REPORT
ON
THE POSSIBILITY OF PRODUCTION OF
SALT IN ICELAND

BY

M. S. PATEL

Raforkumálastjóri

— Jarðhitadeild —

THE STATE ELECTRICITY AUTHORITY — GEOTHERMAL DEPARTMENT

Reykjavik in December 1959

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TO: THE SECRETARY
MINISTRY OF COMMERCE
THE GOVERNMENT OF ICELAND

SUBMITTED THROUGH
THE DIRECTOR
THE STATE ELECTRICITY AUTHORITY
OF ICELAND, REYKJAVÍK

Reykjavík, in December 1959

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LETTER OF TRANSMISSAL

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The State Electricity Authority,
Reykjavík, Iceland

The Secretary to Government,
Ministry of Commerce,
Government of Iceland,
Reykjavík.

Nov. 30th, 1959

Dear Sir,

Through the agency of the International Cooperation, Administration, Washington 25, D.C., an agreement was signed between your Government and myself, by which I was given an assignment to investigate and prepare a feasibility report on the manufacture of salt from sea water, using geothermal steam as a source of heat. The objective and scope of the work to be performed by me in connection with this assignment is as follows:

A. Objective

To explore and determine the economic feasibility of extracting salt from sea-water by evaporation, using geothermal steam, as well as the feasibility of a more ambitious mineral extraction plant for the recovery of magnesium and other constituents of sea-water.

B. Duties

1. Review data and reports assembled by the Authority.
2. Visit sites of drilling for geothermal steam and advise on their suitability for the erection of a salt plant.
3. Advise on the feasibility and location of a plant.
4. Advise on the method of processing, and
5. Advise on how salt extraction may be harmonized most economically with other projected uses of geothermal steam.

I am submitting herewith my report which I hope will be found useful, if and when it is decided to install in Iceland a plant for the production of salt to meet the requirements of Iceland's most important and vital industry, namely the fishing industry.

Yours sincerely,

M. S. Patel
(sign.)

Respectfully submitted through:
The Director of State Electricity Authority,
Reykjavík,
Iceland.

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ON

THE POSSIBILITY OF PRODUCTION OF SALT IN ICELAND

I.

ICELAND - ITS SOCIAL AND ECONOMIC POSITION COMPARED WITH SOME OTHER NATIONS

1. Iceland is a large island in the North Atlantic (see map No. 1). The latitude of the southernmost point is 63°24' North, and that of the northernmost point is 66°32' North. If islands off the coast are included, the point farthest south has the latitude of 63°19' North, and that of the farthest north has the latitude of 67°10' North. The western extremity of Iceland has a longitude of 24°32' West of Greenwich, and that of the easternmost point has a longitude of 13°30' West of Greenwich. Iceland has an area of about 103,000 square km (about 39,00 square miles). From North to South the greatest span is about 300 km (190 miles) and from West to East about 500 km (300 miles). The distance from Iceland to Greenland is about 350 km (215 miles). The distance from Scotland is 850 km (520 miles), from Norway 1050 km (645 miles and from New York 4336 km (2681 miles).

2. The coast of Iceland is much indented with bays and fjords (see map. No. 2), especially in the western and northern parts of the country, and also to some extent in the eastern part. In the South there are hardly any bays and fjords. The coast-line on the Southern part of the country mostly consists of sandy shores. Excellent natural harbours in Iceland, therefore, exist on the Western, Northern and Eastern parts of the country. The total length of coast-line, including the fjords and inlets is about 6,000 km (3700 miles).

3. The present population of Iceland is about 165,000. Even with this small population, Iceland is a unique country. Its people are ahead in several ways, when compared to the people of several countries of the world, including some of the countries of Western Europe and Scandinavia, as well as those of the U.S.A., in standards of health and in material standard of living. In Appendix I are given comparative figures for eleven countries for:

(1) Population.
(2) Birthrate - number of births per thousand population.
(3) Death rate - number of deaths per thousand population.
(4) Population increase rate - increase per thousand population.
(5) Infant mortality rate - deaths of infants under one year, per thousand.
(6) Net food supply per capita:
    a) calories per day
    b) in grammes of protein
    c) percentage of animal origin
(7) Fish catches - in tons per capita.
(8) Merchant shipping registered - tons per thousand population.
(9) Civil Aviation:
    a) kilometres flown per capita by airlines of Iceland
    b) passengerkilometres per capita by airlines of Iceland
(10) Foreign trade
    a) imports in value in dollars per capita
    b) exports in value in dollars per capita
(11) Motor vehicles in use per thousand population.
(12) Telephones in use per thousand population.
(13) Radio receiving sets in use per thousand population.
(14) Daily newspapers - copies sold per thousand population.
(15) New books - number of titles published per thousand population.
(16) Electricity installed - in kW per capita.
(17) Electricity produced per kWh per capita.

4. From the Tables in Appendix I, it will be observed that Iceland has the highest birth rate and the lowest death rate and, consequently, highest rate of increase in population amongst the eleven nations shown in the tables in Appendix I.

5. From the figures in Appendix I it will also be observed that Icelanders are very well fed people, standing third in net food supply in the form of per capita calories per day, and stand first in per capita consumption of proteins. Iceland has the lowest infant mortality rate amongst the eleven nations under consideration.

6. In material standards of living Iceland also is ahead in many respects. She has appreciably larger number of motor vehicles, (as Iceland does not have any railwaylines in the country) telephones,

radio receiving sets in use per thousand population than most of the countries. In installed capacity of electricity in kW per capita and in production of electricity in kWh per capita, Iceland stands fourth amongst the nations mentioned in the Appendix; Norway standing first, Sweden second, U.S.A. third and Iceland fourth. Iceland has the highest per capita foreign trade both in imports and exports. For example per capita imports for the year 1957 amounted equivalent to about 507 Dollars per capita and the exports amounted equivalent to about 368 Dollars per capita. In registered shipping Iceland is second to Norway in tons of shipping registered per thousand population, and is ahead of all the other countries.

7. In number of books of new titles published, Iceland stands first and in circulation of daily newspapers Iceland stands fourth. Even in civil aviation, the airlines of Iceland have flown more kms. per capita and more passenger kms. per capita than any other country. This will show that Icelanders as a nation have a comparatively higher material standard of living amongst some of the nations in Western Europe and Scandinavia. The most outstanding thing about Icelad is that Icelanders catch per capita more fish than any other country in the world. The per capita catch of fish per year by Icelanders is about 3 tons as against about 0.5 ton by Norwegians and 0,02 by the British.

II.

IMPORTANCE OF FISHING INDUSTRY TO THE ECONOMY OF ICELAND

8. In Appendix II are given figures for gross national product and the share of fishing industry, agricultural industry and other items contributing to the overall national economy of Iceland.

9. From Appendix II it will be observed that total value of fish and fish products in Iceland, amounts to about, on an average, more than 26 per cent of the total national product, while that of agricultural products amounts to about 17 per cent. If, however, one considers the contribution of the fishing industry in terms of export trade, exports of fish and fish products contribute on an average more than 62 per cent of the total exports of both commodities and services combined. If exports of commodities alone are taken into consideration,

exports of fish and fish products contribute on an average more than 90 per cent of the total exports of commodities, as against about 6 per cent contributed by products of agriculture. All the services combined constitute only about on an average 10 per cent of the gross national product and 31 per cent of the total exports of both commodities and services put together.

10. In Appendix III are given figures for total value of exports of commodities and those of fish and fish products from Iceland during the years 1930 - 1958. From the Table in Appendix III, it will be observed that in some years the total share of value of exports of fish and fish products amounted to more than 95 per cent of the total value of exports of commodities.

11. It will thus be seen that the fishing industry contributes very considerably to the economy of Iceland. Almost all, if not all the commodities necessary for the comparatively high standard of living, as enjoyed by the people of Iceland at present, have to be imported, because Iceland is not producing and cannot produce the commodities for high standard of living at economic cost. The high material standard of living enjoyed by the people of Iceland depends, therefore, very considerably on the exports of fish and fish products, as fish and fish products contribute, as stated above, more than 60 per cent of the total foreign exchange earned by the export of commodities and services, and more than 90 per cent of the foreign exchange earned by the exports of commodities alone. This will show that the fishing industry as a whole is vital and most important industry for Iceland.

It is just possible that people abroad may not understand the importance of a fishing industry to any not highly industrialized country like Iceland, because in hardly any industrially advanced country of the world does the fishing industry play such an important part as it does in the economy of Iceland. A general idea about the importance of the fishing industry to Iceland may be further realized, over and above what has been said before, from the figures of exports of fish and fish products of some industrially advanced countries of the world, when compared to those of Iceland. Appendix XXI shows the figures of total exports of fish products from some countries of the world during 1957.

12. In Appendix IV are given figures of exports of fish and fish products, and those of saltfish from Iceland. From Appendix IV, it

will be seen that exports of saltfish is an important item in the export trade of fish and fish products. During the early thirties, as will be seen from the Appendix, export of saltfish alone was as high as 80 per cent of the total exports of fish in quantity and 75 per cent in value. Due to the introduction of the use of frozen fish, however, the exports of saltfish have declined as far as Iceland is concerned; not because of lack of sufficient demand for saltfish in the world market, but due to several other reasons beyond the scope of this report. There is, however, sufficient demand for saltfish in different parts of the world, in spite of the increased use of frozen fish. The advantage of this demand for saltfish is taken at present, however, by countries like Norway, Canada, France etc.

13. In Appendix V are given figures of total production of saltfish in different countries of the world, and also those of Iceland. From the Appendix it will be seen that the level of production of saltfish in the world has remained more or less about the same, in spite of increased use of frozen fish.

14. Even as recently as 1955, exports of saltfish from Iceland amounted to about 40 per cent of total exports of fish and fish products. It is possible to maintain this volume of exports for saltfish, if proper steps are taken to do so on sound systematic lines. Production of saltfish, therefore, has been and can be an important item of exports, contributing appreciably to the economy of Iceland. This is likely to continue to be so for many years to come provided sufficient attention is given to the production of saltfish by persons concerned in maintaining the economy of Iceland.

III.

IMPORTANCE OF SALT IN THE ECONOMY OF ICELAND

15. Production of saltfish requires salt. It is estimated that for the production of one ton of marketable grade of saltfish, it is necessary to have about one ton of salt. All the salt consumed at present inIceland has to be imported, because there are no sources of supply of salt at present in Iceland. Appendix VI shows the imports of salt into Iceland from the year 1930 to 1958. In this Appendix are also given along with figures of total imports of salt into Iceland,

cumulative average for two years, three years and four years. From the Table in this Appendix, it will be seen that during the years 1930 and 1939 the imports of salt varied from about 43,000 tons to as high as 113,000 tons in one year. The cumulative average for two years for this period varied from about 46,000 tons to about 100,000 tons per year, that for three years varied from 48,000 tons to 90,000 tons per year, and that for four years varied from about 51,000 tons to 88,000 tons per year.

16. Then came the war period, which began from 1940 and ended by 1946. During those years the imports of salt varied from as low as about 6,000 tons to as high as 20,000 tons in one year. After the war the imports of salt into Iceland began to increase, and they went as high as about 70,000 tons during the year 1956, from about 21,000 tons in 1948. Since 1956 there has been a decrease in the imports of salt in Iceland, because of more attention being paid at present to the exports of frozen fish than saltfish. The cumulative average for two years from the year 1947 to 1958 has varied from about 21,000 tons to 63,000 tons per year, that for three years has varied from about 28,000 tons to 60,000 tons per year, and that for four years has varied from 22,000 tons to almost about 59,000 tons per year.

17. It will be interesting to compare the figures of per capita use of salt in some of the industrially advanced countries of the world, with those of for Iceland. In Appendix VII are given figures of average total use of salt in some of the countries of the world during the years 1953-1957, as well as average per capita use of salt in those countries. From the figures in this Appendix, it will be observed that Iceland has the highest per capita use of salt than any other country in the world. It is almost three times that of the United States and four times that of the United Kingdom. This is mainly due to the use of salt in Iceland for its fishing industry, which plays, as mentioned above, a very important role in the overall economy of the country.

18. From what has been stated above, it will be seen that salt is a very important raw material for the fishing industry of Iceland. Without an adequate and dependable source of supply of salt, the economy of Iceland might perhaps suffer to an appreciable extent, under certain circumstances. It is, therefore, desirable to explore the possibility of production of salt in Iceland, in order to make the

country almost self-sufficient for the requirements of salt for its fishing industry.

IV.

GENERAL METHODS OF PRODUCTION OF SALT

19. Salt is produced in the different parts of the world from three main sources. They are:

1. Sea water
2. Rock salt
3. Salt lakes and salt brines

20. Almost all the salt produced in the world, from sea water, is by means of evaporation of sea water by solar heat. In some instances sea water is evaporated by solar heat until an almost saturated solution is formed. This solution is then further treated and evaporated by means of steam for the production of suitable grades of salt.

21. Salt from rock salt is produced by two methods. One consists of mining the rock salt, more or less like the mining of coal, and then crushing the rock salt into suitable particle sizes, according to the purpose for which it is to be used. The other method for producing salt from rock salt consists of pumping water under high pressure through pipes, to the rock salt strata underground. This results in the formation of an almost saturated solution of salt. The pressure at which the water is pumped into the rock salt strata is such that the brine produced underground is forced up to the surface through another pipe. The saturated brine thus obtained at the surface, is then evaporated by steam and converted into salt of suitable grades for the requirements of various industries, or for use for human consumption.

22. Salt is produced from salt lakes either entirely by solar evaporation or partly by solar evaporation and partly by means of artificial heat, generally in the form of steam. Salt from salt brines is also produced either by solar evaporation entirely or by means of artificial heat, depending upon the location of the salt brines.

23. Large quantities of salt are used in industrially advanced countries of the world for manufacturing chemicals. For this purpose the saturated solution from the rock salt and/or from the salt brines

is used directly without the recovery of salt as a solid substance. In such a case very often the brine is generally purified before it goes for further processing for the production of soda ash, caustic soda and chlorine, and other chemicals.

V.

RAW MATERIALS FOR THE PRODUCTION OF SALT IN ICELAND

24. There are no deposits of rock salt nor sources of natural salt brine in Iceland. Looking at the formation and the nature of the rocks in Iceland, it can be stated that it will not be possible to find deposits of rock salt or sources of natural salt brines containing more salt than sea water. If the production of salt in Iceland is to be undertaken, the source of salt will, therefore, have to be sea water. Several millions of tons of salt is produced at present directly from sea water all over the world, especially in tropical and sub-tropical countries. Almost all the salt from sea water is made by solar evaporation. Only in Japan salt is produced on a comparatively small scale from sea water by artificial heat under special circumstances, for the production of high-grade table salt, which fetches a very high price, when compared to the salt required for the industrial and other non-edible uses.

25. Iceland has more than 6,000 km (or 3700 miles) of coast-line. It will be possible, therefore, to get large quantities of sea-water without much difficulty. It will not be, however, possible to produce salt in Iceland from sea water, either entirely or partly by solar evaporation, and under ordinary circumstances, it would have been considered futile even to think of producing salt in Iceland from sea water. As stated above, almost all the salt from sea water is entirely made by solar heat, or solar evaporation all over the world. Climatic conditions in Iceland make it impossible to produce salt economically by this method.

26. Iceland is wellknown for its sources of geothermal or natural steam, as well as hot water springs. At present the use of steam and hot water is made in Iceland for domestic heating, heating of office buildings and space heating in some factories. An appreciable amount of heat in the form of both steam and hot water is also used

for heating greenhouses for growing flowers and vegetables. For example the city of Reykjavík has a central heating system utilizing natural hot water, which serves about 50 per cent of the population of the city, as well as most of the down-town industrial - and office buildings. Besides Reykjavík, there are several small communities spread throughout the country near the sources of supply of steam and/or hot water, for domestic or greenhouse heating. Many greenhouses have been built throughout Iceland on the sites where natural steam or hot water is available, and new villages have sprung up in the recent years in such areas. The most important of such villages is Hveragerdi, about 46 km (about 29 miles) east of Reykjavík (see map No. 2 and 3).

27. Sofar, natural steam has not been used for any industrial purpose. Details pertaining to some of the important localities with large reserves of steam in Iceland are shown in the following Table:

Name of Locality	Elevation above mean sea level in metres	Elevation above mean sea level in feet	Area of the Steam Field in sq. kms.	Area of the Steam Field in sq. miles	Estimated quantity of steam obtainable in tons per hour
Reykjanes	15	50	1	0.4	120
Krísuvík	150	500	3	1.2	200
Hengill	30-600	100-2000	50	20	800
Torfajökull	900	300	100	40	3000
Námafjall	350	1150	2,5	1	300
Theistareykir	330	1100	2,5	1	200

Sources: 1) Gunnar Böðvarsson, State Electricity Authority, Iceland Natural Heat in Iceland, Paper 197 k/8, 5th World Power Conference.
2) Gunnar Böðvarsson, Private Communication.

28. From the above Table it will be observed that resources of geothermal or natural steam of Iceland, are more than adequate for use for industrial purposes, if they are harnessed on sound economic lines.

29. Large quantities of cooling water will be required during the process of evaporation of sea water for the production of salt. The lower the temperature of the cooling water, the better the economy of

its use as a cooling medium in evaporating systems. Iceland has enormous resources of fresh water at comparatively low temperature, at several localities, and so it should not be difficult to obtain sufficient quantities of cooling water at a reasonable cost.

VI.

SUITABLE LOCATION FOR A SALT PLANT IN ICELAND

30. Taking into consideration several factors, such as area of concentrated production of salt fish and consequently of consumption of salt by the fishing industry of Iceland, as well as facilities for supply of electric energy at a comparatively cheap rate, and also from the point of view of distribution and administration, the most ideal site, for a salt plant in Iceland, would have been on a suitable site on the water front, with proper harbour facilities, either near Reykjavík or Hafnarfjördur. Unfortunately, at these two places there is no source of supply of adequate quantity of steam, at a very reasonable cost. Steam is not likely to be available in the near future for the production of salt, near these two places at a reasonably low cost. Under the present circumstances, therefore, it will not be possible to set up a salt plant at, or very near, either of these two places. It is, therefore, necessary to find the next most suitable site for the production of salt.

31. After examining sources of steam in Iceland, the most suitable source of natural steam that can be exploited for the production of salt, near important saltfish production centers, is the natural steam field near Krísuvík (see map No. 2 and 3), which is 33 kms. (20 miles) south east of Reykjavík and 22 kms. (14 miles) from Hafnarfjördur by road.

32. This steam field near Krísuvík is situated at an elevation of 150 metres (500 feet) above sea level, and a suitable place on the sea coast for pumping sea water to the proposed site, is south of the steam field, at a distance of 8 kms. (5 miles) from the steam field. Location of a salt plant using steam from Krísuvík steam field will involve pumping of sea water from the sea coast to the site of the plant, and also transport of salt for a distance of from 22 to 33 kms. (14 to 20 miles) to the important consuming and distributing centers

for salt, namely Hafnarfjördur and Reykjavík.

VII.

GENERAL NATURE AND TYPE OF SALT REQUIRED BY THE FISHING INDUSTRY OF ICELAND

33. The fishing industry of Iceland does not require salt of very high purity. In Appendix VIII are given the analysis of salt used by the fishing industry of Iceland. Most of the salt at present used by the fishing industry of Iceland is solar salt, produced in the Southern European countries, especially Spain, Portugal and Italy, from sea water. From the analysis given in the Appendix it will be seen that sodium chloride content in the salt varies from 93.5 per cent to as high as 98 per cent. The calcium sulphate content varies from as low as 0.22 per cent to as high as 1.51 per cent. Magnesium sulphate content varies from 0.09 per cent to 0.23 per cent. The contents of insolubles in water vary from 0.01 per cent to as high as 0.75 per cent. Iron content of the salt varies from 11 parts per million to 30 parts per million and copper contents varies from zero parts per million to as high as 0.4 parts per million.

34. There is one definite condition, which must be observed with regard to the salt required by the fishing industry of Iceland, and that condition is, that the salt must be absolutely free from copper as far as possible, and should not contain more than 0.2 parts of copper per million if at all any. It is on record that great damage was done at one time to the salt fish treated with salt containing copper, which resulted in the development of highly undesireable yellow spots on the salted fish, and this involved a loss of several millions of krónur worth of fish, because of the copper content of the salt used.

35. Salt made from sea water entirely by solar evaporation is not likely to contain copper, but salt made from sea water in modern evaporators, using steam as a heating medium, is likely to contain copper, unless special precautions are taken in the construction of equipment for the production of salt, and also during the process of its manufacture. While planning a plant for the production of salt in Iceland, particular attention will have to be given to this special condition, i.e. salt will have to be free from even traces of copper.

36. The salt required by the fishing industry of Iceland will have to more or less conform to the following particle size or sieve analysis:

Micron	1	2	3	4	5	6	7
				PER CENT			
2830	52.9	32.2	37.6	41.9	36.8	52.3	38.3
2830-2000	24.5	32.5	37.6	18.3	24.4	22.6	25.4
2000-1680	8.8	11.4	12.6	7.3	9.0	12.5	10.6
1680-1410	2.9	7.0	3.3	5.0	5.4	2.6	8.3
1410-1190	3.6	5.0	2.6	5.2	5.2	3.5	5.4
1190- 840	5.3	5.8	3.1	7.5	10.0	4.5	5.9
840- 710	0.7	1.7	0.6	3.4	2.8	0.5	1.8
710- 590	0.6	1.2	0.3	2.7	1.4	0.4	1.2
590- 500	0.4	0.8	0.1	2.1	0.9	0.2	0.7
less than b 500	0.2	1.0	0.1	2.7	0.4	0.1	1.0

From: 1) Cagliari, Sardinia, Italy; 2) Torrevieja, Spain; 3) Roquetas, Spain; 4) Pinatar, Spain; 5) St. Pola, Spain; 6) Ibiza, Spain; 7) Lesqeneau, France.

Source: Geir Arnesen and Þórdur Þorbjarnarson, ÆGIR, Vol. 47, No. 6 (June 1954), Monthly Journal of the Iceland Fishing Industry Association.

VIII.

SUGGESTED PROCESS FOR THE PRODUCTION OF SALT IN ICELAND

37. It has already been mentioned that the only suitable source of salt in Iceland, under the present circumstances, will have to be sea water, which contains besides common salt (sodium chloride) many other salts, such as magnesium chloride, magnesium sulphate, calcium sulphate, potassium sulphate, calcium carbonate, magnesium bromide etc. If sea water contained only common salt (sodium chloride) and no other salts along with it, the problem of production of salt from sea water would have been comparatively very simple. But since common salt is associated in sea water with other salts, production of common salt from sea water presents some complicated problems.

38. The average analysis of sea water is as follows:

Chemicals in sea water	Percent of total chemicals	Grams per litre of sea water
1) Sodium Chloride	77.758	27.213
2) Magnesium chloride	10.878	3.807
3) Magnesium sulphate	4.737	1.658
4) Calcium sulphate	3.600	1.260
5) Potassium sulphate	2.465	0.863
6) Calcium carbonate	0.345	0.123
7) Magnesium bromide	0.217	0.076
	100.000	35.000

Source: Clarke, F.W., U.S. Geol. Survey Bull. 770, "The Data of Geochemistry" p. 203 (1924), as reproduced in Roger's Industrial Chemistry.

39. The above contents of sea water are based on a salinity (total salt content) of sea water equal to 35. The salinity of sea water is not uniform all over the world, and it varies from place to place and also from season to season. It also varies from day to day and also it varies from hour to hour, due to several factors, such as high and low tides, climatic conditions, evaporation, dilution due to rain and snow, and also due to inflow of water from rivers etc. These variations are comparatively of low range at most places, where there is no inflow of large volumes of fresh water from large rivers.

40. Engineers and chemists of the State Electricity Authority of Iceland have carried out investigations for determining the salinity of sea water from the proposed site for pumping sea water for the production of salt in Iceland. They have taken samples of sea water at regular intervals, every week, and also they have drawn samples continuously at an interval of one hour during a day of 24 hours for several days during one year. On the basis of results of these investigations it can be stated that, at the place from which sea water will be pumped for the production of salt, for most of the time, the average salinity will be approximately 34. On the basis of this salinity the average composition of sea water, which will be used for the production of salt will be as follows:

	Grammes per litre
Sodium chloride	26.434
Magnesium chloride	3.698
Magnesium sulphate	1.610
Calcium sulphate	1.223
Potassium sulphate	0.838
Calcium carbonate	0.119
Magnesium bromide	0.073

41. This means that theoretically it will be possible to get from 1000 tons of sea water about the same quantity of the different chemicals in tons shown against each chemical. It is however well known that it is not possible to get 100 per cent recovery in any chemical process, and especially so when the chemical to be recovered is associated with several other chemicals.

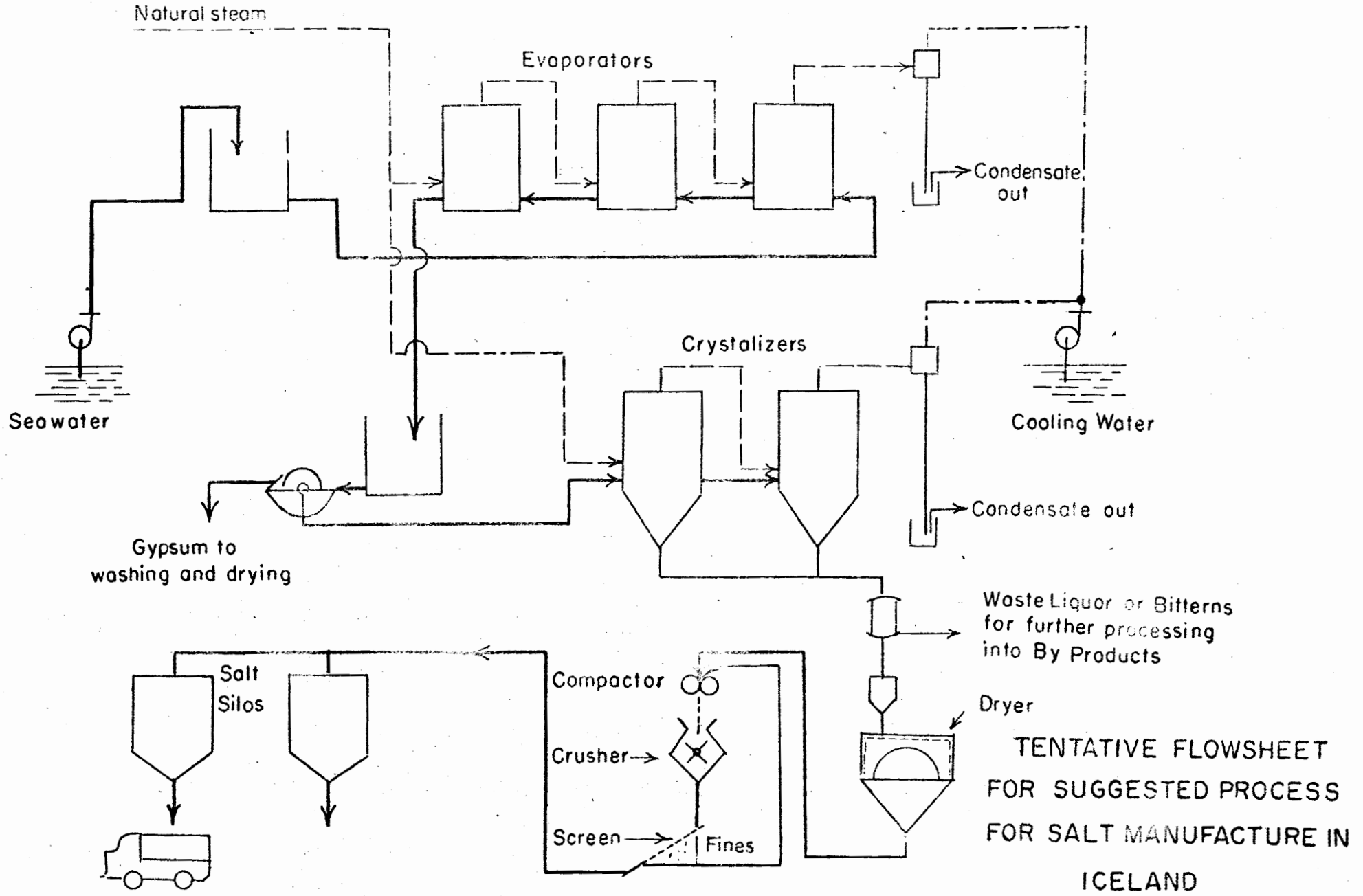
42. The samples of sea water drawn during the investigations by the engineers and chemists of the state Electricity Authority, were from the surface. It is well known that at a depth of about 6 metres (20 feet) below the surface of the sea the composition of sea water does not change to any appreciable extent, at places which are far from any fresh water rivers or stream flowing into the sea. As the place selected for drawing sea water for the proposed salt plant is far away from any stream (see map No. 3) it may be possible to get uniformly throughout the year sea water of 35 salinity. Sea water of this salinity will contain theoretically about 2.7 tons of salt per 100 tons of sea water. On the basis of data available in literature and on the basis of the experimental work carried out by the Chemical Engineers at the State Electricity Authority, it can be stated that it will be possible to obtain on practical scale, about 2.3 tons of salt of marketable grade for the fishing industry from 100 tons of sea water, or one ton of salt from about, at the most 43.5 tons of sea water, drawn from the suggested spot on the southern coast of Iceland.

43. The salt required by the fishing industry of Iceland, as stated above, will not have to be of very high grade, and so the production of salt from sea water in Iceland can be carried out by a somewhat simpler process, than if the salt was to be of comparatively higher grade. In view of this the most suitable and economic process for the production of salt will consist in evaporation of sea water in proper type of multiple effect evaporators initially to a certain degree of concentration, which in this case will be about 25° Baume. Sea

water evaporated upto this stage, will then have to be transferred to a settling tank, and allowed to settle, where impurities like gypsum and perhaps a little calcium carbonate, separated during the concentration, will be thrown out. The clear liquid from the settling tank will be further concentrated in suitable types of evaporators, where salt will begin to crystalize out in the form of very small crystals. At a certain stage the contents of the evaporators and crystalizers, after the recovery of a very appreciable quantity of salt, will have to be discarded.

44. The salt obtained at this stage will have to be washed and then dried. Salt obtained after drying, will be in the form of small crystals and will be suitable for ordinary industrial use, for the manufacture of chemicals etc. As the fishing industry of Iceland requires salt in the form of large crystals of particular shapes, as mentioned above, it will be necessary to further process the salt after washing. This will involve a more intense drying of the fine salt. The dried salt will have to have less than 0.5 per cent moisture. Salt dried to the extent of 0.5 per cent moisture, will have to be compacted into thick blocks of salt in suitable type of compacting equipment. The blocks or thick compacted sheets of salt will have to be crushed in a suitable type of crusher. The crushed salt will have to be screened in suitable types of screens, which will give salt of desired particle size. During the process of crushing, some very fine salt will also be produced. This fine salt will be recycled or sent back to the compacting machines and converted into blocks, along with the salt coming from the dryers. The general tentative Flowsheet for the suggested process for salt manufacture in Iceland is shown on the next page.

45. By this process it will be possible to recover as stated above about 2.3 tons of common salt from 100 tons of sea water. The remaining salt from the sea water, will have to be discharged along with the waste liquor, or bitterns, which will contain mostly magnesium salts and some potassium sulphate. The bitterns can be further processed for the recovery of magnesium salts in the form of magnesium chloride and magnesium sulphate, or in the form of magnesium oxide or magnesium carbonate by treatment with lime. This treatment will give another by-product in the form of calcium dhloride. A part of the calcium chloride obtained can be further used for the treatment of the bitterns for the recovery of more gypsum and


Natural steam
Evaporators
Condensate out
Seawater
Crystalizers
Cooling Water
Condensate out
Gypsum to washing and drying
Waste Liquor or Bitterns for further processing into By Products
Salt Silos
Compactor
Crusher
Screen
Fines
Dryer
TENTATIVE FLOWSHEET FOR SUGGESTED PROCESS FOR SALT MANUFACTURE IN ICELAND
Baldur Líndal
M.S.Patel Nov. 26. 1959
Petrína Jakobsson
Ver 63 1-Etnav Fnr. 4848

some magnesium chloride. The magnesium bromide contents of the bitterns, after the recovery of other chemicals or without, can be treated with chlorine by a suitable process for the recovery of bromine.

46. During the process of production of salt, most of the gypsum occurring as such in sea water, will be recovered in the proposed salt plant. For the recovery of other chemicals, special equipment will be required. If products like magnesium oxide or carbonate are to be recovered, it will be necessary to install equipment for the production of lime, from sea shell sands. Recovery of these products will give additional by-products in the form of gypsum and calcium chloride. Gypsum, coming out in the process at this stage, will be in addition to the gypsum that will be recovered during the process of evaporation of sea water. Production of lime from sea shell sand for the recovery of by-products like magnesium oxide and magnesium carbonate will need imported fuel oil. If recovery of bromine is to be undertaken, it will be necessary to import chlorine.

IX.

ASSEMBLING OF RAW MATERIALS AT THE PROPOSED SITE OF THE SALT PLANT

47. The main raw materials required for the production of salt in Iceland as mentioned above are:

1. Sea Water
2. Natural Steam
3. Cooling Water.

1. Seawater

Sea water will be drawn from the sea at a point on the south coast of Iceland at a distance of about 8 kms (5 miles) from the site of the plant (see map No. 4). Necessary investigations have been carried out in connection with the selection of a suitable site by the State Electricity Authority for the location of the pumping station in this area. The investigations have revealed that there is a suitable place on the sea coast, where the water remains for all the 24 hours of the day, irrespective of the tides. The difference between the highest tide and the lowest tide in this area is 3.73 metres (12.25 feet), but at lowest tide there is sufficient water at that spot for

pumping sea water for the salt plant. Fig. 1. shows the nature of the sea shore in the vicinity of the site selected for the setting up of the pumping station. Sea water will have to be pumped and taken to the site of the salt plant by means of a pipeline. The proposed site of the salt plant is about 150 metres (500 feet) above mean sea level. The alignment of the pipeline for the sea water is shown in map No. 4.

2. Natural Steam

48. Steam will be drawn from the boreholes which will have to be drilled in the Krísuvík steamfield. In map No. 4 and 5 is shown the location of the Krísuvík steamfield, and also the location of the existing boreholes which were drilled during the years 1950 - 1951, for investigation and testing purposes. In Fig. 2 is shown the steam field at Krísuvík. In Fig. 3 are shown greenhouses on the Krísuvík steam field using natural steam. In Figs. 4 and 5 are shown installations on the steam field for measuring and testing the flow, pressure and quality of the steam.

As the surface of the ground as well as sub soil near the boreholes on the steam field, is not suitable for the installation of the plant, it has been found desirable to locate the site for the plant at a distance of about 800 metres from the boreholes. A pipeline will have to be installed for taking steam from the steam field to the site of the plant. Fig. 7 and fig. 8 show the site for the proposed salt plant between the steam field and lake Kleifarvatn (in the background). The site is near the fencing poles near the Hafnarfjördur - Krísuvík road.

3. Cooling water

49. Cooling water will be drawn from fresh water lake Kleifarvatn, which covers an area of about 9.5 square km. (3.7 sq miles). It is situated at the bottom of a valley with steep slopes and its bottom is mostly flat. The surface of the lake is about 140 m (430 feet) above mean sea level. The lake is deep for the most part, perhaps half of the area being of more than 50 metres (152 feet) deep. The maximum depth has been measured as 87.6 metres (267 feet). The maximum thickness of the ice on the lake during very cold winters is about 0.5 to 0.6 metres (1.5 to 2 feet). The mean surface temperature of water in July is 10° C. Fig. No. 6 shows the view of the lake Kleifarvatn from the north-western bank of the lake.

FIGURES 1 AND 2

Fig. 1 Typical view of the rocky coast line south of Krísuvík steam field, showing the nature of the sea shore in the vicinity of the site selected for setting up of the pumping station for pumping sea water to the proposed site of the plant.

Fig. 2 The steamfield of Krísuvík, showing boreholes and the discharge of the steam.

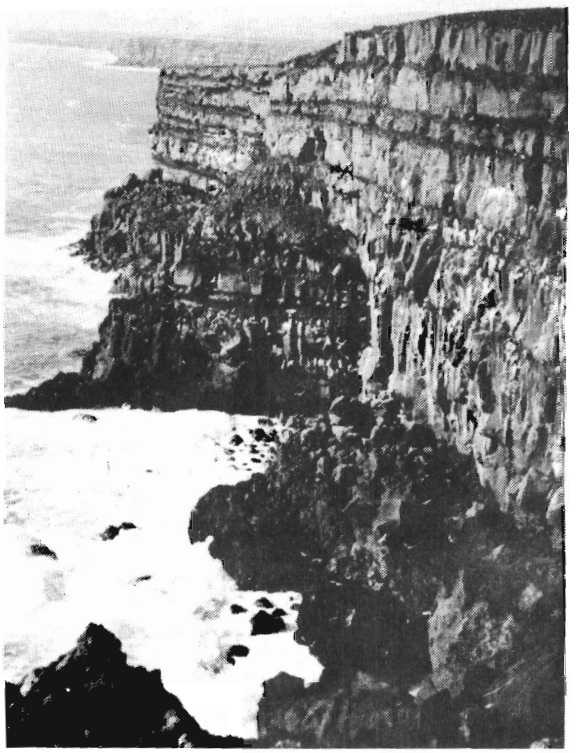


Fig. 1

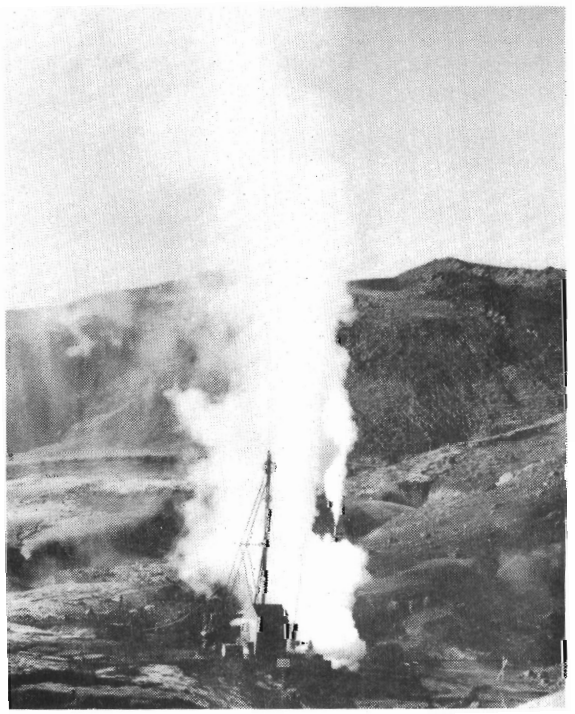


Fig. 2

FIGURES 3, 4 AND 5

Fig. 3 Greenhouses on Krísuvík Steam field, using natural steam.

Fig. 4 Views of Krísuvík steam field showing the installations on the steam field for measuring and testing the flow, pressure and quality of steam.

Fig. 5 Another view of the installation for measuring the flow, pressure and quality of steam.

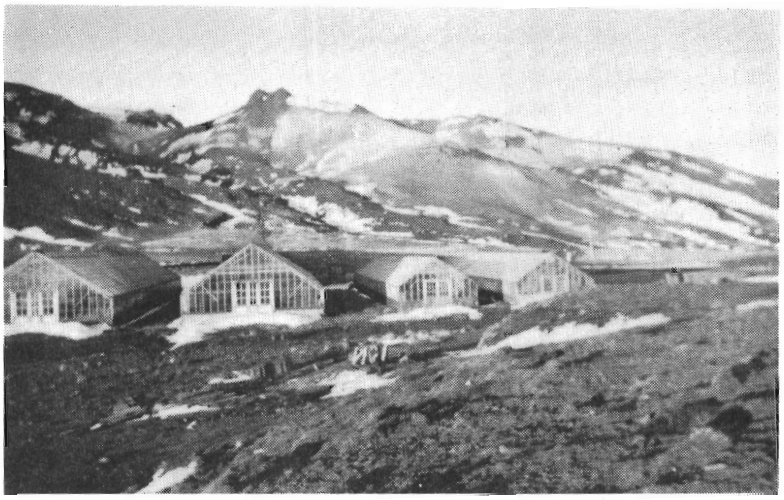


Fig. 3

Fig. 4

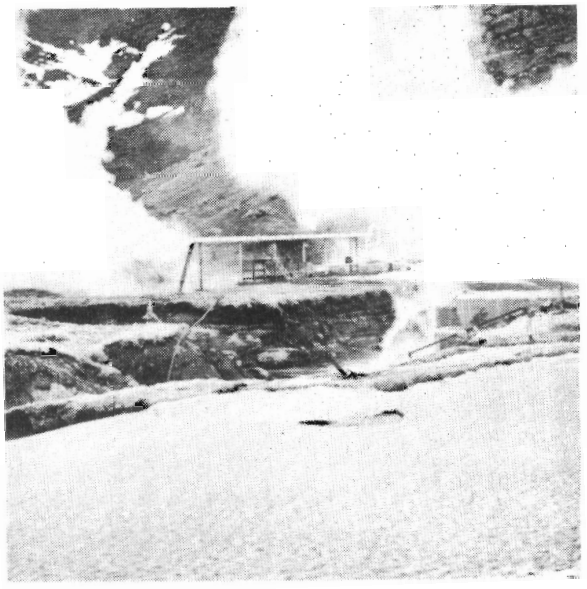


Fig. 5

FIGURES 6, 7 AND 8

Fig. 6 View of the lake Kleifarvatn from the north-western bank of the lake.

Fig. 7 Site for the proposed salt plant between the steam field and the lake Kleifarvatn in the background. The site is on the level ground near the fencing post near the Hafnarfjördur - Krísuvík road.

Fig. 8 The same view from the farm house near the greenhouses.

Fig. 6

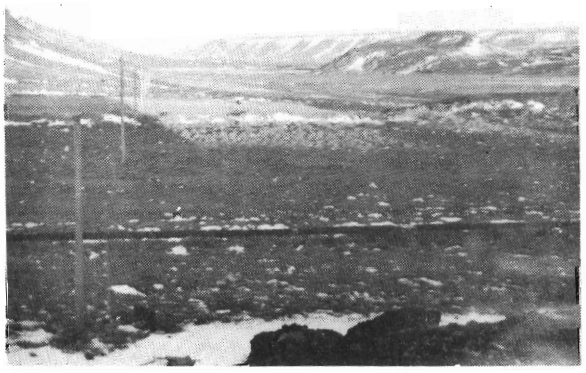


Fig. 7

Fig. 8

X.

CAPACITY OF PRODUCTION OF THE PROPOSED SALT PLANT

50. In Appendix VI have been given the figures of imports of salt into Iceland, which represent the consumption of salt by the fishing industry of the country. From map No. 2 it will be seen that the centers of production of saltfish, consequently of consumption of salt, are spread all over the country, but the concentration of important centers of saltfish production are in the south-western part of Iceland. Reykjavík, Hafnarfjördur and Keflavík in this area happen to be very important centers of saltfish production and salt distribution. During the year 1956 these centers imported more than 40,000 tons of salt, out of which Reykjavík alone imported about 34,000 tons. From this it will be seen that these centers are not only important centers for the production of saltfish, but also important centers for the distribution of salt. Taking into consideration the freight rates from Reykjavík and/or Hafnarfjördur to other centers of salt consumption in the country, when compared to the freight rates on salt from ports of salt supply in Spain, Italy and other European countries, to the centers of saltfish production in the northern and east part of Iceland, such as Akureyri, Húsavík and others, it appears that under the present circumstances, the capacity of production of salt in Iceland may be limited to meet the requirements of salt by the salt-fish industry in the south-western part of Iceland. This will have to be done under the present circumstances, because the cost of production of salt from sea water in Iceland, plus the freight on salt from the south-west part of Iceland, will be higher than the cost of imported salt at other centers of salt-fish production far away from Reykjavík and Hafnarfjördur. It will, therefore, be desirable to produce about 40,000 tons of salt per year in the proposed salt plant for Iceland in the initial stage.

XI.

COST OF INSTALLATION OF A SALT PLANT IN ICELAND WITH A CAPACITY OF 40,000 TONS OF SALT PER YEAR

51. The proposed salt plant in Iceland will perhaps be the first plant of its kind and capacity in the world, as there is not a single plant at present located on one spot or site in the world, which produces salt from sea water for industrial use, by evaporation of sea water entirely by means of steam. There are salt plants in the world, where sea water is evaporated partially by solar evaporation, and where the final evaporation of the resulting brine, and crystalization of salt from it, is carried out by means of steam. Recently, several plants have been established in different parts of the world for the evaporation of sea water for the production of fresh water. One can, therefore, have sufficient chemical engineering data and know-how regarding the evaporation of sea water efficiently and economically from one source, namely from those firms which have designed and installed plants for the production of fresh water from sea water, and for the production and crystalization of salt from concentrated sea water, from firms which have designed and installed plants for this purpose. It will, therefore, be possible to have complete engineering data and know-how from the different firms specializing either in one or the other phase of salt production from sea water entirely by the evaporation of sea water by steam. There are some firms which have designed equipment for both these phases, but installed at different places for two or more different customers.

52. On the basis of estimates obtained from an American, a British, a German and a French firm for a plant for the production of salt from sea water, with a capacity of 200 metric tons of salt per day, involving evaporation of sea water by steam for all phases of evaporation and salt production, an estimate has been prepared for a salt plant in Iceland, with a capacity of 125 metric tons of salt per day, suitable for the requirements of the fishing industry of Iceland. The details of the estimates are given in Appendix IX.

53. From the estimate shown in Appendix IX, it will be seen that the total cost of a salt plant installed and put into operation in Iceland, with a capacity of aboyt 125 metric tons per day, or about 40,000 tons of salt per year, will amount to about $ 2,500,000.-, exclusive of the

import duty and sales tax of Iceland, and also exclusive of any investment for the development of the steam field at Krísuvík for the production of steam and piping the steam from the steam field to the site of the plant.

It is possible to obtain exemption from payment for both the import duty and sales tax by a special sanction of Parliament of Iceland, if the machinery and equipment to be imported is connected with or for the fishing industry, in any particular case. Since the entire production of the salt plant is meant for the use of the salt-fish industry of Iceland, it is assumed that at the proper time there will not be much difficulty in obtaining a sanction from the Parliament for the exemption from payment of both import duty and sales tax on machinery and equipment imported for the proposed salt plant. If this exemption from the payment of both import duty and sales tax is not obtained, the total cost of installation of the salt plant will increase to the extent of the sum equal to the sales tax and duty paid. This will increase the cost of production of salt in the form of higher rate of depreciation.

54. The estimate is to be taken, as far as details are concerned, as provisional and tentative, because the figures of cost are only approximate. But taking the estimate as a whole, it can be stated that, if the planning of the salt plant is done on very sound systematic and economic lines, without any direct or indirect personal considerations, and if the implementation of the project, from the time a final decision is taken for installation of the plant, to the bringing of the installed plant, to full capacity production is carried out, also on sound systematic lines, in the shortest possible time, involving very few mistakes, if at all any, in that case it should be possible to install a salt plant with a capacity of 125 metric tons of salt per day or about 40,000 metric tons of salt per year, and bring it into full capacity production with a total cost of about $2,500,000.

XII.

ESTIMATES OF COST OF PRODUCTION OF SALT IN THE PROPOSED SALT PLANT IN ICELAND

55. For the purpose of arriving at the total cost of production of salt, estimates have been prepared, involving consumption of steam, power etc., as well as other items that make up the total cost of production of salt delivered at the site of the plant. The most important item in the cost of production of salt in Iceland will, of course, be the incidence of cost, due to the amortization of the plant and interest on the total capital invested in the plant.

56. A plant of this type has a long life, provided it is maintained on sound systematic lines. Such plants have operated and have been operating for more than 25 years. It will, therefore, be safe to allow for an amortization period of 15 years for this plant. The interest on the capital invested in a plant of this nature and importance to the country, may be taken at a slightly lower rate than usual in Iceland, of 5 1/2 per cent. On the basis of amortization of the plant at this rate of interest within a period of 15 years, the annual charge will amount to 10 per cent per year, on the total capital invested in the plant, exclusive of the working capital. The total incidence due to interest as well as amortization of the plant, will amount to $250,000 per year.

57. The working capital required for the plant will amount to about $120,000 per year, which will mostly be in the form of some sort of a revolving capital. The average rate of interest will most probably work out at about 5 per cent. The annual charge as interest on the working capital will amount to $6,000 per year.

58. On the basis of the figures of consumption of steam and power obtained from the different designers of plants of this nature and/or also fabricators of equipment, it has been estimated that a plant with a capacity of 125 tons of salt per day will require 16 tons of steam per ton of finished salt, when the plant works at full capacity, or on an average of 40,000 tons of salt per year. If the plant works at a lower capacity, the consumption will be slightly higher, which may be put down at 16.5 tons of steam per ton of salt.

59. Total power requirements, inclusive of the power required for pumping sea water, and cooling water to the plant, as well as for the

operation of the process equipment, and material handling equipment, plus the power required for instruments, lighting etc. will amount to about 180 kWh per ton of salt, when the plant works at full capacity, and about 185 kWh if the plant works at a lower capacity.

60. In Appendix X are given details regarding the manpower required for operating the plant, consisting of that required for administration as well as for operation. As the salt will be sold directly to consumers and distributors of salt in Iceland, it will not be necessary to have any kind of sales organization. The remuneration etc. of the personnel, given in the Appendix has been arrived at after consultation with proper authorities concerned in Iceland. On this basis the total cost of operating the plant will amount to approximately 120,000 dollars per year. The cost of other expenses for operating the office, such as office supplies, stationery etc., and communications will amount to about $15,000 per year, making a total of 135,000 per year.

61. The officers of the State Electricity Authority of Iceland concerned with the development of steam and power supply, estimate that the cost of steam from the Krísuvík steam field delivered to the site of the plant should be taken equivalent to about $0.13 per ton of steam and the cost of power at the site of the plant should be taken at the rate of $0.007 per kWh.

62. Simultaneously with the production of salt some gypsum will also be produced as a byproduct, which will amount to at least about 0.04 ton of gypsum per ton of salt produced. Gypsum is at present imported into Iceland for use by the cement factory. Their average cost of gypsum c.i.f. Akranes amounts to about $12.00 per metric ton. Taking into consideration the freight and handling charges from the proposed site of the plant to Hafnarfjördur by road and from Hafnarfjördur to Akranes by boats, the expenses involved in delivering gypsum at Akranes will amount to less than $3.00 per ton. It will therefore be possible to realise at least about $9.00 per ton of gypsum delivered at the site of the plant. It will be possible, therefore, to realize about $0.36 for gypsum per ton of salt produced.

63. On the basis of the above rates of consumption of steam and electricity at the rates, worked out by the State Electricity Authority and rates of interest and amortization mentioned above, and with total cost of manpower etc., the cost of production of salt delivered at the plant will work out as shown in the following Table.

ESTIMATED COST OF PRODUCTION OF SALT IN ICELAND AT THE PROPOSED SALT PLANT NEAR KRÍSUVÍK

	Cost of production per ton of salt in $ Annual production	
	35,000 tons/year	40,000 tons/year
1. Power: 185 and 180 kWh per ton of salt respectively at $0.007 per kWh	1.30	1.26
2. Total Steam: 16.5 and 16 tons per ton of salt respectively at $0.13 per ton of steam	2.15	2.08
3. Maintainance supplies at an average of 1.5% (on the total investment capital of $2,500,000) or $37,500 per year	1.07	0.94
4. Other supplies at $15,000	0.43	0.38
5. Manpower and office expence at $135,000	3.86	3.38
6. Average interest on working capital of $120,000 at 5%. $6,000 per year	0.17	0.15
7. Total cost due to interest and amortization at 10% on the capital of $2,500,000, or $250,000	7.15	6.25
8. Contingencies and rounding up	0.15	0.12
Total Cost	$ 16.28	14.56
Credit for gypsum:	0.36	0.36
Cost per ton of salt delivered at plant:	$ 15.92	14.20
Freight per ton of salt to Reykjavík by trucks:	1.20	1.20
Cost of salt delivered at Reykjavík	$ 17.12	15.40

64. From the above Table it will be seen that the cost of salt produced at the proposed salt plant and delivered at Reykjavík will amount to about $15.40 per ton if the plant operates at full capacity, or 40,000 tons per year, and will amount to $17.12 per ton if it operates at a lower capacity of about 35,000 tons per year.

65. The present cost of salt delivered at the factories of the consumers, works out at about $16.00 per ton, and so if the plant operates at full capacity, there will be a margin of profit of approximately $0.60 per ton of salt produced. If, however, the plant operates at appreciably lower capacity than 40,000 tons of salt per

year, there will be a loss of about $1.12 per ton of salt produced. The loss is due mainly to the appreciable decrease recently in the rates of freight between Reykjavík and ports from which salt from Spain, Italy and other countries is imported. The margin of profit under the present circumstances is indeed low. Taking into consideration, however, the present trend in the increase in the freight rates, it can be stated that production of salt at the proposed salt plant at full capacity will not bring any financial harmship to the consumers of salt in the South-western part of Iceland or the investors in the proposed salt plant for Iceland.

66. In Appendix XI is given the analysis of the fish export and the salt import trade of Iceland during the years 1945 - 1958. In column 9 of this Appendix are given figures of average c.i.f. Iceland port price of salt during these years. From these figures it will be seen that during the years 1945 to 1952 the average c.i.f. Iceland price of salt, except for the year 1950, has been appreciably higher than the estimated cost of salt produced at the proposed plant at Krísuvík and delivered by trucks to Reykjavík.

67. To the c.i.f. value of salt have to be added expenses for clearing, bank discounts, port duties, etc. This adds up to about $1.50 per ton of salt and has to be added to the c.i.f. value of salt to arrive at the landed and delivered cost of salt.

68. Again during the years 1956 and 1957, and also 1958 the cost of salt delivered to the consumers amounted to more than the estimated cost of salt at Reykjavík from the proposed salt plant. It will therefore be obvious that looking from the long-term point of view, and taking into consideration the overall interest of the economy of the country as a whole, production of salt in Iceland is not going to be an unprofitable enterprise, nor a source of hardship to the consumers, and even to investors, as an interest of 5 1/2 per cent is included in the cost of production of salt.

XIII.

RECOVERY OF BY-PRODUCTS

69. It has already been stated in some of the previous paragraphs that besides common salt (sodium chloride), sea water contains other chemicals such as magnesium chloride, magnesium sulphate, gypsum or calcium sulphate, potassium sulphate and magnesium bromide. The recovery of some of these salts and converting them into useful compounds like magnesium oxide and/or magnesium carbonate, calcium chloride and even bromine, often becomes profitable under certain circumstances. Recovery of gypsum has already been mentioned in connection with the cost of production of salt. Over and above recovery of 0.04 tons of gypsum per ton of salt produced as mentioned above it is possible to recover more gypsum when the bitterns from the process of salt production are further treated for the recovery of magnesium oxide and/or magnesium carbonate.

70. Treatment of the bitterns and recovery of marketable products involves chemical process which have to be carried out under very delicate control of temperature, pressure and hydrogen ion concentration. It also involves complicated equipment when compared to the equipment required for the production of salt from sea water. These products also have to be packed in special containers or bags etc.

71. The main products that can be recovered from the bitterns can be put down as follows:

1. Magnesium oxide and/or magnesium carbonate.
2. Calcium chloride
   Gypsum
   Bromine
   Potassium chloride.

Out of this gypsum produced during the further treatment of bitterns will have a ready market in Iceland. It may be possible to find a market for even calcium chloride, but all the production of magnesium oxide and/or magnesium carbonate, as well as bromine will have to be exported, which will involve importation of containers and/or packing materials and wooden cases will be required in the case of bromine.

72. The value that could be realized from these by-products depends

considerably on the quality and the grade of the material produced.

73. There are import duties on these materials imposed by certain countries. In view of this it is highly desirable to undertake the recovery of by-products from the bitterns from the proposed salt plant in Iceland at a later date. It will be necessary in the first instance to find out which countries will buy the products, of what grade. and the freight involved in shipping the materials from Iceland to the consuming countries, It will be necessary to estimate very closely the price that could be realized f. o. b. Reykjavík.

In Appendix XII are given the figures of imports of dead-burned magnesia into USA during the year 1955-1958.

In Appendix XIII are given the imports of lump or ground caustic calcined magnesia into USA during the years 1955-1958.

In Appendix XIV are given the figures of import of dead-burned sintered magnesia, caustic calcined magnesia and calcium chloride into Canada during the year 1958.

In Appendix XV are given the figures of imports of magnesite into different countries during the years 1955 to 1957.

In Appendix XVI are given the figures of exports of magnesite from different countries during the years 1955-1957.

In Appendix XVII are given the figures of production of bromine in different countries during 1955-1957, as well as figures of exports from different countries and figures of imports into different countries of bromine during the years 1955-1957.

74. The figures in Appendix XII - XVII will give a general idea about the requirements of different countries of magnesium oxide and magnesium carbonate in different forms, as well as those of bromine. Taking into consideration various factors in the economics of recovery of by-products from the bitterns produced at the proposed salt plant for Iceland, if it is found that there will be market for magnesium oxide and/or carbonate produced in Iceland, in that case planning for the production of these chemicals may be seriously considered and a plant set up at the same site as the salt plant for the production of various products.

75. The economics of recovery of the magnesium compounds from

the bitterns in the form of magnesium oxide and magnesium carbonate, will be not so favourable in Iceland, because Iceland does not happen to have not only any deposits of delomite, but not even of limestone. It will, therefore, be necessary to recover these substances by somewhat uneconomic means, by using comparatively low grade sea shell sands for the production of lime required for the treatment of bitterns for the recovery of magnesium oxide and/or carbonate. A special plant will have to be set up at the site of the salt plant for the production of lime for the sea shell sands, which will have to be brought from their sources (see map 3). These sea shell sands are used at present as the main raw material for the production of cement in Iceland at Akranes.

76. Roughly estimated cost of the total equipment required for the installation of a plant for recovering of by-products will amount to approximately anywhere from $800,000 to about $1,000,000. If all the products that can be produced can be marketed at a reasonable profit, it may bring an annual profit amounting to about $140,000 over and above the interest charges at the rate of 5 1/2 per cent on the invested capital. The total investment of both the salt plant and the by-product recovery plant will amount to about $3,500,000. If the anticipated profit is realized, it will be possible to make a profit on the total investment of about 4 percent over and above the interest included in the cost of production at the rate of 5 1/2 per cent. If this profit is looked into from the point of view of cost of salt by recovery of by-products, it may be possible to bring down the cost of production of salt by about $3,- per ton. This possibility will require to be investigated, if and when it is decided to set up a salt plant in Iceland.

77. It may be desirable to state at this stage that, under the present circumstances it will not be economically possible to produce magnesium metal in Iceland from the by-products of the proposed salt plant. The decision for the installation of a salt plant should not, therefore, be based on the likely or probable returns from the production of magnesium metal, improving the economy of production of salt in this country.

XIV.

OTHER CONSIDERATIONS IN CONNECTION WITH THE ESTABLISHMENT OF A SALT PLANT IN ICELAND

78. It may perhaps be argued that if production of salt is undertaken in Iceland, it will not be possible to sell saltfish or even fish to countries from which salt is at present imported in appreciably large quantities, namely Spain and Italy. In this connection it may be of interest to examine the share of export trade of Iceland with Spain and Italy, when compared to the total exports of commodities from Iceland, as well as when compared to the total exports of fish and fish products from Iceland to Spain and Italy. In Appendix XVIII are given figures for the share of Spain and Italy in the total export trade of Iceland. From these figures it will be seen that the share of both Spain and Italy can be considered not so very important, because the total exports to Spain have varied during the last five years, from 3.4 to 1.6 percent of the total export trade in commodities from Iceland. This amounts to on an average about 2.5 percent. The corresponding figures for Italy are from 7.7 percent to 3.2 percent, and the average comes to about 5.4 percent.

79. From Appendix XIX it will also be seen that Iceland has an unfavourable balance of trade with Spain for all the five years period of 1954-1958 varying from as high as about 25.8 million krónur in 1954 to as low as 5.4 million krónur in 1958. On the other hand, Iceland has a very favourable balance of trade with Italy for all the five years period of 1954-1958. It has varied from as high as 45.1 million krónur to as low as 2.5 million krónur in 1957. This will show that production of salt in Iceland is not going to be detrimental to the export trade of Iceland in any way whatsoever.

80. In view of the proportionally higher rates of freight between the port of Reykjavík and the other ports of Iceland, and between the ports of salt supplying countries and ports in Iceland near the salt consuming centers, it has been already suggested that the capacity of the salt plant should be about 70 - 75 percent of the total salt requirements of the country, at least in the beginning. Most of the salt imported into Iceland is brought by ships belonging to countries other than Iceland. Icelandic ships, according to the information available sofar, have not brought in any year more than 30 per cent

of the total salt imported into Iceland. For example in 1956 Icelandic ships brought only 26 percent of the total salt imported, and the remaining 74 percent of the salt was brought by non-Icelandic ships. In 1957 Icelandic ships brought only 12 percent of the total salt imported into Iceland, while the non-Icelandic ships brought about 88 percent. It will thus be seen that the shipping companies of Iceland are not going to lose income by reduction in the imports of salt, resulting from about 40,000 tons of salt being produced per year in Iceland. Production of salt in Iceland, therefore, is not going to affect in any way adversely any other source of income by Icelanders.

81. At present Iceland is having a very unfavourable balance of trade, as well as balance of payments. The deficit in the balance of trade is very appreciable and also it is appreciable in the balance of payments. This has resulted in the very severe difficulties with regard to foreign exchange. One of the ways of minimizing these difficulties is to increase the exports and reduce the imports. If production of salt-fish is given serious attention by all concerned, it will be possible to increase the export trade in salted fish, which will require imports of salt. If salt production is undertaken on sound systematic and economic lines, it will be possible to curtail a very appreciable part of imports of salt into Iceland, which will bring about some reduction in the total imports of all commodities. In Appendix XX is shown the present position regarding the share of imports of salt in the total imports of all commodities in this country, and also the relation between the value of imports of salt and the total imports of all commodities in Iceland, and deficit in the balance of trade and deficit in the balance of payments. From the figures shown in this Appendix, it will be seen that production of salt in Iceland will help appreciably in minimizing the unfavourable position of Iceland, with ragard to balance of payments and balance of trade.

82. From what has been stated above, it will be seen that installation of a salt plant in Iceland, even though not a highly profitable enterprise in itself, is likely to result in many other indirect advantages to the people of Iceland, and to the overall economy of Iceland, without in any way affecting the export trade of Iceland, or any disadvantage to the shipping interests of the country.

83. It will be interesting to know the destination of fish and fish products exported from Iceland. At present Iceland exports fish to

50 countries in all the continents of the world (see map no. 1). The countries importing fish from Iceland are as follows: -

# United Kingdom	# Italy	# Uruguay
# Germany	Austria	# Venezuela
Holland	# Spain	# Jamaica
Ireland	# Portugal	# Trinidad
# U.S.A.	Trieste	# Puerto Rico
Canada	Cyprus	Nigeria
# U.S.S.R.	# Greece	Kenya
# France	# Egypt	Tanganyika
Czenchoslovakia	Saudi-Arabia	French Middle Africa
Hungary	Iraq	Mauritius
Israel	Argentina	Ceylon
# Denmark	# Cuba	Ghana
# Finland	# Brazil	Liberia
# Sweden	Chile	Nigeria
Faroe Islands	Columbia	Sudan
# Poland	# Panama	Indonesia
Roumania		Australia

Source: Verzlunarskýrslur 1955 - 1957
(External Trade of Iceland)

Out of these countries, those marked with # are the ones which import salt-fish from Iceland.

The standard of living and economic conditions of a very large part of the population in many of the countries importing salt-fish from Iceland, especially those on the Mediterranian coast and in South and Central America, is such that it will take several decades before suitable facilities for refrigeration are installed at the ports, for receiving frozen fish from ships, and those for the proper distribution and consumption of frozen fish to the inhabitants of the countries concerned. The demand for salt-fish is, therefore, going to continue for some decades, and Iceland will require salt for the production of salt-fish for exports to these countries. It is therefore necessary to seriously consider the question of production of salt in Iceland.

84. The advantages that will be gained from the installation of a salt plant in Iceland may be summarized as follows:

The installation of a salt plant in Iceland:

1. will make the country appreciably self-sufficient as regards supply of salt. Consequently the fishing industry of Iceland will not have to depend upon a foreign or imported raw material for the manufacture of salt-fish, to the extent of local production of salt.

2. will open up new avenues of employment, in a small way, for the rapidly increasing population of Iceland.

3. will bring about appreciable saving in the foreign exchange requirements of the country.

4. will lead the way, or make a very good beginning, for future development of the use of steam for industrial purposes, as no industrial use of steam has sofar been developed.

5. will present several technical, scientific, economic, psychological and political (local politics) and allied problems, while planning, implementing and bringing into full capacity production a salt plant using natural steam as a source of heat, on sound lines. These problems will have to be solved for economic and efficient production of salt in Iceland, and perhaps in the future, of some by-products. Experience gained by the citizens of Iceland in facing and solving these and allied problems will enable them to undertake with courage and confidence other projects of larger magnitude for utilizing the enormous resources of natural heat or natural steam scattered all over the country.

85. The only disadvantage about the installation of the salt plant in Iceland will be that the financial returns from the operation of the plant will not be so very attractive, as to give a return in the initial stage of its operation, of more than 5 1/2 percent.

RECOMMENDATIONS

86. Establishment of a salt plant in Iceland, with a capacity of about 125 tons of salt per day, or say about 40,000 tons of salt per year, will appreciably help in improving the foreign exchange position of Iceland, and make the fishing industry of Iceland self-sufficient for its requirements of salt.

87. Even though the salt plant will not be, from a strictly financial point of view, a highly profitable enterprise, it is not likely to impose any financial burden on the economy of Iceland. On the contrary, it will help as stated above, in reducing the unfavourable balance of trade and unfavourable balance of payments of Iceland.

88. As the production of salt in Iceland will not require any other

basic raw materials in the process of production, salt production in Iceland will be an entirely 100 percent self-sufficient industry, as far as basic raw materials are concerned, which is not the case with the cement industry and the fertilizer industry, both of which require imported fueloil, and the cement plant also requires imported gypsum. Production of salt will also help to some extent in making the cement industry partially self-sufficient, with regard to its requirements of gypsum. If, however, the recovery of by-products from the salt industry is undertaken, it will be possible to recover sufficient gypsum from the production of salt, as well as from by-products recovered, to make the cement plant self-sufficient for its requirements of gypsum, up to an annual production of cement of about 100 - 110,000 tons of cement per year.

89. In view of the advantages that will be gained by the establishment of a salt plant in Iceland, it is suggested that a competent committee be appointed by the Government of Iceland, consisting of engineers, economists, financial experts, users of salt, respresentatives of the fishing industry, as well as respresentatives of the shipping interests, and some prominent statesmen and politicians, to objectively study and examine and report on the economy and other advantages and dis-andvantages involved in the establishment of a salt plant, and then recommend to the Government whether a salt plant should be established in Iceland or not.

ACKNOWLEDGMENTS

90. I am thankful to the Government of Iceland for giving me this assignment for preparing the report on the possibility of production of salt in Iceland. I am also thankful to The International Cooperation Administration, Washington D.C., U.S.A., for making it possible for the Government of Iceland to give me this assignment, and thus enable me to be of some assistance to Iceland. My thanks are due to Mr. Jakob Gíslason, the Director of The State Electricity Authority of Iceland, for putting at my disposal the facilities of his office and for giving me valuable suggestions in connection with my work. My thanks are also due to Mr. Baldur Líndal of The State Electricity Authority, for assisting me in all possible ways in the work connected with the preparation of this report. I must make a special mentionof the valuable assistance I have received from Mr. Ísleifur Jónsson for

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91. I hope that the facts and figures and information supplied in this report may prove to be of some use to the planners of industries in Iceland, and may some day result in the establishment of a salt plant in Iceland, so vital to the economy of the country.

M. S. PATEL

Reykjavík, 30th November, 1959.

APPENDIX I

STATISTICS SHOWING COMPARATIVE POSITION OF SOME COUNTRIES

Country	Population in 1957 in thousands	Birth Rate No. of Births per thousand population	Death Rate No. of Deaths per thousand population	Population Increase Rate per thousand population	Infant Mortality Rate Per thousands Births
U.S.A.	171,196	25.0	9,6	15,4	26.3
U.K.	51,657	16.5	11.5	5.0	23.9
W. Germany	53,692	17.0	11.3	5.7	36.5
France	44,071	18.5	12.2	6.3	33.3
Holland	11,021	21.2	7.5	13.7	17.2
Belgium	8,989	17.0	11.9	5.1	35.0
Sweden	7,317	14.6	9.9	4.7	17.4
Denmark	4,500	16.7	9.3	7.4	24.9
Norway	3,494	18,2	8.6	9.6	21.2
Finland	4,336	20.1	9.4	10.7	27.9
Iceland	165	28.7	7.0	21.7	17.3

	Net Food Supply per Capita Per Day			Fish Catches in Tons per Capita	Merchant Shipping Reg. Tons per. 1000 population
	(a) calories total	(b) protein grammes	(c) % animal origin		
U.S.A.	3,100	94	42	0.016	151
U.K.	3,290	86	38	0.020	384
W. Germany	2,990	81	34	0.014	67
France	2,920	103	30	0.012	91
Holland	2,890	78	29	0.027	393
Belgium	2,930	88	33	0.007	66
Sweden	2,950	85	39	0.027	417
Denmark	3,500	98	40	0.118	413
Norway	3,190	90	41	0.498	2430
Finland	3,100	95	37	0.015	275
Iceland	3,230	120	43	3.045	540

	Civil Aviation		Foreign Trade per Capita	
	Flown Km per Capita by Airlines (a)	Passanger Km per Capita by Airlines (b)	Imports (a)	Exports (b)
U.S.A.	9.2	292	76	121
U.K.	2.6	75	212	180
W. Germany	0.3	9	140	160
France	2.3	87	139	115
Holland	5.9	179	373	281
Belgium	3.9	103	382	354
Sweden	3.6	101	332	294
Denmark	3.3	99	302	261
Norway	5.3	142	365	235
Finland	2.3	39	205	190
Iceland	36.2	946	507	368

APPENDIX I CONTINUED

Country	Motor Vehicles in Use	Tele-phones in Use	Radio Receiving Sets	Daily Newspapers copies sold	New Books No. of Titles Published
	Per Thousand of Population				
U.S.A.	392	372	877	337	0.08
U.K.	106	142	284	573	0.40
W. Germany	62	88	273	277	0.29
France	121	80	247	244	0.27
Holland	46	120	284	264	0.66
Belgium	77	110	257	383	0.34
Sweden	163	330	368	462	0.78
Denmark	80	211	345	376	0.68
Norway	71	185	282	374	0.87
Finland	42	121	259	420	0.52
Iceland	108	202	271	390	3.32

Country	Electricity Installed KW per Capita	Electricity Produced kWH per Capita
U.S.A.	0.853	4,180
U.K.	0.609	2,043
W. Germany	0.357	1,709
France	0.403	1,303
Holland	0.384	1,213
Belgium	0.401	1,403
Sweden	0.959	3,959
Denmark	0.339	810
Norway	1.410	7,395
Finland	0.473	1,778
Iceland	0.612	2,679

MOST OF THE STATISTICS IN THE ABOVE COLUMNS ARE FOR THE YEAR 1957, EXCEPT THOSE FOR NET FOOD SUPPLY WHICH ARE FOR THE PERIOD 1948-1950. THE LATEST STATISTICS FOR THESE ITEMS FOR ICELAND ARE AVAILABLE ONLY FOR THAT PERIOD.

Source: Statistical Yearbook 1958 of United Nations

APPENDIX II

SHARE OF FISHING INDUSTRY AND AGRICULTURAL INDUSTRY TO THE GROSS NATIONAL PRODUCT OF ICELAND

		1955	1956	1957	1958
		(in millions of Krónur)			X
1	Gross National Product	3,860	4,460	4,780	5,500
*2	Value of Fish and Fish Products	920	1,160	1,270	1,680
3	Per Cent Fish Products of Gross National Product (1)	23.9	26.0	26.5	30.5
4	Gross Value of Agricultural Products	663	745	820	900
5	Per Cent, Agricultural Products of Gross National Product (1)	17.2	16.7	17.2	16.4
6	Total Exports of Commodities and Services	1,349	1,503	1.376	1,517
#7	Total Exports of Fish Products	778	927	895	973
8	Per Cent Fish Products of Total Exports of Commodities and Services (6)	57.7	61.6	65.1	64.1
9.	Exports of Commodities only	848	1,032	988	1,069
10	Per Cent Exports of Fish and Fish Products of Exports of Commodities only (9)	91.7	89.7	90.6	91,0
11	Per Cent Exports of Fish and Fish Products to Total Value of Fish and Fish Products (2)	84.6	79.9	70.5	57.9
12	Total Exports of Agricultural Products	50	72	59	66
13	Per Cent Exports of Agricultural Products of Exports of Commodities and Services (6)	3.7	4.8	4.3	4.4
14	Per Cent Exports of Agricultural Products of Total Exports of Commodities only (9)	5.9	7.0	6.0	6.2
15	Total Exports of Services only (6-9)	501	471	388	448
16	Total Exports of Services Per Cent of Gross National Product (1)	13.0	10.6	8.1	8.1
17	Per Cent Exports of Services to Total Exports of Commodities and Services	37.1	31.3	21.2	29.5

X All figures for 1958 are estimates and provisional only.

*The value of fish and fish products in the gross national product contains export subsidies.

The value of exports of fish and fish products is calculated at the official rate of 16.32 kronur per dollar.

Source: Framkvæmdabanki Íslands and Verzlunarskýrslur 1955-1958. (Bank of Development of Iceland)

APPENDIX III

TOTAL VALUE OF EXPORTS OF COMMODITIES AND THAT OF FISH AND IFSH PRODUCTS FROM ICELAND DURING 1930 - 1958

Year	Total Export 1000 kr.	Exp. of Fish and Fish prod. 1000 kr.	Fish prod. Per Cent of Total exp.
1930	60,096	54,564	90.8
1931	48,009	42,731	89.0
1932	47,785	44,033	92.1
1933	51,833	46,880	90.5
1934	47,854	42,868	89.6
1935	47,772	40,852	85.5
1936	49,642	41,189	83,0
1937	58,988	47,795	81.0
1938	58,607	48,423	82.6
1939	70,536	59,262	84.0
1940	133,030	127,361	95.7
1941	188,629	179,509	95.2
1942	200,572	192,785	96.1
1943	233,246	205,205	88.0
1944	254,286	236,917	93.2
1945	267,541	242,034	90.5
1946	291,368	242,926	83.4
1947	290,776	267,022	91.8
1948	395,699	364,379	92.1
1949	290,044	277,788	95.8
1950	421,870	368,074	87.3
1951	726,631	665,171	91.5
1952	641,322	583,651	91.0
1953	706,414	664,683	94.1
1954	845,912	808,224	95.5
1955	847,849	778,439	91.8
1956	1,031,512	926,508	89.8
1957	987,602	894,873	90.6
1958	1,070,200	977,300	91.2

Source: Verzlunarskýrslur 1930 - 1958
(External trade of Iceland)

APPENDIX IV

EXPORTS OF FISH AND FISH PRODUCTS FROM ICELAND DURING 1930 - 1958

Year	Total Exports of Fish and Fish prod.		Total Exports of Salted Fish		Exports of Salted Fish Per Cent of Total Fish Exports	
	Quant. Tons	Value 1000 kr.	Quant. Tons	Value 1000 kr.	Quantity	Value
1930	112,074	54,564	90,300	41,632	80.6	76.4
1931	117,438	42,731	87,340	29,943	74.4	70.1
1932	138,737	44,033	101,742	32,464	73.3	73,7
1933	129,572	46,880	101,790	35,619	78.6	76.1
1934	114,073	42,868	84,315	30,049	73.9	70.1
1935	97,522	40,852	68,211	27,422	69.9	67.2
1936	103,214	41,189	64,405	22,375	62.4	54.3
1937	101,377	47,795	59,663	22,794	58.9	47.7
1938	122,927	48,423	77,346	26,623	62.9	55.1
1939	114,454	59,262	68,616	29,553	60.0	49.9
1940	160,202	127,361	22,000	23,028	13.7	18.1
1941	182,922	179,509	31,200	29,180	17.1	16.2
1942	183,648	192,785	13,720	16,884	7.5	8.8
1943	192,526	205,205	5,945	8,972	3.1	4.4
1944	202,376	236,917	4,039	6,550	2.0	2.8
1945	188,233	242,034	13,835	20,903	7.4	8.6
1946	167,733	242,926	29,186	49,647	17.4	20.5
1947	165,085	267,022	35,684	62,289	21.6	23.4
1948	255,619	364,379	28,170	54,575	11.0	15.0
1949	206,740	277,788	30,405	60,528	14.7	21.8
1950	137,912	368,074	52,842	149,258	38.3	40.5
1951	204,857	665,171	57,036	199,595	27.9	30.0
1952	277,645	583,651	65,855	248,139	23.8	42.6
1953	162,283	664,683	61,433	246,735	37.8	37.2
1954	187,827	808,224	59,480	225,190	31.7	27.9
1955	183,286	778,439	73,093	303,084	39.9	39.0
1956	218,345	926,508	77,428	308,417	35.5	33.3
1957	217,149	894,783	67,043	260,876	31.0	29.2
1958	240,672	977,300	64,920	264,779	27.0	27.1

Source: Verzlunarskýrslur 1930 - 1958
(External trade of Iceland)

PRODUCTION OF SALTED FISH IN THOUSANDS METRIC TONS

SALTED HERRING

	1938	1948	1950	1951	1952	1953	1954	1955	1956	1957
Total for all countries	756.0	644.0	-	751.0	776.0	860.0	852.0	868.0	927.0	1,057.0
Iceland	34.8	11.5	18.7	15.4	12.0	23.1	13.9	27.1	37.4	19.3
Iceland per Cent of total product.	4.6	1.8	-	2.1	1.5	2.7	1.6	3.1	4.0	1.8

SALTED COD

	1938	1948	1950	1951	1952	1953	1954	1955	1956	1957
Total for all countries	271.0	236.0	-	284.0	307.0	277.0	286.0	314.0	325.0	314.0
Iceland	34.8	9.0	33.1	21.0	41.6	25.7	23.3	29.1	26.7	21.0
Iceland per cent of total product.	12.8	3.8	-	7.4	13.5	9.3	8.2	9.3	8.2	6.7

Source: United Nations Statistical Yearbook 1958

APPENDIX VI

IMPORTS OF SALT INTO ICELAND

Year	Total Imports of Salt Tons	Cumulative Average for Two Years Tons	Cumulative Average for Three Years Tons	Cumulative Average for Four Years Tons
1930	86,970			
1931	65,319	76,144		
1932	87,551	76,435	79,947	
1933	113,096	100,324	88,655	88,324
1934	70,433	91,764	90,360	84,100
1935	62,588	66,510	82,039	83,417
1936	49,660	56,124	60,894	73,944
1937	43,517	46,588	51,922	56,550
1938	52,204	47,860	48,460	51,992
1939	61,114	56,659	52,278	51,624
1940	17,692	39,403	43,670	43,632
1941	16,612	17,152	31,806	36,906
1942	13,141	14,876	15,815	27,140
1943	7,072	10,106	12,275	13,629
1944	10,379	8,726	10,197	11,801
1945	5,896	8,138	7,782	9,122
1946	20,198	13,047	12,158	10,886
1947	43,307	31,752	23,134	19,945
1948	21,067	32,187	28,191	22,617
1949	21,314	21,190	28,563	26,472
1950	56,503	38,908	32,961	35,548
1951	27,502	42,002	35,106	31,596
1952	35,489	31,496	39,831	35,202
1953	52,164	43,826	38,385	42,914
1954	55,875	54,020	47,843	42,758
1955	55,992	55,934	54,677	49,880
1956	70,166	63,079	60,678	58,549
1957	53,429	61,798	59,862	58,866
1958	46,060	49,744	56,552	56,412

Source: Verzlunarskýrslur 1930 - 1958
(External trade of Iceland)

APPENDIX VII

AVERAGE TOTAL USE OF SALT IN SOME COUNTRIES OF THE WORLD DURING THE YEARS 1953 TO 1957 AND AVERAGE PER CAPITA USE OF SALT

Country		Average consumption of Salt per Year in M. Tons	Total Population Approximate	Approximate per Capita Consumption of Salt in kilos	in lbs.
1.	U.S.A.	20,275,800	171,196,000	118	260
2.	U.K.	4,478,100	51,657,000	87	192
3.	Germany	2,573,270	53,692,000	48	106
4.	France	3,068,500	44,071,000	70	154
5.	Holland	303,605	11,021,000	28	62
6.	Belgium	518,780	8,989,000	58	128
7.	Sweden	352,600	7,317,000	48	106
8.	Denmark	122,790	4,500,000	27	60
9.	Norway	253,340	3,494,000	73	161
10.	Finland	131,070	4,336,000	30	66
11.	Iceland	57,525	165,000	350	772

Sources:

(1) Statistical Summary of the Mineral Industry 1952 - 1957 published by Her Majesty's Stationery Office, London.

(2) Statistical Yearbooks of Different Countries

(3) World Almanac, New York.

ANALYSIS OF SALT FOR THE FISHING INDUSTRY OF ICELAND

	Germany	Italy Sardinia	Spain Torre-vieja	Spain Roque-tas	Spain Pinatar	Spain St. Pola	Spain Ibiza
	%	%	%	%	%	%	%
Moisture	0.0	3.9	2.4	3.5	3.1	3.3	4.5
Sodium Chloride	98.0	95.3	97.3	96.2	95.2	95.3	93.5
Calcium Sulphate	1.26	0.56	0.25	0.22	1.47	0.80	1.51
Calcium Chloride	-	-	-	-	-	-	0.38
Magnesium Chloride	0.02	-	-	-	-	0.28	0.32
Magnesium Sulphate	-	0.12	-	0.09	0.09	0.23	-
Insolubles in water	0.75	0.02	0.01	0.03	0.03	0.1	0.09
Iron/Parts per million	30.0	15	25	12	16	11	26
Copper/parts per million	0.0	0.0	0.0	0.1	0.2	0.3	0.4

Source: Geir Arnesen and Thordur Thorbjarnarson
ÆGIR, Mánaðarrit Fiskifélags Íslands (Monthly Journal of Icelands Fishing Industry Association)

APPENDIX IX

TENTATIVE ESTIMATES OF COST OF INSTALLATION OF A SALT PLANT IN ICELAND

CAPACITY:- 125 METRIC TONS PER DAY OR 40,000 TONS PER YEAR

		Total Cost Installed in $
1	Preliminary chemical engineering study and investigations	20,000
2	Engineering fees	60,000
3	Cost of all imported process equipment with essential spare parts	1,000,000
4	Cost of freight and insurance charges to Iceland of process equipment etc.	20,000
5	Landing and other charges, port dues etc., import licence fees, bank commission etc., exclusive of duty and sales tax	25,000
6	Cost of equipment, materials and cost of installation of sea water and cooling water pumping stations, of pipelines as well as of building for the plant, offices laboratory, canteen, some residential quarters etc., cost of foundations for the process equipment, tanks for seawater and small storage for salt etc.	650,000
7	Cost of pipes valves and fittings inside the plant boundary.	100,000
8	Cost of workshop and laboratory equipment	50,000
9	Cost of installation of all process and other equipment, inclusive of the cost involved in the negotiations of contract for the equipment, placing of orders handling of equipment at port, transportation of the equipment from port to the site of the plant, administration during the construction period etc.	180,000
10	Cost of installation of communications etc. and also cost of office equipment and furniture, equipment for the canteen etc.	15,000
11	One automobile and one station wagon	15,000
12	Financial losses during the initial starting up to the plant.	20,000
13	Interest on capital required during construction period.	125,000
14	Storage Facilities for salt at Hafnarfjördur and Reykjavík.	25,000
15	Unexpected, contingencies and rounding up	195,000
	Total	2,500,000

APPENDIX X

MANPOWER REQUIREMENTS FOR THE PROPOSED SALT PLANT

	ADMINISTRATIVE	Icel. Krónur Per Year
1	Managing Director & General Manager	150,000.-
1	Secretary to the General Manager	75,000.-
1	Chief Accountant & Purchasing Agent	85,000.-
1	Secretary to the Chief Accountant	70,000.-
1	Payroll clerk & Accounts clerk	75,000.-
1	General Office clerk	65,000,-
1	Receptionist & telephone operator	50,000.-
1	Messenger boy	30,000.-
1	Part-time janitor	50,000.-
9	Total for Administrative Manpower	650,000.-

	OPERATIVE	
1	Plant Superintendant	130,000.-
1	Secretary to Plant Superintendant	50,000.-
1	General clerk for the plant office	60,000.-
1	Master Mechanic	90,000.-
1	Pipe Fitter	80,000.-
1	Electrician	80,000.-
1	Instrument Mechanic	80,000.-
1	Welder	80,000.-
1	Plant storekeeper & record keeper	70,000.-
1	Chemist	100,000.-
1	Chemist´s helper	65,000.-
1	Truck & car driver	65,000.-
1	Pipeline & pumping station supervisor	80,000.-
3	Shift foremen (each 100,000.-)	300,000.-
4	Evaporator room operators (each 80,000.-)	320,000.-
3	Vacuum set & crystalizers room operators ... (each 80,000.-)	240,000.-
4	Compacting, grinding & screeningroom ..... operators (each 80,000.-)	320,000.-
1	Janitor	60,000.-
2	Overall general helpers (each 70,000.-)	140,000.-
1	First Aid Nurse	70,000.-
2	Canteen Operators (each 50,000.-)	100,000.-
33	employees for Operative Total Operative	2,580,000.-
9	" Administrative Total Administrative	650,000.-
42	Total	3,230,000.-
	Other benefits	320,000.-
	Total Remuneration for Manpower Per Year	3,550,000.-

FISH EXPORTS AND SALT IMPORTS OF ICELAND 1945 - 1958

Year	Total Exports Value in 1000 $	Exports of Fish and Fish products 1000 $	Fish prod. Per Cent of Total Exports	Exports of Salt Fish in Tons	Exports of Salt Fish 1000 $	Salt Fish Per Cent of Fish products	Import of Salt in Tons	Import of Salt Value in 1000 $	Average CIF Price of Salt $ pr. Ton	Salt Imports Per Cent of Salt Fish Exports Value
1945	27,800	25,150	90.5	13,835	1,160	8.6	5,896	115	19.5	5.3
1946	30,250	25,220	83,4	29,186	5,170	20.5	20,198	364	18.0	7.0
1947	30,200	27,720	91.8	35,684	6,480	23.4	43,307	653	15.1	10.1
1948	41,050	37,900	92.2	28,170	5,685	15.0	21,067	351	16.7	6.2
1949	30,100	28,800	95.8	30,405	6,280	21.8	21,314	323	15.2	5.2
1950	25,850	22,600	87.4	52,842	9,140	40.5	56,503	638	11.3	7.0
1951	44,500	40,750	91.7	57,036	12,230	30.0	27,502	437	15.9	3.6
1952	39,300	35,700	90.8	65,855	15,210	42.6	35,489	620	17.5	4.1
1953	43,300	40,650	94.0	61,433	15,120	37.2	52,164	661	12.7	4.4
1954	51,900	49,500	95.5	59,480	13,800	27.9	55,875	715	12.8	5.2
1955	51,950	47,700	91.8	73,093	18,580	39.0	55,992	849	15.2	4.6
1956	63,250	56,800	89.8	77,428	18,920	33.3	70,166	1,187	16.9	6.3
1957	60,500	54,800	90.6	67,043	15,990	29.2	53,429	886	16.6	5.5
1958	65,550	59,950	91.2	64,920	16,220	27.1	46,060	660	14.3	4.1

Source: Verzlunarskýrslur 1930 - 1958
(External trade of Iceland)

APPENDIX XII

IMPORTS OF DEAD-BURNED AND GRAIN MAGNESIA INTO U.S.A. DURING 1955-1958

1955

Country of origin	Quantity Metric tons	Value in $ FOB port of origin	Average price pr. metric ton FOB port of origin
Canada	3.714,9	945.955	254,5
Austria	55.755,3	3.672.000	66,9
Italy	1.499,6	87.000	58,0
Switzerland	18.082,8	1.265.796	70,0
Yugoslavia	14.107,6	757.723	53,7
Total	93.160,2	6.728.514	72,2

1956

Canada	2.723,4	697.320	256,2
Austria	60.128,8	4.091.056	68,0
Italy	6.454,6	423.946	65,7
Switzerland	49,9	3.500	70,2
Yugoslavia	16.720,2	887.479	53,1
Total	86.076,9	6.093.301	70,8

1957

Canada	310,8	64.153	206,5
Sweden	10,0	2.064	206,4
Austria	23.471,3	1.071.936	45,7
Trieste	18.142,4	978.131	53,9
Yugoslavia	26.109,3	1.286.967	49,3
Total	68.043,8	4.033.251	59,2

1958

Canada	738,7	197.020	267
W. Germany	2.500,0	158.675	63,4
Austria	37.423,2	2.743.458	73,3
Switzerland	7.839,6	604.969	78,2
Trieste	5.041,0	372.531	73,9
Yugoslavia	14,699,3	720.405	49,0
Total	68.242,0	4.797.058	70,2

Source: Minerals Year Book U.S. Bureau of Mines 1957 and 1958.

APPENDIX XIII

IMPORTS OF LUMP OR GROUND CAUSTIC-CALCINED MAGNESIA INTO U.S.A. DURING 1955-1958

1955

Country of origin	Quantity Metric tons	Value in $ FOB port of origin	Average price pr. metric ton FOB port of origin
Canada	27,2	2.375	87,3
Austria	79,8	2.815	35,3
France	29,9	1.440	48,2
Netherlands	14,5	866	59,7
United Kingdom	45,3	9.817	216,5
Yugoslavia	1.250,1	51.240	41,1
India	1.773,6	75.179	42,5
Total	3.220,4	143.732	44,6

1956

Canada	29,1	2.459	84,5
Austria	114,3	6.791	59,5
Netherlands	149,7	9.095	60,8
Switzerland	29,9	1.776	59,4
United Kingdom	63,5	14.353	226
Yugoslavia	2.150,0	86.527	40,4
India	4.486,1	228.961	51,1
Total	7.022,6	349.962	49,9

1957

United Kingdom	40,7	9.371	230
Netherlands	484,4	30.205	62,4
Yugoslavia	1.710,1	69.997	40,9
Austria	100,0	4.300	43,0
India	2.776,1	150.955	54,4
Total	5.111,3	264.828	51,8

1958

United Kingdom	22,2	5.596	252
Netherlands	479,5	29.814	62,2
Austria	60,0	2.623	43,7
Yugoslavia	800,0	33.659	42,1
India	811,8	43.103	53,1
Total	2.173,5	114.795	52,8

Source: Minerals Year Book U.S. Bureau of Mines 1957 and 1958.

APPENDIX XIV

IMPORTS OF DEAD BURNED SINTERED MAGNESIA, CAUSTIC CALCINED MAGNESIA, AND CALCIUM CHLORIDE INTO CANADA DURING 1958

	Quantity in Metric Tons	Value in Canadian $	Average Value Per Metric Tons in Canadian $
Magnesia Dead Burned Sintered			
100 U. Kingdom	72.8	5,158	71.0
335 Germany W.	0.3	191	638.0
388 Yugoslavia	7,019.4	369,443	52.7
400 U. States	7,101.6	689,119	96.9
Total	14,194.1	1,063,911	75.2
Magnesia Caustic Calcined			
100 U. Kingdom	24.2	1,511	62.5
215 India	25.4	4,025	158.4
354 Netherlands	11.2	717	64.0
338 Yugoslavia	11.2	567	50.6
400 U. States	1,326.7	111,184	84.0
Total	1,398.7	118,004	84.5
Calcium Chloride			
100 U. Kingdom	0.6	1,093	1825
306 Belgium	78.5	4,931	62.9
335 Germany W.	9.6	985	102.7
400 U. States	34,629.3	1,016,210	29.3
Total	34,718.0	1,023,219	29.5

Source: Foreign Trade of Canada 1958

APPENDIX XV

IMPORTS OF MAGNESITE, ETC. INTO DIFFERENT COUNTRIES IN LONG TONS

Importing Country and Description	1955	1956	1957
Union of South Africa			
Carbonate	9,369	6,939	3,495
Canada			
Calcined and dead-burned	12,444	21,482	10,456
Carbonate and oxide	4,908	5,693	2,190
Australia			
Oxide	66	128	116
Carbonate	175	233	138
Belgium-Luxemburg E. U. -			
Calcined	2,119	2,978	2,297
Oxide	384	402	331
Denmark			
Oxide	95	141	104
Finland			
Oxide	37	40	20
Carbonate	216	128	105
France			
Calcined	16,252	17,799	17,611
Carbonate	162	171	166
Oxide and hydroxide	149	122	113
Germany			
Calcined	168,870	169,612	170,358
Carbonate	83	171	171
Oxide and hydroxide	41	131	195
Hungary			
Dead-burned	38,871	37,462	35,311
Italy			
Caustic	10,457	18,504	13,315
Netherlands			
Calcined	17,100	18,082	15,525
Carbonate	269	391	506
Norway			
Calcined	558	545	fig. not available
Portugal			
Carbonate	96	111	96
Oxide	313	8	509
Sweden			
Crude and calcined	1,459	1,650	1,473
Carbonate	196	140	172
Yugoslavia			
Calcined and ground	-	-	-
Algeria			
Calcined	6	8	-
Belgian Congo			
Oxide	688	658	615
Cuba			
Oxide	129	59	fig. not available
Mexico			
Oxide	511	327	678
United States			
Calcined	3,169	6,911	5,030
Dead-burned	91,689	84,718	67,000
Sub total	380,872	395,744	348,096

APPENDIX XV

IMPORTS OF MAGNESITE, ETC. INTO DIFFERENT COUNTRIES Contd.
IN LONG TONS

Importing Country and Description	1955	1956	1957
United States			
Oxide	101	176	348
Carbonate, precipitated	252	235	274
Argentina			
Carbonate	950	341	436
Brazil			
Carbonate	114	310	430
Oxide	92	68	98
Columbia			
Carbonate	7	11	8
Oxide	75	85	110
Peru			
Carbonate	7	12	31
Oxide	2	5	3
Hydroxide	42	50	53
Japan			
Crude and calcined	52,638	94,876	121,766
Turkey			
Oxide	11	4	12
Total	435,163	491,917	471,685

APPENDIX XVI

EXPORTS OF MAGNESITE, ETC. FROM DIFFERENT COUNTRIES
(Domestic Produce)
IN LONG TONS

Exporting Country and Description	1955	1956	1957
Southern Rhodesia			
Crude and calcined	10,454	7,212	2,255
Tanganyika			
Magnesite	285	243	254
Idia			
Magnesite	24,637	34,546	21,443
Australia			
Crude and calcined	55	110	73
Austria			
Crude	596	368	549
Caustic	75,404	79,221	82,196
Dead-burned	149,650	148,471	150,413
Belgium-Luxemburg E. U.-			
Crude	36	1,079	659
Calcined	43	5	141
Carbonate	17	2	1
France			
Crude and calcined	87	109	259
Carbonate	536	258	493
Oxide and Hydroxide	59	246	240
Germany			
Crude and calcined	639	3,426	4,595
Carbonate	693	449	509
Oxide and Hydroxide	340	370	332
Greece			
Calcined	36,430	36,040	29,517
Italy			
Crude	50	46	28
Caustic	131	41	13
Carbonate	123	43	53
Oxide	232	210	184
Netherlands			
Calcined	16,248	15,263	13,879
Norway			
Crude	10	30	-
Sweden			
Crude and calcined	98	148	224
Yugoslavia			
Crude	2,175	-	46
Ground & dead-burned	40,066	55,154	57,118
Mexico			
Crude & calcined	-	44	-
United States			
Dead-burned	8,278	7,735	24,250
Total	367,372	390,869	389,724

APPENDIX XVII

BROMINE

PRODUCTION OF BROMINE (in M. Tons)

Producing country	1955	1956	1957
France (b)	1,264.60	1,284.14	1,487.80
Italy	501.58	506.96	(a)
Spain	76.68	143.70	217.12
United States (c)	84,620.84	89,236.78	87,078.11
Israel	(a)	(a)	(d)
Japan	1,338.12	1,247.85	(a)
Total	87,801.82	92,419.43	88,783.03

Bromine is also produced in the United Kingdom from sea-water.

(a) Information not available
(b) Sales
(c) Includes bromine content of compounds
(d) Production of bromine and Compounds in 1957 was 650.00 tons Separate figures for production of bromine not available

EXPORTS OF BROMINE ETC., (Domestic Produce)

Exporting country	1955	1956	1957
United Kingdom:-			
Bromine	11.48	(a)	(a)
Bromides	258.37	243.81	241.95
France:-			
Bromine	387.40	80.10	162.10
Bromides	507.40	489.40	498.90
Germany (Federal):-			
Bromine	125.10	103.10	295.00
Bromides	85.30	77.90	51.30
Italy:-			
Bromine	0.23	3.29	1.60
Bromides	17.23	4.09	0.20
Netherlands:-			
Bromides, etc.	116.00	125.00	195.00
United States (c)			
Bromine & compounds	1,655.58	2,772.11	4,767.66
Japan			
Bromine Compounds	7.97	28.62	15.29
Total	3,172.06	3,927.42	6,220.00

(a) Information not available
(c) Includes organic compounds

IMPORTS OF BROMINE, ETC. (Less Re-exports)
(in M. Tons)

Importing country & description	1955	1956	1957
British Countries			
United Kingdom			
Bromine	126.10	25.40	184.62
Union of S-Africa			
Bromine	0.48	9.59	0.85
Canada			
Bromine	14.37	12.00	8.65

APPENDIX XVII

BROMINE (contd.)

IMPORTS OF BROMINE, ETC. (Less Re-Exports)
(in M. Tons)

Importing Country and description	1955	1956	1957
Austria (b)			
Bromine	(£194)	(£186)	(£186)
New Sealand			
Bromine (£N. Z.)	(a)	(a)	(a)
OTHER COUNTRIES			
Belgium-Luxemburg E. U.-			
Bromine	5.20	6.70	15.30
Germany (Federal)			
Bromine	11.00	2.60	149.50
Italy			
Bromine	74.38	100.00	34.90
Netherlands			
Bromine	68.00	103.00	(a)
Norway			
Bromine	0.48	0.27	0.64
Sweden			
Bromine	11.00	2.00	2.00
Algeria			
Bromine	-	-	1.60
Cuba (c)			
Bromine	1.47	0.22	(a)
Mexico (c)			
Bromine	(a)	71.65	146.72
United States			
Bromine & compounds	0.31	1.32	0.69
Argentina			
Bromine & compounds	23.00	39.04	88.37
Brazil (c)			
Bromine	1.54	0.67	1.02
Chile			
Bromine	0.43	(a)	(a)
Colombia			
Bromine	-	0.56	0.52
Peru			
Bromine	0.10	0.12	0.16
Turkey			
Bromine	0.25	0.8	1.82
Total	338.11	366.94	637.36

(a) Information not available
(b) Years ended March 20 following that stated
(c) Total imports

Source: Statistical summary of the Mineral Industry 1952-1957. H. M. Stationery Office, London.

APPENDIX XVIII

TOTAL EXPORTS FROM ICELAND TO SPAIN AND ITALY DURING 1954 - 1958

Year	Total Exp. of all Commodities from Iceland in 1000 kr.	Total Exp. of all Commod. to Spain in 1000 kr.	Exports to Spain Per Cent of Total Exports	Total Exp. of all Commod. to Italy in 1000 kr.	Exports to Italy Per Cent of Total Exports
1954	845,912	22,215	2.6	59,946	7.1
1955	847,849	28,922	3.4	65,267	7.7
1956	1,031,512	31,055	3.0	53,021	5.2
1957	987,602	16,055	1.6	35,834	3,6
1958	1,070,200	22,560	2.1	34,189	3,2

EXPORTS OF FISH AND FISH PRODUCTS TO SPAIN AND ITALY DURING 1954 - 1958

Year	Exports of Fish and Fish prod. from Iceland in 1000 kr.	Exports of Fish to Spain in 1000 kr.	Exports to Spain Per Cent of Total Exports	Exports of Fish prod. to Italy in 1000 kr.	Exports to Italy Per Cent of Total Exports
1954	808,224	22,215	2.7	59,946	7.4
1955	778,439	28,922	3.7	65,267	8.4
1956	926,508	29,687	3.2	53,020	5.7
1957	894,873	13,236	1.5	35,824	4.0
1958	977,300	22,560	2.3	34,189	3.5

EXPORTS OF SALT FISH TO SPAIN AND ITALY DURING 1954 - 1958

Year	Exports of Salt Fish from Iceland in 1000 kr.	Exports of Salt Fish to Spain in 1000 kr.	Exports to Spain Per Cent of Total Exports	Exports of Salt Fish to Italy in 1000 kr.	Exports to Italy Per Cent of Total Exports
1954	225,190	21,723	9.7	32,488	14.4
1955	303,084	28,264	9.3	64,698	21.4
1956	308,417	25,664	8.3	39,464	12.8
1957	260,876	11,502	4.4	28,535	10.9
1958	264,779	11,245	4.2	20,455	7.7

Source: Verzlunarskýrslur 1954 - 1958

APPENDIX XIX

TOTAL IMPORTS INTO ICELAND FROM SPAIN AND ITALY DURING 1954 - 1958

Year	Total Imp. into Iceland in 1000 kr.	Total Imp. from Spain in 1000 kr.	Imports from Spain Per Cent of Total Imports	Total imp. from Italy in 1000 kr.	Imports from Italy Per Cent of Total Imports
1954	1,130,488	48,023	4.3	23,785	2.1
1955	1,266,072	35,803	2.8	20,134	1.6
1956	1,468,541	42,713	2.9	28,034	1.9
1957	1,361,705	29,632	2.2	33,328	2.5
1958	1,405,946	27,968	2.1	20,760	1.5

BALANCE OF TRADE IN COMMODITIES BETWEEN ICELAND AND SPAIN

Year	Imports 1000 kr.	Exports 1000 kr.	Exports - Imports 1000 kr.
1954	48,023	22,215	- 25,808
1955	35,803	28,922	- 6,881
1956	42,713	31,055	- 11,658
1957	29,632	16,055	- 13,577
1958	27,968	22,560	- 5,408

BALANCE OF TRADE IN COMMODITIES BETWEEN ICELAND AND ITALY

Year	Imports 1000 kr.	Exports 1000 kr.	Exports - Imports 1000 kr.
1954	23,785	59,946	+ 36,161
1955	20,134	65,267	+ 45,135
1956	28,034	53,021	+ 24,978
1957	33,328	35,834	+ 2,506
1958	20,760	34,189	+ 13,429

APPENDIX XX

BALANCE OF PAYMENTS OF ICELAND DURING 1955 - 58 SHOWING SHARE OF THE VALUE OF IMPORTS OF SALT IN THE DEFICIT IN THE TOTAL BALANCE OF PAYMENTS

Year	Debit (Import)	Credit (Export)	Deficit	Import of Salt	Salt Imports Per Cent of Deficit
	(million dollars)				
1955	91,7	83,0	8,7	0,85	9.8
1956	102,3	92,5	9,8	1,19	12.1
1957	95,3	85,2	11,1	0,89	8.0
1958	100,0	93,5	6,5	0,66	10.2
1959, preliminary	103,7	94,2	9,5		

Source: (1) Framkvæmdabanki Íslands (Bank of Development of Iceland)

(2) Verzlunarskýrslur 1955 - 1958 (External trade of Iceland)

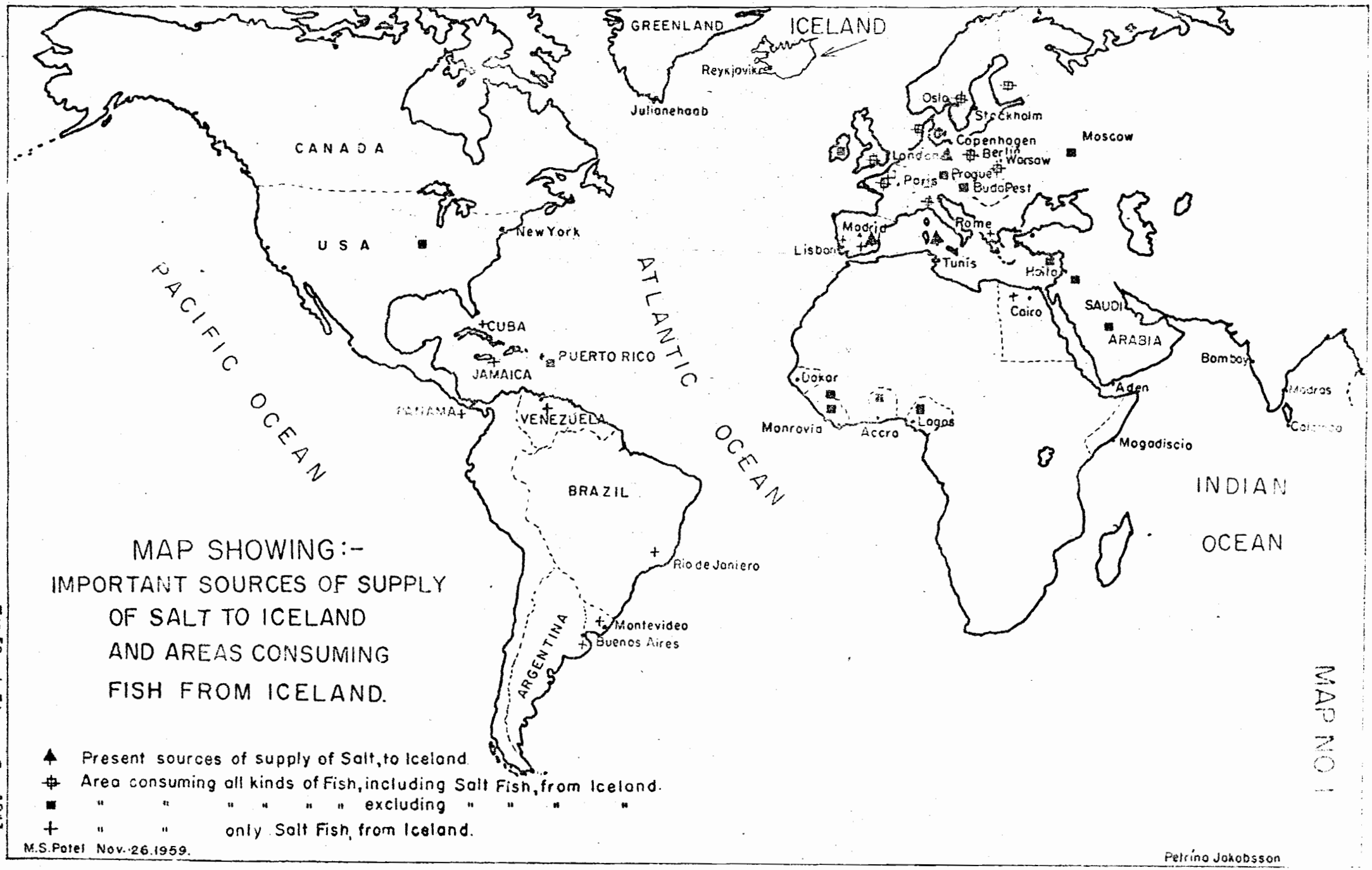
APPENDIX XXI

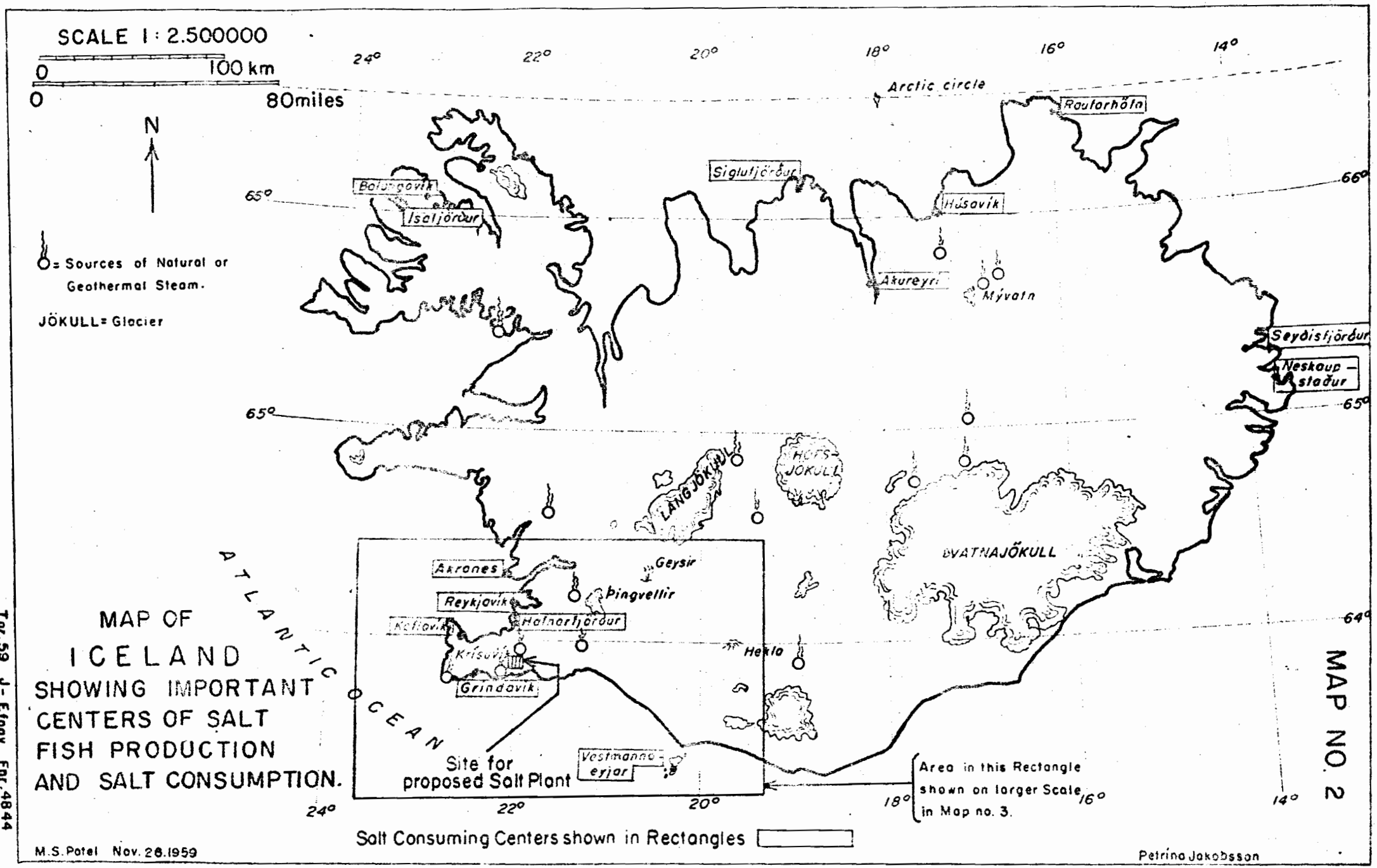
TOTAL EXPORTS AND EXPORTS OF FISH PRODUCTS FROM SOME COUNTRIES OF THE WORLD DURING 1957

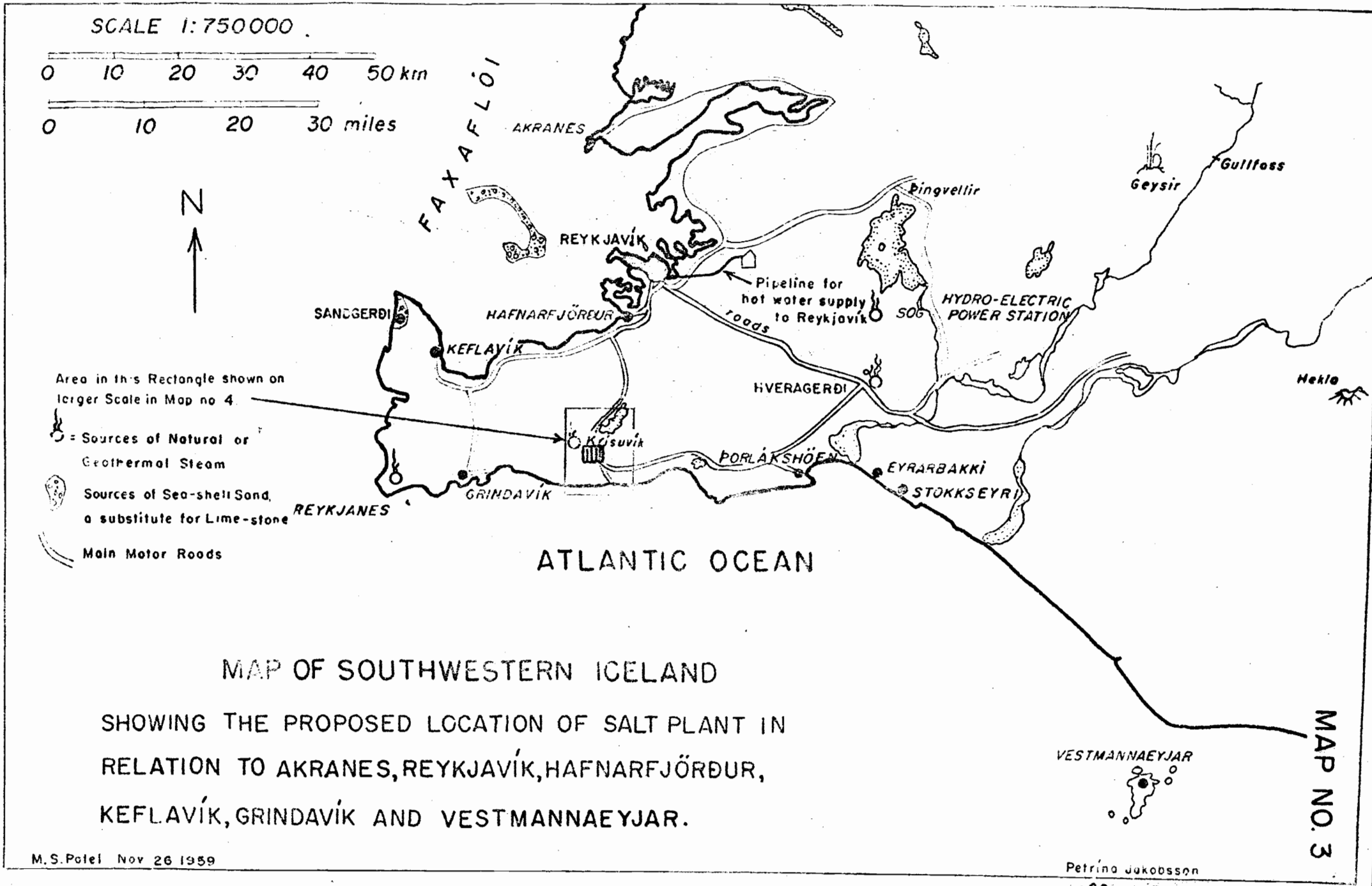
Country	Total Exports Value in 1000 Local Currency	Exports of Fish and Fish Products 1000 of Local Currency	Fish Products Per Cent of Total Exports
U. S. A.	20,630,460	20,550	0.10
U. K.	3,324,412	5,798	0.17
Germany	35,968,043	52,007	0.14
France	1,215,800,000	2,440,000	0.20
Sweden	12,567,000	38,214	0.30
Denmark	7,979,282	237,093	3.0
Norway	5,866,992	760,755	13.0
Iceland	987,602	894,873	90.6

Sources:

1. Bureau of Census Foreign trade report for 1957
2. Annual statement of the trade of United Kingdom 1957
3. Der Aussenhandel der Bundesrepublik Deutschland 1958
4. Annuaire statistique de la France 1958
5. Handel Berättelse för år 1957
6. Denmarks Vareinførsel og Udførsel i året 1957
7. Statistisk Årbok for Norge 1957
8. Verzlunarskýrslur árið 1957




SCALE 1 : 2.500000
0 100 km
0 80miles
N
= Sources of Natural or Geothermal Steam.
JÖKULL = Glacier
MAP OF
ICELAND
SHOWING IMPORTANT
CENTERS OF SALT
FISH PRODUCTION
AND SALT CONSUMPTION.
M.S.Potel Nov. 26.1959
Tnr.59 J-Efnav Far.4844
Arctic circle
Raufarhöfn
Siglufjörður
Ísafjörður
Húsavík
Akureyri
Mývatn
Seyðisfjörður
Neskaup-staður
LANGJÖKULL
HOFS-JÖKULL
VATNAJÖKULL
ATLANTIC OCEAN
Akranes
Geysir
Þingvellir
Reykjavik
Keflavik
Hafnarfjörður
Krísuvík
Hekla
Grindavik
Vestmanna-eyjar
Site for proposed Salt Plant
Area in this Rectangle shown on larger Scale in Map no. 3.
Salt Consuming Centers shown in Rectangles
Petrina Jakobsson
MAP NO. 2
24°
22°
20°
18°
16°
14°
66°
65°
64°



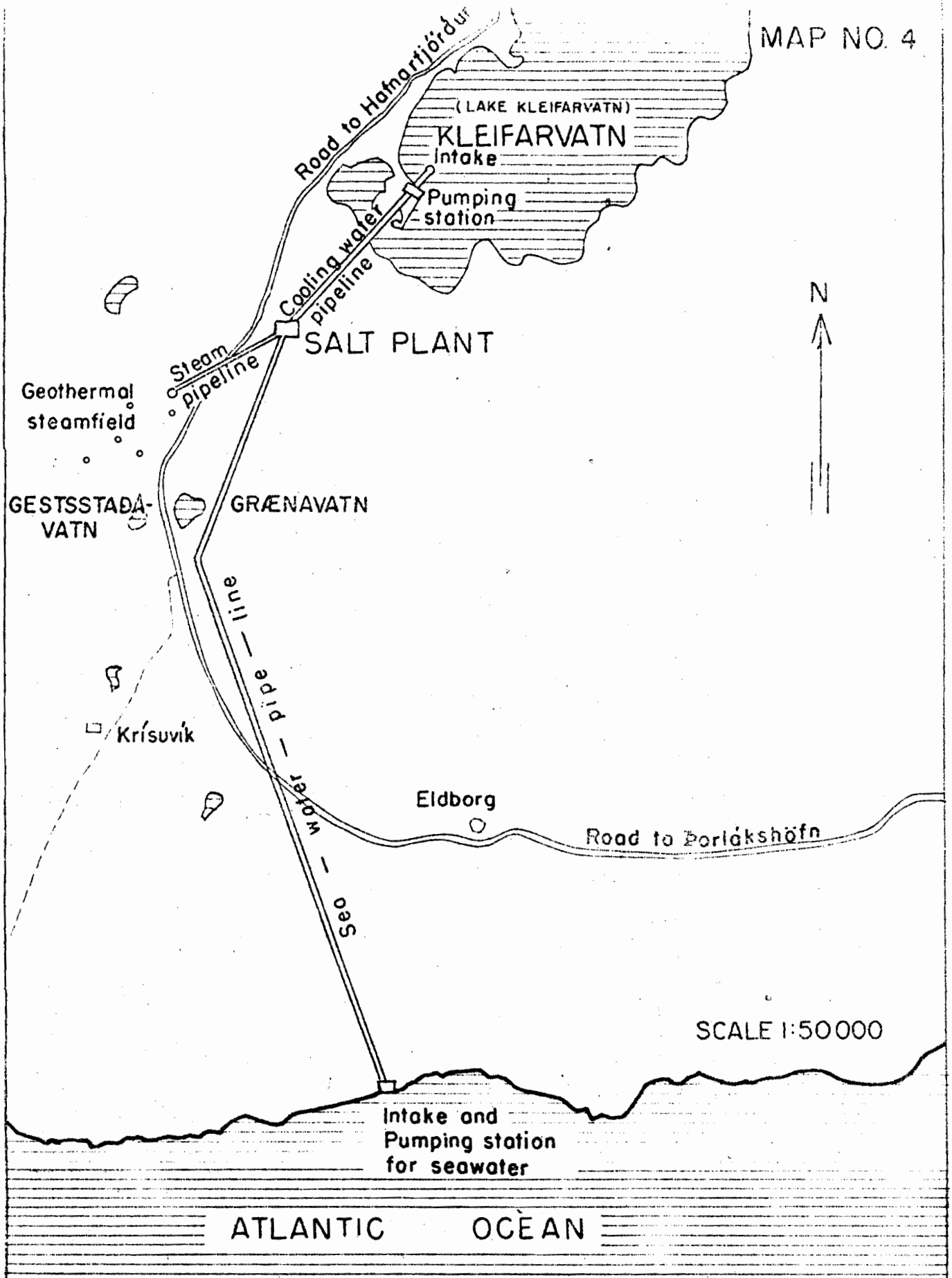
MAP OF SOUTHWESTERN ICELAND

SHOWING THE PROPOSED LOCATION OF SALT PLANT IN RELATION TO AKRANES, REYKJAVÍK, HAFNARFJÖRÐUR, KEFLAVÍK, GRINDAVÍK AND VESTMANNAEYJAR.

MAP NO. 3

M.S. Patel Nov 26 1959

Petrína Jakobsson
60. ú-Efnav Fnr. 4845



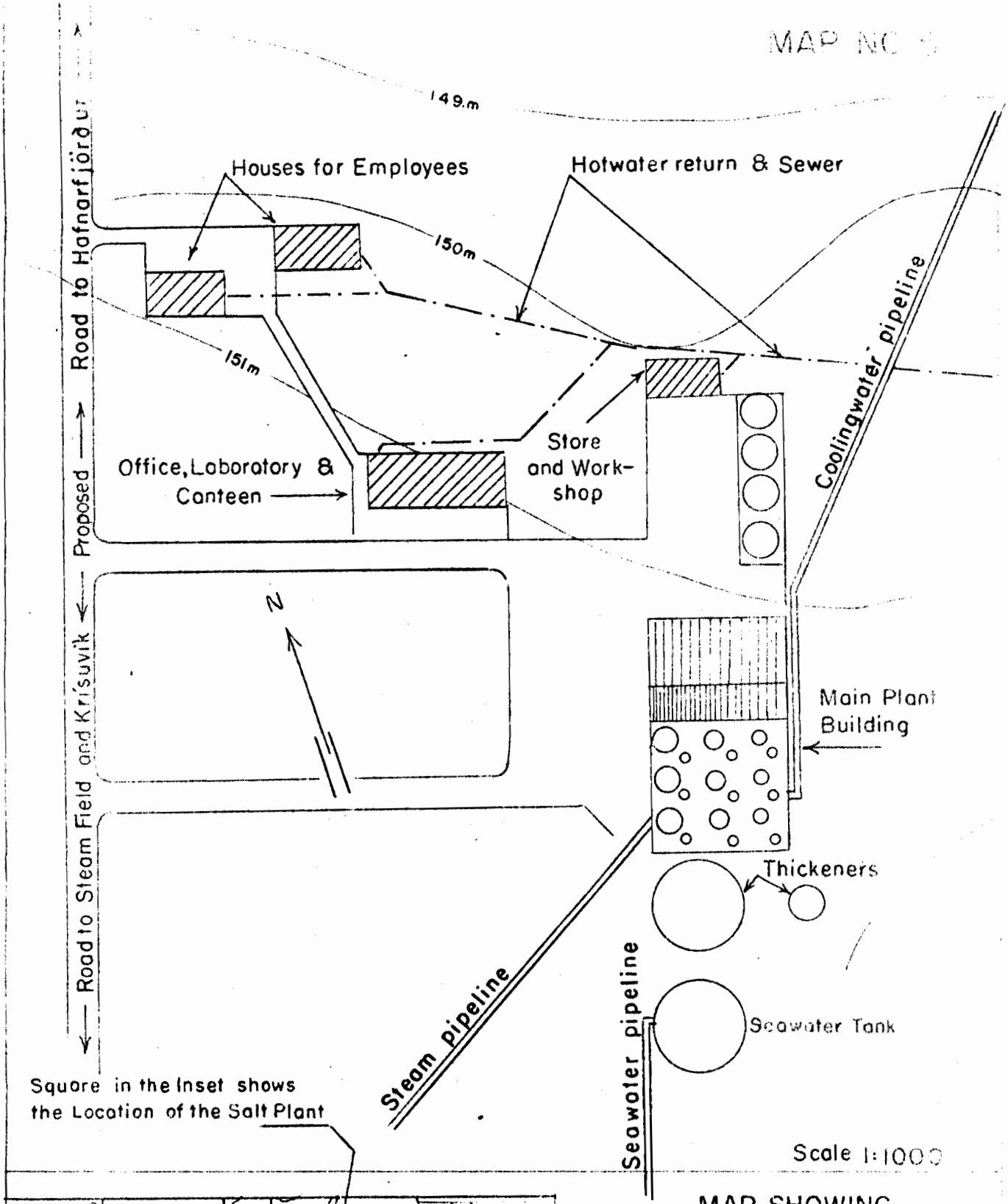
MAP SHOWING THE LOCATION OF THE PROPOSED SALT PLANT AND APPROXIMATE ALIGNMENT OF SEAWATER, COOLING WATER AND STEAM PIPELINES

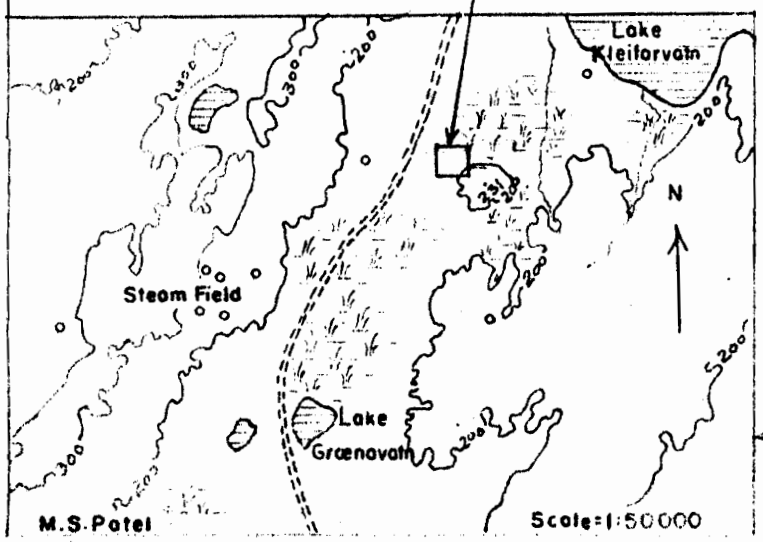
M.S.Patel Nov. 26. 1959

Petrína Jakobsson

Tnr. 61 J-Etnav. Fnr. 4846

MAP NO. 5





MAP SHOWING TENTATIVE LAYOUT PLAN OF THE PROPOSED SALT PLANT FOR ICELAND

As planned by:
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN, REYKJAVÍK

for
THE STATE ELECTRICITY AUTHORITY, REYKJAVÍK ICELAND.

← Inset Map shows location of the Salt Plant in relation to the Steam-field.

Petrína Jakobsson

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