



The Salt Industry at Sterling, Kansas.

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Arts

By

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BIBLIOGRAPHY.

Works from which material has been drawn for use in this thesis are the following:

Encyclopedias:- Americana, Britanica, New International, Nelson's.

Davis' Physical Geography

Dana's Manual of Geology

Winchell's Sketches of Creation

Ostwald's Principles of Inorganic Chemistry

Walker's Introduction to Physical Chemistry

University of California Publications, Botany
Volume 2, Numbers 8, 9, 10, 11

Botanical Gazette, Volumes 42, 44

Smith's General Inorganic Chemistry

Kansas City Star, July 11, 1897

Haworth's Mineral Resources of Kansas, 1897

Scientific American and Supplement

Water-Supply Paper 273, United States Geology
Survey

Mineral Resources of the United States, 1911.

Origin of Salt.

Those who take to the nebular hypothesis of the earth's origin have little difficulty in believing with Professor Alexander Winchell, in "Sketches of Creation", that at some stage of development all the heavier elements, as Si, Al, Fe, Ca, K, Na, etc., constituted a molten globe which was surrounded by lighter elements, H, O, C, S, Cl, etc., in the gaseous state. When sufficiently cool O and H united to form water which fell as rain, bringing down C, S, Cl, etc., in form of acids which united with various mineral elements forming carbonate of lime, gypsum, Glauber and Epsom salts, sodium chloride, etc.

How the Ocean got its Saltiness.

If we believe the above we can easily agree with the same author in saying that the ocean got salt as a result of chemical actions between fire-born rocks and the chemical acids washed down by primeval rains. Carbonate of Lime, refusing for the greater part to be dissolved in the sea water would settle to the bottom and become limestone, while Chloride of Sodium remained in solution, and this gave its characteristic salinity to the sea.

Of course we have those who claim that the ocean always has been, and still is, receiving its salt from the land, and they proceed triumphantly to determine the age of the ocean thereby; but it ought not to be hard for us to believe with Professor Winchell and other geologists that the land came up brine-soaked from the sea, and that in giving salt to the sea through the rivers, the land is only returning a part of its borrowings. Indeed, it is estimated that if all the known salt on land were dumped into the sea, it would add only about 6% of what is already there.

Formation of Salt Deposits.

Again we can almost completely agree with Professor Winchell and other geologists in saying that all salt beds are dried up remnants or gulfs of the ocean.

A minor exception is the Sambhar salt lake in Northern India, over four hundred miles inland, which appears to receive at least a great part of its salt from dust-laden winds, the salt being lifted from the sea as spray and blown inland. Analysis of the air indicates the addition of three thousand metric tons of salt per annum, to the lake in this way. Of course the surrounding land is receiving salt in the same ratio.

Another minor exception is the drainage of Lake Titicaca in South America. This water does not reach the ocean but after flowing one hundred to three hundred miles, it spreads out on level plains and evaporates, thus forming broad salinas, the largest being four thousand square miles in area and covered with a layer of white salt about four feet thick.

Of course the salt is dissolved in minute quantities from the soil around the lake. The lake serves as a settling basin from which the water flows clear, but carrying the salt in solution to be deposited almost pure on the salinas.

Any inland lake if evaporated to dryness would leave a surface coating containing more or less salt.

Any inland lake lying in a drainage basin and having no outlet other than evaporation will be salty and if it persists will increase in saltiness. It matters not whether such lake were ever connected with the sea, if it were eventually evaporated to dryness, it would leave considerable salt beds. So long as inlets continue to flow, the point of saturation would hardly be reached, but it may be closely approached.

Saturated brine at 15⁰ C would be 36% salt.

The average salinity of the ocean is 3.5%; that of Great Salt Lake, Utah, is 18%; that of the Dead Sea, Palestine, is 24%; that of Lake Van in Eastern Turkey is 33%. The latter is the densest known body of water. The presence of other Chlorides or other Sodium Salts in such

water might cause salt beds to be ppt'd on the bottom.

However, all these are only minor exceptions to the common rule that salt beds are remnants of dried up gulfs of the ocean.

A striking example, until men spoiled it seven years ago, was the Salton Sink in Southern California. Here a portion of the Gulf of California had been cut off by deposits of silt at the mouth of the Colorado River and had evaporated to dryness, leaving a sink or portion of land lower than sea level. The track of the Southern Pacific Railway extended through it. Some ten years ago men rushed in there and began irrigated farming and land speculating. In the lowest part they found a thick deposit of pure salt. They began plowing it and throwing it into "windrows" with roadscrapers and piling it up in huge piles dumping it into cars on the nearby tracks and shipping it away. It was the most paying salt industry known for a little while, but soon the tinkering irrigators let the Colorado River in on it, and covered millions of tons of harvested salt with silt, and buried it all in the "Salton Sea".

Here was a salt bed formed in the Quaternary or most recent, viz. the present, geological era, and if the situation and the salt and the inundation were not enough to convince men that the beds were of marine origin there were remains of sea animals present to confirm it.

Occurrence of Salt Beds.

In the sedimentary deposits of nearly all geologic eras back to the primary rocks, men find somewhere in the world, deposits of salt. Some now in actual formation are at the Dead Sea, Great Salt Lake, Lake Elton in Astrakhan, The Bitter Lakes at the Isthmus of Suez, The Kara Boghaz on the shores of the Caspian Sea, the Limans of Bessarabia, the Rann of Cutch in India and parts of the Sea of Azoff.

By way of interesting variety, a hanging salt bed is being formed as a roof over a lake nine miles long and seventeen miles wide at Obdorsk in Siberia. A heavy coat of crystals formed at the surface and the water sank away, leaving the crust suspended. Occasional inflows from the surrounding salty shores flow over the top and evaporate, leaving the salt roof thicker each time.

The rock salt deposits of Louisiana on Avery Island and the Island of Petit Anse are counted as recent. Those of Bayonne, Dax, and Camarade in France are Tertiary.

Those of Wieliczka in Galicia, Cardona in Spain and some in Algeria are Cretaceous. Those of Austria, Central Germany and Western England are Triassic. Those of Kansas, Yorkshire in England, the Punjab in India, and a vast extent in Russia are Permian. Those of the Northern counties of England are Carboniferous. Those of Michigan, Ohio, and West Virginia are Lower Carboniferous. Those of New York and Canada and the deeper beds in Michigan are the Salina Series of the Upper Silurian.

Abundance of Salt.

Kansas has a bed of rock salt perhaps eighty miles long, forty miles wide and two hundred feet thick, at a depth of seven hundred to one thousand feet. Utah has four hundred million tons evaporating in Great Salt Lake. Ohio has a bed five hundred feet thick at a depth of two thousand feet. New York and Michigan have beds of salt and shale several hundred feet thick and in some places reaching the surface.

Cordona, Spain, has a hill of rock salt five hundred feet high. Persia is said to be the most favored country in abundance of salt. Russia has inexhaustible deposits almost coextensive with its vast Permian formation.

England has beds of salt one hundred feet thick, four hundred fifty feet below the surface.

Austria and Austrian Poland have beds extending two hundred fifty miles and two hundred feet thick, at a depth of one thousand feet. At Sperenberg, near Berlin, Germany, there is a bed of rock salt four thousand feet thick.

Uses for Salt.

Salt is the starting point in preparation of metallic sodium and of all other sodium compounds. In the electrolytic process, salt liquor or brine is used in production of soda ash, sodium bicarbonate and sodium hydroxide.

Salt is used in the production of HCl.

Salt is used in refrigeration and in cold storage.

Salt is used in giving assurances of hospitality, in making covenants and as offerings to the gods.

Salt is used as a preservative of fish, hides, meats, and hay.

Salt is used in the chlorination process for the reduction of silver from ores.

Salt is used both as a fertilizer and as a weed killer.

Salt is used for glazing stoneware.

Salt is used in melting snow and ice from street railways.

Salt is used as an emetic and in neutralizing poisons.

Salt is used as a preservative and condiment in butter and cheese, and as a condiment in vegetable and meat foods.

Salt is used in stock feeding. Horses learn the days of the week by salt. If young horses pasture in a rugged open country and their owner is accustomed to salt stock on Sundays only, these horses come home only on Sundays. Sheep are very fond of salt. In the mountains of Eastern Oregon and Washington, trains of pack horses and mules are kept going all summer, each animal going in with about two hundred fifty pounds of salt for the sheep.

Salt is the source of the HCl which forms an essential part of the digestive secretions of the vertebrate stomach. There has been much controversy as to why vegetable eaters require more salt than meat eaters. A carnivorous animal will not touch salt while an herbivorous animal will take as much pains and risk to get salt as to get water. A travelling white man could hardly take to an inland, vegetable-eating savage in a saltless country, a more acceptable gift or a more tempting article of merchandise than a lump of salt.

The carnivorous animal needs salt but gets enough from its meat food. It has been attempted to explain the greater demand of the herbivorous animal for salt in the following way:

That vegetable matter contains far greater quantities of K than does flesh and that K readily enters the cells of the animal body and there stimulates the excretion of salt; more salt is required to make up for the heavy loss by excretion. Whether this be the true explanation, it is certain that horses and men excrete large quantities of salt through the skin and kidneys.

Since there is no common Indo-European word for salt, it is inferred that salt was first used as an aliment at the transition from a pastoral and nomadic to a sedentary and agricultural life.

Correlation of NaCl and Other Salts in
Living Cells.

There is no lack of biologists who attribute many of the vicissitudes of plant and animal cells to disturbances of osmotic pressure. We know, however, that eels go down to the sea to spawn, and salmon come up from the sea to spawn. Professor W. J.V. Osterhont dropped the osmotic theory when he observed members of all great classes of algae adhering to the steamers plying on the waters tributary to the Bay of San Francisco. On a steamer arriving at the city in the morning these algae are in sea water of 2.7% salinity. In five or six hours the steamer is unloaded and the algae are raised out of the water and become dry and very hot and covered with an incrustation of salts. In another five or six hours they are submerged again by loading the vessel. In the evening the steamer puts off for inland points and the algae experience all degrees of salinity from that of the bay to that of perfectly fresh water, and changes of temperature amounting in the twenty-four hours to 70 or 80 degrees, F., and all without any ill effects.

Osterhont took to the laboratory from a tide flat, three kinds of marine plants, *Iyngbya aestuarii*, *Enteromorpha Hopkirkii* and *Ruppia maritima*. These lived in the laboratory five or six months in ordinary sea-water. In distilled water they lived one to three months. In tap-water they lived longer than in distilled water. In sea-water to which three or four volumes of distilled water had been added, they lived nearly as long as in ordinary sea-water. In saturated sea-water they lived nearly as long as in ordinary sea-water. The same is true of the more delicate algae. Hence it was concluded that osmotic pressure plays but a small rôle in the life processes of many plants.

Osterhont then experimented with both marine and fresh water plants by growing them in solutions containing the several sea salts in various numbers and proportions. The solutions were all isotonic so as to eliminate the osmosis factor. It was found that the plants soon died in a solution of any one of the salts alone. Each salt was therefore regarded as poisonous to the plants when used in concentration.

so great as to be isotonic with sea-water.

The poisonous effect of NaCl largely disappeared on addition of a little Ca Cl₂. Addition of K Cl to the mixture of Na Cl and Ca Cl₂ enabled the plants to live still longer.

Since the anions were here all identical, it was concluded that the poisonous effects are due to the metal ions. Distilled water prepared in contact with a metal kills the plants.

Addition of Mg Cl₂ and Mg SO₄ to the above mixture enabled the plants to live practically as long as in sea-water. Although Ca Cl₂ added singly to Na Cl inhibits the poisonous effect of Na Cl the same is not true of K Cl or Mg Cl₂ when added singly to Na Cl.

It was also concluded on further experimentation that the poisonous effect of Mg Cl₂ is inhibited by K Cl added singly but not by Na Cl singly. Professor Jaques Loeb found practically the same results with animal cells. The general conclusion is, not as some biologists would put it, that each of the salts found in sea-water is necessary for the maintenance of the life of the cell, but only for the purpose of counteracting the poisonous action of some other constituent of the solution.

Salt Industry in Various Countries.

For centuries the Arabs have collected salt crystals from the shores of the Dead Sea and sold it throughout Syria.

The same method is known in Siberia.

Australia, also, has many salt lakes.

The peoples living on the shores of the Mediterranean Sea evaporate the sea water in the sun. Tramp steamers can lay this salt down very cheaply in the ports of the Atlantic and Indian Oceans. Indeed they sometimes bring it to the United States for practically nothing, as ballast. Inland salt makers cannot easily compete with it. It would be foolish to expect our Atlantic fishermen to cure their fish with Kansas salt. The sun and the steamship can work more cheaply than coal and the railroad.

For such reasons the salt industry of Great Britain has dwindled steadily for some years. In twenty-two years her exports shrunk one half. She has no effective sunlight and all her salt plants are inland, and all pump

brine. Heretofore they have evaporated in open pans fired by Mond gas and coal. Competition has driven all producers into a union which practically owns and manages all the plants in common. Two striking improvements have recently been made. One is the Hodgkinson process for open pans heated over fire. By newly designed stirrers any size of crystal which is known to the trade can be precipitated directly. This eliminates all subsequent labor and expense in preparing various grades. In addition, the fuel is completely burned and the heat extracted by the pans to such an extent that the flue gases are cool when drawn off by a fan. The result is seven to ten tons of salt per ton of coal.

The other improvement is at a new works located at Weston Point, on the Manchester ship Canal and thus practically on the seaboard. It receives brine through a pipeline twelve and a half miles long. This plant works on a triple-effect vacuum evaporation system. Brine in open pans will boil at 226⁰ F. At the new plant it is made to boil at a much lower

temperature. There are three evaporators coupled tandem. Preliminary heaters raise the brine to 140⁰ F. It is then charged into the evaporators. Exhaust steam of the engine plant is admitted to the first evaporator and warms the brine, then passes to the second and warms it less and condenses, causing a partial vacuum in the first where the brine then boils violently. The vapor thus produced passes on through the second into the third and is there condensed by the brine, causing a partial vacuum in the second, whereupon the second boils. Vapor thus produced in the second goes over to the third and warms it slightly and is condensed by a jet condenser, whereupon the third boils.

Each evaporator has its own electric propeller stirrers and its own electric elevator to remove the salt. Nearly all the handling is done by electric conveyors until the salt is discharged through chutes directly into the holds of ships. The capacity is near 200,000 tons per annum, of a superior article produced at a cost which competes with the solar process along the Mediterranean coast.

Germany has an abundance of rock salt mines. In order for salt beds to escape dissolution by surface waters in a humid climate they must generally be not much less than a thousand feet below the surface.

The oldest known and most notable rock salt mine is a government monopoly at Wieliczka in Galicia or Austrian Poland. This mine has been worked continuously for near a thousand years. Here is a great city with streets and alleys, homes, churches, theatres, and many wonderful things carved out of the salt and all a thousand feet underground. The ponies which draw the cars on the railways have had no use for eyes for so many generations that they are now born blind. There is a subterranean river, lakes and ferry boats. Blind fish inhabit these waters. A ballroom three hundred feet long and one hundred ninety feet high is a feature. Six thousand men work there in three eight hour shifts, at twenty cents per day.

In Germany near Stassfurt, the KCl of the original salt brine has been found in beds near the top of the rock salt. Metamorphosis has combined it with $MgCl$ and $NaCl$ so that the separation of the KCl and the explanation

of its origin and relations has been a great whetstone for the wits of chemists and geologists.

Economically also the K Cl is more important than the Na Cl, since this is the one great supply of the world. However, rock salt is mined in great abundance in Germany.

In the United States.

In the United States all sorts of methods of obtaining salt have been followed, but most of the salt supply was imported prior to 1878. Spaniards, Mexicans and Indians gathered salt crystals on the shores of Alameda Bay, where the sun evaporated the sea water in natural pools. Plows and road graders enabled men to gather unlimited quantities of salt from the surface of the Salton Sink.

At Great Salt Lake men throw a dirt embankment around one or more acres of the low shore land, or mud flats, then pump the lake water into these artificial reservoirs and let the sun evaporate it. Then they plow the salt and gather it with road graders. 30,000 tons per annum are thus secured.

Near the site of Syracuse, New York, Jesuit missionaries were shown salt springs by Indians in the seventeenth century.

The source of the brine is in the denuded Salina Formation of the Upper Silurian System. The rock salt beds naturally dissolved away in the surface waters and fortunately left a low bog, eight to fifteen miles wide, extending westward across the state from the Mohawk river to the Niagara river, thus making a natural roadway for the Erie Canal and the New York Central and other Railways connecting New York City with Buffalo, and the West. At Syracuse since 1788 the brine from springs and shallow wells has been evaporated in the sun or in kettles and pans over fire. In 1878 rock salt beds were discovered beneath the surface. Wells were sunk to these beds and by the leaching process New York has come to be the largest producer of salt among the states today. Michigan stands second. The Salina Formation extends westward through Canada into Michigan and southward into Ohio. In Canada it is protected by glacial drift and in Michigan and Ohio, it dips and is protected by later formations. Extensive salt wells are operated at Goderich, Ontario.

near Lake Huron. Ohio stands third and Kansas fourth today in salt production in the United States. Since the discovery of rock salt in this country we produce nearly all the salt consumed by us. A little is imported by the Atlantic fisheries because of cheap ocean transportation. Probably the first rock salt mine in the United States was opened in 1867 on Avery Island, La.

In Kansas.

Salt has been found in Kansas since earliest times. The saliferous shales of the Pennsylvania Series extends over the Eastern portion of the state, and those of the Dakota formation across the middle. Between these the great salt beds of the Permian have been exposed and eroded. Brackish lakes and marshes are numerous from which salt has been taken, and shallow wells have supplied a good deal of salt, notably at Solomon from wells seventy-five feet deep, where solar evaporation was employed. In the fall of 1887 when prospectors were pricking the deep crust far and near in search of oil and gas here, the drill struck rock salt, first at Wellington at two hundred fifty feet, then at Ellsworth, then at Hutchinson, then at Lyons, at

depths of seven hundred to one thousand feet, the beds of salt being three hundred to four hundred feet thick. Probably a triangle with vertices at Kingman, Kanopolis, and McPherson would include most of these beds.

They are found to underly parts of the counties of Ellsworth, Barton, Rice, McPherson, Stafford, Reno, Pratt, Kingman, Sedgwick, Harper and Sumner. Salt making plants soon sprang up throughout this territory. There were seven plants in the one little town of Kingman. The first to make salt was at Hutchinson, which has kept the lead until the present time. About twenty-five wells are located there. Sterling was not far behind in point of time, as it began saltmaking January 1, 1889, with one well. In 1890 a shaft was put down at Lyons and rock salt mining has continued there ever since. An expert English coal miner, Jesse Ainsworth, the superintendent, has been with it from the beginning and to him no doubt, much credit belongs for the perpetuity of the works. Mines have been opened at other points, notably

Kingman and Kanopolis, the latter being under the same management as that at Lyons. The one at Lyons and a more recent one at Little River are perhaps the only ones in operation today. There are two reasons for this. First, there is but a small margin of profit in salt, say twenty-five dollars per car. A salt mine cannot afford to run pumps to free itself from water. Therefore wherever the underflow of the Arkansas River is present, a salt mine would be sure to fail, e. g., in Sterling or Hutchinson. A second reason is impurities, giving salt a red color at Kingman. A third reason is the limited demand for rock salt among the over-prosperous, over-particular American people. About the only use of rock salt here is in curing hides and fish. The fisheries are practically out of reach of Kansas because of carrying charges. The Lyons mine has a capacity of one thousand tons per day and that about suffices for the demand. The salt is crushed in rolls and graded. The mine is one thousand feet deep. The elevator makes this distance in forty seconds. The main street in the mine is one hundred feet wide and has a permanent track. Side streets are made at right angles at either side. These are fifty

feet wide with fifty-foot walls of salt left between, to support the earth above. These side streets are supplied with temporary tracks which are handled in sections.

In November 1911, an evaporating salt company began work at Lyons. There are also evaporators at Hutchinson, Ellsworth and Anthony.

At Sterling.

Here, two companies have labored. One, the Sugar and Salt Company failed before making a pound of salt. Their well is midway between the Sterling Salt works and Missouri Pacific Station. It is owned by the Sterling Salt Works today. Its buildings also were moved to the Sterling Salt Works.

Sterling Salt Works Company.

On August 18, 1888 this company was organized by the following persons who were all directors; T. H. Brown, President, Dr. P. P. Trueheart, Secretary, J. C. Turner, Vice President, J. D. Ford, and Emma J. Brown.

They built the plant along the tracks of the Missouri Pacific Railway not far from the crossing of the Santa Fe Railway. They dug well No. 1 a few feet south of the works, striking salt at seven hundred feet, and continuing to nine hundred sixteen feet through alternating beds of salt and thin layers of salty shale. They opened for business January 1, 1889, and the business has continued ever since. On December 15, 1904 T. H. Brown bought all the stock and still owns it. On February 14, 1910, nearly all the plant was burned down. By July 9, 1910, new concrete buildings were completed and salt making began again. Mr. Brown is the oldest continuous owning saltmaker in Kansas. Others who have been in the business as long have passed from ownership to managing or some other capacity.

The Sterling Salt Works is small, having a capacity of only about thirty tons per day. It has received scant notice and often none at all from those who have descanted upon the mineral resources of Kansas. Salt plants that were dead long ago have received more notice. However, the buyers of Kansas Salt have much reason to thank the Sterling Salt Works for the maintenance of stable and reasonable prices.

The many failures of salt plants in Kansas were not altogether due to inexperience and lack of funds, though this is the cause annually assigned in official documents. ~~There came a time when the big operator wanted to play the hog and kill off his small competitors.~~ American-like, though rich he was impatient of small profits and made haste in unscrupulous ways to be richer. He saw how he could sell salt at the cost of production and still make money out of it. This would kill competitors so that he and his wealthy neighbor could put the prices where they pleased after competitors were out of business. He saw how he could bleed the stock holders of the railroads for his profits while killing off the smaller plants and then later put up the prices

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and also continue bleeding the railroads indefinitely. He was ~~an~~ no need. His was perhaps the biggest salt works in Michigan, and his was the biggest salt works in Kansas and the world; and besides he owned or near owned the Colorado Fuel Company.

Under cover of his big brother who was a vice president in the Santa Fe system he built two or three freight cars and set them on his mile of private side tracks about the salt works and then misused the sovereign powers of the state by incorporating the side tracks as the "Hutchinson and Southwestern Railway". Thus he claimed and secured a share of the carrying charges on every shipment from his works. Also his "pull" with the Santa Fe gave him additional rebates which every other competing railway felt compelled to meet.

By such tactics all competing wells outside of perhaps Hutchinson and Sterling were killed at the expense of the railroads only. Years later the Interstate Commerce Commission declared the "Hutchinson and Southwestern" to be only a rebating scheme.

Why did the Sterling Salt Works not perish with the others?

It so happened that none of the Sterling people depended on saltmaking for a living. They sold salt whenever they could do so at a profit and whenever they could not, they did not sell.

Salt did not deteriorate nor go out of fashion when held, nor did its manufacture require any skilled labor to be kept in touch with during idle periods.

Finally the stockholders discovered a move of the enemy that would help their cause. The Hutchinson people began selling under a guarantee that they would meet any price offered before remittance was made.

Now the Sterling company had a list of all patrons of the industry from Texas to Dakota; so the stockholders held a meeting and sent out about a thousand quotations at ten cents per barrel, or ten dollars per car, less than cost of production. Of course every patron of the Hutchinson people having salt on account, would settle up at the Sterling quotation.

In cases where the quotation brought orders to Sterling, a reply was sent saying: "We are out of salt but think you can get it at Hutchinson".

Soon the manager from Hutchinson appeared in Sterling and inquired of the Sterling brethren how they were getting along. They replied that they were "feeling fine". In a very few days an agreement to stop cutting prices was concluded.

Mr. Brown is very kind and considerate of his customers and easily retains a nice trade by mail without any solicitation. He was considerate of his enemies also when they sought to destroy his company's business. He told them frankly that his plant was not a means of support and that they never would succeed in killing it. He wrote to the owners of the railroads and pointed out the folly of their assuming enormous losses in transportation just for the sake of killing one little insignificant salt works at Sterling. ~~He assured them that~~
~~that would be broken up and they would be~~
~~sterling or otherwise even they succeeded in~~
~~closing the Sterling Salt Works~~

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Location of Works.

The Sterling Salt Works is located on the east side of the Missouri Pacific tracks only a few hundred feet from the Santa Fe Railway. (See photograph)

Location of Brine Wells.

The first well is near the southeast corner of the works. This eventually caved in about five hundred feet below the surface, it being perhaps a two hundred-forty foot layer of slate or shale that fell. The second well was then bored north of the works three hundred feet from the first.

The well purchased from the Sugar and Salt Company is one thousand feet north of the works and about two hundred fifty feet east of the Missouri Pacific Railway track.

Location of Fresh Water Wells.

The well supplying water to the brine wells is just across the Missouri Pacific Railway tracks westward of the works.

The first well for boiler water was twenty-four feet deep and close to the north side of the works.

It became contaminated by brine seepage and was abandoned.

The one in present use is one hundred feet north of the works and forty-eight feet deep. Near the latter is a well used for drinking water.

Source of Fresh Water.

The only source is in the sixty-two feet bed of sand near the surface. This water is the underflow of the Arkansas River lying three miles to the south. The log of the test well at the Sterling Water Works shows the general features of this water supply.

Sand Mine.

Sand is mined in connection with the salt works. There is a large open sand pit containing water two hundred feet southeast of the works. A centrifugal pump run by a gasoline engine delivers the sand and water through a seven-inch pipe into cars whence the water hurries back to the pit and leaves the sand in the cars on a switch.

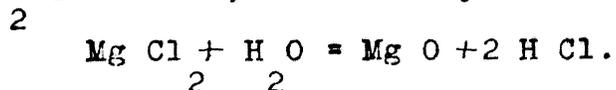
Location of Brine Dump.

To empty the pans a wooden plug is pulled from

a pipe extending from the bottom at the west end of each pan. The brine escapes through drains to the ditch along the Missouri Pacific Railway tracks about one hundred feet from the mine supply well across the tracks.

Contamination of Fresh Water Wells.

Since there is a sixty-two foot bed of sand only eight feet below the general soil surface, it would seem that here is a chance for $Mg Cl_2$ to pass in a pernicious circle from pans to mine and back to pans. Our analysis indicates this condition in spite of the fact that the underflow moves in opposition. The first well for boiler water also became contaminated from the brine dump. This is dangerous to boilers, since $H Cl$ results by hydrolysis when a solution of $Mg Cl_2$ is heated, as shown by the following reaction.



The writer found holes in a brine-bespattered coat after visiting the salt works. Being suspicious of its being the work of $H Cl$, a piece of the same garment was dipped in the hot brine but with negative results. Perhaps the $H Cl$ if formed in the pans is so volatile that no appreciable amount accumulates. Such escape is not possible in a boiler.

Treatment of Boiler Water.

The water is not softened. Use is made of a specially prepared graphite so finely divided that it remains in suspension. It forms a protective coating on the shell and tubes of the boiler to hinder the adhesion of scale. At the end of two weeks service each boiler is emptied and cleaned out, the scale being dislodged by a stream of water from a hose.

Location of Boilers.

The boilers are at the northwest corner and extend along the West side. Beginning at the corner we find first three large boilers and a smokestack all put in after the fire. Next there are four boilers and a smoke stack which were in use before the fire. The boiler room was about all that escaped the fire. A switch for coal lies along the west side of the boiler room.

Location of the Pans.

The pans are at the southwest corner of the works and lie east and west. The series of pans extends along the west side to the boiler room.

Location of Storage Room.

This extends along the east side of the works where a switch accommodates the cars while being

loaded with salt.

Other Buildings.

A stave shed where barrels are set together is located north of the works. An office and a garage lie southeast of the works.

Piping and Operating the Brine Wells.

For geological section of the wells see log at the back of this thesis and compare with log of Lyons test well.

An eight-inch drive casing is put down to rock, about one hundred sixty feet. A five and five-eighths inch pipe is put down inside the drive casing and sixty feet further and is cemented to the rock at bottom. A two and one-half inch pipe is put down inside of both the others and two hundred fifty feet into the salt beds. It is connected tightly with the five and five-eighths inch pipe at top. From the five and five-eighths inch pipe connection is made with the storage tank⁷¹. The fresh water well is connected with a double-action pump and the pump is connected with the two and one-half inch pipe. The pump pressure of ninety to one hundred pounds is sufficient to fill the cavity in the salt^a beds with water and to force the resulting brine up through

the five and five-eighths inch pipe into the storage tank. The pump pressure is kept on all the time, though it is varied according to needs. Under the arrangement now to be described there is no waiting for the brine to become saturated. When the first well caved in, the second was bored, but it gave a weak brine. Then the purchased well, one thousand feet away from the pump was coupled on with the second. This required a pump pressure of one hundred eighty pounds, or twice that required to pump from nearby wells.

Later it was discovered that the second well had become connected with the cavity at bottom of the first. From that time the purchased well was shut off and the fresh water was pumped into the second and the brine received from the first. In this passage of three hundred feet through a large cavern, the brine becomes practically saturated without any waiting.

Another advantage is that for some unknown reason the second well always produced more gypsum than the first. Under the present arrangement the excess of gypsum is not manifest. At some works it is said to be nec-

essary to put down a special casing to shut off the gypsum.

Distribution of Brine.

The storage tank south of the works, acts to some extent as a settling tank. However, the salt beds are so pure that very little mud accumulates. Some salt is precipitated here. From this tank the brine flows into a pan called the "settling pan". Here are two sets of steam pipes, one carrying exhaust steam from the evaporating pans and returning this as condensed water back to the feed water for the boilers. The other set of steam pipes carries auxilliary live steam from the boilers in sufficient quantity to get the temperature of the brine up to that of the evaporating pans. This small amount of auxilliary steam is not returned to the feed water.

From the "settling pan" a pipe extends across the west ends of the three evaporating pans and supplies all of them with hot brine; (See flow-sheet.)

Evaporating Pans.

These three pans are about ninety feet long, twelve feet wide and eighteen inches deep. They are made of steel but when they begin to leak by reason of corrosion after six or seven years use, they are lined throughout with concrete and become concrete pans. Two of the three have been thus transformed, their walls being about six inches thick. It is believed by the owner that they will lose less heat than steel pans lose.

The brine stands about one foot deep in these pans. Through the brine and about five inches from the bottom, a system of pipes carries live steam to produce evaporation. In each of the concrete pans eight three-inch pipes run lengthwise. In the steel pan sixteen two-inch pipes run lengthwise. These pipes are connected in a continuous circuit in each pan.

Salt Separation.

Since the evaporated water escapes at the surface, the brine is left most concentrated at the surface; hence the salt is precipitated

at the surface and goes tumbling to the bottom whenever a mass gets heavy enough to break the surface tension. For some unknown reason salt accumulates on the lower half of the steam pipes. This is removed with a broad push-hoe. If not removed early it is likely to "burn on" so as to be very difficult to remove. It is very easy to distinguish from gypsum since the latter is of a pinkish cream color and dense and smooth while the salt is white and spongy and irregular.

Raking out Salt.

A system of rakes with blades extending across the bottoms of the pans is suspended to a wooden framework rolling on wheels which rest upon a track along the upper edges of the sides of the pans. The whole system is pushed back and forth through a distance of twelve feet by long wooden pitmans attached to bullwheels operated by a small steam engine. When going westward the rake blades drag gently over the salt, but going eastward they are rigid and push the salt before them. Each blade catches what its neighbor gathered at the previous stroke and pushed it another twelve feet

forward.

At the east end of the pans the bottoms slope gently up out of the brine to a trough where the conveyor belt runs. Here the end rake dumps the salt upon the conveyor.

Storage.

The conveyor elevates the salt and dumps it from near the roof of the storage room. The salt is dumped alternately in two great heaps. While one is forming, the other is "curing" or drying and being shipped out.

Purity.

The salt is over 99% pure and cakes but little on standing. Gypsum would make it cake. After standing in the pile for months it shovels easily and a workman attempting to stand in a niche in the side of the pile will come down in an avalanche of salt. The writer filled a small sack with the salt and laid it away during two months of the driest, hottest weather. At the end of that time the salt was all easily crushed with the hand.

Shipment.

Shipments are made in bulk and in barrels of two hundred eighty pounds, and in sacks of one hundred pounds. The greater part is taken by packers in bulk. The loading and packing is all done by hand labor. A shovel and a push cart holding about one thousand pounds is all the apparatus used in getting salt into a car. We believe machinery would do this more economically.

Output.

About thirty tons of salt is produced per day. The production is interrupted every thirty days in order to clean the steam pipes in the pans.

Formation of Scale in Pans.

Under the method of heating the brine by steam, gypsum does not form on the pan nor with the salt. Above 40 C, gypsum becomes less soluble as the temperature rises; hence it is precipitated at the hottest part, viz., on the

surface of the steam pipes. In the "settling pan" gypsum is cleaned off the pipes once in two months. In the evaporating pans it is more troublesome. In thirty days it becomes one-half to five-eighths inches thick.

The optimum temperature for the pans is 205 F., since the salt "burns on" the pipes much more readily at 210 F. than at 205 F. By the end of thirty days the gypsum scale so interferes with the radiation of heat that the temperature can hardly be raised above 200 F. Then the pans are emptied and the scale is knocked off the steam pipes with hammers and carted out. Neither steam nor cold water is run through the pipes to crack the scale before using the hammer, as the owner believes such practices tend to warp the pipes.

The scale is about 81% gypsum, 12% salt and 7% volatile, presumably water. The weight of this scale produced per month was calculated by calculating the surface of the steam pipes in the brine and by weighing an average piece of scale having a measured surface on the pipe. The result was 3.5 tons per month.

No account was taken of the "settling pan". The result obtained is only about one third of the gypsum indicated by analysis of the brine. The brine thrown out is good brine saturated with salt and nearly boiling hot. This entails a great loss of heat and of brine. Probably it is unavoidable. In England at the large plant at Weston Point, a part of the brine is used in making sodium hydroxide by which the salt union eliminates the gypsum and $Mg Cl_2$ in another plant where high grades such as table and dairy salt are produced. Doubtless it is impracticable to use such a method in a small plant.

Rate of Flow of Brine into Pans.

This was calculated in the following way; Taking as a basis the sodium found in the saturated brine we find three pound of salt per gallon of brine. Ostwald says that saturated brine is 36% salt. A gallon of water weighs 8.3389 pounds and 36% of this is three pounds. To make thirty tons of salt per day would therefore require 20,000 gallons of saturated brine.

On a hot day the air is perfectly clear over the pans and it is difficult to believe that 20,000 gallons of water per day is passing off there. The writer measured the plunger of the pump and timed it with a stop watch. The plunger moves one foot and is seven inches in diameter and passes ten times in 59.2 seconds. This figures out as 29,177 gallons per day. The pump does not run at a constant rate but the above figures enable us to allow the customary ten percent for slippage and still have considerably more than 20,000 gallons of brine per day.

In the Boiler Room.

Coal slack is the fuel. Only about 10% of the total thermal units of the fuel is utilized. Formerly the best herringbone grates were used, but about November, 1912, new and improved grates and a blower were put in. By means of an automatic steam valve the blower is so regulated as to keep a constant steam pressure in the boilers. The boilers are tubular and sixteen feet long. The tubular flues in the boilers are cleaned by blowing the soot

out with live steam at the beginning of every eight-hour shift. The writer believes this to be a wasteful practice. The back ends of these flues are likely to be partially full of steam-impacted soot which acts as an insulator wasting heat and aiding the formation of more soot. An iron flue scraper used instead, once a day, would probably save some fuel.

The new grates are arranged as follows: Over the ash pit is an iron box about six inches deep and running back six feet from the doors. It occupies the full width of the furnace under each boiler. The bottom of this box has slots covered by movable shutters or flat iron bars fixed to cross pieces so as to be connected with a lever in front of the doors. By means of this lever the shutters are made to discharge all ashes through the slots and then to close the slots. Air from the fan blower is admitted to this box from the rear side.

The top of the box consists of flat iron bars perhaps ten inches wide. These are laid close and jointed with asbestos cement. In these bars are numerous circular openings about six inches in diameter and beveled to receive lids like a stove. These openings receive flat

iron rings which in turn receive iron disks or lids about three inches in diameter. By means of small lugs ⁰ 120' apart around the margins of these parts, a space about one-eighth inch wide is left both inside and outside of the flat rings.

The top of the box, then, is a smooth flat surface having in it numerous narrow circular openings. This is the grate on which the fine coal slack is burned. Through the narrow openings the air from the blower is forced and the fine ashes fall. No fuel is lost in the ashes and none in the clinkers. The clinkers from the former herringbone grates used to burn and remain hot for a considerable time after removal from the grate. They also gave off much suffocating gases. The clinkers from the new grates cool very quickly so that they are loaded directly into cars and need only a little wetting down during loading. They do not give off any gases noticeable by workmen.

Dampers in the flue partially check the escape of gases up chimney, while the blower slightly compresses the air in the grates thus increasing the available supply of oxygen in

the combustion chamber. The gases burn fiercely throughout the combustion chamber and entering the boiler tubes at the rear they continue burning in the tubes until near the front end of the boiler, at least when the tubes are clean.

The new grates and blower have reduced the fuel bill by 27% and enable two boilers to do the work of three formerly used with herring-bone grates.

The disks and rings in the grate are inexpensive, costing about ten cents each, and if burned out can be replaced very quickly and easily. So long as there is sulphur in the fuel the heavy iron sulphide clinker is bound to be formed at the expense of the grate.

Although combustion appears very complete there is a considerable amount of smoke issuing from the stack. It probably contains 8% of the fuel used. (See small photograph.) Had a mechanical stoker been put in when the change of grates was made, it would save nearly all the 8% of fuel wasted in smoke, or a ton of coal every day in the year.

The new grates did not lessen the number of workmen since there were originally only two men, a fireman and a pan-man, on a shift. The

The new grates do lessen the work of the fireman since the coal consumption is reduced by 27% and the number of grates by 33 1/3%, the fan regulates the steam pressure, the ashes are very light and cool and the clinkers cool and free from gases.

The presence of the extra boiler is a great convenience when a boiler is to be cleaned or a grate to be repaired. It eliminates the need to hurry and fight the fire and cook one's self, in order to get the matter attended to without shutting down the works. The new grates gave this extra boiler.

The steam from the two boilers does the following work: Heats the brine, evaporates twenty thousand gallons of water daily, pumps over twenty thousand gallons of fresh water, moves twenty thousand gallons of brine through the mine and elevates it into the storage tank, operates the blower, the rakers and the conveyors.

Laborers.

In addition to three firemen and three panmen daily there are in daytime, an office man,

a foreman and varying numbers to unload coal, to set up barrels and to pack and load salt. It would seem that hand labor is not economical in unloading coal. A trestle, a chute and self dumping cars would lay the fuel down in the furnace room much cheaper than a man with a shovel can do it.

Pounds of Salt per Pound of Coal.

Only cheap coal slack is used under the boilers. This is economical. It has been demonstrated at the Sterling Water Works that the ordinary fireman will actually get more work out of a ton of slack than out ^{of} _^ the more expensive ton of good coal.

The output of salt is about thirty tons per day and about thirteen tons of slack per day are consumed. This is about two pounds of salt for one pound of fuel. By Hodgkinson's method, already described, seven to ten pounds of salt are obtained in England for one pound of fuel. Doubtless his fuel is of a more expensive kind than slack, but hardly four or five times as expensive. Superiority of method accounts for most of the difference in production in the two

cases. However, since Hodgkinson fires directly under the pans he could produce only an impure salt unless he incurred a considerable expense in eliminating gypsum from the brine.

Analyses.

During the summer of 1913 the writer undertook to analyse the brine from the well, the brine after ten days evaporation, and the brine after thirty days evaporation. At the same time Mr. F. W. Bruckmiller analysed the scale from the steam pipes in the pans and Mr. R. P. Hron made a partial mineral analysis of the water which is pumped into the salt beds from the well west of the tracks.

Owing to lack of time the writer did not run duplicate analyses and as some of the manipulations were first attempts by him he does not have full confidence in some of his results. The results of these analyses are tabulated and shown herewith.

Methods.

It is proposed now to show somewhat fully

some of the methods followed in these analyses.

Total Solids.

Portions of 100 cc of the water and 25 cc of the brines were evaporated to dryness in weighed platinum dishes and the weight of solids determined by a second weighing.

Densities.

The density of distilled water and of the well water and brines were all taken on a Westphal balance at the temperature of 30⁰ C. Then all were calculated on the basis of distilled water as a standard.

Chlorine.

An asbestos mat was formed in a Gooch crucible and the whole dried to constant weight at 130⁰ C and weighed. Ten cc of brine was diluted to 50 cc with distilled water; ten drops of H N O₃ added and a solution of Ag N O₃ added slowly with stirring until no further precipitation. The beaker containing the mixture was

then heated over a boiling waterbath out of direct sunlight until the Ag Cl went to the bottom readily, leaving clear liquid. Filtered through the weighed Gooch filter under suction, Washed thoroughly with hot water. Dried the crucible and the precipitate to constant weight at 130⁰ C., cooled in dessicator and weighed.

Removal of Salt.

For all other determinations it was necessary first to remove most of the salt. This was very troublesome. First a liter of each brine was put in a porcelain evaporating dish over a boiling water bath. Soon the salt would show up in discouraging quantities and creep out of the dish, "freeze" over the liquid, attract water vapor, etc.

At first it was attempted to filter in a large porcelain funnel. A Buechner funnel with suction was soon found better, but later decantation was considered the better method. Washing was invariably with hot water which dissolves the other ingredients more readily than it dissolves salt.

It was assumed that evaporation to three-tenths volume would not involve loss of anything other than salt. For potassium determination, evaporation was carried to dryness and the residue washed with a little hot water to dissolve and carry away the K Cl by decantation. This was done because of the great cost of the reagent for potassium, since it would be used up by salt. Great difficulty was encountered in evaporating because of the tendency to spirt whenever precipitated salt thickened the liquid. After reducing to about 150 cc the slowness over the water-bath made it necessary to proceed in a casserole over a free flame. Nothing smaller than a 250 cc casserole seemed adequate. It was held in the hand and centrifuged over the flame. Even then it sometimes spirted and sometimes centrifuged out over the edge of the dish. Sometimes a watch glass was put down tight over it and it was allowed to sit on a hot plate and spirt until dry. This involved careful cleaning of the watchglass in order to prevent loss of material.

Siliceous Matter.

Evaporated 1000 cc nearly dry. Added 1 cc H Cl 1:1 and took down to dryness. Dried at 180 C ⁰ 1/2 hour. Moistened with H Cl. Expelled excess acid on waterbath. Took up with hot water, filtered, washed with hot water. Used filter whose ash weight was known. Dried filter ignited in weighed crucible and weighed.

Iron, Aluminum, and Phosphates.

Above filtrate was heated to boiling, oxidized with a few drops of H N O₃, evaporated to 25 cc, added slight excess N H O₄ H, boiled one minute and filtered. Dried the filter, ignited in weighed platinum crucible and weighed.

Calcium.

Last above filtrate evaporated to 100 cc and while hot and ammoniacal, added drop by drop a concentrated solution of ammonium oxalate. Kept warm and stirred at intervals until precipitate sank readily leaving clear liquid. Filtered, washed five times with hot water, dried filter,

ignited in weighed platinum crucible and weighed as calcium oxide.

Magnesium.

Acidulated last above filtrate with H Cl, evaporated to 100 cc, added 25 cc saturated solution of microcosmic salt, cooled, made slowly alkaline with N H O H, let stand four hours, filtered, washed with 3% N H O H, dried filter, ignited in weighed porcelain crucible and weighed as Magnesium pyrophosphate. It seemed to take nearly a day to fully ignite over a Meeker burner. Sometimes a drop or two of H N O was added to hasten it. It never got completely white.

Manganese.

From 1000 cc of thirty-day brine the salt was removed as above described, evaporated to 100 cc, added H S ϕ and dry ammonium persulphate and heated. No evidence of manganese. Tested method by reducing K Mn O with H S O and then restoring the pink color of permanganate. Tried the lead peroxide method with both

Pb O₂ and Pb O_{3 4} without evidence of manganese.

white
Sulphanion.

From 300 cc of brine removed salt, siliceous matter, iron, aluminum and phosphates as described above. Acidified with H Cl, heated to boiling, added Ba Cl₂ a little at a time with stirring till no further precipitation. Warmed and stirred at intervals for a half hour or until precipitate settled readily leaving clear liquid. Filtered, washed, dried, ignited in weighed platinum crucible and weighed as Ba S O₄

Potassium.

Evaporated last above filtrate to dryness, added hot water and saturated solution of barium hydroxide till slight film collected on surface. Filtered, washed with hot water, added to filtrate an excess of ammonium carbonate. Filtered, evaporated to dryness, dried, covered, ignited at low red heat to expel salts of ammonia. Repeated application of barium hydroxide and procedure following it until no further precipitation. Evaporated to dryness, added

25 cc of water and a few drops of H Cl, added 5 cc of platinic chloride solution. Evaporated to dryness in platinum dish, washed with 95% alcohol till no longer colored. Cut a small filter, folded it, put it in a weighing bottle. dried it, weighed it in the stoppered bottle. Washed the potassium chlorplatinate with alcohol on this filter to remove sodium chlorplatinate. Put filter in weighing bottle, dried and weighed in stoppered bottle.

Whenever potassium was determined in a portion separate from sulphur the reagents for sulphur, calcium and magnesium could be practically all added at once, but it made a precipitate of great volume and impossible to filter in the usual way. A buchner funnel and suction made the filtering of this nasty mess very easy.

Sodium.

Sodium was determined from total solids by difference, except in the fresh water where it was determined directly and sulphur was determined by difference.

Interpretation of Analyses.

West Well Water.

This water shows six times as much chlorine as the well two hundred feet north of works. As compared with the river at Sterling, the west well shows twice the total solids, 8% more silica, 12% more calcium, nearly 5% more magnesium, two and a half times as much sodium and over three times as much chlorine. It seems conclusive that this well is contaminated by the brine dump and a considerable amount of gypsum and of magnesium chloride are going around in a circle. Owing to the great solubility of magnesium chloride it may increase to troublesome proportions in the distant future unless the location of the well is changed.

The Brines.

The most prominent features are that the fresh brine from the pump is almost saturated with salt and that all three brines show over ninety-nine per cent of total solids to be salt. Saturation in the well economizes fuel.

The next prominent feature is gypsum, which

amounts to not over four-tenths of one per cent of total solids. In no case does it show two thousand parts per million which is the saturation figure. It could not do so in brine from the pans, since it is less soluble when hot. It is a nuisance but fortunately the grainer process of evaporation here used keeps it out of the salt by depositin^g it on the pipes. During the last twenty days of evaporation chloranion and sulphanion are on the increase while sodion and calcion are on the decrease. This is what might be expected. The solubility product of sodium chloride and calcium sulphate had been reached in the ten-day brine. If such soluble chlorides and sulphates as those of magnesium, potassium and sodium sulphate are present in small quantities in the well water or the salt beds, then the concentration of chloranion and sulphanion would increase throughout the period of evaporation and therefore calcion and sodion must decrease. But potassium and magnesium and siliceous matter also appear to decrease during the last twenty days of evaporation. This would seem to be unexplainable except as error. The alkaline earth and alkali metals, do not form any complex cations and the double salts which they form, such as carnallite, behave exactly as the simple salts when in solu-

tion.

Siliceous matter does not become insoluble in such solutions until evaporated to dryness.

Considering the theoretical salts present, magnesium chloride is next in abundance to calcium sulphate. It is less than three tenths of one per cent of total solids. Its great solubility prevents its precipitation and assures its draining off well from the salt. When heated it may form some H Cl to attack pipes and other iron parts in the building over the pans. It will not increase at all rapidly since the brine shows no appreciably greater concentration of it than does the fresh water of well and river.

The next most abundant substance appears to be potassium chloride which does not exceed seven hundredths of one per cent of total solids. Its great solubility and small quantity render it unimportant.

Iron, aluminum, phosphates and siliceous matter do not altogether aggregate much over one hundredth of one per cent of total solids, and are negligible.

It is assumed that there are no bicarbonates or carbonates in the brines from the pans, since bicarbonates are decomposed by heat and carbonates in the presence of calcium would

precipitate out. The scale on the pipes was tested for carbonates and the exceeding few bubbles appearing were attributed to displaced air.

The scale was also tested for iodine with a negative result.

The substances which would increase on continued evaporation of the brine are iron, aluminum and phosphates, magnesium, chlorine, siliceous matter, sulphur, and potassium.

It is not probable that the fall of temperature as the scale grows thicker during the thirty days of evaporation has any effect on the appearance of the results of the analysis.

It does not seem worth while to theorize on uses to which the waste matters could be put in so small a plant. The manufacture of hydrochloric acid or Epsom salts from the magnesium chloride would be impracticable and unremunerative. Erosion of salt beds has left in our country enormous beds of pure gypsum near the surface. Hence the gypsum is of no value. Potassium in these brines is in too small concentration and too difficult of separation to be considered. All other ingredients are in negligible quantities.

Conclusions.

1. The Sterling Salts Works management deserves credit for maintaining reasonable prices in this and neighboring states in the face of an unscrupulous monopolist who killed off other small competitors and sought to kill this one.

2. It has demonstrated the advantages of pumping water through two connected wells, two or three hundred feet apart.

3. It shows economy in fully condensing the steam in the "settling pan" and returning it to the boiler; in using slack rather than coal fuel; in the use of fully saturated brine; in the installation of an automatic regulator blower and grates which volatilize all the fuel; in eliminating the travelling salesman by fair dealing; in securing packing house patrons who buy in bulk without grading; in using worn steel pans insitu as forms for concrete pans; in maintaining a centrifugal sand loader under the same superintendence, since the foreman and office man have rather light work..

4. It would seem that further economies might be introduced by mechanical means of unloading coal and of loading salt in bulk; by

burning the smoke; by pumping from a well beyond reach of seepage from the brine dump; by use of an iron flue scraper, and possibly by cracking the gypsum on the pipes by steam heat.

It is questioned whether substitution of direct heat instead of steam would result in further economy if a salt free from gypsum is to be produced.

5. The salt in the brine is over ninety-nine per cent pure and the salt in the store-room as pure if not more so.

6. The concentration of chloranion, sulphurion, magnesion, calcion and potassion are increased by evaporation of the brine.

7. Of the cations named, only calcion is precipitated.

8. Magnesion comes almost entirely from the fresh water.

9. The findings which indicate that the concentration of potassium, magnesium, or siliceous matter in the brine decreases during evaporation are probably due to errors in the analysis.

10. No practical and lucrative use appears for any of the waste matters in the brine.

Analyses.
Parts per Million.

	Fresh Water	Fresh Brine	10-day Brine	30-day Brine
Density	1.0023	1.1978	1.2052	1.2052
Total Solids	3244	316208	321008	320912
Siliceous Matter	24.7	18.0	56.1	14.5
Chlorine	1383.2	184820	187220	199940
Iron & Aluminum Oxides & Phosphates	2.2	8.125	12.7	22.3
Manganese	0	0	0	0
Magnesium	42.97	40.55	235.1	229.9
Calcium	166.95	186.625	378.5	238.8
Sulphanion		483.6	932.0	1069.0
Potassium	Trace?	80.3	120.65	113.7
Sodium	971.2	130570	132052	119283

Analyses.

Per cent. of Total Solids.

	Fresh Water	Fresh Brine	10-day Brine	30-day Brine
Siliceous Matter	0.760	0.006	0.017	0.005
Chlorine	41.670	58.448	58.323	62.304
Iron & Aluminum Oxides & Phosphates	0.068	0.003	0.004	0.007
Magnesium	1.324	0.013	0.073	0.072
Calcium	5.146	0.059	0.118	0.074
Sulphanion	21.092	0.153	0.290	0.333
Potassium		0.025	0.038	0.035
Sodium	29.940	41.293	41.137	37.170
	100.000	100.000	100.000	100.000

Analysis
of
Scale on Steam Pipes in Pans.

Calcium sulphate	81.55 per cent.
Sodium chloride	12.04 " "
Loss on Ignition	<u>7.00</u> " "
	100.59 " "

Log of Test Well
 one hundred seventy-four feet deep
 at
 Sterling Water Works.

Soil and Sand	10 feet
(Water)	
Sticky Clay, "Gumbo",	10 inches
Sand	20 feet
(Water)	
Sticky Clay, "Gumbo",	4 feet
Sand and Water	25 feet
Clay and Shale	114 feet

Note. First sheet of water at ten feet under-
 laid by ten inches of "gumbo".

Second sheet of water at thirty feet under-
 laid by four to five feet of "gumbo".

5 Third sheet of water throughout sand at
 thirty-five to sixty feet.

No water below sixty feet. Rock at one
 hundred seventy-four feet.

Log of First Salt Well at Sterling Salt Works.

Soil	8 feet	Total
Sand	62 feet	70 feet
Clay, Soapstone,		
Lime rock ^{and} Gypsum	44 feet	114
Clay and Sand	16 feet	130
Sand	8 feet	138
Red Rock	332 feet	470
Slate	240 feet	710
Salt and Slate	12 feet	722
Salt	4 feet	726
Salt and Slate	15 feet	741
Salt	12 feet	753
Salt ^{and} Slate	10 feet	763
Salt	50 feet	813
Salt and Slate	8 feet	821
Salt	18 feet	839
Salt and Slate	6 feet	845
Salt	30 feet	875
Salt and Slate	5 feet	880
Salt	11 feet	891
Salt and Slate	5 feet	896
Salt	20 feet	916

Struck Salt Water at seven hundred. Struck Salt
at seven hundred ten.

Log of a Prospect Well Drilled for Lyons
Natural Gas, Oil and Mineral Company.

Yellow Clay	40 feet	Total
Sand Clay	10 feet	50
Yellow Clay	50 "	100
Red Shale	300 "	400
Red Shale & Gypsum	30 "	430
Gray Soapstone	255 "	685
Black Shale	35 "	720
Gray Shale	65 "	785
Salt	40 "	825
Gray Shale	5 "	830
Salt	100 "	930
Gray Shale	10 "	940
Salt	90 "	1030
Gray Shale	10 "	1040
Salt	20 "	1060
Gray Soapstone	40 "	1100
Gypsum and Shale	70 "	1170
Ghent	30 "	1200
Blue Soapstone	10 "	1210
Sandstone and Natural Gas	} 15 "	1225

Substratum, Soapstone.

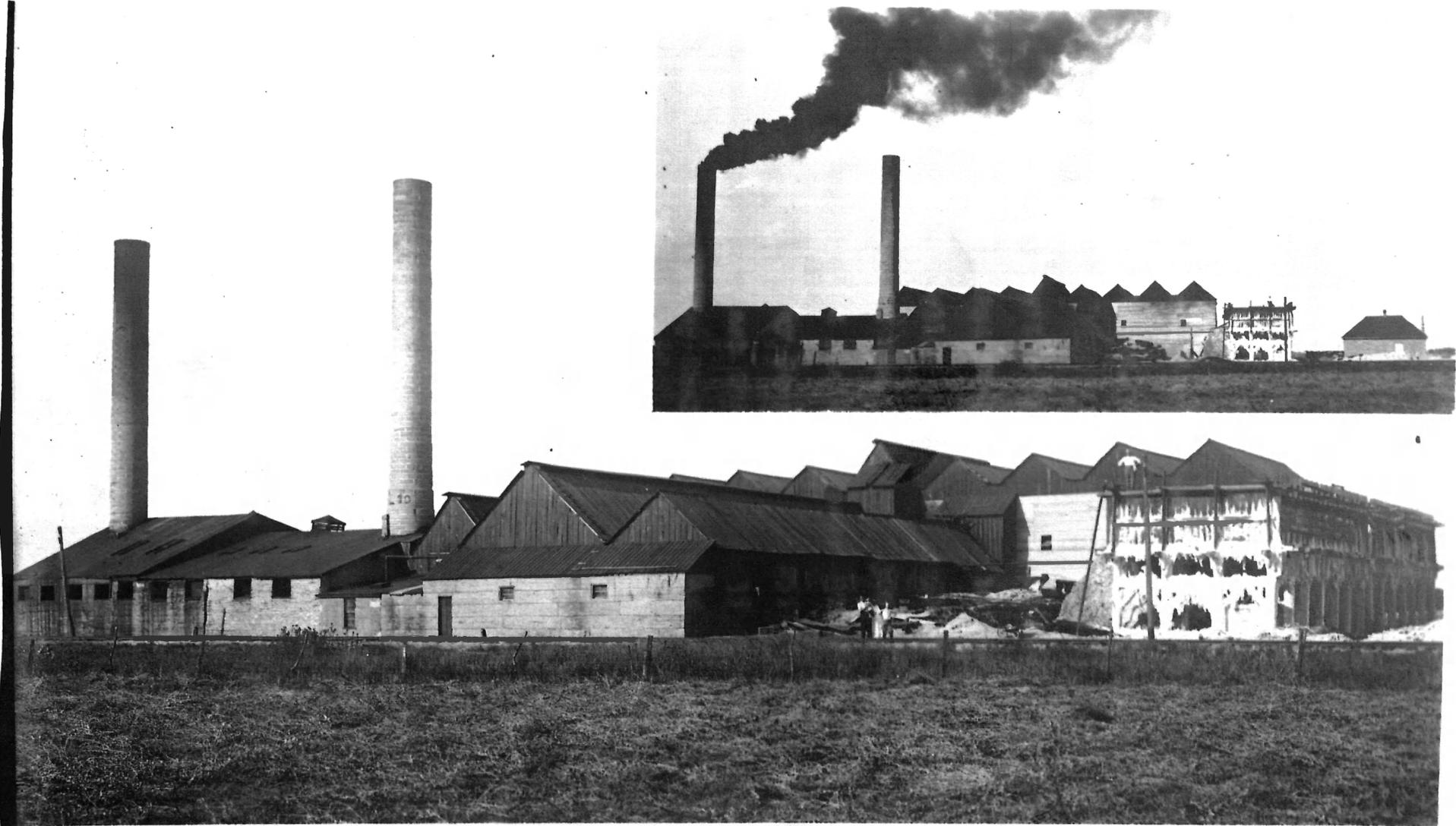


Plate I.

Explanation of Plate L.

View of west side of Sterling Salt Works showing the owner T. H. Brown on storage tank at extreme right.

The large view shows stack at an interval when there is no loss of fuel in smoke.

The small view shows the more frequent condition as to smoke.

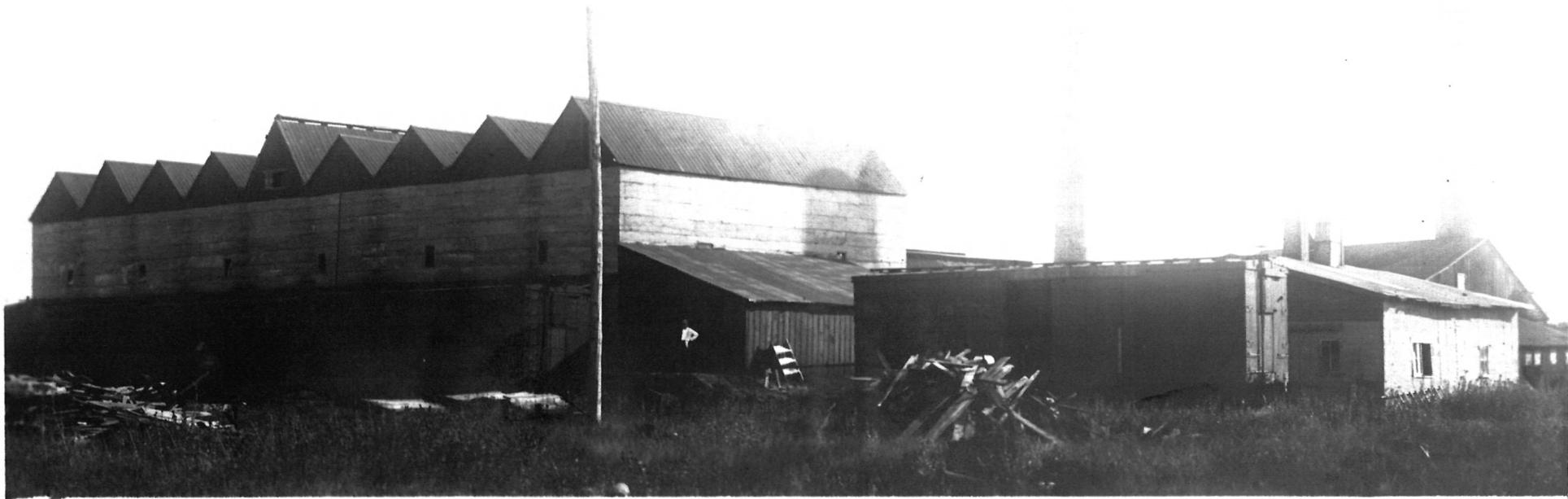
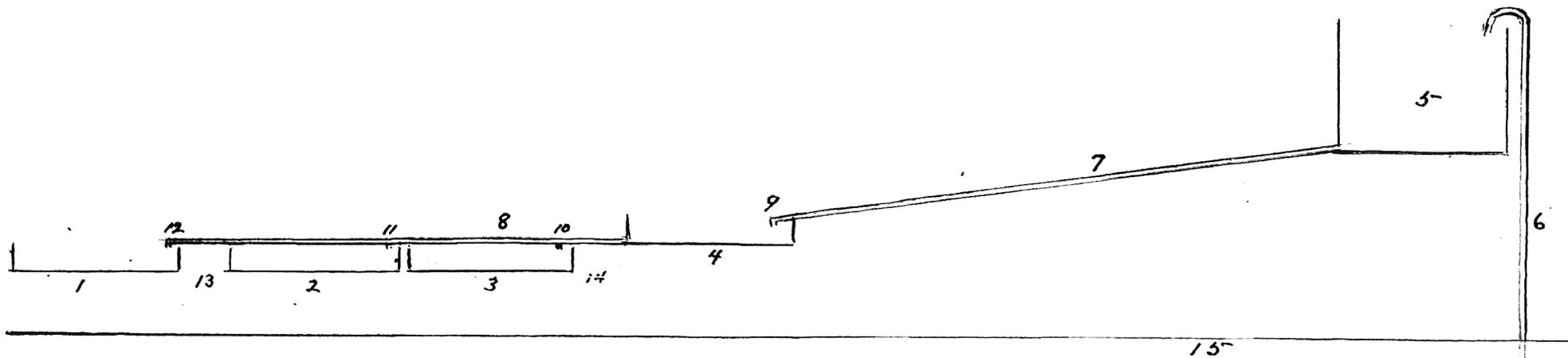


Plate II.

Explanation of Plate II.

View of east side of Sterling Salt Works
showing cars in process of loading from the
storage room.



Flow-Sheet.

Explanation of Flow-Sheet.

- 1,2,3- Evaporating pans.
- 4. - "Settling pan" or warmer.
- 5. - Storage tank.
- 6. - Pipe from brine wells.
- 7,8. - Distributing pipes.
- 9,10,11,12.- Cocks.
- 13,14.- Alley ways.
- 15 - Surface of ground.