BNWL-B-110

FOREIGN AND DOMESTIC DISCUSSIONS ON NATURAL GEOTHERMAL POWER AND POTENTIAL USE OF PLOWSHARE TO STIMULATE THESE NATURAL SYSTEMS

J. B. Burnham and D. H. Stewart
Battelle, Pacific Northwest Laboratories
Richland, Washington

July 6, 1971

DISCLAIMER

FOREIGN AND DOMESTIC DISCUSSIONS ON NATURAL GEOTHERMAL POWER AND POTENTIAL USE OF PLOWSHARE TO STIMULATE THESE NATURAL SYSTEMS

J. B. Burnham and D.H. Stewart

INTRODUCTION

A world survey of the major geothermal areas was made by the authors during May 1971. The trip was sponsored by the USAEC. The Dept. of State graciously assisted in making innumerable arrangements through their foreign offices. The tour included visits to Iceland, Italy, Australia, New Zealand and Hawaii. In the U.S., visits were made to the Geysers in California and several discussions were held with USGS and geologists experienced in geothermal power.

PURPOSE

The purpose of the trip was to obtain the first hand experience of geothermal plant geologists, drillers, and plant operators. Discussions were also held on the proposed USAEC Plowshare-Geothermal Stimulation research program.

This report is arranged by country and it should be noted that to attain reasonable brevity much of the information acquired has been summarized.

ICELAND - J. B. Burnham, D. H. Stewart - May 11-13, 1971

Contacts:

Dr. G. Palmason - Department of Natural Heat
Mr. J. Zoega - Reykjavik Municipal District Heating Service
Mr. K. Ragnars - Department of Natural Heat

Summary

Iceland has widely dispersed geothermal resources. These are characterized as low and high temperature fields. The latter are concentrated near the Quaternary volcanic activity associated with the crest of the Atlantic Ridge, which crosses the country from SW to NE.

The country has abundant energy resources (only 5% of its hydro has been developed). Most of the geothermal development has been concentrated in the heating of homes and hothouses. One experimental generating plant of 2.5 MW capacity has been operating successfully at Lake Myvatn for over a year.

Location of Geothermal Areas

While Iceland has widespread areas of geothermal activity, the most active geothermal fields are located in a zone which runs through the country from the southwest to the northeast. This area corresponds roughly to the crest of the Mid-Atlantic Ridge.

Geothermal areas of Iceland are characterized as low-temperature - below 150°C - or high temperature. While a number of low-temperature fields are known to exist throughout the country, the development of these has been concentrated around Reykjavik.

High temperature areas which have been studied in some detail are the Reykjanes area on the southwest tip of Iceland and the Namafjall area in the north-central part of the island. The former has been studied as a possible source of chemicals produced from geothermal brine. The latter has been developed as a source of process heat for the production of diatomaceous earth from Lake Myvatn. An experimental generating station of 2.5 MW is connected with the Myvatn installation.

Geology

The predominate rocks of Iceland are volcanic - basalts, andesites, and rhyolites. The basaltic lava flows of the Tertiary age are found in the western, eastern, and the north-central regions and the NW Peninsula of Iceland. Separating these regions are the younger volanic rocks of the Quaternary age - basaltic tuffs, palagonite breccias, lava flows, and pillow lavas.

Iceland is in the unique position of being energy-rich. They have developed only 5% of their available hydro power. As a result, they generally use their geothermal resources (which are extensive) for space heating. The exception to this is the 2.5 MW experimental station at Myvatn. With their energy situation being what it is, they were not particularly interested in the Plowshare geothermal concept. They did express some interest, though, in the results of the stimulation study, for they have tried increasing production in their Reykjavik field by hydrofracturing. Due to the high permeability of the structure, these efforts were largely unsuccessful. They think that the use of explosives may prove to be much more effective.

Production

About 75,000 inhabitants of Reykjavik live in homes heated by geothermal energy. The discovery of a new field (Ellidaar) near Reykjavik has caused postponement of a project to pipe high-temperature steam from the more distant Hengill field. It has been found economical to use supplemental oil firing of the low-temperature steam in periods of high demand.

Wells are rotary-drilled and cased only for the first 50-100 m. The operation of the production, collection, and distribution system is well automated. The cost of this energy to the homeowner is about 96¢/M Btu of which 66% is distribution costs. This is only a little over half the cost of oil heating in that area.

The Hveragerdi area was visited. In this region is concentrated most of the country's 105,000 square meters of greenhouses. Iceland produc most of its tomatoes, cucumbers, and lettuce in these hothouses heated by geothermal water. About a third of the area is devoted to the raising of flowers.

Plans to visit the Myvatn experimental power plant had to be cancel because of bad flying weather - a not uncommon situation in north-central Iceland. The government-owned Kisilidjan Company developed this area in cooperation with the Johns Manville Corp. in 1966. The plant producing 12,000 tons per year of diatomite was started up in 1967. Production was doubled in 1970.

Power Plants

In 1959 the Laxa Power Works built a 2.5 MW generating station at Lake Myvatn. This is an atmospheric exhaust installation. As such, it utilizes only a small part of the energy available in the wet steam. A condensing system can be added later, though, if demand warrants the expans The turbine operates at 147 psia and a back pressure of 15 psia. Under these conditions it has a heat rate of 42,000 Btu/KW hr. The turbine blading is a special 10% chromium-35% nickel alloy.

Steam is produced from four production wells about 1000 m deep. The wells are rotary-drilled. They are cased as follows: 16 inches to 30 m, 9-5/8 in. to 200 m, and 7-5/8 in. to 600 m.

Future Plans

A company town is under construction at Namafjall (Lake Myvatn). It is planned to pipe by gravity flow the hot (183°C) water from the well-head separators to this town some 3 km away. To avoid the corrosion problems associated with using the high-sulfur water in home heating systems, a fresh water heat exchanger will be used.

ITALY - J. B. Burnham - D. H. Stewart, May 13-17, 1971

Dr. Pietro Aron - ENEL - Rome
Dr. R. Cataldi - ENEL - Rome
Mr. Gian Carlo Ferrara - Larderello
Mr. Pier Domenico Burgassi - Larderello
Dr. Mario Farrelli - Geologist, Pisa
Kay-Han Gurani - Eng. on 1 yr. training program - from Turkey

Summary

The Larderello field produces around 400 MW_e from dry superheated steam. A new field, Monte Amiata, also shows great promise. These two fields lie in a band which runs north and south along the West Coast of Italy.

Locations

Two proved geothermal areas lie about 60 Kms south of Pisa and Florence. One area, Larderello covers roughly 90 Km^2; the other known as Monte Amiata, perhaps 40 Km^2.

Geology

The Larderello field areas lie under a surface of neogenic deposits, flysch-facies formations which constitutes an impervious layer. The porous reserve consists of limestone and dolomites and the area is well faulted. Larderello can be considered a hoist - a tectonic high. The underlying boraciferous region corresponds to a vast gravity deficit due to presence of a magmatic acid mass at a depth of 6 - 8 Km. The water derives its heat from the magmatic mass through the country rocks of the basement. The Monte Amiata area is somewhat similar. Thermal gradients as high as 50°C/100 meters have been measured. Electrical resistivity has proved a valuable exploration technique to 1000 meters with values ≥ 100 ohm meters.

Monte Amiata may be the only geothermal field discovered by geologic evaluation alone - no surface indications were present. This field also appears to be extensive and further wells are being drilled.

Production

Most of the bores are less than 1000 meters deep and produce steam containing gas at an average of 5% by wt. Temperatures run from 150°C to 260°C at the well head. Temperatures tend to increase with time. Flow rates average between 50 and 100 tonnes/hr. Shutdown pressures range from 88 psi to 617 psi. The Monte Amiata fields of Italy, Geysers in California and Matsukawa (Japan) are the only geothermal areas now producing dry steam.

Bore diameters are larger than those in New Zealand and are generally 13-3/8". Heavy mud is used when drilling and blowout preventers are always installed. Loss of drilling fluid is generally an indication that the producing layer has been reached. Casings are carefully cemented.

When a well is first produced the flow rate drops rapidly with time until a steady state level is approached asymptotically. Larderello is apparently in equilibrium with water inflow and no substantial increase in power from this field can be expected. It would be interesting to try reinjection in the production area. The geologists have estimated the natural water inflow takes some 40 years for fresh surface water to be removed as steam.

Steam temperatures run from 140°C to 190°C at the power plant.

Power Plant

On remote isolated wells, noncondensing turbines are used. Although simple and reliable, about 20 Kg of steam at 4.8 atmosphere and 185°C is required for one Kwhr net. It is also a useful cycle when gas content is high (i.e., as high as 30% by wt.) as the gas is troublesome to remove in a condensing cycle. A new - 15,000 Kw - noncondensing cycle achieved a steam rate of 13.8 Kg of steam per Kwhr.

In the condensing cycle, 10 Kg of steam per Kwhr is required. The steam is condensed, the water cooled in large natural draft cooling towers, and reused to condense more steam. Total capacity installed is 470 Mw and production is running around 400 MW_e. It is believed that further production at Larderello cannot be easily achieved as the field is about in equilibrium with water recharge. In a major power station, gross electrical output was much greater than the net. This was mainly due to the large amount (>20%) of power which was required to operate the noncondensable gas pumps.

Plowshare Geothermal

The ideas behind Plowshare stimulation were discussed at ENEL and the Geothermal Institute at Pisa. Both groups expressed interest in the program and expressed a desire to be kept informed. As Italy is a densely populated country, they felt dry geothermal required devices too large to be of interest but that the small devices for stimulation could prove helpful in some new areas they hope to discover.

TURKEY

Discussions with Mr. Gurani disclosed that Turkey could well be interested in Plowshare Stimulation of natural geothermal. They have what appear to be extensive deposits of 190°C hot water-steam mixtures. Mr. Gurain plans to return to Turkey soon to participate in the development of geothermal power.

NEW ZEALAND - D. H. Stewart, May 23-27, 1971

Principal Contacts:

Mr. J. H. Smith - Ministry of Works, Wellington, N.Z.
Mr. W. Basil Stillwell - Project Engineer, Wairakei, N.Z.
Mr. J. Giardin - Plant Manager, Wairakei, N.Z.

Summary

Wairakei is a large hot water-steam field. The hot water is separated from the steam and reflashed at low pressure. About 180 MW_e are being generated. A new field Broadland shows similar production capability.

Location

Wairakei is part of a large geothermal area extending north from Lake Taupo to Rotarura. It is approx. 20 miles wide and 150 miles long. Wairakei appears to be in a graben. As steam leaks and boiling pools of mud are quite prevalent in the area, its location has been known for centuries.

Geology

The area is covered with about 300 ft. of light pumice. Below this is 100 to 200 feet of impermeable, dense, fine sandstone and mudstone rock. The next layer consists of a porous mass of cemented and fissured pumice and rhyolite. 2000 feet below this lies a thick layer of massive ignimbrite. The ignimbrites are fragmented rocks which were erupted explosively at high temperature and the dense clouds of incandescent particles became welded and compacted into hard dense rock as they settled. The area is approximately 500,000 years old. Extensive faulting of the earth has occurred in this area. This is believed to provide steep permeable zones along which the hot fluids ascent from depth.

Production

Bore holes in the area produce steam and water mixtures. Approximately 1/2 of the wells produce at 80 psi and the other 1/2 at 180 psi. The deepest bore hole in use is 4,000 feet deep and the shallowest 563 feet. Average production depth is 2,200 ft. and the pipe diameter is 8 in. Average steam production is 48,000#/hr and maximum is 1,400,000#/hr. Steam lines up to 12,000 ft run to the power house. The highest steam temperature is 500°F. Bores only 90 ft. apart do not appear to interact. There has been a general decline in both temperature and pressure although it is believed the present power output can be maintained by utilizing more of the waste hot water with additional flashing to steam. Only about 7% of the total heat is actually utilized.

The site must be consolidated by pumping an average of 65 tons of concrete in the ground before drilling. Heavy drilling muds are used to avoid blowout. Loss of circulation is common when the steam producing formations are located. Blowout preventers are always used.

The bores produce about 80% by wt. water and 20% steam. The water, after separating the steam, is flashed to produce low pressure steam. Three piping systems are used, one for H.P. steam (160 psi), one for I.P. steam (52 psi), and one for L.P. steam (2 psi).

Power Plant

Installed max. capacity is 240,000 KW_e and approx. 180,000 KW_e is being generated - limited by steam production. They believe water inflow limits steam production at this level. No reinjection has been tried. The three steam pressures are fed to separate turbines and condensed by a river water cooling system. Most of the (80% by wt.) hot water is run through concrete trenches into a river. Silica deposits in these trenches as the water cools and these must be removed annually. No silica deposition on the turbines has been noted and one turbine in operation 12 years appeared in good condition. Noncondensables are low - .26% by volume - and are removed by a steam jet ejector. Carbon steel used extensively has good corrosion resistance providing oxide is kept from unused equipment.

Plans

Although geothermal costs are low and a large new field (Broadlands) has been proved nearby, it is unlikely new geothermal plants will be constructed soon. A natural gas field has been discovered off the shore of New Zealand, and its development will cost on the order of $150 million. This in turn requires a market so that new power plants over the next few decades are likely to run on natural gas.

Plowshare Geothermal

Discussions of the tentative plans for trying Plowshare in connection with geothermal stimulation in the U.S. were held with New Zealand geologists. They believed that such techniques could prove of great value and wished to be informed of the results of future programs. They were interested in the possibility that a Plowshare cavity might provide a convenient way to reinject all the hot water now being wasted - thus increasing the total output from the field. (The author can see no reason why reinjection has not already been tried.) Concern over radioactivity levels was expressed.

JAPAN - J. B. Burnham, May 24-27, 1971

Contacted:

Dr. Hisayoshi Nakamura - Geological Survey of Japan
Dr. Konosuki Sato - The Dawa Mining Company
Professor Hideo Iga - Japan Geothermal Energy Association
Mr. Yoshimi Hara - Chief Engineer - Otake Geothermal Plant

Summary

The Japanese Archipelago is widely covered with active geothermal regions. Two of these - Otake, Kyushu (10 MW) and Matsukawa, Honshu (20 MW) - are producing electricity. The operating history of these plants has been excellent with a 96-97% capacity factor and a minimum of maintenance problems. The Matsukawa plant has acidic conditions which cause some corrosion problems but a minimum of scale deposition. The Otake plant with less acidic conditions has no corrosion problems but must hold up the hot water effluent for one hour to allow settling of silica. The Japanese geophysicists are interested in the long-term potential of Plowshare geothermal for possible use in some of their small, uninhabited islands of northern Honshu. They think the use of Plowshare geothermal is technically feasible, but they expressed some concern over the possibility of contaminating the water table.

Location of Geothermal Areas

The major geothermal areas of Japan are listed in Table I below. While there are some 1300 hot springs and fumaroles in Japan, only those in which geothermal development has been (or will be) emphasized are listed here:

Table I

MAJOR GEOTHERMAL FIELDS OF JAPAN

Geothermal Area	Island	Area (km^2)	Total Heat Flow (10^6 cal/sec)
Atosanupuri	Hokkaido	0.9	7.8
Sounkyo	Hokkaido	0.8	1.9
Noboribetsu-Yunuma	Hokkaido	0.07	19.3
Noboribetsu-Zigokudani	Hokkaido	0.1	11.2
Showa-shinzan	Hokkaido	(0.1)	(3)
Nigorikawa	Hokkaido	3.6	3.0
Shikabe	Hokkaido	0.3	1.0
Tamagawa	Honshu	0.1	15.2
Matsukawa	Honshu	0.2	(33)
Kusatsu	Honshu		24.4
Hakone-Owakudani	Honshu	0.06	4.8
Beppu	Kyushu	7	37.3
Otake	Kyushu	0.1	44.6
Obama	Kyushu	1.5	52.4

The geothermal areas are fairly well distributed over the islands of Hokkaido, Honshu, and Kyushu. Shikoku is the only one of the four major islands of Japan which has few hot springs. Most of the hot springs are located along Quaternary volcanic zones and derive their energy from volcanic activity of that period.

Geology

Japan lies in the Pacific orogenic zone - the boundary between the stable continent and the Pacific Ocean. Very extensive faulting occurred through most of the Japanese Archipelago during the Tertiary Period. This faulting was followed by a period of igneous intrusion which deposited lava and tuff in a large geosynclinal basin. This tuff is a distinctive green-spotted variety called "green tuff" and the geosynclinal basin is called the "green tuff" region. Over this tuff thick deposits of marine sediments were laid down. Later intrusions of granite (and metamorphic rock) occurred in this green tuff region along with some additional faulting. Toward the end of the Tertiary Period, most of the green tuff regions were uplifted. During the Quaternary Period more deep fracturing occurred and the new volcanoes of the Quaternary arose.

Some 265 volcanoes came into existence during the Quaternary Period of which almost 50 are still active. These fall into two chains - the eastern one which runs from Hokkaido through northeast Japan to the Marianas and the western chain which runs from Kyushu through the Ryukyu Islands to Taiwan.

The geothermal areas derive their heat from the Quaternary volcanic activity. Most of the hot areas are closely associated with the volcanic zones. The hot springs generally have basements consisting of green tuff, although some occur in areas of Palezoic and Mesozoic formations and granite.

In the opinion of the Japanese geologists contacted, a small nuclear explosion in such formations could stimulate steam production through the creation of a large diameter well bore. They do not think that the fracture zones would be sealed off in the process. They did express concern about the possible contamination of the ground water.

Production Details

The two areas of Japan which have been developed to date for power production are the Matsukawa of northeastern Honshu and the Otake of north-central Kyushu.

The Otake plant was visited on May 25. This plant has a design capacity of 10 MW. Five production wells were drilled, but calcium carbonate deposits caused a shut-off of one of these after three years of operation.

The Otake area was developed by the Kyushu Electric Power Co. starting in 1950. The five production wells were drilled in the time period 1963-1966. Power production began in August of 1967.

The basement rock in this geothermal area consists of two-pyroxene andesite, hornblende-bearing two-pyroxene andesite lavas, and associated tuff breccia. This basement is overlain by the Kujyu volcanic complex generally composed of hornblende andesite.

Geophysical prospecting in the area has been carried out with magnetic, electrical, and gravitational techniques. These surveys indicate that an area approximately 1.5 km by 3.0 km has been hydrothermally transformed to a depth of 800-1000 m.

The Otake field produces a steam-water mixture of about 25 wt% steam from an average well depth of about 450 m. The wells are rotary-drilled and are typically cased to about 250 m depth with 8-5/8 inch casing. Steam is separated by a rotary separator at the well head, piped to a collection tank, passed through the turbine, a vacuum ejector (for noncondensable gas removal), a barometric condenser, and cooled by three forced-draft cooling towers. There were some corrosion problems due to the SO_2 in the steam until the vacuum ejector was installed. SiO_2 was a problem in the hot water lines until a baffled holdup tank was added. The one-hour holdup time allows the SiO_2 to settle out in the bottom of this tank, the outlet of which runs to the Kusu River in an open channel. The turbine has been shut down once a year for inspection and water jet washing for SiO_2 removal. This schedule has been changed to a two-year one because of the excellent performance characteristics of the system which has run at a 96% capacity factor. The turbine throttle steam conditions are 127°C, 2.5 atm (37 psi), 0.1 atm (2.9 in. Hg) back pressure at a steam consumption rate of 110 t/hr.

The Matsukawa geothermal field was developed through efforts of Japan Metals and Chemicals Company and the Geological Survey of Japan. Test wells were sunk in 1952 and an extensive survey program was begun in 1956. Four production wells were sunk in 1964 and 1965. The area started power production of 20 MW in 1966.

Basement rock in the area is Paleozoic slate and chert. This is overlain by Tertiary green tuff, the Tertiary Yamatsuda formation (sandstone and shale), then dacite tuff and dacite lava of the Tertiary period. The upper beds are Quaternary volcanic rocks, primarily andesite.

The four production wells were rotary drilled to a depth of about 1000 m. A standard casing program consisted of a 16-inch casing to a depth of 30 m, 11-3/4 inch casing to 250 m, and 8-5/8 inch casing to a depth of 500 m. Several wells produced superheated steam.

Special features of the turbine include stellite facing on the steam inlets of the last two stages for corrosion resistance, moisture extracting buckets, and grooves to remove condensate from the inlet nozzle.

Plans

A new production area is currently under development several kilometers to the south of the Otake installation on Kyushu. Four wells have been completed at Hachabara and two more are being sunk. Ten more wells are planned for this phase of the plant construction. The output will be 50 MW. Eventually the production from this geothermal area will be increased to 150 MW. The wells are about 1000m deep in this area and produce a steam-water mixture which is about 33 wt% steam.

There are currently under active development several geothermal areas on Hokkaido. The most promising of these are: the Shikabe area on the Nasu volcanic zone, the Shawa-shinzan, the Tokachi-Daisetsu volcanic region, and the Kurile volcanic region.

On Honshu, the Onikobe and the Oshiraka regions show the most promise. Ten wells have been sunk at the former. One of them is producing 20-30 t/hr of superheated steam from 500 m depth.

HAWAII - J. B. Burnham, May 28, 1971

Contacts:

Dr. Walter Arnell, Center for Engineering Research
Dr. John W. Shupe, Dean, School of Engineering, U of H.
Dr. Richard Fand, Head, Mech. Engr. Dept., U of H.

The islands of Hawaii have ample geothermal reserves, but there has been no development of them to this date. The reason for this is a combination of hydrologic and geologic phenomena which make the recovery of energy most difficult.

Although the annual rainfall on the Islands is very large, the permeability of the volcanic rocks of the area is so great that the water moves very rapidly through the formations and back to the sea. The surface manifestation of this condition is the scarcity of rivers and streams; throughout the Islands there are only a handful of streams and no major rivers. This means that the ground water must be moving very rapidly and has little chance of being heated to high temperature even when passing through a geothermal anomaly.

The same highly fractured rock formations mean that even with a more favorable water table, the hot water would have no competent layer of rock above it. While such a cap layer may not be absolutely necessary for the generation of geothermal power (assuming some alternate turbine working fluid proves economic), its lack certainly makes the probability of natural geothermal power very remote.

Plowshare geothermal is not a very likely solution to the recovery of this energy, for the Islands are not suited tectonically or geologically for such development. The most feasible method of developing this power source may be the tapping of the magma pools which underlay Kilauea and other volcanoes. While such systems of energy conversion do not exist today, their development would seem to be within the reach of technology.

GEYSERS, CALIFORNIA - D. H. Stewart, June 25, 1971

Contacts:

Dr. Carel Otte - Union Oil Co.
Mr. Tony Chastain - Geysers
Mr. Al Bruce - PG&E

Summary

The Geysers field in California is the largest known geothermal field in the world, covering at least 20 square miles. It is one of three fields producing dry, superheated steam. Current production of 82 MW_e is being expanded by additions of 110 MW_e power plants and ultimate production could run from 1000 to 4000 MW_e.

Location

The Geysers is located in the coast range about 90 miles north of San Francisco, Cal. It covers an area of at least 20 square miles, and as numerous step-out wells have been successful, the full extent of the area is still unknown.

Geology

The reservoir at the Geysers consists of Franciscan graywacke. The graywacke itself has a very low porosity, but is highly fractured and the bulk permeability is very high.

It is likely that the heat source is volcanic as widespread young volcanic activity is a feature of this portion of the coastal range. Facca's theory is that the Geysers was a self-sealing reservoir, forming its own cap rock through deposition of minerals and thermal alteration of the upper layers of the graywacke. A major fault has been located by drilling, and it is likely that this fault provides a passage for the water to the volcanic heat at depth. There is agreement that at least 90% of the steam is of meteoric origin.

Production

Air drilling is generally used and the bores run from 1000 to 7000 feet. The drilling record is extraordinary with 70 producing wells against 5 dry holes. Present proven capacity is 400 MW_e and the capacity of the drilled area is 1300 MW_e. Very little ground water is encountered as on the whole the cap rock is impervious.

The wells are cased to from 700 ft. to 1200 ft. Casing from 9-5/8 to 13-3/8 is used. On many wells no further casing is used and the well is produced as a barefoot completion. If objectionable quantities of water are encountered, further casing is required.

Union Oil supplies the steam to the Power Plant where it is purchased by PG&E for about 2.9 mills/kwhr of electrical power generated. This results in an average income of $240/day per average well. Shut off well pressures range from 210 psig to 479 psig. Max. steam flow from a single well is 220,000 lb/hr at 110 psig.

Power Plants

The original two units 1 & 2 provided 20 MW_e and produced power to the system for 5.65 mills. Units 3 & 4 total 56 MW_e and power costs dropped to 4.71 mills/kwhr. The two units presently being installed are 55 MW_e each and will show a further reduction in power costs. The original units used forced draft cooling towers and barometric condensers. The water surplus, formerly added to the creek is now being reinjected into the producing formation. No loss in production from adjacent wells has been noted as a result of reinjection.

The steam supplier is required to remove the carryover rock and particulate matter from the steam before delivery to PG&E. Noncondensables run quite low, 1 to 2% by wt. for new wells, but this drops off as the well is produced.

The power production is reliable and no operators are present for two shifts each day. A 90% load factor is the general experience.

Plowshare Stimulation

The proposed AEC program was discussed with Carel Otte and Tony Chastain. Union Oil is interested in the program and bids. They are considering contacting the AEC for participation in the proposed program.

DHS:JBB:jd