GEOTHERMAL ENERGY IN ICELAND

A Trip Report: June 16 - 21, 1979

By

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MASTER

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I. Objectives of Trip

The idea of the trip originated from an invitation extended to me by Dr. Jon Steinar Gudmundsson of the National Energy Authority, Geothermal Division and Professor Thorbjörn Karlsson of the University of Reykjavik. The purpose was to become acquainted with the personnel of the Geothermal Division of the Icelandic National Energy Authority, to make site visits to the Krafla Power Plant, the Reykjavik District Heating Plant, and to Svartsengi (Sudurns District Heating Plant), and to deliver a seminar lecture on "The Application of the Concept of Available Work in Geothermal Energy".

II. Itinerary and Contacts

June 15 Leave Providence for Reykjavik via New York, Kennedy
(Friday) (only connection available).

June 16 Personal visit to the house of Dr. Jon Steinar
(Saturday) Gudmundsson.

June 17 Icelandic National Holiday. Personal visit to the
(Sunday) house of Halina and Atli Freyr Gudmundsson.

June 18 Visit to Krafla via Akureyri (air) and Soviet jeep
(Monday) as guest of the Icelandic National Energy Authority.
Escort: Dr. Einarson.

Contacts: Gunnar Ingi, Plant Manager
 Einar Tjörfi Eliarsson, Manager & Director of
 Krafla Project
 Asgrimur Gudmundsson, Geologist
 Valdimar K. Jonsson, Professor

June 19 Visit to Sudurns District Heating Plant at Svartsengi
(Tuesday) as guest of the Icelandic National Energy Authority.

Contacts: Dr. Jakob Björnsson, Director of National Energy
 Authority
 Dr. Jon Steinar Gudmundsson, Geothermal Division of
 NEA
 Sigurdur V. Halsson, Chemist, Salt Plant
 Bragi Eyjolfsson, Plant Engineer

June 20 Visit to Reykjavik District Heating Plant and lecture
(Wednesday) at the University of Reykjavik.

Contacts: Johannes Zoëga, District Heating
 Gunnar Kristinsson, Chief Engineer
 Professor Valdimar Karlsson

III. Geothermal Installations in Iceland

Námafjall

The geothermal field at Námafjall is located in northern Iceland on the main rift zone that runs through the central portion of the island. At this site the most significant commercial use of geothermal energy takes place. A diatomite plant, named Kísilidjan, situated on the edge of Lake Mývatn, employs geothermal steam from wells at Namafjall as the motive force for several processes in the production of filter aids. The diatomaceous earth is dredged from the lake bed into storage reservoirs adjacent to the plant. It is piped into the plant as a slurry and heated to 90°C (194°F) by direct injection of geothermal steam. Next, it is filtered and dried in a rotary, steam dryer fed by geothermal steam.

Until recently a portion of the electrical power needed for the plant was supplied by a 3 MW, flash-steam geothermal power plant located 500 m (1640 ft) from the plant. However, volcanic activity during the past few years damaged the power plant and some of the wells feeding it. As a result of this and other considerations (for example, the owners of the diatomite plant do not wish to be treated as a utility), the power plant is no longer in operation and the turbine has been removed for use elsewhere.

The first wells were put down at Namafjall from 1947-1953 for sulfur mining. The drilling of the current production wells was begun in 1963. Drilling is still proceeding and it is expected that 2-3 additional wells will be completed soon. The steam from the boreholes is just sufficient to meet the requirements of the Kísilidjan plant at this time, and there are no plans to restore the power plant to operating conditions.

The wells are spaced about 90 m (295 ft) apart, along two faults. The wellhead separators include a U-bend section of pipe to remove solid particles (sand, mud, pebbles, etc.) that occasionally are ejected from the wells along with the geofluid. The geothermal steam carries about 1% (wt) noncondensable gases consisting mainly

of hydrogen sulfide (52%, vol), carbon dioxide (32%, vol), and hydrogen (12%, vol). Bottomhole temperature is about 300°C (572°F), and steam delivery temperature is about 183°C (361°F). Under normal conditions each well produces about 25 t/h (55,000 lbm/h) of separated steam at a pressure of 1.08 mPa (156 lbf/lm²).

Krafla

The principal geothermal electric power project in Iceland is underway at Krafla, about 7 km (4 mi) north of Namafjall. The plan is to install 60 MW of capacity in two 30 MW units. Presently one of the units is installed; the other is on-site but stored for future installation. Unfortunately, the first unit has not lived up to the expectations of its designers, primarily because of difficulties in securing sufficient amounts of steam at the correct conditions.

The development of the Krafla project is described in the attached brochure, "Kröfluvirkjun - Krafla Geothermal Power Plant", published by the Krafla Geothermal Project Executive Committee, Akureyri. We shall concentrate on those matters and events that have occurred recently and therefore could not appear in the brochure.

The project appears to have been plagued by troubles of two kinds: administrative (i.e., man-made) and technical (partly man-made, mostly natural "Acts of God"). The coordination of the several agencies and contractors (p. 3 of brochure) has been inadequate. The main problem appears to be the premature placing of the order for the energy conversion equipment. The necessary field development lagged behind thereby creating the potential for a mismatch between the actual resource characteristics and the proposed energy conversion equipment. The extremely attractive delivery time promised by the turbine-generator manufacturer (Mitsubishi Heavy Industries, Ltd.) turned out to be irresistible, but it has left the Krafla project in an uncertain state.

Besides these administrative and management troubles, the region in which the plant is located has been plagued by seismic activity. The earth on which the plant is built and into which the wells are drilled slowly rises, presumably because it is forced upward by magmatic intrusions relatively close to the surface. At a

certain point, the magma breaks through subterranean cavities and flows into them, relieving the pressure and allowing the surface to subside. This series of events repeats itself and the elevation of the uprisings grows each time, presumably as the subsurface cavities become filled with magma. It is felt that eventually, and in the not-too-distant future, the magma will erupt and produce lava flows that may conceivably damage the plant or cause injury.

Another technical problem resides in the structure of the reservoir and in the water-bearing layers in it. The hottest portion of the reservoir is at a depth of about 1700 m (5580 ft) where fluid is encountered at a temperature of close to 360°C (680°F). However, there is another production zone that lies at a depth of less than 1200 m (3940 ft) which contains fluid at 220°C (428°F). All 12 wells drilled to date cut through both zones. The depth of the cooler zone seems to vary across the field from well to well. The conditions of the fluid at the surface (i.e., temperature and steam quality) depend strongly on which zone happens to be producing at the time. The upper zone has been cased off in one well to maintain the high-temperature flow. However, the fluid now appears to be flashing in the formation since dry and sometimes superheated steam is being produced from the well. This condition is not desirable since deposits of various solids (e.g., calcium carbonate) may eventually lead to loss of permeability and possibly permanently damage the reservoir.

As it stands, the Krafla 30 MW power plant is generating 7-8 MW. It is not clear whether more power than this will ever be generated at this plant. There is a possibility that a new set of wells will be drilled at another site, nearby but further away from the active volcanic area. Perhaps the other 30 MW unit, waiting in boxes, will be relocated to another field, one that will be better understood and more stable than the present one at Krafla.

Svartsengi

The greatest success in utilizing geothermal energy in Iceland is being achieved in direct heating of water for residential and commercial applications. About 65% of the island's 220,000 inhabitants have their homes heated by geothermal hot water, and this is expected to reach 80% in the near future. It is safe to say, in this regard, that geothermal energy has saved Iceland from bankruptcy in the light of the escalating price of petroleum. Nevertheless, the Icelandic economy is caught in an inflationary spiral.

There are two 1 MW geothermal steam turbines installed as part of the Sudurns District Heating plant at Svartsengi near Grindavik on the Reykjanes peninsula in southwestern Iceland. The plant provides 85°C (185°F) water to the 12,000 inhabitants of the area, including the towns of Grindavik and Keflavik. In the near future it will be able to supply water at 125°C (257°F) for distribution to more distant communities.

A simplified flow diagram is given of the plant in Fig. 1, and the temperature, pressure, and flow rates are listed in Table 1 for the important state points in the plant. There are two such units currently in operation. If one allows that the 1000 kW of electric power may be called an output of the plant (as opposed to being totally consumed to maintain the plant in operation), then the net plant utilization factor is 47% while producing 125°C water and 37% while producing at 85°C. These values are found by comparing the energy of the useful output streams (plus the electrical power) to that of the incoming streams from the wells, both hot and cold. Five geothermal steam wells are needed to supply the two units in the plant.

Table 1. Fluid Properties at Svartsengi Plant

<u>State^(a)</u>	<u>Temp., °C</u>	<u>Press., bar</u>	<u>Flow rate, kg/s</u>
1	235	~ 30.6	25.3/30.0 ^(b)
2	155	5.4	4.38/5.16
3	155	5.4	20.95/24.84
4	65/75	0.23/0.39	3.42/3.63
5	155	5.4	0.03
6	155	5.4	4.06/3.07
7	155	5.4	0.29/2.06
8	155	5.4	0.29/0.23
9	155	5.4	0.00/1.83
10	5	n.a.	44.58/34.20
11	49.2/64.9	0.23/0.39	48.00/37.83
12	68.7/64.9	n.a.	48.00/37.83
13	107	n.a.	48.00/37.83
14	100	~ 1	0.92/0.72
15	85	n.a.	47.08/0.00
16	125	n.a.	0.00/37.11
17	155	5.4	0.99 (max.)
18	115	1.7	0.99 (max.)

(a) See Fig. 1 for location of state points.

(b) Wherever two entries appear, the number before the slash refers to plant operations when producing only 85°C water; the number following the slash applies when only 125°C water is being produced.

Fig. 1 Sudurns District Heating at Svartsengi.

Key: S = separator;
 BC = barometric condenser;
 F/S = flasher/silencer;
 DCHX = direct-contact heat exchanger;
 PH = preheater;
 IH = intermediate heater;
 DG = degasser;
 FH = final heater;
 T-G = turbine-generator;
 D = discharge to drain;
 V = vent.

Note that numerous bypass and auxiliary lines have been omitted for clarity.

IV. Summary of Discussion and Impressions

It is no exaggeration to say that geothermal energy - predominantly in the form of heat - has saved Iceland from bankruptcy even though it is unable to help to stop Iceland's runaway inflation. The district-heating installations operate reliably and their development is well coordinated with a drilling program. Even though 2 MW of electric power are produced at Svartsengi (for use within the system only), no attempt to optimize the installation is made because electricity is treated as a byproduct in this operation.

The production of electric power at Krafla would make possible a significant addition to the industrial potential of this 250,000-man strong nation which now bases its economic solvency on fishing. Inadequate coordination between three authorities (now merged) and an incomplete program of exploratory drilling combined with unforeseen (but not unforeseeable) volcanic eruptions have stalemated the project.

The events around Krafla stress, if further stress is needed, that the design of the mechanical, energy-conversion equipment for a geothermal plant must not be started before the existence of an assured supply of working fluid of known characteristics is present. A patient period of geological exploration must be planned and endured. This may put an additional economic drain on the project but adherence to this rule, provided that a suitable reservoir has been located, makes geothermal energy development a sure bet.

Experience of the kind described here, and an ability to profit from it is far more important than academic optimization efforts.

As a postscript the writer cannot help but express surprise that American Jeeps are being replaced by 4-wheel drive Tchaikas on the dirt-roads of Iceland.

page 11-14 deleted (travel expenses)

Appendix

Brochure published by The Krafla Geothermal Project
Executive Committee, Akureyri, Iceland.

KRÖFLUVIRKJUN

Krafla Geothermal Power Plant

Kröfluvirkjun

Krafla Geothermal Power Plant

In April 1974, the Parliament in Iceland, Alþingi, passed act Nr. 21 which calls for the construction of a 55 MW geothermal power plant near Krafla or east of Námafjall in Suður-Þingeyjarsýsla in North-Iceland. In June 1974, the Minister of Industries commissioned a committee of five members to undertake the planning and execution of the plant construction, in so far the establishment of North-Iceland Power Corporation is not yet a reality.

The Krafla Geothermal Project Executive Committee is presided over by Hon. Jón G. Sólnes, Member of Parliament, also acting director of the Committee. Other members are Hon. Ingvar Gíslason, Member of Parliament, vicechairman, Hon. Ragnar Arnalds, Member of Parliament, Mr. Páll Lúðvíksson, mechanical engineer and Mr. Bragi Þorsteins-son, civil engineer. In addition, the National Energy Authority of Iceland (OS) was commissioned to undertake the drilling and steam procurement, the design and construction of the steam supply system and the establishment of a waste water disposal system. Later, the State Electric Power Works (Rarik) was assigned the task of planning a 132 KV power transmission line from Krafla to Akureyri.

The entire project, especially the waste water disposal, is subject to consent and supervision by the Nature Conservation Council, confer with act Nr. 36/1974 on the conservation and protection of Lake Mývatn and the river Laxá in South-Þingeyjarsýsla. From the beginning, good relationship between the Council and the executing agencies has prevailed.

The Krafla Geothermal Power Plant is designed by Sigurður Thoroddsen and Partners in Reykjavík in

joint venture with Rogers Engineering Co., Inc. in San Francisco. The Krafla steam supply system is designed by Virkir Ltd., in joint venture with Sigurður Thoroddsen and Partners both in Reykjavík. Raf-teikning Co. in Reykjavík has assisted with the electrical design and Manfreð Vilhjálmsson and Þorvaldur S. Þorvaldsson, architects in Reykjavík, are responsible for the architectural design of all buildings. The main building contractor has been Miðfell Ltd. in Reykjavík.

Construction management for the Committee is undertaken by Dr. Einar T. Elíasson, chief engineer, whereas Mr. Karl Ragnars, mechanical engineer, is in charge of OS construction programme. Mr. Samúel Ásgeirsson, civil engineer, supervises the erection of the 132 KV transmission line for Rarik.

The Krafla Geothermal Power Plant is of unique construction and with few precedents in the energy industry. With this first large geothermal power plant in Iceland, new scope is added to our power utilization structure. The Krafla Executive Committee therefore hopes with this information brochure to enlighten the public about the construction history and the technical features of the Power Plant.

Akureyri in July 1976,

on behalf of Krafla Geothermal Project Executive Committee,

chairman

The Research Phase

Preliminary investigation of the high temperature geothermal fields near Krafla and east of Námafjall was conducted by OS during 1970–1973. Thorough investigation into the geology of the fields, supplemented by geophysical measurements such as Ohm resistivity and magnetic field surveys, was carried out during this period. Moreover, earlier research and experimental drilling east and west of Námafjall should also be mentioned.

The surveys did show that the Krafla field is considerably larger than the Námafjall field. Their geological development is different, even though both belong to the same rift zone.

The ground water system of the Krafla field seems independent of the Námafjall field. It is contained within an old half-filled caldera or a kind of circular pot of subsidence. Thermal manifestations are only encountered in the middle of the caldera. In the Námafjall area, such manifestations are omnipresent.

A magnetic low, produced through deterioration of magnetite rock by heat alteration, encompasses the southern part of the Krafla caldera where thermal signs are widespread. The resistivity measurements, on the other hand, depict sharp outlines of the geothermal field which precisely conforms to the hot spring coverage and youngest of rock alterations.

In late 1974, two 1100 meter exploration wells were drilled at Krafla. In well Nr. 1, bottom temperatures of 298° C were measured. The temperature gradient of this well indicated that bottom temperatures of about 330° C would be reached at 2000 meter depth, which was the proposed depth of production wells. Well Nr. 1 was not very powerful since only few water arteries were struck. Contrariwise, well Nr. 2 struck rich water arteries but comparatively cool yet strong arteries from the 340 meter level caused low bottom temperatures of about 210° C.

The National Energy Authority presented its report on the Krafla Geothermal Field in February 1975. The main points of the report call out the Krafla field as more advantageous for development than the Námafjall field. The potential of the Krafla field is believed to support a 50–60 MW power plant with later extensions. It is furthermore proposed that drilling of production wells be set into action during summer 1975.

Local Geology

Krafla and Námafjall belong to the volcanic rift zone which transpierces the country from southwest to north. Since the end of last glacial period, about 10 thousand years ago, 20 volcanic eruptions have taken place in this area. During the „Fires of Mývatn“ in 1728, the Námafjall area had its last eruption which caused the lava formation on which the nearby Diatomaceous Earth Plant is located. The volcanic eruptions of Námafjall have all been lava eruptions with the exception of Hverfjall (Mountain of hot spring) which was formed during an explosive eruption under water about 3000 years ago.

About 10 lava eruptions have occurred near Krafla in this same period. The lava flows have mostly originated from the fissure zone which is situated in the western part of the Krafla field and from there the flow is westwards with the land.

A number of explosion craters is characteristic for the Krafla Geothermal Field. The youngest and most famous is „Viti“ (hell) which was formed at the beginning of „Fires of Mývatn“ in 1724. The „Viti“ eruption started as a mixture-eruption of basalt and rhyolite but ended as an enormous steam eruption. The downpour of tephra was seen as far as across the country in the southern part of Iceland. It mainly consisted of clayish gravel due to heat alteration by the geothermal field.

The connexion between the geothermal activity and volcanic fissures and tectonic dislocations is inherent both in Námafjall and at Krafla. Description of the beginning of „Fires of Mývatn“ in 1724 clearly indicates that many new fissures have appeared in the Námafjall–Krafla rupture zone from Bláfjall in the south until Gjástykkir in the north. Where the new fissures transpierced the geothermal fields, new hot springs and mud pots were formed.

In July 1975, earthquake tremors were noticed which steadily increased in strength during the autumn. 20th December 1975, the microtremor activity reached its peak and a volcanic eruption started in Leirhnjúkur about 3 km from the power plant site. For few hours, minor flow of lava emanated, but the eruption rapidly changed character to a steam eruption and petered out before the end of the year. The microtremor activity was still

great and 2000-4000 tremors were daily recorded.

In January 1975, seven earthquakes of Richter magnitude more than four were recorded with foci less than few kilometers from the power plant site. Two earthquakes had magnitude five. In February 1976, the earthquake activity decreased and in March it was down to 20 tremors a day.

In June 1976, the microtremor activity reappeared, concentrated southwest of the Krafla caldera towards the Diatomaceous Earth Plant in Bjarnarflag. Today, the area is almost quiescent. However, continuous and diligent observance of the area is conducted through earthquake monitors and field observations.

Construction History

In November 1974, the Krafla Executive Committee commissioned two consulting engineering firms, Sigurður Thoroddsen and Partners in Reykjavík and Rogers Engineering Co. in San Francisco to undertake the planning and design of the geothermal power plant. They were to submit a construction schedule and budgetary proposal as soon as the power plant location was decided. In concordance with the instructions and authorization given to the Executive Committee by the new

Minister of Industries, Dr. Gunnar Thoroddsen, in the Government of Iceland which came to power in August 1974, the consulting firms were requested to hasten as much as possible the design and planning of the power plant.

From the beginning, it was obvious that the procurement of heavy equipment for the plant would be most time consuming and as such govern the construction schedule and set the com-

pletion date. It was therefore decided to contact outstanding manufacturers of turbomachinery with experience in geothermal operations and solicit their interest in submitting informal offers to furnish and deliver the turbine-generators. The offer made by Mitsubishi Heavy Industries in Japan was deemed to be the most attractive regarding price, delivery time and technical design.

In February 1975, it was decided to go ahead with the final design of a geothermal power plant at Krafla. Also, it was decided to enter into negotiations with Mitsubishi Heavy Industries for delivery of two 30 MW turbine-generator units. The purchase contract was signed with the consent of the Government of Iceland on April 10th 1975. Shortly after or April 15th, the consulting engineers submitted their preliminary design report with a budget and construction schedule. The total cost of the Krafla Geothermal Power Plant, excluding the wells, steam supply system and the transmission line to Akureyri, was projected as U.S. \$ 25,500,000,-.

The extremely attractive delivery time of the turbine-generator units gave way to hopes that it could be possible to build the power plant and complete the testing of the main equipment before the end of the year 1976. With a 100 week master construction schedule it was decided to set out for this goal.

The Nature Conservation Council permitted the construction of the power plant at Krafla in April 1975. At a joint meeting of all parties concerned and the landowners in Reykjahlíð on May 8th 1975, presided over by the Minister of Industries, all necessary agreements and mutual understanding was reached.

The major construction contract was signed with Miðfell Ltd. in Reykjavík on July 4th 1975. Accordingly, Miðfell Ltd. was given the task to complete the power house building before the beginning of heavy equipment installation in summer 1976.

The Power House was closed-in in November 1975 and during the winter 1975/76, work continued indoors on the turbine foundations and the hot well pump enclosures. In July 1976, the Power House is almost completed and installation of the

plant equipment has started. The foundation work in the high voltage substation is well under way and the first cooling tower near completion. About 300 men are at work on the Site during summer 1976.

The State Drilling Contractors under the auspices of OS started production drilling in the beginning of June 1975 with their 2000 meter rig (Dofri). When they stopped in October 1975, two production wells had been sunk and the third was drilled down to 1300 meters but not completed. (Wells Nr. 3, 4 and 5).

The bottom temperature in well Nr. 3 was measured 260° C. In the beginning, its output was rated 70 kg/sec (7 MW) but has decreased considerably since the volcanic eruption in Leirhnjúkur. The bottom temperature of well Nr. 4 was measured above 310° C. The wellhead valve broke and the well was destroyed in January 1976. A large boiling hot spring is what remains of this well. Well Nr. 5 has a bottom temperature of 300° C, but the drilling is not completed. It will presumably be sunk deeper and lined this summer (1976).

The drilling operations were resumed in July 1976 and the two big drilling rigs (Jötunn and Dofri) will be deployed. Special effort has been made to procure stronger head valves and steel casing in order to cope with the high temperature and pressure of the Krafla Geothermal Field.

In early autumn 1975, OS commissioned the consulting engineering firms of Virkir Ltd. and Thoroddsen and Partners, both in Reykjavík, to undertake the planning and design of the wells and the steam supply system with flash tanks, separators and control equipment. Most of the material for the Krafla steam supply system has been procured and transported to the Site. Materials for the transmission line to Akureyri were received in March 1976 and the rigging up of the double wooden pole masts has started. It is scheduled that the 132 KV transmission line be completed before end of the year 1976.

Technical Features of the Plant

The two turbine-generators of the Krafla Geothermal Power Plant consist of five stage double pressure, double flow steam turbines with 37.5 MVA brushless generators. The turbines are condensing with a direct contact condenser located immediately under the turbine. The steam is condensed in the condenser at such temperatures that the pressure drop through the turbine is considerably increased and the output power of the turbine is more than doubled in comparison with direct to air exhaust turbines. The steam turbines have a maximum capacity of 35 MW each during most favourable external conditions.

To ensure full capacity of the Plant, a total of 15 production wells, 3 of which are held in reserve, is expected to suffice.

The steam production will be as follows: From each well an average flow of 45 kg/sec of 270° C hot water is led into the High Pressure (HP) cyclone steam separators under about 9 ata (kgf/cm²) pressure. The well fluid immediately boils and separates into steam and water 175° C hot. The HP steam is then led through carbon steel piping to the Power House, manifolded and upon passing through a moisture separator brought to the HP stages of the turbine under about 7.7 ata pressure.

The water effluent, that is the 175° C water from the separator, is led through special piping and manifolded into the Low Pressure (LP) steam separator (the flasher) which will be situated about 400-500 meters northeast from the Power House. In there, a second steam separation takes place under about

2.2 ata pressure yielding 120° C steam and water. The 120° C water effluent from the LP separator is not utilized any more but released into a concrete channel where it flows into the cooling pond which will be located where the quarry pit south-east of the Power House is situated. The LP steam, however, is led through to the Power House, manifolded and upon passing through moisture separation brought to the LP stages of the turbine where it mixes with the HP steam.

The steam flows through the turbine and into the condenser where it is condensed by spraying cool water (22° C) from the cooling tower over the steam in upper part of the condenser. A small portion of the steam, about 1%, consists of non-condensable gases (CO_2 , H_2S). They are led through specially cooled channels in the condenser and ejected to the atmosphere through gas ejectors, inter-condensers and silencers.

In the main condenser, the pressure drops to 0.12 ata and the steam condenses to 46° C hot water which flows from the condenser basin to the hot well pumps. The highly corrosive condensate is then pumped by four 500 H.P. pumps, two for each condenser, through stainless steel piping up to the top of the cooling towers. From there the water splashes down the fill material of the towers while large motordriven fans in the cooling tower shafts draw cool air through the towers. On its way down to the cold basin of the tower, the water is cooled down to about 22° C if the outdoor temperature is 15° C.

The pressure differential between the condenser and the cold water basin in the cooling tower ensures the flow of cooling water from the basin to the condenser spray nozzles from where it is sprayed over the turbine exhaust and the cooling water circuit is closed. When the outdoor temperature is very low (-30° C), the cooling process is more efficient and the condenser vacuum increases. In the wintertime, the power output of the Plant may increase to 70 MW if sufficient quantity of steam is available.

The effluent from the second steam separator measures approximately 360 litres/sec. On its way to the cooling pond it cools a little and is now 90° C hot. The cooling pond storage

capacity is about 120.000 cubicmeters and the waste water will be delayed in the pond for about four days. During this time, most of the hydrogen sulphide (H_2S) will have evaporated and the silica (SiO_2) has started to polymerize and fall out. The effluent from the cooling pond is about 10-20° C hot and runs off into the Skarðsels-stream in Hlíðardalur on its way to the Bürfell lava field comparatively harmless.

The potential of the Krafla geothermal field has been assessed in the range 300-500 MW. There is nothing to hinder that a later extension of the Krafla Geothermal Power Plant should be feasible. An additional 100 MW power plant could be especially advantageous. (2x50 MW turbines in tandem with one 100 MW generator). The new power plant could do with much of the auxiliary equipment already in use in the power plant under construction. Also, no extra office space nor staff accommodation would be needed.

The financing of the power development of the Krafla Geothermal Field has been effectuated through the Ministry of Finance. The vendors of the turbomachinery and the cooling towers have provided financing through the Bank of Tokyo and the Bank of America in Chicago.

The total cost of the Krafla Geothermal Power Plant is to day projected as follows: The Power House with all equipment, high voltage substation and staff housing, U.S. \$ 26.000.000,-. Production wells and the complete steam supply system, U.S. \$ 10.000.000,-. The overhead transmission line to Akureyri, U.S. \$ 3.300.000,-.

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Kröfluvirkjun

Krafla Geothermal Power Plant