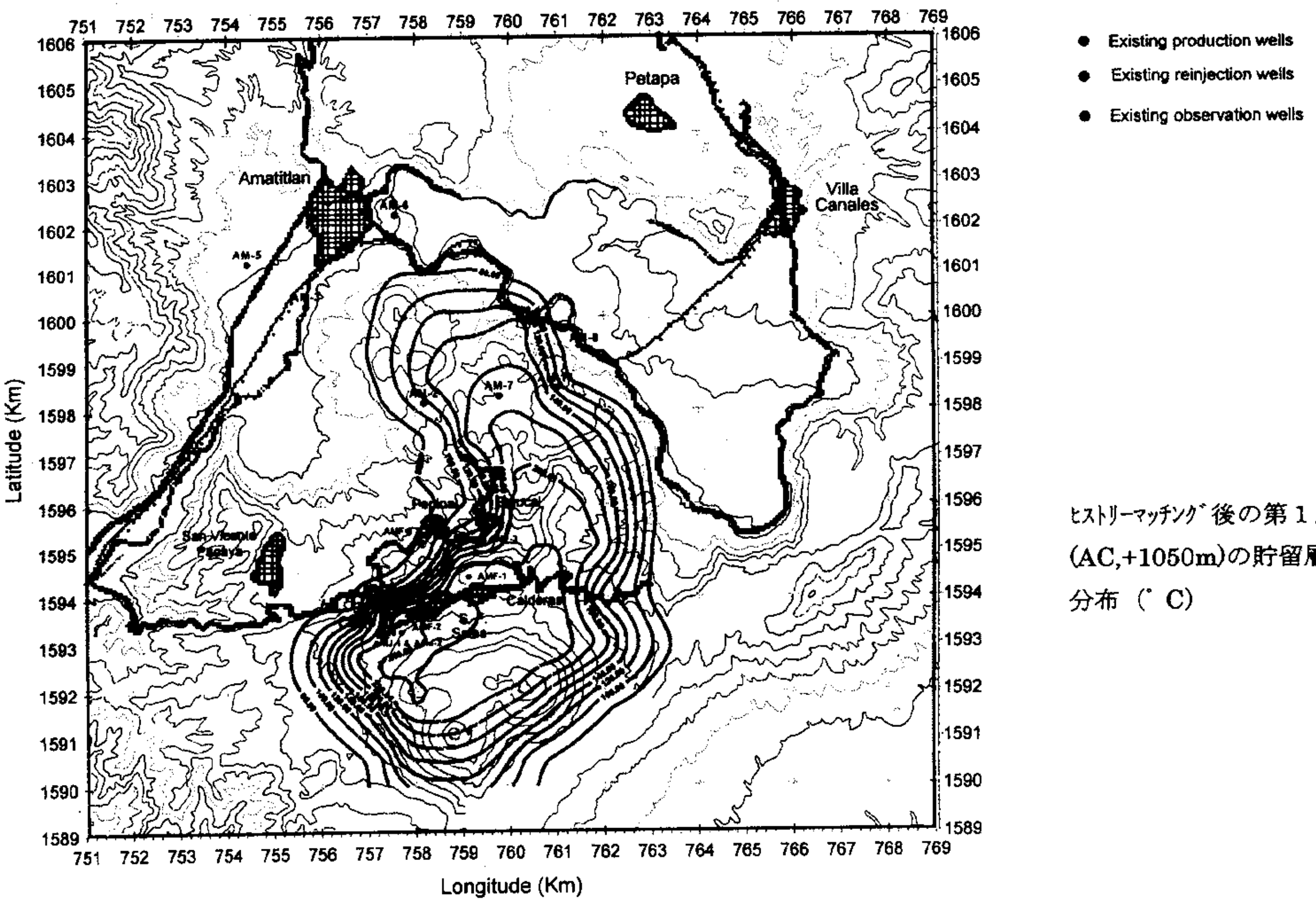


Fig. 3-1-12 Well AMF-3 Injection history

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-13 Temperature (C) distribution after history matching calibration, Layer 1 (AE, +1050)

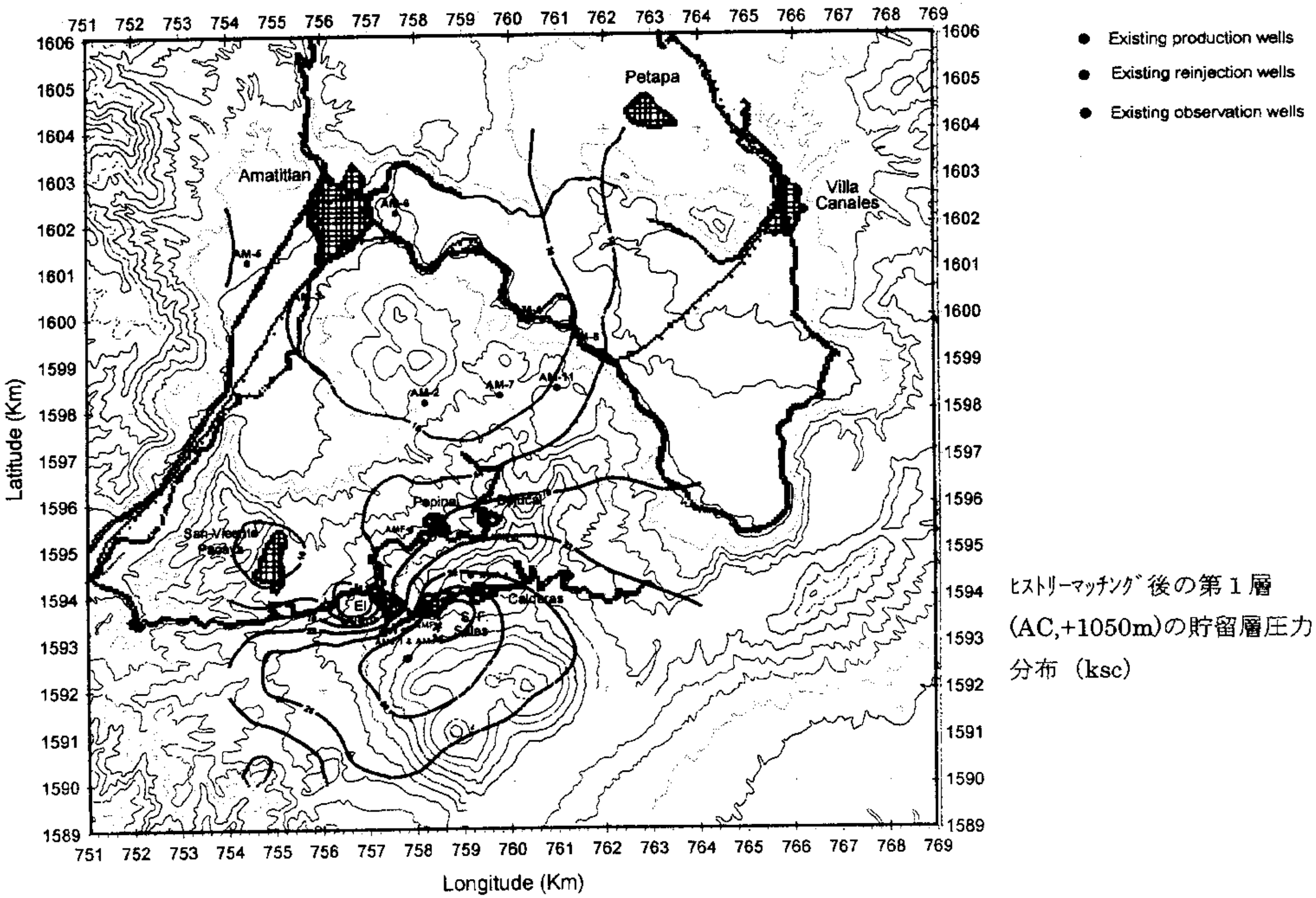


ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第１層
(AC,+1050m)の貯留層温度
分布（゜C）

INDE/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-14 Pressure (ksc) distribution after history matching calibration, Layer 1 (AE, +1050)



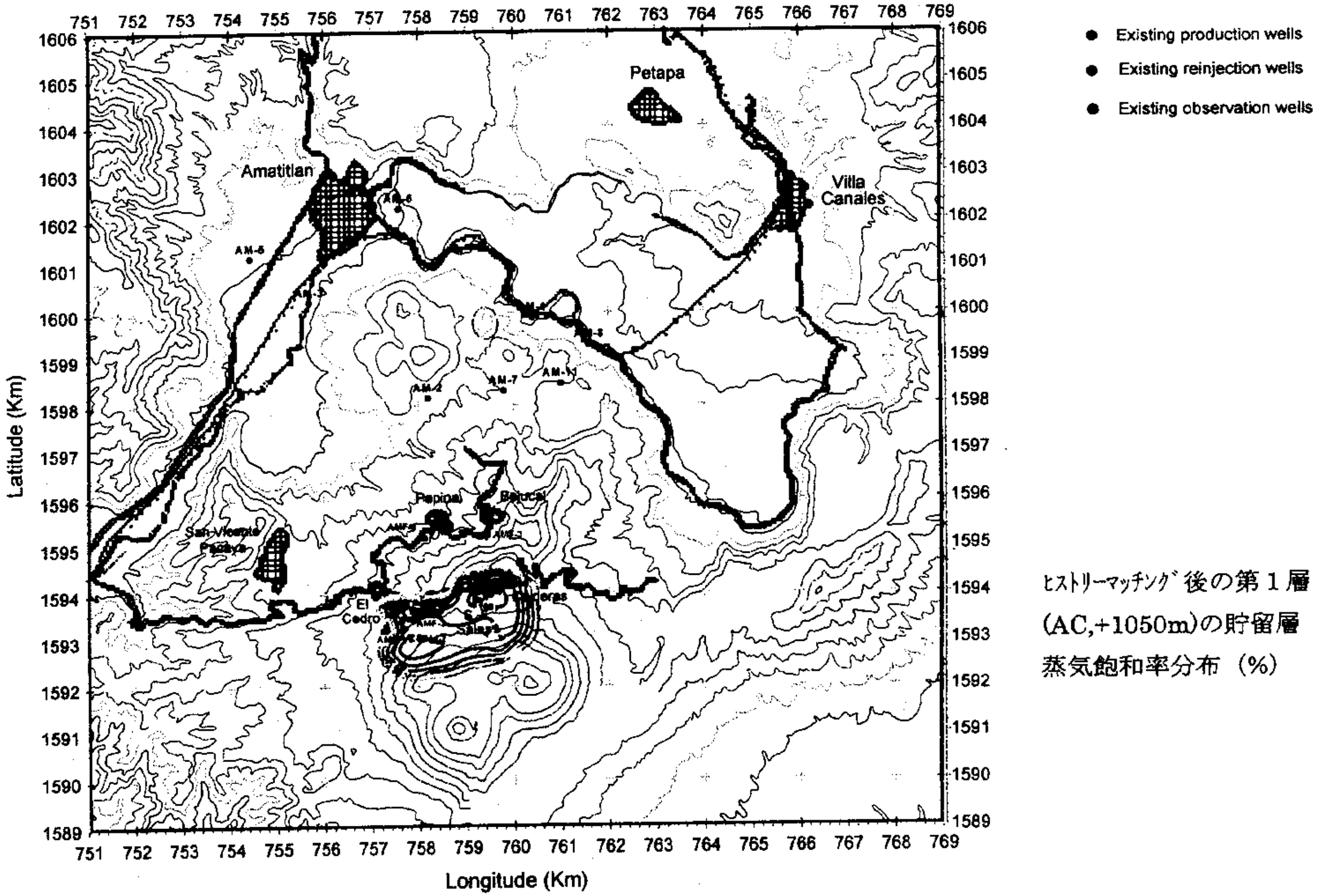
ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第１層(AC,+1050m)の貯留層圧力分布（ksc）

INDE/West Jec

AMTI-P_Last_1050.surl

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-15 Steam Saturation (%) distribution after history matching calibration, Layer 1 (AE, +1050)



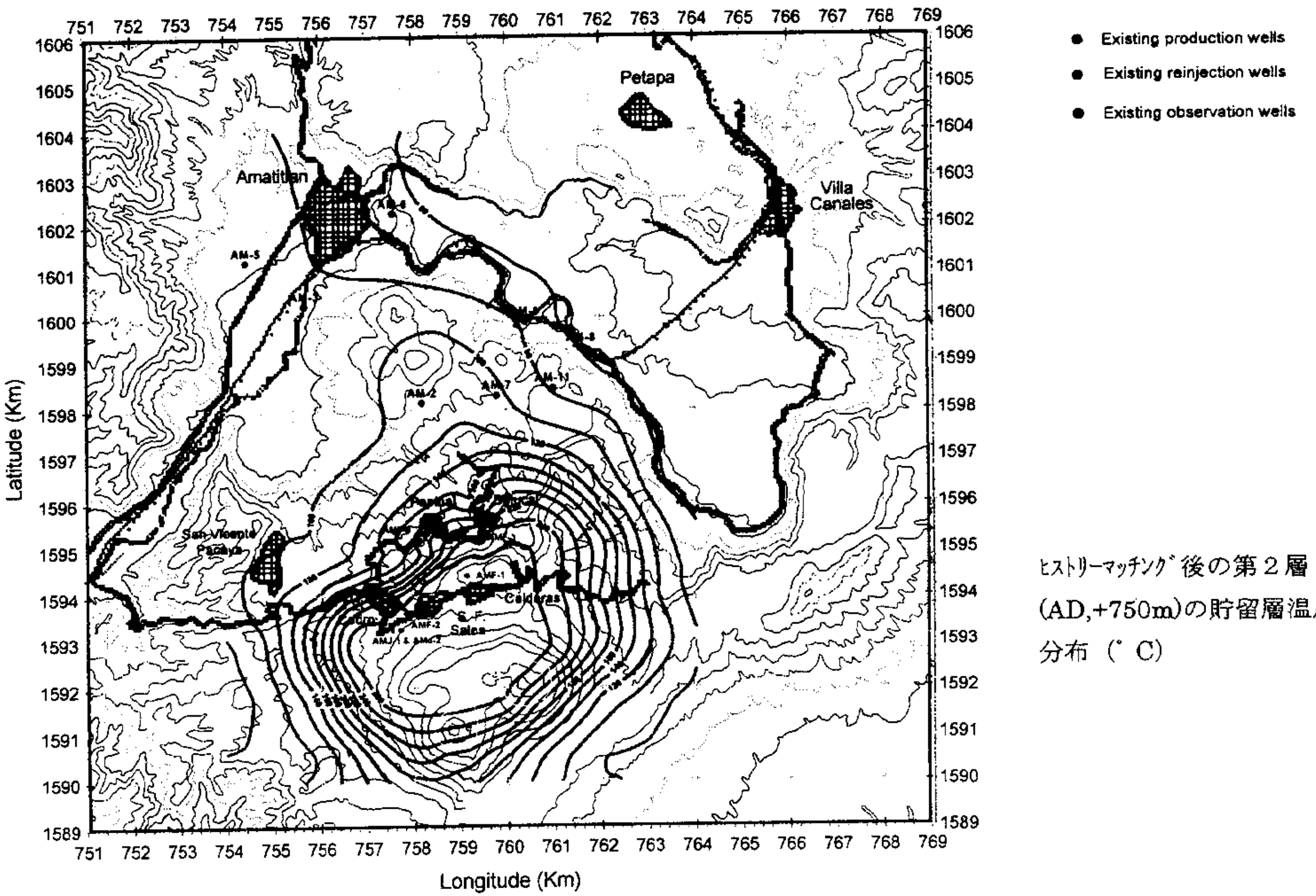
ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第１層
(AC,+1050m)の貯留層
蒸気飽和率分布 (%)

AMTI-S_Last_1050.surf

INDE/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-16 Temperature (C) distribution after history matching calibration, Layer 2 (AD, +750)



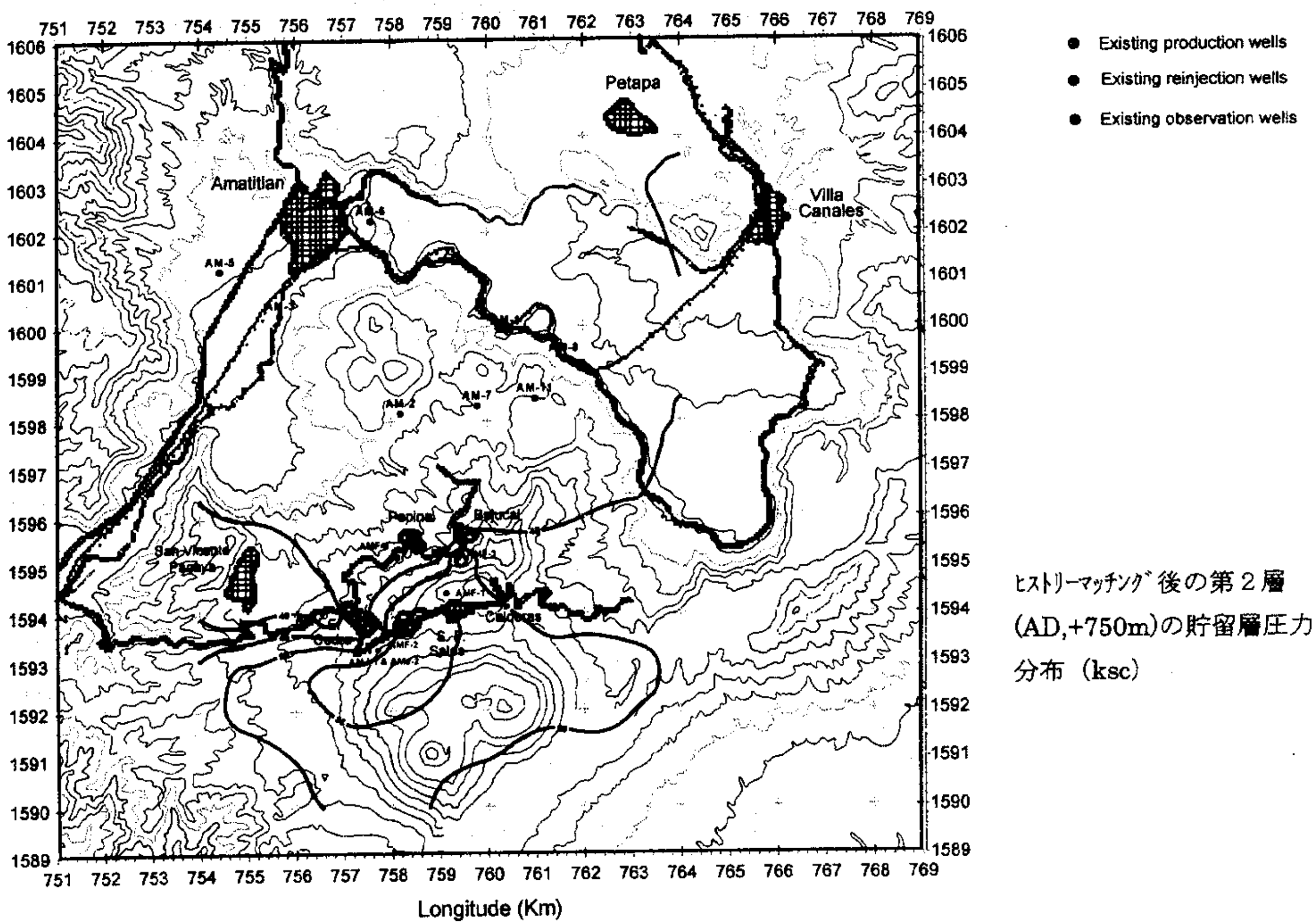
ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第２層(AD,+750m)の貯留層温度分布（゜C）

AMTI-T_Last-750.surf

INDE/West Jec

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-17 Pressure (ksc) distribution after history matching calibration, Layer 2 (AD, +750)



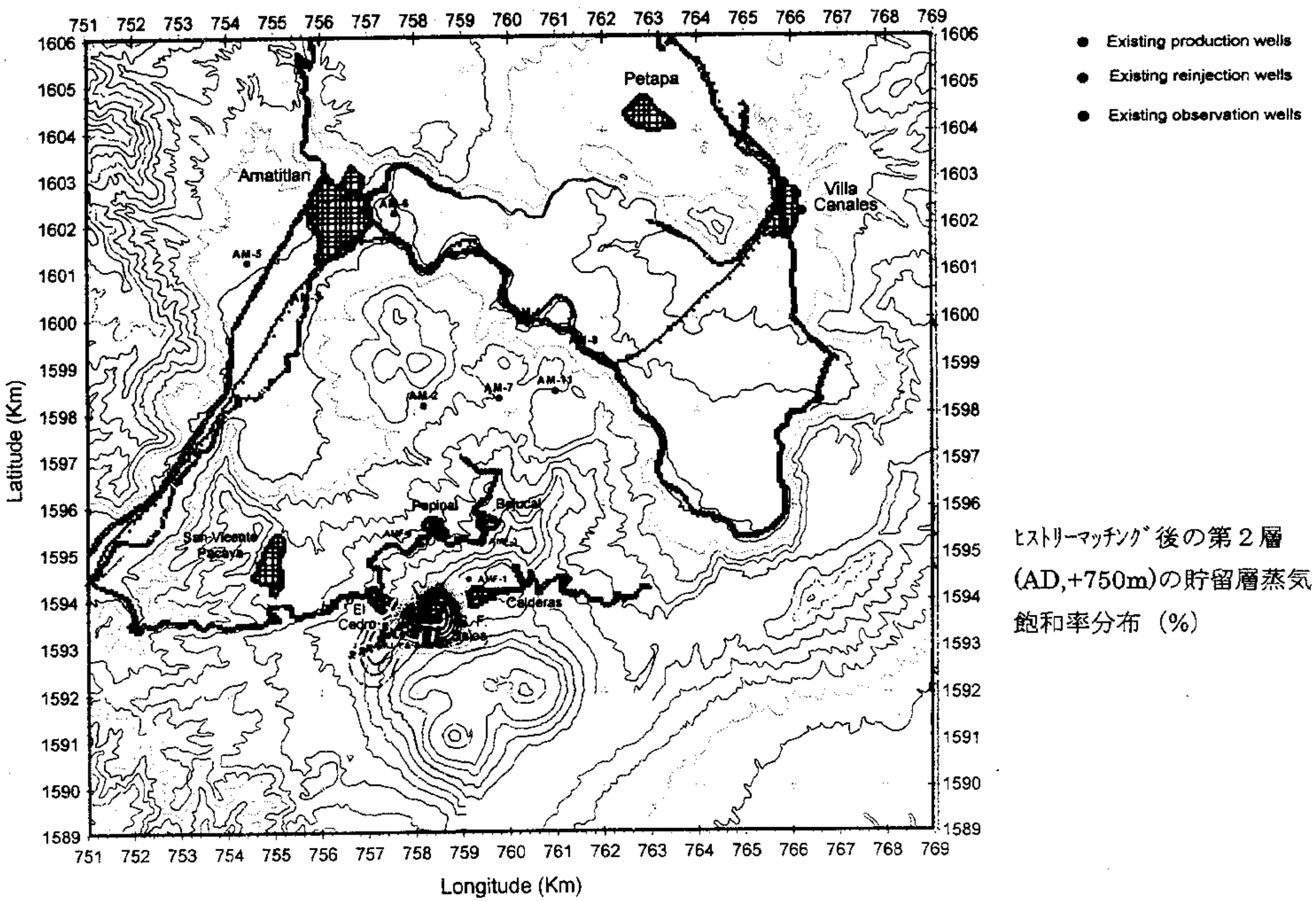
ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第２層(AD,+750m)の貯留層圧力分布 (ksc)

AMTI-P_Last_750.surf

INDE/West Jec

Amatitlan Geothermal Field Reservoir Simulation

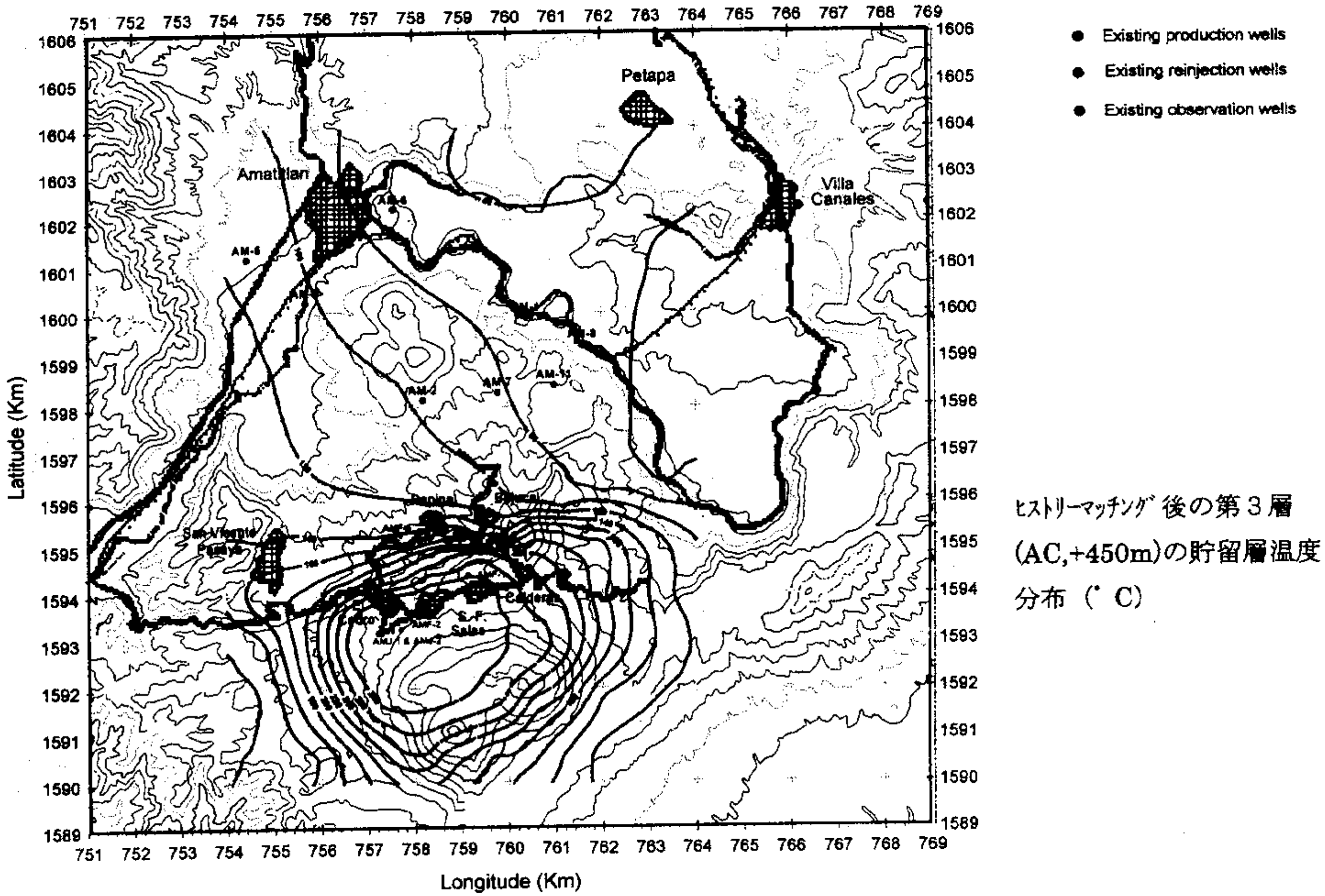
Fig. 3-1-18 Steam Saturation (%) distribution after history matching calibration, Layer 2 (AD, +750)



ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第２層(AD,+750m)の貯留層蒸気飽和率分布（%）

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-19 Temperature (C) distribution after history matching calibration, Layer 3 (AC, +450)



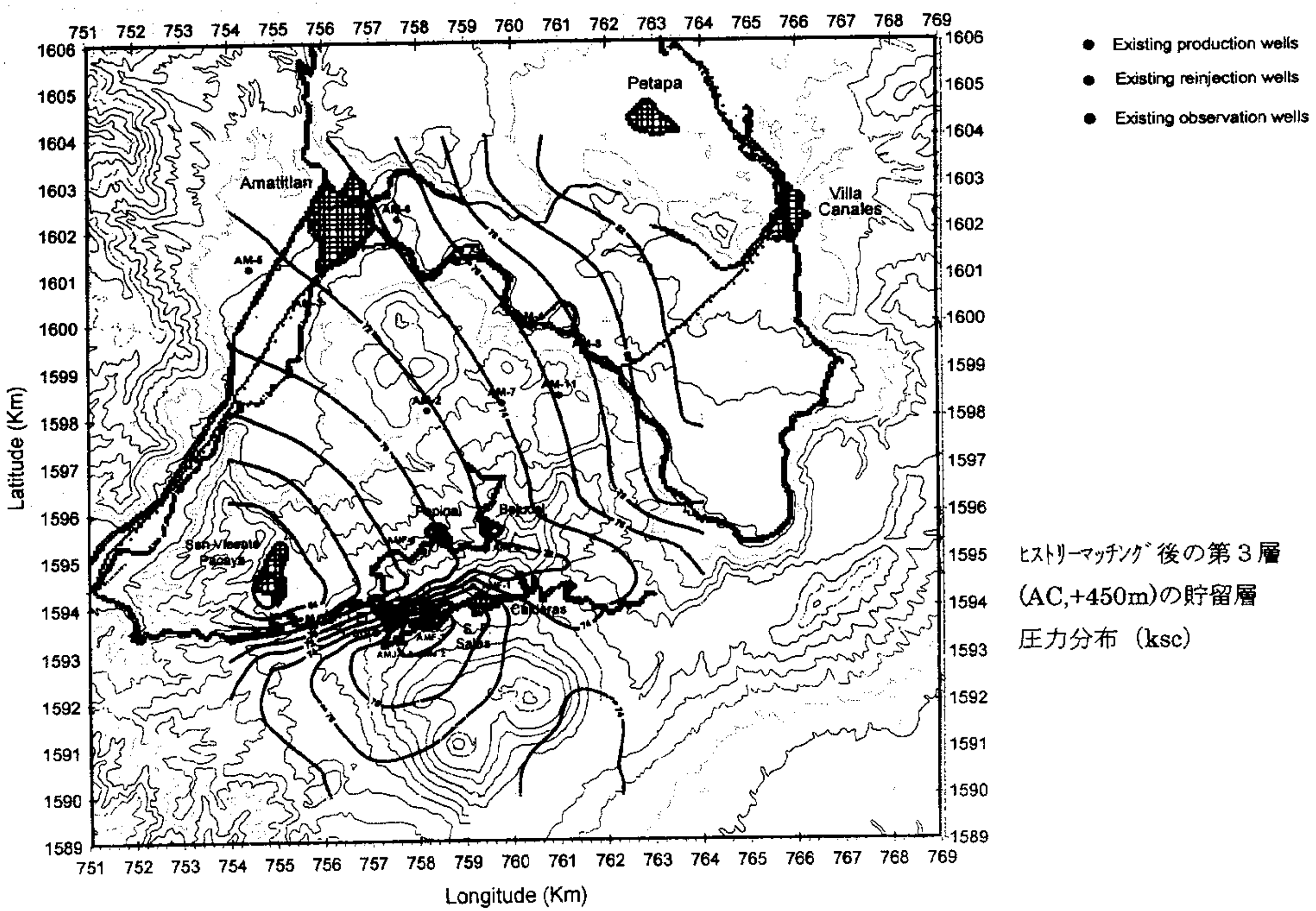
ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第３層
(AC,+450m)の貯留層温度
分布（°C)

INDE/West Jec

AMTI-T Last-450.surf

Amatitlan Geothermal Field Reservoir Simulation

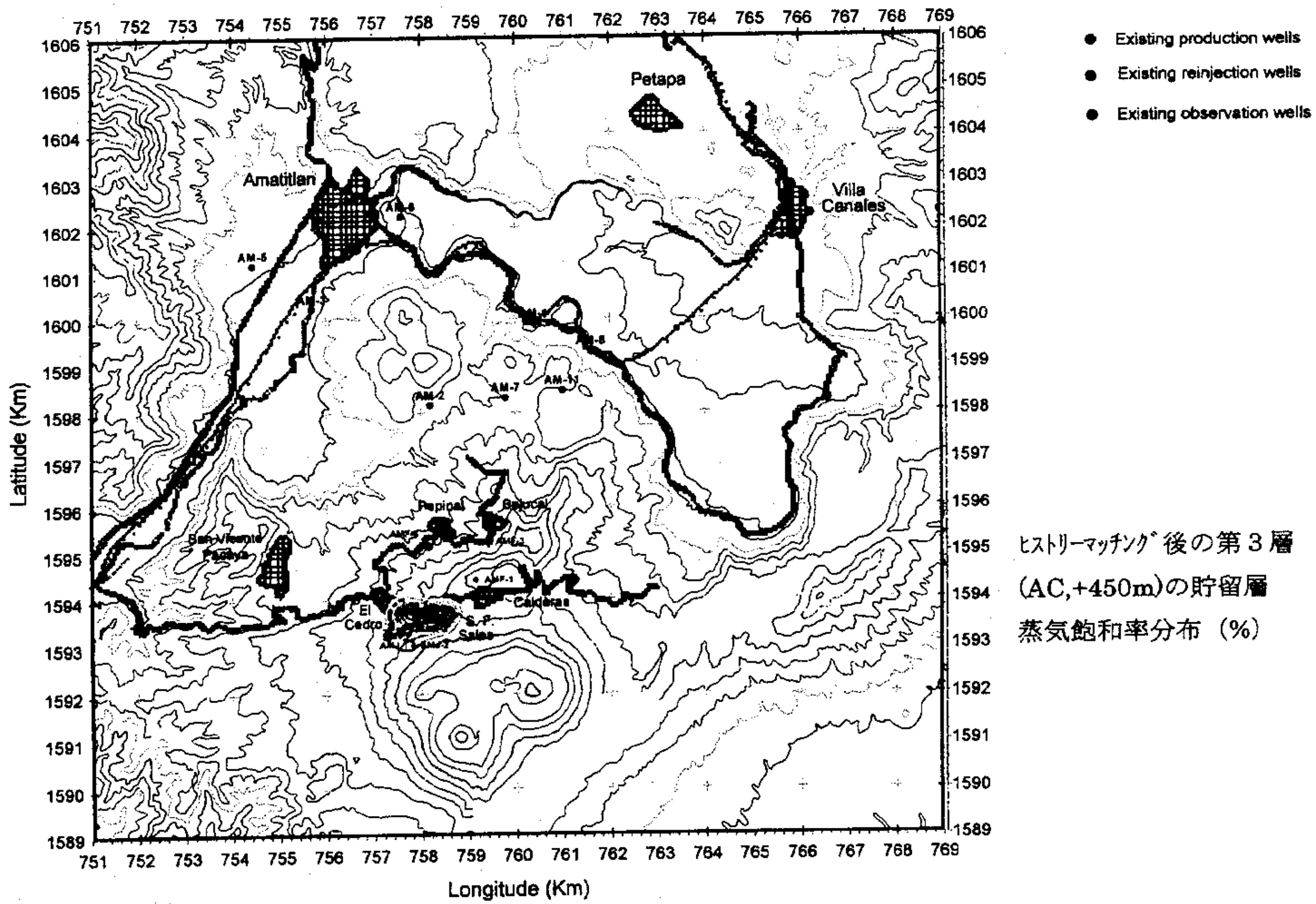
Fig. 3-1-20 Pressure (ksc) distribution after history matching calibration, Layer 3 (AC, +450)



ﾋｽﾄﾘｰﾏｯﾁﾝｸﾞ後の第３層
(AC,+450m)の貯留層
圧力分布（ksc)

Amatitlan Geothermal Field Reservoir Simulation

Fig. 3-1-21 Steam Saturation (%) distribution after history matching calibration, Layer 3 (AC, +450)



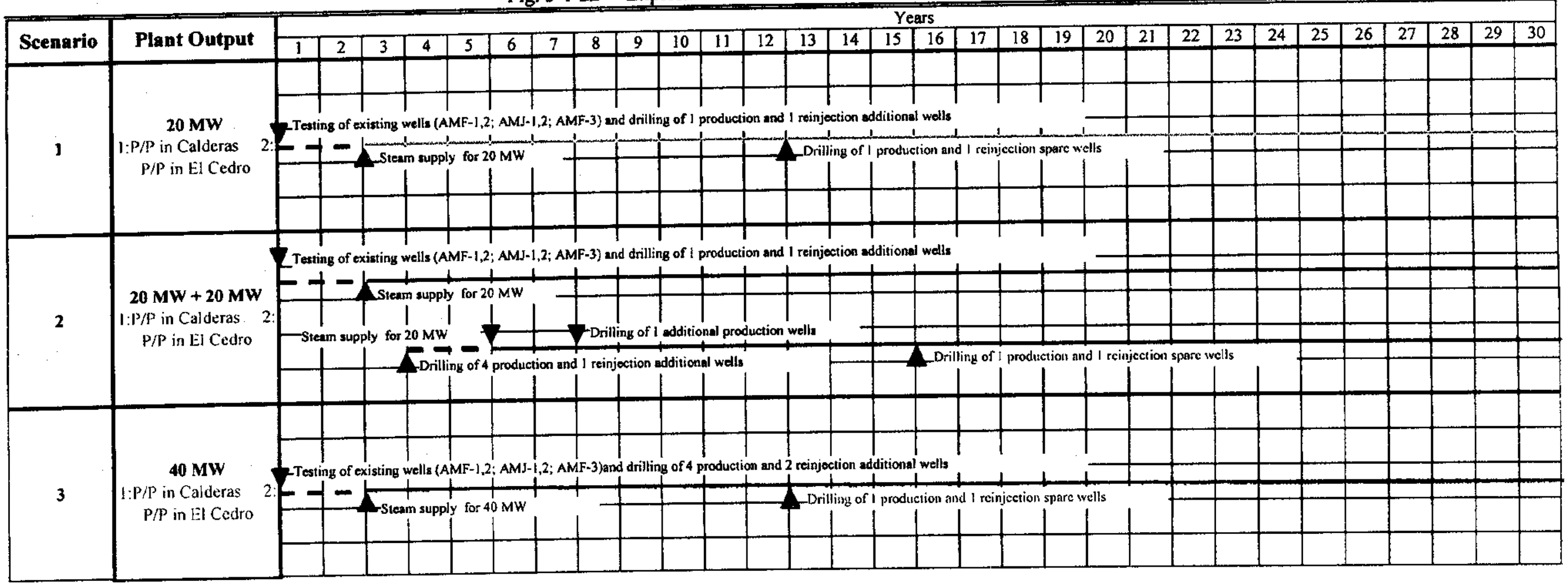
ヒストリーマッチング後の第３層
(AC,+450m)の貯留層
蒸気飽和率分布（%）

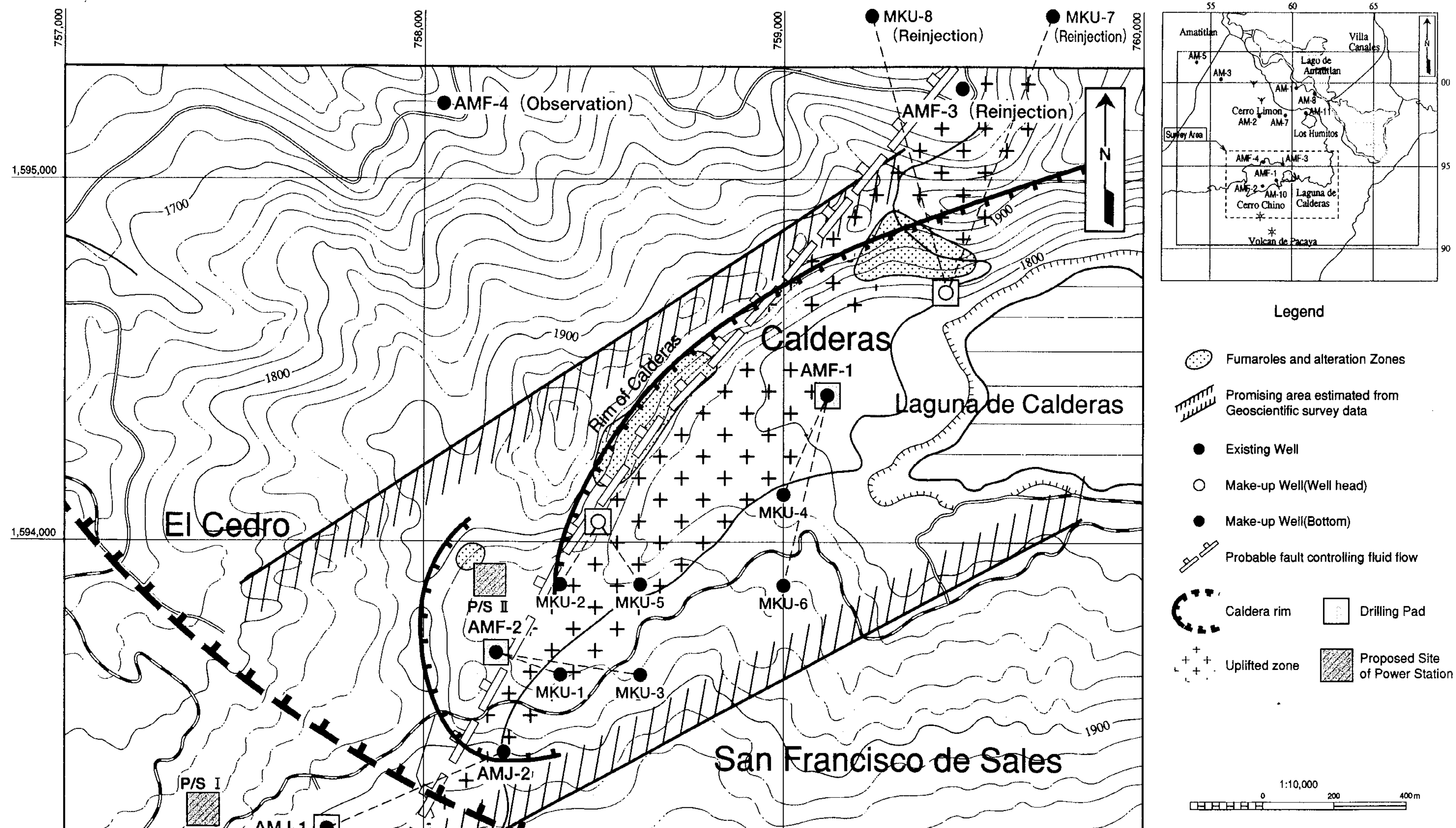
AMTI-S_Last_450.surf

INDE/West Jec

貯留層の開発シナリオ

Fig. 3-1-22 Exploitation Scenarios for the Amatitlan Reservoir





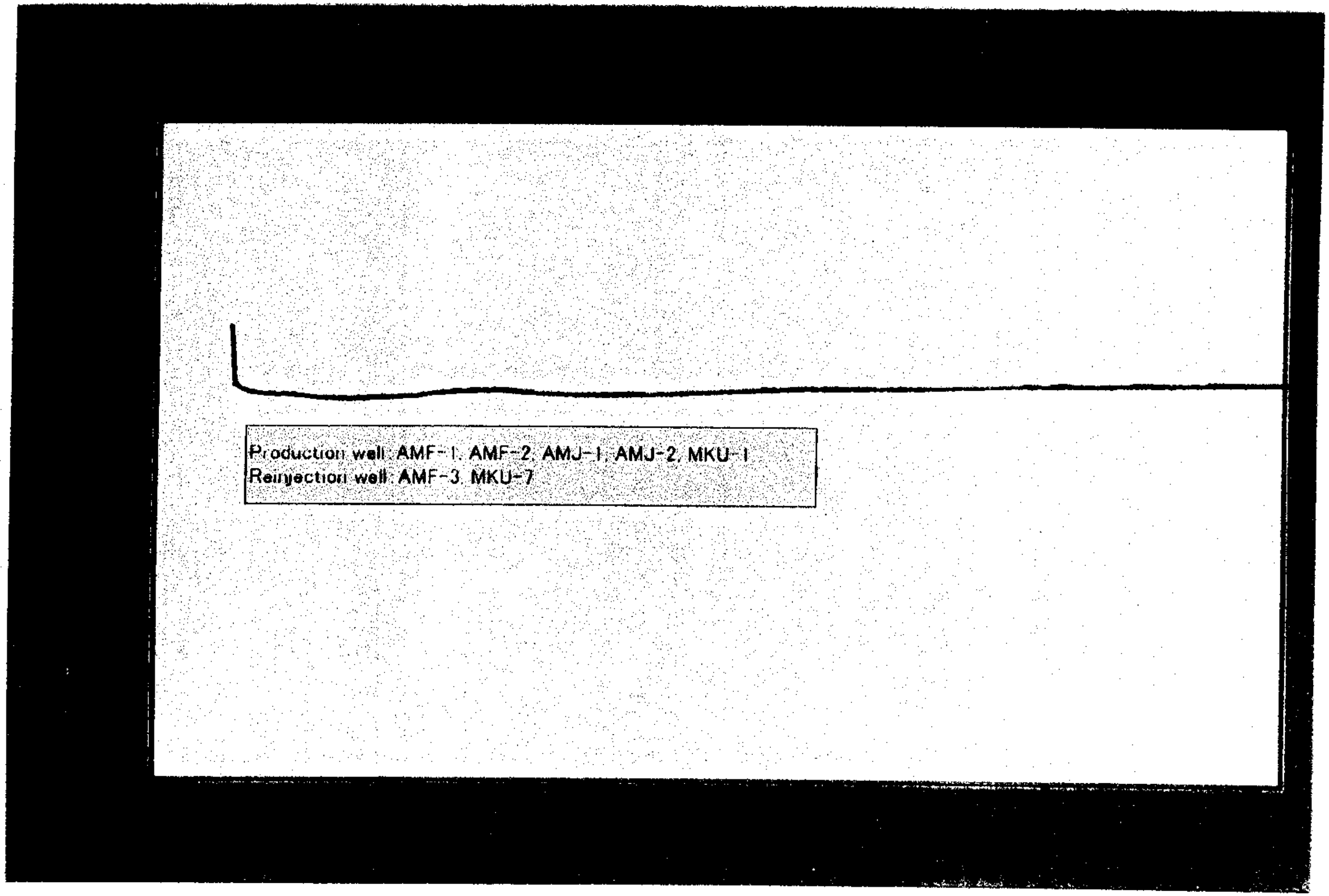
Amatitlan Geothermal Development Project

既存坑井および補充井の掘削ターゲット

Drilling Pads and Targets of Existing and Additional Wells

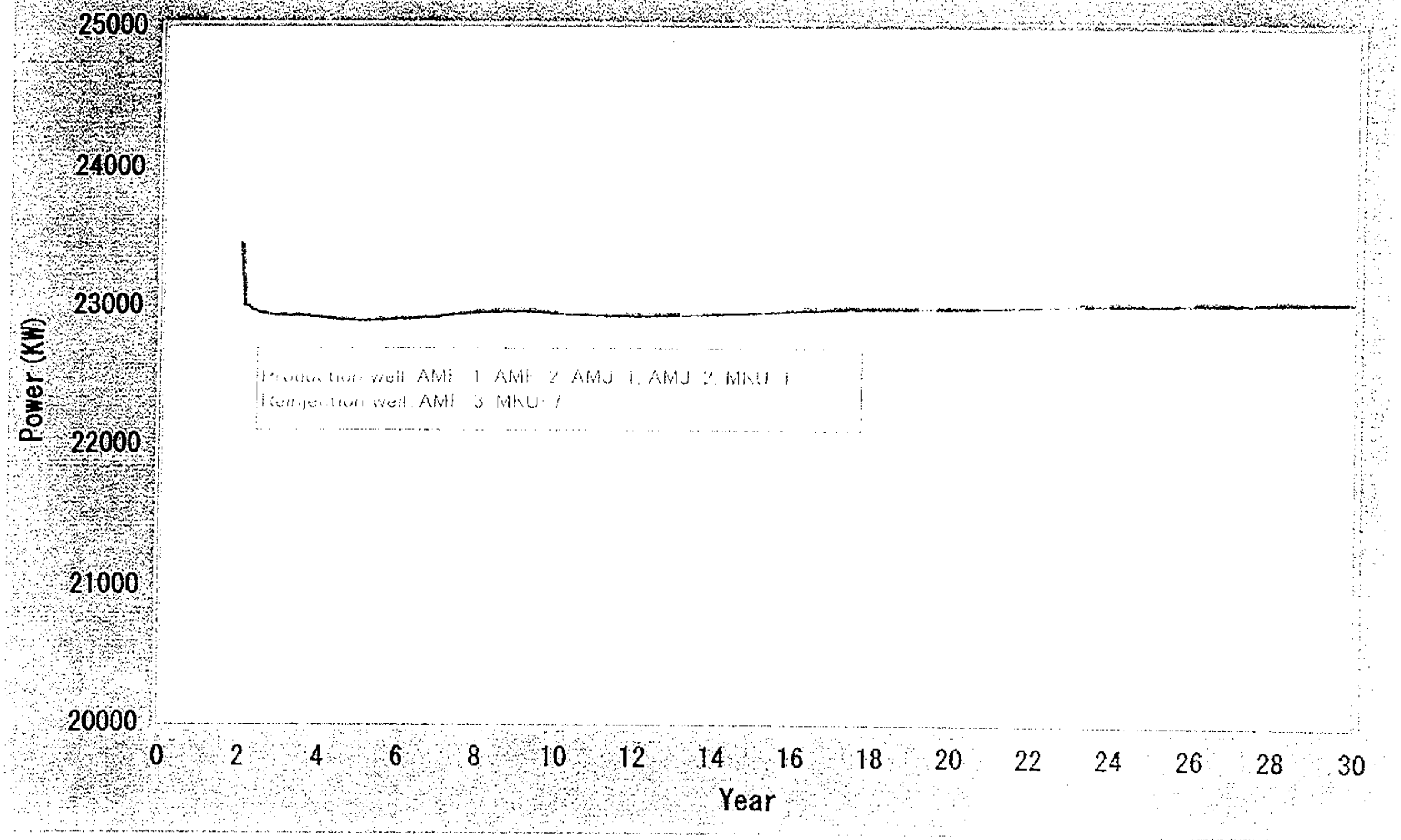
JICA-WEST JEC | Fig. 3-1-23

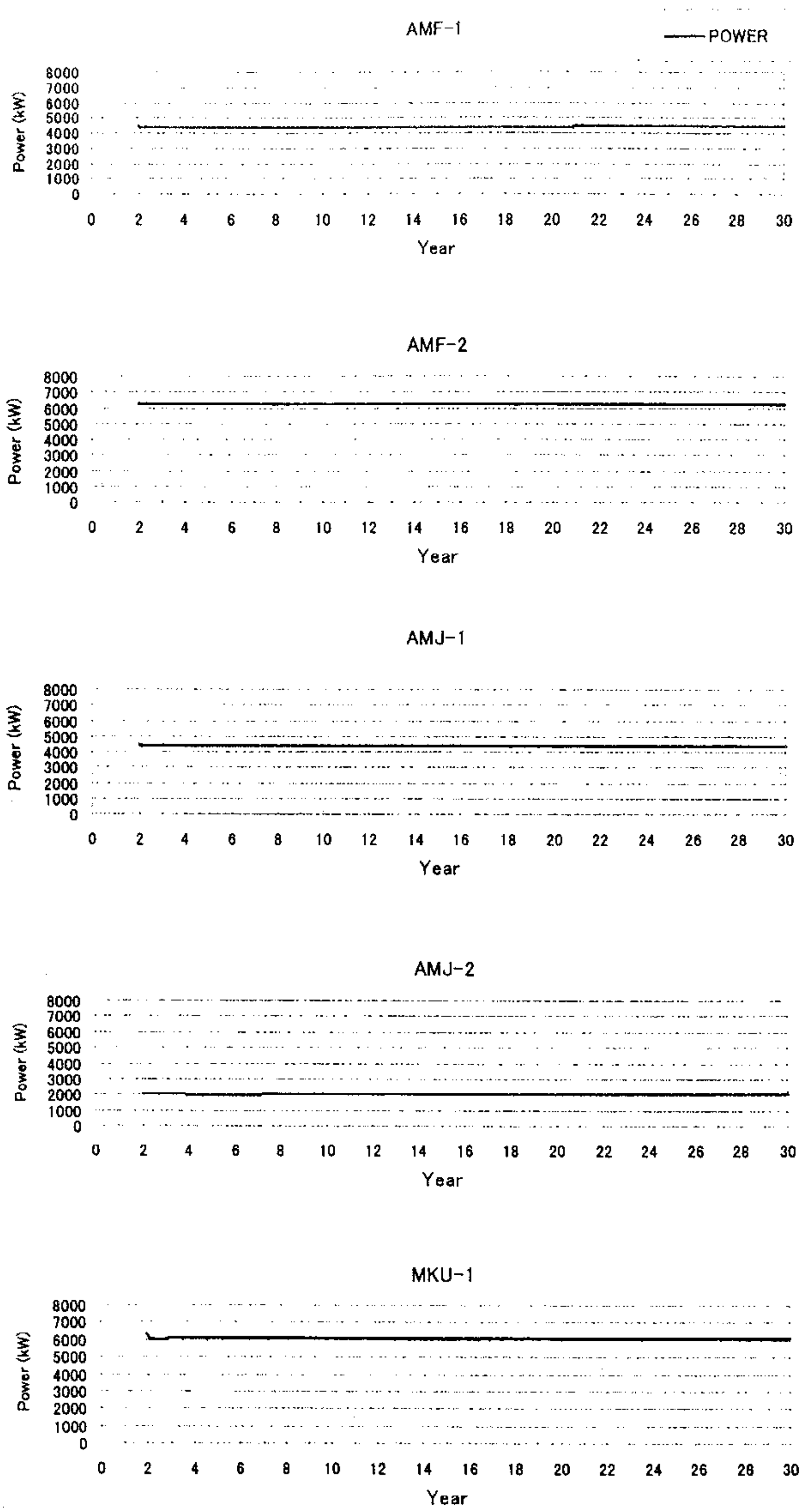
シナリオ 1: 20 MW 発電の場合の出力予測



シナリオ1: 20 MW 発電の場合の出力予測

Fig. 3-1-24 Scenario-1: 20 MW Results of Forecasting





* Power : Output from primary steam (Single flashed)

Fig. 3-1-25　Scenario-1: Forecasted well production

シナリオ 1: 各生産井の出力予測

シナリオ 2: 20MW + 20 MW 発電の場合の出力予測

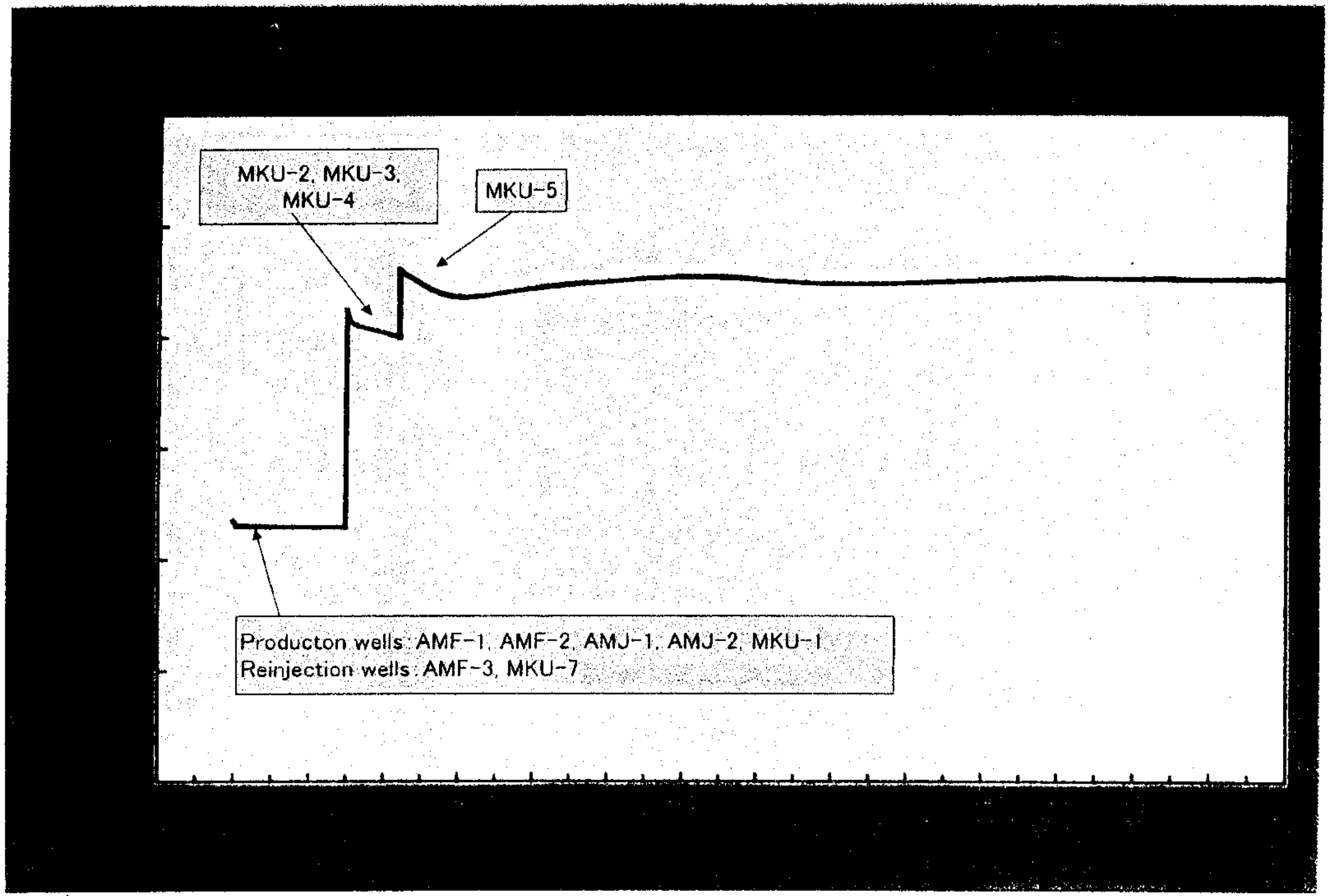
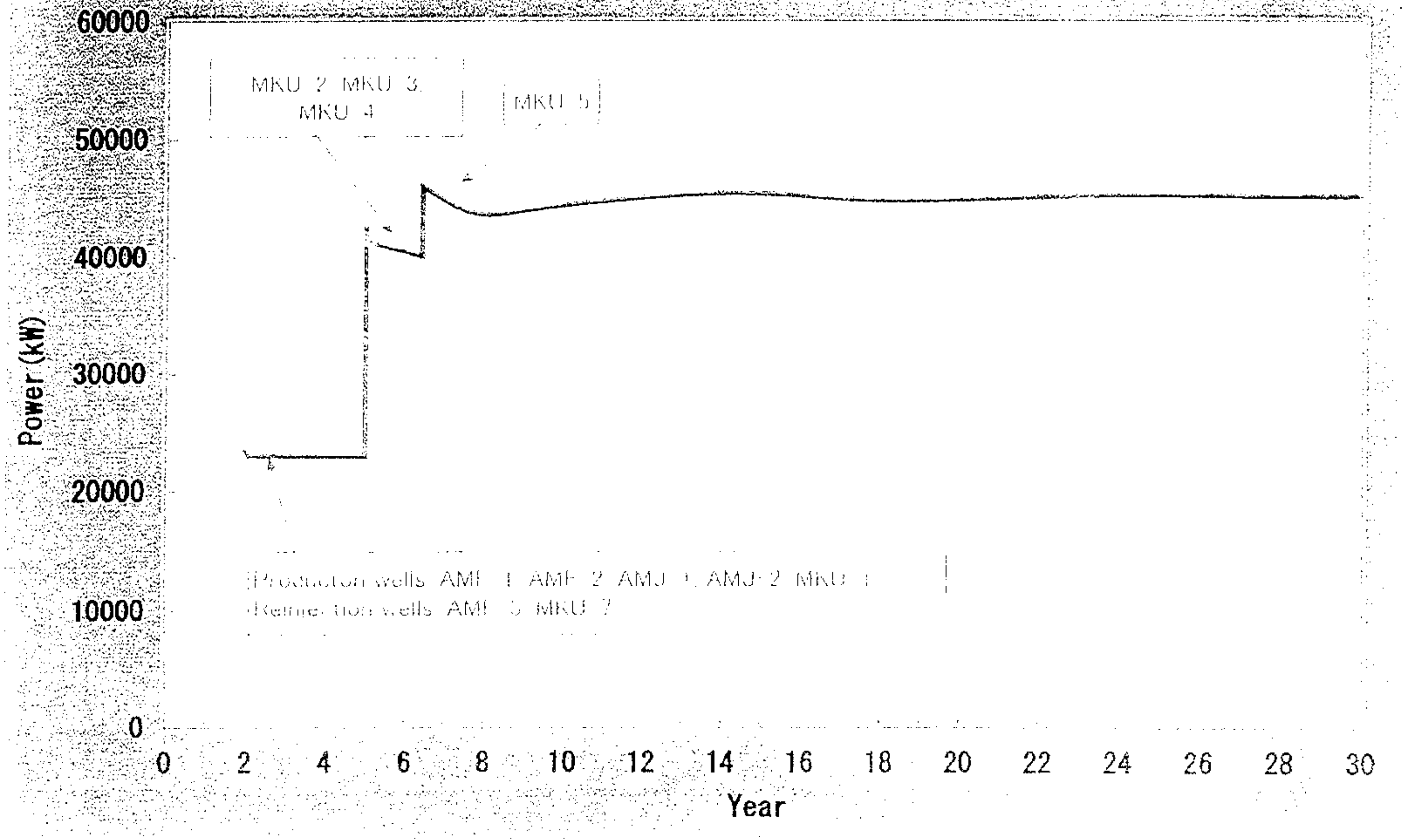
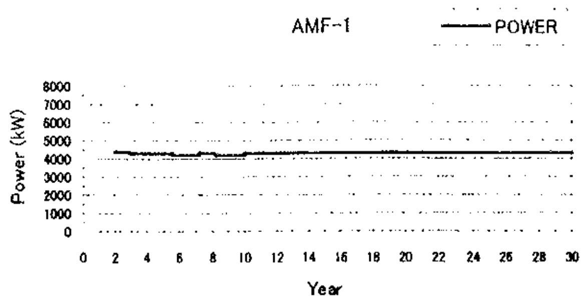
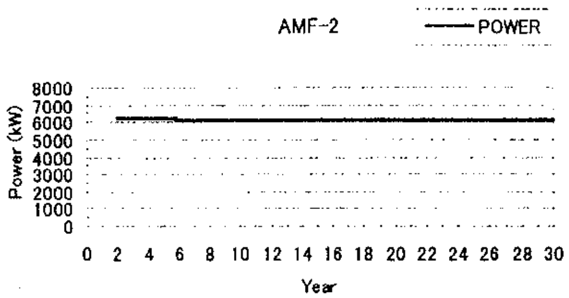
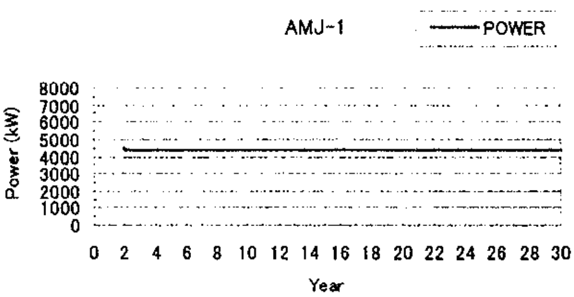


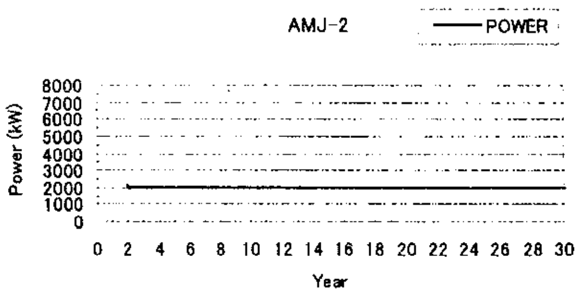
Figure 3-1-26 Scenario-2: 20MW + 20 MW results of forecasting

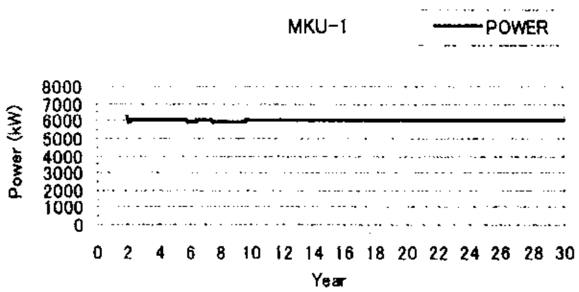








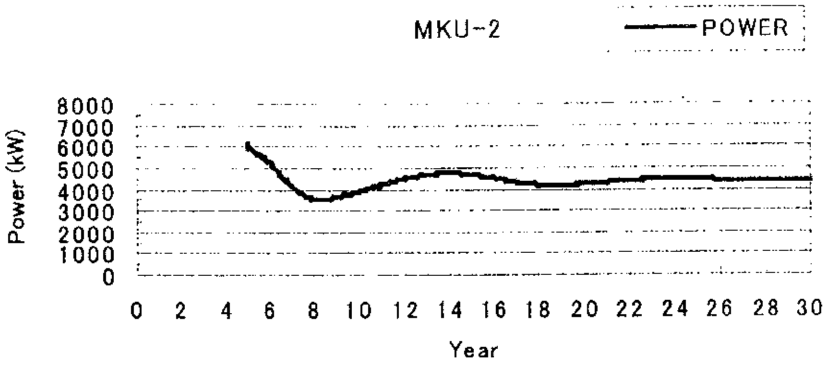


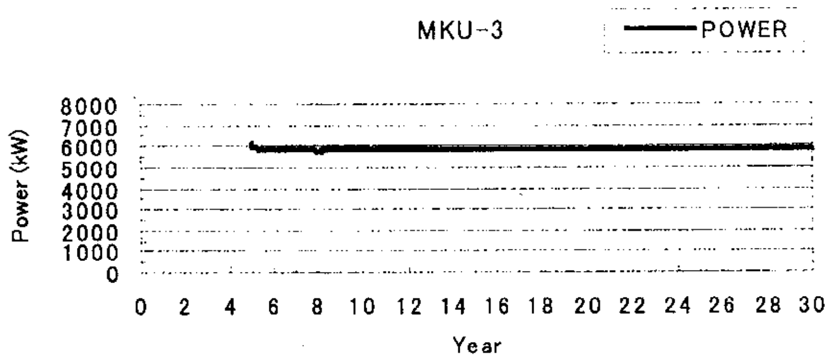


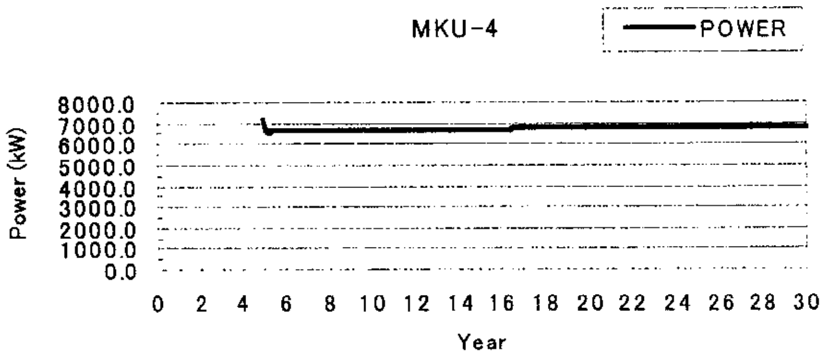
* Power : Output from primary steam (Single flashed)

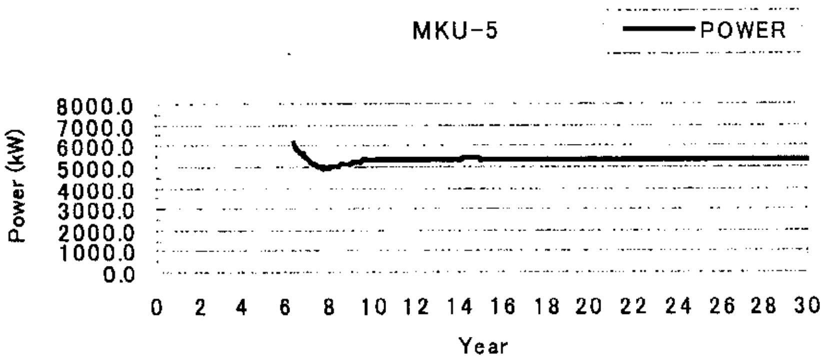
Figure 3-1-27 Scenario-2: Forecasted well production-a

シナリオ2: 各生産井の出力予測(a)







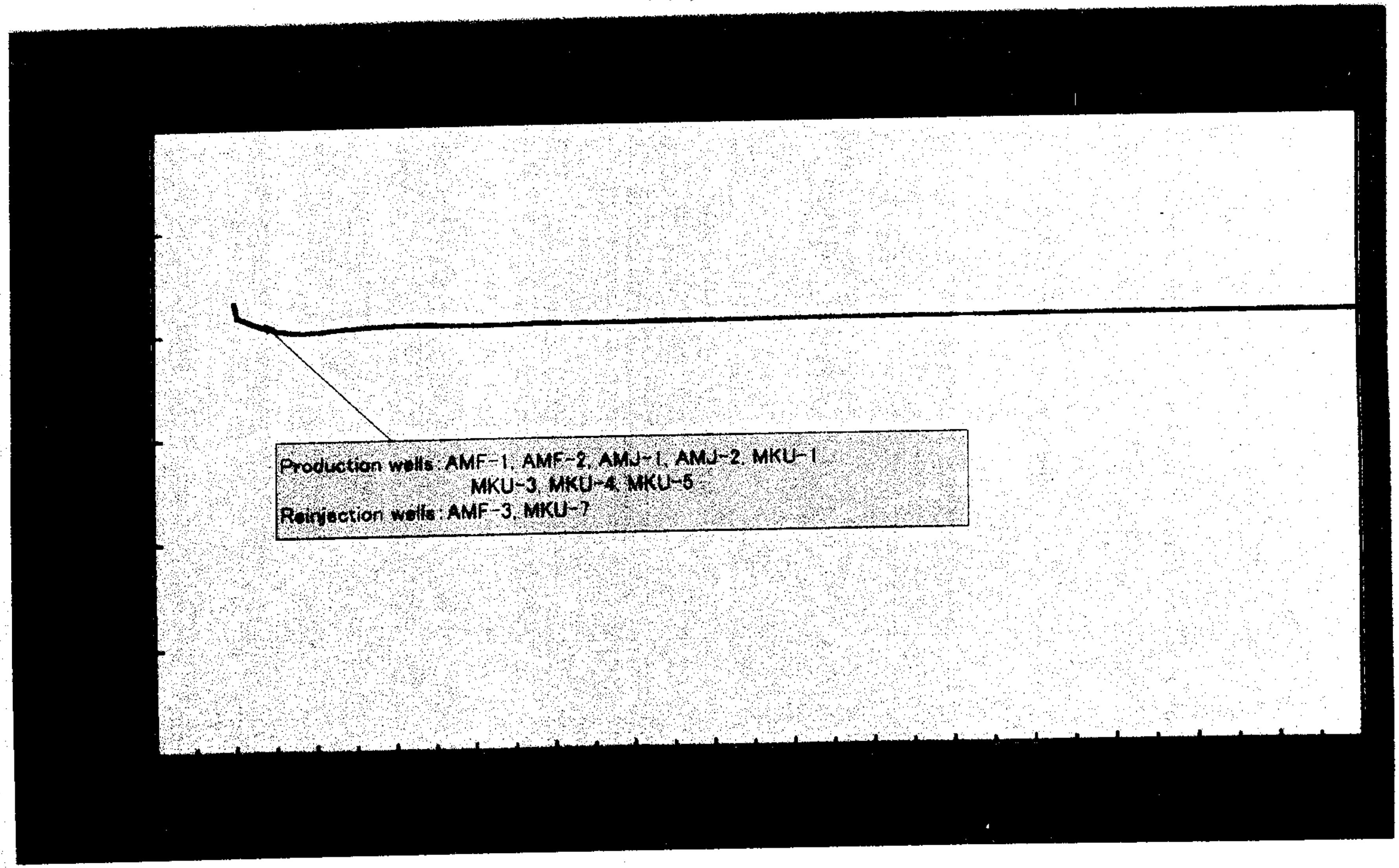


* Power : Output from primary steam (Single flashed)

Figure 3-1-28 Scenario-2: Forecasted well production-b

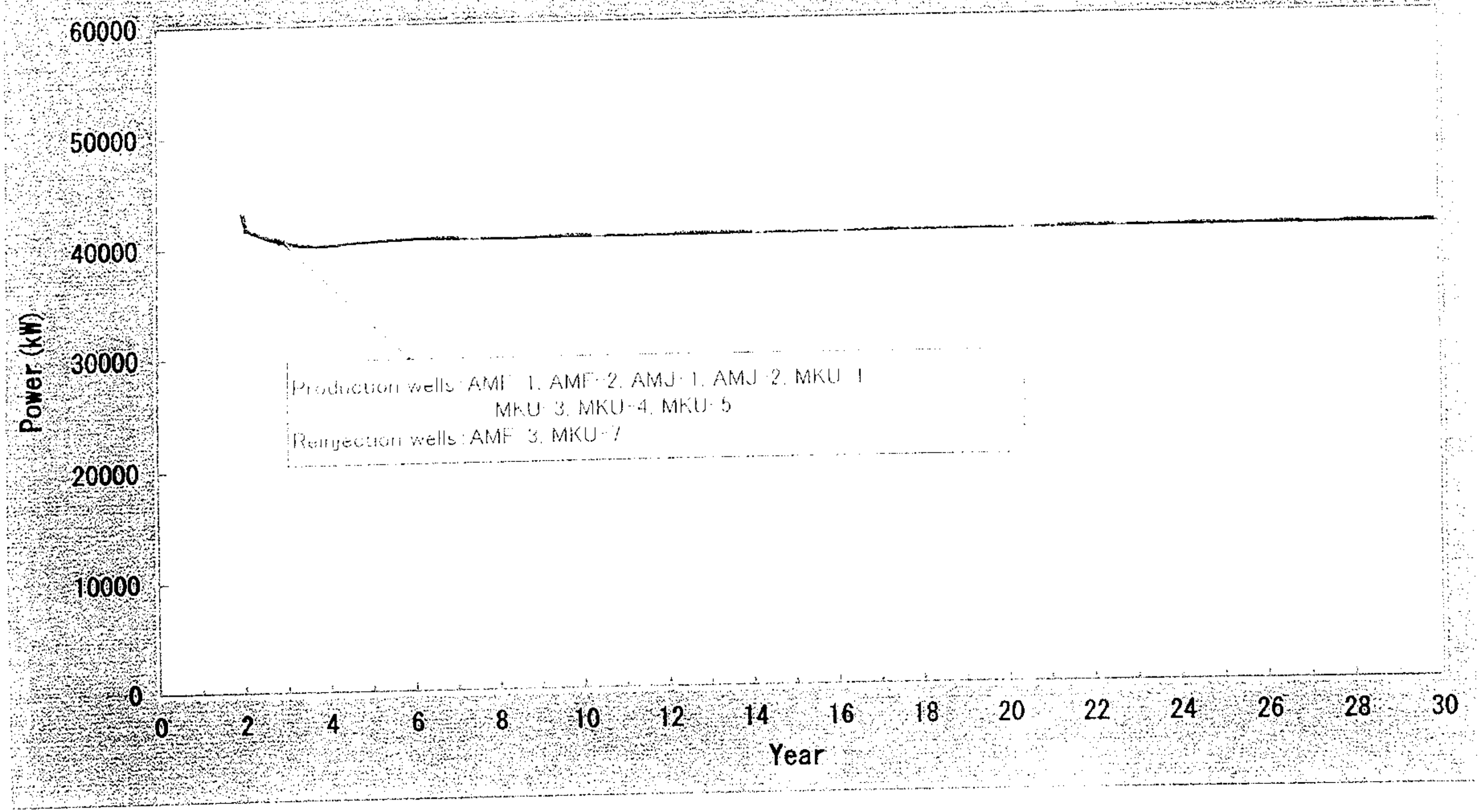
シナリオ 2: 各生産井の出力予測(b)

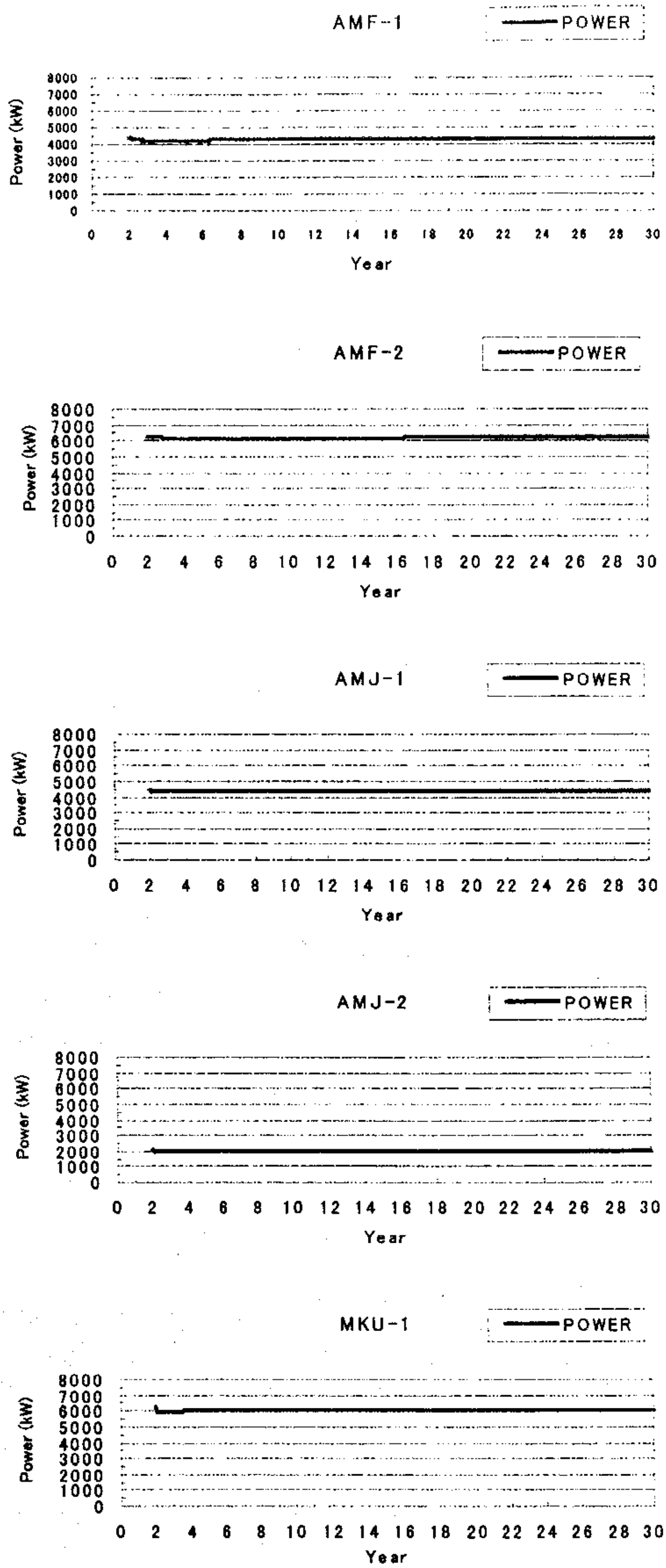
シナリオ 3: 40 MW 発電の場合の出力予測



シナリオ 3: 40 MW 発電の場合の出力予測

Figure 3-1-29 Scenario-3: 40 MW results of forecasting

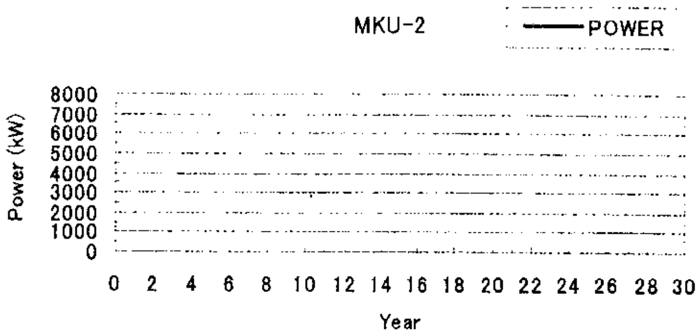


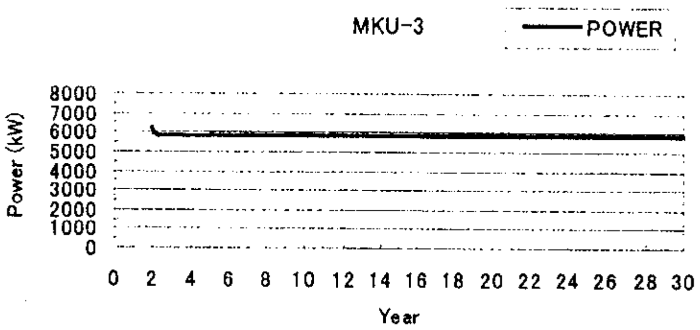


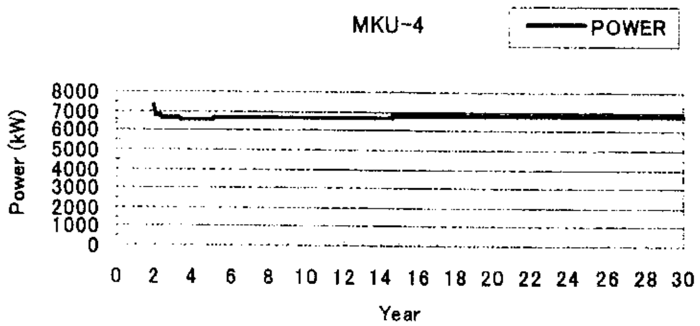
* Power : Output from primary steam (Single flashed)

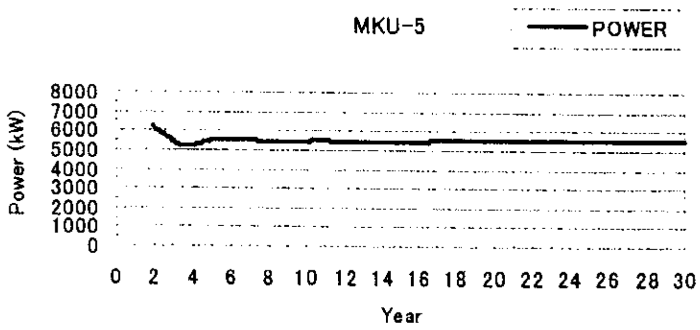
Figure 3-1-30 Scenario-3: Forecasted well production-a

シナリオ3: 各生産井の出力予測(a)









* Power : Output from primary steam (Single flashed)

Figure 3-1-31 Scenario-3: Forecasted well production-b

シナリオ 3: 各生産井の出力予測(b)

数値モデルの岩石物性値

Table 3-1-1 Physical properties of materials in the numerical model

ROCK	DENSITY ROCK	POROSITY	PERMEABILITY X	PERMEABILITY Y	PERMEABILITY Z	HEAT CONDUCTIVITY	SPECIFIC HEAT
	Kg/m3		m2	m2	m2	W/m-Deg. C	J/Kg-Deg. C
AIR01	2200	0.9000	0.000E+00	0.000E+00	0.000E+00	0.03	50000
TOP01	2200	0.9000	0.000E+00	0.000E+00	0.000E+00	2.20	50000
ROK01	2200	0.1000	1.000E-16	1.000E-16	1.000E-16	2.20	1000
ROK02	2200	0.1000	2.000E-15	2.000E-15	2.000E-16	2.20	1000
ROK09	2200	0.1000	3.000E-15	3.000E-15	5.000E-16	2.20	1000
ROK03	2200	0.1000	8.000E-15	8.000E-15	1.000E-14	2.20	1000
ROK04	2200	0.1000	2.000E-14	2.000E-14	3.000E-14	2.20	1000
ROK05	2200	0.1000	6.000E-14	6.000E-14	7.000E-14	2.20	1000
ROK06	2200	0.1000	7.000E-14	7.000E-14	2.000E-16	2.20	1000
ROK07	2200	0.1000	9.000E-14	9.000E-14	2.000E-16	2.20	1000
ROK08	2200	0.1000	4.000E-15	4.000E-15	2.000E-14	2.20	1000
AQU01	2200	0.1000	6.000E-14	6.000E-14	7.000E-14	2.20	50000
BAS01	2200	0.1000	0.000E+00	0.000E+00	0.000E+00	2.22	50000
LIM01	2200	0.1000	2.000E-12	2.000E-12	3.000E-12	2.20	1000
LIM02	2200	0.1000	6.000E-14	6.000E-13	2.000E-13	2.20	1000
AQU02	2200	0.1000	6.000E-12	6.000E-12	7.000E-12	2.20	50000

3.2 Development Plan of Power Plant

3.2 CONSTRUCTION OF POWER GENERATING FACILITY

3.2.1 CONDITIONS FOR PLANNING

1. Power Plant Site

Two sites are proposed for power plant construction taking into consideration distances from the production and reinjection wells, easiness of pipeline installation, topographic/geological feature, distance from existing road, and environmental issues. Site-I is near INDE's warehouse to west of the caldera where is advantageous in access and H_2S gas dispersion. Site-II is near the existing production well AMF-2 in the west of caldera, and is advantageous in transportation of geofluid.

Locations of each site are shown in Fig.3-2-1 and Fig.3-2-2.

2. Type of Power Plant

The results of resource evaluation suggest medium sized power plant, medium specific enthalpy geofluid, and relatively low non-condensable gas (NCG) content. For those conditions of Amatitlan geothermal area, five generating technologies shown in Table 3-2-1 might be suitable.

Combined binary cycle will have advantage when the steam is high pressure and high non-condensable gas (NCG) content. But, it is not the case for Amatitlan where NCG content is relatively low and the optimum steam pressure is predicted to be medium.

In double flashed steam cycle with condensing turbine, two-phase binary cycle, and hybrid type binary cycle, the temperature of brine in the reinjection system must be low enough to utilize thermal energy of brine and to get advantage of increased output over single flashed steam cycle. For the silica-rich brine produced in Amatitlan geothermal area, low brine temperature would cause trouble in the reinjection system due to deposits of silica scale. Validity of anti-scaling measures such as chemical dosing and settling basin needs to be judged after analyzing actual operating data. It, therefore, will be risky to apply those three technologies to this project.

For the reasons above, the single flashed steam cycle with condensing turbine is recommended for this project, and the brine in the reinjection system will be kept at high pressure and high temperature.

When analysis of actual operating data shows that a proper anti-scaling measure allows low brine temperature, a bottoming cycle plant that may be installed in the caldera so that additional electricity output is obtained utilizing thermal energy of the brine.

3. Capacity of Power Plant

In line with the development strategy suggested in the resource evaluation. The exploitation of the geothermal field will be in two stages. The first stage (Unit-1) will be using the confirmed geothermal resources and the steam equivalent to 15 MWe already available from the existing wells. The geothermal resources for the next stage will be developed taking into account the response of the reservoir to the exploitation of the first stage. The output of these two stages will be 40 MW in total. The specifications of the power-generating unit for each stage will be the same so that designing cost and spaceports inventory can be minimized.

Those two units may be ordered to the manufacturer at a time for lower price, but the design of power generating facilities will be the same as that of the two-step development mentioned above. Unit-1 and Unit-2 will be installed at the same site in order to suppress costs for land acquisition, civil works, and operation and maintenance.

4. Connection to the System

Transmission network in Guatemala grid has three different voltages i.e. 230kV, 138kV and 69kV. As the result of the meeting with INDE transmission group, the output of Amatitlan geothermal power plant will be connected to 138kV substation, named Palin 2 substation that is planned to be constructed newly by INDE. This substation will be approximately 8km west from Amatitlan geothermal power plant, as shown in Fig.3-2-8.

Palin 2 substation will be cut-in between Guate Sur substation and Jurún Marinalá power plant and has 138kV single busbar. The output of Amatitlan geothermal power plant therefore, will be connected to this 138kV busbar. See Fig.3-2-9.

5. Major Design Conditions

a. Steam Conditions at Turbine Inlet

Taking account of predicted characteristics of production wells and pressure loss of pipelines, the optimum steam pressure is set to 7 bar for both power plant sites (outside and inside caldera). The contents and composition of non-condensable gases in the steam are estimated on the basis of actual data of the existing wells.

Pressure	7	bar (abs.)
Temperature	165	C
NCG content	1.78	wt%
Composition of NCG		
CO_2	93.0	vol%
H_2S	5.5	vol%
others	1.5	vol%

b. Meteorological Conditions

Dry-bulb temperature	Average: 20 C
	Annual mean of monthly average of max. temp.: 25 C
	Max. of monthly average of max. temp.: 28 C (Feb)
Wet-bulb temperature	80 % (average) must be in centigrade
Rainfall	Dry season (Nov to Mar): 20 mm/month
	Rainy season (Jun to Sep):300 mm/month
Dominant wind direction	North
Wind speed	3 to 4 m/s

c. Topography

The project area lies in and to the west of the caldera which is located at the northern flank of Pacaya volcano. The east of the caldera is a lake, and the west is relatively flat land. One of the power plant sites (Site-II) and the existing production well AMF-2 at the western corner of the caldera are surrounded by a ridge (about 60 m high) from north to west. There are residential houses along the road that is about 250 m south of Site-II. The other power plant site (Site-I) is located on the gentle slope on the west of the caldera. There are INDE's warehouse and existing road adjacent to Site-I. The slope is grassland. There is no residence near the Site-I.

d. Altitude

Power plant site outside caldera (Site-I):	1840 m
Power plant site inside caldera (Site-II):	1860 m
Production well pads	
AMF-1, MKU-4, MKU-5 :	1794 m
AMF-2, MKU-1, MKU-3 :	1868 m
MKU-2, MKU-5 :	1870 m
AMJ-1, AMJ-2 :	1905 m
Reinjection well pad	1810 m

e. Geology and Soil

The area around Site-I is suitable for power plant construction site because of the scarce of the soft/loose soil near the land surface. AMJ-2 columnar section shows the deposition of Pacaya Volcanic Rocks from the top.

On the other hand, Site-II is located inside caldera where the talus sediment is easily deposited. Since well AMF-2 adjacent to Site-II is reported to exist the soft soil, cementing is necessary for basement of the plant in around 20m from the surface.

f. Seismic Conditions

An acceleration of 0.30G or 0.35G is recommended in the vicinity of the Amatitlan area on the basis of the records of past earthquakes.

g. Water Supply

There is no river around the project area. Taking water from the Caldera Lake will be difficult from the environmental point of view. Drilling a well for water supply to the power plant will be practical.

3.2.2 FLUID COLLECTION AND REINJECTION SYSTEM

1. **Route of Pipeline**

   The Fluid Collection and Reinjection System (FCRS) consists of separators, steam pipeline, and brine pipelines. Fig.3-2-1 and Fig. 3-2-2 show the routes of pipelines for Site-I and Site-II respectively.

   The pipeline route between AMF-1 and AMF-2 is the same as the route of existing two-phase pipeline. The route of the brine pipeline from AMF-1 to the new reinjection well will be the same as that of the existing reinjection line of the 5 MW power plant.

   Pipelines between AMF-2 and AMJ-1 cross the ridge on the west of the caldera in order to avoid the residential area south of AMF-2.

2. **Process**

   FCRS can be roughly classified into two groups: (1) two-phase pipeline in which the geofluid is transferred to the power plant in the form of steam-brine mixture, and (2) separate pipelines in which steam and brine are separated near production wells and then are transferred to the power plant and reinjection wells separately. For this project, the latter is employed because it has advantages over the other in pressure loss and flow stability when the pipeline cross the ridge as mentioned above.

   Fig.3-2-3 and Fig.3-2-4 illustrate the FCRS for Site-I (outside caldera) and Site-II (inside caldera) respectively. Dashed lines indicate additional portion for Unit-2.

   The geofluid (steam-brine mixture) from the production wells is separated into steam and brine in the separator adjacent to the production wells. The separated steam together with non-condensable gases is transferred to the steam header of the power plant through the steam pipeline, and then flows into Units-1 and 2.

   In the event of forced outage or emergency stop of the power plant, the blow-off valve opens to reduce the pressure of the steam piping. The steam is discharged to a rock muffler before finally released to atmosphere. Condensed water from the rock muffler is led to the wastewater basin of the power plant and then pumped to the reinjection well for wastewater.

   Separated brine from the separator is sent via pipeline to the reinjection wells. Geographic feature of the project area and characteristics of the reinjection wells allow reinjection by separator pressure and gravity. No reinjection pump will be installed. In case of abnormality in the reinjection system, the brine is automatically disposed into the emergency holding pond through a silencer/flasher adjacent to the production well for a period until the problem solved or the wellhead valve of the production well is closed. From the emergency holding pond, the brine will be sent to the reinjection wells by a portable pump.

3.2.3 POWER PLANT FACILITIES

1. Layout

a. Layout of Power Plant

1) Fig 3-2-5 shows the layout of the power plant
2) The plant site is about 150 m x 120 m, and includes two 20 MW generating units, switchyard, and administration office.
3) The cooling towers should be in the downwind of the switchyard and the turbine buildings so that cooling tower exhaust with corrosive non-condensable gas and mist will not affect plant equipment. The cooling towers are placed in the south of the power plant site considering the annual prevailing wind direction.
4) The switchyard is located in the opposite side of the cooling towers, i.e. in the north of the plant site.
5) The main transformers will be installed in the switchyard.
6) The turbine building(s) is in the center of the plant site. It accommodates the steam turbine and the generator. The control room and electrical rooms are packaged in the separate prefabricated housings.

b. Layout of Equipment

1) The turbine-generator unit including lube/control oil units, main stop valves (MSV), and control valves (CV) is installed in the turbine building.
2) The condenser, gas removal system, mist eliminator, etc. are placed outdoor between the turbine building and the cooling tower.
3) The control and electrical rooms accommodate electric facilities such as switchgear cubicles and DC power supply panel, and control equipment such as turbine-generator monitoring console, protective relays, and data acquisition system.
4) Auxiliary transformers are located outdoors adjacent to the electrical rooms.

2. Civil and Architectural Works

a. Access Road

The access road to be constructed for Site-I (outside caldera) will be of 20 to 30 meters long from the existing road. For Site-II (inside caldera), the existing access road for AMF-2 will be paved and extended about 150 meters to the power plant.

There are access roads for the production wells AMJ-1, AMF-1, and AMF-2. For the reinjection well pad, a new access road is to be constructed from the site of AMF-1. Another access road will be needed for MKU-2 and MKU-5 when they are drilled for Unit-2.

b. Site Preparation

Sites for the power plant and the reinjection well pad will be prepared. An additional production well site will be prepared when Unit-2 is constructed.

Production well site:	Approx. 0.6 ha (for Unit-2)
Power plant site:	Approx. 1.8 ha (including Unit-2)

Reinjection well site: Approx. 0.36 ha

c. Power Plant

1) Foundation

Major equipment such as turbine-generator and condenser will be installed on reinforced concrete foundation. The modular design of the generating facility makes most of its equipment be installed on the floor level.

2) Building

The turbine building is steel-framed structure with aluminum exterior and roof panel. It accommodates the turbine-generator, an overhead traveling crane and related ancillary equipment.

3. Power Plant Equipment

The same design will be applied to both of Units-1 and 2 so that designing cost will be suppressed, and spare parts can be shared between the units.

a. Mechanical Equipment

Fig.3-2-6 shows the schematic process of the plant. Function of each equipment are described below:

1) Turbine

The steam turbine for this project shall be designed and proven for geothermal application. Skid-mounted modular type turbine is preferred because of:

- Shorter design and manufacturing period,
- Easy to transport,
- Smaller foot print,
- Faster installation at site, and
- Lower construction cost.

Main specifications of the turbine:

Type	Single flow, condensing, modular
Rated output	20 MW
Steam conditions	7 bar, 165 C
Exhaust pressure	0.095 bar
Speed	3,600 rpm
Ancillary equipment	
• Turbine control system	1 set/unit
• Turbine protection system	1 set/unit
• Lube oil unit	1 set/unit
• Gland seal system	1 set/unit

2) Main Steam Pipe

a) Mist Eliminator

In order to prevent inflow of mist or drain into the turbine, a mist eliminator is installed in the main steam piping.

b) Steam Flowmeter

For control and monitoring of plant operation, a steam flowmeter is installed at the downstream side of the mist eliminator. The effect of scale buildup to the accuracy shall be minimal.

c) Main Stop Valve (MSV) and Control Valve (CV)

Turbine inlet steam pipe splits in two, and both are connected to the turbine through main stop valves and control valves. This arrangement allows opening/shutting test during turbine operation, and preventing sticking of these valves due to scale deposition.

3) Condenser

After it drives the turbine, the steam flows into the main condenser. In the condenser, the steam is cooled by the cooling water and condenses into warm water. The condenser is direct contact spray jet type. Cooling water is sucked from the cold water basin of the cooling tower by the vacuum of the main condenser.

4) Gas Removal System

Gas removal system removes non-condensable gases that are contained in the main steam from the main condenser. The gas removal system consists of steam jet ejector(s), inter-condenser, liquid ring vacuum pump, and seal water separator. The driving steam for the steam jet ejector is drawn from the main steam line. Drain of inter-condenser and seal water separator is led into the main condenser. The non-condensable gases are diffused by the cooling tower exhaust and discharged into atmosphere.

5) Cooling Water System

Condensate is pumped to the cooling tower from the hot well of the main condenser. The condensate is cooled at the cooling tower and is recycle as cooling water. The auxiliary cooling water pump supplies cooling water for turbine lube oil cooler, generator cooler, gas removal system, air compressor, etc.

6) Cooling Tower

The cooling tower is induced draft type with wooden or FRP structure and reinforced concrete cold water basin.

b. Electrical and Control equipment

1) General

The voltage of the generator output is stepped up to 138kV by Main transformer and transmitted to Palin 2 substation via 138kV switchyard in the power plant. On the other hand, the 480V power for the auxiliary equipment in the power plant is supplied through Unit transformer.

Circuit breakers (CB) in the main circuit are located as follows.

Generator CB : between Generator and Main transformer
Main transformer CB : High voltage side of Main transformer
Auxiliary supplies CB : Low voltage side of Unit transformer

Single line diagram of the power plant is shown in Fig.3-2-7.

2) Generator

A module-type, air-cooled, three-phase synchronous generator shall be applied with easy operation, less maintenance and well proven in geothermal environment. Corrosive gas like H_2S shall be removed from the cooling air for Generator utilizing oxidized catalytic filters etc., since the atmosphere around geothermal field contains highly corrosive H_2S gas. Brushless exciter system shall be adopted.

Specifications of the generator are as follows.

Type	: Cylindrical revolving-field rotor type, totally enclosed, air- cooled, three-phase synchronous generator
Rated output	: 25MVA x 2 sets
Rated voltage	: 13.8kV
Frequency	: 60Hz
Speed	: 3,600rpm
Power factor	: 0.8 (lagging)
Neutral grounding method	: Transformer
Excitation system	: Brushless

3) Specification of other major electrical equipment

Equipment	Q'ty/ Unit	Specification
a) Main transformer	1 set	25MVA, 13.8kV/138kV
b) Unit transformer	1 set	2,000kVA, 13.8kV/480V, For auxiliary equipment
c) 13.8kV Metal-Clad Switchgear	1 set	13.8kV Gas circuit breaker, For generator output
d) 480V Power Center	1 set	480V Air circuit breaker, For auxiliary equipment not less than 75kW
e) 480V Motor Control Center	1 set	480V, MCCB, For auxiliary equipment less than and equal to 75kW
f) Distribution panels	1 lot	230V/110V, For control , instrumentation, lighting and others
g) Control panels	1 lot	Turbine control panel, Electrical panel, Auxiliary equipment panel and others
h) Protection panels	1 lot	Generator protection panel, Transformer protection panel, Transmission protection panel and others
i) DC power supply	1 set	125V DC, Charger, Battery and DC distribution panel
j) Uninterruptible Power Supply (UPS)	1 set	110V AC, Distribution panel, For Digital control equipment

4) Control and Instrumentation equipment

Distributed Control System (DCS) based on micro-processor will be applied in order to control the system and monitor the various data of the geothermal power plant. This DCS system contributes fail-safe operation with high reliability and productivity of the plant.

a) Automatic Turbine and Generator Controller

This controller can control as below.

- Automatic start-up and shut-down of the Turbine (from turbine start-up at cold condition to 100% load and vice versa)
- Automatic start-up of the Turbine and load regulation in conjunction with digital electronic-hydraulic governor.

b) Condenser level

The hot water level in Condenser is controlled by DCS due to protection of Hotwell pumps.

The operation of the plant can be done with CRT and keyboard, which are the interface between DCS and operators, at the Control room.

Plant interlock system will be provided in addition to the control system. The interlock system for equipment operation will be included in DCS system, while the one for emergency trip shall be of hard-wired relays.

c. Ancillary Facilities

1) Water Supply

Make up water and service water will be pumped from a well.

2) Fire Fighting System

Hydrants and/or fire monitor nozzles will be installed outdoor around the turbine building and the cooling tower. Diesel and motor driven fire pumps will supply water from the cold water basin of the cooling tower to the hydrants and monitor nozzles. Deluge systems will be provided for main and auxiliary transformers. Portable dry-chemical extinguishers are to be placed in the turbine building, control room, and electrical rooms.

3) Facilities for Maintenance Work

An overhead traveling crane will be installed for overhaul of the turbine-generator. A maintenance shop and a storage area for spare parts and tools to be provided.

4) Air Conditioning System

Air conditioning system for the control room, electrical rooms, and the administration office.

5) Emergency Generator

Emergency power will be supplied by a diesel emergency generator to the power plant, in case of power failure of the power system.

6) Communication System

A microwave communication system will be used for communication among the power plant, INDE, and other related organizations. For plant monitoring and controlling, SCADA (Supervisory Control And Data Acquisition) system will be installed.

4. Facilities for Environmental Preservation

a. Noise

A rock muffler is installed at the outlet of the blow-off valves of the main steam line.

The turbine-generator will be installed indoor to reduce noise emission.

b. Waste Water

Condensate of the rock muffler, overflow of the cooling tower, and other drains flow into the wastewater basin. From there, all the wastewater is sent to a dedicated reinjection well.

c. Hydrogen Sulfide (H_2S) Gas

The steam at Amatitlan geothermal area is not very rich in H_2S compared to other geothermal fields in the world. It, therefore, is expected that the H2S concentration on the ground will be low enough when the non-condensable gases are diffused by large amount of cooling tower exhaust air in the same way as many other geothermal power plants.

Since H_2S gas is heavier than air, there is a concern about buildup of H2S in the caldera on a windless day when the power plant is constructed at Site-II (inside caldera). To check possibility of such H_2S buildup, detailed wind survey and simulation of gas dispersion would be needed. In case that the H_2S buildup was problem, installation of a de-H_2S system or other measure would be necessary. There is a number of de-H_2S processes commercially available, e.g. Stretford process applied to geothermal power plants in the Geysers, USA and Lo-Cat II process in Leyte, the Philippines. Selection of the process must be based on required removal efficiency, reliability, construction cost, and costs of operation and maintenance.

3.2.4 TRANSMISSION LINE AND SUBSTATION

1. **Switchyard**

The switchyard consists of main transformers, 138kV switchgear and dead-end structures for transmission lines. The switchyard is located at north side of the plant in order to avoid the corrosive gas from the cooling tower.

Main characteristics of the switchyard equipment are shown below.

Equipment	Specifications
Gas Circuit Breakers	145kV, 630A, 40kA
Disconnecting Switches	145kV, 630A, 40kA
Voltage Transformers	$138/\sqrt{3}$kV − $110/\sqrt{3}$V − 110/3V
Current Transformers	For metering and protections
Dead-end structures, & others	For transmission lines

2. **Transmission line**

One circuit of 138kV transmission line will be installed newly up to Palin 2 substation of INDE, approximately 8km west from the power plant. See Fig.3-2-8. The transmission line will be routed along the ridge in order to facilitate its construction.

The wires used for the line will be of Aluminum Conductor Steel Reinforced (ACSR) with 477MCM, named hawk, which is INDE's standard.

3.2.5 PROJECT IMPLEMENTATION

1. Development Schedule

The development strategy that is suggested in the resource evaluation is the development in two stages aiming at minimizing risk of resource development. Another strategy is to order two units at a time aiming at reducing construction cost the power plant. Thus, the following three scenarios are studied in this report. Construction schedules of these scenarios are shown in Fig.3-2-10 to Fig.3-2-12.

Scenario 1: As the first stage, Unit-1 (20MW) is constructed utilizing existing production wells. One makeup production well (MKU-1) and one reinjection well are drilled. The transmission line and the fluid collection and reinjection system (FCRS) will have provisions for Unit-2.

Scenario 2: Following the reservoir monitoring period for one year after completion of Unit-1, construction of Unit-2 (20MW) will be launched. Three makeup production wells (MKU-3, 4, and 5) and one reinjection well will be drilled in addition to the wells drilled for Scenario 1. A platform for MKU-4 and 5 will be prepared.

Scenario 3: Unit-1 and Unit-2 are constructed at a time. Four makeup production wells and two reinjection wells are drilled.

a. Well Drilling

Well drilling will be completed before testing and commissioning of the power plant, which will start in 23rd month after placing the order.

b. Power Generating Facility

In Scenarios 1 and 2, the power plant will start commercial operation in 24th month after placing order. In Scenario 3, it will be 27th month since construction of Unit-2 will be three months behind Unit-1.

Construction and testing of the fluid collection and reinjection system (FCRS) will be completed before testing and commissioning of the power plant (about 23.5 months after placing order).

c. Transmission Line and Substation

Construction of the transmission line, modification of INDE's substation, and testing of these facilities will be completed before the power plant starts receiving power from the grid (about 22.5 months after placing order).

2. Transportation of Material and Equipment

a. Means of Transportation

Material and equipment of generating facilities will be transported by trucks from the port of unloading to the site.

b. Port of Unloading

The nearest port appropriate for unloading equipment/material for this project is Puerto Quetzal on the Pacific Ocean. Equipment and material of San Jose coal-fired thermal power plant were unloaded and cleared the customs at this port. Its main wharf is 800 meters long with 11 meters of water depth. In case of unloading at Atlantic side, Puerto Barrios will be the port of entry and unloading.

c. Road

The road conditions from the ports to the site, as described below, are good so that transportation of equipment and material for the generating facilities is feasible.

From the Pacific Ocean :

Route: Puerto Quetzal / Highway (CA9) / San Vicente Pacaya
Load limit : none
Height limit: 5.4 m (by grade separation and pedestrian bridge over CA9)

From the Atlantic Ocean :

Route: Puerto Barrios/ Highway (CA9) / San Vicente Pacaya
Load limit : 90 ton
Height limit: 5.0 m (by frame structure of bridge of CA9)

From San Vicente Pacaya to the Site :

Unpaved. The width of the road is 4 to 6 meters. There are 50 degrees curves with radius of 22.9 m.

Typical size and weight of major equipment is as follows:

	Weight	Length	Width	Height
20MW steam turbine	40 ton	4.3 m	3.8 m	2.9 m
20MW generator stator	22 ton	4.3 m	3.2 m	3.2 m
Main transformer	30 ton	4.5 m	2.5 m	3.0 m

d. Access Road

There are access roads for AMF-1, AMF-2, and AMJ-1 & 2. The access road for the power plant is to be constructed

3. Environment Preservation

During construction period, environment preservation measures will be taken as described below.

a. Prevention of Soil Erosion

During construction of road, and preparation of sites of the wells and the power plant, appropriate slope protection will be applied to prevent soil erosion.

b. Appropriate Disposal of Surplus Soil

Surplus soil come out of construction sites will be buried at a designated place.

c. Suppression of Noise and Vibration

During test of production wells, a silencer will be installed to suppress noise emission. There will be no problem of noise from heavy equipment at Site-I (outside caldera). At Site-II (inside caldera), there are residences near the site. Some measures to reduce noise nuisance will be taken as necessary, e.g. noise-proof cover, sound-insulating wall, and limitation of night work.

d. Prevention of Water Pollution

Drilling mud will be recycled during well drilling, and adequate measure for prevention of outflow will be taken. Used mud will be solidified and buried at a designated place after drilling. Oily waste will be collected to the mud-collector, and will be solidified/buried with the mud. All brine produced during well test will be reinjected underground.

e. Protection of Vegetation

Design and planning of construction works of the facilities will be of minimizing removal of vegetation.

3.2.6 PROJECT COST ESTIMATE

1. Basics of Cost Estimation

As described in Section 3.2.5 "Project Implementation", project costs are estimated for Scenario 1, 2, and 3. Tables 3-2-2 and 3-2-3 show estimated project costs for Power Plant Site-I (outside of caldera) and Site-II (inside caldera) respectively.

2. Components of Cost

The costs cover engineering/designing, material, transportation, civil/building works, and installation works, and are estimated in the following components:

- Drilling of production/reinjection wells and wellhead equipment
- Fluid Collection and Reinjection System
- Power plant
- Transmission line and switchyard
- Geoscientific, general and administrative cost
- Land acquisition and compensation
- Contingency

3. Conditions of Cost Estimate

a. Scope of the Project

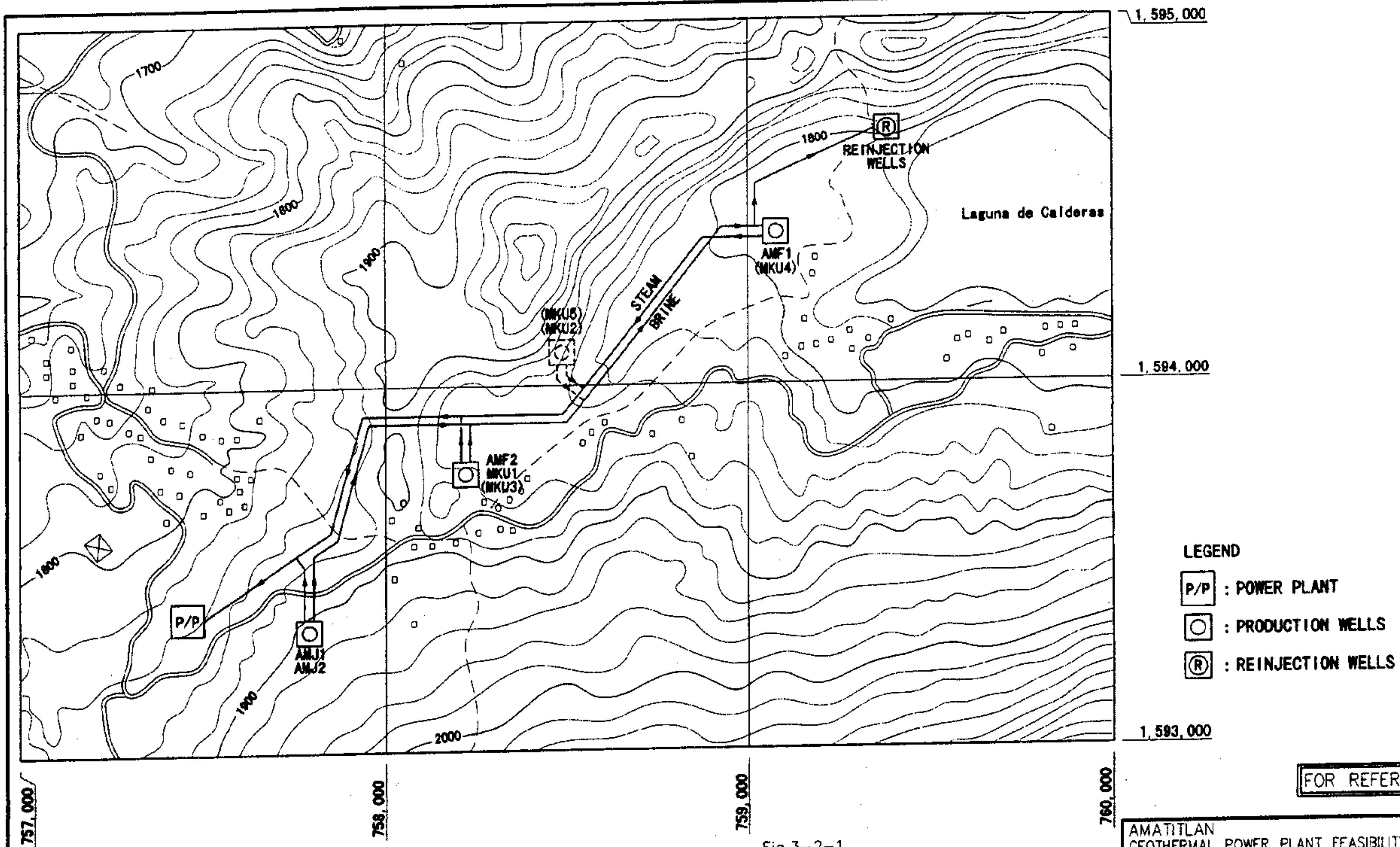
The project includes the following:

1) Construction of access roads from the existing road to the sites
2) Land leveling
3) Construction of water intake and supply facilities
4) Drilling of production/reinjection wells and installation of wellhead equipment
5) Construction of Fluid Collection and Reinjection System
6) Construction of power plant and appurtenant facilities
7) Construction of switchyard of the power plant
8) Construction of transmission line
9) Communication facilities

b. Contingencies

Contingencies are included as follows.

1)	Well drilling	5%
2)	Fluid collection and reinjection system	5%
3)	Power plant	3%
4)	Transmission line and substation	3%
5)	Geoscientific, general and administrative cost	5%
6)	Land acquisition and compensation	5%
7)	Price contingency	2%



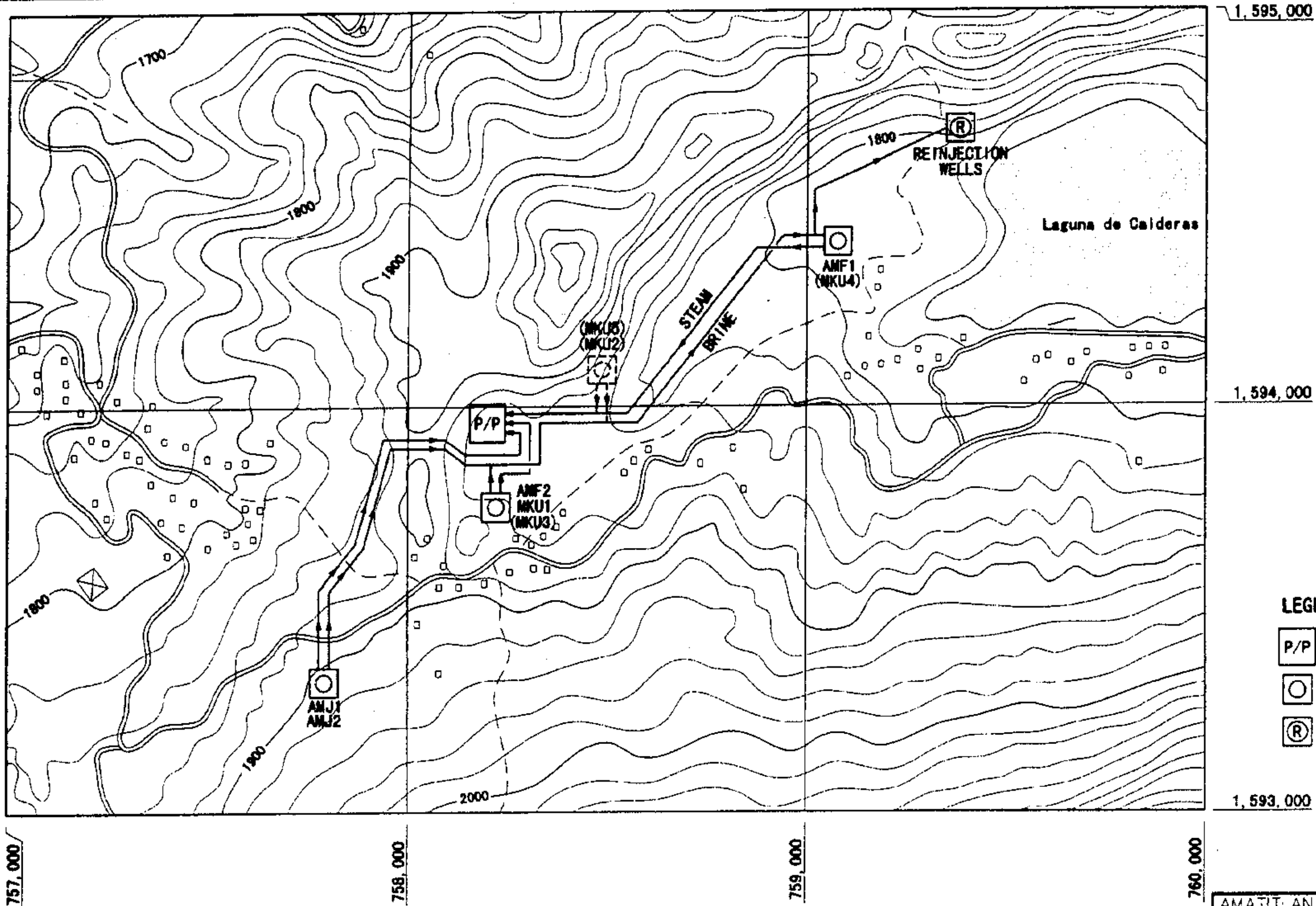
FOR REFERENCE

Fig.3-2-1
ROUTE OF STEAM AND BRINE PIPELINES
(OUTSIDE CALDERA)
蒸気・熱水配管ルート
「発電所建設地点Ⅰ（カルデラ外）」

AMATITLAN
GEOTHERMAL POWER PLANT FEASIBILITY STUDY

DWG.TITELE ROUTE OF STEAM AND BRINE PIPELINES (OUTSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 JOB.No DWG.No.	REV.No.
NON					◇

WEST JAPAN ENGINEERING CONSULTANTS INC.



LEGEND

P/P : POWER PLANT

○ : PRODUCTION WELLS

Ⓡ : REINJECTION WELLS

FOR REFERENCE

Fig.3-2-2
ROUTE OF STEAM AND BRINE PIPELINES
(INSIDE CALDERA)
蒸気・熱水配管ルート
[発電所建設地点Ⅱ(カルデラ内)]

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE ROUTE OF STEAM AND BRINE PIPELINES (INSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER,2001 JOB.No	
NON				DWG.No.	REV.No. ◇
WEST JAPAN ENGINEERING CONSULTANTS INC.					

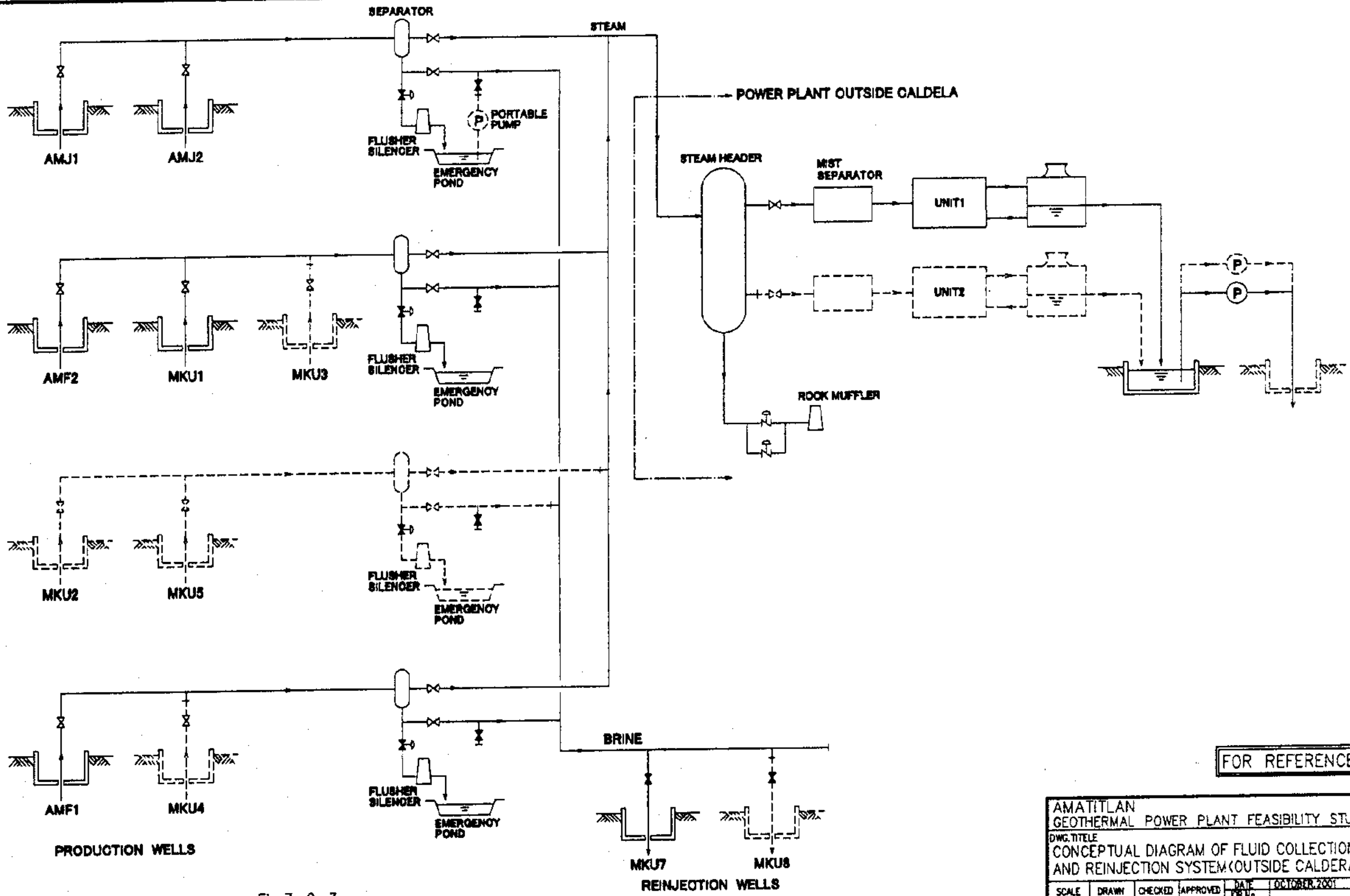


Fig.3-2-3
CONCEPTUAL DIAGRAM OF FLUID COLLECTION
AND REINJECTION SYSTEM(OUTSIDE CALDERA)
地熱流体輸送・還元設備系統図
「発電所建設地点Ⅰ(カルデラ外)」

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE CONCEPTUAL DIAGRAM OF FLUID COLLECTION AND REINJECTION SYSTEM(OUTSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 JOB.No	
NON				DWG.No.	REV.No.
WEST JAPAN ENGINEERING CONSULTANTS INC.					

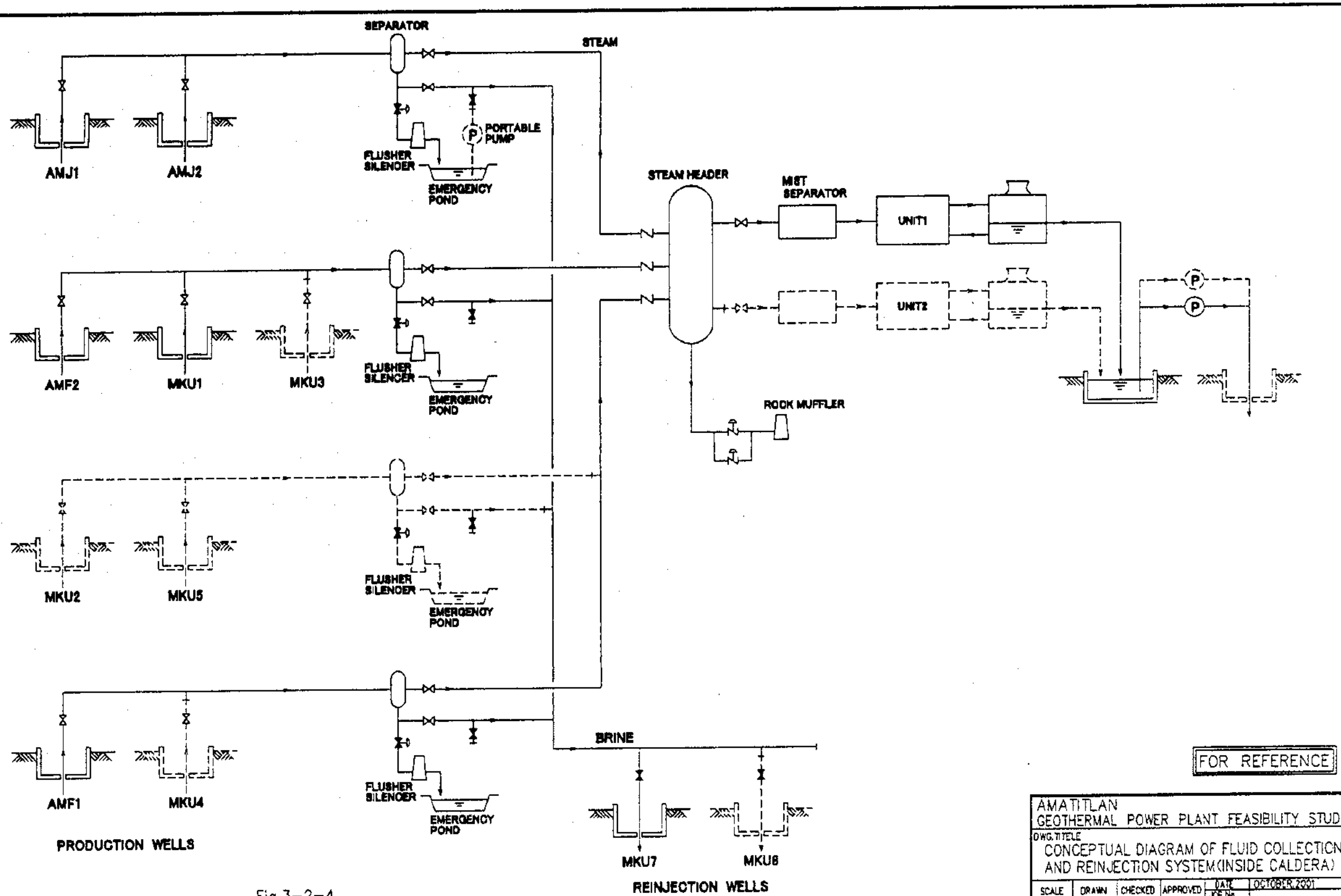


Fig.3-2-4
CONCEPTUAL DIAGRAM OF FLUID COLLECTION AND REINJECTION SYSTEM (INSIDE CALDERA)
地熱流体輸送・還元設備系統図
「発電所建設地点Ⅱ（カルデラ内）」

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY

DWG.TITLE
CONCEPTUAL DIAGRAM OF FLUID COLLECTION AND REINJECTION SYSTEM (INSIDE CALDERA)

SCALE	DRAWN	CHECKED	APPROVED	DATE	OCTOBER.2001
NON				DWG.No.	REV.No.

WEST JAPAN ENGINEERING CONSULTANTS INC.

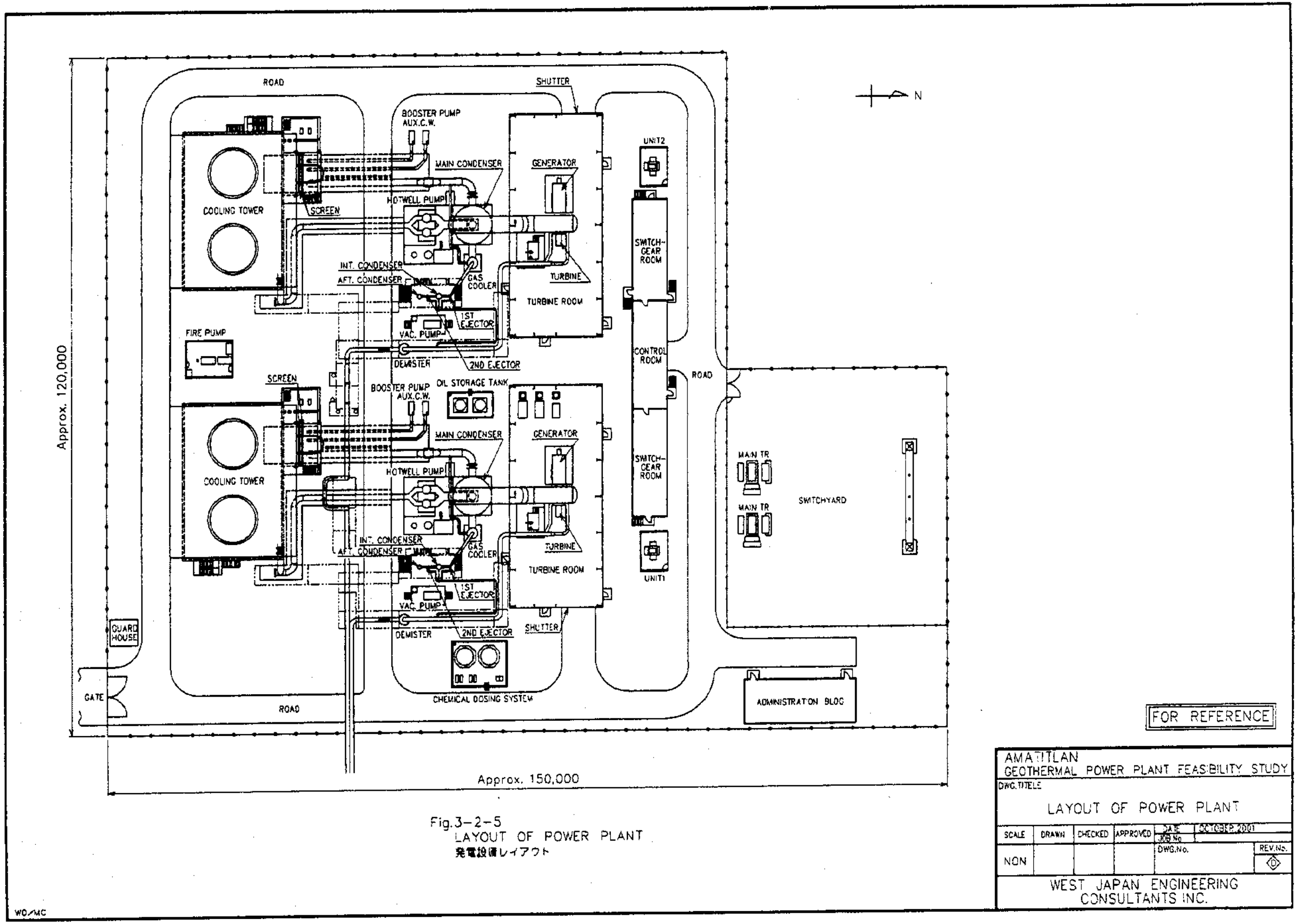


Fig.3-2-5
LAYOUT OF POWER PLANT
発電設備レイアウト

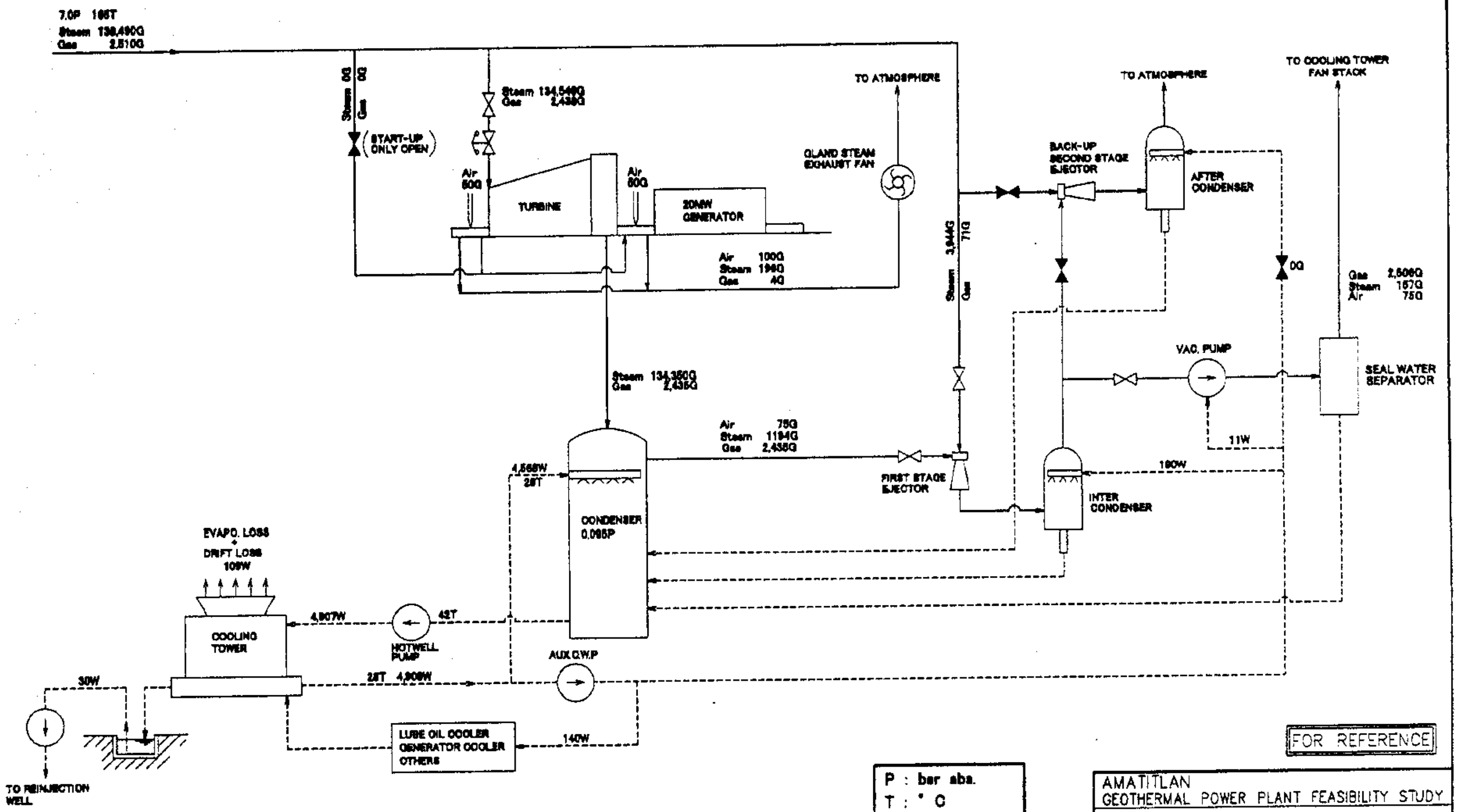


Fig 3-2-6
HEAT & MASS BALANCE DIAGRAM
ヒートバランス

P	bar abs.
T	°C
G	kg/h
H	kJ/kg
W	m³/h

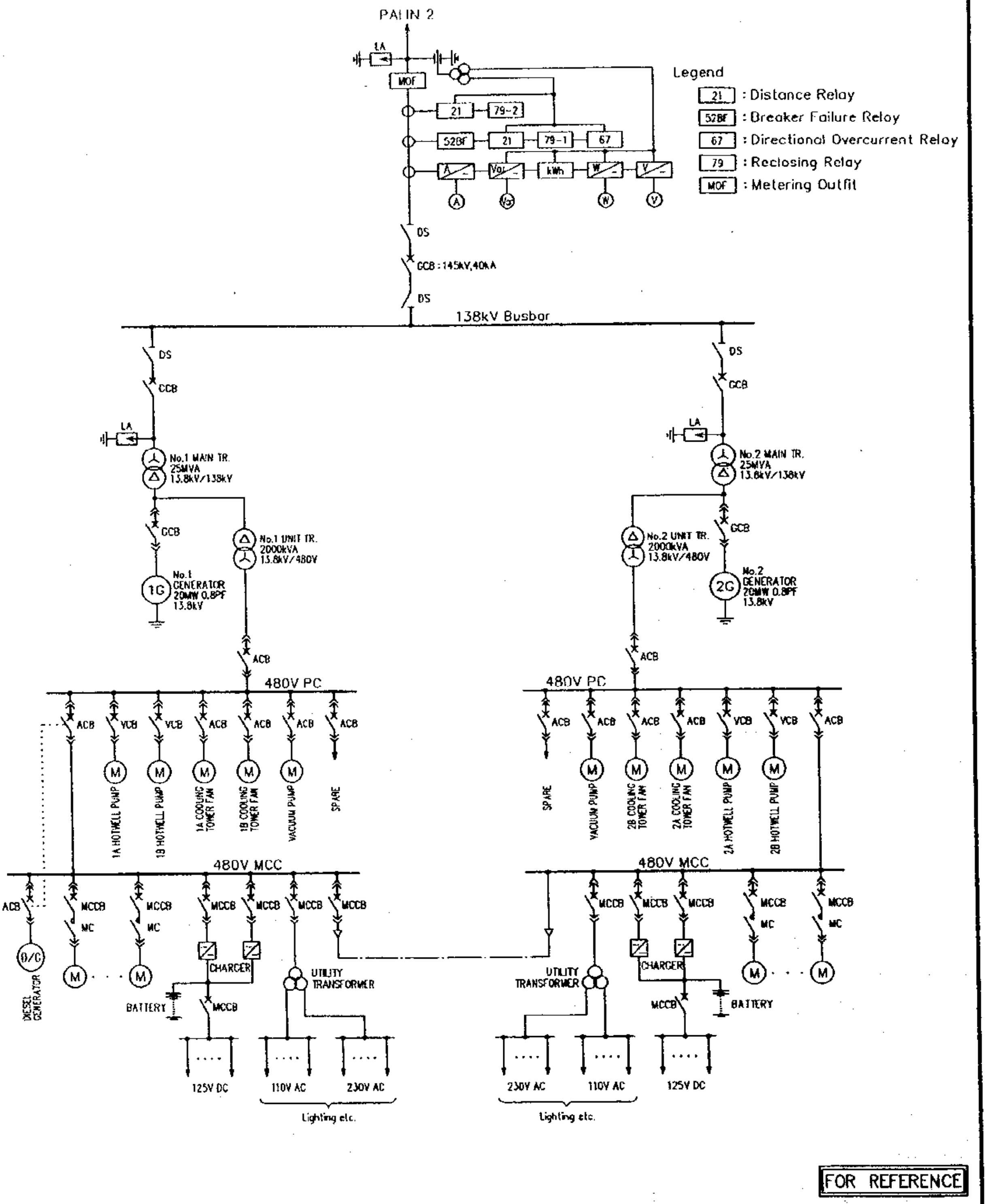
FOR REFERENCE

AMATITLAN
GEOTHERMAL POWER PLANT FEASIBILITY STUDY

DWG. TITELE
HEAT & MASS BALANCE DIAGRAM

SCALE	DRAWN	CHECKED	APPROVED	DATE	OCTOBER.2001
				JOB No.	
NON				DWG.No.	REV.No.

WEST JAPAN ENGINEERING CONSULTANTS INC.



AMATITLAN
GEOTHERMAL POWER PLANT FEASIBILITY STUDY

DWG. TITLE: SINGLE LINE DIAGRAM

SCALE	DRAWN	CHECKED	APPROVED	DATE: OCTOBER,2001 / JOB.No. / DWG.No.	REV.No.
NON					0

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Fig 3-2-7
所内単線結線図
SINGLE LINE DIAGRAM

WO/MC

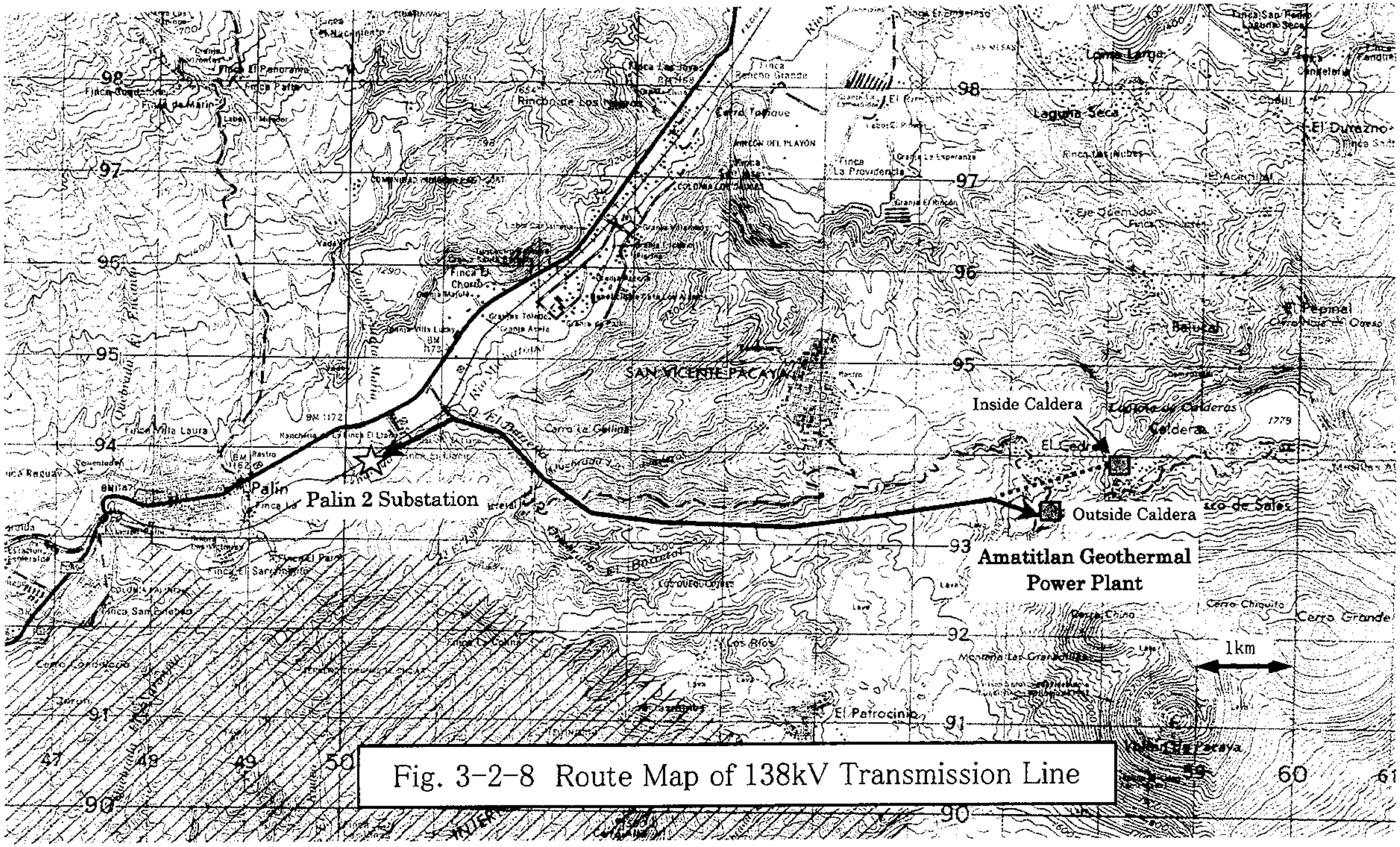

Fig. 3-2-8 Route Map of 138kV Transmission Line