UTILIZATION OF NATURAL HEAT AT THE KEFLAVIK AIRPORT

MEMORANDUM

by

Gunnar Bodvarsson June 30th, 1952

INTRODUCTION.

This memorandum is made at the request of the Iceland Defence Force for the purpose of giving a preliminary analysis of the possibilities for the utilization of natural heat obtained in the thermal area on cap Reykjanes for the heating of buildings on the Keflavík Airport, and furthermore to work out a program for the necessary research work involved in this project. The memorandum is based on studies which the writer has carried out in the thermal areas of the Reykjanes peninsula. It was written during the latter half of June and had to be finished on June 30th.

A preliminary cost estimate for a pipe-line project of the smallest economic size is furnished. The results are to be regarded as preliminary estimate only, made in order to give a first overall picture of the economic aspects of this matter. The project dealt with includes only the piping of hot water to the airport, but the distribution system on the airport is not taken into consideration. A great deal of information had to be at hand in order to make the design of this system possible.

A geophysical research program was recently carried out in order to find subsurface thermal activity in the region around Keflavík, especially at the Lake Seltjörn. A major fault line which yields thermal activity in a number of locallities runs through this region, and it is not improbable that it may also yields thermal water in the region east of Keflavík although no hot water reaches the surface. The whole region around Keflavík is covered by an interglacial doleritic lava flow which would prevent thermal water from getting to the surface.

The result of this survey was partially negative. It was found out that the glacial sediments which are found under the dolerite are invaded by sea water in the whole region and the electrical resistivity measurements were thus useless as a method to find thermal activity because of the low resistivity of the saline water.

Drilling of test wells is consequently the only remaining method to find thermal activity in this region. A comprehensive test drilling program would, however, have to cover a great area and would thus be very expensive and it is the opinion of the writer that it could not be justified at this juncture.

Large scale thermal activity is on the other hand founda south of the Keflavík region, i.e. at the cap Reykjanes some 11 miles south of the Keflavik Airport. This thermal area is one of the 12 steam fields of Iceland and could probably furnish the heat necessary for the airport. It is the scope of the memorandum to discuss the piping of hot water from this area to the airport.

THE STEAM FIELD AT THE REYKJANES.

The thermal activity at the Reykjanes is found at an altitude of 30 to 100 feet and wovers an area of approximately 0,4 square miles. Only small steam vents are present with the exception of one boiling water pool which contains practically genuine sea water. This is a rather strange phenomenon and must be explained by some sort of "steam-lift" of the sea water.

The surface formation of the area is a postglacial but prehistoric basaltic lava flow. The hills Bæjarfell and Sýrfell which break through the lava afe formed of the basic tuffs commonly found in the central and southern parts of Iceland. The aforementioned lava flow may cover another postglacial flow under which we may again find the interglacial doleritic flow found at the surface in other parts of the Reykjanes. The presence of the latter two lava flows at the cap Reykjanes is, however, only a guess.

The geological profile of the area is probably as follows.

1) Postglacial basaltic lava flow	I	
2) " " " "	II	uncertain
3) Interglacial doleritic lava flow		uncertain
4) Glacial sediments		uncertain
5) Basic tuffs		
6) Tertiary basalt plateau.		

The thickness of the basaltic flows can be between 50 and 100 feet, and the doleritic flow could be up to 200 feet thick. The sediments are probably rather thin.

The sea water which invades the area and formes the boiling pool may either come through the sediments or between flows I and II. The former possibility is more probable as the aforementioned geophysical survey did show that the sediments are invaded by sea water in other regions on the Reykjanes peninsula. The presence of sea water under the thermal area is of importance as it may lead to severe corrosion of steam well casing.

The thermal area is most probably fed by water having a temperature of 200°C erichre which ascends through faults in the basalt plateau and spreads in the overlying formations. Wells drilled in the area will therefore produce in most cases a mixture of steam and water. The steam which comes through steam vents at the surface contains about 0,05 cubic feet per pound of gases. The composition of the gases is approximately

CO_2	H_2S	H_2	CH_4	Rest	
95,0	1,8	1,3	0	1,9	o/o

The thermal activity on the Reykjanes is connected to the aforementioned major fault line which runs from the mountain Esja to the Reykjanes, and on which thermal activity is found in 4 other places, i.e. Kollafjörður, Álfsnes, Laugar and Hlíð.

THE POTENTIALLITIES OF THE STEAM FIELD AT THE REYKJANES.

There are certain major difficulties ebcountered in the estimating of the amount of steam which may be produced by means of well drilling in a steam field, the drilling itself is in fact the only reliable answer to this question. But the situation is, however, not completely obscure and a certain amount of facts can be stated through surface observations and experience from other fields.

There two factors which contribute to the steam production. The first is the steady flow of high temperature water or steam up through the faults in the Tertiary basalt. A grêat part of this ascending fluid can be recovered by the drilling of wells which cut the major channels in the faults zones and at the dikes. The amount of the ascending fluid can be roughtly estimated through the steady heat dissipation at the surface. The underground drainage of the field is the most uncertain factor. The temperature of the ascending water is a figure of major importance as it determines the ratio between steam a nd water in wells producing from faults. Higher temperatures give more steam.

The composition of the gases in the steam given off from the vents at the surface can probably in some cases give hints about the temperature of the ascending water. High content of CO_2 in the gases and low gas content of the steam indicate comparatively low temperatures, i.e. around 200°C but some steam fields seam to have considerabely higher temperatures. The temperatures in the Reykjanes field seem thus to be at the lower end. i.e. in the neigbourhood of 200°C.

The second factor is the heat accumlated in the rock under the steam field. The ascending high temperature fluid has heated up a vast volume of rock which can give off a large amount of steam in those places where the porosity and permeability are high enough. The possible steam production of the unit volume of rock can in fact be calculated if the temperature and the porosity are known.

It would go beyond the scope of this memorandum to discuss the physical principles of the natural steam production any further, and only the results of the writers preliminary estimates for the steam field at Reykjanes will be given.

The conditions at the Reykjanes are in many ways obscured by the lava flows which cover the whole field and its vicinity. But having regard to the heat dissipated at the surface in the field and experience from other fields the writer is of the opinion that a production of 100 to 150 tons per hour of steam at zero to 50 psig pressure can be regarded as likely figures for the field at least for a comparatively long period of time, i.e. 5P years or more.

This is of course only to be regarded as a tentative estimate.

It must at this juncture be emphasized that steam wells are in most cases only active for a certain period of time and that they must be redrilled or new wells drilled. This can either be due to deposits in the fissures around the wells or local depletion of porous horizons.

THE HEAT-CARRYING MEDIUM.

The steam from the Reykjanes field can not be piped to the Keflavik Airport. Pingin of steam over long distances is not economical, especially in this case as the natural steam contains corrosive gases and may even form deposits if it is slightly wet.

Water of good chemical quality is consequently the only possible heat-carrying medium. This water has to be obtained from a source near to the steam field, and has to be heated up by the natural steam in a heat exchanger and thereupon to be piped to the airport.

This system has to be based on a suitable source of water, but the region around the steam field is, due to its volcanic character, completely short of surface water, and the water has consequently to be obtained from drilled wells. It must however, be emphasized that it is an open question whether the region contains an aquifer within reasonable depths. This will largely depend on the presence of the glacial sediments mentioned on page 3 as these have proven to be good aquifers in the region around Keflavik; most of the water in this region is in fact obtained from wells drilled into this formation.

TECHNICAL DETAILS OF A HEATING PLANT.

It has not been possible to obtain reliable informations about the present annual fuel consumption and the annual fuel costs at the Keflavik Airport, Any future plans were of course not at hand. The dimensions of a heating plant fulfilling the present needs can therefore not be calculated at this juncture.

The writer has therefore decided to make another approach to the problem, i.e. to calculate the dimensions of a proposed plant of approximately the smallest economic size. The details of these calculations will for simplification purpose not be reproduced in this memorandum, and only the main results will be furnished, i.e. the proposed engineering data and the preliminary cost estimates for this smallest economic size. The plant deatl with will furthermore, as has been mentioned in the introduction, be limited to the supply of hot water to the Keflavik Airport, and the distribution system on the airport will not receive attention.

The writer has assumed that different grades of fuel oil are now used on the airport and that the main price of the oil is 10,5 cents/gallon at the consumer. Based on this and furthermore an interest of 5%, a depreciation during 15 years and usual operating expences, the writer has estimated that piping of hot water from the Reykjanes field to the Keflavík Airport could be economical when the fuel oil consumption on the airport exceeds 15.000 tons (long) per year. The smallest economical hot water plant has consequently a heating capacity equivalent to the consumption of 15.000 tons of fuel oil per year, and the following data refer to this size of plant.

The main technical details of the plant are furnished on the attached sketches, the proposed site of the pipeline on sketch 1) and the flow diagram on sketch 2).

It is assumed that the water is obtained from 20 water wells in the vicinity of the steam field, the area north-east of the field is probably the favourable. It is furthermore assumed that the water need some purfication as softening and purification plant is included in the project. Deareation is also to be performed in connection with the heating process.

From the purfication plant the water is pumped through two heat exchangers. The first one is termed as low pressure heater and operates at zero pressure gauge on the steam side. Here the well water is to be heated to 100°C. In order to run only a part of the steam walls at higher pressure than atomospheric the water is heated to the final temperature of 130°C in a separate heat exchanger termed as the hig pressure exchanger which operates at 45 psig pressure at the steam side. A higher pressure than this would probably not be economical as the output of the wells is highly dependent on the pressure.

From the heat exchangers the water is pumped through a 12" I.D. insulated pipe-line to the airport. The terrain through which the pipe-line has to run is unusual and difficult as it consists largely of postglacial lava. The pipe could therefore not be burried into the ground as may be economical in some regions. It must therefore be placed into a concrete conduit on the surface or it may be placed on adequately spaced concrete supports without a special conduit. The latter possibility is less expensive and the writer is of the opinion that it will be possible in this case and has therefore assumed this arrangement. The insulation of the pipe has then to be covered by a watertight material as e.g. galvanized steel plates or even stainless steel plates.

The temperature drop in the pipe-line is at full load calculated to 6°C and water at 124°C is consequently delivered at the airport where it is distributed for the individual buildings. A system of storage tanks are assumed on the airport in order to equalize the peak load during the coldest days. The equalizing process will, however, not be discussed here.

Numerical data of the plant are calculated and estimated as follows: (tons are metric tons)

Equivalent fuel oil consumption	15.000	tons/year
Annual load factor	0,37	
Peak load	120.10^6	Btu/hr
Daily load factor on peak day	0,60	
Distribution efficiency on the airport	0,80	
Average demand on peak day	90.10^6	Btu/hr
Temperature of water at airport	124°C	
Temperature of waste water	50°C	
Maximum flow in pipe-line	1,350	GPM
Length of pip-line	12,4	miles
Diameter of pipe-line	12"	
Pressure drop in pipe-line	125	psi
Temperature of water from heater	130°C	
Temperature of water from wells	3°C	
Flow of steam wells	75	tons/hr
Number of steam wells	6	
Power required	200	kw

Preliminary estimates of cost are as follows:

1) Water wells, pumps, purification plant cold water piping, electricity supply, housing		380.000,oo
2) Steam wells, steam piping heat exchangers, pumps		300.000,oo
3) Pipe-line to airport		1.220.000,oo
	Total	1.900.000,oo
Addition 16 %		300.000,oo
	Total	2.200.000,oo

Annual operating cost:

1) Interest 5%, depreciation 4,6% overhead, repairs etc		310.000,oo
2) Drilling		40.000,oo
	Total	350.000,oo

The annual operating costs are thus estimated to be some 16% of the erection cost. This sum divided by the annual fuel consumption, i.e. 15.000 tons or 45.000.000 gallons give the equivalent cost of fuel of fuel oil of 7,8 cents/gallon. The actual fuel price was assumed to be 10,5 cents/gallon and an equivalent of 2,7 cents/gallon can thus be used to cover the distribution cost on the airport, i.e. a sum of 120.000,oo which should suffice to cover the operating cost of the distribution system within the airport. The plant is thus just on the economical limit, i.e. it is the smallest size which can be justified. Larger plants could be operated with profit.

THE MAIN PROBLEMS.

The calculations above were based on a number of geological and engineering assumptions which are at this juncture more or less uncertain. These main problems of the project will in the following be reiterated.

1) The steam supply. It was assumed that the Reykjanes field would be able to produce between 100 and 150 tons/hr of steam at least during a period of 50 years. This is of course only an assumption which has to be tested. The writer is of the opinion that the drilling of one or two steam wells in the area would furnish the geological and physical information necessary to get a thorough picture of the situation. These wells do not have to be of the same size as the projected steam wells. A comprehensive geological and geophysical survey should be made in combination with the drilling.

2) Corrosion of steam well caring. The infiltration of sea water into the thermal area can lead to a very serious corrosion of the steam well casing and special expencive measures may be necessary in order to minimize the corrosion attack.

3) The cold water supply. Some 1350 GMP of cold water are required as heat carrying medium. It is at this juncture not known whether this water is available in the vicinity of the steam field. Geological and geophysical studies and the drilling of one or two test wells are necessary in order to study the conditions.

4) Corrosion and deposits in the main pipe-line. Although purification and deareation of the well water are included in the project the high water temperatures may lead

to a measureable corrosion in the main pipe-line. The ganger is probably not serious but must receive attention when the quality of the well water is known.

5) Problems of design. The project does, due to its unusual character, include some new features of design which can be regarded as special engineering problems, although they will not be very diffiuult to solve. It is primarily the design of the main pipe-line which is of great economic importance and must receive special attention.

RECOMMENDATIONS:

In the case the project receives favourable attention the writer recommends that further studies be carried out in the following steps:

1) A thorough geological survey of the Reykjanes steam field should be made. This would include as a major item a geophysical survey in order to study the prospects for an adequate cold water supply. The costs of this survey are estimated at 3,000,oo and the duration at 3 months.

2) Drilling of one or two test wells should be carried out in accordance with the results of the geological survey. Their flow characteristics should be studied during 18 to 24 months. This first test drilling can be made with a cable tool rig but the rotary method should be used if possible. Cost of this drilling is estimated at 40.000,oo if normal cable tool equipment is used, and the duration of the whole drilling and test period at 24 to 30 months.

3) Drilling of one or two water wells to test the conditions of the water supply. Duration 5 months and cost estimated at 10.000,oo

4) Some of the essential design problems should receive attention at an early date, e.g. in connection with the geological survey. Cost estimated at 1,500,oo.

CONCLUSIONS.

The conclusions of the writers study can be summarized as follows:

1) The piping of hot water from the Reykjanes steam field to the Keflavík Airport appears to be economical when the annual consumption of fuel oil on the airport exceeds 15.000 metric tons per year.

2) There are seemingly godd prospects that sufficient natural steam may be produced at the Reykjanes, but this assumption is to be regarded as uncertain, and must in any case be tested by special test drilling.

3) A preliminary cost estimate indicates that the cost included in the errection of a plant capable of piping 1.350 GPM of water at 124°C to the airport, which is the smallest economic capacity, is 2.200.000,oo. The distribution system on the airport is not included in this figure.

4) A comprehensive test drilling and research program is necessary in order to get reliable informations about the steam supply and other figures. The cost of this program is estimated at 54.500,oo and the duration of the whole test period at 24 to 30 months.

Reykjavík, June 30th, 1952

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