

THE UTILIZATION OF A
DEPOSIT OF MAGNESITE LOCATED NEAR PORTERVILLE, CALIFORNIA
AS A SOURCE OF RAW MATERIAL FOR THE
MANUFACTURE OF C.P. EPSOM SALTS.

Thesis

by

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An outline of the work on this subject may be divided into three main heads and their respective subdivisions which are as follows:

- (I) Preliminary experiments on a Laboratory Scale, which may be further sub-divided into:
 - (a) Qualitative analysis of the raw material, with special emphasis on the impurities present.
 - (b) Quantitative analysis of the raw material.
 - (c) Solution data on the raw material, consisting of :
 - (1) Data on effect of size of particles of magnesite.
 - (2) Data on effect of heating during solution.
 - (3) Data on effect of acid-strength used in leaching.
 - (4) Data on effect of agitation during leaching.
 - (5) Data on effect of parallel and counter-current leaching.
 - (6) Data on acidity of solutions, suspensions, and other factors occurring during leaching.
 - (7) Data on methods of treating suspensions and excess acidity of solutions.

(d) Crystallization of the Epsom Salts and the obtaining of data on :

- (1) Methods of Crystallization.
- (2) Size and number of crops.
- (3) Purity of each crop.
- (4) Volume changes of liquid during crystallization.
- (5) Phenomena affecting crystallization.

(II) Experiments on a Semi-Commercial Scale consisting of :

- (1) Reduction of the raw magnesite mineral by crushing and pulverizing operations.
- (2) Dissolving the crushed magnesite by counter-current leaching, obtaining data on :
 - (a) Solution time.
 - (b) Advisibility of using heating and agitation during solution.
 - (c) Completeness of solution.
 - (d) Acidity of solutions.
 - (e) Character of residues and suspensions and necessity for filtering or other treatment.

(III) Conclusions, drawn for the foregoing experimental work, on the following heads :

- (a) Method of preparing raw material.
- (b) Method of dissolving raw material.
- (c) Method of crystallization.
- (d) Form and installation of apparatus preferred.

The chemical reaction involved in the manufacture of Epsom Salts from magnesite is simple, consisting of the action of concentrated sulphuric acid on magnesium carbonate, with the resultant formation of hepta-hydrated magnesium sulphate, carbon dioxide and water. Placing the reaction on a commercial basis is more complicated, however.

Experiments on a laboratory scale preceding experiments on a commercial or semi-commercial scale were used because it was possible by this means to obtain much valuable information with the minimum expenditure of effort. As previously outlined, the first phase of the problem attacked was a qualitative and quantitative examination of the raw material, with especial attention to the kind and amount of materials present. On examination of the magnesite, as it comes from the deposits, it was seen to consist of large chunks of a rock-like character, generally white in color but sometimes stained with iron deposits. The material is hard and heavy, presenting a strong resistance to crushing action. To obtain a sample for use in subsequent experimentation, a three hundred pound lot of magnesite was reduced to a five pound sample by the quartation method and then pulverized to a fineness, allowing it to pass through a sixty mesh screen.

The qualitative analysis for the basic constituents was conducted by carefully following the usual analytical procedures. A small sandy-appearing residue was obtained on dissolving the raw material and the presence of small amounts of iron, aluminum, and a trace of calcium as impurities were ascertained.

A portion of the raw magnesite was then carefully analyzed by quantitative methods and the following results were obtained.

MgCO ₃ (determined as MgSO ₄)	96.20 %
Insoluble residue	1.70 %
Iron (determined gravi-metrically as Fe ₂ O ₃)	0.51 %
Aluminum (determined gravimet- rically as Al ₂ O ₃)	0.24 %
Calcium (precipitated as CaC ₂ O ₄)	Trace
Water	Balance

It can be seen from these results that the magnesite is comparatively pure to start with, the total soluble impurities running about 0.75%. In control work the iron would be analyzed by a colorometric method against solutions containing a known amount of iron, such as FeCNS. Since the aluminum impurity is about half the amount of iron present and the solubilities of aluminum and iron sulphate are of the same order of magnitude, it is entirely possible to estimate the amount of aluminum impurity in the finished salts by the amount of iron present as an impurity. Iron may be determined volumetrically, but there are no available means of determining aluminum or magnesium volumetrically and consequently existing methods are slow and tedious.

The problem of dissolving the raw magnesite by leaching with sulphuric acid was next attacked and in this connection five variables were considered.

To determine the effect of particle size on speed of leaching, raw material of 20, 40, and 60 mesh size was leached with 17% excess acid, agitation and heating with a hot-plate being used. The times of solution were as follows :

20 Mesh	5 hours 50 min.	
40	1	40
60	0	45

From these results it was decided to use 60 mesh material, as the magnesite may readily be reduced to this size and the saving in leaching time is marked.

The acid strength was next varied, with the factors of particle size, heating, agitation, and direction of leaching held constant.

Results were as follows :

	Weight "Raw" Material	% Excess Acid	Time of Solution	Weight Residue
(1)	19.2 gm.	0 %	3 hr. 0 min.	1.35 gm.
(2)	19.2	5	2 0	1.36
(3)	19.2	10	1 10	1.30
(4)	19.2	17	0 40	1.30

To determine the amount of retained salts and undissolved raw material in these residues, the residues were again leached with dilute sulphuric acid and the following results were obtained :

	Weight Final Residue	Wt. Retained Salts and Undissolved "raw" Mat'l.
(1)	0.73 gm.	0.62 gm.
(2)	0.70	0.66
(3)	0.98	0.32
(4)	1.02	0.28

From these values it may be seen that an increase in acid strength above the theoretical is accompanied by a decrease in solution time and also by a decrease in the amount of undissolved raw material in the residue. These advantages are counter-balanced, in parallel leaching, by the disadvantages incumbent upon handling an acid liquor, which must be neutralized before being filtered or else must be filtered and crystallized in acid resistant apparatus.

The next variable considered was agitation and the procedure used was as follows :

A sample of magnesite was dissolved in 17 % excess acid at room temperature without agitation and the time of solution was found to be six hours. On treating the same amount of sample with the same acid strength at the same temperature, but with the use of agitation, the solution time was found to be cut to four hours. This reduction in solution time was considered to be so important that agitation was adopted for all further experiments.

On dissolving the same amount of sample, as used above, with the aid of agitation and heating with a hot plate, the time of leaching was cut from four hours to forty minutes and in consequence the use of heating wherever possible during the leaching operation was decided upon.

It was found that on dissolving the raw material with sulphuric acid a great deal of heat is given off by both the dissolving action and the addition of water to the acid. Violent foaming, due to the rapid evolution of carbon dioxide, is also present. This foaming is of sufficient magnitude to cause trouble unless provision

is made to either prevent the foaming or to provide apparatus with dimensions designed to take care of it. Foaming may be lessened by omitting both external heating and agitation during the first part of the dissolving action. The heat generated during the first part of the reaction is enough to speed the reaction up sufficiently for at least half the solution time and the violent evolution of carbon dioxide gives sufficient agitation until the time that artificial heating is started. In this manner loss of material by foaming may be avoided and at the same time a saving may be effected in heat and in energy used for agitation.

As noted before, parallel operation has the disadvantage of giving an acid liquor or of not entirely consuming the raw material and thus leaving a sludge to be filtered, assuming that the solvent action is allowed to take only a reasonable time. Either one of these conditions constitute important draw-backs to parallel leaching and in consequence a system of leaching on the counter-current principle was considered, in which a charge of raw material is placed in contact with the theoretical amount of acid and the leaching is allowed to proceed as long as the action is fairly rapid. When the rate of dissolving begins to fall off rapidly the nearly spent acid is placed in contact with a fresh charge of raw material and a new charge of acid is placed in contact with the material remaining from the first charge of magnesite. Thus the "potential of solution" between the spent charge and the fresh acid and the fresh charge and the spent acid is relatively high and a complete and rapid dissolving action could be anticipated. The remaining acid from the second acid charge is added to a fresh batch of magnesite and the

cycle repeated. Experiments were performed on this method of counter-current leaching and data were obtained on the rapidity and completeness with which solution took place in the various steps of the cycle.

A theoretical quantity of acid was placed in contact with a charge of raw material and leaching without agitation or heating was allowed to take place for twenty four hours and the resulting liquor was then drawn off and titrated against standard NaOH (N.F.= 0.10567). A 2 cc. sample of the liquor required 14.8 cc. of the standard base. This liquor was then put in contact with another equal charge of raw material and allowed to stand in the cold without agitation for one hour and a 2 cc. sample was again drawn off and titrated against the standard base, 4.80 cc. of the base being required to neutralize the excess acid, showing a decrease in acidity of over $\frac{2}{3}$ in one hour's contact. The counter-current cycle was next followed through with the use of both heating and agitation. The first charge of acid and magnesite was allowed to react for thirty minutes and then the nearly spent acid solution was drawn off, placed in contact with a fresh charge of magnesite and allowed to react. By the end of fifteen minutes the acidity was reduced to a point where there was no color change produced in methyl orange indicator. In a similar manner the spent charge of magnesite was placed in contact with a fresh charge of acid and by the end of fifteen minutes no further reaction was discerned. In the first two steps of the counter-current cycle no trouble was experienced from suspensions of finely divided material but in the third step of the cycle, where the nearly spent acid was added to the fresh charge of magnesite there was enough finely suspended material

to make filtration necessary. This suspended matter could be taken care of in four ways by :

(1) Allowing the suspended matter to settle by gravity. This took six hours with a laboratory size sample.

(2) Filtering the suspended matter in a filter-press. This is an expensive operation, especially as the suspension under discussion would quickly clog the filters.

(3) Adding just enough acid to dissolve the suspended raw material. This is slow and uncertain. A one per cent excess of acid dissolved the suspension but gave a slight acidity.

(4) Adding an excess of acid and neutralizing with caustic soda or other base. This method has the disadvantage of introducing impurities into the salt solution.

The method that would probably be used in practice is number one or a combination of number two and three where the suspension is allowed to settle, or treated with a little less than the theoretical quantity of acid needed to dissolve the suspension and then filtering what suspension remains.

The problem of crystallizing the Epsom Salts from the mother-liquor was next investigated.

Under methods of crystallization three systems may be considered. They are as follows :

- (1) Crystallization by change of temperature of the solvent.
- (2) Crystallization by change of volume of the solvent.
- (3) Crystallization by a combination of temperature change and volume change of the solvent.

In method (1) the mother-liquor must be saturated with the

solute at a higher temperature and then cooled to a lower temperature. This saturation at the higher temperature occurs when the raw material dissolves in the acid solution and precipitation occurs upon cooling the mother-liquor to a lower temperature and is proportional to the solubility difference between the two temperatures. After the crystals have been separated from the cold mother-liquor, it could be heated up again and used to leach another portion of magnesite with the addition of the necessary acid. Upon becoming saturated at the higher temperature, it could be cooled again and part of its salt content would crystallize out and the cycle could then be repeated.

A limit on the number of times that the cold mother-liquor might be put back into the cycle is imposed by the amount of impurities that it can hold in solution.

In method (2) the problem becomes one of simple evaporation and can be made practically continuous. If steam is to be used for evaporation, a large saving can be effected by using multiple effect evaporators and using the steam from the evaporators to heat feed-water and the dissolving apparatus. If waste heat was available in flue gases etc., a large saving might be made by using it for evaporation.

Method (3) is a combination of (1) and (2) and has the advantages under these respective heads. Larger crops can be obtained with less handling of the liquid and less heat loss. For these reasons it was decided to adopt a system of crystallization using

both temperature change and volume change.

The size and number of the crops to be produced constituted the next step to be investigated. Two samples of magnesite, each 19.2 grams in weight were dissolved in sulphuric acid and subjected to crystallization by combined evaporation and temperature change. Solution (1) was diluted to 100 cc. and solution (2) was diluted to 90 cc. The crystallization was carried on as shown in the following tabulation.

Solution (1) =

	Wt. Crop.	Temp. Soln.	Vol. Change	Impurities
1st crop	8.23 gm.	100-102° C.	100-65 cc.	Faint Trace iron
2nd	13.13	102-104	65-18	Trace of iron
3rd	5.86	104-105	18-11	1/20 % iron
4th	1.83	105-105½	11- 4	Small iron
m. l.	<u>0.30</u>	105½	4- 0	Small iron
Total	29.25 gm.			

Solution (2) =

1st crop	5.98	100-101	90-75	Faint Trace iron
2nd	9.33	101-102	75-35	Faint Trace iron
3rd	3.43	102-104	35-25	Trace iron
4th	4.53	104-105	25-15	Trace Iron
5th	3.43	105-105	15-10	1/20 % iron
6th	2.13	105-105½	10 -5	Small iron
m. l.	<u>0.45</u>	105½	5 -0	Small iron
Total	29.28			

From these results it is seen that a large percentage of the salt obtained has a high purity, as the iron content of 93% of the first sample and 91% of the second sample is under 0.05% and the purity of this percentage of the salt is 99.9% or over, which comes within the limits of C. P. standards and also the U. S. P. standards. The next step was to run a sample in order to see how few crystallizations could be made and these standards still upheld. A sample of raw material weighing 19.2 grams was dissolved in acid and made up to 100 cc. and then evaporated at a moderate rate. Observations at various stages of volume change were made as follows :

Evaporated from 100 cc. :

at 50 cc. crystals formed

at 38 cc. solution foamed

at 30 cc. solution foamed and bumped so that

evaporation had to be discontinued. A very heavy precipitate with no free mother-liquor was formed. From this data it is seen that the crystallization can be made in two stages in order to have approximately 90% of the crystallized salt within the required range of purity. The logical points to take these two crops during the evaporation would be at points corresponding to a volume of between 50 cc. and 38 cc. and a volume of 10 cc. The remainder of the salts might be utilized as lower grade Epsom Salts or might be discarded altogether, depending upon the price obtainable. Another course would be to collect this last portion of the salt and recrystallize it as C. P. Epsom Salts. There is a market for low grade Epsom Salts to be used for cattle and live stock medicine.

The procedure in evaporating would be to take down the solution until crystals are formed and a slight foaming noted and then further crystallization effected by cooling to room temperature. The mother-liquor could then be mostly drained off by pouring the crystals and liquor over a screen and residual liquor could be removed by subjecting the crystals to suction.

At the conclusion of these small scale laboratory experiments, a run was made on the largest scale that could be conveniently handled in the laboratory. Starting with two 40 gram samples of magnesite ground to a fineness of 60 mesh or under a mixture of 50 grams sulphuric acid (Sp. Gr. 1.835) and 80 grams water was added to sample (1). Altho' the acid was added slowly, there was a violent reaction accompanied by profuse foaming of carbon dioxide and a considerable evolution of heat. The reaction was allowed to proceed for fifteen minutes without heating or artificial agitation and then heating and artificial agitation were used for fifteen minutes. The nearly spent acid from sample (1) was then decanted and found to be fairly free from suspended materials. This acid liquor was then added to sample (2) and heating and agitation used for fifteen minutes. 130 grams of fresh acid mixture was then added to the nearly consumed sample (1) and the mixture was stirred and heated for fifteen minutes and then decanted. This decantation was also fairly free from suspended particles of magnesite. The completely spent acid from charge (2) was then decanted and the nearly fresh acid from charge (1) was added to the nearly fresh magnesite of charge (2). A vigorous reaction took place accompanied

by violent foaming and the reaction was allowed to take place for fifteen minutes with no artificial heat or agitation and then for fifteen minutes with heat and agitation. The nearly spent acid solution was then decanted and added to an excess of raw magnesite and the reaction allowed to proceed for fifteen minutes with agitation and heat. On decantation much fine undissolved magnesite was seen to be held suspended and filtration was necessary. The heat of reaction proved great enough to necessitate the addition of 50 cc. of water to keep the salts in solution, due to loss of water from evaporation.

Crystallization was effected by a combination of volume and temperature change and was divided into three stages. The two solutions obtained by dissolving the magnesite, as stated above, were combined and made up 280 cc. This was evaporated to approximately 140 cc. at which point crystals were formed in the hot solution and quite a little foaming took place. Further crystallization was then caused by lowering the solution to room temperature and the crystals were filtered off on a Buchner funnel and weighed. The first crop yielded 181 grams. The remaining liquor was then taken down to approximately 75 cc. by the same process and crystallized as before. The yield obtained was 36 grams. A third crop was obtained by taking down the remaining liquor to 20 cc. and crystallizing again. This crop weighed 12 grams. The mother liquor was then evaporated and the residue was found to weigh 9 grams. The entire yield of Epsom Salts obtained was 238 grams and the theoretical yield was 240 grams. The percentage of yield obtained in the first two crops was 91.3% and the product fulfills the specifications for C. P. Epsom Salts.

The conclusions reached from this run are as follows :

- (1) Leaching apparatus should be used of such proportions that the full benefits of the heats of reaction and solution and of agitation by evolution of carbon dioxide may be obtained and excess foaming still be prevented.
- (2) That heating and artificial agitation should be used only towards the end of the dissolving process.
- (3) That provision must be made for removing finely suspended insoluble matter or undissolved magnesite.

From the foregoing experiment, a tentative process was outlined for use on an industrial scale. This is as follows :

- (1) Grind raw material to a moderate degree of fineness by the use of jaw crushers and pulverizers.
- (2) Dissolve by the use of counter-current leaching. In this leaching each charge of acid gets thirty minutes with one charge of magnesite and fifteen minutes with another. Each charge of magnesite gets thirty minutes with a strong batch of acid and fifteen minutes with a weak batch. In each case where strong acid comes in contact with fresh raw material neither heat nor agitation is supplied until the last fifteen minutes of the particular leaching period. When weak acid comes in contact with strong raw material or weak raw material comes in contact with strong acid heat and agitation are to be used for the entire period.
- (3) In cases where there are fine suspensions, a very slight excess of acid is to be added and agitation used for fifteen minutes.

(4) Solution is to be crystallized by combined volume and temperature change in three steps, as follows :

- (a) Take solution down to point where crystals begin to separate out in hot solution and then cool solution to room temperature and filter off crystals.
- (b) Repeat process with remaining liquor until volume is reduced to 25% of original volume and again effect crystallization.
- (c) Evaporate remainder of liquor to dryness and recover salt.

The proportions by weight of materials used are :

Magnesite	1	part
Sulphur Acid (Sp.Gr. 1.835)	1.25	parts
Water	2.6	parts

In applying this outline to industrial scale operation in the Engineering Laboratory, several important changes had to be made because of restrictions imposed by lack of available time and apparatus. The main changes were the abandonment of heating during the leaching, the settling of suspensions instead of dissolving them with a slight excess of acid, and the substitution of small scale for large scale crystallization.

The experimental run on a semi-commercial scale was made as follows :

(1) A charge of 50 lbs. of magnesite, charge (1) ground to a fineness of 60 mesh was placed in a wooden tub and 62.5 lbs. of commercial sulphuric acid (Sp. Gr. 1.835) and 136 lbs. of water were added. The mixture was stirred by agitation with compressed air passing thru a coil of perforated lead pipe placed in the bottom of the tub.

Emission of carbon dioxide into the laboratory was avoided by fitting the tub with a tight wooden cover and allowing the fumes to escape thru a metal pipe leading out of the window.

Leaching was continued for four hours, using air agitation, and then the nearly spent acid was pumped into another similar tub containing a fresh 50 lb. charge of magnesite, charge (2) and agitated for one and one-half hours. The entirely spent liquor was then pumped into a storage tub and a fresh charge of 62.5 lbs. of acid and 136 lbs. of water were placed in the first tub in contact with the remainder of the magnesite of charge (1) and the whole agitated for one and one-half hours. The partially spent acid was then transferred to the second tub containing the undissolved portion of charge (2). Agitation was used for three hours and then 50 lbs. of fresh magnesite was added and the whole agitated for one and one-half hours more. This last operation was used to complete the cycle of dissolving and at the conclusion of the leaching period the spent liquor was pumped into the storage tank with the liquor obtained in the first part of the cycle. This liquor was slightly acid. A 400 cc. sample was taken for crystallization.

The 400 cc. sample of salt solution was evaporated until the salts began to crystallize out in hot solution and the liquor was then cooled to room temperature and the salt crystals separated from the liquor. A yield of 212 grams was obtained. The remaining liquor was again evaporated to a point where the salts commenced crystallizing out in hot solution and the salts separated as before. This crop weighed 40.8 grams. The mother-liquor was then evaporated to dryness and the residue was found to weigh 27.4 grams. The theoretical quantity of

salts in 400 cc. of solution is 284 grams and the percentage of the theoretical obtained was 98.8%. The first two crops comprised 90.1% of the yield obtained and upon being tested showed less than 0.1% impurities.

400 cc. of the salt solution weighed 508 grams or 1.12 lbs. The yield of salts obtained from 1.12 lbs. of solution weighed 0.62 lbs. and the yield of salts in the first two crops was 0.558 lbs.

The suspensions of undissolved magnesite encountered were of a rather slow-settling character and would have to be removed by some means before crystallization was effected. They settled nicely in twenty-four hours, however, and could be easily disposed of by running the spent acid solutions into settling tanks for that length of time. No trouble with foaming was encountered, partly due to the absence of artificial heating and partly due to the diameter of the tanks as compared to the depth of solution. In fact, tanks of much smaller capacity but having the same diameter might have been used, e. g. A tank the height of which is two-thirds the diameter.

The acidity of the Epsom Salt solution was very low, showing that the combination of counter-current leaching, agitation, and excess of magnesite used tended to make the reaction approach nearly to completion. The amount of acidity remaining in the salt solution was not enough to damage iron filter presses or copper or iron evaporating pans and crystallizers. This would allow the use of apparatus that was not made from special material such as "Duriron" or glass and would make filter-pressing possible if it was considered desirable.

The time of leaching, which was approximately seven hours, could have been greatly reduced by the use of artificial heating. This could have been carried on by leaching in a jacketed vessel or a vessel containing steam coils. Both of these types of apparatus could be heated with waste steam from crystallizers or evaporating pans or by waste flue gases from boilers.

An air line pressure of two pounds per square inch was ample to provide vigorous agitation, and this type of agitation was completely satisfactory.

From the foregoing industrial scale experimentation, the following outline for a commercial process is recommended :

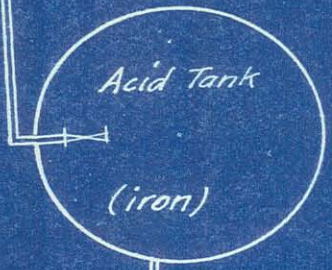
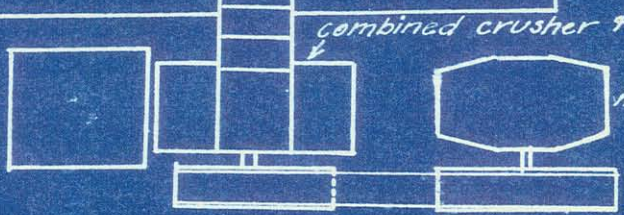
- (1) Crushing material to 60 mesh in jaw crusher and pulverizer.
- (2) Leaching by counter-current method, employing heat during the entire leaching period and air agitation during the periods when weak acid comes in contact with fresh raw material or strong acid comes in contact with weak raw material.
- (3) Settling suspensions in settling tanks.
- (4) Crystallizing out the Epsom Salts in three steps. The first two steps obtaining 90% of the available salts and the third step consisting of complete evaporation of the mother-liquor.

The principal units of an installation that would handle efficiently the commercial process outlined are shown in the accompanying sketch. The installation is designed for a capacity of 1000 lbs. of C. P. Epsom Salts per day or eight hours. The raw material corresponding to this quantity of finished product is as follows :

Magnesite Bin
cap. 75 cu. ft.

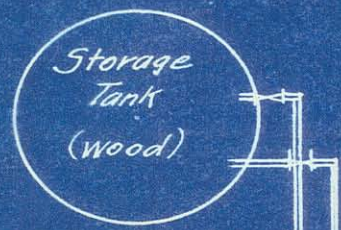


Platform scales for weighing crushed magnesite

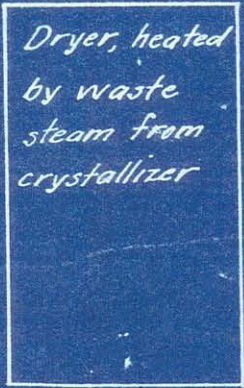
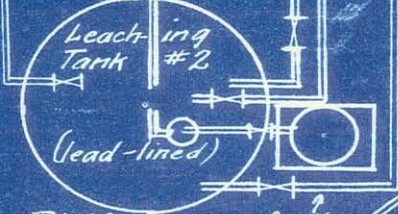


line for blowing acid

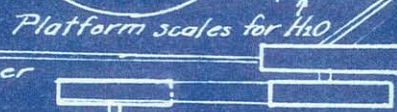
Platform scales for weighing acid



tank transfer pump, steam, Duriron.



from storage to crystallizer



motor



95% Sulphur Acid (Sp.Gr. 1.835)	= 444 lbs.
Pulverized Magnesite	= 356 lbs.
Water	=1074 lbs.

The weight of solution containing 1000 lbs. of C. P. Salts is 1800 lbs. and of this there is approximately 700 lbs. of water to be evaporated per eight hour day, which comes to 87.5 lbs. of water per hour.

The raw magnesite is presumably loaded into the bin by truck and is carried from there to the jaw crusher and pulverizer by means of a portable conveyer. From the crusher the magnesite drops into the pulverizer, which is placed directly beneath the crusher, and the pulverized magnesite falls into a box mounted on a truck which in turn stands on a pair of platform scales. From here it is wheeled to the leaching tanks and charged into them by hand.

The leaching tanks are lead-lined and provided with steam-jackets to permit of artificial heating. Compressed air is used for the necessary agitation and ventilation is obtained by the use of tight-fitting covers and conduits similar to those used in the semi-commercial scale operations.

The magnesite is charged by hand into tank (1). The requisite amount of strong sulphuric acid is weighed out in the acid reservoir "A", which is mounted on platform scales, and is then run into tank (1) onto the magnesite and the requisite amount of water, which has previously been added by means of a similar apparatus "B". As soon as the water and acid are added, steam heating is begun and at the proper time agitation is started and is kept up until the

spent acid solution containing the salts is run into tank (2), into which a fresh charge of magnesite has been placed. After reaction, aided by heating and agitation, has ceased, the saturated salt solution is run into the wooden storage tanks, which have a capacity of three days run. A fresh charge of water and acid is run into tank (2) and reacts with the magnesite remaining there. After reaction has taken place to the desired extent the solution is pumped into tank (1), a fresh charge of raw material added, and the reaction carried to completion. The salt solution is then run down to the storage tanks and the process repeated. The insoluble residue remaining in the leaching tanks must be shoveled out from time to time as required. After the suspended materials have settled in the storage tanks the salt solution is pumped to the vacuum crystallizer and 90% of the available salts recovered. This is done by running the crystallized salts and mother-liquor from the evaporator thru a centrifuge provided with an automatic washer which washes the salt crystals with the least amount of water that can be used. From here the washed crystals are passed through a drying closet heated with waste steam from the evaporator and are then ready to be packed for the market. The mother-liquor and wash water may be discarded or evaporated to dryness as economic reasons may dictate. In this installation pumping is reduced to a minimum and filtration is not used at all.

Styles, capacities, and materials of apparatus used are as follows:

The storage bin for magnesite has a capacity of 75 cu. ft., one month's supply of raw material. The acid storage tank is iron and has a capacity of one month's supply of concentrated sulphuric acid, 14,000 lbs. or 120 cu. ft. The acid is blown into the storage tank from drums or tank-cars by means of compressed air. The jaw crusher and pulverizer have a capacity of 500 lbs. of 60 mesh magnesite in three-quarters of an hour. The leaching tanks are lead-lined and heated with steam-jackets. Their diameter is 40", height 22", which gives ample capacity and takes care of foaming. The storage tanks are made of wood, are three in number, each one having a capacity of one days run with an additional height of 4" to take care of deposits of undissolved magnesite, and are 46" in diameter and 32" in height. The crystallizer is of the vacuum evaporator style. This combines the advantages of vacuum evaporation with the ability to take salt solutions down to a thick consistency without interference with heat transfer efficiency, and the fact that steam jackets are used instead of coils, makes the handling of the crystals and mother-liquor much easier. This crystallizing evaporator has a capacity of 100 lbs. of water evaporated per hour from and at one atmosphere and 212°F. and a higher capacity depending on the vacuum used. The centrifuge and drying oven are of a size to handle 1000 lbs. of finished salts per eight hour day. The air compressor is designed to carry a load of 15 lbs. to the square inch and both the compressor and the pulverizer and crusher are run from a line-shaft operated by a motor. The tank transfer pump is made of "Duriron" and driven by steam to get the desired flexibility while

the feed-line pump to the crystallizer is a centrifugal pump driven by a separate motor. All piping and tanks coming in contact with strong acid only are of iron, while the piping coming in contact with diluted acid is either made of lead or is lead-lined. The piping which handles the salt solution to and from the storage tanks is made of iron. The centrifuge is driven by a separate motor.