SECOND EDITION **REPORT NUMBER 6**

Natural Sodium Sulphate
In
Saskatchewan

By

R. V. TOMKINS

PROVINCE OF SASKATCHEWAN
DEPARTMENT OF MINERAL RESOURCES

HON. J. H. BROCKELBANK
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INDUSTRIAL MINERALS RESEARCH BRANCH
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(Photograph by Surveys Branch, Department of Natural Resources)

I. SASKATCHEWAN MINERALS' SODIUM SULPHATE PLANT AT CHAPLIN

A part of two 60-million-gallon brine reservoirs may be seen to the right of the dehydration plant. Harvested Glauber's salt is piled between these two reservoirs.

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PREFACE

The material contained in the first edition of "Natural Sodium Sulphate in Saskatchewan" has been revised, and brought up to date. A number of errors have been corrected, and summaries of information on some major deposits have been added from L. H. Cole's original comprehensive report "Sodium Sulphate of Western Canada." The section on markets has been condensed, and parts of the technology section have been shortened or eliminated.

The ackowledgements of the first edition are repeated here, as these persons contributed in many ways to the preparation of the original project: Mr. L. H. Cole, formerly of the Department of Mines and Technical Surveys, the late Mr. Walter H. Hastings of the Department of Mineral Resources, Dr. T. Thorvaldson, former Head of the Chemistry Department at the University of Saskatchewan, and Mr. A. A. Holland, formerly manager of Saskatchewan Minerals plant at Chaplin.

Mr. A. J. Williams, former Director of this branch, provided a great deal of assistance and helpful criticism on the first edition. Mr. C. A. L. Hogg, Deputy Minister of Mineral Resources reviewed both editions.

The Dominion Bureau of Statistics, the United States Bureau of the Census, the United States Bureau of Mines, the United States Pulp Producers' Association, and the Canadian Pulp and Paper Association freely provided the statistical information used.

SODIUM SULPHATE

FORMS AND PRICES

Sodium sulphate is marketed in three forms: salt cake, anhydrous sodium sulphate, and Glauber's salt.

Salt cake is a crude form of anhydrous sodium sulphate, the amount and composition of impurities being dependent on the source of the material. For most purposes, consumers require that salt cake contain at least 97% sodium sulphate. Sodium sulphate produced from natural deposits may contain silica and magnesium. Salt cake made as a co-product of the manufacture of hydrochloric acid should contain less than 1% of free acid or sodium chloride. For glass manufacture, not more than 0.01% of iron oxide is permissible.

TABLE I

UNITED STATES SODIUM SULPHATE PRODUCTION BY FORM, FOR SPECIFIED YEARS

	1942		1947		1952	
Form	Tons	Percent of Total	Tons	Percent of Total	Tons	Percent of Total
Salt Cake	570,869	78.0	693,517	75.6	662,373	70.3
Refined Anhydrous	71,784	9.8	134,969	14.7	202,813	21.5
Glauber's Salt, as 100% Na_2SO_4	87,983	12.2	89,005	9.7	78,289	8.2
Total	730,636	100.0	917,491	100.0	943,475	100.0

Source: Bureau of the Census, United States Department of Commerce.

Anhydrous sodium sulphate is prepared by refining salt cake from any source. In some plants, the salt cake is put into solution and crystallized as Glauber's salt, which is then dehydrated. Sodium sulphate, precipitated from natural brines under carefully controlled conditions, may attain purity sufficient to meet the specifications for anhydrous sodium sulphate. Some of the sodium sulphate produced by evaporation of rayon spin-bath liquors is of refined quality. Standards for anhydrous sodium sulphate require that the product contain at least 99.7% sodium sulphate, with no more than 0.2% sodium chloride or 0.1% moisture, and no magnesium or calcium.

Glauber's salt is the decahydrate of sodium sulphate, $Na_2SO_4.10H_2O$, and contains 55.9% water of crystallization. Neglecting the water, it is prepared to the same specifications as anhydrous sodium sulphate.

Canadian production of sodium sulphate is almost entirely limited to salt cake. Table I shows the amount of each form produced in the United States in 1942, 1947 and 1952.

These products, especially salt cake, are sold chiefly on a contract basis arranged by consumer and producer; hence it is difficult to arrive at a "market" price. Salt cake has sold from \$12 to \$50 f.o.b. domestic plant (U.S.) during the past three decades. During the ten years preceding World War II, the average price was under \$15 per ton. The producers of natural salt cake received a lower price at the plant because of higher transportation costs to consuming points. Prices at Saskatchewan plants have ranged from less than \$7 to over \$20, the higher figure being for spot sales. The contract price in 1953 averaged about \$14. Both Glauber's salt and refined anhydrous sodium sulphate are selling for about \$45 per ton. The present price of Glauber's salt is the highest since 1924, while a low of \$17 was reached in the middle thirties. The range for anhydrous sodium sulphate has been from \$23 to \$60 per ton.*

USES OF SODIUM SULPHATE

Production of Kraft Pulp

The sulphate or kraft pulp industry is the major consumer of sodium sulphate. Kraft pulp is used chiefly in the manufacture of brown wrapping papers, corrugated board packing cases, and other types of pulp products in which high strength is required and the brown colouring is not undesirable. Methods for producing a bleached pulp have been developed, extending the use of sulphate pulp to the manufacture of fine papers and other products.

Sodium sulphate, as such, does not enter into the actual digestion of the wood. Chips are cooked in a digester with a complex solution containing sodium sulphide, sodium hydroxide, sodium carbonate and smaller amounts of other chemicals. After digestion the fibre is washed and drained, and the spent solution is concentrated by evaporation. Salt cake is added to this thick liquor and the mixture is burned in the black liquor recovery furnace, where a mixture of sodium sulphide and sodium carbonate is formed. The soluble salts are leached from the furnace ash, and lime is added to the solution to convert most of the sodium carbonate to sodium hydroxide. The resulting solution, after the precipitated calcium carbonate is filtered off, is the liquor used for digestion. The cycle is repeated with only salt cake, wood, and lime being added to the system. The consumption of salt cake is mainly in the form of dust losses in the recovery furnace gas, and varies considerably depending on the efficiency with which the dust is recovered. Actual chemical consumption during digestion is small. In 1952 Canadian plants consumed an average of 207 pounds of salt cake per ton of pulp produced. Consumption of salt cake is well under 150 pounds per ton in newer plants equipped with electrostatic dust recovery equipment.

Diluent for Synthetic Detergents

Some of the dry detergent cleaning preparations contain up to 75% of sodium sulphate added as diluent. This application is partly responsible for the increase in the output of anhydrous sodium sulphate shown in Table I.

Glass Manufacture

In the production of flat glass, a small amount (about 7%) of salt cake is used to facilitate fusion of the raw materials and inhibit

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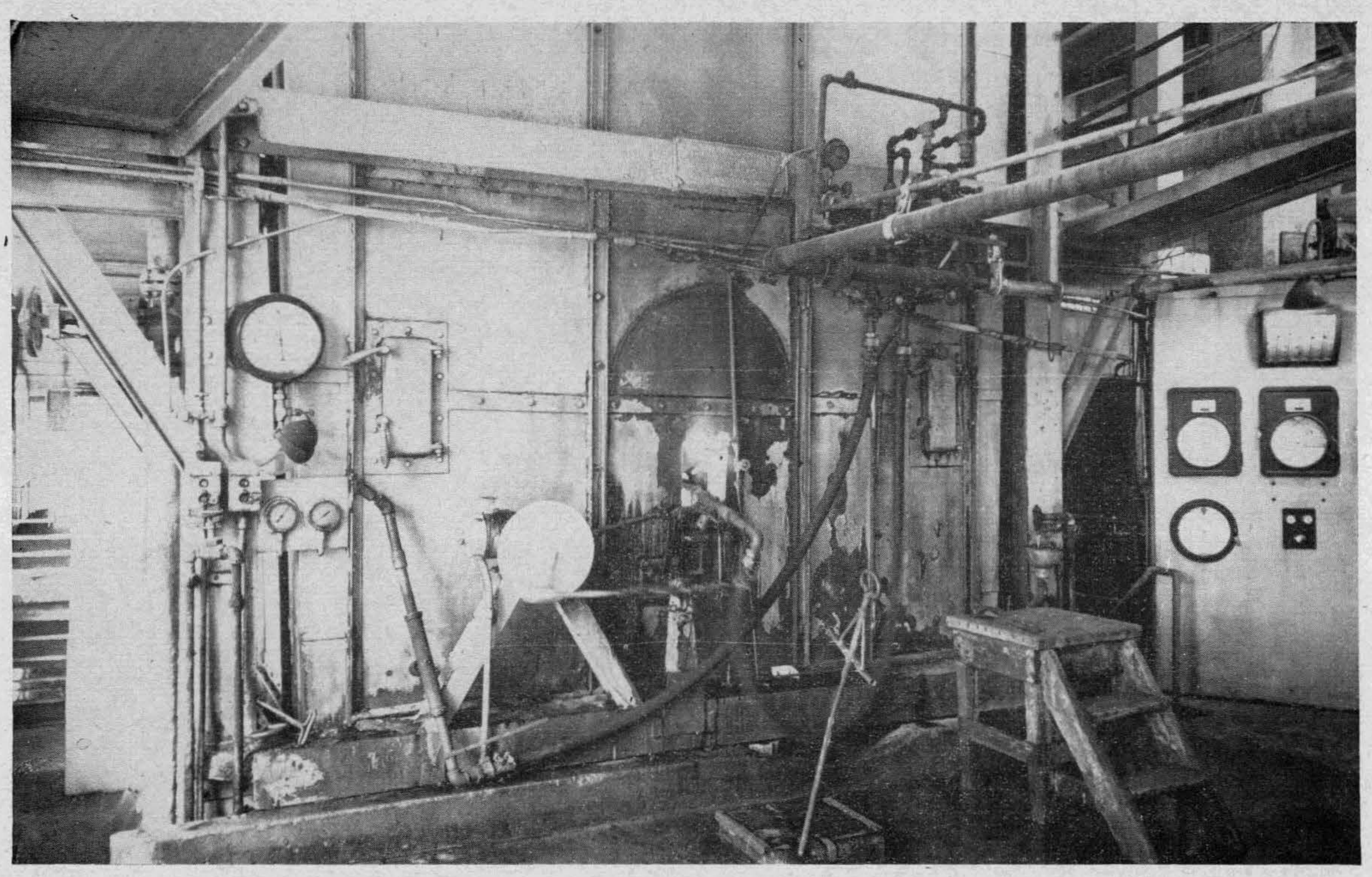
* "Oil, Paint and Drug Reporter", "Chemical and Engineering News" and "Canadian Chemical Processing" were used as sources of price data.



(Photograph Courtesy Pacific Mills Ltd., Ocean Falls, B.C.)

II. BLACK LIQUOR RECOVERY FURNACE

This is a typical furnace in which spent liquor from pulp digesters, with added salt cake, is burned. The concentrated solution is sprayed into the furnace through the nozzle in centre of photograph.

crystallization. Sodium sulphate corrodes furnace refractories and improvements in the technology of glass-making are leading to the use of less salt cake in the batch.

In the manufacture of other types of glass, salt cake and coal may be substituted for the sodium carbonate, but very close control of the proportions of each component is required. The price of salt cake per unit of Na_2O is usually lower than that of soda ash, but the additional skilled labour required and corrosion of refractories may outweigh the advantage of lower raw material cost. At present very little sodium sulphate is used to replace sodium carbonate in glass manufacture.

Production of Heavy Chemicals

A number of heavy chemicals are produced from sodium sulphate, mainly at hydrochloric acid plants. The natural sodium sulphate producers have not as yet diversified their operations by the manufacture of derived chemicals. As freight costs make up such a large portion of the delivered price of salt cake, upgrading the material to more valuable compounds would, in effect, decrease the adverse effect of high transportation charges, when competing in distant markets.

Sodium Carbonate: The LeBlanc process, by which all sodium carbonate was produced prior to the introduction of the Solvay process, consisted of two major steps; the production of sodium sulphate from sodium chloride and sulphuric acid; and the conversion of sodium sulphate to sodium carbonate by fusing with coke and limestone. The Solvay process which uses sodium chloride as raw material has completely superceded this process. However, the Solvay plants require high capital investment, and must be very large to operate profitably. Where natural sodium sulphate is available, the first step of the LeBlanc process would be eliminated. Hydrogen sulphide would be a by-product from which sulphuric acid could be made. Each ton of sodium sulphate with about 0.2 ton of coke and 0.7 ton of limestone would produce 0.75 ton of sodium carbonate and hydrogen sulphide equivalent to 0.65 ton of sulphuric acid.

Another process, which produces the same products by burning a reducing gas in a bath of molten sodium sulphate, was described by A. Zieren (Belgian Patent 453,085, December 1943). Sufficient unburned gas enters the bath to reduce the sulphate to sulphide, while the combustion gas (water and carbon dioxide) decomposes the sulphide into hydrogen sulphide and sodium carbonate.

Sodium Sulphide: The larger part of the sodium sulphide marketed is made by reducing sodium sulphate with coke or coal in a reverberatory furnace. The process is costly, as the molten sulphide strongly attacks furnace brick, requiring frequent replacement. Nyman and O'Brien[1] have reported a method of reducing sodium sulphate with hydrogen in the presence of an iron catalyst, at temperatures below the fusion point of the reactant and product. Development of this process would eliminate many undesirable features of the older carbon reduction procedure.

Sodium Silicate: At present, sodium silicate is made by fusing sand (silica) with sodium carbonate. One of the first reactions used, however, was that between sodium sulphate, coke, and silica. Disadvantages of this

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[1] C. J. Nyman and T. D. O'Brien. "Catalytic Reduction of Sodium Sulphate." Ind. Eng. Chem. *39*, 1019, 1947.

method include the necessity for close control of the proportion of the ingredients, especially the carbon, to avoid formation of undesirable side products. The proportion of coke or coal required is under 5%, and the cost of sodium sulphate is lower per unit of Na_2O than sodium carbonate. Consequently, at a natural sodium sulphate plant, the cost of raw materials might be far enough below those for the sodium carbonate process to overcome purification and high maintenance charges, allowing competition with the sodium carbonate product. Sulphur dioxide is produced during the fusion which could be converted to sulphuric acid. About 1.75 tons of sodium silicate glass would be produced from each ton of sodium sulphate, using 1.4 tons of sand and 160 pounds of carbon. Sulphur dioxide equivalent to 1,200 pounds of sulphuric acid would be produced.

Sodium Thiosulphate: During the reduction of sodium sulphate to produce sodium sulphide, sodium carbonate and sodium sulphite are formed. These are separated from the sulphide and serve as raw material for the manufacture of sodium thiosulphate. The liquor (also containing a small amount of sodium sulphide) is treated with sulphur dioxide, resulting in the formation of sodium thiosulphate. This compound is also manufactured from sulphur and sodium carbonate.

Non-Ferrous Smelting

The International Nickel Company at Sudbury used to make sodium acid sulphate from sodium sulphate and sulphur dioxide for use in the separation of nickel and copper ores. This process, which consumed over 30,000 tons a year, is no longer used.

Minor Uses

Both Glauber's salt and anhydrous sodium sulphate are used in textile dye baths to encourage even distribution of the dye. Anhydrous sodium sulphate is added as a diluent to bring coal-tar dyes to standard strength.

Glauber's salt is used medicinally as a purgative, especially for animals. Small amounts are also used in the preparation of chrome tanning solutions.

Ultramarine blue, a pigment, is manufactured from a batch containing about one-sixth sodium sulphate in addition to kaolin, soda ash, sulphur and coal.

SOURCES OF SODIUM SULPHATE

1. Co-product of Hydrochloric Acid Manufacture

Hydrochloric acid is produced from sodium chloride by three processes, each of which results in the formation of sodium sulphate as a co-product.

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4 \quad (1)$$
$$NaCl + NaHSO_4 = HCl + Na_2SO_4 \quad (2)$$
$$4NaCl + 2SO_2 + O_2 + 2H_2O = 4HCl + 2Na_2SO_4 \quad (3)$$

Reactions (1) and (3) yield about 2.2 tons of salt cake per ton of hydrochloric acid, while reaction (2) yields double this amount. These figures are higher than the theoretical values, as some unreacted acid and salt are retained in the salt cake. Most of the chemical salt cake is made by reaction (1), although reaction (2) is used when nitre cake is available at low cost. The third reaction, the Hargreaves process requires cheap sulphur.

Factors are in operation which tend to reduce production of by-product salt cake. Nitre cake ($NaHSO_4$) used to be a waste product of nitric acid production from Chile saltpeter (sodium nitrate) and sulphuric acid. This nitre cake was utilized in the manufacture of hydrochloric acid, and being a waste product, was available at low cost. The production of synthetic ammonia was introduced, and a process for the oxidation of ammonia to nitric acid was developed which has practically replaced the older method for making nitric acid. Hydrochloric acid producers then turned to reaction (1) and only half as much salt cake was turned out per ton of hydrochloric acid produced.

In the past 15 years, the sodium chloride-sulphuric acid process has been supplanted to a large extent by direct combination of chlorine and hydrogen. In 1939, 67% of the hydrochloric acid produced in the United States was made from salt; in 1952 only 24%.

2. Natural Deposits and Brines

Sodium sulphate occurs naturally as *mirabilite,* a crude Glauber's salt; *thenardite,* a crude form of anhydrous sodium sulphate; and in solution as a brine. The larger portion is found as mirabilite, as climatic conditions in the areas in which it occurs are more favorable to the formation of this mineral. Large amounts occur in Canada, Chile, the United States, and the U.S.S.R., and natural sodium sulphate is produced in all these countries. The major deposits in the United States are found in California, Nevada, North Dakota, Texas, and Wyoming, although sodium sulphate is found in other States. The Great Salt Lake in Utah contains large amounts of mirabilite. Canadian occurrences are largely in Saskatchewan. Natural deposits are the only source of sodium sulphate where this chemical is the primary product.

3. By-Product of the Rayon Industry

In the viscose process for making rayon, a solution of sodium hydroxide and cellulose xanthate is forced through small orifices into a bath of sodium sulphate, sulphuric acid and a number of other compounds. The sodium atoms in the hydroxide and xanthate form sodium sulphate with the sulphuric acid, and a cellulose filament is formed. The spent spin-bath liquor is evaporated, producing a sodium sulphate of high quality.

This source accounted for one-quarter of the sodium sulphate (all forms) produced in 1952 in the United States as shown in Table II.

4. Double Decomposition of Magnesium Sulphate and Sodium Chloride

This method of production is used only in Germany where large quantities of magnesium sulphate accumulate from the refining of potash. The magnesium sulphate and sodium chloride undergo a double decomposition under controlled conditions.

$$2\,NaCl + MgSO_4 = MgCl_2 + Na_2SO_4$$

TABLE II

UNITED STATES PRODUCTION OF SODIUM SULPHATE BY SOURCE

Short Tons

Source	*1951*	*1952*
Viscose Rayon	244,559	231,731
Hydrochloric Acid	318,228	306,804
Sodium chromate and bichromate	117,199	80,685
Other	357,842	323,356
TOTAL	1,037,828	942,576

Source: Bureau of Census, United States Department of Commerce.

5. Processes in which Sulphate and Sodium Radicals are Incidentally Combined

The most important of these reactions is the conversion of sodium chromate to the dichromate:

$$2\ Na_2CrO_4 + H_2SO_4 = Na_2SO_4 + Na_2Cr_2O_7 + H_2O$$

About 0.6 pounds of "chrome cake" are produced per pound of sodium dichromate. Production from this source is entirely dependent on the demand for sodium dichromate, as the value of the sodium sulphate is small relative to the value of the primary product.

Minor amounts of sodium sulphate are produced when various acids such as formic, are made from the sodium salt of the acid and sulphuric acid.

6. Substitutes

Synthetic salt cake is a sintered mixture of soda ash and sulphur. As Solvay plants manufacturing sodium carbonate operate most profitably at high capacity, this is a good use for soda ash when the market for that compound is limited and the price of salt cake makes such an outlet attractive. A mixture of gypsum (calcium sulphate) and soda ash has also been used as a salt cake substitute.

MARKETS

All the salt cake produced in Saskatchewan is shipped to kraft pulp mills and therefore the market is directly controlled by the condition of the kraft industry, and indirectly by the condition of those industries producing salt cake as a by-product. Salt cake is a low-priced commodity and the cost of shipping to distant markets is frequently higher than the value of the salt cake at the plant. Figure 1 shows the distribution of salt cake and kraft pulp production in North America. It is obvious that Saskatchewan is unfavourably located with respect to the major market in the Southeastern United States. Only when salt cake is in short supply, and the demand increases the delivered price, can Saskatchewan producers overcome the obstacle of high freight costs, and profitably reach the South Atlantic and Gulf Coast States. In times of adequate supply of salt cake, the market for Saskatchewan salt cake is limited to Ontario, Minnesota, Michigan, Wisconsin, and possibly Quebec and British Columbia.

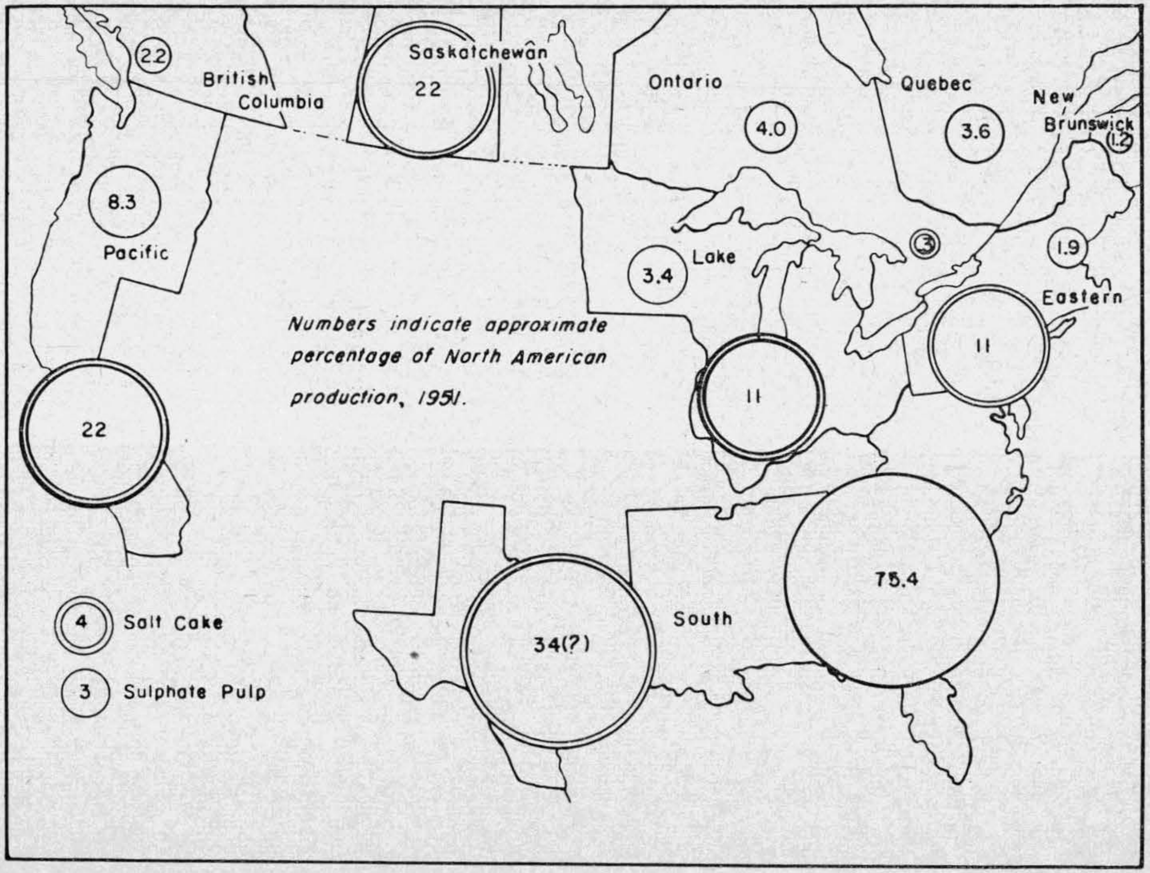

Fig. 1. North American sodium sulphate and sulphate pulp production for 1951, showing regional distribution.

CANADA

The main statistics for Canadian trade in salt cake are given in Table III. Production of Glauber's salt and refined anhydrous sodium sulphate in Canada is small relative to salt cake. Since 1938, natural salt cake producers have supplied Canadian demands, and at times have had a surplus for export. Record production of 192,371 tons was reached in 1951. Existing plants could likely reach the 300,000 ton mark at full capacity. Imports take place on the east and west coasts where United States plants are competitive with Canadian producers.

TABLE III

CANADIAN PRODUCTION, IMPORTS, EXPORTS, AND APPARENT CONSUMPTION OF SALT CAKE

For Specified Years, 1926-1953; Short Tons

	Production					
Year	Natural	By Product	Total	Imports	Exports*	Apparent Consumption
1926	6,775	....	....	41,945	Small	....
1930	31,571	....	....	24,554	Small	....
1933	50,080	....	....	2,595	12,423	....
1936	75,598	....	....	11,747	6,589	....
1937	79,804	3,746	83,550	14,117	7,797	89,870
1938	63,009	2,955	65,964	5,786	8,262	63,488
1939	71,485	2,661	74,146	6,542	9,518	71,170
1940	94,260	4,100	98,360	8,295	16,444	90,211
1941	115,608	5,191	120,799	7,819	32,983	95,635
1942	131,258	4,945	136,203	7,070	50,744	92,529
1943	107,121	4,256	121,377	11,904	14,672	108,609
1944	102,421	3,758	106,179	20,460	16,200	110,439
1945	93,068	2,850	95,918	13,535	17,564	91,889
1946	105,919	2,582	108,501	20,881	22,446	106,936
1947	163,290	3,179	166,469	9,829	46,935	129,363
1948	150,700	3,198	153,898	12,394	29,612	136,680
1949	121,664	3,738	125,402	4,294	21,090	108,606
1950	130,750	3,674	134,424	15,705	31,778	118,351
1951	192,371	3,297	195,668	19,432	63,179	151,921
1952	122,590	2,386	124,976	19,576	27,144	117,408
1953	115,565	2,395	117,960	32,802	20,132	130,630

* Exports of Sodium Sulphate are not recorded separately in the official trade statistics of Canada. As Canadian exports go to the United States, the official import statistics of the United States are given.

Source: Dominion Bureau of Statistics, Trade of Canada, Department of Trade and Commerce, Canada; Foreign Trade and Navigation of the United States, United States Department of Commerce.

Since the International Nickel Company stopped using sodium sulphate for refining nickel ores, the kraft pulp industry uses nearly all the salt cake consumed in Canada (Table IV). The total quantity used for making kraft pulp has tripled since 1940, while the amount used to produce one ton of pulp has been reduced from 300 to 200 pounds (Table V).

TABLE IV

SALT CAKE CONSUMPTION IN CANADA BY INDUSTRIES

1940 - 1953; Short Tons

Year	Kraft Pulp	Non-Ferrous Smelters	Glass	Total Accounted For*
1940	53,540	27,562	143	81,245
1941	61,679	28,294	556	90,529
1942	70,078	21,541	641	92,260
1943	67,292	33,885	892	102,069
1944	70,954	37,097	770	108,821
1945	67,654	30,000	621	98,275
1946	81,161	13,500	2,660	97,321
1947	95,975	24,000	8,383	128,358
1948	107,592	20,000	1,234	128,826
1949	105,112	8,700	995	114,807
1950	114,494	nil	1,279	115,773
1951	141,640	nil	1,587	143,227
1952	113,322	nil	1,976	115,298
1953	125,332	nil	2,662	127,994

* Other consumption is small.
Source: Dominion Bureau of Statistics.

TABLE V

PRODUCTION OF SULPHATE PULP AND CONSUMPTION OF SALT CAKE IN THE PULP INDUSTRY IN CANADA

For Specified Years 1937-1953

Year	Sulphate Pulp Production (tons)	Salt Cake Used in Pulp Production (tons)	Salt Cake Used (pounds per ton pulp)
1937	312,741	50,584	324
1938	225,032	33,213	295
1939	292,066	40,685	279
1940	371,569	53,540	288
1941	426,743	61,679	289
1942	449,254	70,078	312
1943	441,421	67,292	305
1944	467,726	70,954	304
1945	478,740	67,654	282
1946	562,233	81,161	289
1947	689,435	95,975	283
1948	815,076	107,592	264
1949	855,784	105,112	246
1950	1,053,588	114,494	217
1951	1,216,907	141,640	233
1952	1,092,038	113,322	207
1953	1,221,348	125,332	205

Source: Dominion Bureau of Statistics.

TABLE VI

UNITED STATES PRODUCTION, IMPORTS, EXPORTS AND APPARENT CONSUMPTION OF SALT CAKE

For Specified Years 1925 - 1953; Short Tons

Year	Production (1)	Imports	Exports (2)	Apparent Consumption
1929	214,152	91,634	21,308	284,478
1933	189,687	99,269	799	288,157
1936	248,868	151,421	4,601	395,688
1941	531,488	75,571	923	606,136
1943	564,941	32,790	7,096	590,635
1945	543,371	20,293	5,568	558,096
1946	527,746	22,510	8,718	541,538
1947	693,517	49,157	7,584	735,090
1948	668,246	29,612	12,394	685,464
1949	537,843	21,090	4,294	554,639
1950	561,395	61,612	11,401	611,606
1951	707,388	77,559	11,531	773,416
1952	662,373	50,822	17,336	695,859
1953	737,146	53,468	21,476	769,138

(1) Production figures to 1936 from U.S. Tariff Commission Report. Bureau of the Census figures prior to 1941 include only production for sale.

(2) Export data for sodium sulphate are not recorded separately. Canadian imports given, as Canada is principal importer.

Source: U.S. Bureau of the Census, Foreign Trade and Navigation of the United States, Trade of Canada.

UNITED STATES

Salt cake production in the United States has tripled since 1936, the increase being mainly the result of more natural sodium sulphate production, and more by-product salt cake from the expanding rayon industry. In addition to supplying the increased demands of the growing kraft pulp industry, United States salt cake producers have also made up over 150,000 tons annually which was formerly imported from Germany. There are indications that the United States may become more dependent on imports to supply any further demand. The level of imports has remained higher in the past four years than in the period preceding. Table VI shows the production and trade statistics for salt cake in the United States. The figures shown for production are lower than the consumption in the kraft industry alone. There is undoubtedly some anhydrous sodium sulphate used in kraft pulp, making up the deficit. From Table VII it can be seen that the production of refined anhydrous sodium sulphate has increased steadily until 1951. Natural sodium sulphate production is shown in Table VIII.

TABLE VII

UNITED STATES PRODUCTION OF GLAUBER'S SALT AND ANHYDROUS SODIUM SULPHATE

1941 - 1953; Short Tons

Year	Glauber's Salt	Anhydrous Sodium Sulphate
1941	164,067	56,922
1942	199,962	71,784
1943	212,067	76,608
1944	231,200	69,997
1945	200,782	91,340
1946	167,153	122,573
1947	202,285	134,969
1948	184,744	169,018
1949	156,634	136,276
1950	185,626	184,254
1951	219,942	233,666
1952	177,929	202,813
1953	204,159	219,751

Source: Bureau of the Census, United States Department of Commerce.

FACTORS AFFECTING SUPPLY AND DEMAND

Natural deposits are the only source of sodium sulphate where it is the primary product. Hence, the conditions in those industries where sodium sulphate is a by-product strongly affect the natural sodium sulphate producer. By-product salt cake appears to be supplying a smaller part of the market, leaving a bigger fraction for the natural producers.

TABLE VIII

NATURAL SODIUM SULPHATE SOLD OR USED BY PRODUCERS IN THE UNITED STATES

1941 - 1953

Year	*Short Tons*
1941	154,327
1942	169,870
1943	160,622
1944	168,923
1945	178,196
1946	198,781
1947	257,294
1948	265,862
1949	186,223
1950	186,537
1951	n.a.
1952	234,175
1953	252,555

Includes Glauber's Salt converted to Na_2SO_4.

Source: Bureau of Mines, United States Department of the Interior.

Production of hydrochloric acid by direct combination of hydrogen and chlorine is replacing the older salt cake process. It is unlikely that any more plants will be built to produce hydrochloric acid from sulphuric acid and salt, and the existing plants should gradually be replaced by chlorine-hydrogen plants.

Rayon is meeting stiff competition from new synthetic fibres such as orlon, dynel and nylon. The present (1954) salt cake shortage has likely been caused by a cut-back in rayon production, with reduction of the amount of by-product salt cake available.

These are the two major sources of salt cake other than natural sodium sulphate deposits. Therefore, the future for the natural salt cake producers looks quite bright.

On the darker side, it will be seen from Table V that the kraft mills are rapidly reducing the amount of salt cake required to produce a ton of sulphate pulp. In the past ten years the average consumption of salt cake per ton of pulp has dropped from 300 to 200 pounds, and new mills are reported to be using only about 100 pounds. During this period, however, kraft pulp capacity has tripled, so overall demand for salt cake has been steadily increasing.

If the supply of by-product salt cake decreases, and more natural salt cake is needed to supply the demand, Saskatchewan producers will be in a more favorable competitive position for the southern market. The major United States producers of natural sodium sulphate are located in California and West Texas, and also have a long freight haul to contend with to the southeastern states. There are deposits in North Dakota which could be developed to meet any permanent increase in demand. Also, during the nineteen-thirties a large part of United States requirements were supplied from Germany. Many of the mills are on tidewater, which facilitates such trade. Should these shipments resume, the inland suppliers would be adversely affected.

TECHNOLOGY OF NATURAL SODIUM SULPHATE PRODUCTION

The production of a marketable salt cake from natural sodium sulphate deposits may be broken down into three operations:

1. Harvesting crude Glauber's salt
2. Removal of impurities
3. Dehydration

Dehydration is the most expensive of the operations listed, and the cost of removing the water of crystallization usually accounts for more than half of total production cost in a simple rotary kiln plant. Removal of impurities is a minor item as practised at present, and where crude salt harvested from brine ponds is used, is often not necessary. Harvesting costs vary considerably with different procedures and raw material, but should not exceed two dollars per ton of product at the present time (1954). Overall cost of production has risen from under six dollars per ton in the mid-thirties, to over ten dollars per ton in recent years.

HARVESTING

Sodium sulphate in the form of crude Glauber's salt may be obtained from brines, intermittent crystal, or the permanent bed of the sodium sulphate lakes*, the choice being governed by ease of harvesting, climatic conditions, and quality of the deposit.

Only one of the operating plants still recovers crystal from the permanent bed of the lake. However, the permanent bed of this lake is of relatively high purity, and it is doubtful that many of the deposits could be operated in this manner. The consumers demand a consistent product of high purity, and it is difficult to guarantee that the crystal obtained in this manner will be uniform.

Intermittent crystal has been harvested during the winter at deposits where little mud intervenes between the permanent and intermittent beds. This method requires harvesting a large area to obtain sufficient salt for a year's operation. Also, it is very dependent on the climatic conditions, as the amount of brine, and hence the amount of intermittent crystal formed, will be small in dry years. If the brine contains much magnesium sulphate, then the completely crystallized salt and the dehydrated product will likely contain too much of this compound to allow marketing. This difficulty was encountered during early operations at Whiteshore Lake. Various types of scrapers and earth-moving machinery have been used for harvesting intermittent crystal.

The more recently developed method of obtaining Glauber's salt directly from the brine has replaced mining of permanent bed salt to a large extent. Brine, near saturation, is pumped into earth-wall reservoirs, during the summer. As the temperature drops in fall, Glauber's salt crystallizes because of the reduced solubility (see Figure 2). At the eutectic temperature, near 30°F, the remaining liquor containing about 4% sodium sulphate and most of the soluble impurities is drained back to the lake. The resulting bed of Glauber's salt is then harvested using various combinations of bulldozers, scrapers, draglines, loaders and trucks.

This procedure gives a consistently high quality raw material, but can be used only at deposits where water supply can be relied upon. As with intermittent crystal, a dry year would seriously hinder operations, and consequently a reserve of raw salt should be accumulated for such contingencies. Excessively cold, wet summers, which prevent the brine from reaching a satisfactory salt content will also seriously reduce the harvest.

Plants located on lakes of relatively small area should not be entirely dependent on brine for raw salt, but should be equipped to mine and purify permanent bed salt if necessary.

REMOVAL OF IMPURITIES

Undesirable impurities which occur in crude Glauber's salt are chiefly insolubles (sand and clay) and magnesium sulphate. Permanent bed material contains 8 to 15% of these impurities, while salt from brine reservoirs usually does not contain over 2%. Therefore, little purification of reservoir material is required. Stockpiles of Glauber's salt are usually exposed to rain and snow, and part of the readily soluble magnesium

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* See pages 48-49 for a description of these forms.

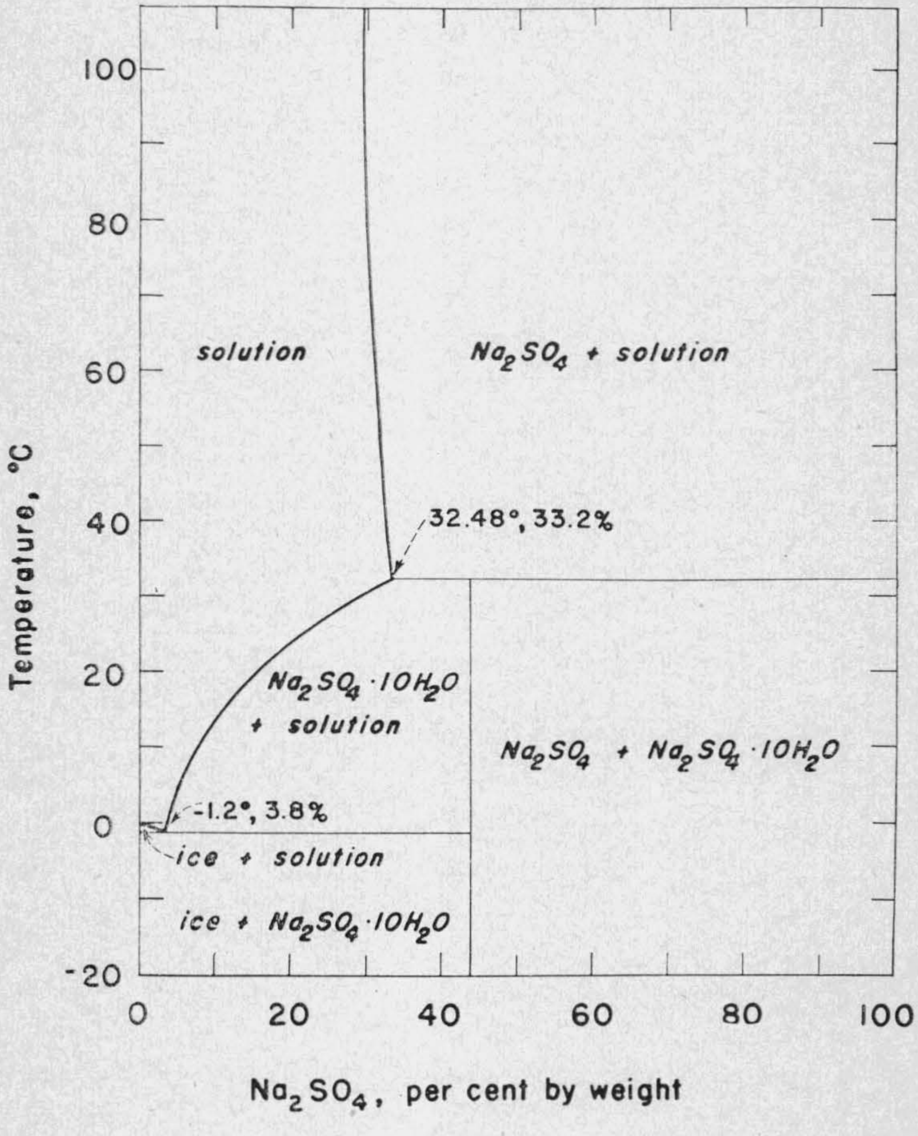

Fig. 2. Temperature—composition diagram for the sodium sulphate-water system.
(Drawn from data taken from International Critical Tables, Volume IV)

sulphate is leached out by this water. Removal of part of the insoluble impurities in permanent bed salt is accomplished by passing it through a "log washer" or spiral classifier supplied with either fresh water or brine.

DEHYDRATION
PHYSICAL AND CHEMICAL PRINCIPLES

The System Sodium Sulphate—Water

The temperature-composition diagram for the sodium sulphate and water binary system from -20°C to 100°C is shown in Figure 2. The slope of the solubility curve for anhydrous sodium sulphate becomes positive above 100°C.

Glauber's salt, the decahydrate of sodium sulphate, does not exist in a stable condition above 32.4°C. According to the phase rule, a system of two components at constant pressure is invariant when four phases co-exist. There are two such points in this system. At 32.4°C, vapor, solution (33.5%) decahydrate, and anhydrous salt are present, while at -1.2°C, vapor, solution (3.8%), decahydrate, and ice exist in equilibrium.

To illustrate the use of the diagram consider the events on cooling a number of solutions and mixtures of solution and anhydrous salt from 40°C.

Case 1: Total composition 0. to 3.8% sodium sulphate (solution only). After reaching a temperature along the solubility curve, ice will separate as the temperature decreases until the solution composition reaches 3.8%. Then a mixture of decahydrate and ice will separate, at a constant temperature of −1.2°C until crystallization is complete.

Case 2: Total composition 3.8 to 33.5% sodium sulphate (solution only). After reaching a temperature along the Glauber's salt solubility curve, decahydrate will separate as the temperature decreases until the solution composition reaches 3.8%. A mixture of decahydrate and ice will then separate at a constant temperature of -1.2°C until crystallization is complete. This is what occurs in the brine reservoirs, but the dilute brine is drained to the lake before ice can form.

Case 3: Total composition 33.5 to 44.1% sodium sulphate (solution and anhydrous salt). On reaching 32.4°C, decahydrate begins to separate. As four phases are present, the temperature must remain constant until one disappears. The crystallization of the decahydrate (55.9% water) leaves the solution (which was 66.5% water) under-saturated. Therefore, anhydrous sodium sulphate goes into solution, more decahydrate precipitates and so on, until all the anhydrous salt has disappeared. The behavior of the remaining solution then is the same as in Case 2, with a mixture of ice and decahydrate being the final phases.

Case 4: Total composition 44.1 to 100% sodium sulphate (solution and anhydrous salt). On reaching 32.4°C, decahydrate begins to separate. As in Case 3, four phases are present, so the temperature must remain constant until one phase disappears. Also as in Case 3, the precipitation of decahydrate leaves the solution undersaturated and anhydrous salt goes into solution. In this instance, however, all the water is consumed in the formation of decahydrate before all the anhydrous salt is dissolved, so the phase disappearing is solution. Therefore, a crystallized mixture of decahydrate and anhydrous sodium sulphate forms at 32.4°C, the temperature remaining constant until solidification is complete.

If pure Glauber's salt is heated, at 32.4°C, a mixture of saturated solution and anhydrous salt results. Conversely, if a solution and anhydrous salt mixture of exactly 44.1% sodium sulphate total composition is cooled, pure Glauber's salt will be the solid product.

Three-Components Systems Containing Sodium Sulphate and Water

Sodium Chloride as Third Component

The addition of sodium chloride to the sodium sulphate-water system changes the transition temperature to 17.9°C. The solid phases decahydrate, anhydrous sodium sulphate and sodium chloride are in equilibrium with a solution containing 22.43% sodium chloride and 7.64% sodium sulphate at this temperature. To present the system completely requires a three dimensional representation which is quite difficult to interpret. However, Table IX shows the compositions at various temperatures, beyond which addition of NaCl will cause no further precipitation of anhydrous sodium sulphate.

TABLE IX

COMPOSITION OF SOLUTIONS IN EQUILIBRIUM WITH SODIUM CHLORIDE AND SODIUM SULPHATE

	Percent by weight in solution	
Temperature, °C	NaCl	Na_2SO_4
35	23.46	6.14
40	23.60	6.10
50	23.89	5.20
60	24.60	4.69
80	25.30	4.48
100	25.57	4.41

Source: Volume IV, International Critical Tables.

To illustrate the practical implication of these data, consider the effect of adding sodium chloride to a saturated solution of sodium sulphate at 40°C, containing 32.5% sodium sulphate. Calculations show that by adding 22.7 grams of sodium chloride per hundred grams of solution, 26.7 grams or 82% of the total sodium sulphate will be precipitated in the anhydrous form.

Ethanol as Third Component

A three component system requires five phases to become invariant. As ethanol and water are miscible in all proportions in the presence of sodium sulphate, three solid phases are necessary, which do not occur at ordinary temperatures. Hence the system does not become invariant except at low temperatures. As shown in Figure 3, the addition of ethanol to the sodium sulphate-water system greatly decreases solubility of sodium sulphate. Considering a saturated solution of sodium sulphate containing 32.1% sodium sulphate at 36°C, the addition of 64.5 grams of ethanol per hundred grams of solution will precipitate 31 grams of anhydrous sodium sulphate or 96.5% of that originally in solution.

Other volatile solvents such as acetone, and numerous salts have a depressing effect on the solubility of sodium sulphate. Acetone, however, forms two liquid phases with the bulk of the sodium sulphate in solution

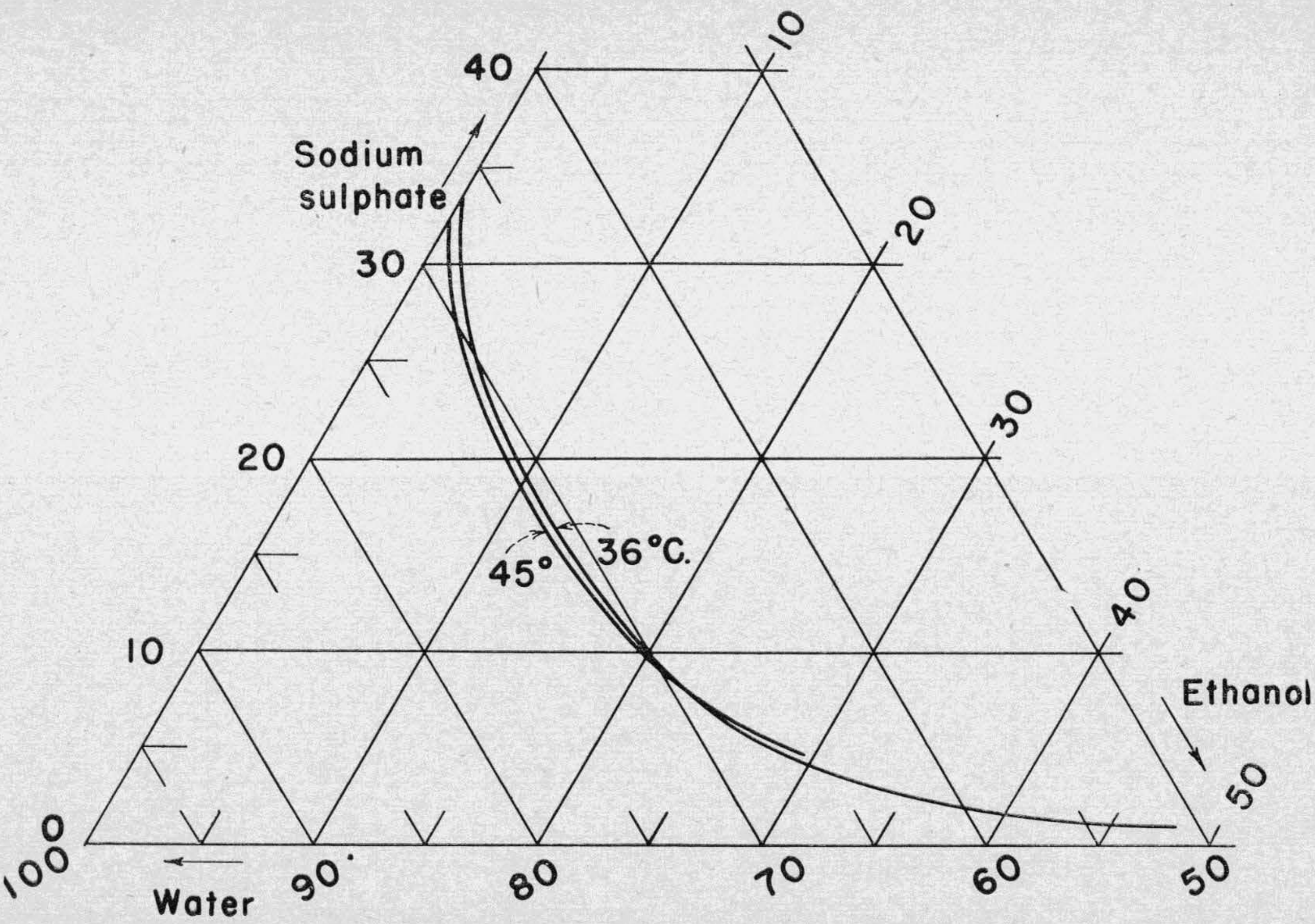

Fig. 3. Ethanol—sodium sulphate-water system at 36°C. and 45°C.

(Drawn from data from International Critical Tables, Volume IV) in the water-rich layer. Few volatile solvents are available at the price of acetone and ethanol, and it is doubtful whether even these relatively inexpensive compounds could be used economically to precipitate anhydrous sodium sulphate. Similarly few salts are as cheap as sodium chloride. Therefore, only sodium chloride and ethanol have been considered here.

Thermodynamics of Dehydration

The thermodynamic properties of sodium sulphate and its solutions have been investigated by Kobe[2]. His values have been used in the calculations to obtain figures quoted in the following section.

There are a number of possible ways in which sodium sulphate can be separated from the water of crystallization with which it is combined in Glauber's salt.

I. The water can be evaporated directly from the salt by circulating dry air over it. The vapor pressure of water in this air must be less than that of Glauber's salt at the prevailing temperature. When both the products and the Glauber's salt are at 65°F, 1,585 B.t.u. per pound of anhydrous salt are required for the evaporation.

II. The water is evaporated by the application of heat to the Glauber's salt. Heat is required to raise the salt to the boiling point of water, to supply the latent heat of fusion of the salt, and the latent heat of evaporation of the water. Theoretical values for this process per pound of anhydrous sodium sulphate are:

Sensible heat 65° to 212°F	207	B.t.u.
Heat of Fusion of Glauber's salt at 90°F	237	
Heat of Vaporization of water at 212°F	1,230	
Total	1,674	B.t.u.

In practice in a rotary kiln, where hot gases are used to convey the heat to the salt, the final temperature of the water vapor is well above 212°F and the salt product is very hot. Figure 4 shows the theoretical requirement for various terminal temperatures of the two components.

III. The water can be removed without evaporation by adding precipitants to reduce the solubility of sodium sulphate, or by merely melting the Glauber's salt and removing the portion of anhydrous salt which is precipitated at the transition temperature. When precipitants (sodium chloride, ethanol) are used, it is necessary only to raise the temperature of the salt above the transition temperature so that the product will be anhydrous sodium sulphate. To raise the salt to 90°F and melt it theoretically requires only 258 B.t.u. per pound of anhydrous salt.

If the "transition point deposition" process is used, and the salt is heated to 90°F and melted, the theoretical heat requirement per pound of anhydrous salt deposited is 650 B.t.u.

It is obvious that great savings in heat will be achieved if evaporation of the water can be avoided.

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[2] K. A. Kobe and C. H. Anderson, "The Heat Capacity of Saturated Sodium Sulfate Solutions." J. Phys. Chem. *40,* 429-33 (1936).

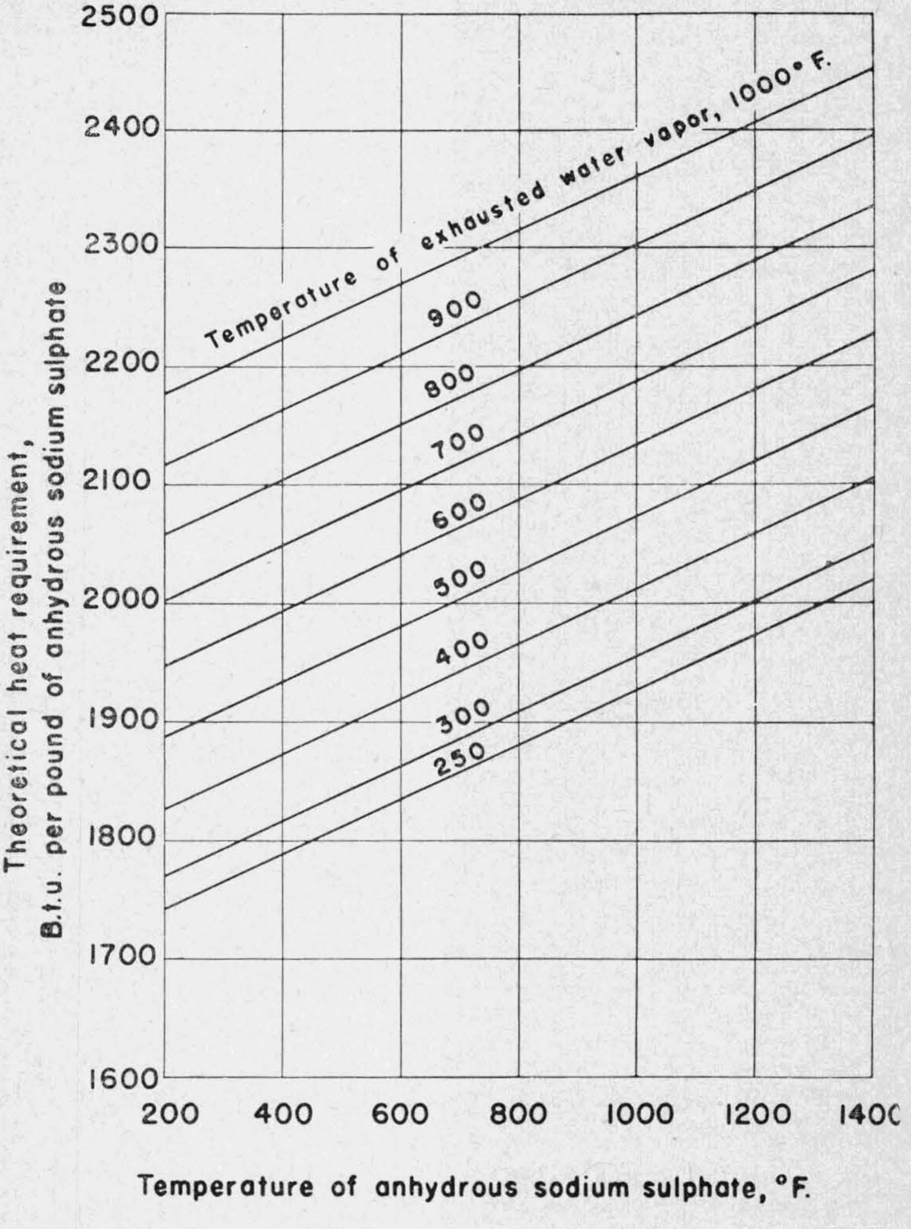


Fig. 4. Heat requirements for convection dehydration processes.

COMMERCIAL PROCESSES

The following methods of dehydrating Glauber's salt have been considered, and include all common drying processes. The type of equipment suitable for each process is, of course, subject to variation with different manufacturers and designers. Only two processes—simple rotary kilns and Holland evaporators—are in use in Saskatchewan.

1. Evaporative Processes:

   Convection

   1. Simple Rotary Kilns.
   2. Holland Evaporators.
   3. Flash Driers.
   4. Spray Driers.
   5. Submerged Combustion.
   6. Tray Driers.

   Conduction

   7. Multiple Effect Evaporators.
   8. Drum Driers.

2. Non-Evaporative Processes:

   9. Anhydrous sodium sulphate precipitation above transition temperature.
   10. Precipitation of anhydrous sodium sulphate with a solid precipitant.
   11. Precipitation of anhydrous sodium sulphate with a volatile precipitant.

General Considerations

Steam Economy

In designing a chemical plant, very efficient use of the heat units released from the fuel can be attained if high pressure steam is used to drive a turbo-generator set, and the exhaust steam is then used to supply process heat. Of the processes listed above, this is applicable only to the non-convection methods, processes 7 to 11. In addition to supplying heat at low cost, cheap power is made available for running plant equipment and harvesting machinery, with the attendant ease of operation and low cost of maintenance of electric equipment.

Water Supply

Supplies of suitable water for plant operation are not easily obtained. Most of the water obtained from wells in the province contains large amounts of dissolved salts. Modern ion-exchange units offer an economical method of purifying these water supplies as long as the quantity is not excessive. As water is required mainly for condensers and boiler feed, it is not a difficult matter to design a plant so that the water is re-used and only a small percentage loss must be made up.

Fuel

Two plants use lignite coal, two use bunker oil, and one uses crude oil. Lignite coal is available at very low prices in the southeast part of Saskatchewan. Heavy bunker oil is produced at refineries at a number of points including Regina, Moose Jaw, Saskatoon, Lloydminster. Crude oil is also available in the southwest and west central portions of the province. Natural gas is also available in the west central area, and many new discoveries are being made each year. The Trans-Canada Pipeline will bring gas close to several sodium sulphate deposits.

Electric Power

The older plants generated electric power with diesel engines. As the network of the Saskatchewan Power Corporation expands, it is usually more economical to take power from the transmission lines.

Labor

The isolated location of most sodium sulphate deposits, and the shortage of recreational, medical and other facilities has presented problems in procuring labor. The operating plants are providing housing for their employees and assisting in recreational developments. Part of the labor force is permanent, while a portion is drawn from the farms of the district. The cost of labor in Saskatchewan is generally lower than in the more industrialized provinces.

Capital Charges and Scale

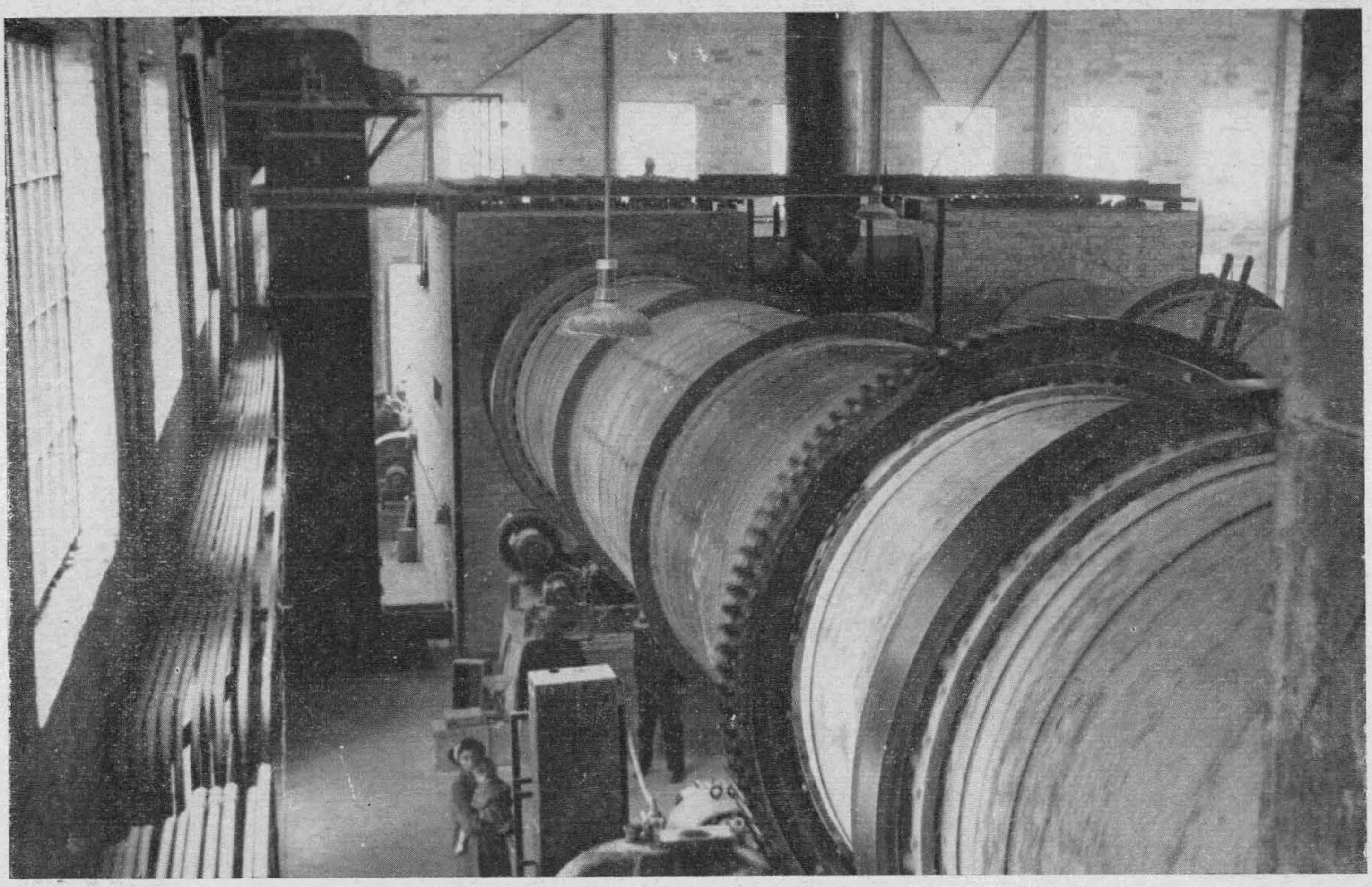
Of the processes listed, multiple-effect evaporation and the volatile precipitant process would likely be the most expensive in original cost. These procedures are amenable to automatic control with attendant saving in labor, and consistently reliable product. A simple rotary kiln installation is probably the cheapest, but suffers from low thermal efficiency. Capital charges should not exceed 20 percent of the total production costs. Increase in size of plant does not, therefore, result in any large saving in capital charges. Harvesting costs also increase roughly in proportion to production. However, labor may be conserved considerably as the scale of operation is increased as larger equipment does not necessarily require additional operating staff.

Evaporative and Non-Evaporative Processes

Evaporative processes have an inherent disadvantage in that they require heat sufficient to vaporize the water of crystallization in addition to that required for non-evaporative methods. Also, except for drum drying and the use of multiple-effect evaporators, the processes require high-temperature heat, with subsequent radiation losses, and losses in the convection medium. Their chief advantage is low first cost and relatively simple operation, requiring a minimum of technical skill or supervision.

Multiple-effect evaporation has the advantage of high thermal efficiency, the heat requirements for a triple-effect being of the same order as for non-evaporative processes.

The non-evaporative processes have much lower theoretical heat requirements. However, where precipitants are used, the cost of these compounds may be prohibitive. Those processes using volatile precipitants are not strictly non-evaporative, as the solvent must be evaporated during recovery for re-use.



(Photograph by Department of Mineral Resources

III. ROTARY KILN AT SASKATCHEWAN MINERALS' SODIUM SULPHATE PLANT

This is a sixty by eight foot rotary kiln fired by crude oil through furnace in background.

Product Form

The pulp mills require a free flowing granular product containing a minimum of dust. These mills are the major market for Saskatchewan salt cake, and consequently processes which result in very dusty products must be ruled out.

Rotary Kiln

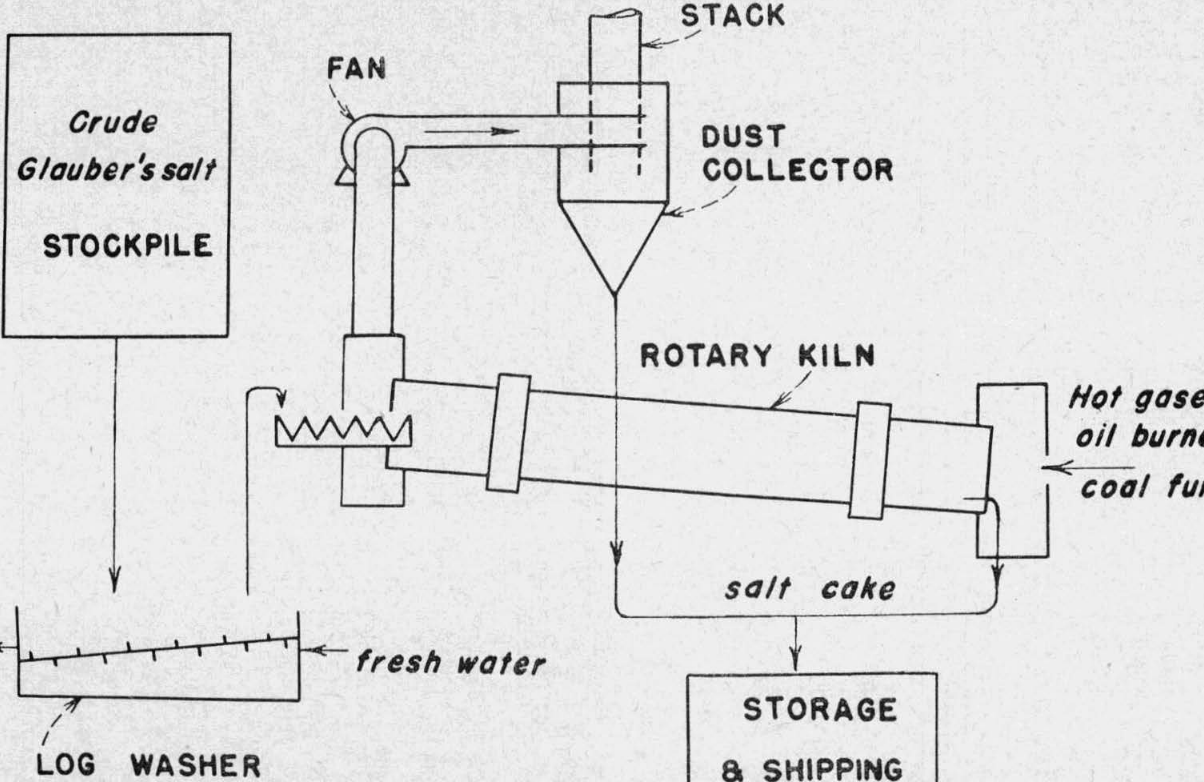
Simple rotary cylindrical kilns are used by all plants but Saskatchewan Minerals' to remove the water of crystallization from Glauber's salt. Figure 5 is a typical flow sheet for a plant of this nature. Either oil or lignite coal is used as fuel, the latter being fed on chain-grate stokers. The kilns used vary in length from 80 to 110 feet, and in diameter from 6 to 8 feet.

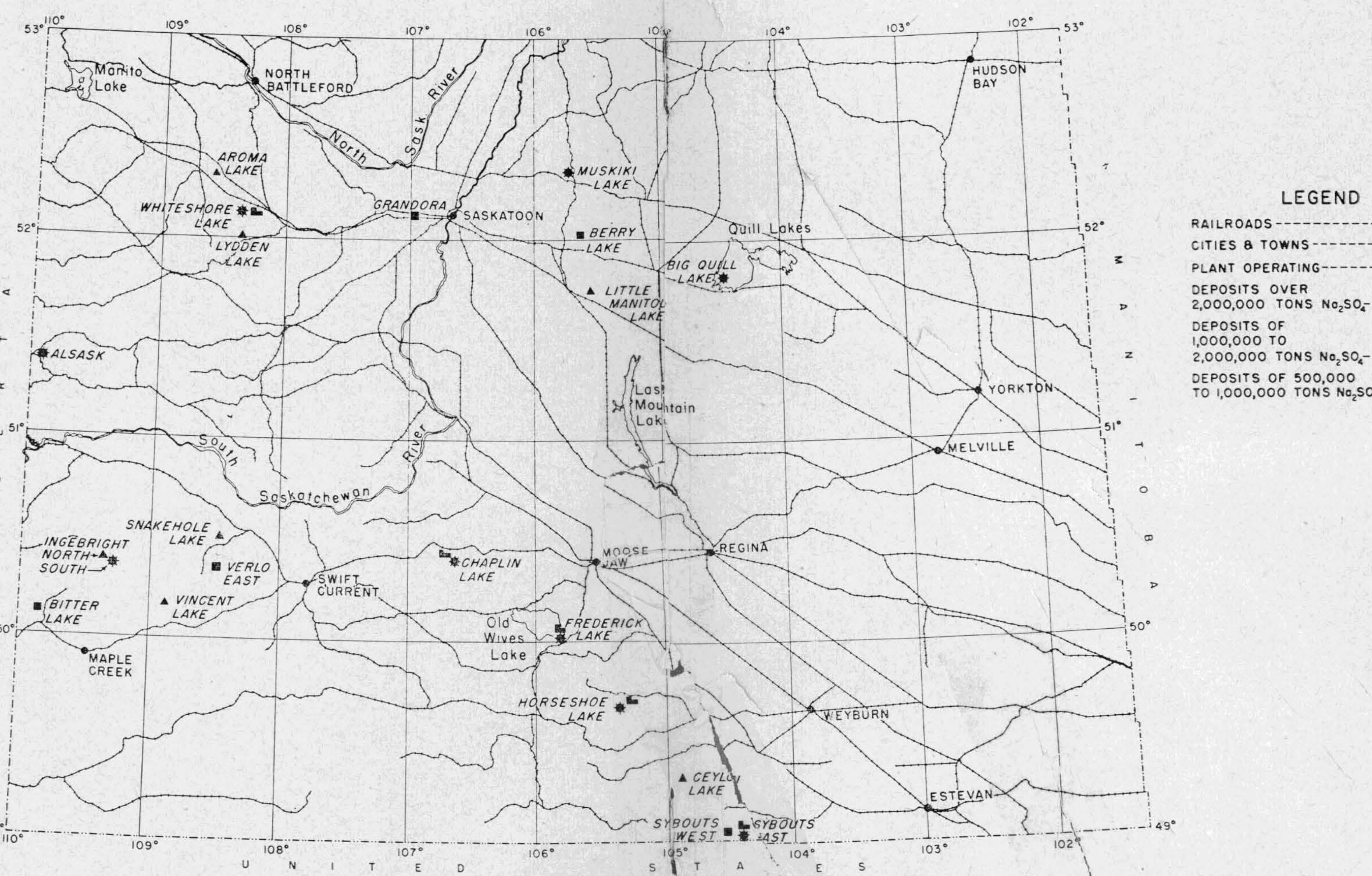
Possibly for a small plant this type of equipment is the most economical, despite its thermal inefficiency, because of relatively low capital cost and the type of labour required in its operation. This would account for the use of this procedure in the province. Aside from the thermal consideration, the use of rotary kilns has usually been accompanied by difficulties caused by the partially dehydrated salt sticking to the kiln. Recycling of dried salt to avoid the sticky concentration has been tried, but at present, the use of automatic knockers at the sticky zone, and careful control of feed rates and kiln temperatures largely eliminate this trouble. The recycle process was patented by W. F. Seyer (Canadian Patent 319 415, Feb. 2, 1932).

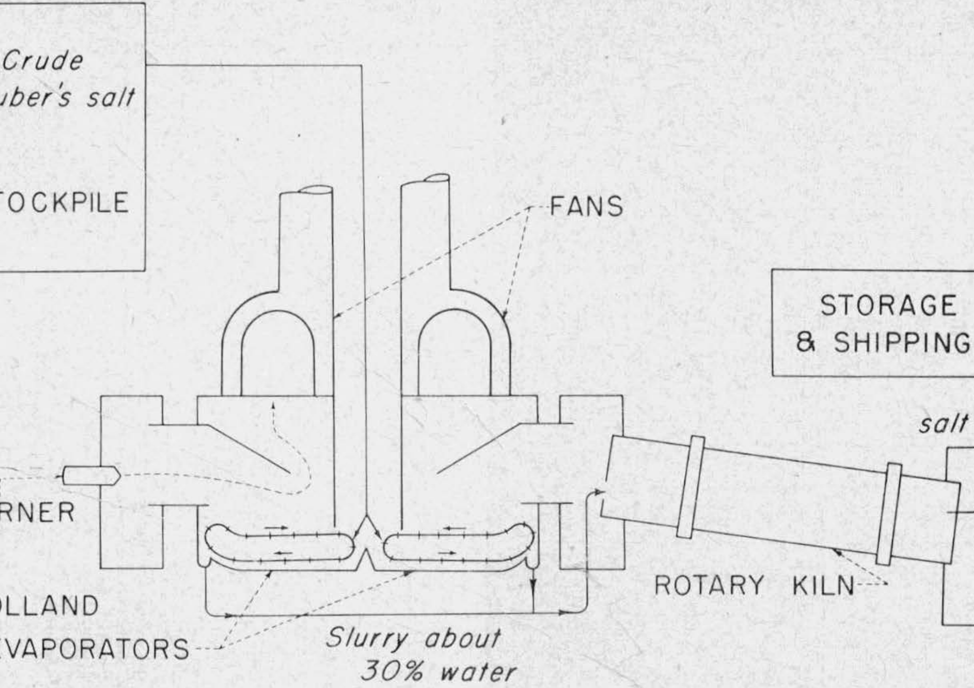
Although the rotary kiln process appears simple, feed rate, kiln length and diameter, hot and exhaust gas temperatures, and radiation losses are related in a complex manner, and a set of conditions should be selected for minimum heat consumption. In addition to the above mentioned variables, the effect of high temperatures on the furnace end of the kiln, which is not lined with refractories, must be considered.

The radiation loss is a function of the temperature of the gases fed to the kiln. This temperature is, in turn, controlled by the amount of excess and tempering air mixed with the furnace gases. It can be readily seen that, as the temperature of the gases is increased, the weight of hot gases required to deliver a given amount of heat decreases, and consequently, the heat lost in the exhaust gases going up the stack is reduced. This is offset by increasing radiation loss with rising temperature. Therefore an optimum gas temperature might be selected where the total loss of heat is at a minimum. Reduced radiation loss achieved by reducing the hot gas temperature below a certain temperature does not justify the large increase in the amount of air and gases which must be handled. Also, heat and mass transfer rates decrease at lower temperatures. At higher temperatures, in addition to increased radiation losses, there is much wear and tear on the hot end of the kiln necessitating frequent repair.

From the above, it can be seen that the theoretical heat requirement as shown in Figure 4 cannot be approached as heat is lost in the exhausted gases and by radiation. A small amount of heat (up to 300 B.t.u. per pound of dry sodium sulphate) might be recovered from the product by using air heated by the hot dry salt for combustion.


Crude
Glauber's salt
STOCKPILE
FAN
STACK
DUST
COLLECTOR
ROTARY KILN
Hot gase
oil burne
coal fu
salt cake
fresh water
STORAGE
& SHIPPING
LOG WASHER


LEGEND
RAILROADS
CITIES & TOWNS
PLANT OPERATING
DEPOSITS OVER 2,000,000 TONS Na_2SO_4
DEPOSITS OF 1,000,000 TO 2,000,000 TONS Na_2SO_4
DEPOSITS OF 500,000 TO 1,000,000 TONS Na_2SO
110°
109°
108°
107°
106°
105°
104°
103°
102°
53°
52°
51°
50°
49°
Manito Lake
NORTH BATTLEFORD
North Sask River
HUDSON BAY
AROMA LAKE
MUSKIKI LAKE
WHITESHORE LAKE
GRANDORA
SASKATOON
LYDDEN LAKE
BERRY LAKE
Quill Lakes
BIG QUILL LAKE
LITTLE MANITOU LAKE
ALSASK
Last Mountain Lake
YORKTON
MELVILLE
South Saskatchewan River
SNAKEHOLE LAKE
INGEBRIGHT NORTH SOUTH
VERLO EAST
CHAPLIN LAKE
MOOSE JAW
REGINA
SWIFT CURRENT
VINCENT LAKE
BITTER LAKE
Old Wives Lake
FREDERICK LAKE
MAPLE CREEK
HORSESHOE LAKE
WEYBURN
CEYLON LAKE
ESTEVAN
SYBOUTS WEST
SYBOUTS EAST
ALBERTA
MANITOBA
UNITED STATES


Crude
uber's salt
TOCKPILE
FANS
STORAGE
& SHIPPING
salt
RNER
ROTARY KILN
OLLAND
VAPORATORS
Slurry about
30% water

In calculation of radiation and convection heat losses, many assumptions must be made regarding the temperature gradient along the kiln, and rate of transfer of heat through the kiln wall. Accurate figures may be obtained only by conducting a heat and material balance about an operating kiln. In Saskatchewan practice about 35 gallons of fuel oil or 1,000 pounds of coal are used per ton of anhydrous salt produced This amounts to 3,500 B.t.u. per pound or approximately 1,500 B.t.u. per pound in excess of the theoretical requirement as shown in Figure 4, indicating an efficiency of about 55%, the remainder of the heat being lost in the exhaust gas or by radiation.

Holland Evaporators

The Chaplin plant of Saskatchewan Minerals makes use of convection evaporators patented by A. A. Holland. Figure 6 shows a simplified arrangement of the equipment. The evaporator consists of a rectangular chamber, having large ducts on one side and at the top for entry and exhaust of gases, respectively. Glauber's salt is fed directly into the evaporator and "melted" slurry is maintained to a few inches on the floor of the unit. This liquid is thrown into the hot gas stream by rotating paddles, evaporation occurs, and the partially dehydrated salt falls onto a chain conveyor running somewhat above the floor of the chamber, which carries it to screw conveyors. Induced draft fans are mounted above the evaporators and the interior is baffled to hinder entrainment of liquid drops. As arranged at Chaplin, two evaporators operate on exhaust gas from two final drying kilns, while two others are connected to separate oil-burning furnaces. The slurry from the four evaporators, containing about 30% moisture is distributed to two 60-foot rotary kilns where the remaining moisture is removed.

The same heat will be required to supply heat of fusion, heat of vaporization, and sensible heat in the water vapor and product as when the operation is carried on in a simple kiln under similar terminal conditions. This amounts to about 2,000 B.t.u. per pound of anhydrous sodium sulphate. A considerable amount of heat saving results from the low temperature at which the exhaust gases are discharged (about 140°F). Some economy will be effected because the area available for radiation per unit of product is lower than for the simple kiln. Stainless steel is used in construction of the evaporators to combat corrosion, which is a major problem at all sodium sulphate plants.

Flash Drying and Spray Drying

Flash drying is usually used for drying materials which are in a semi-solid condition rather than solutions. The wet substance (if necessary, mixed with dried product) is fed into a hammer or cage mill through which hot gases are drawn from a furnace by a blower running on the hammer shaft. The pulverized material is carried by the hot air up a long duct in which very rapid evaporation occurs because of the turbulent motion of the particles in the gas stream. The dried product is separated in a cyclone, or a series of such collectors. For the dehydration of Glauber's salt, a portion of the dried product must be mixed with the Glauber's salt, to avoid the formation of a sticky phase in the hammer mill. The product from this treatment, due to the grinding it has received, and other inherent features, is dusty and fine. Some subsequent treatment would likely be necessary to make it suitable for the pulp producer.

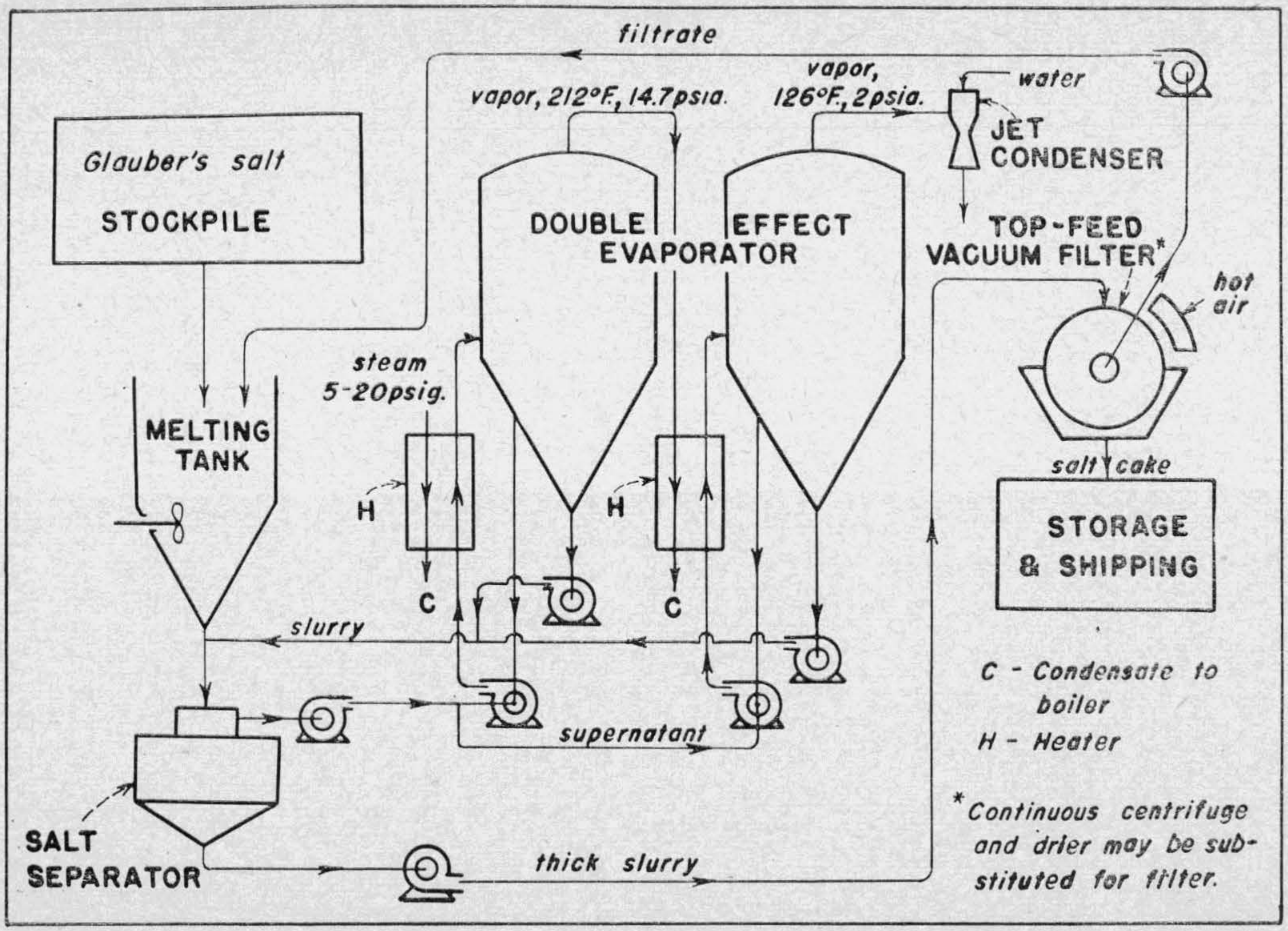


Fig. 7. Flowsheet for a sodium sulphate plant using multiple-effect evaporators.

Spray driers consist primarily of a large chamber, usually cylindrical with a conical bottom, into which the material to be dried is pumped and atomized into a stream of hot gas. Auxiliary equipment includes a furnace to supply hot gases, a blower, and a cyclone-type dust collector. The feed may be a suspension or a true solution, the type of atomizer being selected to suit the material fed. Dried product drops to the bottom of the spray chamber and is carried away continuously by conveyors. The system can be operated almost entirely by automatic controls, with consequent labor saving and standard product. The equipment may be insulated to conserve heat, an important feature as the surface available for radiation and convection losses of heat is large. However, the temperature of the chamber walls will normally be well below that of the hotter portion of rotary kilns, as the temperature of the hot gases is reduced very rapidly by the evaporating water. Heat requirements for both spray and flash driers should be less than for rotary kilns. Capital cost would probably be higher.

Submerged Combustion

The process of submerged combustion, which consists of burning natural gas under the surface of a solution has been described by K. A. Kobe[3], with particular reference to sodium sulphate dehydration. This process provides for very effective heat transfer, and is undoubtedly the most efficient evaporative process, where natural gas is available. One United States sodium sulphate plant uses the process. The gases leave the solution at the boiling point and consequently heat losses up the chimney are small. Also, the whole vessel is at relatively low temperature and radiation losses are held to a minimum.

This method could be used to merely melt the Glauber's Salt in the "transition point deposition" process described further on.

Multiple-Effect Evaporators

Forced-circulation multiple-effect evaporators are used by the rayon industry to produce anhydrous sodium sulphate by dehydration of Glauber's salt recovered from spinning liquors. One United States natural sodium sulphate plant is also using this procedure. The method offers large savings in heat compared to the convection processes. Steam exhausted from turbo-generators may be fed to the first effect, and the vapor from each effect serves as the heating medium for the next. Two effects appear to be the most economical for a plant having a capacity of two hundred tons of anhydrous salt per day.

The recommended method of operation is to feed Glauber's salt to a settler or salt separator into which liquor from product filters would be fed supplying sufficient heat to melt the Glauber's salt. The liquor from the settler would be pumped to the two evaporators, in parallel. Salt slurry from the evaporators is transferred to the settler. The settled salt would be delivered to three top feed filters, each equipped with a small hot air furnace for drying the filter cake. Continuous centrifuges might be substituted for these filters with a small rotary drier to remove moisture from the cake.

Heat requirements total only 1,725 B.t.u. per pound of anhydrous sodium sulphate according to manufacturers estimates, and the steam

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[3] K. A. Kobe, Carl W. Hauge, and Carl J. Carlson. "Evaporation by Submerged Combustion. III: Sodium Sulphate Decahydrate" Ind. Eng. Chem. *28*, 589-93, 1936.

supplying this would also generate the plant's power requirements before being turned over to the processing department. In addition, about 100 B.t.u. per pound would be supplied, by fuel oil or coal, to the filters or drier. Possibly flue gas from the steam boiler might be utilized for this purpose, making other sources of heat unnecessary.

Drum Drying

Drum driers consist of either single or double hollow cylinders fitted so that steam may be admitted through the axis, and the drum rotated slowly against a blade. The material to be dried is fed to the top of the drums, and by the time it has rotated to the blade, is dry. The space surrounding the drums may be either at atmospheric pressure or under vacuum as desired.

For drying Glauber's salt in quantity, the area of drum surface required is very large, and would involve an expenditure out of proportion to the job performed. Although this method requires too much equipment for large scale operation, it could possibly be used for small scale production of chemically pure sodium sulphate. Internally heated drum-driers were used at one time by J. B. Pierce at the Horseshoe Lake deposit to accomplish part of the dehydration, but have since been abandoned.

Transition Point Deposition

When Glauber's salt, containing 44% sodium sulphate, is heated above 90°F anhydrous sodium sulphate and a saturated solution are the resulting phases. Table X shows distribution of the anhydrous sodium sulphate between the two phases at various temperatures.

From this, it is apparent that by simply melting the Glauber's salt. from 39 to 46% of the sodium sulphate may be filtered off in the anhydrous form. In practice higher quantities are obtained because of salt contained in the adhering solution which cannot be removed completely by ordinary methods. Table XI shows the recovery which may be effected if the centrifuge or filter cake contains the given percentages of water.

Only 40 to 50% of the total anhydrous salt can be recovered by this method; therefore, the remaining portion should remain in circulation in the system in some manner. This may be accomplished by sending the filtrate to secondary reservoirs for recrystallization, as shown in the accompanying flowsheet (Figure 8). In effect, then, the sodium sulphate,

TABLE X

PERCENTAGE OF ANHYDROUS SODIUM SULPHATE PRECIPITATED BY HEATING GLAUBER'S SALT ABOVE TRANSITION TEMPERATURE

Temperature °F	Percent of Na_2SO_4 in solution	Percent of Na_2SO_4 precipitated	Precipitated Na_2SO_4 as Percent of Original Glauber's Salt	Concentration of Solution, Percent Na_2SO_4
100	61.1	38.9	17.1	32.5
120	59.0	41.0	18.0	31.7
140	57.0	43.0	18.9	31.0
160	55.9	44.1	19.4	30.5
180	54.5	45.5	20.0	30.0
200	54.3	45.7	20.1	29.9

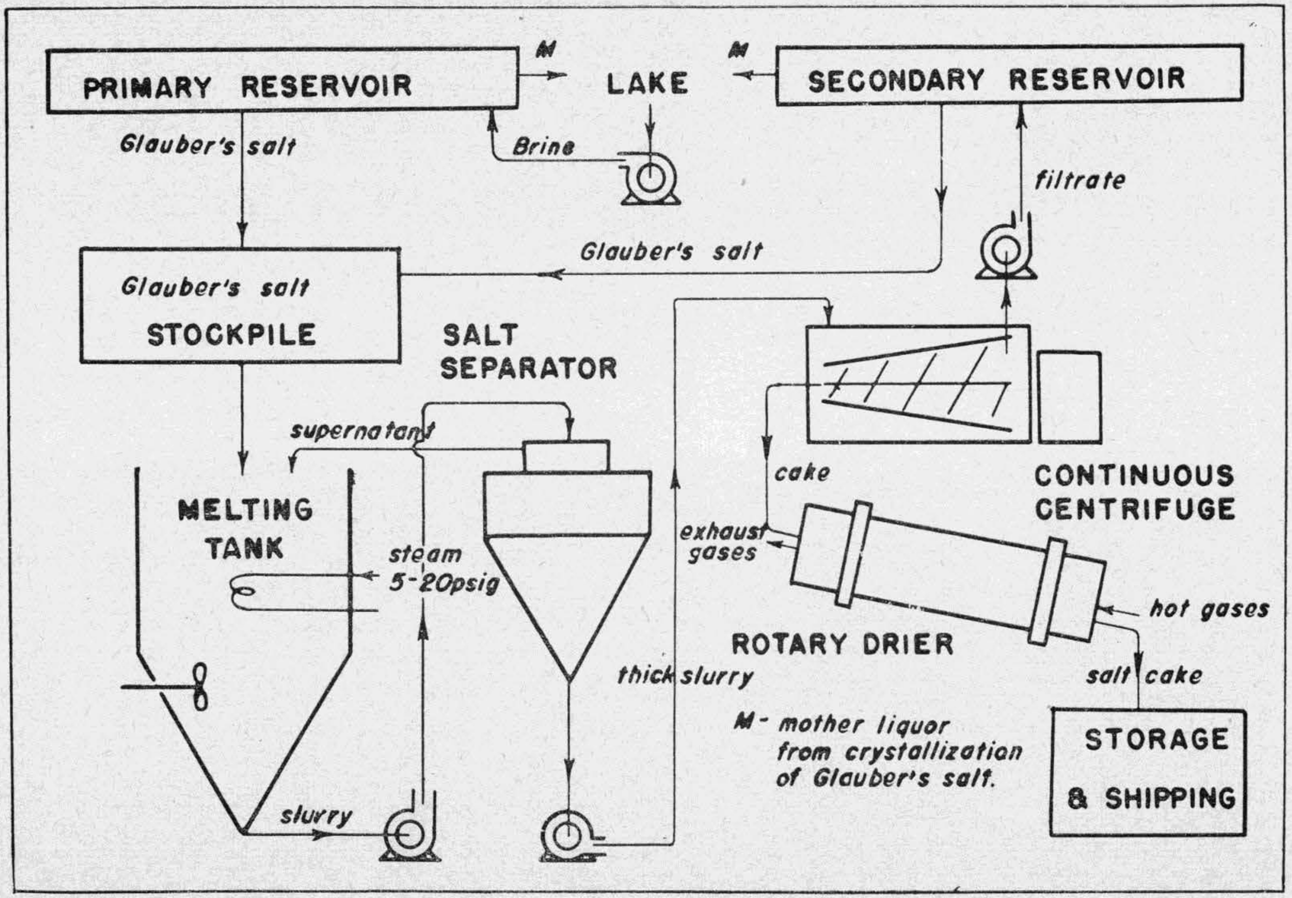

Fig. 8. Flowsheet for a sodium sulphate plant based on precipitation of anhydrous sodium sulphate above 90° F.

must be crystallized, harvested, and melted two to two and a half times. This feature somewhat reduces the great advantage of not having to evaporate the water of crystallization. Vacuum crystallizers might be used instead of reservoirs. Theoretical heat requirements include only the heat necessary to raise Glauber's salt from its ambient temperature to the final temperature, and the heat of fusion. For salt at 50°F to final conditions of 110°F, only 335 B.t.u. per lb. of total anhydrous sodium sulphate in the Glauber's salt, or 845 B.t.u. per pound of salt cake precipitated are required. Under plant conditions, when a perfect separation cannot be effected, and some 10-15% superficial moisture in the cake must be removed, approximately 1,200 B.t.u. per pound of finished salt cake are required. This can be supplied almost entirely by exhaust steam from power generation.

TABLE XI

RECOVERY OF ANHYDROUS SODIUM SULPHATE FROM PRECIPITATION PROCESS FOR FILTER PRODUCTS OF VARIOUS WATER CONTENTS

(As percent of total anhydrous sodium sulphate)

Temperature °F	Water Content of Cake, Percent by Weight				
	2	5	10	15	20
100	39.3	39.7	41.1	42.5	44.2
140	43.3	44.0	45.2	46.7	48.1
180	45.9	46.5	47.7	49.2	50.9

Recent experiments have shown that good heat transfer rates can be obtained, so that practical size equipment could be designed[4]. Also, if a simpler plant were desired, submerged combustion of a gas would provide an efficient method of melting the Glauber's salt. This would eliminate the need for a steam plant, but would nullify the efficiency which would be obtained if steam were first used to generate power, then to supply heat to the melters.

A patent for a process of this nature was issued to L. E. Drummond (Canadian Patent 314, 908, Sept. 1, 1931) and attempts were made to use similar methods at Ceylon Lake, Whiteshore Lake, and Muskiki Lake, but none achieved steady commercial production. However, the process is reasonably simple and a properly designed plant should function smoothly.

Precipitation by Sodium Chloride

The preceding process might be modified so that the sodium sulphate remaining in solution is precipitated by the addition of sodium chloride, either simultaneously with melting or as a separate step. This would avoid the necessity for recrystallization. Heat requirements for this

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[4] R. V. Tomkins and J. W. Spyker "Dehydration of Glauber's Salt by Transition Point Deposition" Rept. Inv. No. 5, Saskatchewan Department of Mineral Resources. In preparation.

process are very small, probably of the order of 600 B.t.u. per pound of anhydrous salt in practice. However, the sodium chloride must be purchased and has to be available at very low cost. Hancock and Ide (in Canadian Patent 216, 621, March 14, 1922), described a similar process, and included evaporation of the sodium chloride solution for re-use. This accomplishes nothing unless solar energy or other costless heat is used; the water might as well be evaporated directly from the sodium sulphate solution. Estimates indicate that this method can compete only where salt is available at $2 to $3 per ton. Capital cost for equipment should compare very favorably with other methods.

An attempt to use this process at Muskiki Lake was a disastrous failure, due to the high price of sodium chloride at that point relative to the value of the salt cake produced.

The American Potash and Chemical Corporation at Trona, California makes use of surplus salt, available from other parts of their plant, in the separation of sodium sulphate.

Precipitation by Volatile Compounds

The addition of ethanol to a sodium sulphate solution above the transition temperature causes precipitation of anhydrous sodium sulphate. This salt may be filtered off, and the ethanol recovered by distillation for re-use. It is doubtful if this procedure would be as economical as other processes described. The distillation equipment required would be large and costly. Although some heat economy may be effected over simple convection processes, still sufficient heat must be supplied to vaporize the ethanol during recovery, and this would amount to one-quarter to one-half of the heat necessary to vaporize the water of crystallization in the Glauber's salt. Losses of alcohol in the filter cake and during rectification would be unavoidable. The necessity to use explosion-proof equipment in part of the plant adds further to costs.

Ammonia has been suggested as a precipitating agent for anhydrous sodium sulphate (H. L. Robson, Canadian Patent 268, 056, February 28, 1928). This compound would be subject to greater losses than ethanol because of its volatility. For the same reason, however, much simpler distillation equipment could be used to separate ammonia and water.

OCCURRENCES OF SODIUM SULPHATE IN SASKATCHEWAN AND HISTORY OF DEVELOPMENTS

During the first World War, when imports of German potash were cut off, an extensive search was made for new sources of supply. An erroneous report of the discovery of potash in Western Canada in 1918 led to the staking of claims at a large number of the alkali lakes of Saskatchewan. Finding no potash, most of the leaseholders allowed their claims to lapse. Others, however, discovered that their claims contained large quantities of Epsom and Glauber's salts, the hydrated forms of magnesium and sodium sulphate.

L. H. Cole, mining engineer of the Dominion Department of Mines, made an extensive survey of Saskatchewan's sodium sulphate occurrences from 1921 to 1924, and his report, "Sodium Sulphate of Western Canada"[5] has been of great value to those interested in development of these deposits.

Since Canadian Salts and Potash Company of Canada was formed in 1915 to produce salts from Muskiki Lake, more than twenty companies have been formed for the purpose of producing sodium sulphate, as shown in Table XII. Production reached a maximum of 192,000 tons of salt cake in 1947, and has been in the 100,000 to 150,000 ton range for many years. There are now five plants in operation (1954).

Some explanation regarding the failure of a large number of operators to make a success of their projects is in order. The salt cake market fluctuates sharply in both demand and price, and these variations are particularly hard on the Saskatchewan producers, who are handicapped by their distance from the large markets. The price of salt cake at Saskatchewan plants has ranged from $6.50 to $20 per ton during the past decade, the average during the late thirties being about $7. With production costs near $6 per ton, the profit margin was very slim.

The causes of failure were not, however, entirely due to unfavorable market conditions. When profits are limited to such a narrow range, it is essential that the plant be established and operated on a sound technological basis. Some developments were undertaken with little understanding of the factors involved in the dehydration of Glauber's salt. Others were started with a sound process, but were unable to get into large scale commercial production because of lack of operating "know-how", or financing.

Cole's work in the early twenties clearly disclosed the extent of the sodium sulphate deposits. Most of the major deposits were drilled in detail, and many minor deposits were located. Work in recent years by the Industrial Minerals Research Branch has included drilling Verlo East and Lydden Lake, sounding some of the larger lakes, and examination of major deposits in 1947 and 1951.

Table XIII lists the deposits which contain over 500,000 tons of sodium sulphate, and their locations are shown in Figure 9. These twenty-one deposits contain nearly 60 million tons of anhydrous sodium sulphate. Just how much of this is recoverable is difficult to estimate. The amount which can be recovered by solution is limited by the mud cover which forms on the lake as the impure salt goes into solution. This, and depletion of the purer part of a salt bed could prevent the brine from attaining a salt content high enough to warrant pumping it into reservoirs. This method of mining, however, will likely result in the highest total recovery. When the bed is mined mechanically, the recovery is limited by the low grade of the ore making up a significant part of most deposits. With deeper beds, such as at Ingebright lake, there is the problem of mining salt, resting in oozing mud, at depth out of reach of a dragline.

Dilute lakes, such as Big Quill, have not yet concentrated sufficiently to allow commercial exploitation. When a dry cycle occurs again, such lakes may dry up enough to provide a supply of brine containing the 12% or more of sodium sulphate required for economical brine operation. In this category are Little Quill Lake, Tramping Lake, Willowbunch Lake,

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[5] L. H. Cole "Sodium Sulphate of Western Canada" Canada Dept. Mines Rept. 646, 1926.

Big Muddy Lake, and Lake of the Rivers. All of these, however, contain less than the 500,000 tons which has been arbitrarily set as the lower limit for a major deposit. This figure has been selected as the reserve necessary to supply a small plant of 100 tons per day capacity for 10 years. Some of the smaller deposits, which are referred to later, may be good auxiliary supplies for plants operating in larger deposits in the general vicinity.

TABLE XII

COMPANIES FORMED TO PRODUCE SODIUM SULPHATE IN SASKATCHEWAN

Years	Name of Company	Location
1918 - 1919	Canadian Salts and Potash Co. of Canada Limited	Muskiki Lake
1919 - 1923	Salts and Chemicals Limited	
1934 - 1938	Muskiki Sulphates Limited	
1920 - 1923	Soda Deposits Limited	Fusilier North
1927 - 1931	The Sodium Sulphate Refining Co.	
1931 - 1938	Dominion Sodium Refineries	
1921 - 1954	Bishopric and Lent Company Natural Sodium Products	Frederick Lake *
1921 - 1925	Soda Lake Chemical Co.	Alsask
1926 - 1941	Sodium Corporation Ltd.	
1941 - 1954	Natural Sodium Products	
1930 - 1938	Horseshoe Lake Mining Co. (Subsidiary of Barium Reduction Corp.)	Horseshoe Lake *
1938 - 1950	Horseshoe Lake Mining Co. (Subsidiary of International Nickel Co.)	
1950 - 1954	Ormiston Mining and Smelting Co.	
1931 - 1933	Canadian Salines Ltd. (Leases held by Whiteshore Salts and Chemicals)	Whiteshore Lake *
1934 - 1954	Midwest Chemicals Ltd. (Part leases held by Whiteshore Salts and Chemicals)	
1935 - 1937	Oban Salt Co. Ltd.	Oban Lake
1932	G. M. Lyons	Sybouts East *
1941 - 1954	Sybouts Sodium Sulphate Co.	
1932 - 1933	Metallics and Non-Metallics (Leases held then and now by E. L. Harvie)	Ingebright South
1933 - 1934	Fred Solomon (Leaseholder and operator)	Regina Beach South
1935 - 1954	Sodium Sulphate Co. of Sask.	Ceylon Lake
1947 - 1954	Saskatchewan Minerals Sodium Sulphate Division	Chaplin Lake *
1952 - 1954	Saskatchewan Minerals Sodium Sulphate Division	Snakehole Lake *

* Deposits being operated in 1954.

TABLE XIII

MAJOR SODIUM SULPHATE DEPOSITS IN SASKATCHEWAN

Cole No.	Name	Million tons Na_2SO_4
—	Big Quill Lake	11.0
9	Ingebright South	9.0
15	Whiteshore Lake	6.5
30	Horseshoe Lake	3.7
42	Sybouts East	3.3
1	Muskiki Lake	3.0
4	Chaplin Lake	3.0
48	Alsask	2.6
2	Frederick Lake	2.4
19	Vincent Lake	2.0
7	Snakehole Lake	1.7
56	Little Manitou Lake	1.2
—	Aroma Lake	1.1
82	Ingebright North	1.1
13	Ceylon Lake	1.0
41, 45	Verlo East	1.05
12	Sybouts West	0.8
62	Bitter Lake	0.8
11	Berry Lake	0.8
37	Grandora	0.6
—	Lydden Lake	0.9

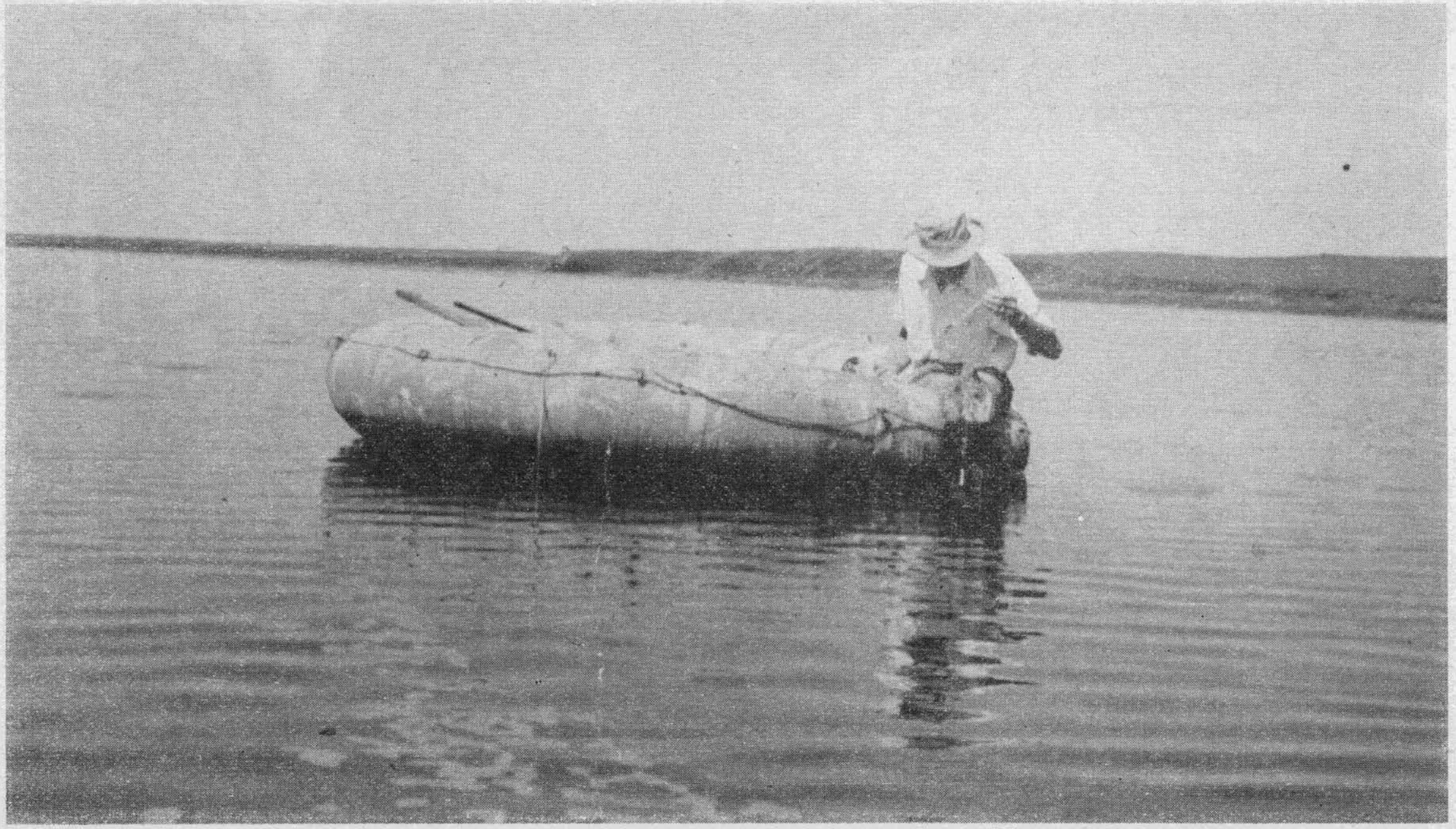
The descriptions of sodium sulphate deposits which follow are summaries of Cole's findings supplemented by recent observations. For details, Cole's report should be consulted. Where Cole did not describe the deposit, the description is based on investigations by Industrial Minerals Research Branch members conducted since 1947. Analyses of brines have omitted small amounts of salts other than magnesium sulphate, magnesium chloride, sodium chloride, and sodium sulphate. Specific gravities given are corrected to 15°C. For an approximation in field work, figures following the decimal, plus one, will give the percentage of salt in the brine. For example, a brine with specific gravity 1.15 will contain about 16% of dissolved salts. Tonnages are all given in terms of anhydrous sodium sulphate.

Descriptions of developments in the Saskatchewan sodium sulphate industry were compiled largely from reports of the late Walter H. Hastings of the Saskatchewan Department of Mineral Resources.

GENERAL DESCRIPTION OF DEPOSITS

Sodium sulphate occurs in three main forms in the natural deposits of Saskatchewan.

1. In solution in brines of varying salt content.
2. As an intermittent crystal in the form of *mirabilite* (Glauber's salt, $Na_2SO_4.10H_2O$) which deposits from brines or goes back into solution depending on climatic conditions.
3. As a permanent salt bed in the form of *mirabilite* more or less contaminated with mud and other salts (mainly magnesium sulphate, sodium chloride, calcium sulphate) which may have been present in the original brine.



(Photograph by Department of Mineral Resources)

IV. TESTING BRINE ON SODIUM SULPHATE DEPOSIT

A rubber boat provides a convenient means of examination in calm weather.

In addition, an intermittent crystal made up of anhydrous sodium sulphate *(thenardite)* is occasionally precipitated at those deposits containing substantial amounts of sodium chloride in solution. This salt lowers the transition point of the sodium sulphate-water system (see page 25) so that anhydrous sodium sulphate rather than Glauber's Salt is formed.

No typical deposit can be described, as each has its own characteristics. In general, however, the larger deposits are made up of a permanent bed of varying thickness and composition, covered by a thin layer of mud, on top of which brine occurs in the early part of the year. As the brine becomes more concentrated, the intermittent crystal precipitates, and in most instances, the lake becomes dry in late summer. The deposits in which brine is the commercial form of sodium sulphate may not have any extensive permanent bed. If not, they must cover larger areas and contain greater depths of brine.

ORIGIN

The sodium sulphate deposits occur in undrained basins, usually in sandy or gravelly areas. At nearly all deposits, seepages are in evidence and artesian water is commonly obtained near them. It appears that these deposits occur where aquifers closely approach the surface, and waters containing a small amount of salts in solution accumulate in the low areas. Cole suggested that ultimate source of the sodium sulphate may be from calcium sulphate (common in prairie drift) dissolved in ground water, which passes through bentonitic clay beds exchanging the calcium for sodium ions. The springs around the lakes, although not true brine springs, contain sodium sulphate to the extent of over 1,000 parts per million. If the inflow to a basin were 100 gallons per minute, 12,000 years would be required to produce a deposit of three million tons of sodium sulphate, comparable in size with Muskiki Lake. This seems to be a reasonable length of time for the formation of a post-glacial deposit.

MAJOR OCCURRENCES

BIG QUILL LAKE

Big Quill Lake covers about 100 square miles in Townships 33, 34, Range 16; Townships 32, 33, 34, 35, Range 17; Townships 32, 33, 34, Range 18; all West of the Second Meridian. It is approximately 100 miles north of Regina, on the Winnipeg-Edmonton branch of the C.P.R. The villages of Dafoe and Kandahar on this railroad are within a mile of the south shore of the lake.

The Brine

The lake is shallow, having an average depth of 4.3 feet (maximum: 5.6 feet), and is drying up at rather a fast rate. Rawson and Moore[6] give an area of over 100,000 acres in 1939, while aerial photos show the present area to be about 64,000 acres. As would be expected, the salinity has increased.

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[6] D. S. Rawson and J. E. Moore. "The Saline Lakes of Saskatchewan", *Can. J. Research* D, 22:141-201, 1944.

Month	Year	Percent Total Solids
May	1920	1.655
June	1938	2.85
July	1939	3.00
June	1947	5.77
August	1949	5.60
June	1952	4.65

With the exception of 1949, all summers have been abnormally wet and cool since 1947, so that there was actually an increase in the level of many lakes in Saskatchewan. While the rise in salinity may be temporarily halted or reversed, with the return of drier, warmer weather, the recession of the lake will likely begin again.

Three analyses of Big Quill Lake are shown below.

Component	June, 1947	August, 1949	June, 1952
Magnesium sulphate	2.61	2.79	2.48
Sodium sulphate	2.33	2.02	1.54
Sodium chloride	0.72	0.70	0.63
TOTAL*	5.77	5.60	4.65
Specific Gravity	1.053	1.050	1.043

* The total includes small amounts of carbonates and bicarbonates.

Based on the 1949 analysis, the lake contains 10.9 million tons of magnesium sulphate, 7.9 million tons of sodium sulphate and 2.7 million tons of sodium chloride. If all the sodium is calculated as sodium sulphate then the total sodium sulphate amounts to 11.1 million tons. If the brine does concentrate so that Glauber's salt is formed, the sodium and sulphate ions will eventually combine to form Glauber's salt, leaving magnesium chloride rather than sodium chloride.

INGEBRIGHT SOUTH

Ingebright South is located in Sections 13, 14, 23, 24, 25, 26, Township 16, Range 25, West of the Third Meridian. It is twelve miles from Fox Valley on the Fox Valley-Pivot branch of the C.P.R. Maple Creek is 40 miles south, and Leader about the same distance north. The lake covers about 700 acres in the centre of a rather small drainage basin. Many springs occur around the lake and carry small amounts of dissolved salts, and brine springs are found in the crystal bed at the south end of the lake, which build up cones of salt around their orifices.

The Brine and Salt Bed

Cole reports as much as three feet of brine on the lake in the spring with one foot more at the north end than at the south. By the time the brine reaches its maximum salt content there is not more than a foot left at the north end, and the south end is dry. In May, 1951, there was an average of 10 inches of brine on the lake containing 8.6% Na_2SO_4, 0.89% $MgSO_4$ and 0.66% NaCl (s.g. 1.092 at 15°C). Intermittent crystal up to two feet thick in places has been reported, and may average over six inches.

The salt bed occupies 680 acres with an average depth of 22 feet. It is the largest deposit of this kind in the province, containing nine million tons of anhydrous sodium sulphate. There are two places where the bed is over 100 feet thick, and such depths have not been found in any other deposit. In the northern portion of the lake, the first twenty-five feet of salt contains numerous mud partings; in the southern part the crystal is relatively free from mud. Analyses of the upper twenty-five feet, on a dry basis, show the following average composition: insolubles 12.5%, sodium sulphate (Na_2SO_4) 72%, calcium sulphate ($CaSO_4$) 6.5%, magnesium sulphate ($MgSO_4$) 3%, sodium chloride (NaCl) 2%, and smaller amounts of sodium bicarbonate ($NaHCO_3$) and sodium carbonate (Na_2CO_3). The average quality remains the same as this to 40 feet, then improves to about 80% sodium sulphate to 100 feet. However, the crystal bed does not exceed 25 feet in thickness in the greater part of the deposit.

History

No developments have occurred at the lake itself, although leases have been held since 1920. The main factor hindering development is the long distance from rail, but the permanent bed of the lake contains considerable impurities, and there is a problem presented in mining the salt from the thicker portions of this bed.

In 1932 and 1933 a concern called Metallics and Non-Metallics carried on experimental work at Hull, Quebec, with the object of commercial production at Ingebright South. The process was a form of air drying, the crystal being thrown into the air by disintegrators with a stream of air at 160°F passing through the chamber. In this manner, the salt is dried to a stage where it could be passed to a direct heat drier without fear of melting. The system is similar to the modern "flash-drying" arrangements. However, the company did not put the process into operation.

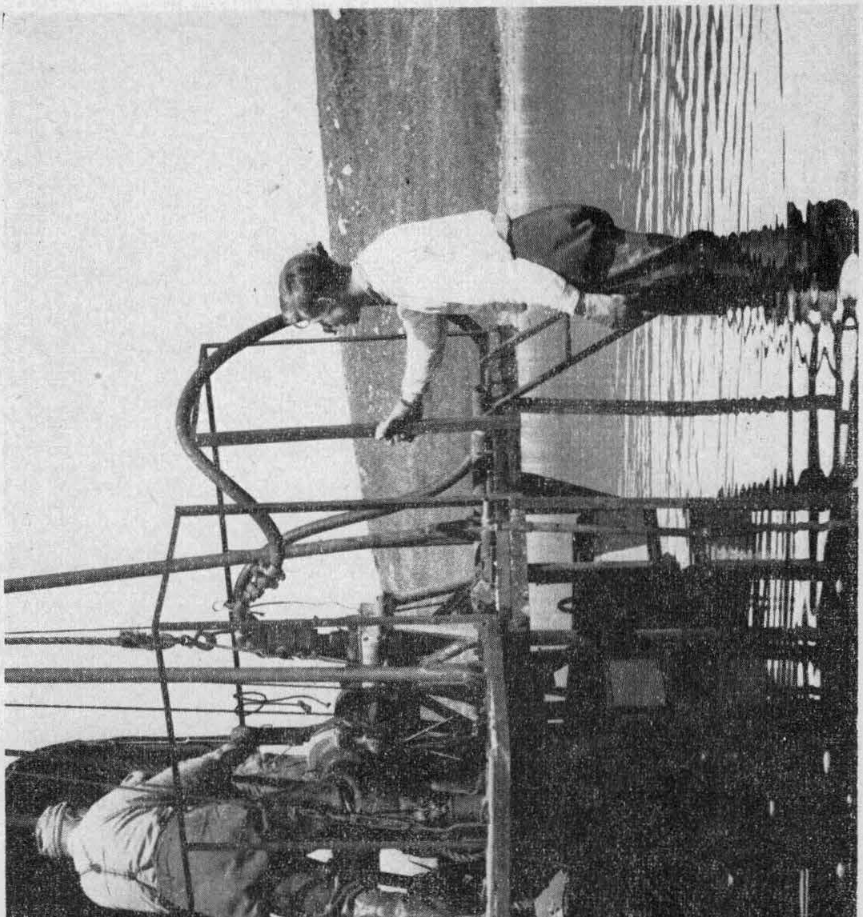
WHITESHORE LAKE

Whiteshore lake is 62 miles west of Saskatoon, and lies parallel to the main line of the Canadian National Railways in Township 36, Ranges 16 and 17, West of the Third Meridian. A spur line from Palo connects the plant of Midwest Chemicals Limited with the main line. The lake is ten miles long and varies in width from one-quarter to one and three-quarter miles. Total area is approximately three square miles.

The Brine and Salt Bed

Cole reports that in midsummer of 1924 part of the lake was dry, but up to two feet of brine of specific gravity 1.16 was left near the narrows. This is still typical in normal years. A large quantity of brine occurs in the spring, and it reaches saturation early in the summer. Two samples taken during 1951 had the following composition:

	May	July
Na_2SO_4	9.12%	13.65%
$MgSO_4$	1.15	3.11
NaCl	0.36	1.05
TOTAL	10.63	17.81
Specific Gravity	1.097	1.172



(Photograph by Department of Mineral Resources)

V. CORE DRILLING A SODIUM SULPHATE DEPOSIT

The drill is mounted on a caterpillar-type trailer to facilitate moving over mud near shore.

Intermittent crystal forms in greatest thickness along the centre line of the lake, and over the two main areas of permanent bed.

The main permanent bed is five miles long, in the eastern portion of the lake, with an average width of ¼ to ½ mile and an average depth of about five feet. Maximum thickness encountered was 14 feet. The bed contains considerable amounts of mud and has a covering of mud from ½ inch to over one foot thick. In the western portion of the lake there are several smaller permanent beds. These also are muddy, and have a heavy covering of mud. Average analyses of the permanent bed are given below as reported by Cole.

	0-5 feet	5-10 feet	10+ feet
Insoluble	8.73	6.77	11.10
NaCl	0.86	0.69	0.72
$NaHCO_3$	0.81	0.69	0.83
$CaSO_4$	4.50	3.04	4.31
$MgSO_4$	6.99	7.78	11.57
Na_2SO_4	77.66	80.62	71.02

The Whiteshore lake deposit contains over 6.5 million tons of anhydrous sodium sulphate.

History

Whiteshore Salts and Chemicals Limited controls the alkali mining rights to most of the lake. Canadian Salines Limited in 1931 arranged with those leaseholders to erect an experimental plant using the "transition point deposition" process. Some operating difficulties were encountered, a rift developed among the promoters, and the project was abandoned.

In 1934 Midwest Chemicals Limited, the present operator, was formed. Intermittent crystal was used as raw material in the initial stages, but was found to contain too much magnesium salts. Raw Glauber's salt is now obtained from brine which is pumped into large reservoirs near saturation, and the Glauber's salt precipitates as the brine cools in the fall. The remaining liquor, containing most of the undesirable magnesium salts, is drained back to the lake.

Description of Plant: The precipitated Glauber's salt in the brine reservoir is scraped up and loaded into trucks which carry it to the stockpile. A bulldozer feeds the salt from stock to a bucket elevator which fills bins in the plant. The raw salt is fed directly to three rotary kilns, which are oil-fired. The anhydrous salt is crushed and screened into two size ranges: ¾ inch to 8 mesh, and minus 8 mesh.

During 1935-1937, the Oban Salt Company Limited, erected an experimental plant near the east end of Whiteshore Lake, on a small lake known as Oban Lake. The Company controlled alkali rights on over 2,000 acres of Whiteshore Lake as well as those to Oban Lake. Brine from Whiteshore was pumped through 6,200 feet of 10-inch pipe to Oban Lake, on which a sump had been constructed to act as a settling basin. The brine was then repumped to a reservoir 40 feet above the lake for crystallization.

The dehydration equipment consisted of a rubber-lined stainless steel Oslo-type crystallizer, which is essentially a specially designed vacuum evaporator. The Glauber's salt was melted before feeding to the crystallizer, and a small rotary drier was used to remove surface moisture from the finished salt. Apparently financial backing was not adequate and the plant operated only for a few months during the winter of 1936-37.

HORSESHOE LAKE

Horseshoe Lake is located in Sections 5, 7, 8, 9, 16, 17, 20, and 21, Township 9, Range 25, West of the Third Meridian. Ormiston, on the Cardross branch of the Canadian Pacific Railway is one mile north, and Moose Jaw is 50 miles north of the deposit. The lake is slightly more than two miles long and at the widest point is one mile wide.

The Brine and Salt Bed

At the time of Cole's survey, the brine on Horseshoe Lake was 8 to 10 inches deep in early summer, and dried up by the middle of July, and conditions are similar now. In May, 1951, there was about six inches of brine (specific gravity 1.060) on most of the lake, and 18 inches on that portion from which the mud cover had been stripped.

The permanent bed is found in the southern portion of the lake, mainly in Section 8. It has a maximum thickness of 24 feet and averages about 15 feet. This is one of the cleanest permanent beds found and contains an average of 92% Na_2SO_4, 4% insolubles, 1% $MgSO_4$, and minor amounts of other salts. The total anhydrous sodium sulphate available is 3.7 million tons.

History

The Horseshoe Lake Mining Company was organized in 1929 as a subsidiary of the Barium Reduction Corporation of Charleston, West Virginia. A plant was erected in 1930 and salt was produced during the summer months each year to 1937. A description of the plant was published by J. B. Pierce[7], the president of the company.

Most of the production was shipped to the International Nickel Company at Copper Cliff, Ontario, for use in nickel-copper refining. International Nickel took over the plant and redesigned it in 1938. In 1950, the plant again changed hands and was purchased by a group of paper companies as International Nickel had ceased using sodium sulphate. The name of the company was changed to the Ormiston Mining and Smelting Company Limited. This company leases only the southern portion of Horseshoe Lake.

Description of Plant: Part of the raw salt is obtained from two large reservoirs on the lake bed into which brine is pumped each summer. The remainder is mined directly from the lake bed.

For the mining operation, blasting is required to loosen the Glauber's salt. A ¾-yard, caterpillar-mounted, diesel-powered shovel is used to load the loosened material onto cars and also to strip surface mud from the deposit. One-hundred cubic foot Granby cars are hauled by a 6-ton Diesel locomotive to the plant. The salt is dumped through a grizzly, which serves to disintegrate the larger pieces of crystal. A spiral washer, using fresh water, is used to remove surface impurities. The washed salt is elevated to a common stockpile with reservoir salt, and allowed to drain

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[7] J. B. Pierce "Anhydrous Sodium Sulphate from Lake Crystals" *Chem. and Met. Eng. 44,* 718, 1937.

thoroughly. Drag scrapers feed this salt into screw conveyors running to three 8 by 110 feet rotary kilns. These are direct fired with lignite coal on a chain-gate stoker, using forced draft. The dried salt is conveyed by screws and elevator to the box car loader. Plant power is produced by a 400 hp. diesel engine coupled to a 200-volt, 60-cycle generator. A similar 165 hp. unit is used as an auxiliary.

SYBOUTS EAST

Sybouts East Lake is just north of the International Boundary, in Township 1, Ranges 18 and 19, West of the Second Meridian. It is nine miles south of Gladmar on the Minton branch of the Canadian Pacific Railway. The lake is about 3 miles long from east to west, and over a half mile wide.

The Brine and Salt Bed

In early June, 1924, Cole reports from 4 to 12 inches of brine, which was saturated with sodium sulphate, having a specific gravity of 1.14. The intermittent crystal from the brine is very clean, and is deposited directly on the permanent bed, without any intervening mud. In late May, 1951, there was 10 inches of brine on this lake, having the following analysis: Na_2SO_4 9.81%, $MgSO_4$ 1.53%, NaCl 0.26%. The specific gravity was 1.10.

The permanent bed occupies the centre of the lake basin, covering 630 acres, at an average depth of 5.5 feet. The greatest depth is 32 feet, in the western portion, and for a considerable area the bed is 10 feet thick. The top ten feet contains an average of 81% Na_2SO_4, 13% insolubles, and 6% soluble impurities. Total anhydrous sodium sulphate amounts to 3.5 million tons.

History

Local men formed the Gladmar Sodium Sulphate Company in the early twenties but no active development occurred. A small plant was erected in 1932 by Grant M. Lyons, but was never put into operation. The intermittent crystal was harvested from the top of the permanent bed by a road scraper, and dehydration was to be carried on in a small rotary kiln.

No further development occurred until about 1941 when Walter E. Seibert of New York formed the Sybouts Sodium Sulphate Company Limited. This company erected a rotary kiln plant, which was expanded in 1947.

Description of Plant: The raw material for this plant was originally intermittent crystal, which is deposited on the clean hard surface of the salt bed each year. During the winter, a scarifier-tooth scoop and chain conveyor is used to harvest the crystal and load trucks. A brine reservoir has been constructed by damming a natural inlet on the lakeshore, and salt is now obtained by pumping saturated brine into this reservoir and harvesting Glauber's salt which crystallizes in the fall.

The crystals are fed directly to two 6 by 110 foot rotary kilns, which are fired by lignite coal shipped in from Bienfait. The salt cake produced is crushed in a hammer mill and elevated to storage bins. The plant is nine miles from its shipping point, Gladmar, and the salt cake is hauled by trucks taking 7-ton loads. Coal is hauled back from Gladmar on some of the return trips.

MUSKIKI LAKE

Muskiki Lake is one mile north of Dana, a station on the Winnipeg-Edmonton line of the Canadian National Railways, and lies in Townships 38 and 39, Ranges 26 and 27, West of the Second Meridian. The lake covers about seven square miles, and is divided by narrows into three main sections southern, central, and northwestern.

The Brine and Salt Bed

The brine in Muskiki Lake contains more magnesium sulphate than most sodium sulphate deposits, and when the lake dries up completely, there is a layer of intermittent crystal rich in magnesium sulphate deposited on top of the usual intermittent Glauber's salt. In the northwestern section up to two feet of brine may be found early in the year, and only about one foot in the south section. The lake is usually dry by the end of summer. Some recent analyses of Muskiki Lake brines are given below.

Component	August, 1949	May, 1951	July, 1951	May, 1952
$MgSO_4$	15.58	4.28	6.79	7.53
Na_2SO_4	12.30	6.70	11.67	7.08
NaCl	2.05	0.45	0.88	0.83
Total	29.93	11.43	19.34	15.44
Specific Gravity	1.319	1.103	1.192	1.152
Depth, inches	2	18	13	18

The layers of intermittent crystal were sampled by Cole, and he found that the top layer contained about 80% $MgSO_4$ while the crystal layer deposited first contained about 85% Na_2SO_4 and 7% $MgSO_4$.

The permanent beds at this lake are relatively thin, averaging about three feet in thickness. Five separate areas were outlined, which are separated by mud from one another. The thickness of crystal varies a great deal in the individual areas, and there are many muddy patches within them. The permanent beds are quite impure. Cores from the northwest section contained from 57 to 87% Na_2SO_4, from 5 to 21% $MgSO_4$, and from 4 to 22% insolubles. The permanent salt in the central section is much more uniform, average composition being 80% Na_2SO_4, 8% $MgSO_4$, and 7% insolubles. On the southern section, the crystal has a similar composition. None of this permanent bed salt can be considered suitable for direct mining. The deposit contains three million tons of sodium sulphate, and one million tons of magnesium sulphate.

History

The mining rights for Muskiki Lake were secured in 1915 by the Canadian Salts and Potash Company of Canada, capitalized at $500,000 for the purpose of producing Epsom salt (magnesium sulphate) from the brine of the lake. Further examination disclosed large quantities of sodium sulphate present, and rights to all salts present in the lake and mud beneath were obtained.

Extensive tests were made on brine shipped to Kitchener, Ontario, and a pilot plant was erected there in 1919. The shipping costs on the brine prevented this arrangement from being successful, and an evaporating plant was built at Muskiki. The crude salt was then shipped to Kitchener where Epsom salt, Glauber's salt and magnesium carbonate were produced. The cost of production, including freight, by this method was also too high for profitable operation.

A new company, Salts and Chemicals Limited, was then organized to produce salt cake, having an authorized capital of $2,500,000. At this time (1920) the demand for salt cake was very great and the price at eastern plants reached $50 per ton for a short period. Under these conditions, considerable money could be spent on dehydration of the Glauber's salt and the operation would still be financially successful. The process used was one patented by Handcock and Ide, two of the company's organizers. Sodium chloride was added to the melted Glauber's salt (harvested from the lake by ice cutters) causing nearly all of the sodium sulphate to precipitate in the anhydrous form. The sulphate was then separated, and the remaining brine was evaporated to obtain the sodium chloride for re-use. The cost of production was high because of the price of make-up sodium chloride and the large amount of fuel used to recover the sodium chloride. The water of crystallization was evaporated during salt recovery, so that no evaporation charges were saved. The eastern price of salt cake dropped steadily to $18 in 1922 and the plant ceased operations in 1923, when it was sold for salvage. It is estimated that a million and a half dollars were spent to this point at Muskiki Lake.

No further development occurred until 1934 when Muskiki Sulphates Limited was formed to produce high grade anhydrous sodium sulphate for the textile industry. In 1937 a 20-ton trial plant was constructed, which was to use the transition point deposition method of dehydration. Glauber's salt was melted by closed steam and a portion of the sodium sulphate was precipitated in the anhydrous form. This was moved from the melter by screws and delivered to centrifuges for dewatering. The mother liquor was then cooled to crystallize Glauber's salt, which was returned to the melters. The plant was run for only a very short period in 1938 and was never brought into production.

CHAPLIN LAKE

Chaplin Lake is located south of the Village of Chaplin on the main line of the Canadian Pacific Railway, 100 miles west of Regina. The lake covers nearly 20 square miles.

The Brine and Salt Bed

Chaplin Lake is at an earlier stage of development than some of the lakes previously described. There is a thin bed of permanent crystal beginning to form but it is only about six inches thick. The brine is the source of commercial sodium sulphate at this deposit. During the dry period in the nineteen-thirties, this lake was dry most of the time and the dry salt blew over the countryside for miles. With the return of wetter weather, the lake built up large quantities of brine which would concentrate to as high as 20% Na_2SO_4 by midsummer. During weather that is exceptionally wet, as in the past few years, as much as five feet of brine occurs on the west side of the lake but it does not concentrate to a high enough salt content for efficient harvesting.

In an attempt to overcome this unfavorable situation, the lake has been divided into two sections by a dam, and nearly all the brine has been pumped from the east section into the west. This allows the remaining shallow brine to reach a higher concentration with a minimum of evaporation. For example, if a normal net evaporation of 12 inches could be expected during the summer, and there was originally 48 inches of brine containing 5% Na_2SO_4, the concentrated brine would still contain only about 7% Na_2SO_4. If, however, the brine depth were reduced to 18 inches before evaporation began, after evaporation the brine would contain 15% Na_2SO_4 which is a satisfactory concentration for pumping into the reservoirs. This procedure has been moderately successful.

An analysis of the brine taken in 1954 in the western (deep) section of the lake showed 6.6% Na_2SO_4 with 0.5% of all other salts. At that time the brine was over four feet deep, and there was 2.5 million tons of sodium sulphate in solution. There is at least another 0.5 million tons in the thin salt bed on the bottom of the lake, making a total of 3 million tons anhydrous sodium sulphate.

History

The Sodium Sulphate Division of Saskatchewan Minerals, a Crown Corporation of the Province of Saskatchewan was formed in 1945 to produce sodium sulphate at this deposit.

Description of Plant: Three brine reservoirs, each 1,000 feet square and with a capacity of 10,000,000 cubic feet have been constructed. Brine is pumped into these during the summer, and as the temperature drops in the fall, Glauber's salt crystallizes. The remaining liquor is drained to the lake, and the salt harvested by scraper and truck. The Chaplin plant makes use of a kind of spray drier called the Holland evaporator described in the previous chapter. Two evaporators are direct-fired; another two are mounted on the exhaust ends of 60-foot rotary kilns. The slurry from all four evaporators, containing about 30% water, is distributed to the two rotary kilns where drying is completed. Kilns and evaporators are fired by crude oil. The salt cake product is ground to the desired size in a rod mill in closed circuit with a vibrating screen. It is stored in steel storage bins, and loaded into cars by conveyors.

ALSASK

The Alsask deposit is located in Sections 21, 27, 28, 33 and 34 of Township 27, Range 28, West of the Third Meridian, about seven miles southeast of Alsask. Hardene, on the Alsask-Delisle branch of the Canadian National Railways, is two miles west. The lake is crescent-shaped, about two miles long and less than one-half mile wide, covering 545 acres.

The Brine and Salt Bed

There is very little drainage into this lake, and only a small amount of brine is formed each year. Cole reports four inches of brine in March 1924, and in May 1951, there was a similar amount. Samples of the brine taken by Cole contained as much sodium chloride as sodium sulphate. A sample taken in May 1951 contained 7% Na_2SO_4 and only 1% NaCl. The brine and intermittent crystal contain only very small amounts of magnesium. The permanent bed covers 345 acres and has a maximum thickness of 35 feet. The crystal is relatively pure, averaging about 87% sodium sulphate, with 5 to 10% insolubles, and small amounts of other salts. There are two lenses of mud in the crystal bed, and an overburden of mud on top. The total sodium sulphate in the deposit is 2.6 million tons.

History

Interest in this deposit was first shown in 1921, when the Soda Lake Chemical Company was formed. Some experimental work was carried on, but no active production occurred. A new organization known as the Sodium Corporation Limited was organized in the middle twenties to operate the deposit.

As the brine at this deposit contains considerable quantities of sodium chloride, the anhydrous form of sodium sulphate is precipitated instead of Glauber's salt during the hot summer. The presence of sodium chloride lowers the transition temperature of the sodium sulphate-water system. Because of this phenomenon, the first plant was designed simply to remove the adhering moisture from the harvested anhydrous sodium sulphate. However, during very wet years, the sodium chloride concentration is not sufficient to cause precipitation of anhydrous sodium sulphate, and the plant could not operate satisfactorily on Glauber's salt. It was decided that the plant should be able to handle either material and a new plant was started in 1933, originally intended to produce 200 tons per day, but only 50 tons capacity was installed. The raw salt was harvested by gasoline tractor and scraper and fed to two rotary driers in series, the first direct-fired, and the second acting as a cooler. The company produced small amounts each year until 1938.

In 1941, the leases were acquired by Natural Sodium Products, which operated the deposit at Frederick Lake. A large 4-kiln plant was erected and salt cake was produced from 1942-1944, using salt mined from the lake bed. The plant was reopened in 1948 for a short period, but has not been in operation since then. In December 1954 the leases and plant were acquired by Saskatchewan Minerals.

FREDERICK LAKE

Frederick Lake is about 38 miles southwest of Moose Jaw. Bishopric, on the Moose Jaw-Assiniboia branch of the Canadian Pacific Railway, is right beside the lake. The lake is located in Sections 20, 21, 29, 33, Township 12, Range 28, West of the Second Meridian. It is separated from Old Wives Lake, a large slightly saline body of water, by a narrow gravel ridge. The area of the lake is about 825 acres.

The Brine and Salt Bed

In May 1951, there was about four inches of brine (s.g. 1.096) on Frederick Lake, and a small amount of intermittent crystal. The brine does not get much deeper than this; Cole reported 2 to 8 inches. A few inches of mud separate the permanent bed from the brine. The permanent bed fills the whole lake, and is remarkably uniform, varying in thickness only from 3 to 5½ feet. Cole's drilling shows it to be clean, containing about 85% Na_2SO_4 and less than 5% insolubles. The magnesium sulphate content is quite high, averaging 6.6%, and calcium sulphate 3.2%. Since Cole's drilling a large area of the lake bed has been mined and the salt has been dissolved and redeposited in the excavations. The lake originally contained 2.4 million tons of sodium sulphate.

History

Frederick Lake was first staked in 1920 by local parties, and in 1921 the Bishopric and Lent Co., of Cincinnati, Ohio, took over all claims. The same company operated this deposit until 1954, although the name was changed to Natural Sodium Products Limited. The plant is located at the Village of Bishopric, named after one of the original company's partners. Many methods of dehydration, including vacuum evaporation and spray drying, were experimented with, but oil-fired rotary kilns were finally selected, and since 1929 the plant has been in production. All the raw salt used was mined from the lake bed until 1948. Reservoirs have been constructed on the lake by building dams on the salt bed. The company did not operate in 1952 and 1953, but resumed production in 1954. Saskatchewan Minerals purchased the leases and plant in December 1954.

Description of Plant: Salt taken from the lake bed was mined without blasting using a 1½ yard shovel, and was hauled in 4-car (5 yards each) trains by diesel locomotive to the plant. Salt from the reservoirs is harvested using tractors and scrapers. A "log washer" was used to loosen impurities, a classifier to remove fine clay. The clean crystal was stockpiled. Four oil-fired rotary kilns 80 feet long by 7 feet in diameter are used for dehydration. Salt cake from the kilns is crushed in a hammer mill and screened before going to storage bins.

VINCENT LAKE

Vincent Lake is located in Sections 3 and 4, Township 15, and Sections 33 and 34, Township 14, Range 22, West of the Third Meridian. It is 14 miles north of Sidewood on the main line of the Canadian Pacific Railway, in a rather sparsely settled area, accessible only by local roads. It is in a deep depression about 200 feet below the general level of the surrounding country, and the drainage basin is fairly large.

The Brine and Salt Bed

Brine up to two feet deep was reported by Cole in late July 1922, which was nearly saturated. It contained 1.5% $MgSO_4$, 1.9% $NaCl$, and 13.4% Na_2SO_4. In May 1951, there was about 14 inches of brine on the lake but it had a specific gravity of only 1.06 and there was little intermittent crystal. This suggests that some of the salt which formed the rich brine and 7 to 12 inches of intermittent crystal reported by Cole, may have got covered by mud during the dry years and is now part of the permanent bed. The permanent bed covers 325 acres to an average depth of about eight feet. This is one of the best quality beds found; some of the analyses show over 90% Na_2SO_4 and under 5% insolubles. The total sodium sulphate present amounts to two million tons. No developments have been attempted at this deposit because of its remote location.

SNAKEHOLE LAKE

Snakehole Lake is about two miles north of Roseray on the Verlo branch of the Canadian Pacific Railway. It lies in Sections 7 and 18, Township 18, and Sections 1, 2 and 12, Township 19, Range 18, West of the Third Meridian. The lake has a circular portion about one mile in diameter at the north, and a narrower tail about 2,000 feet wide extends about 1½ miles to the southeast.

The Brine and Salt Bed

Up to two feet of brine is commonly found on this lake in the spring. There is little mud on the crystal bed, but it is perforated by a large number of mud "chimneys" which mark the location of sub-crystal springs. The composition of two samples taken in spring and summer of 1951, show how the brine had concentrated. In some years the lake is completely dry by August.

	May, 1951	August, 1951
Na_2SO_4	7.25%	13.30%
$MgSO_4$	0.77	1.60
NaCl	0.26	0.63
TOTAL	8.28%	15.53%
Specific Gravity	1.07	1.15
Depth	20 inches	12 inches

As would be expected from the depth of concentrated brine, several inches of intermittent crystal is usually formed.

The permanent crystal bed covers about 460 acres to an average depth of six feet. The quality is quite variable with sodium sulphate content from 65 to 85%, insolubles from 4 to 14%, magnesium sulphate and carbonate (total) from 5 to 13%, and calcium sulphate from 2 to 10%. A total of 1.7 million tons of sodium sulphate is available.

History

In 1952, when it became apparent that adverse weather might limit harvest at Lake Chaplin, Saskatchewan Minerals acquired a lease on Snakehole Lake and built a large reservoir by damming a slough to the north of the lake. Brine was pumped into the reservoir each summer and a substantial reserve of Glauber's salt was built up. In 1954, this salt was being harvested to supplement the supply at Chaplin Lake. The salt is stockpiled on shore and trucked to Roseray for shipment by rail to Chaplin.

LITTLE MANITOU LAKE

Little Manitou Lake is a narrow lake about 12 miles long running roughly parallel to the main line of the Canadian National Railways in Township 32, Ranges 24, 25, 26, West of the Second Meridian. Young, Xena, and Watrous on the Canadian National Railways are within four miles of the lake. Soundings show the average depth of Little Manitou Lake is only 2.8 feet, and recent aerial photographs show the area is now 4.82 square miles. Maximum depth is 5.2 feet. The lake level has dropped ten feet or more during the past twenty years.

The Brine and Salt Bed

Little Manitou Lake does not have a permanent salt bed, but large amounts of Glauber's salt are precipitated in the fall, forming a compact intermittent bed on the lake bottom in places. The brine is very rich in magnesium salts as shown in the following analyses.

Because of the alternate deposition and re-solution of sodium sulphate as Glauber's salt, the composition of the brine varies with the climatic conditions, and of course, with the time of the year. It may be noted that the ratio of chloride to magnesium ions remains approximately constant as would be expected; these ions do not enter into the formation of Glauber's salt.

	August 1949	Sept. 1949	Nov. 1949	May 1951	July 1951	June 1952
$MgSO_4$	11.24	11.43	9.00	6.66	10.195	8.23
$MgCl_2$	....	....	3.29	2.61	0.10	1.49
Na_2SO_4	0.27	1.32	....	....	....	....
NaCl	7.22	7.30	4.44	3.53	7.07	4.65
Total	18.9	20.2	17.0	12.8	17.3	14.4
Specific Gravity	1.178	1.193	1.156	1.116	1.162	1.135

The sample of November, 1949, was taken when a large part of sodium and sulphate ions had been precipitated as Glauber's salt, leaving the brine rich in magnesium chloride. The May, 1951 and June, 1952, samples are also rich in magnesium as not much of the Glauber's salt precipitated during the winter had dissolved.

Based on the July 1951 analysis, the total sodium sulphate which could be crystallized from the brine is 1.2 million tons.

Little Manitou Lake is quite famous for alleged curative powers of its waters. Numerous summer cottages and several baths have been built at the lake.

AROMA LAKE

Aroma Lake covers three square miles in the west side of Township 38, Range 18, West of the Third Meridian. The Saskatoon-Macklin branch of the Canadian Pacific Railway is about a mile from the north end, while the main line of the Canadian National Railways passes the same distance from the south end.

The Brine

This lake has not yet developed a permanent bed, and like Big Quill, the brine is not sufficiently concentrated for economic recovery of sodium sulphate. The average depth is 8.3 feet. Two analyses are given below.

	August, 1947	July, 1951
$MgSO_4$	2.61	2.91
Na_2SO_4	4.45	2.68
NaCl	0.83	0.68
TOTAL	7.89	6.27
Specific Gravity	1.076	1.057

The total sodium sulphate in the lake is one million tons based on the 1947 analysis. It is likely that in 1951, a very cool, wet year, some sodium sulphate, precipitated during the winter, was still not dissolved by July.

INGEBRIGHT NORTH

This lake is located in Sections 4 and 9, Township 17, Range 25, West of the Third Meridian, a few miles north of Ingebright South. It is 10 miles from the nearest railway at Fox Valley. The lake covers only about 150 acres, being 1½ miles long and from 500 to 1,200 feet wide.

The Brine and Salt Bed

The brine never reaches more than five inches in depth, as any increase would cause it to flow out of the lake to the south. As there is from 10 inches to two feet of mud covering the permanent bed, the brine would not likely dissolve much salt. The permanent bed is quite clean, and is 80 feet thick at one point. The average sodium sulphate content approaches 90%, and insolubles under 10%. The total sodium sulphate available is 1.1 million tons. As the lake is in a remote area, and is close to the much larger Ingebright South deposit, it has little attraction for development. The exceptionally thick bed presents a difficult mining problem.

CEYLON LAKE

Ceylon Lake is a series of four lakes joined by narrow channels, located in Section 1, 12, 13 and 24, Township 4, Range 21, West of the Second Meridian. Hardy, on the Radville-Willowbunch line of the Canadian National Railway is 12 miles north, and Minton, the end of a Canadian Pacific Railway branch line is 10 miles southeast.

The Brine and Salt Bed

About one foot of brine is found on the lake in early spring, and by the time it has become concentrated about six inches remains. In late May, 1951, the brine had reached saturation, having a specific gravity of 1.124, and containing 12.7% Na_2SO_4, 0.73% $MgSO_4$ and 0.15% NaCl. There was about four inches of intermittent crystal and an equal depth of brine. The intermittent crystal is very clean. A sample taken by Cole contained 98.3% Na_2SO_4.

The permanent bed is from 2 to 8 feet thick, and contains quite a lot of included mud. Sodium sulphate content varies from 58 to 89% in Cole's cores, and insolubles from 7 to 32%. Total sodium sulphate available is one million tons.

History

Small shipments of Glauber's salt were shipped from this lake for a number of years, but no attempt at dehydration was made until 1934, when the Sodium Sulphate Company of Saskatchewan was organized. This company still holds leases on the deposit, although no operations have been carried on since 1936.

The plant was constructed in 1935, which was to operate on intermittent crystal harvested by scrapers. The dehydration process consisted of melting the Glauber's salt in a steel tank with open steam, draining off the mother liquor for recrystallization of Glauber's salt, and raking out the precipitated anhydrous sodium sulphate. The adhering moisture was then removed by raking the salt over steel plates set above the horizontal flue of a furnace. The use of open steam seriously affected the

(R.C.A.F. Official Photograph)

VI. AERIAL PHOTOGRAPH OF CEYLON LAKE

The white border is sodium sulphate deposited as the lake begins to dry up.

efficiency of the process so that instead of recovering the theoretical 38 percent of the sodium sulphate per cycle, only 10 percent was obtained, as part of the precipitated salt dissolved in the steam condensate. The company never got into large scale production, and the plant has been dismantled and removed.

VERLO EAST

This deposit consists of two lakes, joined by a channel about 1,000 feet long which is usually dry. They are located in Sections 7, 8, 9, 17 and 18, Township 16, Range 18, West of the Third Meridian. They are about 10 miles from Verlo, Hazlet, or Roseray on the Verlo-Wickett branch of the Canadian Pacific Railway. The north lake covers about 200 acres, and the southern one about 400 acres. The north lake, which contains a permanent bed was drilled in 1954[8].

The Brine and Salt Bed

The smaller lake, which is almost completely underlain by a permanent crystal bed, usually does not have much brine on it, and dries up by July. Up to four inches of clean intermittent crystal is formed, and there is only a small amount of mud separating this from the permanent bed. In recent wet years as much as 20 inches of brine has been found on this lake, and over one foot of intermittent crystal was formed. The permanent bed averages 12 feet in thickness, and covers 175 acres. At one point 34 feet of salt was found. There is quite a bit of mud in the permanent bed, and in calculating the reserve, it was assumed that the bed was half mud. Along with the intermittent crystal, the total amount of sodium sulphate available is 950,000 tons.

The larger lake to the south contains at least 100,000 tons of sodium sulphate in solution which could be added to this reserve. Some depths and analyses of the south lake are given below.

	July, 1947	May, 1951	August, 1951
$MgSO_4$	—	0.50	1.75
Na_2SO_4	—	6.81	13.60
NaCl	—	0.08	0.32
TOTAL	—	7.39	15.67
Specific Gravity	1.19	1.07	1.15
Depth, inches	8	20	15

It would be quite simple to pump the saturated brine from this lake on to the solid bed of the north lake, which would be used as a large crystallizing basin.

SYBOUTS WEST

Sybouts West is directly west of the Sybouts East Lake, in Township 1, Ranges 19 and 20, West of the Second Meridian. Minton, at the end of a Canadian Pacific Railway branch line, is about seven miles north of the west end. The lake is five miles long, and one mile wide at the widest point.

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[8] E. Y. Carlson and W. J. Babey "Core Drilling for Industrial Minerals in Saskatchewan—1953 and 1954". In preparation. Sask. Dept. Mineral Resources.

The Brine and Salt Bed

There is a permanent bed occupying about 30 acres in parts of Sections 23, 24, 25 and 26, Township 1, Range 20, West of the Second Meridian, which averages about six feet in thickness. It is separated from the brine by a foot or more of mud. Cole reports 10 inches of brine in June 1924, having a specific gravity of only 1.066; in late May, 1951, there was 21 inches of brine having a specific gravity of only 1.024. The permanent bed is quite impure, containing about 72% sodium sulphate, with 23% insolubles. Total reserve of sodium sulphate available is 800,000 tons.

BITTER LAKE

Bitter Lake is located in Townships 13 and 14, Ranges 28 and 29, West of the Third Meridian, and is about 12 miles long, varying in width from 400 to 3,000 yards. It is three to five miles north of the main line of the Canadian Pacific Railway. The Golden Prairie-Hatton Branch of that railway crosses the lake at its narrow centre section.

A secondary road connects Hatton with the lake, crossing near the railway. No good roads pass the east end of the lake, but a fair sandy road from Hatton passes by the southwest section. It is this latter part of the lake that contains most of the sodium sulphate.

The Brine

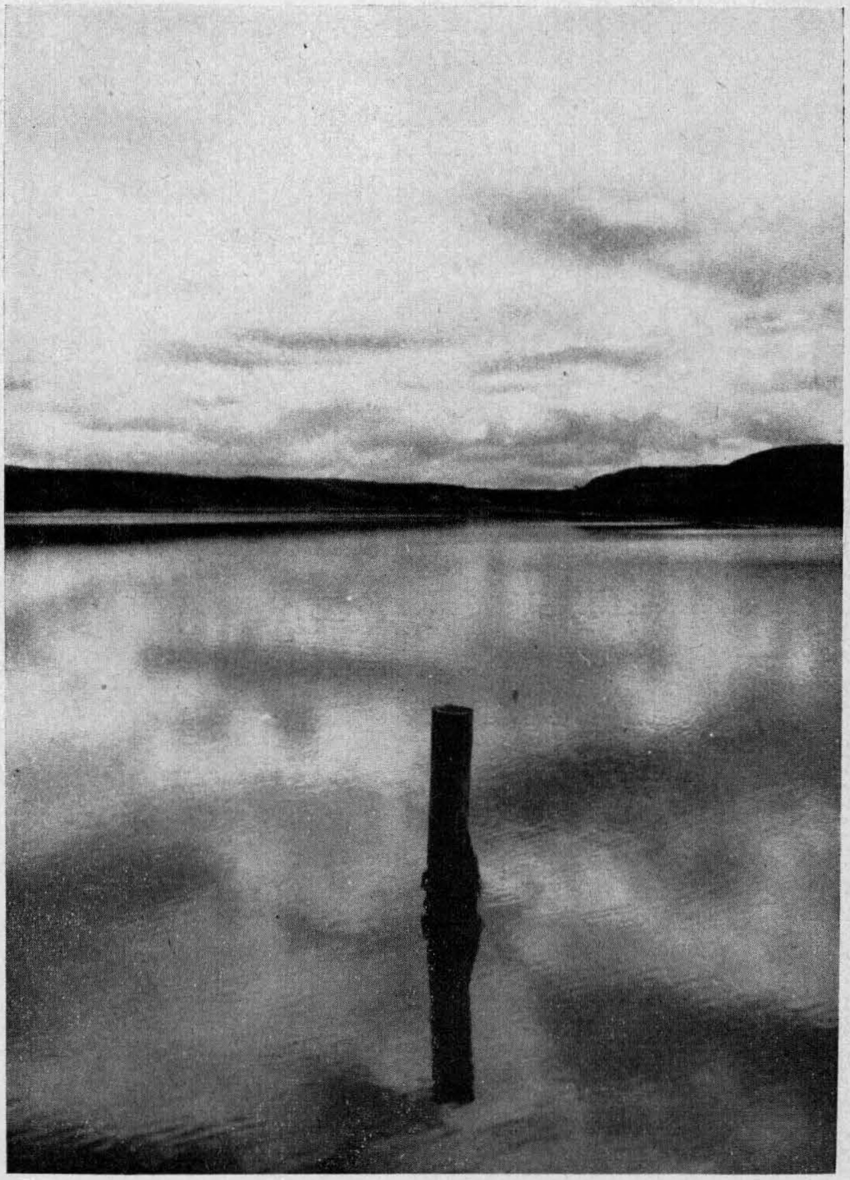
Bitter Lake does not contain any permanent salt bed. Six inches of intermittent crystal forms in the western section of this lake, which was dry in October, 1947, as the brine accumulates in this lowest part of the lake. The eastern section is usually dry, so there is little salt deposited there. There was about two feet of brine in the western section in June, 1947, with a specific gravity of 1.12. An equal depth was found in early May 1951, but the brine had not yet dissolved much salt, as the specific gravity was only 1.035. This lake contains about 800,000 tons of sodium sulphate.

BERRY LAKE

Berry Lake is located in Section 30, Township 35, Range 25, and Sections 23, 24, 25 and 36, Township 35, Range 26, West of the Second Meridian. It is about seven miles east of the Prince Albert branch of the Canadian National Railways and a similar distance north of the Winnipeg-Saskatoon line of the Canadian Pacific Railway. The lake occupies about 935 acres which includes 150 acres of islands.

The Brine and Salt Bed

This lake is dry most of the time, and more than six inches of brine would be unusual. The brine reaches very high specific gravities, as it contains substantial amounts of magnesium sulphate. About three inches of clean intermittent crystal is formed. There are two main crystal beds in the southwestern part of the lake, and a number of smaller ones in the remainder. Maximum thickness is 10 feet, and the average for the various beds runs from 2 to 5 feet. The quality of the bed is quite good as shown by the averages of analysis of all Cole's drill cores: insolubles 4%, $CaSO_4$ 4%, $MgSO_4$ 3%, Na_2SO_4 85%. The deposit contains 800,000 tons of sodium sulphate. It was leased in the twenties, but no development has taken place.



(Photograph by Department of Mineral Resources)

VII. LYDDEN LAKE SODIUM SULPHATE DEPOSIT

When this lake has a foot or more of brine on it, it looks like any freshwater lake.

GRANDORA

The Grandora deposit is about one-half mile north of Grandora, a station of the main line of the Canadian National Railways, 14 miles west of Saskatoon. The Winnipeg-Edmonton branch of the Canadian Pacific Railway is only one-half mile north of the deposit. The lake is about 1½ miles long and has an average width of 900 feet.

The Brine and Salt Bed

The lake is in a flat area and its basin is only a few feet below the general level. There is very little brine on the lake at any time, and it is separated from the crystal bed by a layer of mud and sand up to 18 inches thick. The crystal bed contains an average of 20% insolubles and 75% Na_2SO_4. The total sodium sulphate in the deposit amounts to 600,000 tons.

LYDDEN LAKE

Lydden Lake is the northerly of a pair of lakes occurring in Township 35, Range 17, West of the Third Meridian. It is crossed by Highway 51, an excellent road from Biggar to Kerrobert. Springwater, on the Loverna branch of the Canadian National Railways is three miles distant. The lake is about five miles long, and for the most part is 600 to 1,000 feet wide. The area covered is approximately 400 acres.

The Brine and Salt Bed

When Lydden Lake was first investigated in May 1947, there was only four inches of brine (s.g. 1.22) and four inches of intermittent crystal. On subsequent visits in the recent wet years there has been much more brine. There was 18 inches in May 1951 (s.g. 1.094), 16 inches in July 1951 (s.g. 1.160) and 27 inches in May 1952 (s.g. 1.055). When drilling was attempted in May 1953 there was 21 inches of brine present. Some analyses are given below.

	May, 1947	May, 1951	July, 1951
$MgSO_4$	14.1%	2.4%	3.5%
Na_2SO_4	5.9	7.7	12.4
NaCl	1.1	0.2	0.3
TOTAL	21.1	10.3	16.2
Specific Gravity	1.22	1.094	1.160
Depth, inches	4	18	16

When there is sufficient spring run-off and rain, a foot or more of intermittent crystal forms. The lake was drilled in 1954[8].

The permanent bed covers about 100 acres on the west side and 160 acres on the east side of No. 51 Highway. It has an average thickness of 9.5 feet, and does contain quite a lot of mud in places. The top three feet is clean. A sample contained only 2.2% insolubles, 2.7% $MgSO_4$, and 1.5% $CaSO_4$. The total sodium sulphate available is 907,000 tons. For commercial production, this lake might be operated in conjunction with Eins Lake, a few miles west.

MINOR DEPOSITS

There are a number of smaller deposits which contain from 100,000 to 500,000 tons and may be of value when the larger deposits are

TABLE XIV

SODIUM SULPHATE DEPOSITS CONTAINING 100,000 TO 500,000 TONS

Name	Location	Estimated Tonnage	Nearest Rail
Chain Lakes	Tp. 16, 17, 18, R. 20, W3	350,000	Hazlet, Verlo—1 to 8 miles—C.P.
Boot Lake	Sec. 20, 21, Tp. 15, R. 20, W3	300,000	Verlo—12 miles—C.P.R.
Richmond Lake	Tp. 35, R. 14, 15, W3	300,000	Biggar—4 miles—C.N.R.
Eins Lake	Sec. 5, 6, Tp. 36, R. 18, W3 Sec. 32, 33, 34, Tp. 35, R. 18, W3	250,000	Handel—6 miles—C.P.R.
Akerlund Lake	Sec. 4, 5, 6, Tp. 41, R. 23, W3 Sec. 31, 32, 33, Tp. 40, R. 23, W3	200,000	Swinburne—1 mile—C.P.R.
Coral Lake	Sec. 14, 23, Tp. 14, R. 20, W3	200,000	Carmichael—9 miles—C.P.R.
Fusilier North	Sec. 17, Tp. 34, R. 27, W3	200,000	Fusilier—5 miles—C.P.R.
Horizon South	Sec. 28, 29, Tp. 6, R. 24, W2	200,000	Horizon—2 miles—C.P.R.
Neola Lake	Sec. 19, 20, 29, 30, Tp. 35, R. 13, W3	150,000	Neola—½ mile—C.N.R.
Regina Beach South	Sec. 25, Tp. 20, R. 22, W2	100,000	Valeport—4 miles—C.P.R.
Wiseton South	Sec. 32, Tp. 23, R. 12, W3	100,000	Wiseton—21 miles—C.N.R.

exhausted. At two of these—Fusilier North and Regina Beach South—attempts were made to develop them despite their small size.

Soda Deposits Limited acquired the mineral leases to the Fusilier North deposit in 1920. A plant was built which consisted simply of a shed containing a number of trays in which the salt was spread and air circulated around it. The diffusion rate was so slow that vast areas of trays would have been required to produce commercial tonnages. The small amount of dry sodium sulphate produced was trucked to Fusilier. Operations ceased in 1923. The company was reorganized in 1927 as The Sodium Sulphate Refining Company, which planned a 350-ton dehydration plant near the railroad at Fusilier, the raw salt being trucked from the deposit. The company was not successful as it went into liquidation in 1931, and the plant was acquired by Dominion Sodium Refineries Limited. It was operated intermittently at about 50 tons per day during the period from 1931 to 1938, but total production was very small.

Glauber's salt was harvested and shipped from the Regina Beach South deposit for a number of years entirely by manual labor, using scows into which the crystal was shovelled, and then taken to shore. In 1933-34, Fred Solomon of Regina erected a small experimental plant to test a method of drying which he had devised. A twin-shell drier was used, with hot gases passing down the annulus, and the salt down the centre. Scrap iron was added to the charge to provide greater heating surface and a heating action to hinder caking. The project was abandoned after a few trial runs.

Table XIV is a compilation of pertinent information on the smaller deposits. In addition to these, there are some deposits which were investigated, which contain less than 100,000 tons. These deposits and their locations are given below.

Court South	Sec. 23, 26, Tp. 32, R. 28, W3
Hatton North	Sec. 11, 12, 13, 14, Tp. 13, R. 29, W3
Hatton East	Sec. 2, Tp. 13, R. 28, W3
Maple Creek North	Sec. 1, 2, 11, 12, Tp. 13, R. 26, W3
Collard Lake	Sec. 20, Tp. 41, R. 24, W3
Broadacres	Sec. 26, 35, Tp. 35, R. 21, W3
Landis Lake	Sec. 16, 21, 23, 26, 27, Tp. 37, R. 18, W3
Gull Lake North	Sec. 35, Tp. 14, R. 19, W3
Webb North	Sec. 19, 30, Tp. 15, R. 16, W3
Meacham Lakes	Tp. 36, R. 27, W2
Dryboro and Burn Lakes	Sec. 7, 8, 9, Tp. 9, R. 26, W2
Wheatstone South	Sec. 29, Tp. 8, R. 24, W2
Blooming North	Sec. 1, 2, 11, 12, Tp. 3, R. 16, W2

There are undoubtedly more of these smaller deposits which have not been investigated. It is doubtful if any will be of commercial value in the near future.

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