DHRANGADHRA STATE.

SALT.

Technology and Manufacture of By-Products

BY

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Navsari Chambers,
Hornby Road Fort,
Bombay, 6th March 1924

His Highness Maharana Shri,
Sir Ghanshyamsinhji Ajitsinhji, G C I E , K C S I ,
Maharaja Raj Saheb of Dhrangadhra,

DHRANGADHRA

Your Highness,

I have the honour to submit herewith, through Dewan Saheb Mansinhji Jhala, my Report upon Salt Manufacture which I have prepared at Your Highness' desire

This report deals with the Technology of Salt Manufacture and the recovery of several by-products with particular reference to the rich and almost inexhaustible brine found in Your Highness' State

From this report it will be realised that a complete recovery of the valuable by-products would not only add to the prosperity of the State by the establishment of an important industry, but would also help considerably the great textile industry at Ahmedabad and Bombay on which the prosperity of this Presidency is based

Your Highness will realise from this report that considerable work has been done during the last three years since I first visited Kuda to arrive at definite conclusions regarding these by-products, and it is with a view to comlpete our records that I have embodied in the report the results of my observations at greater length than I originally intended   I am sure this report will help those engaged in this industry, and particularly the Officers who will be called upon to undertake a new administrative department of the State   Confident in the hope of receiving your full appreciation,

I beg to remain,
Your Highness,
Your most obedient Servant,
KAPILRAM H VAKIL,
Consulting Chemist

PREFACE

This report was prepared at the request of His Highness the Maharaja Raj Saheb of Dhrangadhra and is the result of several years' study of salt manufacture in India During my investigations I found considerable difficulties in gathering the information necessary for this report Some curious and in many cases very strange, ideas prevailed on the subject of salt manufacture Even the most experienced Salt Officers of the Government had very limited knowledge on the subject What information I was able to gather, was tainted with superstition and prejudices showing a complete ignorance of the true nature of chemical processes I have, therefore, been obliged to treat at length the Chapters on the Technology of Salt The work however, does not claim to be a treatise on the subject, but it gives in general outlines the process and the nature of the materials in sufficient details to give the reader a general idea of the industry, with particular reference to the prospects of the industry in the Dhrangadhra State The experimental work and the series of observations recorded in this report were carried out systematically during the last six years

ACKNOWLEDGMENT

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SALT

I.

INTRODUCTION

India's place among the Salt-producing countries of the World—India occupies the fourth position among the great salt producing countries of the world, though the Indian use of salt is limited to domestic and agricultural requirements, it produces a very large quantity from various sources In the United States of America, in the United Kingdom and in Germany over fifty per cent of the salt produced is used in Chemical industries In 1920 the world's salt production was 18,000,000 tons, of which the United States of America produced 33 per cent, Germany 15, England 12 5, India 9 5, France 6 5, and the rest of the countries ₋4 5 per cent This industry in India even in spite of a limited use for salt, is of considerable importance Salt for domestic, agricultural and industrial use is obtained from a number of sources It is found in abundance as rock salt at the Salt Range in the Punjab, as natural brine in the Sambhar Lake and in the Rann of Cutch, at Kharaghoda and at Kuda in the Dhrangadhra State It is also recovered from sea water in the Bombay and the Madras Presidencies Besides the salt produced from these sources India supplements its requirements by importing a considerable large quantity from foreign countries, principally from England, Spain, the Red Sea and Aden.

Salt manufacture in Dhrangadhra State —The manufacture of salt in this state at Kuda is of very ancient date   When the Jhala Chieftains retired to Halvad, they set up their salt works at Kuda, and these were guaranteed to the Halvad Jhala chiefs by the Emperor Aurangzeb in the 27th year of his reign (A D 1669-70). These rights were maintained unimpaired during the last two hundred and fifty years, and throughout the many changes in the forms of Government   In 1807 these rights were recognised among others by the British   In 1858 the Proclamation of Queen Victoria also recognised the right of the State to manufacture salt at Kuda. Kuda even then specialized in the production of Vadagra salt (Baragara) which was considered to be the best of its kind   The crystals of Vadagra salt are described in the *Meerut-I-Ahmadi*, which says that the salt resembles pieces of sugar and is exported to Malwa and elsewhere   In 1874 the Government of Bombay initiated certain measures to prevent the smuggling of salt manufactured in the Indian States   The sole object of the Government at that time was the safeguarding of the revenue and not to put any restrictions in the manufacture of fine grained salt   In 1880 the Government restricted the production of salt in the Dhrangadhra State to 90,000 maunds per year   In 1883 the production of Vadagra salt was restricted to 40,000 maunds annually, and in 1900 the manufacture of Vadagra salt was altogether prohibited by the British Government   In compensation of this restriction the State was given Rs 7,000 per annum   In 1915 the State approached the Government requesting a revision of the Treaty of 1900 with a view to encourage the manufacture of Magnesium Chloride and other by-products from the State salt works   After considerable delay the Government of India restored to the State its right of manufacturing both Vadagra and Ghasia salt   On 30th October 1923 the Governor of Bombay—Sir George Lloyd—formally re-opened the Kuda salt works

While the Government was considering the revision of the Treaty, I was asked by the State in 1920 to submit a report on the possibilities of manufacturing various by-products from the mother

liquor remaining after the recovery of salt from the brine at Kuda
While enquiring into the economical uses of the various products
and the possibilities of recovering them, I encountered considerable
difficulties in getting together the information that was necessary
for the purposes of the report, as much curious information was
supplied to me, and as there were no records of observations neces-
sary for the preparation of a comprehensive scheme, the progress
of the report was slow, and much time was taken up in preliminary
investigations and enquiries   For over two years the State had to
give up all its investigations till the Government gave a definite
reply.

GEOLOGY OF THE KUDA BRINE DEPOSITS

Rann of Cutch —On examining the brines of Kuda and Kharaghoda wells it was found that they resembled very nearly in their general composition to concentrated sea water There is no material difference in the nature of the dissolved salts This close resemblance is another proof of the geological formation of the Rann of Cutch on the banks of which both the salt works are located Before proceeding with the discussion of the technology of salt manufacture and the prospects of recovering the by-products from the brine, it would be necessary to determine that the brine in the Rann has originated from the concentration of the sea water in the lower strata of the Rann

To the north of the Dhrangadhra State there is a very large track of open, barren, sandy, lifeless waste, known as the Rann of Cutch It is 80 miles from east to west and 10 to 40 miles from north to south, and covers an area of 2,000 square miles, of which 1,200 square miles are within the boundary of the Dhrangadhra State The little Rann meets the sea at Hansthal creek and stretches north-east to about forty miles—a creek varying from 5 to 30 miles in breadth It stretches east and west, a white three-cornered sea bed, about 40 miles east to the Great Kharaghoda salt works and about 30 miles north to the Chorad Island and Adesar in Cutch The level of the Rann at Hansthal creek is 6 781—2 75 feet above the mean sea level, and at about 30 miles east, opposite the Kuda salt works, the level is 6 781 feet in the middle of the Rann, or two feet, nine inches lower than the mouth of the Hansthal creek It will thus be seen that at the creek there is a bar over two feet above the mean level of the Rann, and that the Rann forms a sort of a depression in which during the monsoon the detritus discharged by the rivers on the banks of the Rann accumulate and flood the

gulf of the Rann   The Rann is completely flooded in September
by the high spring tides which overflow the banks at the creek and
rush in far inland in the Rann   This flood caused by the joint
flow of the sea and river waters rise up to a level of 3 to 4 feet near
the banks and 5 to 7 feet in the middle of the Rann   The level
of the floods begin to go down with the stoppage of the monsoon
and the discharge of the rivers after October   At the end of De-
cember the broad expanse of the waters of the Rann begin to dry
leaving a wide incrustation of salt on the surface   The banks of
the Rann on the Kathiawad side being 18″ to 24″ higher than the
outer fringe of the Rann   remain above the floods   The whole of
the Rann is fairly dry from December to the end of March   About
the end of April or the beginning of May   strong south-west gales
accompanied with sand storms and extraordinary high tide force
the water up the Hansthal creek into   the Rann   During the
summer the barren, lifeless Rann gives rise to the most notable
peculiarity—the Mirage.

The Rann was at one time the bed of an arm of sea which was
raised by some natural convulsion above its original level and thus
cut off from the Ocean   Geologically the Rann is of very recent
formation , as there are records which prove that in the time of
Alexander (320 B C) it was a navigable sea, and as late as the
third century it was known to have several ports on its banks   That
the Rann was a navigable sea is also proved   from   small   wooden
remnants of boats, oars and other articles found very often embedded
in the lower strata in which shells, fossils,   bones   and   other   marine
deposits are found   That the bed of the sea was raised by earth-
quakes is also proved from   the   earthquakes   which   are   very
common   in   Cutch   The   great   earthquake   of   1819   was
very severely felt.   The last shock was in 1864.   In conse-
quence of these repeated earthquakes the   bed   of   the   sea
has risen and given rise to the salty waste   In course of time the
shallow bed gradually filled with clay, sand and gravel discharged
from the rivers on its banks, and as the waters narrowed and the
silt accumulated the last remnant of the sea disappeared, leaving

ın course of tıme dıstınct layers upon layers of the alluvıal soıl.
For many years there has been no general dısturbance ın the
level of the Rann by earthquakes and the salt sand strata near
Kharaghoda ıs gradually gettıng exhausted of ıts natural brıne
whıch ıs recedıng towards the west. The sectıons of the wells as
shown ın Fıg 1 at Kuda and Kharaghoda gıve further proofs of the
Rann beıng orıgınally a bed of sea   The surface layer of the Rann
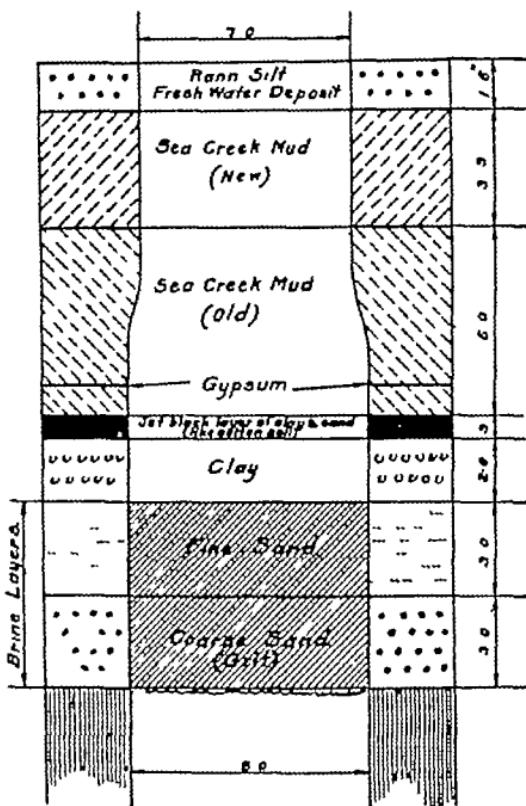
SECTION OF RANN
(Dıfferent Strata ın Wells)
FIG 1

ıs one and-a-half feet of black, stıcky, salt clay, washed out wıth
fresh water durıng the monsoon from the surroundıng coast and
brought as sılt ın the dıscharge of the rıvers Under thıs there ıs
a new deposıt of yellowısh to greenısh colonred mud, whıch seems

to have been deposited when the area was a sea-creek. Under this there is a deep grey to indigo coloured mud layer, at some places varying in thickness from six to twelve feet, this old strata of mud shows another period when it was the bed of the sea-creek. In this zone about nine to twelve feet from the surface there is a gypsum deposit of three-fourths to two inches in thickness, under this there is a layer more or less of black clay and sand resembling black cotton soil, under the old layer of dark mud there is a layer of four feet of argillacious clay and marl. This deposit is over a layer of fine sand from three to four feet in thickness, which in turn lies over a layer of coarse sand or grit, which in places has consolidated from large calcarious matters. Brine is found in the salt-sand and grit strata, although in some unused wells brine comes upto about four feet from the surface. In the old and new mud layers there are a number of shells and remains of vegetation. When wet the sides of wells cave in the old mud horizon and have to be protected. As the main land is approached this old mud gets lesser and lesser, and at places it totally disappears. Sand, consolidated grit and loose grit are fresh water deposits. Below these deposits there is a deposit of brown mud in which there is no brine. The analysis of the brines from Kuda and Kharaghoda wells, the Geological formation of the Rann of Cutch and the analysis of the Arabian sea water leave no doubt that the presence of the brine in the Rann is due to the evaporation of the enclosed sea water during the gradual silting of the Rann. It is commonly believed that as the middle of the Rann is still under the high tide level at Hansthal, and as the salt-sand strata is twelve to eighteen feet below the surface, this strata must finally dip into the sea at Hansthal, and that the constant supply of brine in the Rann is maintained by percolation of sea water through the sand strata all over the Rann—this supposition is yet to be proved. For over 70 years brine has been drawn from the salt-sand strata without the wells running completely dry. It has however been found that the brine is receding to the west at Kharaghoda, and the wells require considerable time in filling up, nd the average depth of the wells has gone on deeper and deeper

year after year   This deficiency is due to the higher level of Khara-ghoda   Nearer Kuda there is a plentiful supply of brine and no shortage of brine has been reported, though at one and the same site brine has been drawn for the salt works for over 600 years There is no likelihood of a deficiency of brine at Kuda The annual high sea inundation flows inland a few miles to the east of Kuda, but it stops 10 miles away from Kharaghoda If this high sea inun-dation had continued to spread over the Kharaghoda district, there would not have been a gradual shortage in the supply of brine as they have experienced during the last few years It must be noted that brine is only obtainable in the salt-sand strata ; deeper borings have not shown any brine at lower depths which at places have given brakish fresh water

We have in the brine of the Rann all the salts in practically the same proportions as are found in sea water, except Calcium Sul-phate which has separated out as a thin layer in the Rann during the spontaneous evaporation of the enclosed waters Magnesium Sulphate present in the sea water has been largely converted into Magnesium Chloride during the exposure in the cold It is for this reason that we find a large percentage of Magne-sium Chloride in the Rann brine   As the materials present in the Rann brine are the same as in the parent source, viz , sea water, it will be necessary at this stage to examine very carefully the composition of sea waters

COMPOSITION OF SEA WATER.

Sea Water—From the different analyses given in the following tables it will be noticed that the general nature of the constituents in the different sea waters throughout the world is very nearly alike. The difference is in degree but not in the character of the constituents. The quantities of the principal salts vary within very narrow limits, and the total of solids dissolved in most of them is also within very narrow limits. A very extensive observation of the composition of sea waters was made by Ditmar, who gives the following average composition of sea salts —

	Per cent
Chlorine	55 292
Bromine	0 1884
Sulphuric acid (SO_3)	6 410
Carbonic acid (CO_2)	0 152
Lime (CaO)	1 676
Magnesia (MgO)	6 209
Potash (K_2O)	1 332
Soda (Na_2O)	41 234
Basic oxygen equivalent to the halogens	(—12 493)
Total	100 000

Wagner gives the following Analyses of Sea Waters —In 100 parts of Sea Water

	Pacific Ocean	Atlantic Ocean	German Ocean	Red Sea
Sodium chloride	2 5877	2 7558	2 5513	3 030
Sodium bromide	0 0401	0 0326	0 0373	0 064
Potassium sulphate	0 1359	0 1715	0 1520	0 295
Calcium sulphate	0 1622	0 2046	0 1622	0 170
Magnesium sulphate	0 1104	0 0614	0 0706	0·274
Magnesium chloride	0 4345	0 3260	0 4641	0 404
Potassium chloride				0 288
	3 4708	3 5519	3 4384	4 534

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The composition of the salt contained in the water of the several seas is shown by the following table —

	Caspian Sea	Black Sea	Baltic	English Channel average of 7 locals	Mediterranean average of 3 locals	Atlantic Ocean average of 3 locals	Dead sea average of 5 locals
Average quantity of salt and water —							
Solid salt	0 63	1 77	1 77	3 31	3 37	3 63	22 30
Water	99 37	98 23	98 23	96 89	96 63	96 37	77 70
The dissolved solid matter consists in 100 parts of—							
Sodium chloride	58 25	79 39	84 70	78 04	77 07	77 03	36 55
Potassium chloride	1 27	1 07		2 09	2 48	3 89	4 57
Calcium chloride				0 20			11 38
Magnesium chloride	10 00	7 38	9 73	8 81	8 76	7 86	45 20
Sodium and Magnesium Bromides		0 03		0 28	0 49	1 30	0 85
Calcium sulphate	7 78	0 60	0 13	3 82	2 76	4 63	0 45
Magnesium sulphate	19 68	8 32	4 96	6 58	8 34	5 29	
Calcium and Magnesium carbonates	3 02	3 21	0 48	0 18	0 10		
Nitrogenous and Bituminous matter							1 00

One cubic meter (35 3165 cubic ft) of sea water contains about 28 to 31 kilos of sodium chloride and 5 to 6 kilos of potassium chloride.

Analysis of Sea Waters

Seas	Na	Cl	Mg	Ca	K	SO₄	Br	CO₂	Fe	Fixed Residues
Atlantic Ocean	11 081	19 400	0 9565	0 4567	0 7604	2 577	0 1069			35 700
Do	10 464	19 012	1 2735	0 4684	0 7252	2 146	0 3102			31 700
Do.	11 719	20 840	1 1981	0 5568	0 4682	3 029	0 3878			38 100
Do	10 457	18 811	1 1763	0 5280	0 5916	2 878	0 1271			31 800
North Sea	10 117	18 054	1 3111	0 4782	0 6811	2 563	0 2924			34 400
Do	10 206	18 168	1 1582	0 4244	0 4538	2 590	(?)			32 800
Straits of Dover	10 142	17 704	1 2305	0 4093	0 0425	2 882	0 1016	0· 078	Traces	32 700
Mediterranean	10 688	21 099	3 0037	0 018	0 0041	5 716	(?)	0 142		40 700
Do	11 706	20 527	1 3104	0 4411	0 2613	2 943	0 434	0 0679	0 0028	37 700
Do	8 779	15 882	1 1616	0 4789	0 4356	2 662	(?)			29 100
Pacific Ocean	10 262	18 950	1 3151	0 4719	0 6038	2 788	0 3102			31 700
Do	10 233	19 321	1 1714	0 4752	0 6336	2 827	0 2301			35 200
Baltic	5 894	10 386	1 6115	0 0363		0 710				17 710
Black Sea	5 512	9 571	0 6822	0 1305	0 0975	1 2505	0 005	0 2475	0 1271	17 605
Sea of Azof	3 997	9 585	0 1010	0 0903	0 0670	0 8045	0 004	0 0695	0 0358	11 900
Caspian Sea	1 111	2 737	0 1098	0 1916	0 1397	1 337	(?)	0 0773	0 0401	6 296
Dead Sea	0 985	17 628	1 177	2 150	0 474	0 2424	0 167	Traces	Traces	27·078
Do	11 300	174 895	4 1128	17 280	4 386	0 6276	7 093	Traces	Traces	278 135

ANALYSIS OF WATER FROM THE IRISH CHANNEL

	Parts per 1,000.
NaCl	26 43918
KCl	0 74619
MgCl₂	3 15083
MgBr	0 07052
MgSO₄	2 06608
MgCO	trace
Mg(NO)	0 00207
CaSO₄	1 33158
CaCO	0 04754
LiCl	trace
NH₄Cl	0 00044
FeC O	0 00503
SiO	trace
Total	33 85946
Sp Gi at 0 C	1 02721
,, ,, 15°C	1 02484

Bombay Sea Water

PARTS PER 1,000 PARTS SEA WATER

Sodium	10 5599
Chlorine	18 7782
Magnesium	1 2851
Calcium	0 3440
Potassium	0 5709
SO₄	2 8870
CO₃	0 0760
Bromine	0 5160
	35 0171

Calcium Carbonate	0 1266
Calcium sulphate	0 9976
Magnesium sulphate	2 7267
Potassium chloride	1 0906
Magnesium chloride	2 6220
Magnesium bromide	0 5934
Sodium chloride	26 8588
	35 0157

Per cent.

$CaCO_3$	0 3615
$CaSO_4$	2 8490
$MgSO_4$	7 7880
KCl	3 1145
$MgCl_2$	7 4880
$MgBr_2$	1·6940
NaCl	76 7050
	100 0000

RECOVERY OF DISSOLVED SUBSTANCES

Substances dissolved in Sea Waters and Brines—From the analyses of sea waters given above it will be found that the principal constituents of the total dissolved solids in sea waters are the following —

> Calcium carbonate
> Calcium sulphate
> Sodium chloride
> Potassium chloride
> Magnesium sulphate
> Sodium sulphate
> Magnesium chloride
> Magnesium bromide

Besides these salts there is a large number of others occurring in very small quantities in sea water, e g , Iodides, Fluorides, Phosphates and Nitrates, Iron, Silver, Gold, Copper, Lead, Arsenic, Zinc, Nickel, Lithium, Rubidium and Ceasium , but as these substances occur in infinitely minute quantities, they are of no technical importance in the recovery of substances from sea water

The dissolved substances give to the sea water their characteristic saline taste There is a limit to the solubility of each of these substances This limit depends upon the temperature of the liquid and the presence of other dissolved salts In each individual case, water at a given temperature will dissolve only a certain quantity of the substance (Fig 2) When this quantity is dissolved, it will dissolve no more of that particular substance The solution in that case gets *saturated* In order to recover the dissolved substance, water which is not chemically changed by the dissolved substance must be removed by evaporation either spontaneously ·n the open air, or by the application of heat Most of the solids

are dissolved in larger porportions by increase of temperature, but in the case of Sodium Chloride, its solubility remains practically constant at higher temperatures.

Temperature C.
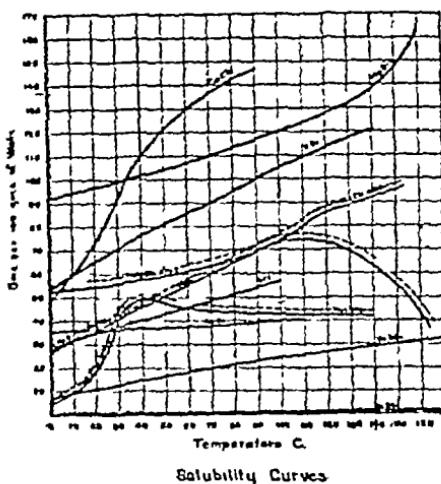
Solubility Curves

FIG 2.

If the saturated solution is lowered in temperature or its volume reduced by evaporation, the equilibrium is disturbed, and the solution in that case holds more salt than it is able to retain in its normal solubility conditions   The solution is at this point *supersaturated*, and the salt in excess will be thrown out of the solution as a solid until again a stable solution is formed under the altered conditions   This process becomes complicated if the solution contains more than one dissolved salt   The separation of the dissolved solids as the evaporation proceeds is in a fixed order The least soluble salt separates first and it is followed by the other salt in the order of its solubility.   By regulating the rate of evaporation it is thus possible to separate out each salt as it reaches its point of saturation   This process known as *fractional crystallisation* is applied in the separation of the various salts dissolved in sea water   In certain cases two salts separate out simultaneously   In such cases the mixture of salts is re-dissolved in fresh water, and the solution again concentrated and the salts re-crystallised. By this process of recrystallisation, pure salts are isolated. If; when the solution

is super-saturated a minute crystal of the salt is introduced into the solution by way of seeding or inoculation, the process of crystallisation starts spontaneously in the solution In many cases if the super-saturation is carried far enough, the crystallisation will grow without the necessity of inoculation When inoculation is necessary, the solution is in the metastable state, and when no inoculation is required and where the crystallisation is spontaneous, the solution is in the labile state In the concentration of sea water we have these three states occurring between the following densities—

From 3 5—17° B the solution is unsaturated

From 17—25° B it is saturated as far as Calcium Sulphate is concerned

From 24—25° B the sea water or brine is in the metastable state

Between 25—29 5° B it is in the labile state as far as Sodium Chloride is concerned

Evaporation—The change in water from its liquid to the gaseous state is brought about in increasing the molecular activity by the application of heat The molecules of water are in a state of perpetual motion (Fig 3) The energy of this motion depends on the temperature and pressure It is continuous, but increases if
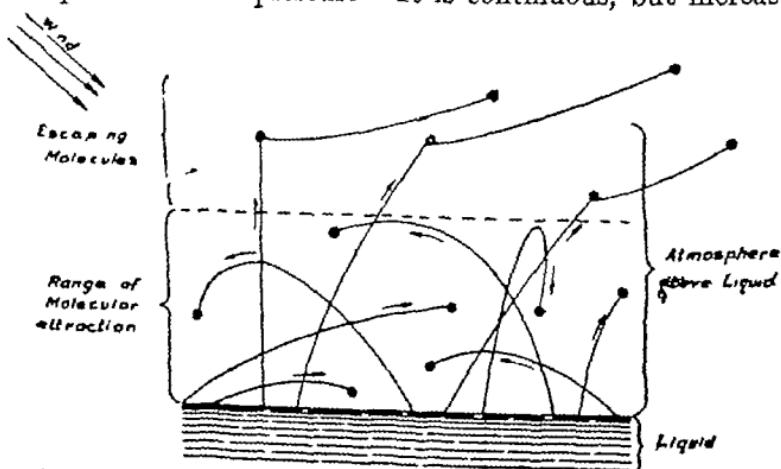
DIAGRAMMATIC REPRESENTATION OF THE MOLECULES JUST ABOVE THE SURFACE OF AN EVAPORATING LIQUID

FIG 3

heat is applied to the liquid When the molecules in motion are in liquid they are attracted by other surrounding molecules but when these molecules reach the surface, some of them are moving with sufficient velocity to escape from the surface of the liquid into the surrounding space and mingle with the air over the liquid Some of the molecules that have thus escaped have not sufficient energy to remain in the space and are thrown back in the liquid Over the liquid there is a certain layer of molecules in gaseous form in constant struggle to go out of and come inside the liquid , the process of coming out of the liquid is known as *evaporation* In short, water appears in gaseous state in the form of vapour at its surface. As the molecules are projected from the surface into the air, they have to encounter a certain resistance in their passage exerted by the pressure of the atmosphere and by the pressure of other molecules of water already existing there If the pressure is great, a number of molecules strike back on the surface and return to the water till for a given temperature a maximum vapour pressure is obtained (Fig 4) The air above the liquid in that case is *saturated* But if,

VAPOUR PRESSURE CURVES OF WATER
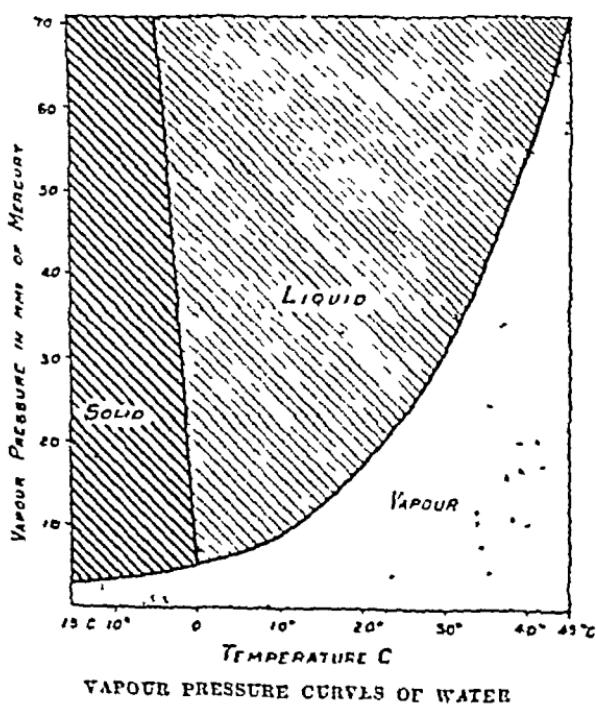
FIG. 4.

as the molecules come out of the liquid they are rapidly carried away by a current of air, they do not get a chance of going back to the liquid state and their place is taken by fresh molecules coming out of the water   The causes therefore which influence the rapidity of evaporation of water in open surfaces are —

(1)   The temperature which increases the molecular activity,

(2)   The quantity of the same vapour in the surrounding atmosphere,

(3)   Renewal of this atmosphere, and

(4)   Extent of the surface of the evaporation inducing a large number of molecules to strike out of the water as vapour at the same

If evaporation is to be accelerated, it is necessary that—

(1)   The molecular activity or temperature should be high. Temperature of the brine would depend on the temperature of air

(2)   The surface exposed should be as large as possible. If the brine is stationary the evaporation will be slow as the area exposed would be constant   If instead of this static condition, the brine is kept moving in thin layers, a very large surface would be exposed to the air and the evaporation in the latter case would be very rapid   The principle of a thin moving film is now widely applied in chemical engineering for concentration of liquids   The exposed surface of a liquid may be considerably increased by a slow trickling over a pile of pebbles or faggots or by spraying from a great height   Both these methods are used in the rapid concentration of brine

(3)   There should be wind   Wind is the greatest factor in the removal of saturated vapours from evaporating surfaces Wind also increases area exposed by creating waves and ripples   In French salterns wind is considered of greater importance than the sun   By increasing the current of air and by increasing the surface a maximum

rate of evaporation may be obtained   This principle is employed in concentrating brines in high towers about 80 feet high by 8 feet in diameter in which a strong current of air is maintained by blowers   This method is also employed in the concentration of sulphuric acid.   The acid towers are generally 50 feet high and 8 feet in diameter

Solar Evaporation — In   tropical   and   sub-tropical   countries salt is recovered from sea water and brines by solar evaporation. If local conditions as regards supply of sea water or brines, soil, level and transport are favourable, salt manufacture by solar evaporation is far more advantageous than by any other   means Solar evaporation requires the general fulfilment of all the above factors, which accelerate the evaporation of water in open surfaces They are best studied from meteorological observations of the place at which it is proposed to locate the factory   The factors of importance are —

(1)   Temperature of the air
(2)   Pressure, direction and velocity of the wind
(3)   Moisture in the air
(4)   Extent of cloudy skies
(5)   Rainy days and rainfall

(1)   Temperature of the Air —The temperature of the air depends upon the altitude of the sun, latitude, elevation, distance from the sea and character of the winds, and also on the amount of clouds and rainfall   During the period—November to February, the temperature of the air in India decreases with the increase of latitude and hence from South to North, the isotherms run across India nearly parallel to the parallels of the latitude   During the next three months (the hot weather season March, April and May) the interior of India is heated more than the coast districts, and the hottest air is generally in the central part of India   During the remainder of the year, from June to September, when salt manufacture by solar evaporation is brought to a stand still, the

south-west monsoon or rainy season prevails The temperature
is highest between the Punjab and Gujarat In India the mean
temperature falls on the average 1° F for every 330 feet of rise in
altitude In the dry hot season the rise is 1° F for every 190-200
feet of elevation

(2) Pressure Direction and Velocity of the Wind —Distance
from the sea and direction and character of the prevailing
winds are of great importance in the location of salt works In the
cold weather, November to February, dry Continental or Land
winds prevail over the whole area In the hot-weather-season
local sea winds prevail in the coast districts, and dry-land-winds
over the more distant interiors During the south-west monsoon
period, winds of oceanic origin charged more with moisture, spread
over the country Damp winds are not conducive to rapid eva-
poration In the table given in this book the moisture in the air is
referred to as *relative humidity* The chief factors determining
the amount of moisture in the air are —(1) Distance from the
sea and (2) character of the winds When air takes up all the
moisture which it can take up at a given temperature it is said
to be saturated With an increase in the temperature the saturated
air will take up more of the moisture The moisture in the air is
determined by the wet and dry bulb hygrometer When air is
cooled gradually, a point is reached, when dew begins to form
Relative humidity is the ratio of the pressure of the aqueous vapour
actually present at a particular temperature to the pressure of the
vapour which would be present if the vapour were saturated at
the same temperature Assuming that the barometric pressure
is constant, the relative humidity is determined by the following
formula —

Relative Humidity $= \dfrac{P_2}{P_1,}$ where $P_1 =$ pressure of the aqueous
vapour when saturated at T_1 , $P_2 =$ the pressure of aqueous vapour
when saturated at T_2 , $T_1 =$ the observation temperature of the
atmosphere in °C , $T_2 =$ the dew point at °C

The following formula also gives sufficiently accurate results —

$$\text{Relative Humidity} = \frac{\text{Mass of water vapour per unit volume of air at observed temperature.}}{\text{Mass of water vapour per unit volume of saturated air at same temperature.}}$$

Of the two thermometers of the wet and dry bulb hygrometer, one is an ordinary thermometer and shows the temperature of the air The bulb of the other thermometer has a piece of clean cotton wick wrapped round it , the other end of it is submerged in a small basin of water. This keeps the bulb moistened If there is much aqueous vapour in the air, there will be little evaporation from the moisture near the bulb, and as evaporation is accompanied by a loss of temperature or cooling effect the mercury will be lowered. But if the air is dry there will be a considerable difference between the temperature recorded by the two thermometers From the readings of the wet and dry bulb hygrometer the dew point may be determined The relative humidity table given in this report is from actual observation of the dry and wet bulb thermometers. The aqueous vapour pressure is obtained from the observation of the wet and dry bulb thermometers, and by the use of special tables prepared by the Meteorological Department In preparing these tables, August's formula as modified by Regnault is used The formula is based on the relation that the difference between the temperatures of the dry and wet bulbs is proportional to the difference between the actual vapour pressure and the saturation vapour pressure at the same temperature, $i\,e\ e = E\text{-}c\,(\text{T-t})$, T and t are the observed temperatures obtained from the dry and wet bulbs, and E and e are the saturation and actual aqueous vapour pressures at the air temperature T. c is a factor, depending slightly on pressure and temperature, and the constant in which is determined the actual experiment

(4) The amount of cloudy skies is estimated in terms of the proportion of the sky covered with cloud by numbers ranging from 0-10. A sky free from cloud is denoted by 0 and the overcast

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is highest between the Punjab and Gujarat   In India the mean
temperature falls on the average 1° F for every 330 feet of rise in
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(4) The amount of cloudy skies is estimated in terms of the proportion of the sky covered with cloud by numbers ranging from 0-10. A sky free from cloud is denoted by 0 and the overcast

sky by 10   The estimate given by the Meteorological Department
is not made by any instruments but by mere personal estimate of
the observers

(5)   The rainfall and rainy days are determined from the average
of the records of the Meteorological Department extending over
83 years   Rainy day is counted when at least 1/10″ rain has
been measured

Evaporation on Open Surfaces in India —Evaporation on open
surfaces varies during the 24 hours of the day as shown in Fig 5
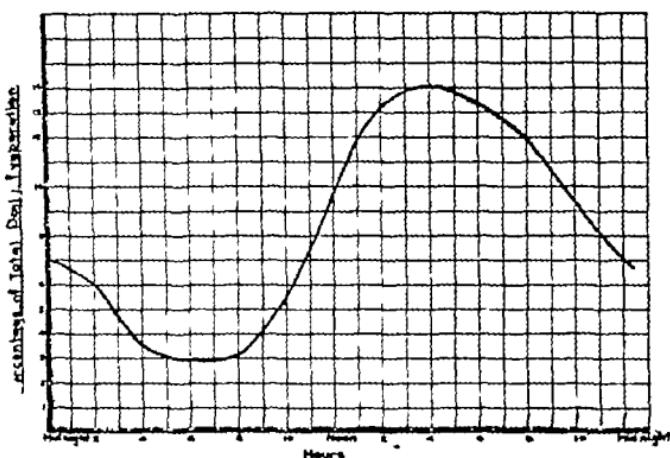
EVAPORATION DURING 24 HOURS
FIG 5

In India for purposes of storage reservoirs, tanks, hydro-electric
water supply and lakes, the general average evaporation
during the year is taken as 5 feet or 60 inches   The following
typical observations are given by Buckley, who shows that the
loss from evaporation alone rarely exceeds 0 4 inch a day in the
hottest and the driest weather   In Sholapur during April and May,
which are the hottest part of the year 0 38 inch a day is the highest
evaporation recorded   At the same place the evaporation during
November to March averaged 0 232 inch a day   In Rajputana
the average daily evaporation is as follows —

	Daily—inches
October to March	0·15
April to June	0 29
July to September	0 21
Average of the year	0 20
Total yearly feet	6 15

The average daily loss during different months in the Bombay Presidency (Poona) is as under —

January 0 17	February 0 14	March 0 17
April 0 27	May 0 38	June
October 0 25	November 0·19	December 0 14

Evaporation in Nagpur

	Daily evaporation. Inches
October and November	0 193
November and December	0 143
December, January and February	0 128
February and March	0 138
March and April	0 234
April and May	0 374
May and June	0 188
Maximum observed on any one day in April	0 428
Maximum observed during the year	0 600

From a series of observations Strange has drawn up the following average monthly loss during the principal seasons of the year —

	Inches		Inches.
Cold weather	3	Total for four months	12
Hot weather	8	,,	32
Monsoon	4	,,	16

Total for year 5 ft or 60 ins.

In **Ajmer** the loss in evaporation is as follows —

	1895-96 ft	1896-97 ft	1897-98 ft	Average- ft
October to March	2 93	2 73	2 58	2 75
April to June	3 26	3 40	3 41	3 36
July to September	1 17	0 79	1 45	1 14
Total for year	7 36	6 92	7 44	7 25

Evaporation in Ajmer will very nearly approximate that in Dhrangadhra State

For record of observations taken at different places in various countries refer to Buckley

The above observations are for open surfaces of fresh water Evaporation of sea water is stated by Buckley to be quicker than fresh water, but this refers only to the fresh sea water of lower densities

Evaporation of sea water and brine is not uniform at various densities as will be seen from Fig 6   Evaporation is very rapid
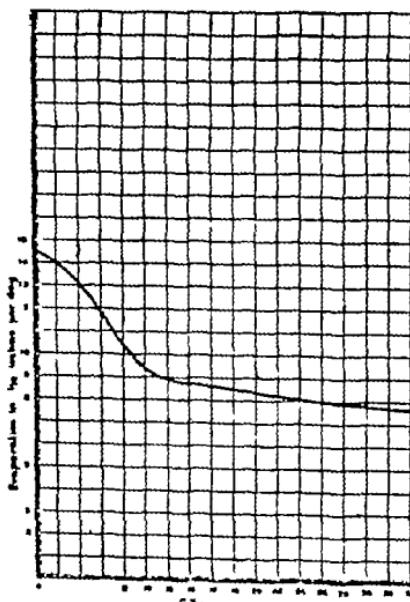
RATE OF EVAPORATION AT DIFFERENT DENSITIES
FIG 6

at lower densities, but as concentration proceeds, the rate of evaporation gradually lowers   Ratton states that the rate of evaporation is as high as one inch in two days when a hot wind is blowing " The mean rate of evaporation on the Coromandel Coast for the whole salt season is considered to be one inch in three days and numerous experiments of the author (Ratton) confirm this conclusion   Nevertheless for the sake of keeping this estimate within safe limits, it will be taken at 1 inch in five days, or say 6 inches a month At San Francisco Bay during the summer the following evaporation of sea water was noted by Phalen —

		Evaporation.
		Inches
April		3 38
May		5 31
June		6 62
July		7 81
September		4 94
October		2 94
	Total	38 81

Absorption —There are no regular observations taken of loss in brine by absorption in channels, condensers and pans   No analogy could be drawn from observations recorded by Buckley for fresh water reservoirs   In Salt works the heavier density brines are not so rapidly absorbed as in the case of fresh waters   The absorption is considerably checked by the separation and deposit of Calcium Sulphate   For this reason at the end of the season and in older works there is very little loss of brine by absorption   In well constructed salterns ten per cent is usually allowed for the loss by absorption.

Trough Experiments.—In order to determine the rate of evaporation per day in Kathiawad and the influence of density of the solution on the rate of evaporation on open surfaces under Indian conditions, a series of experiments were carried out in open troughs   The

following meteorological readings were taken side by side at the same place These figures will give an idea of the influence of the various causes which accelerate or retard the evaporations of saline solutions   For this purpose several wooden troughs 48 2″ × 36 3″ and 6″ deep were used   These troughs had an exposed evaporating surface of 1,750 square inches The troughs were made perfectly water-tight with pitch   The inner surface of the trough was black   As salt works are in full operation during February, March and April, and as in the month of March the weather factors are generally mean of the extremes, the readings will be of considerable value   During the period of observations the weather conditions were as follows —

	Dry bulb F		Wet bulb F		Temperature					
							Moving Creek water		Water in the Trough	
	M	F	M	F	Max	Min	M	F	M	F
Feb 10-28	70 8	84 4	55 7	67 6	91 7	57 7	62 7	79 0	57 1	72 9
March 1 31	78 4	86 2	66 4	73 4	90 3	66 1	72 3	80 8	67 1	70 5
April up to 8	82 6	87 7	71 1	76 1	96 2	71 2	76 0	86 7		

M (morning) E (evening)

The direction of wind was throughout NE except in the beginning of April when it was SW   NE wind is very dry , its velocity ranges from 2 to 10 miles per hour

The temperatures in the troughs varied from 50 85° F   The lowest was at sunrise and the highest at 4 p m   As the evaporation is rapid in brines of lower density, it was observed that the temperature of the brines under 12° B were also 10° F lower than those of higher density   The troughs were filled uniformly in each experiment   A depth of 4 inches water was taken at the commencement of the experiment   This quantity measured 117 litres   Each litre corresponds to 1 091 division on 1/32 inch scale The exact inches evaporated were determined from the number of litres remaining at the end of every 24 hours   Thus it has been possible to determine very accurately the rate of evaporation per

day to within 1/32 inch   The following is the summary of the trough experiments :—

Number of days to reach saturation 25° B			12 30
Water evaporated	litres		102 45
Brine remaining	,,		14 55
Average evaporation per day	,,		8 33
Evaporation per sq ft per day	galls		0 16
Quantity of salt recovered from 117 litres	lbs		7 7
Calculated quantity of salt in 117 litres	,,		9 3
Salt percentage recovered	,,		83
Bittern remaining	,,		8 9
Number of days required for evaporation between 24—30° B			3
Salt obtained per day	lbs		2 5
Salt obtained per sq ft	,,		0 21

The evaporation varied as follows —

	Evaporation	
	Inches	Average daily
February	10/32—8/32	9/32
March	12/32—10/32	11/32
April	14/32—10/32	12/32
Mean		11/32
Monthly inches		10 3

This figure corresponds exactly with Ratton's observation, *viz* , 1 inch in three days

It must be noted that this rate of evaporation of brine is considerably higher than the rate of evaporation of fresh water given by Strange, *viz* , 5 inches per month   He, however, allows 8 inches per month or a total of 32 inches for four months of hot weather In a dry place like the Rann of Cutch, where during the hot weather the temperature in the shade very often reaches 112° F., and where during the eight dry months of the year the wind is mostly NW the following will be the rate of evaporation —

	Monthly inches	Daily
September (½ month)	5	0 33
October	11 5	0 38
November	10 5	0 35
December	10	0 33
January	10 5	0 35
February	10	0 33
March	11	0 37
April	12	0 40
May	16	0 53
June (½ month)	6	0·40
Total of dry season	102 5	
Mean of dry season	11 4	

These figures have subsequently been verified by the trough experiments now being carried out at Kuda To provide for all the variable meteorological factors, the average rate of evaporation may be taken at 1/3 of an inch per day for the whole of the dry season during which salt manufacture by solar evaporation is carried out

Watt's Dictionary of Economic Products (Larger Edition, 1893) states that,—" the mean rate of evaporation of sea water in salt works is one vertical inch in three or four days, or 8 inches per month "

Crystallization of Salt —When a solid separates out on cooling or concentration of a saturated solution it assumes regular geome trical forms bounded by plane faces These solid symmetrical forms are known as crystals Every chemical substance of definite composition which crystallizes from solution has a specific crystalline form characteristic of that substance This form never changes. " In whatever manner, or under whatever circumstances a crystal may have been formed, whether in the laboratory of the chemist or in the workshop of Nature, in the bodies of animals or in the tissues of plants, up in the sky or in the depths of the earth, whether so rapidly that we may literally see its growth or by the slow aggregation of its molecules during perhaps hundreds or perhaps thou-

sands of years, we always find that the arrangement of the faces of the crystals, and therefore its other physical properties are subject to fixed and definite laws "—(Gurney). When a crystal is suspended in a saturated solution by means of a fine thread it grows uniformly in all directions and the ideal form is obtained, but under ordinary conditions there are various factors which influence the growth of the crystals —

(1) If the concentration of the solution is not uniform, the growth of the different planes is not uniformly rapid and the crystal develops abnormally

(2) If the crystal rests on one plane on the surface of the vessel, then that face is not fully developed Flat crystals parallel with the bottom of the vessels result The formation of flat blocks of salt in French, American and Aden salt works is due to the crystals not being disturbed in the liquid during their growth by accretion If the crystals and the solution be stirred from time to time as in the case of Baragra salt a uniform growth in all directions will result

(3) A cubical crystal sometimes grows rapidly in one direction resulting in needle-like or bar-like form. Sometimes only two faces grow and in that case the growth is like flakes or plates, as in the case of Ghasia Salt, when in all the three directions the crystal is a perfect cube as in the case of a fully developed Baragra salt.

(4) The formation is rapid if the solution is very concentrated Temperature and concentration conditions of solution must be determined for each salt to obtain the best results.

(5) Rapid crystallization results in the formation of smaller crystals.

(6) The growth may be changed by the presence of other dissolved substances

(7) Crystallization in motion gives better and more rapid results than crystallization in repose The crystals

thus obtained are purer than crystals obtained in static conditions

Common Salt Crystals —Sodium Chloride forms symmetrical cubic crystals having nine planes of symmetry   Three are indicated in the fig 7 and six others are obtained by taking planes diagonally through three faces of the cube
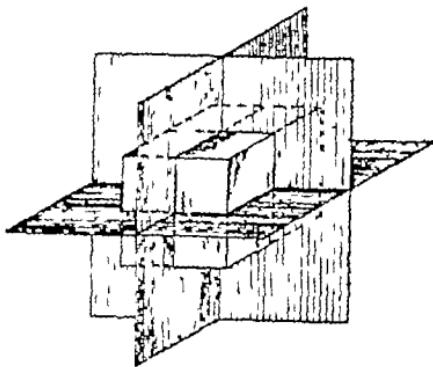
PLANES OF SYMMETRY
SODIUM CHLORIDE
FIG 7

Salt crystals obtained by spontaneous evaporation of sea water or brine without much disturbance are conical or hopper shaped These crystal grains can be altered to some extent by constant stirring which separates the tiny cubes forming the cone or hopper, and also by the addition of alum and the presence of magnesium sulphate or calcium sulphate   The effect of these substances is to form very hard large coarse crystals   When the salt crystals are formed in the presence of soluble sulphates as in the case of salt from sea water or brines, or when alum is added, the salt has the first tendency to crystallize in hollow cubes (Fig 8) on the surface of the water   The cubes grow gradually by the addition of other smaller crystals around them The growth is in the shape of a hopper (Fig 9), and when the aggregate is sufficiently heavy, it settles down to the bottom of the pan   If the aggregate is disturbed by stirring with the help of a rake or a spade the crystals separate out, and each one in turn begins to grow   If, on the other hand, a fine grained salt is

required gelatine or grease is added Salt, if badly prepared has the property of becoming hygroscopic owing to the presence of slight
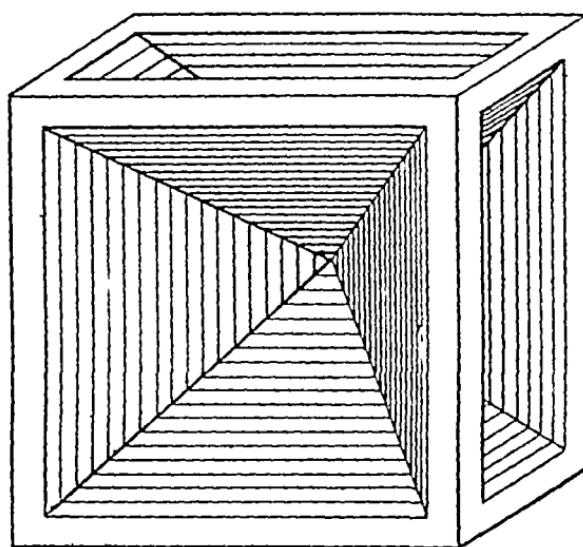
SALT CUBES
FIG 8
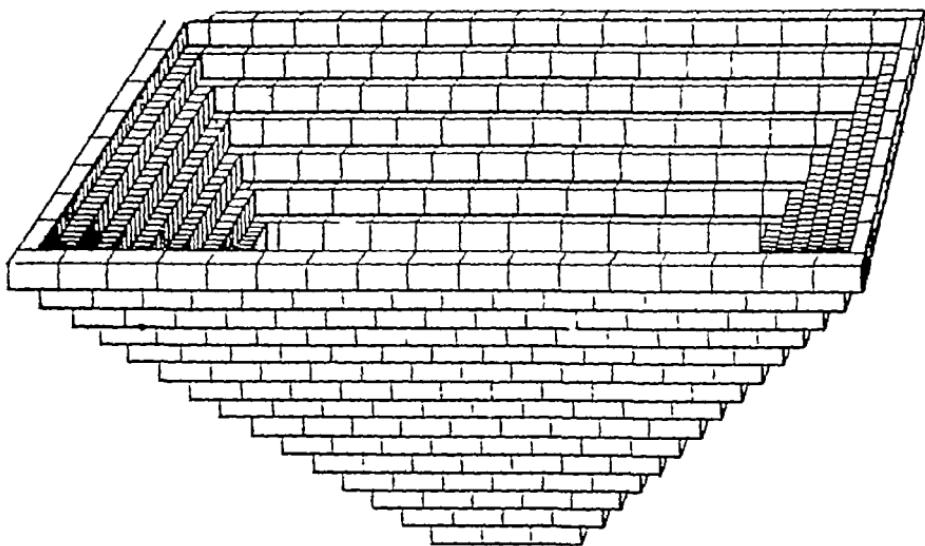
SALT CRYSTAL
HOPPER-SHAPED
FIG 9

impurities of magnesium chloride which remain coated on its surface after it is removed from the bitterns in the pan   If the salt crystals are well washed the hygroscopic property is considerably reduced However carefully salt is prepared it shows a tendency to stick together in lumps   In the preparation of Cerebros table salt 3 per cent phosphate is added in the form of bone meal to prevent the salt from forming lumps   Under identical conditions of temperature, concentration and substances in solution salt will separate in only one form of crystals   The size and the general form will depend entirely on the mode of preparation   Given brine of the same composition, it is possible to manufacture any grade of salt by a variation in the method of recovery

V

TECHNOLOGY OF SALT

The process of obtaining salt (sodium chloride) and other substances which are dissolved in sea water or natural brines is entirely one of gradual evaporation and fractional separation of solids at different degrees of concentration Most of the natural brines contain the same salts as those found in sea water If these brines are reduced in strength to the same density of sea water, the composition of the two is very nearly alike The weights of the total dissolved solids are in both cases within very narrow limits The diagram Fig 10 shows the relation between Volume and Density of the sea water at different stages of concentration
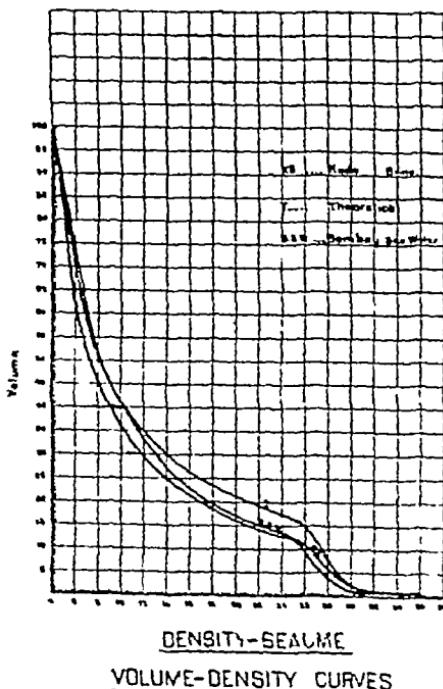

DENSITY–SEAUME
VOLUME–DENSITY CURVES

Fig 10

TABLE SHOWING CONTRACTION IN VOLUME BY EVAPORATION OF BRINES TO DIFFERENT DENSITIES

°Tw	3 0	10	15	16	17	18	19	20	21	22	21	24	25	29 5	32	33	34	35	36	36 5	38 5	36*	38 3
3 0	100																						
6	62 29	100																					
10	40 72	80 39	100																				
11	33 11	62 70	85 82	100																			
12	20 56	80 33	80 1	80 02	100																		
13	20 72	07 81	75 15	81 40	87 56	100																	
14	24 01	02 04	70 02	70 01	82 04	93 70	100																
15	23 11	59 03	71 50	71 50	70 78	82 26	100																
16	21 31	54 01	66 01	66 01	71 00	77 00	88 29	100															
17	10 83	50 44	61 07	63 02	67 70	72 50	82 12	87 00	100														
18	18 52	47 30	58 16	59 98	64 45	69 01	77 41	82 00	03 58	100													
19	17 37	44 05	55 31	58 24	61 15	65 48	73 60	77 08	88 20	04 20	100												
20	10 30	41 50	52 48	58 24	9 58	10 27	09 84	73 08	97 00	80 04	05 10	100											
21	15 94	05 34	5 224	8 921	7 10	7 60	10 05	11 60	70 06	85 08	00 24	04 80	100										
22	14 96	38 84	0 170	6 001	6 60	7 17	8 21	8 70	12 47	13 98	14 15	14 87	15 03	100									
23	13 44	30 00	5 740	0 272	6 08	6 51	7 65	8 10	8 72	9 98	10 61	11 15	11 70	75 00	100								
24	13 78	34 81	5 218	5 058	5 36	5 88	6 94	7 30	7 01	0 31	9 88	10 30	10 25	09 85	03 13	100							
25	12 13	33 03	4 709	5 100	4 80	5 24	6 27	6 64	7 14	8 40	8 07	9 43	8 04	09 43	84 57	90 80	100						
29 5	1 001	5 177	4 108	4 552	4 13	4 49	5 50	5 92	0 37	7 63	8 09	8 51	8 07	57 24	70 72	81 04	00 24	100					
32	1 426	3 884	3 843	3 843	1 08	2 12	4 72	4 00	5 37	0 80	7 22	7 50	7 09	51 02	08 07	73 05	90 44	80 15		100			
33	1 327	3 014	0 740	0 272	1 08	7 60	2 20	2 30	2 58	2 70	2 92	3 07	0 73	40 08	17 14	01 07	07 92	15 20	34 43	47 98		100	
34	1 200	3 284	0 385	5 058	0 41	0 44	9 20	2 30	0 54	0 58	0 01	0 04	0 07	20 67	27 55	20 50	32 30	30 12	40 52	10 00	100	20 80	
35	1 088	2 003		5 100				0 50						4 31	5 75	0 17	0 80	7 50	8 45			100	100

Density of Liquids —The density of a liquid is expressed in different terms Specific gravity is the number, which expresses the relation of the weight of a given volume of the liquid to the weight of the same volume of distilled water at a temperature of 4° C In order therefore to calculate the specific gravity of a body it is sufficient to determine its weights and that of an equal volume of water and then to divide the first weight by the second, the quotient is the specific gravity of the body In the usual works practice, specific gravity is determined by means of a hydrometer These hydrometers consist of hollow-metal or glass cylinders loaded with lead or mercury to which is attached a stem marked with divisions which indicate at the level of a liquid the specific gravity directly As specific gravity is not the same at different temperatures, the hydrometers are marked with degrees Centrigade or Fahrenheit at which they are calibrated

In salt works practice, Beaume's hydrometer is universally employed The graduation of this instrument is made as follows It is so constructed that when immersed in pure distilled water, the stem dips into the water nearly at the top This point is marked zero A solution of 15 parts of salt in 85 parts of water is made and the instrument immersed in it The new point at the level of the brine is also marked and the distance between the two points divided into two equal divisions or degrees Each division indicates one per cent dissolved salt The graduation is continued to the stem upto 40 divisions in salt works practice

There is another hydrometer known as Salimeter, which is used in determining the density of saline solutions The zero point on Salimeter is determined with distilled water and its lower point determined with the salt solution containing 26 5 per cent of salt at 20° C at which point it is completely saturated The distance between the two points is divided into 100 equal parts, or Salimeter degrees In some places Twaddell's hydrometer is used It is graduated in such a manner that the reading or number of degrees on the Twaddell hydrometer stem when multiplied by 5 and added to 1,000 gives the Specific Gravity It will be seen from these des-

criptions that in the case of Beaumé, Twaddell and Salimeters the graduations are entirely conventional For the conversion of the readings by these different hydrometers into Specific Gravity the following formulæ are used —

Specific Gravity compared to water at 15° C=1

A Specific Gravity $= \dfrac{144\ 3}{143\ 3-n}$

where $n=$ °B

B Specific Gravity $= \dfrac{1+5(° \text{Tw})}{1000}$

When the solution contains other substances besides sodium chloride or salt the hydrometer readings do not give a correct idea of the percentage of sodium chloride dissolved But for all practical purposes the Beaumé's hydrometer is of considerable value in salt works

Concentration of sea water and brines—Stages.—The process of concentration may be divided into seven stages (Fig 11) Each stage represents a distinct change in the resulting liquid —

(1) Between 3 9°B and 10 0° B ⎫ Unsaturated
(2)   „   10 0 and 17 0 B ⎭
(3)   „   17 0 „ 24 5 B
(4)   „   24 5 „ 29 5 B
(5)   „   29 5 „ 35 0 B
(6)   „   35 0 „ 37 0 B
(7)   „   37 0 „ 38 5 B

First Stage —Sea water is generally found to have a Specific Gravity of 1 025 to 1 029 at 25° C corresponding to 3 5 to 4° B Usually we get on the Indian littoral 3 9° B By gradual evaporation of sea water the original volume is reduced to 37 per cent when the density reaches 10° B From the diagram it will be noticed, that there is a slight difference between the curves obtained from theoretical calculations and the curves obtained from the actual observation of concentration experiments of sea water and natural

brine   This slight difference is due to errors in observation and manipulation and to the gradual escape of dissolved gases during the progress of concentration   Hunter (Thorpe) has shown that the
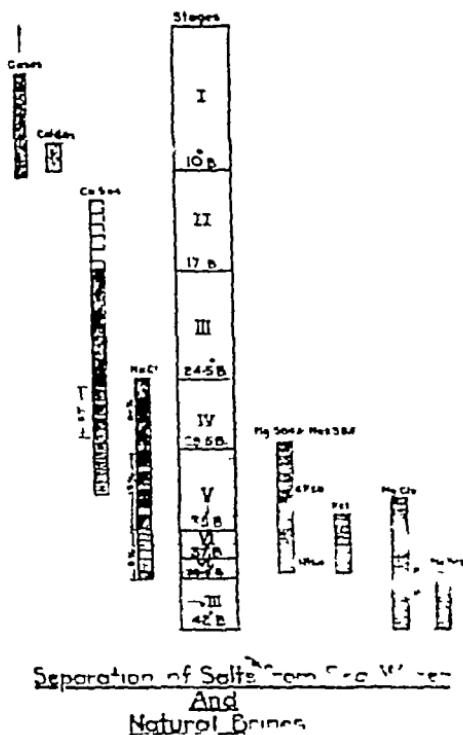
Fig 11.

volume of gas dissolved in water is 2 2—3·5 volumes in 100 volumes of water

	CO_2 per cent	O per cent	N per cent
Volume of water			
2 2 consists of	28 62	49 44	21 94
3 5 do.	48 28	17 22	34 5

The dissolved gases are not entirely removed in open surfaces during solar evaporation   The difference between the theoretical and the observed curves at higher concentration is also partly accounted for by the removal of water with the separated salts Usually salt contains 2 5 to 5 5 per cent of water not as a constituent but as an intermixture   Upto 10° B the first salt that is

thrown out from the solution is Calcium Carbonate   It is extremely
insoluble in water   Its solubility at 30° C is only 0 0052 grms in
100 grms of water   As Calcium Carbonate is abundantly found
in nature, its separation and recovery in salt works is of no practi-
cal value

Second Stage   After the separation of Calcium Carbonate the
liquid remains unsaturated till it reaches a density of 17°B   The
original volume of the sea water is now reduced to 20 per cent or
one-fifth of the original   Gypsum and the remaining Calcium
Carbonate and sometimes also Magnesium Carbonate are very
often noticed to separate out at 12 B

Third Stage —When the concentration has reached 17°B,
Calcium Sulphate begins to separate out as gypsum $CaSO_2H_2O$
The separated gypsum at first floats on the surface of the liquid
as a thin grey film and when it has sufficiently accumulated, it
settles down to the bottom of the pan carrying along with it a little
salt which just begins to come out when the major portion of the
gypsum ceases to separate   The separation of gypsum continues
upto 25°B   Manzella has shown that the total amount of Calcium
Sulphate originally present in the sea water is not entirely thrown
out of the solution even when the brine reaches a concentration of
25°B as will be seen from the following table —

Separation of Calcium Sulphate

°B	Remaining dissolved	Total deposited	Percentage removed
3 5	1 749		
25 0	0 283	1 466	83 8
28 5	0 015	1 734	99 1
32 4	0 000	1 749	100

Only about 84 per cent of the dissolved Calcium Sulphate separate
out during the second stage of evaporation.   When natural brines

are found having a density between 17—25°B, they are generally deficient in Calcium Sulphate   In the Rann of Cutch, from which Kharaghoda and Kuda brines are obtained, there is a layer of about 3″ of gypsum under the clay strata   This Calcium Sulphate seems to have been separated out from the original sea water by its spontaneous evaporation   Similar deposits are found at Stassfurt and in the United States in Virginia-Saltville and at the salines of the Eastern Texas and in many other places   In large sea salt factories Calcium Sulphate gradually accumulates in the condensers or preliminary evaporating basins where the layer of gypsum in course of time reaches a thickness of about 2″   In French salt works and at Aden this deposit is removed from time to time   The accumulated quantity is so great that it is difficult to dispose of the same advantageously   For every 100 tons of salt obtained from the sea water 4 to 5 tons of gypsum are obtained   At Aden in the absence of any commercial demand or technical uses, it is spread out in the making of roads and in making impervious floor or bottom of newly constructed crystallising beds   Calcium Sulphate whether it is used specifically in the preparation of floors or beds of the crystallising pans, is always found there in fairly thick layers   The Calcium Sulphate which separates out in the crystallising pans is part of the Calcium Sulphate left over after 84 per cent of the original bulk was removed before the brine reached a density of 25°B

The volume of the sea water at this stage is reduced practically to one-eighth of the original

Fourth Stage—This stage begins at 24 5°B   Pure salt solution is saturated at 26°B when the percentage of salt in solution is 26 5   But in the presence of other dissolved salts, the solution behaves as if it is saturated at 24 5°B, when salt begins to separate out   As the evaporation proceeds for every 100 grms of water evaporated from the saturated solution, 36 5 grms of sodium chloride are thrown out of solution   The solubility of sodium chloride being 36 5 grms at 30°C in 100 grms of water, the percentage of salt present in the saturated solution would be —

$$\frac{36\ 5}{(100+36\ 5)} = 26\ 74 \text{ per cent by weight}$$

Thus for every 100 grms of saturated solution we have 73 26 grms of water and 26 74 grms of salt If 1,000 grms of saturated solution are gradually evaporated, then for every 100 grms of water removed the following quantities of salt will be separated from and remain in solution —

Water	Salt in sol	Salt separated	Per cent of salt removed.
732 6	267 4		
632 6	230 9	36 5	13 65
532 6	194 4	73 0	27 30
432 6	157 9	109 5	40 95
332 6	121 4	146 0	54 60
232 6	84 9	182 5	68 25
*132 6	48 4	219 0	81 90
32 6	11 9	255 5	95 55
7 6	2 8	264 6	98 95
2 6	1 0	246 4	99 63
		267 4	100

From table on page 43, it will be noticed that the solution remains between 25 and 26' B for a very long time   The rise in density is not rapid on account of the separation of the dissolved salt   The density begins to be appreciably higher than 26 after the separation of over 50 per cent of the dissolved salt   The density fluctuates during the day and the night   When during the day the evaporation is rapid under the influence of the sun and the winds, the brine becomes slightly supersaturated , but when night falls and the temperature of the air is lower there is a drop in the temperature of the brine due to its cooling, and the consequent separation of the excess of salt from the super-saturated solution   This drop in the readings of the density taken in the evening of the previous day and the next day in the morning is very noticeable   As the concentration proceeds, more and more salt is thrown out of the solution till the brine reaches a density of 28 5°—29°B   It is well

* Density 29 5° B

known that the total quantity of salt originally present in the brine is not entirely separated when the density has reached 28 5°B.

Separation of Sodium Chloride.

°B	Total dissolved	Total separated	Per cent separated
3 5	29 696		
25 0	29 696		
28 5	8 889	20 807	70 0
32 4	3 993	25 703	86 6

The yield under Indian conditions would be different, but Manzella s figure for 28 5° B compares very favourably with the calculated figure, for 29° B *viz*, 75 73, and with the actual obtained from trough experiments at 30° B, *viz*, 83 The salt obtained upto 28 5° B is generally of the following composition —

	Brine salt	Sea salt
NaCl	97 40	97 11
$CaSO_4$	0 58	1 10
$MgSO_4$	0 15	0 23
$MgCl_2$	0·08	0 04
Insoluble residue		0 05
Water	1 71	1 40
	99 92	99 93

These typical analyses show that Sodium Chloride is associated with other salts, such as Calcium Sulphate, Magnesium Sulphate and Magnesium Chloride Though Potassium Chloride is not shown in these two typical analyses, it is also found to the extent of 0 012 per cent Magnesium Chloride renders the salt hygroscopic and the presence of the moisture over one per cent is accountable to this salt Magnesium Chloride also intensifies the salty taste If the salt is washed with weak brine or fresh water, most of the above impurities, which are found in the residual coating of the bittern remaining on the surface of the crystals, are removed and the salt thus washed is 99-99 5 per

cent pure The fourth stage is completed when the concentration reaches to 28-29°B The concentration is not carried further as the salt that separates out at this higher concentration is very impure and difficult to separate from the adhering bitterns For this reason, at all the salt factories, the process of recovering salt is stopped when the concentration has reached 29°B At this stage the remaining bittern is only 2 per cent of the original volume and its weight is practically the same as the weight of the 90-94 per cent salt recovered The remaining liquid is known as 'bittern Ballard, the French Chemist, was the first to suggest the recovery of these valuable by products from bitterns During the Great War bitterns received considerable attention in all the leading countries as a very valuable source of several by-products, particularly Potassium, Magnesium and Bromine

Composition of Bitterns—If the composition of sea water or natural brine is known it is possible to calculate the composition of the resulting bitterns Assuming that the average composition of sea water is as given below, the composition of the brine and bittern would be as given in the following table —

	Sea water of average composition at 4° B parts per 1000	Percentage of total solids
Calcium Carbonate	0 035	0 10
Calcium Sulphate	0 735	2 10
Sodium Chloride	27 300	78 00
Magnesium Sulphate	2 625	7 50
Potassium Chloride	0 749	2 14
Calcium Chloride	0 070	0 20
Magnesium Chloride	3 185	9 10
Magnesium Bromide	0 301	0 86
Total	35 000	100 00
Water	965 000	
	1000 000	

Composition of Sea Brine at different Concentrations. (Calculated).

PARTS PER 1000 GRMS

Degrees Baumé	3 5	10	15	20	25	26 25	26 75	27 75	30
Calcium Carbonate	0 035	0 058							
Calcium Sulphate	0 735	2 001	3 180	1 010	0 072	1 100	0 502	0 707	0 423
Sodium Chloride	27 300	74 015	118 130	172 000	211 540	237 470	220 020	170 016	105 032
Magnesium Sulphate	2 025	7 205	11 700	10 010	21 011	25 070	10 011	90 106	123 010
Potassium Chloride	0 749	2 031	3 241	4 500	0 175	7 152	10 541	10 740	5 208
Calcium Chloride	0 070	0 191	0 302	0 427	0 579	0 000	0 080	1 848	5 300
Magnesium Chloride	3 185	8 074	1 781	19 432	20 250	30 408	41 819	83 052	140 074
Magnesium Bromide	0 301	0 810	1 302	1 830	2 481	2 873	4 235	7 012	11 100
	35 000	90 794	141 732	210 802	209 052	101 757	124 051	150 195	432 025
Per cent of salt separated from total in 25°B						15 146	45 130	60 381	75 720

Analysis of Bitterns—28 to 30°B

(American Salt Works—Phalen)

GRMS PER LITRE

	1	2	3	4	5	6	7	8	9	10	11	Average
Calcium Carbonate	20 0	4 0	7 4	2 3	1 7	3 3	0 6	3 7	Trace			3 37
Calcium Sulphate	156 0	203 0	192 7	09 6	7 4	21 1	240 0	152 7	160 4	140 14	54 72	135 38
Sodium Chloride	75 0	33 0	32 8	85 0	61 5	75 3	35 8	60 7	42 7	71 85	70 55	50 89
Magnesium Sulphate	21 4	15 6	25 5	23 2	27 8	41 0	66 7	22 5	1 3	26 09		28 31
Potassium Chloride	91 0	85 0	63 8	144 5	171 1	250 8	4 2	117 5	63 5	128 03	143 90	113 00
Magnesium Chloride	8 6	3 4	3 4	3 4	3 4	2 3	2 3	3 2		2 07		3 50
Magnesium Bromide	2 0											
Calcium Chloride											27 08	14 51

Analysis of Bitterns between 34-36°B

	KHARAGHODA Grms per litre			FRANCE Grms per litre			
	1	2	3	1	2	3	Average
Calcium Carbonate			0 79				0 79
Calcium Sulphate			1 70				1 70
Sodium Chloride	10 80	6 47	16 76	31 73	34 0	51 18	25 16
Magnesium Sulphate	39 65	13 21	32 86	102 00	82 0	76 5	57 62
Potassium Chloride	1 73	1 35	8 25	37 00		54 24	20 51
Magnesium Chloride	373 50	448 41	360 84	237 50	260 0	314 68	332 42
Magnesium Bromide	7 24	11 86	5 50		4 0		7 15
Calcium Chloride					41 0		41 00

Bombay Sea Water Bittern.

Density 29 25° B.

RADICALS

	Grms. per litre.	Per cent.
K	18 90	1 51
Na	55 07	4 41
Ca	Traces	Traces
Mg	43 68	3 49
Cl	198 52	16·89
SO$_4$	58 92	4 71
Br	1 89	0 14
Total	376 89	30 15

CONVENTIONAL COMBINATION

	Grms per litre	Per cent
Calcium Sulphate		
Sodium Chloride	140 14	11 21
Magnesium Sulphate	73 65	5 89
Potassium Chloride	36 09	2 89
Magnesium Chloride	128 80	10 30
Magnesium Bromide	2 07	0 17
Total	380 75	30 46

Fifth Stage—When the bitterns are drained out from the crystallizing pans at 29 5°B they contain various salts in solution. These salts are at 29 5°B very near their point of saturation For this reason the bitterns require very careful treatment As the original volume of sea water has contracted to 2 per cent when it has reached 29 5 B It will be more convenient to take the bitterns of 29 5 B as the starting liquid for the calculation of volume in the subsequent stages of evaporation As the evaporation proceeds, solids continue to separate out The deposits obtained up to 36°B consists mainly of sodium chloride with a small percentage of magnesium and potassium chlorides and sulphates It will be noticed from the solubility curves that magnesium sulphate and potassium chloride are soluble practically to the same extent at the ordinary temperature of the air (25°C) Their separation from saturated solution is very difficult The separation of various dissolved solids from bitterns has been the subject of a very close study by Van't Hoff His classical researches on the subject must be studied in this connection Hildebrand has also contributed a very valuable paper on the subject This paper is reprinted in extenso as an appendix to this report

Bitterns from Bombay sea water, from Kharaghoda and Dhrangadhra brines have been very closely studied in my laboratory

Deposits obtained at different concentrations of the bitterns were separated and examined   In the fifth stage from 29 5°B to 35°B most of the sodium chloride, which remained dissolved in the bitterns, separates out   Manzella has shown that between 28 5— 32 5'B 16 per cent more of the sodium chloride separates out, whereas according to Macnab sodium chloride separates out as follows —

	Sodium Chloride separated.	Per cent.
0°B		
26 25	3 2614	
27·00	9 6550	
28 50	7 9960	70 4
30 20	2 6240	
30 24	2·2720	
35 00	1 4040	
Total	27 1074	91·3
Total salt remaining in 36° B	2 5885	8 7
Total	29 6959	

ANALYSIS OF CROPS FROM BOMBAY SEA WATER BITTERNS BETWEEN 31 & 42°B

Crop No	°B	Sodium Chloride	Magnesium Chloride	Potassium Chloride	Magnesium Sulphate	Moisture	Weight
1	31 to 34	95 55	4 12		1 6	7 2	0 oz
2	34 ,, 36	81 98	4 22		2 56	12 50	1¼
3	34 ,, 36	50 81	6 33		12 17	16 94	¾ ,,
4	35 ,, 36	7 15	5 74		40 25	41 48	¼ ,,
5	36	10 93	4 05	18 93	12 04	36 40	4 ,,
6	36	12 75	4 93	18 10	35 94	22 00	3¼ ,,
7	36	18 43	3 91	23 10	31 21	24 26	1¼
8	36	21 64	7 76	23 15	33 07	13 86	1 ,,
9	30 to 37½	20 85	23 81	22 73	6 32	24 06	1½ ,,
10	37	20 70	12 00	7 61	23 33	21 76	¾ ,,
11	38 to 39	11 50	11 29		31 78	25 86	
12	39 ,, 42		41 61		1 25	48 14	2 lbs 14 oz

RECOVERY OF SOLIDS FROM BOMBAY SEA WATER BITTERNS (KATHIAWAD COAST)

Crop No	Concentration		Volume of Bittern						Crop			Remarks	Dried samples per cent			
	From °B	To °B	Beginning	Remaining	Evaporated	Total evaporated	Percentage original	Percentage preceding	Wt in gms as it is	Moisture & water of crystal	Wt of the dried crop		NaCl	MgCl₂	KCl	MgSO₄
1	29.75	31.70	3,000	2,150	950	850	28.33	28.33	205	130	175		62.02	4.05		2.75
2	31.70	33.8	2,150	1,715	496	1,285	42.93	20.27	140	60	71		93.17	3.64		1.32
3	33.9	39.0	1,715	1,325	190	1,005	55.50	22.16	155	71	84		69.12	8.15		23.43
4	75.00	30.25	1,325	1,150	185	1,920	61.66	13.85	110	41	90	Drop from 76 to 25°B	58.70	7.76	Slight trace	53.50
5	10.25	27.00	1,150	1,030	120	1,670	65.66	10.11	55	71	24		14.11	0.04	31.10	11.05
6	27.00	34.75	1,030	1,000	21	1,991	66.10	2.35	70	28	72		Nil	8.45	20.59	01.07
7	31.75	35.50	1,000	705	211	2,215	71.40	23.0	159	88	71		14.17	25.02	27.74	31.47
8	35.50	36.0	705	605	100	2,335	77.83	13.09	67	30	31		24.25	21.24	27.88	20.65
9	30.0	38.25	605	550	115	2,450	91.66	17.20	25	10	10		8.02	49.21	25.35	17.42
10	38.25	39.25	550	510	10	2,490	83.00	7.27	15	7	8		12.00	91.71	12.00	44.29
11	10.25	40.0	510	125	185	2,675	89.10	76.27	189	117	72	Drop from 40.37.5°B	2.82	09.20	1.73	20.16
12	27.5	40.5	325	200	125	2,800	93.33	62.5	110	50	57			07.82		2.18
								Total	1,410	703	713	Total				

4

ANALYSIS OF THE CROPS OBTAINED FROM KUDA BRINES

	I 20·5—32°B	II 32—34·1°B	III 34·1—36·5° B	IV 36·5—38·5° B	V 30—35°B	REMARKS
	Per cent	Per cent	Per cent	Per cent	Per cent	
Sodium (Na)	31·23	31·13	6·42	1·22	1·05	The remaining liquor was of Sp. Gr. 1·357 (38 B) and contained 0·559 per cent of Bromine by weight
Potassium (K)	0·29	0·55	13·00	0·53	0·00	
Magnesium (Mg)	0·03	0·13	10·01	10·60	10·15	
Chlorine (Cl)	50·06	48·73	40·96	30·82	31·53	
Sulphate (SO₄)	2·22	2·38	3·18	3·95	1·00	
Calcium (Ca)	Traces					
Sodium Chloride	82·03	79·19	10·13	3·00	2·68	
Potassium Chloride	0·56	1·05	24·84	1·05	0·17	
Magnesium Chloride		0·24	25·70	38·05	20·00	
Magnesium Sulphate	2·77	2·07	7·08	4·03	1·76	
Magnesium Oxide	14·12	13·76	0·04	Traces	Traces	
Calcium Sulphate	Traces					
Water by difference	0·51	0·70	23·11	52·88	55·80	

N B —Crops Nos I and II were dried in the air oven at 110-115°C for nearly 10 hot rs Duration of drying was decreased from 10 to 4 hours in No III, hot oven then Magnesium Chloride did hydrolyse to a certain extent and consequently the last two crops Nos IV and V were not dried in the oven at all The crystals of the crops Nos IV and V were dried with the help of the filter paper and at once weighed in a weighing bottle

RECOVERY OF SOLIDS FROM KUDA BRINES

No of Crop	Concentration From °B	Concentration To °B	Volume of liquid Beginning	Remaining	Evaporated	Total evaporated	Crop Percentage original	Percentage preceding	Weight in grm as it is	Moisture and water crystallisation	Weight of the dry crop	Remarks	Dry samples Na Cl	Mg Cl₂	KCl	MgSO₄	MgO	REMARKS
1	20	20·5	64,000 cc	7,400 cc	56,600	56,600	88·4		15,000	2,140	12,750		82·43		0·67	2·78	14·10	Calcium in traces
2	20·5	1·32	7,400	5,600	1,800	58,400	91·3	24·3	530	81	458		70·84	0·24	1·06	2·09	15·80	Crops Nos 2—5 were dried in the oven at 110
3	32	1·34	5,600	4,650	950	59,450	92·7	17·0	385	58	327		21·33	33·12	12·30	5·19	7·83	115 for nearly 10 hours and No. 4 for 4 hours
4	34	1·36	4,650	3,575	1,075	60,425	94·4	23·1	511	77	414							and consequently most of the Mg Cl₂ had
5	36	5·38·5	3,575	3,150	425	60,850	95·0	11·0	} 1,702	255	1,447	(fall from 18°·5—36°·B)	6·58	80·72	2·23	10·40	Trace	hydrolysed Such being the case Nos 5 and 6
6	38·5	30	3,150	1,550	1,600	62,450	97·6	50·1	1,300	200	1,181		6·075	00·40	0·39	3·08	"	were analysed as they were and the water was estimated by difference
7	36	38	1,550	315	1,235	63,685	99·5	70·7			16,603							
								Total	10,623	3,020								

Total solids in the brine 20°B 24·30 per cent
Theoretical quantity of the solids   18,075 grms
Quantity actually recovered   16,603

Mother liquor   315
                —————
                16,918

Shortage   1,152   or about 5 per cent

From the tables showing the analysis of the various crops obtained from sea water and Kuda brines, it will be noticed that sodium chloride is the principal salt to separate out upto 35°B It continues to come out at normal temperature in the subsequent stages 97 1 per cent of salt remaining in the bittern at 29 5°B is removed when the concentration reaches 35°B In the second deposit of sodium chloride thus obtained, there is a fairly large quantity of magnesium sulphate If the deposit is recovered when the solution is at a higher temperature, viz, at the end of the day, most of the magnesium sulphate will re-dissolve into the bitterns owing to its greater solubility at higher temperature than sodium chloride

Sixth Stage —This is a very important stage in the recovery of by-products At this stage potassium salts and magnesium sulphate and also sodium sulphate are recovered if the process of separation is worked out carefully From the solubility curves and the tables of solubility it will be noticed that magnesium sulphate and potassium chloride are of identical solubility In the French salt works the bitterns of 35°B are allowed to cool spontaneously during winter till they reach a temperature of 11-12°C when magnesium sulphate separates out In order to prevent the formation of carnallite which is likely to deposit, the temperature is very carefully maintained at 12°C and not allowed to go below this point Three qualities of magnesium sulphate are obtained These are described in the description of the French salt works If after the removal of the deposits of magnesium sulphate the bittern is further cooled to 6°C and under by means of a refrigerating plant, a double decomposition takes place between sodium chloride and the remaining magnesium sulphate Sodium chloride must be in slight excess than theoretically required for the reaction If it is deficient it must be made up by the addition of the required quantity The double decomposition results in the formation of sodium sulphate ($Na_2 SO_4 10H_2O$) and magnesium chloride, at the end of this stage the original bittern is reduced to 57 per cent of its volume

Seventh Stage.—This stage is in every way as important as the last. If it is desired to recover bromine from the bitterns, it is advisable to pass chlorine in the bitterns at this stage rather than at the final stage. It is found that bromine which occurs originally in sea water or brine mainly as magnesium bromide is gradually lost during the fifth, sixth and the seventh stages. This loss can be reduced to the lowest possible figure if high temperatures are not used in the process and the mother liquor treated with chlorine in the sixth or the beginning of the seventh stage. Chlorine replaces bromine in the bromides and converts them into chlorides. This operation is carried out in volvic stone towers. Chlorine may be generated by any one of the well-known technical methods. A description of the process as carried out in France and in America is given in the respective sections. After the recovery of bromine the mother liquor contains mainly potassium chloride, traces of sodium chloride and magnesium chloride. This liquid if heated and concentrated to 40°B, carnallite KClMgCl 6H$_2$O separates out. If any magnesium sulphate still remains in the liquid it also separates as kieserite. By fractional crystallization pure potassium chloride may be obtained from carnallite. This process as given above, for the by-products is modified considerably according to the quality of the by-products required, and consequently the description given above must be taken as in the nature of an outline of the process carried out. During the final stage the remaining mother liquor will contain mostly magnesium chloride. This is heated in open copper vessels upto 134 C and then gradually cooled to 120°C. At this temperature magnesium chloride containing six molecules of water remains in the liquid form. Any kieserite, sodium chloride or carnallite which has remained in the liquid separates out as a sludge. Magnesium chloride must be handled at this stage with great caution. If the temperature is not properly controlled, the salt is hydrolysed and magnesium oxide is formed. Hydrochloric acid escapes in the air, for this reason the process of melting magnesium chloride must be carried out in a well ventilated building

By-Products obtainable from Salt Industry.—It has been shown that the first grade of sodium chloride recoverable up to 28 29° B is about 75 per cent of the total sodium chloride contained in the brine For every 100 parts of sodium chloride obtained upto 28-29° B, the following by-products are obtained   If care is taken not to allow the temperature of the bittern to fall below 15° C, the whole of the magnesium chloride could be recovered with six molecules of water in the hydrated form, but if the bitterns are exposed to air during very cold nights, part of the remaining sodium chloride will combine with magnesium sulphate, and sodium sulphate and a large proportion of magnesium chloride would be formed as a result of double decomposition

Sodium Chloride (up to 29° B)		100 00
,, (separated after 29° B)		25 000
Magnesium Sulphate ($7H_2O$)		20 807
Potassium Chloride		2 896
Calcium Chloride		0 271
Magnesium Chloride ($6H_2O$)		27 608
Bromine		1 012

VI.

CONSTITUENTS OF SEA WATER AND BRINES

Properties and Uses

Calcium Sulphate.—It occurs widely distributed in Nature   As anhydrite, it is found associated with limestone deposits and in salt layers   The dihydrite is more plentiful as Alabaster and Gypsum or Selenite   When calcium sulphate is precipitated from its solution as in the case of salt manufacture, it separates out as a dihydrate or gypsum   If gypsum is heated to about 120 to 130° C it loses one and a half molecules of water of crystallization and forms the semihydrate $(CaSO_4)$ $_2H_2O$ known as burnt gypsum or Plaster of Paris   Gypsum is largely used in various industries

Crude form	Quantity in short tons	Value in $
For Portland Cement	187,680	3,05,745
Paint material	1,281	1,300
Plaster material	29,516	77,860
Land plaster	27,972	91,883
Other purposes	7,484	11,630
Calcined		
For dental plaster	174	636
As plaster of Paris, wall plaster, etc	1,074,229	35,08,502
For glass factories	14,412	41,102
Portland Cement and other purposes	36,802	99,934
Total	1,389,550	41 38,560

Though there are numerous deposits of gypsum in India, its production is very small as compared with the production in other countries

1910	In 1000 short tons
United States	2,159
France	1,981
Canada	482
United Kingdom	95
Algeria	60
India	7

When finely ground gypsum is heated with finely powdered coal or charcoal or with carbon monoxide, it is reduced to calcium sulphide and carbon dioxide When calcium sulphide is treated with water, it is decomposed with the formation of calcium carbonate and sulphuretted hydrogen which, in turn, may be ignited in air to give sulphur These reactions are made use of in Germany in obtaining sulphur for making sulphuric acid This process is used by Badische Anilin-und Soda Fabrik at Oppau These works are fully described in the Journal of Chemical and Metallurgical Engineering 1921 and 1922

Calcium sulphate is very insoluble in water, at 25°C 0 0208 and at 30°C 0 2096 grms are soluble in 100 ccs of solution The effects of a foreign salt on a solution is to lower the vapour pressure of the solution at a given temperature When gypsum is dissolved in the presence of sodium and magnesium chlorides, as is found to be the case in brines, the vapour pressure of the solution is distinctly lower than the vapour pressure of a solution of gypsum In such cases a lower hydrate separates out This explains the formation of anhydrites in the evaporation of brine If the anhydrite forms on the the surface and is in contact with moisture, it passes slowly in the dihydrite form or gypsum The specific gravity of gypsum is 2 31 When plaster of Paris is wetted with one-third of its weight of water, it forms a plastic mass which sets in form in 15 to 25 minutes to a white porous hard mass This setting is well known for making moulds and in plaster work The slight expansion which

occurs during the setting of the plaster enables us to make a sharp reproduction of the details of the mould

Sodium Chloride.—Generally known as common salt It is very widely distributed in Nature as rock salt known as Halite or dissolved in salt lakes as brine under the surface and in sea water Pure salt is colourless and transparent Salt crystallises in cubes These crystals are anhydrous A little sea water is mechanically held in the crystals This causes the salt to decrepitate when heated Sodium chloride melts at 801° C and sublimes at higher temperatures 36 5 parts of salt are soluble in 100 parts of water at 30° C The saturated solution thus contains 26 74 per cent of dissolved salts Its solubility decreases in the presence of other more soluble salts, such as magnesium chloride, magnesium bromide, potassium chloride and magnesium sulphate This lowering of solubility accounts for the salt separating at 24 5° B instead of 26° B in the recovery of salt from brines Its hardness is 2 5, its specific gravity ranges from 2 1 to 2 6 that of pure crystals being 2 135 In storage pure ¼ to ½" cubes take 36 cu ft per ton or 62 5 lbs per cu ft smaller crystals require 33 4 cu ft per ton or about 67lbs per cu ft The weight of salt in a cubic foot will depend upon the nature of the crystals and the impurities contained The rock salt of Mayo mines weighs 93 lbs to a cubic foot In another case a compact natural block gave 131 44 lbs Well formed dry sea salt weighs 60 lbs The Madras sea salt weighs 38 to 52 lbs which is also the weight of Ghasia salt The angle of repose in large salt heaps is 36 degrees

Salt is used for a number of purposes For culinery and for general domestic purposes salt is very largely used all over the world In the Western countries the consumption per head of population is 16 lbs In India it is 12 lbs per year, 40 per cent of the world's total production of salt is thus used A small quantity is used for agricultural purposes, but the greatest use of salt is in the manufacture of sodium compounds such as soda ash, sodium sulphate, hydrochloric acid, caustic soda and other chemicals Salt is also used in refrigerating plants and in

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a number of miscellaneous industries, *e g*, in the glazing of the coarser kinds of pottery and earthenware, the preservation of wood, fish, meat, butter, the curing of hides, the manufacture of soaps, the dyeing of textile goods the manufacture of inferior glasses used for wine bottles iron metallurgy and in a number of other industries

Magnesium Sulphate.—Magnesium sulphate of commerce is chiefly obtained from kieserite ($Mg SO_4 H_2 O$) At Stassfurt kieserite layer is found between carnallite and rock salt strata   It can also be prepared from magnesite and sulphuric acid   It occurs as kieserite in combination with potassium sulphate and magnesium chloride and contains six molecules of water Magnesium sulphate is also obtained from dolomite—a mineral containing magnesium and calcium carbonate   If kieserite is dissolved in water, it takes seven molecules of water and forms a colourless crystalline salt readily soluble in water   This salt is generally known as Epsom Salt It is efflorescent in dry air and begins to lose its water of crystallization at 150°C   30 9 parts of anhydrous salt are soluble at 10°C in 100 parts of water   At 40°C 45 6 parts of water are soluble If sodium chloride is obtained in the solution with magnesium sulphate, a double decomposition occurs on cooling the solution Two molecules of sodium chloride with one molecule of magnesium sulphate give one molecule of sodium sulphate and one molecule of magnesium chloride   This reaction is made use of in the commercial preparation of sodium sulphate

Magnesium sulphate is generally placed on the market as colourless crystal of 1 6787 sp gr

Epsom salt or magnesium sulphate is used in the tanning and dyeing industries, and in the manufacture of paints and soaps , but its chief use is in the finishing of cotton goods Magnesium sulphate for finishing purposes must not contain any magnesium chloride, as the latter is liable to generate hydrochloric acid in the free state at the temperature of the callender rollers and thus tender the fibre   Epsom salt is also used for agricultural purposes, as weighting ingredient for sizing yarns   It is also used for weighting paper, silk and leather and for fire proofing materials

Sodium Sulphate.—This compound in its anhydrous state is known as salt cake Glauber's salt contains 10 molecules of water of crystallisation If Glauber's salt is allowed to remain exposed to the air or more quickly heated, it passes into the anhydrous form, the commercial variety is the decahydrate—$Na_2 SO_4 10H_2 O$ This salt occurs in nature in sea water natural brine and in several deposits in Persia, Spain, Caspian Sea and Siberia For industrial purposes this salt is prepared at Stassfurt from crude carnallite and also by the decomposition of salt with sulphuric acid Most of the Glauber s salt manufactured is converted into soda It is also found as a by-product in the manufacture of nitric acid The annual output of salt cake is 360,000 tons Glauber's salt forms large monoclinic crystals which melt at 32 4°C and are re-dissolved in the sulphate and water Forty parts of sodium sulphate dissolve in hundered parts of water at 30°C The maximum solubility is 55 parts at 34°C Glauber's salt is largely used by dyers, both in its crystallised and calcined form It is used in the finishing of cotton goods and is found in most of the dyestuffs which are sold in the form of powders or pastes in which it is very often added for reducing the strength of the colours It is used by dyers for purposes of regulating dyeing operations Glauber's salt is principally used in the manufacture of sodium carbonate, and is also extensilvely used in glass making, especially window and bottle glass

Potassium Chloride.—This salt occurs in sea water brines and in various natural deposits It is found in Stassfurt, in Salt-Lake—Uta and at various other places, mainly associated with rock salt or brines It occurs as seybine—KCl, as carnallite—$KCl MgCl_2 6H_2O$ as kainite—$MgSO_4 K_2SO_4 MgCl_2 6H_2O$, as schonite—$MgSO_4 K_2 SO_4 6H_2O$ These potassium salts are used for the recovery of pure potassium chlorides Different methods are employed at Stassfurt to recover the pure salt As potassium chloride and magnesium sulphate are equally soluble in water, the separation of potassium chloride is very difficult Carnallite is, however, very soluble in hot solution of magnesium chloride Magnesium sulphate and

sodium chloride, however are sparingly soluble   The process of separation is based on this property of carnallite   In France the separation is effected by cooling the mixture of magnesium sulphate potassium chloride, magnesium chloride and sodium chloride Magnesium sulphate and common salt separate out leaving the carnallite in solution

Carnallite is separated out and treated as under —

    (1) Lixiviation of the carnallite with hot water

    (2) Crystallising the chloride of potassium by artificial freezing

    (3) Evaporating and cooling the mother liquor to produce a second crop

    (4) Treating the second crop as before

Potassium chloride is a white substance crystallising in cubes melting at about 750°C and slightly volatile at high temperatures 100 parts of water dissolve 32 7 parts at 15°C   Potassium Chloride forms the basis for the preparation of a number of other valuable potassium salts—such as potassium nitrate, carbonate, bromide, chromates and chlorate   By far the most important use of potassium salts is in the preparation of artificial manures

During the war the supply of potassium salts from Stassfurt was suddenly stopped and various other sources of potash salts were brought to light   Potash salts are now prepared as a by-product in cement, salt and sugar industries

Magnesium Chloride—Magnesium chloride is present in sea-water and in natural brines   It forms part of carnallite which is found in abundance in the Stassfurt deposits   Magnesium chloride of commerce is principally prepared as a by-product at Stassfurt and sea-salt manufacture   In both cases the mother liquor remaining after the recovery of the potash salts is evaporated at 134° C to specific gravity of 1 34   The hot concentrated liquor is run into casks or drums where it solidifies into a white mass containing about 46 per cent of magnesium chloride   The cost of producing one ton of crystallised chloride of magnesium in Stassfurt before the war, including containers, was 16 shillings per ton (c f preparation

of magnesium chloride at Kharaghoda) Magnesium chloride is a very soluble and deliquescent substance Its principal technical use is in the preparation of sizing for cotton yarn where it is used on account of its hygroscopic properties to keep the yarn moist, soft and pliable In a dry climate a very large percentage of magnesium chloride is required in sizing In Ahmedabad where the natural humidity in the air is very low, 5 tons of magnesium chloride are, as a general practice required for every 100 looms In Bombay which has a far more humid atmosphere hardly $2\frac{1}{2}$ to 3 tons are required

Calcium Chloride.—Calcium chloride is present in sea water and natural brines In the spontaneous evaporation of the mother liquor it separates out as tachhydrite $Ca\ Cl_2\ MgCl_2\ 12H_2O$ There is no extensive application of this salt but as it is a by-product in several important industries, *viz,* in soda-ash manufacture and potassium chloride and the Welden chlorine process various uses are suggested for its disposal Calcium chloride is a highly hygroscopic substance, which when dissolved in water shows considerable diminution in temperature If a hydrated salt is heated strongly it becomes anhydrous It is placed on the market as a fused solid Its principle uses are as a dehydrating agent, preservative and in fire proofing paints It is also used in freezing mixtures and in the manufacture of ammonium chloride and mineral waters Calcium chloride is sometimes used in sizing, though its use is limited to a very great extent as it cannot be used either with Epsom or Glauber's salt During the war when there was a shortage of magnesium chloride in Bombay certain textile mills had used calcium chlorides as a deliquescent substance in sizing Recently calcium chloride has been largely used in cities and towns for spraying over roads in order to keep down the dust

Magnesium Bromide.—Magnesium bromide is found in the mother liquors remaining after the recovery of salt At Stassfurt it is found as brom-carnallite $MgBr_2\ KBr\ 6H_2O$ The quantity occurring in the mother liquor is sufficiently large for its recovery Magnesium bromide as such is of little technical value except as

raw material for bromine As Magnesium bromide is highly hygroscopic, it is not separated by fractional crystallization but by treatment with chlorine gas bromine is set free This process is employed in France, Germany and the United States Chlorine required for this purpose may be generated by any one of the well-known processes At Stassfurt bromine vapours are passed over wet iron turnings The resulting bromide of iron serves as raw material for the manufacture of potassium and sodium bromides Bromine compounds are largely used in medicine, photography, in the extraction of gold, the refining of platinum and in the manufacture of Prussian blue and potassium permanganate Bromine is now extensively used in the manufacture of dyestuffs The United States of America produce very large quantities of bromine The production is mainly from brines and sea water salt works In Amercia the average yield of bromine is 35 lbs from 700 gallons of bittern having a strength of 40°B

VII

BRINE SALT WORKS—INDIA

Kharaghoda Salt Works.*

These works are near Kharaghoda—a village in the Viramgam taluka of Amedabad District, Bombay, situated in 23° N and 71°, 50°E on the border of the little Rann of Cutch   Kharaghoda is about 24 miles to the east of the Kuda salt pans   When Ahmedabad passed to the British, the eastern shore of the little Rann contained 5 salt works in the possession of the petty chiefs of Bajana, Patri, Saolas, Dhegam and Jhinjuwada   These were gradually acquired by purchase between 1822 to 1840, and were subsequently closed in 1875 in favour of a single factory at Kharaghoda   These, however, proved unequal to meeting the constantly increasing demand for salt, and in 1881-82 new salt works were opened at Udu, which is six miles north of Kharaghoda and is connected with it by a line of rails

These works are jointly named the Pritchard Salt Works   They belong to the Government and are worked departmentally   The ground is the property of the Government, and the salt is manufactured on Government account by Agarias who are paid at a fixed rate

The quality of salt manufactured at these works is known in the Presidency as Vadagra or Baragra salt   Vadagra salt is a cubical crystal from half an-inch to a three-fourth inch in thickness

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* As Nimaknagar will have to supply Baragra salt of the same quality or better than that made at Kharaghoda and as both the works draw their brine from the Rann, a very close study of the Kharaghoda Salt Works was made by personal visits and by examining Agarias in 1920, 1923 and 1924   Only such experienced men were selected as witnesses who had over 35 years working knowledge of Kharaghoda Works   Further information was gathered from Government Officers at Kharaghoda and from the Annual Government Reports

built of a number of smaller crystals In colour it ranges from pale brown to pure white The crystals in some instances are very transparent but yellowish to gray in appearance The opaque crystals are whiter and grayish in colour A good quality of Vadagra salt is extremely hard, and for this reason it is very much valued for transport over long distances The loss in the handling of Vadagra salt is considerably less than in the smaller conical sea salt

Commencement of Work—Soon after the monsoon about the end of Bhadarva (August-September) if the monsoon is bad, or at the beginning of Ashav if the monsoon is good, information is sent round by the Government to all the surrounding villages where Agarias have their homes, notifying the date on which applications are to be received and the date for the commencement of operations The Agarias must present themselves on the notified date The allotments are completed in about a week's time, and thereafter the operations of the season actually commence Each pan is given under contract made out jointly in the names of three Agarias It is immaterial whether one or two of them are minors or women There is no restriction on the number of pans worked by a single family provided there are three persons registered for each pan As soon as the allotments are made the Agarias have to begin operations within a week, but as a rule they start their work immaedtely the next day if their financial arrangements are complete The Agarias have generally no resources of their own, and they have to borrow money from money-lenders at the commencement of the season The Sowkars or money-lenders advance to the pan holders Rs 45 to Rs 60 per pan to help them to begin work The rate of interest charged by these money-lenders is very excessive Usually for sums upto Rs 300 they charge 2½ annas per rupee per month (187 per cent per annum) For sums upto Rs 800 to 1,000 at the rate of annas 3 per rupee per month (225 per cent per annum) This advance is made in the names of the three contracting parties for each pan, and all three of them are jointly held responsible for the loan and interest

It is very difficult to obtain satisfactory labour at salt works Men who know the work ask from annas 12 to one rupee per day of 10 working hours Food is provided to them by Agarias Unskilled labour is at annas 10 to annas 12 per day Women charge 8 to 10 annas and boys 6 annas It costs the Agaria Rs 10 to 12 per month to feed a labourer

Working Hours.—The Agarias work from 9 to 10 hours a day upto March and only 8 hours in April and May when the days are very hot They generally begin work long before daybreak and work till about 8 They then rest for a couple of hours and then resume work at 10 again leave off work between 1 and 2 The work for the day is finished at 6 p m

Wells —The first operation in which they engage is the digging of wells Three adult workmen take 7 to 8 days to sink a circular well 6 to 7½ feet in diameter to a depth of 18 to 30 feet according to the nature of the soil and until the brine stratum is obtained There are few wells over 7 feet in diameter About 6 feet is quite common Some of the wells are broader at the bottom than at the top The interior of the well is encased (Kantvo) with Baval or Tamarisk boughs to prevent the sides from falling in. The " Dhenkva " or the superstructure which is made of boughs and wood resembling a long lever and attached to an upright wooden post and weighted at one end is then erected at the side of the well in order to lift the brine Two levers, for two men to work at a time are provided to each " Dhenkva" Each lever has at the end a rope to which is attached an earthenware pot (ghendu) of about 168-176 ozs capacity These earthenware pots cost at Kharaghoda half an anna per pot The total cost of the superstructure for drawing brine including Dhenkva, Kantvo, Ghendu, complete with ropes and all is between Rs 15 to 20 During the construction of the well and its superstructure besides the contractor two other workmen called " Dandias " are engaged, making in all three workmen The Dandias are paid at the rate of Re 1 per day The Agaria has to pay for his food,

which costs annas 6 extra per head   The total cost of making a well is as follows —

		Rs
1 Agaria Rs 1-8-0 per day for 8 days		12
2 Dandias Rs 1-6 0 ,, ,,		22
Kantvo, Dhenkva, Ghendu and other materials		20
	Total	54

There is generally one well for each pan, but when the wells are made at great distances, either on account of the weak brine—under 16° B, or the difficulty of obtaining a good current, the wells are located at considerably long distances   In such cases a distance from half to three-fourths of a mile is quite common   When the wells are at a long distance from the condenser, two to three wells are required for supplying sufficient brine to one pan   There are several cases in which 6 wells supply brine to one channel one mile long and connecting to two condensers   Though distant channels help in rapidly concentrating the brine, there is a considerable loss of brine by leakages and absorption   The Agarias state that they have to draw for nearly two to three hours more every day to make up for this loss   The loss by leakages is about 30 per cent Distant wells are quite common at Kharaghoda, and the Government has to pay a compensation every year for locating the wells at long distances as will be seen from the following figures   —

	Rs
1920-21	19,660
1921-22	21,595
1922-23	22 820

The site for wells is changed every third year   For two consecutive years the well gives a good supply, but in the third year it gives very little brine   If another well is dug in close proximity of the old site, in some cases even within 10 feet the supply of the brine is normal

During the monsoon—floods the wells are filled up with silt, sand and clay, and as there is no protecting wall over the well the well has to be dug out year after year   It makes therefore no difference to the Agaria whether a site for the well is new or old

Condenser.—On the 9th day after completing the well the men engage in the construction of the condenser or reservoir called by the Agarias " Gamdu "   The well is connected with the condenser by a slough or an earthen channel 9 inches to 12 inches wide and 3 inches deep   The length of the slough depends on the distance of the well from the condenser   It takes three adult workers from 4 to 6 days according to the nature of the soil to complete the reservoir   Each reservoir is 80 ft by 80 ft with a low mud embankment or dike 15 inches to 18 inches high   The ground is first wetted with brine drawn from the well and scraped till a good floor is obtained with a slight slope towards the pan   The dikes are covered from inside with dry twigs or sods on which gypsum, as it separates from the brine deposits   The height of the dike is kept 8 to 10 inches above the level of the brine to allow the play of the waves   The twigs also protect the wash of the waves After completing the dikes they begin filling the reservoir with brine   It takes three men nearly one full week to fill the reservoir to a depth of 5 to 6 inches   If the well maintains a good supply of brine, two men work continuously in drawing the brine   The third man relieves alternately the other two   A man draws from the well, in which the brine level is 10 feet below the surface, on an average at the rate of 10 pots or about 10 gallons per minute, or 600 gallons per hour by continuous working , but as they generally rest from time to time, the average lift is from about 400 to 500 gallons per hour   For a working day of about 9 hours the average per man is 3,000 gallons   If the brine is continuously drawn for three to fours the well gets completely emptied and the men have to wait for 2 to 3 hours till the brine again collects in the well   The best yield does not exceed 6,000 gallons a day of 10 hours   When the reservoir is newly constructed, a good deal of the first draw of brine (about 8,000 gallons) is lost in saturation of the soil, and it

takes about 6 days to bring up the brine level in the reservo r to
6 inches At the end of the sixth day the reservoir of 6,400 square
feet area and 6 inches of brine contains 20,000 gallons of brine

The cost of constructing the condenser is as follows —

	Rs	as
1 Agaria for 6 days at Rs 1-8-0 per day	9	0
2 Dandias ,, ,, ,, 1-6-0 ,,	16	8
Twigs	3	0
Brine for saturation	5	0
Spades, bamboos and wood pieces	2	8
Total Rs	36	0

Cost of Brine—Two men if they work continuously will
draw 6,000 gallons in a day, but as the work in the sun is very
fatiguing a third man is always required to relieve alternately
the other two men As each workman gets Rs 1-6-0 the cost of
6,000 gallons would be Rs 3-12-0 or one anna per 100 gallons
containing about 190 lbs of salt The price of salt would on this
basis done be 5 18 pies per md

The Pans or Crystallisers—On the fifteenth day after the
beginning of the operations and after constructing the condenser
the pan is laid out parallel to the condenser leaving a distance of
6 feet between the two Formerly each pan was 250 feet in length
and 80 feet in width, but at present the size of the pan is reduced
to 250 feet by 70 feet The pans are placed lengthwise to the
direction of the wind in order to promote waves on the surface
of the brine The distance kept between two pans in a row is 50
feet and 100 feet between two opposite rows A railway siding
passes through the 100 feet track Three men are sufficient for
the construction of the pan The work is generally divided into
the following operations —

    (1) Clearing the site and making the clay dikes
    (2) Puddling and tamping
    (3) Levelling
    (4) Hardening and finishing

The surface is first cleaned and weeds removed   After this a low dike about 12 to 15 inches high is built by scraping the dry earth from the floor   The ground is then wetted with brine let in from the condenser through the small feeding channel   As soon as the brine is soaked, all irregularities are noted and a rough levelling is made   This operation takes two days   On the third day the brine is again spread over the pan and allowed to dry during the next two days   While the surface is drying the men are engaged in completing the side embankments or dikes (jibhta) On the sixth day the pan is roughly divided into three parts for the purpose of tamping and puddling   Each part is taken at a time and takes two days for tamping and puddling   The men, keeping their heels at right angles slowly go over the ground in each section six times   The operation in each case takes two days for three men taking in all 6 days to complete this operation   On the 13th day brine is again let in to a depth of one-eighth inch in order to finally adjust the level, leaving an imperceptable slope towards the farther end   After adjusting the level the brine is allowed to dry and once more all the irregularities on the surface are levelled out by the spade   On the 14th day the white crust of salt which is formed is treaded upon so as to embed it into the floor, and once more puddled till no impressions are formed on the soil   The brine is allowed to dry and form the tiny culture crystals   On the 15th day it is once more irrigated to a depth of a quarter inch, the water allowed to dry till a white incrustation of the salt appears on the 16th day   The final process takes two days during which the fine crust of salt is tamped and puddled once again till it is hard, dry and firm   The ground is exposed to the sun for two days more On the 20th day it is examined for its hardness, and if it is found that it is sufficiently hard and free from cracks, it is considered to be ready for crystallisation   The whole of the constructional work is finished in about 34 days from the commencement of the work for the well

During the construction of the pan the condenser is constantly emptied and filled again, and this requires the services of 2 to 3

more men   In all 6 men are engaged during this period   The cost of constructing the pan works out as follows —

		Rs	a
Agaria 20 days at Rs 1-8		30	0
5 men „ „ „ „ 1-6		137	8
Implements		4	8
Dry twigs		8	0
	Total	180	0

The total cost of the layout is as follows —

		Rs
2 wells		108
Slough		6
Condenser		36
Pan		180
	Total	330

This is a recurring expense and must be incurred every year Whether the site of the pan is new or old, it must be prepared every year on account of the annual floods which leave a silt layer over 4 inches thick   As the total area of the pan is (250 feet by 80 feet) 20,000 square feet and that of the condenser (80 feet by 80 feet) the ratio of the condenser to the pan area is 1 3   Each set of condenser and pan requires $(14+80+6+250+50)=400$ feet by $(25+80+25)=130$, i e , 52,000 square feet, excluding the area occupied by the well and the slough

Season.—The season begins in the third week of August when the allotments are made.

SEASON

Year	Pan filled In				Pan emptied				Working days
	First pan		Last pan		First pan		Last pan		
	Kharaghoda	Udu	Kharaghoda	Udu	Kharaghoda	Udu	Kharaghoda	Udu	
1919-20	15th Oct	17th Oct	20th Dec	10th Dec	11th March	10th March	3rd June	10th May	223
1920-21	20th Sept	21th Oct.	28th Dec	24th Dec	17th March	23rd March	10th May	18th May	228
1921-22	24th Oct	24th Oct	18th Oct	16th Dec	23rd Feb	20th Feb	7th May	18th May	207
1922-23	13th Oct	18th Oct	18th Oct	16th Dec			20th Apr	20th Apr	100

It takes a day or two over a month for the preparation of the well, condenser and the pan before the salt crop begins to form About the third week of September the brine is first taken in and the manufacture continued for seven months   During this period 4 men are required for each pan, three for drawing brine and one for raking and spade work   About the middle of March they stop drawing water at the wells   Five or six days after the whole of the water from the condenser is allowed to drain into the pan, where condensation and crystallisation is allowed to proceed for a month till the mother liquor is on a level with the top of the crystals

Working of the Pans —The Kharaghoda and Udu wells give brines of varying densities ranging from 11° to 21° B   In only a few of the wells the density is between 20° to 21° B The average general density of the brine may be taken at 17° B   in the beginning of the season and 18 at the end of the season

Three men are required to work one well containing plentiful supply of brine but if the supply of brine is deficient in one well and another is required, the same men work the two wells alternately   Wherever the wells are deep bullocks are employed to lift the brine

Year	No of pans worked by bullocks	Total No of pans	Per cent
1920-21	254	783	32
1921-22	361	845	42
1922-23	402	857	49

The brine, as it is lifted from the well is run through a channel into a condenser where it is allowed to remain for nearly 10 to 12 days in winter and 7 days in spring before it reaches a density of 23-24°B   After the middle of April and in May the evaporation is so rapid that the brine is let in very rapidly from the condenser A day at times is quite enough   In any case the brine must first settle in the condenser to deposit suspended impurities and calcium sulphate (Khari)   While it is in the condenser between 18   and   24°B most of the dissolved calcium sulphate separates out and collects on the dry sods on the sides of the condenser

Great care is taken to remove gypsum deposited from the condenser The feeding channel which is placed at the end away from the well, is covered over with dry sods through which the brine gradually passes into the pan The connection between the pan and the condenser is made very small A hollow bamboo of three-fourth inch diameter is used as the pipe through which the brine constantly passes from the condenser to the pan Particular care is taken to feed the brine very slowly A rapid flow will lower the density of the saturated brine in the pan and thus ruin the crop During dry cold wintry nights a thick dry film forms on the surface This scum is removed every morning and not allowed to dissolve in the pan After the brine has reached a sufficient density, the hole in this pipe is made still smaller by the insertion of one or two twigs The brine is flooded to a depth of 2 inches in the pan and this level is maintained till the brine reaches about 25 B and the salt crystals begin to appear For a week the level of the brine is raised every day till the pan contains 4 to 5 inches of brine at the end of the first month Eight days after the first flooding of the pan, the men first enter the pan and break the crust of salt which varies from half to three-fourth inch This is done simply by treading upon the salt first and then working the rake both ways along the length and the breadth of the pan until the crust is finely broken and the crystals are separated The rake or Dantara is 68 inches long, 4 inches in diameter and has 14 teeth, each tooth is 11 inches long, three-fourth inch broad at the end and 4 5 inches distant centre to centre The handle of the rake is 5 5 inches long and 3 5 inches in diameter The spade or Pavdi is 2 feet 10 inches in length and 7 inches wide The handle is 7 feet long and about 3 inches in diameter The plank of the spade is made of three-fourth inch thickness

Thereafter the brine is continuously admitted during the 24 hours till the end of the season Throughout the season the level of the brine is kept about 3 inches above the level of the salt The salt is raked the first day and spread out by the wooden spade the next day Thus the raking and the spade work alternate day

after day till the end of the season   The raking takes 6 hours
for each pan, but for the spade work it does not take more than
an hour and a half   As the season advances the 14 teeth of the
rake are reduced to 8, and as the depth of the crystal increases,
two men are required to draw the rake instead of one   The raking
and spade work are very laborious tasks   One man can attend
during the morning only to one pan , in the afternoon he spends
his time in helping the other two men in drawing water   Three
men are thus required to attend to one pan continuously during
the season   This procedure is specially adopted for obtaining
Baragra salt crystal from half to three-fourth inch thickness
The raking and spade work separates the mass and loosens the
crystals which have a tendency to coalesce   The loosened crystals
thus get sufficient room for the growth of the separate crystals   The
density of the brine gradually rises to 26°B at which it maintains
almost upto the end of the season   When the condenser is finally
emptied in the pan the density of the brine is 27 to 28°B, and at
the end of the month when the level of the brine reaches the level
of the crystal, and the mother liquor is ready to be discharged, the
strength of the brine is about 28—29°B   The salt crystal layer
attains a thickness of 7 inches at the end of the season

Harvesting —The Government notifies the date for the closing
of the season   From this day the Aganas begin to collect the crop,
and pile it into long ridges inside the pan in order to drain out
the bittern   They make six ridges in a pan , the distance kept be-
tween two ridges being 10 feet   When the ridges are complete,
the level of the bittern is 3 5 inches over the floor for every 7 in-
ches of the thickness of the crop   Outside labour is required for
making these ridges   Generally a gang of 60 men finish the work in
about 5 to 6 hours   Each man is paid for this work at the rate
of As 12 to Rs 1-4-0 according to the thickness of the crop   The
cost of making the ridges is between Rs 45 to 75 per pan   The
Aganas have to make cash payment for this labour   The ridges
are allowed to drain for three days   During this time the three
Aganas or contractors drain out the brine from the pan and scrape

up the floor with their spades till the floor is practically free from bitterns and a clean surface is exposed   When the ridges have completely drained out the harvest is ready to be lifted   On the 4th or 5th day after the ridges are made, a gang of 300 men is engaged for the day in one pan to gather the salt and to stack it near the rail at one end of the pan   The number of men depends upon the quantity to be lifted   The payment is made at the rate of 5 to 7 annas per man per " Kadam " of 5 feet   There are 50 Kadams in a ridge, and as there are 6 ridges, 300 men are   required for lifting They finish the work in 5 to 6 hours   The salt is carried in baskets by men, women and boys to the end of the pan where it is to be loaded into wagons   Hand trolleys were tried, but   the Agarias prefer the baskets   For the trolley work they can only employ men strong enough to drag the trolley   They can however employ women and boys if the salt is removed by baskets   The 300 men are paid at the rate of 5 to 7 annas per Kadam— and the total cost to the Agaria to bring the salt to the rail per pan amounts to from Rs 120—150.

The Agaria's work ends with the stacking of the salt by the side of the rails   He has to keep a watch till the salt is loaded into the wagons   When the heaps are fairly dry, the open wagons are brought alongside the pans and the Agarias are asked to load the wagons   For loading in the wagons they are paid by the Government at the rate of As 14 per wagon load of 180 mds , i e , about As   2 per ton or a fraction over a pie per maund From 1923 the average load per wagon is fixed at 150 mds   Each pan requires 30 wagons of 7 tons to take its entire crop to the stack   The weight of the salt for which the Agarias have to be paid is determined by taking the difference in the weights of the loaded wagon and the tare of the wagon. Each rake of empty wagons is weighed over a weigh bridge several times during the storage operation and the weight of the full wagon is also determined   From the net weight thus obtained five per cent is deducted for dryage, shortage in handling, etc   The Agaria is paid for only 95 per cent of the net weight.

As soon as the payment is made to the Agaria, the money-lender immediately takes back his advances with interest   This completes the Agaria's work   Before returning to his village the Agarias leave their rakes, spades and the superstructure of the wells and wooden implements into a pit near their pans and cover them up for use during the next season

Yield of Salt.

Year	Average yield per pan mds	Maximum yield per pan mds
1919-20	4,823	13,000
1920-21	6,315	13,832
1921-22	4,883	11,920
1922-23	5,283	10,728
Average	5,326	12,370

As each pan is 250 by 80 feet = 20,000 square feet, the yield per 100 square feet is as follows —

	Per 100 sq ft mds	Per acre mds	Tons
Average yield per pan	26 5	11,68,	429
Maximum yield per pan	61 8	27,253	1,000

Cost of Production

From the beginning to the end of the season the total expenditure per pan is as follows —

	Rs
Construction of well, condenser and pan	330
Five months labour—	
1 Agaria at Rs 1-8 0	228
2 Dandias at Rs 1-6-0	418
Making ridges	50
Stacking near pan	130
	1,156
Add for interest on borrowings	200
Total Rs	1,356

The total wages paid during five months may be apportioned as follows —

	Rs
Brine	400
Raking and spade work	200
General care and supervision	50
	650

If the Agaria can obtain contractors to draw water they willingly pay for 4 months work (not 5) from Rs 150—200, but it is difficult to get such contractors

Agarias' Earnings.—Of the above sum of Rs 1,156. the Agarias' actual out of pocket expenditure is about Rs 700 for outside labour and implements to this must be added his own expenses for food and hut about Rs 100 *plus* interest about Rs 200, making a total of Rs 1,000   As the rate fixed by the Government is 2 as and 9 ps per md the Agaria will just balance his account if the crop raised is 5 500 mds If the yield is under this he will be a loser As a fair outturn is reckoned by the Agaria at 5,500 mds . he hardly makes any profit out of this occupation The only inducements are that of getting a job in non-agricultural season and the hope of earning a good sum by working for a yield larger than 6,000 mds He however, still makes a small profit by employing members of his own family (wife and children) and thus makes a saving in wages and interest, but it must be pointed out that as the fixed rate paid by the Government, *viz*, 2 as 9 ps hardly leaves any margin of profit to the Agaria, it must be taken as the actual lowest cost of manufacture

Cost of Salt to Government.—The Government paid in the 1919-20 season at the rate of as 2 per maund and in 1920-21 the rate was increased by 9 ps per maund, *i e*, at. 2-9 per maund.

Year	Total crop Mds	Total amount Rs	No of pans	No of agari as	No of agarias per pan	Receipt per head Rs	Amount per pan Rs
1920 21	49,44,762	8 49 762	787	2,359	3	362	1,083
1921 22	41,25,751	7,09 113	845	1,976	2 ?	359	839
1922 23	45,27,103	7,78 096	857	1 972	2 3	395	914

Advances by Government—The Government advances per pan about Rs 60 as Tagavi grant in January (Posh) and Rs 30 per pan in March (Fagan) during the collection of salt These sums are deducted from the sums paid at the end of the season

Grants to Agarias—The following grants are made every year as necessity arises —

A   Compensation for damage done by untimely rain
B   Working pans at great distances from the wells
C   Assistance to Agarias in heaping salts and clearing pans
D   Bonus for increased output
E   Prizes for good quality of salt
F   Rewards as an inducement for commencing work early Rs 15, 12 and 9 per pan according to the date notified
G   Reward for preparation of good pans and channels
H   Pugris to Agarias and Patels for giving a good load in wagon in the haulage

The following grants were made under the above headings —

	1920-21	1921-22	1922-23
	Rs	Rs	Rs
A	22,396		
B	19,660	21,595	22,820
C	4,500	5,292	4,422
D	4,026	5,991	5,508
E	400	400	400
F	6,282	4,005	6,165
G	150		

Other Grants—Besides the above advances and grants the Government pays every year for various other purposes

	1920-21	1921-22	1922-23
Provision for quarters	7,800	4,262	4,396
Resconstruction of quarters			4,396
Excess amount for a school house	113		
Repairs to quarters	45	90	135
„ „ plank road and trolleys		849	
Compensation and Royalties to various States whose rights of manufacture of salt are taken over by the Government			

Storage —The storage of salt commences in April at any time during the 1st, 2nd or 3rd week according to the early or late commencement of the season or the prevailing winds   The whole of the salt is stacked before the 15th of June   During the 4 years under review the salt was stacked as follows —

	1919-20	1920-21	1921-22	1922-23
Maunds per day	65,300	78,450	82,515	85 400
Number of working days	52	63	63	53

The salt is stacked partly in closed stores and partly in the open The closed store is a long building, divided into 8 compartments with a clear height of 21 feet for the salt stack   The wagons are led up an incline over the stores   The rails are supported by wooden tressels and masonry pillars   When the wagons are in position the side flaps are opened and the salt dropped into the store The closed store holds about 440,000 maunds   A continuation of the incline was made during recent years for piling the salt in the open   These open stores are surrounded by a high palisade , the flooring being made of masonry   Each stack in the open is made for 5 8 lakhs of maunds   There are six such stacks, making a total provision for storing in the closed and the open stores for 42 lakhs   By the side of these stores there are other heaps about 60 feet at the base and 30 feet at the apex   The angle of repose being 36°, one cubic foot of salt weighs 62 5 lbs or for storing one ton, 36 c ft are required

Cost of Storage.

	1919-20	1920-21	1921-22	1922-23.
	Rs	Rs	Rs	Rs.
Cost per lack mds or 3 673 tons	511	612	676	932
	As ps	As ps	As ps	As ps
Cost per ton	2 3	2 5	2 11	3 11

Loss and Wastage.—Considerable quantity of salt is lost or wasted by handling and in storage   The losses are mainly due to :—

(1) In open stacks carried away by wind and cyclone

(2) Rain dissolves and washes out a considerable quantity

(3) Rain and moisture in the air remove a good quantity of magnesium chloride and along with it some salt, and moisture from the wet salt

(4) Differences in actual weighment and quantity determined by measurements of the stack

(5) Inaccuracy in weights on weighing the wagons on the weigh-bridge

In the closed stores the annual loss and wastage is generally shown at 3 5 per cent as against a loss of 10 5 per cent in the open stores It must be noted that the total loss in storage is not entirely borne by the Government   It was pointed out that the Agaria is given a short weight—5 per cent less than the net weight in order to make up for drainage and handling

Production of Baragra Salt —The total yearly production of Baragra salt at Kharaghoda is given in the following table which also shows the total quantity of sea salt produced in this Presidency

PRODUCTION OF SALT IN THE BOMBAY PRESIDENCY

	Baragra Salt Mds	Sea Salt Mds	Total Mds
1919-20	33,95,925	91,09,129	125,05,054
1920-21	49,44,762	90,72,481	140,17,243
1921-22	41,25,756	79,19,990	120,45,746
1922-23	45,27,110	110,06,631	155,33,741

Packing and Forwarding —During the storage of salt, particularly in the open store, the salt crystals on the surface and far inside harden very firmly   The surfaces exposed to air are so hard that they cannot be broken by pickaxes   In some cases they have to blow the sides with powder   In the closed stores the stacks keep better and no such trouble is experienced   Loose salt is then removed by manual labour, bags filled, weighed and loaded into wagon   The weights of the filled bags are kept uniform   Each bag holds 3 maunds and is legibly marked with consecutive numbers

Sales.—Sales are effected by indents received from traders The charge payable is fixed by the Government This sale price is made up of :—

(1) Cost price fixed by the Government under Section 8 of Indian Salt Act, 1882, which includes cost price paid to Agaria plus Ground Rent at nine pies per maund and haulage charges, also nine pies per maund The haulage charge includes the loading of salt into wagons at pan, haulage and stacking charges

(2) Digging, bagging, weighing and sewing charges, three pies per maund

(3) Duty, Rs 2-8-0 per maund.

(4) Cost of bags, nine annas a bag of three maunds This charge is not compulsory, the trader may supply his own bags

On payment of these charges the permits are issued for despatch. The freight is payable by the trader The bags are despatched in closed wagons Baragra salt is sold through agencies at which a uniform charge is made This charge is made up of (1) the selling price at Kharaghoda plus (2) a certain rate for haulage to the Agencies The Agents receive one per cent on the sales and are allowed one per cent on the amount of salt issued *to them* on account of wastage The sale price is made up as follows —

Selling Price at Kharaghoda.

	Per maund		
	Rs	a.	p
Cost price	0	2	9
Ground rent	0	0	9
Haulage charges	0	0	9
Digging, weighing, sewing, etc	0	0	3
	0	4	6
Duty	2	8	0
Total	2	12	6

The selling price at Agencies —

	Rs	a	p
Selling price at Kharaghoda	2	12	6
Haulage, 4 to 6 pies	0	0	6
	2	13	0
Plus Agency commission and shortage	0	0	6
Total	2	13	6

The extra charge of six pies on account of commission and haulage is intended to meet the cost of distribution   But this figure does not in any way represent the actual net cost price as will be shown later on

SALES OF BARAGRA SALT

	Quantity Mds	Sale proceeds Rs	Rate per md	
			As	p
1919-20	26,81,185	8,41,303	5	0
1920-21	34,70,972	16,43,081	7	7
1921-22	24,26,138	4,06,896	2	8
1922-23	19,04,905	6,43,048	5	3

The average sale price during the last four years is 5 as 1½ pies

Administration Charges —To determine the actual net cost price f o r at the stores, the overhead or administration charges must be added to the cost price of salt   In the annual reports the percentage charge shown on gross receipts (which include the duty) is shown from year to year as under —

	Rs	a	p
1916-17	13	3	6
1917-18	15	0	0
1918-19	15	9	2
1919-20	18	7	8
1920-21	16	13	2
1921-22	33	8	8
1922-23	44	6	0

As these figures give no indication of the actual cost of administration per maund, the following tables have been prepared from the annual reports to determine the required figure as near as it is possible to do so

Net Expenditure of the Salt Department.—In the Government annual report the total expenditure given for salt is inclusive of the expenditure debitable to excise   The net expenditure debitable to salt is made up of (A) " net nine-tenths debitable to salt " as shown in the report plus (B) amount paid for salt purchase and freight and (C) expenditure of the Chief Account Office

	A	B	C	D
	Rs	Rs	Rs	Rs.
1919-20	21,81,521	6,81,527	37,259	22,18,780
1920-21	24,33,951	6 91,018	45,364	24,79,315
1921-22	24,20,431	10,70,543	60,550	24,80,981
1922-23	23,54,380	10,17,719	59,296	24,13,676

From the above table the net cost of the administration of the salt department is obtained by adding the figures of A & C columns as given in column D   The amounts in column A include all items of expenditure of which the following are the main heads —

	Per cent
Pay including supervising establishment	65
House rent, travelling expenses, etc	10
Special allowances (including Kharaghoda)	5
Contingencies and miscellaneous	20

Cost of Administration per Maund —This is worked out from the total salt produced and the total expenditure given in column D of the preceding table

Year.	Total Production.	Total Expenditure.	Per Maund
	Mds.	Rs	As ps
1919-20	12,505,054	22,18,780	2 11
1920-21	14,017,243	24,79,315	2 10
1921-22	12,045,746	24,80,981	3 4
1922-23	15 533,741	24,13,676	2 6

The average cost of administration is thus 2 annas 11 pies per maund

Net Cost Price of Salt

	Per Maund As ps
Cost price paid to Agaria	2 9
Loading wagons at pans, haulage to stores and stacking	0 9
Digging, filling, weighing, sewing and loading into wagons (price of bags not included)	0 3
Ground rent	0 9
	4 6
Add overhead administration charges	2 11
Total cost price	7 5

It seems from the annual reports that the Government is accepting tenders at five annas per maund whereas it actually costs them seven annas and five pies   It must be noted that 7 as 5 ps is again not the proper commercial cost price   To this must be added depreciation of railway trucks, renewals, repairs and interest on Capital invested in Buildings and Stores about Rs 30 lakhs and also interest on Capital locked up for Reserve Stocks and on yearly wastage and shortage of salt in storage

Markets for Baragara Salt—Baragara salt has not been able to stand in competition with sea salts in places south of Baroda Between Mahi and Narbada rivers, both the salts are sold but north of Mahi it is the only salt consumed by the people in the British territory and partly in Kathiawar   Beyond the Presidency it enters into competition with the salts of Rajputana Central India North-West Provinces and United Provinces, as far as Hathras, Faizabad, Benares and Chotta Udaipur

Distribution of Baragara Salt.

	Per cent
Bombay Presidency	31
Central Provinces	27
North Western Provinces	20
Central India, Rajputana Malwa	22

Manufacture of Magnesium Chloride at Kharaghoda —Till 1915 the mother liquor or bittern, locally known as 'res' was wasted During the war Indian imports of magnesium chloride from Germany having stopped, attention was drawn to the possibility of making use of the bitterns at Kharaghoda as a possible source of magnesium chloride A small experimental factory was put up in 1915 in Ahmedabad for the recovery of magnesium chloride from the bitterns which were sent in tanks from Kharaghoda A company was formed in the name of the Pioneer Magnesia Works The Company acquired on lease 20,000 sq yards from the Government for the purposes of factory buildings, workmen's quarters and the drum plant After the pans are emptied, the bitterns are allowed to further concentrate in the fields by solar evaporation till they reach a density of over 34 to 35°B Before the bitterns reach this density various other salts are precipitated along with residual salt left in solution after the bulk is gathered in the pan The bitterns of over 32°B are then collected at the pans by means of a motor rail wagon with a special tank attachment

The plant consists of settling tanks, vertical boiler, feed pump, suction and several copper pans , all except the tank are located in one building

Settling Tank.—The bitterns from the salt works were first brought in drums of 4 gallons capacity and emptied into a tank 15′×15′×6′ The new tank was built in 1917 lined with Shahabad limestone This tank is 40′×40′×6′ and is designed to receive 56,000 gallons of bitterns The bittern is allowed to settle for some time till all suspended impurities settle down When it has settled to a fairly clearly liquid it is syphoned over into another tank 10′×5′×3′ deep for further settling These two tanks are in the

open   From the second pan the clear brine is pumped into the
tank inside the factory   This tank has a well of 2' diameter in
which is lowered a suction pipe which feeds the copper pans

Process—There are 10 kettles made of copper sheets   Each
is 3' deep, 3' in diameter and of $\frac{1}{4}$" plate   The kettles are mounted
in 2 rows on a furnace fired by flue gases   Either wood
or coal is used as fuel   The copper kettles were first
mounted on an old type of brickwork in which there was
a considerable loss of heat   The design was subsequently
altered with a view to lower the cost of fuel   The bittern
is pumped in these kettles and boiled to 135° C till a precipitate
is obtained   When the mass develops a turbid appearance, the
contents of the kettle are ladled out into a settling tank
outside the building and allowed to remain there at 120° C   Mag-
nesium chloride remains liquid at this temperature   This tank
is 60' × 30'   During the process Epsom Salt $MgSO_4 7 H O$ looses
water and forms kieserite $MgSO_4 H_2 0$ which is insoluble in a solu-
tion of magnesium chloride   This magnesium sulphate and also
some salt separates out at the bottom and the supernatent liquid,
while still hot, is poured into sheet iron drums, each holding 5
cwt of fused magnesium chloride   The chloride on cooling
solidifies to a hard grayish mass   The hard sludge which is re-
moved from the settling tank is not made use of, but is treated as
waste   Two tons of bitterns are said to give on an average 1 ton
of magnesium chloride   The daily production is about 10 tons
Forty workmen are required at this factory   The working hours are
from sunrise to sunset—about 11 hours   During the monsoon
the factory stops working for 4 months

The magnesium chloride made at this factory compares well
with the German quality in chemical analysis, but there is one
drawback, *viz*, colour   This factory's product is of a grayish
colour   No method has yet been found for removing this colour   The
colour of the crystal is pure white, but on fusion the gray colour
invariably returns   The Company has tried to solve this difficulty,
but it has not so far succeeded in putting on the market a perfectly

white magnesium chloride similar in appearance to the German article, which is once more in the market at very low prices

During the first year of the factory the Government charged a royalty of annas 8 per cwt , later on this was increased to Rs 1/8 per cwt On the Company's representation this was again revised, in January 1923, and a sliding scale fixed on a profit sharing bases with retrospective effect from 27th February 1922.

PRODUCTION —The production of the factory is shown in the following table, which also shows the imports and their value —

IMPORTS & INDIAN PRODUCTION OF MAGNESIUM CHLORIDE

Year	Imports		Sales of Kharaghoda Production
	Tons	Value Rs	Tons
1914-15	2,705	3,00,570	
1915-16	3,563	9,33,075	
1916-17	1,067	2,81,355	838
1917-18	1,185	2,90,955	1,181
1918-19	Not available		1,970
1919-20	848	2,27,397	1,647
1920-21	2,929	8,39,210	1 171
1921-22	2,330	4,49,680	1,099
1922, April to July, 4 months	1,510	1,89,746	600
1922-23			638

NOTE —Import figures for the years preceding 1914-15 are not available

The labour at this works averaged about 100 men Upto July 1922 the Government has received over 2½ lakhs under royalty

Closing of the Factory.—The factory has unfortunately been obliged to close down owing to the severe competition with foreign (principally German) imported magnesium chloride. Before the war German quality was sold between Rs 3 and 4 per cwt. At

the present time (December 1923) the prices of imported material are as under —

C.i f quotation £3 per ton, 46 per cent solid fused white made in Stassfurt and packed in 5 to 6 cwts strong iron drums

This c i f quotation is made up as follows —

£ s d

1 2 0 for freight

0 6 0 insurance, shipping & landing charges

0 12 0 Agents commission and factory to port expenses

———

2 0 0

Bombay quotation Rs 3-8 per cwt   This leaves to the manufacturer £1 per ton for the material including packing in 6 cwt drums   When competition was very keen and the German stuff was dumped on the market, the lowest quotation was Rs 1-8 per cwt   The Pioneer Company is not in a position to make any profit by sales under Rs 4-8 per cwt   The chief drawbacks are —

  (1) Cost of the drums   The Company's drums are made of thicker sheets than those used for Stassfurt chloride

  (2) Railway freight from Kathiawar to Ahmedabad and Bombay

  (3) Royalty payable to Government

  (4) Heavy cost of manufacture owing to open pan boiling and heavy replacement of copper pans which require constant renewal   One pan lasts hardly a year

Refined Salt.—By the side of the magnesium chloride factory, the Company built in 1921 a refinery for the production of refined salt   Baragara salt is first dissolved, and then after a preliminary treatment for the removal of magnesium and other impurities, it is concentrated in shallow open pans which are fired from underneath   The refined salt is fairly good in quality and stands in competition with the best imported table salt , its production during the last two years was in 1921-22 1,333 maunds , and 1922-23 4,523 maunds

Water Supply.—Considerable difficulties were experienced in supplying fresh water for the town and the Agarias till a boring was made in August 1915 There is a large tank which used to supply water for all the general purposes , but the tank very often became dry during the years of scanty rain The artisan well is of 8 inches bore and draws water from about 317 feet below the surface The water comes out continuously without pumping at the rate of 6,000 gallons per minute when the valve is fully open, but as so much water is not required the valve is partially closed to give about 360 gallons per minute Even this quantity is far in excess of the requirements and over two-thirds of it runs to waste in fields and ponds The pumped up water overflows in a small shallow tank to the south-west where it is used for washing and for watering This water is also largely used by the cattle of the neighbouring villages From the bore hole earthenware pipes are laid out all over the salt works, and the Agarias have to pay a charge of Re 1 per pan for the season of seven months

Welfare Institutions.—Besides the Administration offices the Government maintains a school, a dispensary, a library and an hospital They have also a club for the officers A suggestion was made in 1920 for a Co-operative Credit Society for the betterment of the Agarias by reducing their perpetual heavy indebtedness, but, as was naturally expected, the formation of a Co-operative Society amongst the Agarias was not found feasible, and the reasons given were the great illiteracy, unwillingness to contribute in the share of the initial capital required for the starting of a society, mutual distrust, and the consequent hesitation to stand security for each other It was decided, however, to start a society among the Government servants and thus gradually familiarise the Agarias of the advantages of a co-operative society

Population.—The population in Kharaghoda varies between 3,000 to 3,500 Considering this number it will be interesting to note that the number of patients treated annually at the dispensary is over 5,000 of which one-fifth is for malaria

Chemical Composition of Brines, Bitterns and Salts
Kharaghoda Brine.

	Per cent
Sodium Chloride	14 67
Magnesium Chloride	4 63
Magnesium Sulphate	0 48
Calcium Sulphate	0 44
Potassium Chloride	0 41
Calcium Carbonate	0 01
Magnesium Bromide	0 07

There are several other reports and records of analysis of Kharaghoda brines, bitterns and salts, but the best and most reliable information on this subject is contained in Sir James Dobbies' Report I am obliged to Mr R D Bell, Director of Industries, Bombay Government, for his courtesy in giving me the necessary permission to make use of this very interesting and useful report which I am giving below in extenso

SCIENTIFIC & INDUSTRIAL RESEARCH DEPARTMENT.

16 AND 18, OLD QUEEN'S STREET,
WESTMINSTER, S W 1
27th October 1920

SIR,

I am directed to refer to your letter (R and S 3609 /1918) of April 8th, 1919, and to subsequent correspondence, and to inform you that the Government Chemist has forwarded to this Department a copy of his report upon the examination of samples of brines, salts and bitterns from the Government Kharaghoda Salt Works, Rann of Cutch, India

Perusal of Sir James Dobbie's report indicates that the samples of brines and bitterns collected in accordance with his directions, contain such quantities of potassium and bromine compounds as warrant careful consideration of the possibility of extracting these valuable by-products on a technical scale Thus the five brine samples contained, on an average, 4 9 grms and 0 85 grms per litre of potassium chloride and magnesium bromide respectively, the three samples of bitterns showed an average content of 3 77 grms of potassium chloride and 8 2 grms of magnesium bromide per litre. The Kharaghoda district from which, it is understood, 100,000 tons of common salt are obtained annually, represents but a very small proportion of the whole area of the Rann of Cutch, further, portion of which may be found on survey to yield considerable quantities of salt The figures given above, considered in the light of the present (and relatively small) output of salt and of the potentially great future output, appear to indicate that the valuable by-products potassium chloride and magnesium bromide are obtainable in very considerable quantities in the Rann of Cutch. It is further to be noted that the brines and bitterns from Kharaghoda yield considerable quantities of magnesium chloride, a substance possessing important industrial uses A careful chemical survey of the District may possibly yield evidence of the presence of other commercially valuable materials in workable quantities

In reference to the chemical potentialities of the Kharaghoda and neighbouring districts, the following extract from the Report of the Chemical Service Committee (Simla 1920) page 60, is of interest —

> " It is no less urgent in order to provide adequate data for the bureau of information, that steps should be taken in the immediate future to commence a chemical survey of non-forest lands   For example, little or nothing is known of the vast salt deposits at Kharaghoda, and one of the first duties of the Director of Research appointed to the Bombay Presidency should be to erect a sub-station in this district and to subject the area to thorough investigation by a staff of skilled chemists in order to determine its industrial importance "

The evidence reviewed above suggests that the supplies of the raw materials mentioned are on such a scale as to warrant the expectation that their development will be found desirable   In these circumstances, I am directed to suggest that you may wish to consider whether, pending such action as may be taken upon the Report of the Chemical Service Committee, tests upon a scale larger than a laboratory operation ("semi-large scale ") should immediately be put in hand in order that more exact information may be available when it is found possible to proceed further with the question

<div align="right">I am, etc ,
F G   OGILVIE</div>

The Secretary,
> Revenue and Statistics Department,
>> India Office, St James's Park, S W 1

GOVERNMENT LABORATORY, CLEMENT'S INN PASSAGE, STRAND

<div align="right">LONDON W C 2
September 28th, 1920</div>

SIR,

> *Ref No Revenue R & S 2587-19 and R & S 3172-19*

With reference to your two letters of May 1919, the samples of brine, salts and liquors from the bitterns were received in April

last and have been examined as desired The results of the experiments are given in the enclosed report, from which it will be seen that there is good ground for believing that the brines may form important sources of potash as well as bromine

The subject is deserving of fuller investigation and the services of this Laboratory are at your disposal in the matter.

<div style="text-align:center">

I am, Sir,

Your obedient servant,

J. CONNOR

</div>

The Under Secretary of State for India,
    Revenue Department, India Office, S W 1

Report of the analysis of brines, samples of bitterns and salts from the Rann of Cutch

The samples which were received on April 14th, 1920, consisted of six brines marked 1 to 6, Lab Nos Misc 28, 30, 32, 34, 36 and 38

Four bitterns marked 7 to 10 Lab Nos Misc 40, 43, 44 and 47

Six salts (sodium chloride) marked 1a, 2a, 3a, 4a, 5a, and 6a, Lab Nos Misc 29, 31, 33, 35, 37 and 39

Four salts (magnesium chloride) marked 7a, 7b, 9a and 9b, Lab Nos Misc 41, 42, 45 and 46

One " crystals ' marked 11, Lab Nos Misc 48

One " sludge " marked 12, Lab Nos Misc 49

Samples Nos 32 (brine 3) and 47 (bitterns 10) were broken in transit to the Laboratory and the contents lost although some crystals remained in No 47 These were scraped out of the bottle and weighed 6 ozs On analysis they proved to be magnesium chloride contaminated with small amount of magnesium sulphate, sodium and potassium chlorides and contained bromine amounting to 0 37 per cent

Samples Nos 43 and 44 (bitterns Nos 8 & 9) had deposited crystals probably during the journey to this country In each case they were filtered off, drained at the pump, weighed and analysed The crystals from bitterns Nos 8 weighed 8 0 ozs and proved to

be magnesium chloride very similar in composition to those scrap ed from the broken bottle from which bitterns Nos (10) had been lost, but containing a slightly greater amount of bromine namely 0 47 per cent

The crystals from bitterns (No 9) weighed 1½ ozs and were totally different in character They were crude carnallite (i e, magnesium potassium chloride, Mg Cl₂, KCl, 6H₂0) containing 20 per cent of potassium chloride and, except that they contained less magnesium sulphate, were very similar to sample No 18 (crystals II) which formed in the side of the bitterns storage tank to which reference is again made below (see tables 7 and 8)

Sludge No 12 was filtered and drained as far as possible at the pump

The solid portion weighed 17 ozs but still contained adhering liquid It is substantially a mixture of one part of crystallised magnesium chloride and three parts of kieserite (i e, magnesium sulphate of composition MgSO₄ H₂0) and is slightly alkaline owing to the presence of magnesium hydroxide It contains 0 14 per cent of bromine and small amounts of sodium and potassium chlorides The liquid portion weighed 5 ozs and had a specific gravity of 1 344 and except that it contains less bromine (0 47 per cent) it is similar in composition to bitterns No 8

The following table shows the results of the analysis of the samples which arrived intact —

Table I.

Results of the Analysis of Kharaghoda Brines

Mark	1		2		4		5		6	
Lab Nos	28		30		34		36		38	
	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre
Calcium (Ca)	0 10	1 13	0 11	1 14	0 15	1 77	0 14	1 62	0 19	2 17
Magnesium (Mg)	0 77	8 73	2 61	31 84	1 31	15 48	0 83	9 68	0 91	10 75
Sodium (Na)	5 17	58 63	5 73	69 89	6 52	77 02	6 08	70 22	5 36	61 32
Potassium (K)	0 15	1 70	0 41	5 00	0 18	2 13	2 19	2 19	0 15	1 72
Iron										
Chlorine (Cl)	9·67	109 66	16 37	199 68	14 07	166 21	11 75	145 58	11 09	126 87
Bromine (Br)	0 04	0 44	0 13	1 56	0 05	0 60	0 05	0 53	0 04	0 48
Sulphate (SO₄)	1 18	13 48	0 92	11 22	0 38	4 49	0 59	6 81	0 12	4 80
Carbonate (CO₃)	0 01	0 11	0 01	0 12	0 01	0 12	trace	0 03	0 01	0 11
Total solids	17 09	193 78	26 29	320 65	22 67	267 82	19 63	226 76	18 19	208 20
Water by difference	82 91		73 71		77 33		80 37		81 81	
Sp Gr at 60° F.	1 134		1 220		1 181		1 154		1 154	

Table II.

The results shown in Table I for brines may be explained as follows —

Mark.	1		2		4		5		6	
	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre
Calcium Carbonate ($CaCO_3$)	0 01	0 11	0 02	0 24	0 01	0 12	0 01	0 11	0 01	0 11
Calcium Sulphate ($CaSO_4$)	0 33	3 74	0 33	4 03	0 48	5 67	0 46	5 31	0 60	6 86
Magnesium Carbonate ($MgCO_3$)										
Magnesium Sulphate ($MgSO_4$)	1 19	13 50	0 85	10 37	0 05	0 50	0 34	3 92		
Magnesium Chloride ($MgCl_2$)	2 05	23 25	9 48	115 64	5 06	59 77	2 94	33 92	3 65	41 76
Magnesium Bromide ($MgBr_2$)	0 05	0 57	0 15	1 83	0 06	0 71	0 05	0 58	0 05	0 57
Sodium Chloride ($NaCl$)	13 15	149 13	14 52	177 11	16 58	195 76	15 45	178 28	13 64	156 04
Potassium Chloride (KCl)	0 29	3 29	0 78	9 51	0 35	4 13	0 36	4 15	0 29	3 32
Total solids	17 07	193 50	26 13	318 73	22 59	266 75	19 61	226 27	18 21	208 66
Sp gr at 60°F	1 134		1 220		1 181		1 164		1 144	

Table III.

RESULTS OF THE ANALYSIS OF BITTERNS—7, 8 AND 9

Mark	7		8		9	
Lab Nos. Misc	40		43		44	
	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre	Per cent by wt	Grms per litre .
Calcium (Ca)					0 06	0 78
Magnesium (Mg)	8 09	106 57	8 96	120 76	7 73	101 21
Sodium (Na)	0 32	4 22	0 19	2 56	0 50	6 55
Potassium (K)	0˙07	0 92	0 05	0 67	0 33	4 32
Iron (Fe)			0 02	0 62		
Chlorine (Cl)	21 68	285 50	25 11	333 43	21 61	282 94
Bromine (Br)	0 48	6 26	0 76	10 26	0 36	4 74
Sulphate (SO₄)	2 40	31 61	0 78	10 51	2 09	27 36
Carbonate (CO₃)	0 04	0 53	Traces	Traces	0 04	0 52
	33 08	435 70	35 87	483 45	32 72	428 42
Water by difference	66 92		64 23		67 28	
Sp gr at 60°F	1 317		1 348		1 309	

Table IV.

The results shown in table 3 may be expressed as follows —

Calcium Carbonate (CaCO3)					0 06	0 79
Calcium Sulphate (CaSO4)					0 13	1 70
Magnesium Carbonate (MgCO3)	0 06	0 70	Traces	Traces		
Magnesium Sulphate (MgSO4)	3 01	39 05	0 98	13 21	2 51	32 86
Magnesium Chloride (MgCl2)	28 36	373 59	33 27	448 41	27 56	360 84
Magnesium Bromide (MgBr)	0 55	7 24	0 88	11 86	0 42	5 50
Sodium Chloride (NaCl)	0 82	10 80	0 48	6 47	1 28	16 76
Ferric Chloride (Fe₂Cl6)			0 06	0 81		
Potassium Chloride (KCl)	0 13	1 71	0 10	1 35	0 63	8 25
Total solids	32 93	433 78	35 77	482 11	32 59	426 70
Sp Gr at 60°F	1 317		1 348		1 309	

Table V.

RESULTS OF THE ANALYSIS OF MAGNESIUM CHLORIDE SAMPLES NOS 7a, 7b, 9a and 9b

Mark	7a	7b	9a	9b
Lab Nos, Misc	41	42	45	46
	%	%	%	%
Calcium (Ca)				
Magnesium (Mg)	11 76	11 96	11 79	12 59
Sodium (Na)	0 30	0 31	0 25	0 23
Potassium (K)	0 45	0 13	0 54	0 57
Chlorine (Cl)	34 35	34 65	34 04	36 62
Bromine (Br)	0 67	0 56	0 63	0 54
Sulphate (SO₄)	0 29	0 12	0 19	0 18
Carbonate (CO₃)	0 02	0 01	0 01	0 02
Insoluble Residue	0 05	0 04	0 02	0 04
Water	52 14	52 93	52 79	49 73
Total	100 03	100 71	100 26	100 52

Table VI.

These results may be combined as follows —

Mark	7a	7b	9a	9b
Lab Nos Misc	41	42	45	46
	%	%	%	%
Magnesium Carbonate ($MgCO_3$)	0 03	0 01	0 01	0 01
Magnesium Sulphate ($MgSO_4$)	0 36	0 15	0 24	0 22
Magnesium Chloride ($MgCl_2$)	44 97	45 71	44 54	48 00
Magnesium Bromide ($MgBr_2$)	0 77	0 64	0 72	0 63
Sodium Chloride (NaCl)	0 75	0 80	0 63	0 50
Potassium Chloride (KCl)	0 86	0 25	1 03	1 00
Insoluble Residue	0 05	0 04	0 02	0 04
Water	52 14	52 93	52 79	49 73
Total	99 93	100 53	99 98	100 34

Table VII

RESULTS OF THE ANALYSIS OF SALTS 1a, 2a, 3a, 4a, 5a, 6a

Mark	1a	2a	3a	4a	5a	6a
Lab Nos Misc	20	31	33	35	37	39
Calcium (Ca)	0 56	0 32	0 71	0 30	0 35	0 57
Magnesium (Mg)	0 25	0 24	0 43	0 11	0 31	0 23
Sodium (Na)	36 30	37 19	35 67	37 78	36 87	36 80
Potassium (K)	0 05	0 03	0 08	0 01	0 05	0 04
Chlorine (Cl)	56 55	57 06	56 08	58 01	57 66	57 42
Bromine (Br)	0 02	0 02	0 02	0 01	0 02	0 02
Sulphate (SO_4)	1 66	0 86	1 92	0 90	0 97	1 33
Carbonate (CO_3)	0 02	0 01	0 03	0 02	0 02	0 02
Insoluble Residue	0 07	0 05	0 07	0 16	0 13	0 15
Water	3 98	3 06	5 13	1 70	3 48	2 08
Total	99 46	99 74	100 14	99 69	99 86	99 56

Table VIII.

These results may be combined as follows —

	1a	2a	3a	4a	5a	6a
Calcium Carbonate ($CaCO_3$)	0 04	0 02	0 05	0 04	0 03	0 03
Calcium Sulphate ($CaSO_4$)	1 86	1 06	2 35	1 28	1 15	1 90
Magnesium Sulphate ($MgSO_4$)	0 44	0 14	0 33		0 20	
Magnesium Chloride ($MgCl_2$)	0 63	0 82	1 40	0 44	1 06	0 87
Magnesium Bromide ($MgBr_2$)	0 02	0 02	0 02	0 01	0 02	0 02
Sodium Chloride (NaCl)	92 33	94 52	90 64	96 05	93 69	93 54
Potassium Chloride (KCl)	0 10	0 05	0 15	0 02	0 10	0 07
Insoluble Residue	0 07	0 05	0 07	0 16	0 13	0 15
Water	3 98	3 06	5 13	1 70	3 48	2 08
Total	99 47	99 74	100 14	99 70	99 86	99 58

Table IX

RESULTS OF THE ANALYSIS OF CRYSTALS

Mark.	11	Crystals from Bittern No 9
Lab Nos Misc	48	
	Per cent	Per cent
Calcium (Ca)	0 08	0 06
Magnesium (Mg)	7 95	7 91
Sodium (Na)	3 66	3 65
Potassium (K)	10 52	10 51
Chlorine (Cl)	33 12	37 73
Bromine (Br)	0 17	0 17
Sulphate (SO₄)	7 32	0 49
Carbonate (CO₃)	0 03	0 02
Insoluble residue	0 43	0 20
Water	37·16	39 37
Total	100 44	100 11

Table X.

These results may be combined as **follows** :—

	Per cent.	Per cent.
Calcium Carbonate ($CaCO_3$)	0·06	0 03
Calcium Sulphate ($CaSO_4$)	0 20	0·16
Magnesium Sulphate ($MgSO_4$)	9 00	0 48
Magnesium Chloride ($MgCl_2$)	23 93	30 51
Magnesium Bromide ($MgBr_2$)	0 19	0 19
Sodium Chloride (NaCl)	9·29	9·26
Potassium Chloride (KCl)	20 06	20 04
Insoluble residue	0 43	0 20
Water	37 16	39 37
Total	100 32	100 24

Before considering the interpretations of the results of the analysis it is desirable to indicate the methods of analysis adopted especially as those adopted for potassium, bromine and water, are of the greatest importance   A full description of these will be found in the appendix of this report

The calcium, magnesium, potassium, bromine, sulphate, carbonate, insoluble residue and water were determined directly, but in the case of the brines and bitterns the water was taken by difference. The chlorine was obtained from the total silver halide after deducting the amount due to the bromine which was determined directly The mixed alkali chlorides were weighed together and the sodium chloride was obtained by deducting from that weight the amount of potassium chloride found by direct determination as perchlorate after precipitation by sodium cobaltinitrite   As a check, in some cases, the mixed alkali chlorides were converted to perchlorates and the potassium perchlorate weighed

In the case of the brines and bitterns the results are expressed as per cent by weight and in grams per litre whilst the salts are expressed as per cent by weight only   In all cases the table of determined radicles is given first, following by a table showing how, in our opinion, these radicles may be considered to be combined in the samples   It will be observed that the individual totals in these two tables do not exactly correspond in all cases   This slight discrepancy is due to the inevitable small errors of analysis and to the fact that in combining the various radicles there is always a slight excess of one of them, usually magnesium, at the end   As in our experience the estimation of magnesium usually tends towards results that are a little high, the figure for magnesium chloride given in the table is calculated from the excess of chlorine after all other radicles have been accounted for   In any case it must be emphasized that the difference observed is small and of no importance in considering the results of the investigation

Consideration of the Results of the Analysis

1   THE BRINES AND BITTERS   TABLES 1, 2, 3 AND 4
All the samples contain bromine and potassium chloride, but in

variable amounts   Of the brines No 30 (Mark 2) is the richest in bromine, and in potassium and magnesium salts   The amount of potassium chloride present namely 9·5 grams per litre is comparable with that found in the Dead Sea water having a specific gravity of 1 16 (Surface water)

Bitterns Nos 40 and 44 (Marks 7 and 9) contain respectively 0 48 and 0 36 per cent of bromine, while No 43 (Mark 8) as might be expected contains the greatest amount namely 0 76 per cent   All the bitterns contain large amounts of magnesium chlorides, but the amount of potassium chloride is not so great as might have been anticipated if the potassium chloride has remained in solution. This is due to the fact that, since the bitterns have densities varying from 1 31 to 1 35, they are practically saturated solutions, and the bulk of the potassium chloride has been previously precipitated as crude carnallite   The compositions of the crystals No 48 (Mark 11) which form on the sides of the bitterns pan bears out this explanation   The crystals are in fact crude carnallite

Since the presence of potassium chloride in the brine is of the greatest importance, but was not found in the samples analysed by Mr Mackenzie Wallis, it is desirable at this point to state that experiments have been conducted on the limited amount of brine No 30 (Mark 2) at our disposal with the object of finding out the limits of the specific gravity for the complete precipitation of the potash as carnallite   On concentrating the brine at about 40°C with a stiff breeze blowing over the surface of the evaporating liquid most of the salt (sodium chloride) is precipitated when the hot liquor attains a specific gravity of 1 26   This precipitated salt contained 0 35 per cent of potassium chloride   After removing the sodium chloride, the mother liquor on being concentrated at about 50°C till the specific gravity of the hot liquor reached 1 31, deposited crude carnallite which contained 10 5 per cent of potassium chloride   Owing to lack of material we were not able to fix the precise limits of the specific gravity for the production of carnallite containing 20 per cent of potassium chloride (this being the proportion found in the crystals (Mark 11)

but it is probable that such a carnallite would be produced if the precipitation took place between the specific gravities of 1 28—1 31 It would however be a comparatively simple matter to fix the condition necessary in India for the precipitation of carnallite by trial upon an experimental scale in the works

That potassium chloride of a fair degree of purity can be readily obtained from the carnallite produced in India has been proved by the recrystallisation of sample No 48 (Mark 11) The crystals of crude carnallite from even the sides of the bitterns pan contain 20 per cent of potassium chloride and after a simple process of recrystallisation yield a crude potassium chloride of 70 per cent purity, a small sample of which in a bottle is forwarded with this report

The question of the production of bromine from the bitterns will be taken up after the analysis of the salts have been considered

The brines and bitterns contain no iodine and only spectroscopic traces of lithium in certain cases We have examined the bitterns (so far as the material at our disposal allows) for the presence of rubidium and cassium but with negative results

2 THE SALTS (SODIUM CHLORIDE) TABLES 7 AND 8

The sodium chloride in the salt varies from 90 to 96 per cent , the salt produced from brine No 34 (Mark 4) contains the highest amount of sodium chloride and the least impurity All the samples contain very small quantities of bromine and potassium chloride

3 THE SAMPLES OF MAGNESIUM CHLORIDE TABLES 5 AND 6

The samples contain total solid impurities ranging from 1 89 per cent in No 42 (Mark 7b) to 2 82 per cent in No 41 (Mark 7a) No 46 (Mark 9b) contains the greatest amount of magnesium chloride but this is due to the fact that this sample is the driest All the samples contain small quantities of potassium chloride and definite amount of bromine All the samples may be considered good commercial magnesium chloride (fully hydrates)

Production of Bromine —Bittern No 43 (Mark 8) contains 0 76 per cent by weight of bromine, and bitterns Nos 40 and 44 (Marks 7 and 9) 0 48 and 0 36 per cent respectively The

amount of bromine in the Stassfurt mother liquors (one of the main world's supplies of bromine) after the removal of the carnallite is usually 0 2 to 0 3 per cent and the amount found by experiment in the mothr liquor from brine No 30 (Mark 2) after the removal of the carnallite was 0 40 per cent The amount of bromine present in the bitterns is thus excluding No 43 (Mark 8) which is the final mother liquor after the removal of magnesium chloride greater than in the corresponding bitterns obtained at Stassfurt

It should be noticed however that every salt removed from the brines or bitterns during the manufacture of salt and magnesium chloride contains bromine in greater or less amount The sodium chlorides contain on the average 0 017 per cent of bromine, the carnallite 0 17 per cent, the magnesium chloride 0 60 per cent and the solid part of the sludge 0 14 per cent Every process therefore involving the removal of solid matter from the brines and bitterns by crystallisation or precipitation causes a loss of bromine in the liquid which is small in the original brines, but increasing in amount as the mother liquor becomes more concentrated Consequently it is not possible, knowing only the amount of bromine in the original brine and the degree of concentration to deduce the amount of bromine in the final mother liquor, nor conversely, having analysed only the final mother liquor and knowing the degree of concentration is it possible to deduce the amount of bromine in the original bitterns or brine (See Bulletin No 2, p 9, Department of Industries, Bombay Presidency)

For the purpose of obtaining some idea of the order of the total loss of bromine and the amount lost at each stage of the successive operations a definite quantity of brine 30 (Mark 2) was evaporated From 500 ccs of this brine (specific gravity 1 22) containing 0 128 per cent of bromine 85 grams of salt (sodium chloride) were obtained containing 0 05 per cent of bromine. From the mother liquor which measured 230 ccs and had a specific gravity of 1 26, 30 grms of crude carnallite were obtained containing 0 156 per cent of bromine The mother liquor at this stage (mea-

suring 125 ccs) had a specific gravity of 1 31 and contained 0 403 per cent of bromine 105 ccs of this mother liquor were concentrated to 32 ccs of specific gravity 1 36 and in the process 62 grams of magnesium chloride containing 0 404 per cent of bromine was removed This final mother liquor contained 0 674 per cent of bromine From these figures it can be calculated that 55 per cent of the bromine originally present in the brine has been removed by the various salts taken out on concentration and that therefore most of the loss of bromine occurs during the removal of magnesium chloride when the liquor is most concentrated Further it will be observed that starting with a brine containing 0 128 per cent of bromine and concentrating more than 13 times, the bromine contents of the final mother liquor in only 0 674 per cent In other words the bromine has been concentrated only little more than 5 times, and starting with a bittern containing 0 403 per cent of bromine and concentrating more than 3 times, the bromine contents has only increased 68 per cent It will be observed that the ratio of the bromine contents of bitterns Nos 43 and 40 (Mark 9 and 8) is 100 159 or nearly the same as that found by the above experiment namely 100 168 It is further to be noted that in order to obtain a final mother liquor containing 1 0 per cent of bromine the original bittern must contain 0 60 per cent of bromine whereas the amount present in the richer of the two samples submitted to us was only 0 48 per cent These figures should not be taken as absolute values since the conditions of crystallisations may differ in India from those in this country and further the loss of bromine on a manufacturing scale may be different from that obtaining in the Laboratory, but they serve to indicate the order of magnitude of the loss of bromine that may be expected, without taking into account any possible loss of bromine that may occur through heating the bitterns to a high temperature, or any loss due to leakage from the pans

Although there is this great loss of bromine during the various process of manufacture it does not follow that bromine cannot be economically manufactured in India Apart from the question of

cost of manufacture available labour, and method of manufacture, the determining factor would appear to be the quantity of bittern available. For every 15,000 gallons of bitterns containing 0 50 per cent of bromine, rather more than 900 lbs of bromine are theoretically recoverable, but it would be more satisfactory to ascertain the amount actually recoverable by experiment of a semi-works scale.

Summary and Conclusions.

1 The brines and bitterns contain potassium salts, magnesium salts and bromine but do not contain iodine

2 Crude carnallite crystallises round the sides of the bitterns pans and may be obtained by allowing the bitterns to concentrate between certain limits of specific gravity

3. Crude potassium chloride may be obtained by a simple process from the carnallite

4, Loss of bromine occurs at all stages in the concentration of the brines and bitterns, but this loss does not necessarily make the economic recovery of the bromine impossible The factors of most importance are the percentage of bromine in the final mother liquors and the quantity of such mother liquors available

5 It is necessary to modify the report of Mr Mackenzie Wallis in one most important particular, namely the statement (See Mr. Mackenzie Wallis's report conclusion 6 and the second paragraph on page 4 of the Bulletin No 2 of the Department of Industries, Bombay Presidency) as to the entire absence of potassium in the brine The notable quantities of potassium chloride found in the brines examined in this Laboratory indicate that these may prove to be a useful source of raw material for the manufacture in India of pure potash salts and crude potash salts for fertilising purposes

6 In our opinion it is desirable to make experiments on a works or semi-works scale to decide whether either potash salts or bromine or both can be manufactured economically in India

Methods of Analysis most suitable for Brines and Salts

Estimation of Bromine—No method which depends on the selective oxidation of bromides in the presence of such chloride and the subsequent removal of the liberated bromine by steam distillation is entirely satisfactory, neither is the method of direct titration against chlorine water except within narrow limits for pure dilute solutions of bromides Further, calorimetric methods are generally only approximate and cannot be relied on where exact results are required

The only recent method of analysis which in our experience gives satisfactory results is that of Baughman and Skinner (J of Industrial and Engineering Chemistry, Oct 1919, p 954) The method depends on the liberation of bromine from bromides by chromic acid in concentrated solution in the cold and the removal of the liberated bromine by a rapid current of air The bromine is caught in a neutral solution of potassium iodide and the liberated iodine is titrated against a standard solution of sodium thiosulphate in the usual way

The process is carried as follows —

Into a drying cylinder of about 150 ccs capacity fitted with a ground-in stopper carry an inlet tube terminating on the outside in a small funnel and an outlet tube bent at right angles is placed a definite quantity of the bittern or brine (concentrated if necessary) A solution of 15 grams of chromic acid in about 12 ccs of water is then run in through the funnel taking care that the total volume of liquid in the cylinder does not exceed 25 ccs The cylinder is previously attached to two similar cylinders (without funnels) filled to about one-half of their capacity with a dilute solution of sodium sulphite made slightly alkaline with sodium carbonate A gentle current of air is drawn through the apparatus until the contents of the reaction cylinder are thoroughly mixed The forward end of the apparatus is then closed with a screw clip and by gentle aspiration the internal pressure is slightly reduced, after which the back end

of the apparatus is closed by a screw clip   The whole is then allowed to remain closed for 15 to 18 hours

The next morning the bromine is removed by passing a rapid current of air for three hours, and four 2 ccs portion of 3 per cent hydrogen peroxide at half hour intervals are added to the reaction cylinder   The contents of the absorption cylinder are then transferred to a dish and then evaporated nearly to dryness. In the cleaned out reaction cylinder are placed 15 grams of chromic acid   The absorption cylinders are cleaned and filled to about half their capacity with a neutral solution of potassium iodide (5 per cent) and the three cylinders are connected up   The evaporated solutions and the washings of the evaporation dish are transferred to the reaction cylinder taking care as before to keep the bulk down to about 25 ccs Aspirate as before for one and a half hours and titrate the liberated iodine with thiosulphate

Estimation of Potassium.—(See Analyst 1916, p 165)   A solution of sodium cobaltinitrite is prepared as follows —

50 grams of cobaltinitrite and 300 grams of sodium nitrate are dissolved in water, acidified with 25 ccs of glacial acetic acid and diluted to one litre   Allow the solution to stand for 48 hours and filter before use

10 grams of brine are diluted to 40-50 ccs with distilled as water, (put water in a beaker and 30 ccs of sodium cobaltinitrate solution added) Stir and allow the precipitate to settle for 2 hours   (In the case of the salts, where very small amounts of potash are present allow to stand overnight) Filter at the pump in Gooch crucible fitted with a paper disc and wash with water containing sodium cobaltinitrite   Return the crucible and its contents to the beaker and dissolve in the steam or water bath in a few ccs of hydrochloric acid diluted with an equal volume of water Filter into a small evaporating basin, wash well and take down to dryness Dissolve the residue in a few ccs of water, filter again if necessary and add a slight excess of perchloric acid   Evaporate on the hot plate until nearly dry   Cool, dissolve in a little water, add 2½ ccs of perchloric acid and again evaporate until nearly dry. When cold

add 25 ccs of 98 per cent alcohol, stir, filter through a Gooch crucible with asbestos mat, wash with 98 per cent alcohol containing 0 2 per cent of perchloric acid and saturated with potassium perchloride   Dry at 100°C, weigh, and deduct the amount of potassium perchlorate found in the volume of perchloric acid used, generally about 1 milligram for every 3 ccs and from the weight of potassium perchlorate thus found calculate the percentage of potassium

Estimation of Water —In the case of the salts (sodium chloride) where the amount of the calcium magnesium salts does not exceed 3 to 4 per cent no very serious error is introduced into the analysis if the finely powdered salt is dried at 200°C to constant weight and the resulting loss of weight is considered to be wholly water   But in the case of carnallite or magnesium salts and particularly of magnesium chloride, the salt cannot be freed from water at a temperature below that at which the salt is decomposed with loss of chlorine as well   In order to avoid error from this case the following method of determination of water in such salts has been in operation in this Laboratory for some time

The method depends upon the fact that lead chromate at a red heat will absorb chlorine and sulphuric acid but will not absorb water   Hence if the vapours obtained by heating the salts in question be passed over heated lead chromate in a tube, only the water will pass on into the absorption tube containing pieces of pumice saturated with sulphuric acid   As an additional precaution against traces of hydrochloric acid passing into the absorption tube a spiral of silver gauze is placed in the tube immediately in front of the absorption tube   The mode of procedure is as follows —

A piece of glass combustion tubing 18″ long and ¾″ diameter is cleaned and dried   The middle third of the tube is filled with granulated fused lead chromate kept in position by two short spirals of copper gauze   In the end of the tube nearest the absorption tube containing sulphuric acid is placed a 4″ spiral of silver gauze   The

tube and its contents are first dried by heating to redness in a Fletcher furnace and a current of air dried by passing through sulphuric acid is passed through the tube until all the traces of water are removed The empty third of the tube is then allowed to cool About half a gram of the salt is weighed into a boat and placed immediately in the empty cold part of the tube   The salt must be weighed out as rapidly as possible and preferably by enclosing the boat in a weighing tube of " pig" form , this is particularly desirable with magnesium chlorides A current of dry air is drawn through the tube and the front part of the tube with boat heated gently at first and finally to bright redness and maintained at that temperature for 10 to 15 minutes   Care should of course be taken not to heat the lead chromate to the point of fusion   The absorption tube is finally weighed, the increase in weight being water

<div align="right">A J F.</div>

GOVERNMENT LABORATORY, ⎫
⎬
September 28th, 1920   ⎭

Kuda Salt Works —These works, as was shown in the earlier part of this report, are of very ancient origin Long before Kharaghoda salt works were opened, salt was manufactured at Kuda It is stated that the Agarias of Kuda who had inherited the knowledge of salt manufacture from their ancestors were the first to be called at Kharaghoda when the new works were opened in 1822, and that the practice followed at Kuda from ancient times was copied at Kharaghoda in every detail There is however at the present day absolutely no difference in the practice followed at these two neighbouring salt works The season is the same as at Kharaghoda Two kinds of salt are manufactured at Kuda —

(1) Vadagra (Baragra) or large crystals
(2) Ghasia or small crystals

Ghasia salt crystals are very light, not being allowed to grow as in the case of Baragra salt, but removed as soon as they are formed like flakes For this reason they do not require continued labour in raking and spade work as in the case of Baragra salt. For a number of years the contractors were paid Rs 1-9-0 per 100 maunds of Ghasia salt Before the light railway was brought to the Kuda salt works, the cartage was Rs 4-8-0 per 100 maunds from the site to the old warehouse Contracts for Baragra salt were given at 8 pies per Bengal maund or Rs 1-2-8 per ton In November 1920 a general survey of the wells made for the 1920-21 season was made and it was found that the brine level in the wells was 8 feet from the surface The density of the brine in all the wells was 19 to 20° B at 25°C In one well brine was at a depth of 4 feet from the surface Its density was 20° B In the pans which were just beginning to form salt, a density of 25° B was noted In the pans where salt was already found, the density was 26° B and in the pans which were being emptied the bittern had a density of 30°B

During the 1919-20 and 1920-21 seasons, Magnesium Chloride was recovered from the bitterns At Kuda the bitterns of 30° B were first led into small tanks, where they were allowed to concentrate till about 36° B They were then transferred by buckets into shallow kettles heated by open fire underneath They were boiled at 116° C The method followed at Kuda was very crude , but as the price of imported Magnesium Chloride was very high, it paid the manufacturer to recover Magnesium Chloride from the bitterns, even though the cost of manufacture was very high Analyses of Kuda brines are given in the following tables These analyses show that the Kuda brine is stronger than Kharaghoda brine It should also be noticed that Sodium Chloride in Kharaghoda and Kuda brines of 20° B is less than in " sea water" brine of the same strength

Results of the Analysis of Kuda Brines

Table II

	Per cent by weight								Grams per litre							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
Calcium Carbonate (CaCO$_3$)	0.02	0.02	0.04	0.01	0.02	0.01	0.01	0.01	0.17	0.20	0.42	0.15	0.20	0.12	0.13	0.10
Calcium Sulphate (Ca SO$_4$)	0.28	0.35	0.23	0.30	0.27	0.54	0.54	0.34	3.23	4.08	2.75	3.54	3.93	0.37	0.42	1.03
Sodium Chloride (NaCl)	16.08	15.87	17.38	16.90	18.30	17.57	17.64	13.07	175.70	185.90	204.00	199.40	216.80	203.70	211.00	158.70
Magnesium Sulphate (MgSO$_4$)	0.57	0.47	0.54	0.60	0.43	0.32	0.48	0.28	6.63	5.40	6.30	5.83	5.04	3.70	5.77	3.20
Potassium Chloride (KCl)	0.32	0.25	0.24	0.22	0.22	0.22	0.21	0.14	3.69	2.92	2.77	2.50	2.00	2.50	2.48	1.60
Magnesium Chloride (MgCl$_2$)	4.84	4.09	3.05	4.00	4.21	5.30	5.10	5.43	50.30	54.90	40.31	47.71	40.83	67.03	61.00	62.85
Magnesium Bromide (MgBr$_2$)	0.13	0.05	0.03	0.03	0.04	0.04	?04	0.05	1.51	0.07	0.32	0.37	0.43	0.43	0.50	0.53
Total solids	21.22	21.71	22.41	22.02	23.49	24.00	24.02	19.99	240.83	251.22	262.03	258.30	277.93	289.00	297.30	230.51
Specific Gravity at 10°C	1.143	1.171	1.174	1.173	1.184	1.188	1.190	1.168	1.104	1.171	1.171	1.174	1.184	1.189	1.106	1.159

Highness, and the town and the works were named Nimaknagar (Nimak = salt and Nagar = town, Saltville)   This site is about a mile north to south and a mile east to west   The southern half which is slightly on a higher level is laid out for residential purposes, and in the northern half the salt works proper will be laid out   The natural contours of the selected site have been most ideal giving a drop of 2 feet from south to north and 2 feet from west to east The natural gradient thus helps considerably in the economical layout of the works   A brine channel runs in the centre of the works   This channel is carried to the southern side where it discharges the brine into a forebay   The channel is carried from the works into the Rann of Cutch on a embankment which is of a higher level than the high flood mark   On the two sides of the channel there are brine wells   The distance between each well is 60 feet These wells will be worked by one central compressor plant, and the brine will be pumped by air-lift from each well into the main channel   The brine will be led from the forebay into the condenser, which has a total area equal to forty-five per cent of the total area of the pans   The condenser is divided into three sections, the brine flowing by gravity in a zig-zag way from one condenser to the other In the third condenser there are two sluice valves, from which the brine would be led into the pans   The pans will be 210×70 feet   The area of three pans will make an acre   The brine will be admitted to each set of the pan through a pipe, and its flow will be regulated by valves   At the end of the pan there will be a take off from which the bittern   will flow into· the bittern channel   The bittern would be run off by gravity   All the pans would thus be connected at one side with the   brine channel and on the other with the bittern channel   The bitterns will flow from all the pans by gravity into one main channel which will discharge it into the bittern reservoir   The design of the layout thus makes it possible to take off the bittern without handling   The whole of the layout is so arranged, that there will be a constant flow of bittern from one part or the other of the layout, thus making it possible to recover the by-products continuously   throughout the

flat country with the exception of a few hills   Round about
Dhrangadhra there are several observatories of the Meteorological
Department, whose records extend over 50 years   From the records
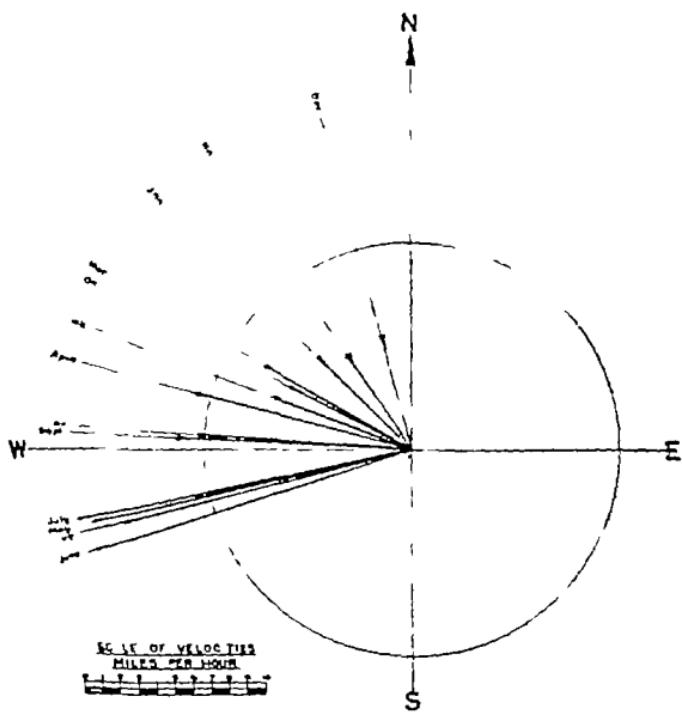
YEARLY VARIATION IN DIRECTION AND
VELOCITIES OF WIND AT KUDA

FIG 12

of these observatories it would be possible to obtain very nearly a
correct idea of the conditions in the Dhrangadhra State   For this
purpose I have given the readings of the following stations —

Veraval which is on the sea coast , Rajkot which is in the interior
of Kathiawar , Bhuj which is to the south-west of the Rann of Cutch,
Ahmedabad which is about 70 miles from Dhrangadhra, and Deesa
which is on the north of Dhrangadhra

At Kuda the weather would resemble more like Rajkot, Bhuj or
Ahmedabad with this difference, that in the month of March and
April when the north-west winds are blowing from the Rann, the
maximum temperature at Kuda would be more than at Ahmedabad

Table II.

MINIMUM TEMPERATURE

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Year
Veraval	58 8	60 7	64 9	72 5	78 4	81 0	79 2	77 7	76 3	72 7	67 7	62 0	71 0
Rajkot	51 1	54 5	62 4	69 4	75 1	77 6	75 8	74 5	72 4	68 1	59 3	52 9	66 1
Bhuj	54 4	58 1	65 4	71 5	76 7	79 8	78 1	76 2	74 6	70 9	62 7	56 1	68 7
Ahmedabad	57 0	60 3	67 8	75 2	79 5	80 7	78 2	77 1	76 2	72 1	65 7	60 1	70 8
Deesa	51 5	55 1	63 8	71 7	77 5	80 6	77 6	75 6	73 9	66 8	57 7	52 7	67 0
Kuda* (Nimakmagar)	54 4	58 1	65 4	71 5	76 7	79 8	78 1	76 2	74 6	70 6	62 7	56 1	68 7

*Expected

Table IV.

WIND

(Mean velocity in miles per hour)

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Year
Veraval	5.9	7.1	7.7	8.4	9.4	11.4	13.4	11.8	7.0	6.1	8.5	5.7	8.4
Rajkot	5.2	6.1	7.7	10.4	14.4	14.1	14.2	12.4	9.1	5.7	5.5	4.7	9.1
Bhuj	6.5	7.3	8.8	11.6	17.4	17.7	18.1	15.7	12.2	8.6	5.5	5.8	11.1
Ahmedabad	4.3	4.0	7.4	7.4	7.0	7.7	6.6	4.0	9.2	3.7	4.3	4.7	5.0
Deesa	8.5	8.6	8.6	9.1	13.4	16.7	15.3	12.0	8.8	6.6	7.7	8.0	10.2
Kuda (Nimaknagar)	6.5	7.3	8.8	11.6	17.4	17.7	18.2	15.7	12.2	6.8	5.5	5.5	11.1

Table VI.

RAINY DAYS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Normal No. of rainy days of year
Ahmedabad	0·1	0·3	0	0·1	0·5	4·8	13·5	10·9	5·8	0·8	0·3	0·1	37·2
Deesa	0·4	0·5	0·3	0·3	0·8	4·3	13·6	11·6	5·4	0·8	0·3	0·4	38·7
Rajkot	0·2	0·3	0	0	0·6	5·3	11·2	6·6	5·1	0·9	0·5	0·2	30·9
Veraval	0	0·1	0	0	0·1	4·6	10·9	8·1	4·6	0·1	0·3	0·4	29·2
Bhuj	0·1	0·3	0·1	0	0·3	2·4	6·2	7·7	2·0	0·5	0·3	0·2	16·1

Kuda (Nimaknagar) same as Rajkot

Table VIII

RELATIVE HUMIDITY

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Year
Rajkot	39 1	38 0	40 3	41 1	51 1	61 6	74 0	74 6	74 5	53 8	38 0	37 5	52 6
Bhuj	48 1	45 0	47 3	49 1	50 1	63 6	74 0	72 6	69 5	43 8	40 0	42 2	54 6
Deesa	36 0	20 5	20 9	26 1	39 8	53 9	71 3	75 9	68 1	45 6	36 0	36 8	45 5

Kuda same as Deesa

" During the past few years the quality of Sambhar salt is said to have depreciated, and it has been suspected that the large quantities which have been removed have at last made an impression on the great stores of salt which must have accumulated in the lake silt, appreciably raising the proportion of the associated compounds sodium sulphate, sodium carbonate and potassium sulphate "

Sambhar lake water contain mostly Sodium Chloride, Sodium Sulphate and Sodium Carbonate in the following proportions —

	Per cent
Sodium Chloride	88
„ Sulphate	7 5
„ Carbonate	4 5

Sodium Sulphate and Sodium Carbonate are present in very large quantities   These are found on the sides of the Lake in layers from 1 to 2 inches deep   Salt is recovered from the brine by solar evaporation in shallow pans or Kyars or obtained by gradual concentration of the waters of the lake itself   Salt forms at Sambhar lake in large crystals of the hopper or pyramid shape   The crystals are white or gray to pink   The manufacture of salt at the lake, it will be seen, depends upon the rainfall which varies from year to year, and the outturn of salt fluctuates in accordance with the quantity of brine in the lake

Production of Salt.

Year	Maunds
1917-18	45,34,747
1918-19	1,11,90,738
1919-20	44,77,199
1920-21	64,35,535
1921-22	50,18,104

The average rainfall at Sambhar is 20 17 inches   The monsoon begins in June and lasts to the end of October   The cost of salt at Sambhar is extremely low as will be seen from the following table —

Manufacture of pan salt was considered troublesome, precarious and uneconomical Considerable improvements have been made since 1920, for the production of an assured quantity of salt from surface and subsoil brines As a result of enquiries made by the Government, it was suggested to construct a large reservoir provided with powerful pumping plant at a cost of rupees four lakhs This reservoir is to be built by the construction of a dam 12,000 feet long and sufficiently high to maintain a level of 5 feet of water for the cold and hot weather These measures will safeguard the Sambhar source against scanty rainfall Other projects at Sambhar are the electrification of the power plant, acceleration in the methods of extraction and in the handling and transport of salt

Pachbadra and Didwana Brine Salt Works —After Sambhar, the Pachbadra salt sources are next in importance Pachbadra is on the banks of Luni (salt river) at a distance of 40 miles from the city of Jodhpur All over the area brine springs exist Pits of an average length of 230 ft by 60 ft are dug to the level of the brine springs and become filled to a depth of 3 feet. The density of the brine varies from 20 to 25° B Another important salt centre is Didwana, also situate in Jodhpur at a distance of 40 miles S W of Sambhar Lake The supply of brine is abundant and believed to be inexhaustible The cost of production at Didwana is extremely low—As 10 a ton—perhaps the cheapest salt made in the world

considerable distances in Northern India, these salts are not marketable in Central and Southern India

Prices of Salt in Rajputana and Northern India—The cost price includes the cost of manufacture and storage, cost of supervision, share of cost of hospital establishment, medicine, etc Interest on capital expenditure and outlay, rent of sources, including royalty and other items of expenditure From the prices given below it will be realised that salt is obtainable at perhaps the cheapest rate in the world

FRICES OF SALT IN RAJPUTANA AND NORTHERN INDIA—PER MAUND

	1017-18				1918-10				1910-20				1020-21				1021-22			
	Cost		Sale		Cost		Sale		Cost		Sale		Cost		Sale		Cost		Sale	
	As	p	As	p	As	p	As	p	As	p	As	p	As	p	As	p	As	p	As	p
Sambhar	4	6 31	4	0	1	1 21	4	0	4	2 53	4	0	2	11 0	4	0	3	8 12	4	0
Didwana	1	5 81	2	0	2	8 07	2	0	1	1 14	2	0	2	3 01	2	0 00	1	4 80	2	0 12
Pachbadra	1	11 64	1	6	3	0 20	1	6	3	5 77	1	0	2	3 83	1	0	3	0 07	3	3 08
Average Brine Salt	4	1 08	3	10 72	1	3 80	2	7 87	3	10 11	3	0	2	10 17	3	0 21	1	4 34	3	10 02
Khewra	1	4 20	1	0	1	8 82	1	0	2	3 04	2	11	1	3 32	2	0 2	1	10 03	3	2 63
Nurpur	0	11 22	1	0	0	11 18	1	0	1	2 05	1	11 20	1	4 01	2	1 47	2	5 83	3	2 09
Warcha	0	11 60	1	0	0	8 77	1	0	5	7 02	4	4 35	2	1 09	2	1 29	1	10 5	3	03
Kalabagh	1	4 60	1	0	1	8 44	1	0	2	8 67	1	11 08	2	2 13	2	3 45	1	1 57	3	07
Average Rocks Salt	1	3 78	1	0	1	0 00	1	0	2	4 05	2	10 04	2	0 10	2	0 22	2	7 42	3	180

Percentage of quantity imported from different countries

	1918-19	1920-21	1921-22	1922-23
United Kingdom	8 88	14 58	12 7	14 41
Port Said	49 90	19 34	18 14	15 82
Spain	4 13	11 93	11 44	10 55
Massovah	11 30	9 10	9 46	11 24
Aden	25 25	28 65	31 92	30 82
Bombay	0 44	2 80	3 88	5 23
Madras	0 90	0 09	3 81	3 81
Hamburg		12 77	8 63	8 05

Wastage of Salt —The following figures show the average percentages of wastage of salt in the Bengal Warehouses —

	1921-22	1922-23
Liverpool	3 22	2 04
Port Said	0 08	1 00
Aden	0 93	6 03
Massovah	0 05	0 64
Hamburg		0 843
General average	2 65	2 25

The average wholesale price per maund was as follows —

	Rs
1920-21	3-2-4
1921-22	3-3-0
1922-23	3-6-6

For wholesale F O B prices see Appendix

Madras Presidency —Salt is manufactured by solar evaporation of sea water all along the coast of the Madras Presidency The salt district of the Presidency is divided into three sections The Northern Section is from Ganjam to Kistna districts, the Central Section is from Kistna to Chingleput districts, and the Southern Section is from Chingleput district all along the east coast, round the Cape and along the west coast upto Udipi district in Malabar. There are in all 48 centres divided into 65 factories spread over a total length of 1,600 miles of sea coast The 65 factories

or about the middle of February, when strong southerly dry wind, often from the landward side, blows without a break and continues till the second week of June   As a rule three condensers are provided for each crystallising bed   The area thus covered by the condenser is three times the area covered by the crystallising bed   In many cases single irrigation system is employed and in others salt is gathered for a few days   In the single irrigation system, brine is taken in into the crystallising beds to a depth of $1\frac{1}{2}$ to 3 inches, and this is gradually evaporated till a density of 28 to 30° B is reached   The crystals of salt are scraped by flat wooden scrappers   The salt thus obtained is allowed to drain in a heap on the platform adjoining the pan   The irrigation of beds and scraping is repeated every third or fourth day according to the weather   After the fifth, scraping the mother liquor which gets charged with magnesium salts is taken out, the bed again puddled and fresh brine taken in   The bittern is drained off into a special small channel which is constructed on a lower level   The crystals thus obtained are hard and greyish. They crush well, and if well washed in brine give fine white salt   The yield is estimated at 1,000 maunds per acre, or roughly about 35 to 36 tons   As regards labour, two men are required per acre to attend to the crystallising pans and the condenser   Women are employed for all purposes except scraping   The wages paid to men are from Rs. 9 to 10 per month   Women get Rs 7 per month   For five acres 5 men and 7 women are required   The Government gives sections of the factory to different contractors on lease   The contractor supplies all the materials necessary, such as slung baskets, scrapers, etc   He finds his own labour and conducts all the operations from the beginning to the end except the control of crystallising in the pans   Government inspectors are responsible for the examination of brine from time to time   The whole outturn is purchased by the Government at the fixed rate of Rs 15 to 20 per " grace " or 120 maunds, or at the rate of As 2 per maund   At this rate the contractor is expected to make a good profit, estimated at about six pies per maund   The Government in turn sells salt at the site to wholesale dealers at the rate of As 3 per maund *plus* the duty.

Sea salt manufacture in the Bombay Presidency.—About two-thirds of the salt produced in the Bombay Presidency is obtained from sea water All along the coast from Dharasna, near Surat, to Sanikatta in the south of Bombay, on about 300 miles of sea coast, salt is manufactured during the dry season from sea water The season commences in October-November if the monsoon is prolonged The sea water is let into the reservoir towards the close of the month in which the operations commence The area is first swept clean of rain water which accumulates in the monsoon The condensers and the pans are repaired and rebuilt, puddled and tamped till a hard and water-tight floor is obtained The crystallising pans are first charged with brines in November and December near Bombay In other salt works, brine is let into the pans in January, and in some cases as late as February It takes about three weeks for the sea water to condense in the beginning of the season The actual manufacturing season lasts from four to five and a half months An acre of land holds 40 pans as will be seen from the following table A pan contains 1,080 square feet An acre contains 43,560 square feet (50′ long+4′ ridge×15′ broad+5′ ridge=54×20=1,080 square feet) Each pan yields on an average 70 to 80 maunds On this basis the monthly outturn per pan can be taken at 12 maunds The outturn of salt per acre is 18 tons or 108 tons per season of six months If in the above area an allowance is made for condensers, 10 pans only can be laid out in one acre The produce per season in that case would be 30 tons The manufacturing season is reckoned from December to May. In Bombay—Dadar salt works, Kuppa salt begins to form in December and continues till the middle of June Formerly it was the practice to lay out larger pans and consequently salt did not form till the end of February , but the present practice is to have smaller pans in order to get salt formed earlier in the season than before The daily wage is As 11 to 12 per labourer When the agar is laid out and the pans are made water-tight to receive brine, a staff of about 56 men, inclusive of the manufacturer-in-chief is required to attend to 100 acres of land 50 out of the 56 men have

where there is a deposit of salt Saran is in Diplo Taluka, Thar Parkar in the Rann of Cutch The cost of transport from Maurypur is 2 as 9 pies per maund

The issue price of salt is calculated as under—

	Rs	a	p
Excise duty	1	4	0
Manufacturing charges	0	1	9
Establishment charges	0	1	5
Conveyance charges	0	2	3
Bagging charge	0	0	6
Storage charges	0	0	5
Railway freight to Sakkar	0	5	9
Total Rs	2	0	1

The Government purchases salt at the three works at the following rates —

	per maund	
	As	P
Maurypur	2	2
Darwari	0	5
Saran	0	9

The loss in transit is from 0 75 to 1 5 per cent from Works to Karanchi The losses in storage are from 0 65 to 4 46 per cent The following table shows the production at the above three centres —

	1917-18 Mds	1918-19 Mds	1919-20 Mds
Maurypur Salt Works	6,22,272	8,59,728	6,93,682
Darwari (Dilyar) Salt Works	3,03,625	5,07,600	1,200
Saran Salt Works	23,706	57,534	32,000
Total	9,49,603	14,24,862	7,26,882

The factories are well laid out   Calcium sulphate separates out in very large quantities in the crystallising beds   Thus Gypsum is accumulated in large heaps   Recently it has been laid on the ground in the making of roads   The pink colour in the final condensing pans of the crystallisers is very noticeable   Salt crystals are formed in large pans and not in small pans as is the practice in Madras and Bombay   These crystals are not raked and turned over as in the Kharaghoda salt works but allowed to grow to a depth of 7 to 8 inches, when thick lumps are taken out and sent to the crushing mills or broken up in smaller pieces   In one of the Mahomedan factory there is a German plant in which the salt is crushed and ground for the Bengal market   Most of the salt produced is shipped to Bengal and Rangoon and part of it to Zanzibar   The following table shows the quantity of salt exported from Aden —

	Tons	Tons	Tons	Tons	Tons
Zanzibar	3,150	1,055	420	931	1,260
Rangoon	20,041	8,275	7,700	9,550	9,000
Calcutta	86,119	90,224	111,820	123,910	161,435
Other places	75	541	12	4	108
Total	110,006	100,093	122,942	134,391	178,803
Value £	76,921	197,300	127,799	150,682	182,538

These figures show that the production of salt in Aden is gradually increasing year after year   The cost price of salt as is shown in the Sea Borne Trade figures works out at £1-1 per ton, or As 9-4 per   Bengal   Maund   This   seems   excessive   From   enquiries made   while at Aden I find that the cost of salt f o b is as under —

FOREIGN SALT WORKS

French Salt Works.—In France solar salt manufacture is carried on the Mediterranean   There are 4 grades of salt made —

(1) Fine salt
(2) Semi-fine salt.
(3) Lump salt
(4) Rough large salt

The differences in prices between grades 1 and 2 is 5 Francs, and between grades 2 and 3 and 3 and 4, 2 to 3 Francs   An average analysis of the French solar salt is —

Sodium Chloride	97 56
Magnesium Chloride	0 07
Magnesium Sulphate	0 37
Moisture	2 00

This salt is produced from Mediterranean sea water, the analysis of which is given below —

	* I	II (Lament)
Sodium Chloride	30 182	27 22
Magnesium Chloride	3 302	6 14
Calcium Sulphate	2 542	0 15
Magnesium Sulphate	1 392	7 02
Potassium Chloride	0 518	*Nil*
Sodium Bromide	0 572	
Calcium Carbonate	0 117	0 09
Ferric Oxide	0 003	
Magnesium Carbonate		0 11
Potash		0 01
Water		959 06

* Works analysis in 1918

This Company has a capital of 8 million Francs and produces annually about 20,000 tons of salt It has salt works at the following places —

    (1) Huyeres (on the other side of Marseilles)

    (2) Aigues Mortes

    (3) Cette

    (4) Villeroi

The Company is a combination of a number of other small concerns scattered at different places on the Mediterranean At Aigues Mortes where there are five works in fairly close proximity the total combined output from the district is 80,000 tons on an average per year The manufacture is entirely by solar evaporation at all these works, and no by-products are recovered in this district Salt is not re-crystallised but a large portion of the salt made is washed with brine before stacking in heaps

Salin de Villeroi —The layout of Salin de Villeroi is typical of the French saltern Sea water of about 3° B is drawn from the Mediterranean where there is practically no tide As there is no rise and fall in the sea level due to absence of tides, the sea water is raised at various stages by means of pumps One of the pumps was made of wood with screw like blades This pump or water wheel or elevator raises large volume of water to a height of about 6 feet, and was considered more economical than the other centrifugal pumps Electric power is used for pumping and all other purposes It was purchased from a public company at about 10 cms per K W H before the War, and at 15 to 16 cms in 1918 The current is brought from the generating station which is over 100 Kms (62 miles) away at 10,000 volts and reduced to 100 volts.

The sea water is led through a series of reservoirs partly natural and partly constructed, varying from 1 foot to 4 or 5 feet in depth and contains 50 to 70 cms (20″ to 28″) of water The brine is concentrated in these reservoirs upto to 25° B till all the Calcium Sulphate precipitates The concentrated brine of 25° B is then run at about the end of June into a specially constructed rectangular pan The depth of the brine in the pans is maintained

of 80,000 tons per year which is the average production of Aigues Mortes works   The salt is brought by a canal into the central store and ground   The grinding mill is made by C   Wagmann of Zurich   It consists of double mills, viz , (1) Disintegrators and (2) Porcelain Rollers   These turn out 2 tons of fine salt per hour and take about 8 to 10 h p.   The approximate cost of a machine of this type   would be 4   to 5 thousand Francs   Before   the War it cost only 2,000 Francs

All the machines, as at Cette, are driven by Electricity   The power cost 17 cms per K W   The cost of grinding to produce the fine so called table salt is said to be 3 Francs per ton   Moveable cranes and elevators were used as at Cette for stacking the salt   Electric wires are run all over the salins, so that pumps, cranes and other machinery can be conveniently worked

Compagnie de Produits Chimique and Electro-metallurgiques d' A lais Forges and Camargue

Salin-de-Giraud —This is a very large company, which makes besides salt for consumption, sea salt for the Solvay Soda Ash factory   Its annual production is from 160,000 to 200,000 tons   During the War the Company was also making explosives for the Government

It extends on the sea coast about 32 miles and along the river about six miles   It is difficult to determine the exact area covered by these works , but the area is estimated at 30,000 hectares (75,000 acres)   These works were founded originally in 1858 and considerably enlarged in the subsequent years   The administration offices, workshop and factories occupy 100 acres near the station of Salin-de-Giraud

Solvay works are about 10 miles from the salt works   A meter gauge railway line, about 16 miles in length, connects the interior of the works with the factory   Of the total area 12,000 hectares (30,000 acres) are at present reserved for the production of 160,000 —200,000 tons   Each Hectare (2,471 acres) gives 180 to 200 tons of salt per year   The salt is harvested from the middle of June

The following working of the Salins will give an idea of the process followed at these works —

(1) Sea water of 3° B is run into reservoirs and brought up in them to 10' B   These reservoirs are shallow, about 3 3 feet deep and made of clay bottom   The French have solved the problem of evaporating huge quantities of sea water of low density in places not very well situated for solar evaporation as in the tropics   This they do by spreading the sea water in thin layers over vast areas and keeping the waters constantly moving by drawing off at various stages into long channels   This is done by a water wheel 15 feet in diameter and 3 feet wide driven by an engine   The water is raised about one metre from one level to another   The efficiency is said to be 60 per cent

(2) This is run into a second series of reservoirs and carried by zigzag courses, partly natural and partly artificially constructed

(3) From this it is run into the salt pans which are all laid together and brought upto 28° B   Salt is gathered upto 29-30° B in these pans

(4) The mother liquor after the gathering of salt is run into a further set of crystallisers and brought upto 33° B where an impure Magnesium Sulphate mixed with salt crystallises out in a layer of about 4 inches

(5) The mother liquor of 33 to 34° B is pumped into three deep reservoirs and kept there during the winter   Here Magnesium Sulphate crystallises out at a low temperature , it is removed on separation, and then the remaining mother liquor is conveyed to the factory for further treatment   The depth of the first two sets of reservoirs in the first and the second stages given above are as shallow as possible   These reservoirs are constructed by earth embankments and the bottom made of natural clay   The depth varies upto one metre

from the deposit of "mixed salt" (sodium chloride and magnesium sulphate) Formerly this was used for the manufacture of sodium sulphate, but this salt is now obtained more economically as a by-product in other industries

The mother liquors are next conveyed to four large communicating brick-work reservoirs (14 feet deep) with outlets for the discharge of the deposits of magnesium sulphate and are allowed to remain there during the winter When the temperature falls to 12°C magnesium sulphate is deposited, whilst to prevent the liquid from cooling below the point, when "carnalite" would also be deposited, the surface is covered with a layer of soft water from the Rhone

There forms at the bottom of the tank a very rich deposit of Magnesium Sulphate This deposit is not of uniform thickness and composition Certain layers are composed of fine crystals which are very white and very small There are also layers of irregular, thin, dirty and sticky crystals

	Small white crystals	Dirty and opaque crystals	Big dirty crystals
NaCl	2 19	0 54	2 20
MgCl$_2$ 6H$_2$O	0 50	0 50	3 04
MgSO$_4$ 7H$_2$O	88 56	97 78	89 79
Water by diff.	8 75	1 18	4 23
Insoluble			0 74

The annual production of this crude sulphate of magnesia is extremely variable It varies from 1,500 to 100 tons per year The product is sold as it is collected—no further attempt is made to refine it

The following spring the layer of the mother liquor, which will then have a density of 32 to 33° B (sp gr 1 285—1 296) is ready for the extraction of bromine This is effected by pumping the mother liquors into vessels each of which has a capacity of 20 cub m (706 c ft) and from this they descend in a regulated stream

The clear supernatent liquid is transferred to a crystallisation vessel in which it is cooled to about 20° C by means of cooling coils and the resulting deposit of carnalite is drawn off by means of buckets and drained in cylindrical vessels with false bottom   The final mother liquor is concentrated to about 40'B (sp gr 1 384) and is used partly for mixing with the liquors coming from the Ponon evaporators, and partly in the manufacture of crystaline magnesium chloride   The carnalite is washed with a limited quantity of water, *e g*, 900 litres of soft water and 600 litres of washings of 28'B (sp gr 1 241) from a previous operation to 2,700 killos of the salt, in cylindrical vessel which is provided with mechanical agitators   After 4 hours, during which a part of the potassium chloride settles down and the mother liquor which is still rich in potassium chloride, is concentrated in Ponon evaporator for further treatment   The crude potassium chloride is washed in 3 ton lots for about an hour with 1 cb m of cold soft water in a cylinder provided with an agitator, and is then transferred into a vessel with a false bottom, where it is drained and is finally dried in a battery of hydro-extractors   The resulting product contains 72 to 75 per cent of potassium chloride but may be obtained in purer form by repeating the washing About 600 tons of 72 per cent potassium chloride are thus obtained annually by the treatment of 15,000 cb m of mother liquors of 33°B (sp gr 1 296) in the marine salt works at Salin de Giraud   The Company produces at this works 4 to 5 tons of Magnesium Chloride per day, though for every 20 000 tons of salt they can obtain 24 tons of Magnesium Chloride For every 1 ton of Potassium Chloride the possible production of Magnesium Chloride is 6 tons, and 10 tons of Epsom salt

Other French Salt Works—There are other French salt works in Nantes district   The salt produced in this district is dirty and requires to be re crystallised   At Nancy there are rock salt deposits, which are worked on the same lines as at the works in England

nesium and calcium sulphate   A detailed   description   of the
Stassfurt industry is given in Thorpe (Vol IV, p 377)   These
deposits were worked mainly for potassium salts and epsom salts
Magnesium Chloride was treated as a by-product   In 1907 the pro-
duction of the different salts was as under —

	Tons *
Potassium Chloride	473,138
Magnesium Chloride	32,891
Glauber Salt	80,340
Potassium Sulphate	60,292
" Magnesium "	33,368
Magnesium Sulphate	41,105
,, ,,	59,473
Alum	4,200
Total	7,848,814

Bromine is separated by treatment of the residual liquors with
chlorine

Manufacture of Salt in England —In England salt is obtained
from rock salt deposits in Cheshire, Lancashire and several other
places   At Northwich, the top bed is 75 feet thick and lies
130-150 feet below the surface   Similar deposits are   found in
Marston, Sandbach, Einsford, Lawton and Holford   Salt deposits
are also found in Staffordshire and Yorkshire   The industry
is confined mainly in Cheshire where the rock salt consists of a vary-
ing mixture of marls and salt, containing 98 per cent sodium
chloride, 1 65 per cent calcium sulphate and 0 05 per cent Magne-
sium sulphate   The lower beds are worked by mining , the salt
thus obtained is used chiefly for agricultural purposes   The
Cheshire rock salt is chiefly associated with coloured marls
to the extent of about 5 per cent of salt   The colour varies from
red, brown and yellow to white   Natural brine is generally found on
the upper surface of these salt deposits   This is drawn up through

of Cheshire in 1889, they issued a list of prices for the different grains of salt   The original prices were revised as under —

The price of common salt was raised from   7/6 to 13/6
,,   ,,   butter   ,,   ,,   ,,   ,,   7/6 ,, 16/6
,,   ,,   Calcutta salt   ,,   ,,   ,,   8/6 ,, 16/6
,,   ,,   handled squares for domestic uses
           was raised from   13/6 ,, 35/0

The cost of production was at that time calculated as follows —

	Per ton of salt
For larger grains—	
10 Cwts of coal at 5/-	2/6
Labour	1/0
	3/6
Fine grain for India—	
14 Cwts Coal at 5/-	3/6
Labour	1/0
	4/6

With the ordinary open pans 1 ton of fuel (slack with 15—20 per cent of ash) will make 2 5 tons of salt

More recently considerable improvements have been made in the production of salt by Vacuum Evaporators   A well constructed tripple—effect plant makes considerable saving in the cost of fuel , it does not require an extensive layout and the production is considerably increased   A good size of evaporator would yield from 500—700 tons in 24 hours as against 10 to 20 tons in direct fired pans \A tripple effect evaporator gives from 5 to 6 tons of salt per ton of fuel

It is usual to purify the brine used in these evaporators   The cost of purifying is reckoned at about 5/- per ton of brine   In a quadruple—effect evaporator there would be further economies in the consumption of coal   In a good quadruple effect evaporator a pound of coal which would give 6 lbs of steam in an ordinary boiler would give 21 5 lbs of steam   Consequently 2 5 to 3 cwts of coal would be required for obtaining salt from saturated

It will be seen that the cost price of salt has gone up from 14s to very nearly 42s or three times in seven years   In certain plants where instead of coal, waste gas from blast furnace or steam from power stations have been used, there had been a striking economy in the cost of production   By this means, one firm in 1913 was able to produce salt at 50 per cent of the cost of the Salt Union By the Vacuum method the Salt Union, Ltd , can produce salt more cheaply, at about 6s per ton than by the open pan method Vacuum salt however, being 25 per cent denser than open pan salt cannot be economically used for many of the purposes for which the more coarse grained salt is used   As the greater quantity of salt made in England is salt produced by the open pan method, the ruling prices are fixed on the basis of the cost by that method After the Armistice the Salt Manufacturers' Association proposed to regulate their price by 6d per ton for each subsequent increase of 1s in the rate of wages and 9d per ton for each subsequent increase of 1s per ton in the price of coal   The total cost of distribution, including warehousing, delivery, administration, etc , was in 1913 9s per ton for all qualities, whereas in 1919 it was 27s or an increase of 21 per cent   The cost of delivery alone, comprising horses, vans and carmen is put at 2s 11d per ton in 1913, and 11s 2d in 1919 In 1920, an increase of 5s 6d per ton was made in the Manufacturers' price fixed by the Association This increase was due to an increase of wages by 8s per week, and an increase in the price of coal by 2s 2d per ton due to increased railway rates   Subsequent to this increase in the price of salt, wages and coal have gone up, and the total rise in the price of coal would be 4s 8d   If salt is intended for shipment to India, the following charges have to be added —

Loading into barges , canal dues , weighing and bonding at Liverpool wharfage—About 3 to 6s per ton

Freight from Liverpool to Calcutta   In pre-war days it was 5s when it was shipped mostly as ballast   The total cost from mines to Calcutta would be—

depth of 1,600 feet and over   At Ludington the deposit is at a depth of 2,300 feet and at Manistee at 2,000 feet

New York—New York is second among the States in regard to salt production   The important deposits are at Wyoming Otken Valley-Genessee Valley and round about Onondaga Lake particularly at Syracuse   At Ithaca, salt was found at a depth of 3,185 feet   In the Onondaga valley water from Tully lake flows by gravity to the salt layers and becomes saturated with it This brine was transported through pipes to the Soda Ash factory of the Solvay Process at Syracuse   The site of this factory is 360 feet lower than the mouth of the wells

Ohio—Ohio is third in importance for salt production   At Hadseli the salt deposits are found at a depth of 3,258 feet   At Pomeroy natural brine is obtained in a salt sand strata of 170 feet at a depth of 960 feet   At this place brines were struck at 320 feet, density 6° B, at 710 feet density 9° B, at 980 feet, density 9°B, and at 150 feet density 16°B   At Hartford brine was obtained at 1,050 feet   The density varies with the dip of the rocks, *viz*, from 8 to 10 5°B, the heavier brines seeking the lower level

West Virginia—Is an important producer of salt from brines These brines are a good source of Bromine and Calcium Chloride,

Pennsylvania—Is also known for its brine wells   In Pittsburg one well, one of the deepest in Pennsylvania—reached a depth of 4,089 feet   Brine appeared in this well at 1,405 feet   Another well known as the Derrick City or Bradford City well reached a depth of 5,820 feet and struck 4 beds of salt ranging in thickness 10 to 47 feet Another deep well—the McDonald well gave brine at a depth of 6,825 feet and rock salt between 6,825 and 7,175   In Virginia formations, limestone, Gypsum and salt deposits occur at the same place in different strata

Recovery of Salt from Sea Water—This is confined mainly to the West Coast   The season begins about the middle of April and ends about the middle of October—generally about 5 months The longest season known is of 210 days   During the summer

to the ponds for concentration and crystallisation   It then settles for 5 or 6 days in the settling ponds, and is then led to the stock or evaporating ponds, where it is allowed to remain till it is completely saturated and the salt is about to deposit   It finally passes on to the harvesting ponds   The ponds are separated from each other by clay enbankments, 2 feet wide and 22 inches high, held in place by boards set on edge   The brine flows by gravity from pond to pond its flow being controlled by small gates   It takes 30 days for the brine to reach from the lake to the crystallising beds   The bitterns is drawn off twice during the season   Care is taken to prevent the crystallisation of sodium sulphate which is said to take place when the water reaches 25°F Talmage believes that the critical temperature of formation is 35° F   Careful experiments carried out in the laboratory of the U S Geological Survey have shown that brine from the lake of 1 145 sp gravity becomes saturated with mirabilite $Na_2 SO_4 10H_2O$ at 1°C or 34° F   The average Crop is about three inches

Solar Salt from natural brines —Formerly   natural brine varying in density from 17-20°B was successively led to 3 sets of " rooms " or shallow wooden vats or " covers" provided with low moveable roofs in sections of 16 feet and running on rollers   The area of each section was 288 sq feet

Size of lime salt rooms —18 feet wide, 400-500 feet long, 6″ deep   Two-thirds of the total area is taken up by these rooms

Deep Rooms —Brine is first led into these   They serve mainly for the storage of pumped up brine   Their sizes vary considerably but they are from 12 to 14 inches deep   These deep rooms serve for settling brine

Lime Rooms —They are so called, not because of any lime being used in the process, but on account of the Gypsum that separates out in these rooms

Salt Rooms —In these vats brine is concentrated to saturation and the salt separated from the pickle   In all these rooms the brine is moved by gravity   The difference in levels between these sets of rooms is 6-8 inches

sides are provided with drain board 3 feet wide along the entire length of the pans The pans are in three sections The section at the back where brine enters is from 30 to 48 feet long The front part is divided into two sections, the one nearest the back is 30 feet long and the remaining about 70 feet long These pans are heated by fuel, mainly coal or natural gas In some instances the brine before it is admitted to the back pan is preheated in a tank built at the base of the chimney, where the waste heat of the flues is made use of The draining of the separated salt is very carefully controlled The resulting bittern is removed from time to time

Manufacture of Salt by Steam evaporation --Phalen has described in great detail the preparation of salt by the Grainer Process The following description will give a general idea of the process carried out in the States, though it differs in details in different districts The manufacture of salt by the grainer process is often carried on in conjunction with some other industry In Michigan the industry has grown up largely with the lumbering industry In some places heat is derived from waste heat, from electric plants and other exhaust steam

The brine which usually comes as stated before from 700 feet below the furnace is first passed into the settling tanks, where gases like Hydrogen Sulphide which are present in the brines are allowed to escape In the settling tanks iron compounds also separate on æration of the brine Milk of Lime is then added, the brine agitated and then again allowed to stand for several days If there is an excess of lime soda ash is added The clear brine is either sent to the grainer, or in some cases passed through preheaters, where the heat of the chimney gases is utilised In the grainer process the purification of brine is of considerable import-ance The grainer or Michigan process of salt making is entirely of American origin It consists in passing live or exhaust steam through metal pipes that are emerged in the brine to be evaporated The grainer is a long, narrow shallow vat, built of wood or metal, supported on a framework or on cement or concrete supported

and heated by exhaust steam that entered at an average temperature of 216 6° F, and had an average quality of 97 per cent   The grainer was 143 feet long and 10 67 feet wide at the average level and was filled with brine to an average depth of 1 229 feet   It contained 1,072 feet of 3 5 inch pipe, the ratio of the evaporating (grainer) area to the heating surface being 1 34   The brine at 92 5 per cent saturation was run into the grainer at a temperature of 71 6°F and the test was continuous for 192 hours, at the end of which time the saturation of the bittern unduly impeded evaporation   At the start, evaporation was continued till the level of the brine had lowered nearly to the steam pipes in the grainer   The quantity evaporated was then restored   by introducing new brine, and this process of alternate evaporating and filling was continued throughout the test   The results of the run are summarised in the following tables —

Results of Operating a Grainer in Michigan for 192 Hours

Item	Pounds
Total production of hot salt	110,950
Production of hot salt per hour	577 8
Equivalent in seasoned packed salt per hour	534 5
Total condensation of water from grainer pipes	410,368
Condensation per hour	2,137
Equivalent condensation of dry steam per hour	2,073
Production of hot salt per square foot of grainer surface	72 7
Production of hot salt per square foot of heating surface	97 9
Production of hot salt per linear foot of 3 5 inch steam pipe	102 5
Production of hot salt per cubic foot of brine	13 46
Condensation of dry steam per cubic foot of brine	46 8

Willcox calculates that the efficiency represented by these figures corresponds approximately to the evaporation of 8 322 pounds of water by one pound of coal   He adds that in the usual operation of this grainer the bittern is replaced by new brine every 5 days, 2 hours being lost at each filling, and that services of 4 men for 3 hours are required to scale the pipes every 30 days

At this time, when the country is suffering from an acute shortage of potassium salts, the amount of potassium chloride indicated above is of considerable importance   During the first half of 1917 the total potash production of the country, calculated on the basis of K_2O, was 14,000 tons, which amount was but 10 per cent of the normal amount used before the war   It is evident that the amount of potash that could be extracted from the bitterns of the salt works on San Francisco Bay alone would add about 10 per cent to the country's present annual production of potash   The amount of salt actually produced in this region is nearly 140,000 tons per annum, so that a liberal allowance for losses in working up the bittern should leave still 3,000 tons of potassium chloride   By utilizing the bitterns from other regions on the Pacific Coast, notably San Diego, this amount would be very greatly increased

The other materials mentioned in the above table also represent very considerable values, although they have less relation to the present national emergency

After the removal of most of the common salt in the salt ponds the other salts would be contained in approximately 100,000 tons of bittern, having a volume of approximately 100,000 cubic yards

The values represented by these materials, and their importance both as a natural resource of California and in supplying the country with potash in the present acute emergency, made the study of this problem seem a proper one to undertake at this time

Scientific Basis of Methods for Recovery of the Constituents of Bittern

We are very fortunate to possess a vast fund of information upon the solubility relationships of the various salts obtainable from sea water through the classic work of van't Hoff and his co workers   This work is described in great detail in " Uber die Bildungs-verhaltnisse der ozeanischen Salzablagerungen " (Leipzig Verlagsgesellschaft, 1912)   During the progress of the work two smaller volumes were published in 1905 and 1909 by van' Hoff, entitled " Zur Bildung der ozeanischen Salzablagerungen (Braunschweig, Vieweg)

The solubility of a given salt is varied by the introduction into the solution of another salt The effect of the second salt can be predicted qualitatively by remembering that where the salts possess a common ion, the solubility of each is usually decreased by the presence of the other   If, however, there is a strong tendency to form a complex salt the solubility of one may be increased by the presence of the other Again, where there is no common ion, the solubility of one is increased by the presence of the other owing to the interaction of the two salts

There are various ways of representing graphically the solubility relationships of salt pairs   The method adopted by van't Hoff is to represent the amount of each salt in the solution in terms of mols of anhydrous salt per 1000 mols of water, measured along two axes at right angles to each other, as illustrated in Fig II, Each curve
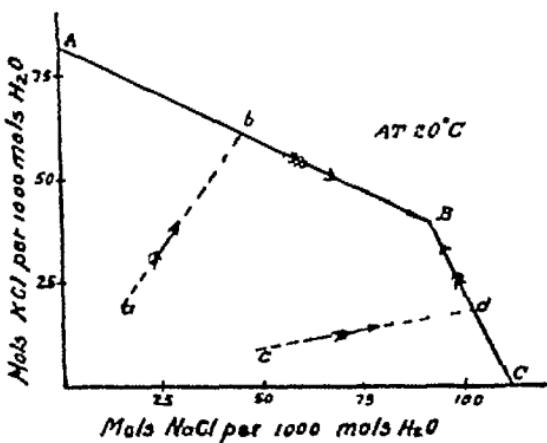
Fig II

here represents the composition of a solution saturated with one component   The intersections of the curves represent the composition of a solution saturated with both components   A point between these curves and the origin denotes the composition of an unsaturated solution   A point outside of the curves would represent a mixture of a saturated solution with one or both solid salts, depending upon its position   On evaporation of an unsaturated solution, the relative amounts of the two salts would remain the

that in Fig IV   This diagram represents the solubility at 30°
of mixtures of sodium sulfate decahydrate, and magnesium sulfate

FIG IV
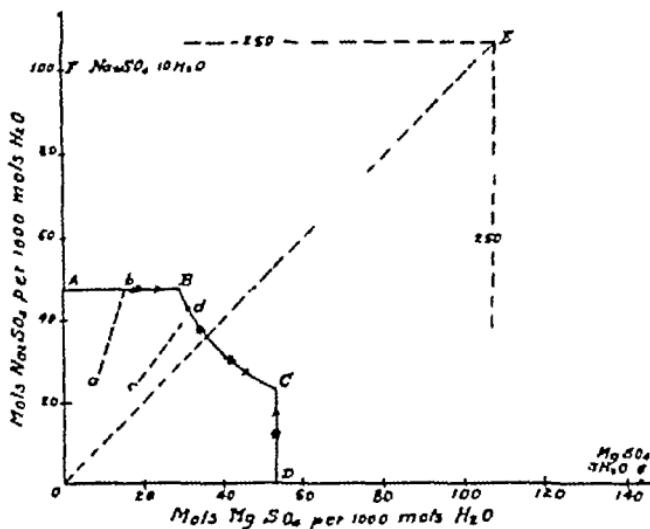
heptahydrate, which form the double salt, astrakanite, $Na_2 Mg(SO_4)_2$
$4H_2O$ The middle portion of the curve seen in this figure
represents the composition of solutions saturated with astrakanite
Solid astrakanite, which contains equivalent quantities of the
two salts, has a composition lying upon a line bisecting the angle
between the two axes   The composition of the solid salt is repre-
sented by a point on this line at E, expressing the number of mols
per 1000 mols of water in the solid salt   The composition of solid
sodium sulfate, Na_2SO_4 $10H_2O$, which lies along the line OA, is at
a distance from the origin corresponding to its water content at F
Similarly, solid magnesium sulfate has the composition represented
by the point G When an unsaturated solution containing these
salts is evaporated, its composition will, as in the previous case,
move along a line away from the origin until one of the curves
representing the composition of the saturated solution is reached,
when the solution will change in composition along this line in the
direction away from the line representing the composition of the
solid which is separating   Thus a solution having the composition

sition till *b* has been reached, whereupon potassium chloride begins to crystallize out, and the solution, becoming richer in magnesium chloride, will move along *bC*. When the solution has reached the composition represented by *C*, carnallite will begin to separate but since carnallite contains more potassium chloride than does the saturated solution at *C*, it is evident that while carnallite crystallizes, the solution will tend to move along the line *CB* instead of remaining at *C*. The phase rule, however, requires that while both potassium chloride and carnallite are present, the solution must remain constant in composition at *C*. Therefore, instead of the liquid phase disappearing at this point, as was the case in the former salt pair, it is one of the solid phases, potassium chloride, which will now disappear, being changed over into carnallite. It is not until all of the potassium chloride has been so changed that the solution can move from *C* to *B*. *B* will thus represent an end-point of crystallization, while *C* will not. It is evident, therefore, that in order to prepare crystals of carnallite it is necessary to use a solution containing more than the equivalent amount of magnesium chloride, the relative amounts of the two salts being such that, on evaporation, the line *BC* will be intersected slightly above *C*. Similar considerations show us that on treating solid carnallite with water, instead of dissolving as such, it would tend to change into solid potassium chloride and a solution whose composition is that represented by *C*. It is obvious, therefore, that it is not difficult to obtain potassium chloride from carnallite, a point of importance in the treatment of salt bitterns, as will be discussed later. After the removal of the potassium chloride the solution can be evaporated, carnallite separating, while the composition of the solution changes from *C* to *B*. This carnallite can be treated with water, leaving solid potassium chloride, etc.

Solutions containing magnesium and potassium chlorides and sulfates are in equilibrium with solid phases at 25° according to the data in Table 1, and are represented by van't Hoff along four axes as in Fig. VI, each pair of axes representing solutions containing a

common ion   The boundary lines correspond to solutions saturat-
ed with the two constituents represented by the enclosing axes
Where salt pairs containing no common ion are present, it is
impossible to represent the composition by a point in the plane of
this figure   A mixture of equivalent quantities of potassium
sulfate and magnesium chloride would evidently lie at the
origin O and would be indistinguishable from pure water by its
position in the plane   In order to make this distinction it is
necessary to introduce a vertical axis representing the sum
of the constituents of the solution   Again, since equivalent
quantities of potassium sulfate and magnesium chloride in
solution may be represented equally well as equivalent amounts of
magnesium sulfate and potassium chloride, by plotting along the
potassium chloride axis not mols of potassium chloride, but double
mols, namely, K_2Cl_2, it is possible to construct a solid model express-
ing the composition of solutions containing any amounts of these
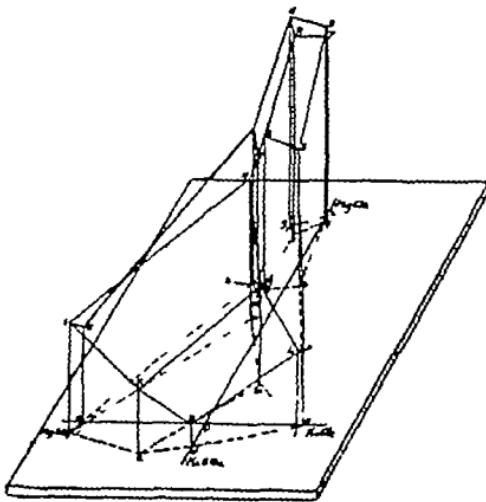
Fig VII

ions   Such a model, a perspective drawing of which is seen in
Fig VII, may be constructed by inserting needles at the intersec-
tions of the lines in the plane figure, the heights of the needles being
equal to the total number of mols of dissolved salt in the solu-
tion at this point, always remembering to consider the mol of potas-

diagonal which joins the origin with the point representing the composition of this solution will be found to intersect the schonite face, showing that this would be the first salt to separate on evaporation As evaporation proceeds the crystallization path would meet the boundary line of this face with the magnesium sulfate face, after which these two salts would separate together Suppose, for example, we wish to calculate the actual amounts of these two salts separating and the amount of water that must be removed when the point N has just been reached, at which potassium chloride just begins to separate The solution at N has the following composition $1000H_2O + 9 K_2Cl_2 + 16 MgSO_4 + 55MgCl_2$ The amount of this solution we may represent as an unknown quantity by p, the amount of schonite separating we may represent by q, the magnesium sulfate by r, and the amount of water removed by s We may then represent what has become of the original solution during evaporation by means of the following equation—

$$1000H_2O + 8MgSO_4 + 10MgCl_2 + 2 K_2Cl_2 = p(1000H_2O + 16MgSO_4 + 55 MgCl_2 + 9K_2Cl_2) + q(K_2 Mg(SO_4)_2 6H_2O) + r(MgSO_4 7H_2O) + sH_2O$$
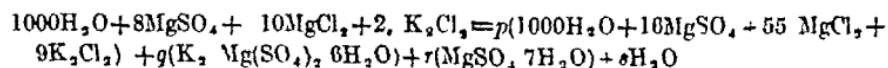
By equating co-efficients of the various substances present, it is possible to set up the following equations

Co-efficients of H_2O	1000	$=$	$1000p + 6q + 7r + s$
Co-efficients of Mg	18	$=$	$71p + q + r$
Co-efficients of K_2	2	$=$	$9p + q$
Co-efficients of Cl_2	12	$=$	$64p$

The solution of these equations gives the following values

$$= 188, q = 0 31, r = 4 38, s = 770$$

These values of q, r and s represent the amounts of the respective substances which have separated by evaporating the original solution and p represents the amount of solution left If, instead of taking the amount of the original solution represented by 1000 mols of water, a different amount is taken, proportionate amounts of the solids and water are obtained from the solution on evaporation to the same point When we come to consider the evaporation of sea water, we have in addition to the above components large amounts of sodium salts Since during evaporation sodium chloride is always present, it is possible to represent saturated solutions

chloride as another component no new degrees of freedom are introduced, provided it is stipulated that solid sodium chloride shall always be present   Van't Hoff and his co-workers have determined the solubility relationships at 25° and 83°   Fig VIII represents the results for 25° contained in table 2 , results for 83° are

Fig VIII
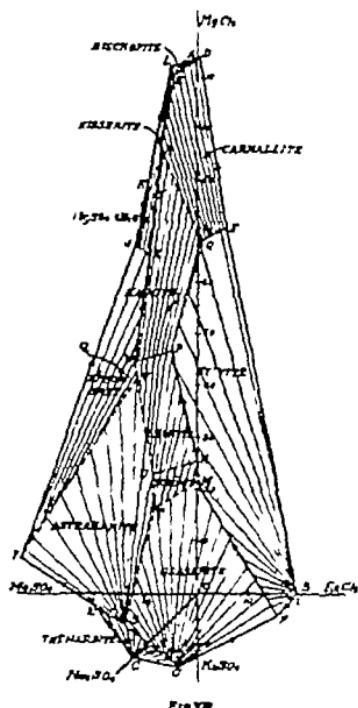
found in Table 3 and Fig IX.   The amount of sodium chloride present is not considered in the projection, but is counted in the total number of dissolved mols which would be represented in a solid model   Sodium sulfate may be expressed in terms of the other salts present, since $Na_2SO_4 = Na_2Cl_2 + MgSO_4 - MgCl_2$, or $= Na_2Cl_2 + K_2SO_4 - K_2Cl_2$. Thus point C, Table 2, is represented in Fig VIII by counting $12\frac{1}{2}$ divisions to the left of the origin and $12\frac{1}{2}$ divisions along the K_2SO_4 axis   Its position in a space model would be $63\frac{1}{2}$ divisions vertically above the point so obtained   Such a model may be constructed in a way similar to that previously described

point a, where Epsom salts would begin to separate   The composition of the solution at this point is approximately 1000 H$_2$O,11 Na$_2$Cl$_2$,   6K$_2$Cl$_2$,   20MgSO$_4$,   41MgCl$_2$ Further   evaporation would lead to the boundary between this field and the kainite field *WX*, after which these two salts would separate together   It is possible to calculate as before the amounts of each substance removed from the solution when the latter has the composition indicated, say, by *X*   Suppose that 10,000 g of the original solution are used   The number of grams corresponding to the number of mols of each substance in the original solution is 24,790, so that 10,000 g of solution would contain, instead of the previous number of mols of each constituent, only 0 404 of these quantities, namely, 404H$_2$O, 19Na$_2$Cl$_2$, 0 42K$_2$Cl$_2$, 3MgCl$_2$ and 1 44MgSO$_4$ On evaporation this solution would yield p mols of the solution saturated at *X*, containing its constituents in the proportions indicated in Table 2, together with qMgSO$_4$ 7H$_2$O+rNa$_2$Cl$_2$+ sKCl MgSO 3H$_2$O+tH$_2$O   We can, therefore, write the following equation

$$404H_2O+19Na_2Cl_2+0,42K_2Cl_2+3MgCl_2+1\text{'}44MgSO_4 = p(1000H_2O+3,5Na$$
$$Cl_2+{}_4K_2Cl_2+05\ 5MgCl_2+13MgSO_4)+ qMgSO_4\ 7H_2O+rNa_2Cl_2+SKCl\ MgSO_4$$
$$3H_2O+tH_2O$$
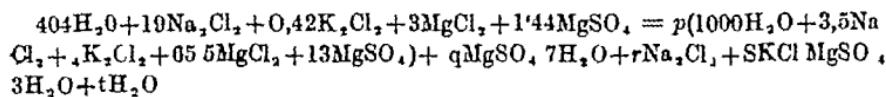
By equating corresponding coefficients and solving the resulting equations, we obtain the following values

$p = 0\ 0458$, $q \overset{=}{} 0\ 37$, $r = 18\ 9$, $s = 0\ 47$, $t = 354$

Hence we conclude that 354 mols of water have been evaporated, and 0 37 mol of epsom salts, 18 9 mols of Na$_2$Cl$_2$ and 0 47 mol of kainite are in the solid portion   Similar calculations may be made to determine what will happen during all sorts of changes   For example, instead of removing water, a certain salt may be added to a solution saturated with other salts, and by the aid of geometric and algebraic considerations it will be possible to determine what will take place

It is evident from the position of point a in the diagram for 25° that only a small amount of Epsom salts will have been crystallized by evaporation of the mother liquor from sea water before kainite

H O is obtained   The fact that the solubility of magnesium sulfate tends to decrease at higher temperatures, while the solubilities of potassium chloride and magnesium chloride, and hence carnallite, increase, causes the kieserite field at 83° to become large at the expense of the fields of potassium chloride and carnallite It is evident, therefore, that most of the sulfate present in the solution could be removed as kieserite by evaporating the bittern at higher temperatures until the carnallite boundary is approached During this evaporation, the solids which separate would be sodium chloride and kieserite   By removing these from the hot solution they could be obtained relatively uncontaminated with potassium If, now, the mother liquor from these crystals is cooled, the growth of the carnallite field as lower temperatures are reached indicates that this salt would separate as the solution cools, while the mother liquor from the carnallite would consist largely of a solution of magnesium chloride   These considerations seem to indicate the possibility of a satisfactory process for the separation of the bittern into three main constituents   magnesium sulfate, carnallite, and a solution of magnesium chloride   There would remain the necessity first, of separating magnesium sulfate from the sodium chloride accompanying it, second, of treating the carnallite for the recovery of potassium chloride, according to the principles discussed earlier, and, third, the evaporation and cooling of the magnesium chloride liquor to obtain $MgCl_2 6H_2O$

Evaporation Experiments.

The process outlined above, on the basis of the equilibrium diagrams, was first tested on a laboratory scale by evaporating weighed quantities of bittern   In one set of experiments the evaporation was carried on at the boiling point of the solution Crops of crystals were removed from the solution from time to time by centrifuging the liquid through a muslin bag   The density of the solution was read by the aid of a hydrometer made of pyrex glass, the small coefficient of expansion of which made its readings nearly correct in spite of changes of temperature   The

evaporation, the solution is saturated with sodium chloride but not with magnesium sulfate, hence the first crystals to separate consists largely of sodium chloride, which was found to be the case with the aid both of the microscope and of a chemical analysis   It is possible, therefore, to remove an additional amount of sodium chloride from the magnesium sulfate by filtering the hot solution by the aid of the centrifuge during the early stages of the evaporation   This procedure simplifies the   further purification of the magnesium sulfate which separates as evaporation proceeds   Table 4 gives the results of the analysis of the crystals removed from the solution by the aid of the centrifuge at the stages of evaporation indicated in Fig X

TABLE 4

	Crop 1	Crop 2	Crop 3	Crop 4	Crop from cooled mother liquor from 4	Crop from final evaporation
MgSO$_4$	15 1	24 6	20 1	24 1	1 3	3 5
MgCl$_2$	12 0	12 3	21 8	16 9	39 2	38 2
KCl	4 8	6 3	4 4	17 1	3 6	1 1
NaCl	20 3	20 3	13 3	17 0	1 3	
H$_2$O	52 8	36 4	40 5	24 9	54 7	57 5

The centrifuge employed was not very efficient, and some cooling took place during the process, so that the respective crops are contaminated with the salts that should remain in the mother liquor It is evident from the results of this analysis, together with the course of the density and boiling-point curves, that the process contemplated furnishes the desired separation   In a second experiment, based upon the results of the first, the solution was evaporated until the density had reached a value of 1 35 at the boiling point of the solution, 121°   The crystals separating up to this point were removed and the mother liquor allowed to cool   The crystals separating on cooling should be carnallite, and it will be seen from the analysis of these crystals in Table 5 that their composition

temperature than that in Fig X   This is doubtless due to the use
of different samples of bittern in the two experiments, so that the
carnallite field is encountered at different points in the two cases
It may be noticed that the break is more pronounced in the case
where it occurs at the lower temperature which is just what would
be expected on the basis of the solubility diagram in Fig IX   The
composition of the two samples of bittern used in the above experi-
ments is given in Table 6   The sodium content is not
given.

<div style="text-align:center">TABLE 6</div>

	Bittern used in getting curves	
	in Fig X	in Fig XI
K	1 48	1 76
Cl	15 82	18 22
SO₄	5 81	3 88
Mg	5 38	6 32

(SO₄ should be SO_4)

Outline of Proposed Process

1   **Evaporation of the bittern** —The bitterns from various
sources will vary somewhat depending on the temperature
of the liquid in the last salt pond, and whether or not
any Epsom salts are allowed to separate   There is, in
fact, no reason apparent why a crop of Epsom salts should not
be removed by cooling either artificially or by storage till winter,
before the subsequent process of separation is applied   The process
of solar evaporation should not, however, be carried far enough
to cause any potassium salts to crystallize, as it is probably not
desirable to separate the potassium content into two portions
The variations in the composition of the bittern caused by any of
the above factors would not cause any serious difficulty, as during
the later evaporation the separation of NaCl and $MgSO_4$ H_2O,
kieserite, would take place in such proportion as to make the
resulting liquid converge towards a fairly uniform composition

It is more important, under present conditions, to recover all
of the potassium salts, and hence to prevent their contaminating
the NaCl and kieserite fraction, than it is to recover all of the Epsom

and kieserite is run into centrifuges, previously heated, where it is separated from the adhering mother liquor, which is run into the cooling tank mentioned above The separation of the NaCl from the material remaining in the centrifuges and the recovery of Epsom salts will be discussed later

2   **The Recovery of the Carnallite** —The liquor containing the carnallite may be cooled by the fresh bittern going to the evaporator in order to utilize the heat content of the latter   After it has been thoroughly cooled, the carnallite which has separated is removed and freed from its mother liquor by centrifuging   The recovery of the potassium chloride from this carnallite will be discussed later

3   **The Recovery of Bromine and Magnesium Chloride** —The mother liquor from the carnallite contains a very little potassium, a little sulfate, a considerable amount of colloidal organic matter, the bromine content of the sea water, and a large amount of magnesium chloride   The liquid must be evaporated further in order to recover $MgCl_2 6H_2O$ During this evaporation, however, the temperature rises considerably, unless vacuum evaporation is employed, charring the organic matter, and strongly darkening the magnesium chloride which separates on cooling   To destroy this organic matter, therefore, as well as to recover the bromine, preliminary treatment with chlorine is desirable   The details of this treatment are now the subject of investigation in this laboratory   We can only say at the present time that there seems to be good prospect of success

The disposal of the large quantities of magnesium chloride that would be obtained from these bitterns presents an economic problem The possible outlets seem to be as follows magnesium oxychloride cement, magnesium oxide and hydrochloric acid, and metallic magnesium   The use of magnesium oxychloride cements might be greatly increased by skilful advertising, hydrochloric acid might be substituted for sulfuric acid for certain purposes, and there seems to be good reason to anticipate a large production of magnesium in the future.

Now the material obtained from the first stage of our process contains $MgSO_4$ and NaCl in nearly equivalent amounts and hence, if dissolved in water, would be represented by a point lying nearly vertically above the origin, at a distance increasing as the solution is evaporated   It might, therefore, cut the surface of the solid model in the astrakanite face, which would prevent the separation of the sodium from the magnesium   A little magnesium chloride however, would, if added, raise the solution away from the astraka- nite field, so that we would have only NaCl and $MgSO_4$ $7H_2O$ to deal with

The solubilities of these two salts are affected so differently by the temperature that we may anticipate their separation by first cooling, removing Epsom salts, then evaporating partly at higher temperatures, removing sodium chloride, then cooling again, etc The portion of the equilibrium diagram that can be constructed for 83 from van't Hoff's data shows that at that temperature

TABLE 7

System $NaCl-MgCl_2-MgSO_4-Na_2SO_4$, at 25°

Solid phases	Na_2Cl_2	$MgCl_2$	$MgSO_4$	Na_2SO_4
Na_2Cl_2	55 5			
Na_2SO_4 10 H_2O				35 5
$MgSO_4$ $7H_2O$			58	
$MgCl_2$ $6H_2O$		108		
$MgCl_2$ $6H_2O$, Na_2Cl_2	2 5	103		
Na_2Cl_2 , Na_2SO_4	51			12 5
Na_2SO_4 , Na_2SO_4 $10H_2O$(*)	30			27
Na_2SO_4 $10H_2O$, $Na_2Mg(S O_4)_2$ $4H_2O$			35	35
$MgSO_4$ $7H_2O$, $Na_2Mg(SO_4)$ 2 $4H_2O$			48	26
$MgSO_4$ $7H_2O$, $MgSO_4$ 6 H_2O		73	15	
$MgSO_4$ $6H_2O$, $MgSO_4$ H_2O		Not	deter|mined	
$MgSO_4$ $6H_2O$, $MgCl_4$ $6H_2O$		104	14	
Na_2Cl_2 , Na_2SO_4 , $Na_2Mg(SO_4)_2H_2O$	46		16 5	3
Na_2SO_4 , Na_2SO_4 $10H_2O$, $Na_2Mg(SO_4)_2$ $4H_2O$	Not de	termin	ed.	
Na_2Cl_2 , $MgSO_4$ $7H_2O$, $Na_2Mg(SO_4)_2$ $4H_2O$	26	7	34	
Na_2Cl_2 , $MgSO_4$ $7H_2O$, $MgSO_4$ $6H_2O$	4	67 5	12	
Na_2Cl_2 , $MgSO_4$ $6H_2O$, $MgSO_4$ H_2O	2 5	71	9 5	
Na_2Cl_2 , $MgSO_4$ H_2O , $MgCl_2$ $6H_2O$	1	102	5	

(*) From the experimental work of Professor W C Blasdale, which is still in progress in this laboratory, this point may be considerably in error

used somewhat more water would be required, but relatively less KCl would be dissolved

The liquor used in extracting the carnallite may then be partly evaporated and cooled whereupon another crop of carnallite crystals will be obtained To obtain the maximum amount of carnallite but no magnesium chloride, the solution should be evaporated to such an extent that on cooling with separation of carnallite its composition will correspond to point B in Fig V, which is 1000 $H_2O + 105MgCl_2 + K_2Cl_2$. The amount of evaporation necessary is calculated from the following equation

$$1000H_2O + 72\ 5MgCl_2 + 5\ 5K_2Cl_2 = x\ H_2O + y\ KMgCl_3\ 6H_2O + z(1000H^2O + 105Mg\ Cl_2 + K_2Cl_2)$$
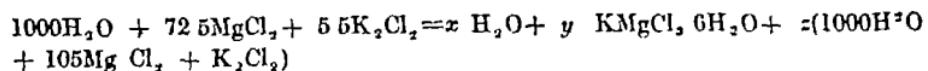
This gives $x = 340$, $y = 9\ 8$, $z = 0\ 6$, hence 25720 g of solution should lose 6120 g of water, giving 2720g of carnallite on cooling; or, 1 ton of solution should lose 0 238 ton of water, and deposit

0 107 ton of carnallite

It will probably not pay, here or in stage 2 of the process, to recover the small amount of potassium chloride remaining in the mother liquor from the carnallite

Condensed summary of the above process

Evaporate bittern till boiling point becomes about 120°, and density (hot) 1 35 Separate solid and liquid while hot (settling tank and centrifuge)

A Solid NaCl and $MgSO_4\ H_2O$ Dissolve out NaCl with cold water (containing some $MgCl_4$?), dissolve residue in hot water and cool with ice machine, getting $MgSO_2\ 7H_4O$

B Liquid. Cool.
  I. Solid carnalite Extract with minimum amount cold water, leaving
    1 Solid KCl
    2 Solution Evaporate partly cool
      a Solid carnallite, add to I.
      b Solution of $MgCl_2$, add to II
  II. Solution mainly $MgCl$ Bleach with Cl_2 and remove Br_0 Evaporate cool, recover solid $MgCl_2\ 6H_2\ O$

The above process is being tested in this laboratory on a semi-commercial scale under the direction of Professor Merle Randall and will be described in a later publication. It may be mentioned, however, that an excellent separation of actual bittern has been

IX.

TABLES

Table I

CONVERSION OF WEIGHTS AND MEASURES

One Imperial gallon
= 277 274 cubic inches
= 0 1604 cubic foot
= 10 lbs pure distilled water
62 F
= 4 5459631 litres
= 1-8 Bushel
= 70,000 grains

One cubic foot of water
= 1728 cubic inches
= 6 2355 gallons
= 62 35 lbs 62°F
= 28 32 litres

One pound of water
= 27 73 cubic inches

One cwt of water
= 1 796 cubic feet
= 11 2 gallons

One ton of water
= 35 93 cubic feet
= 224 gallons

One litre of water
= 0 21998 gallon
= 61 027 cubic inches
= 2 1998 lbs

One ounce of water
= 1 773 cubic inches

One metre
= 3 2808 feet

One cubic metre
= 35 3148 cubic feet

One mile
= 5,280 feet

One acre
= 4 840 square yards

One square mile
= 640 acres

TABLE II—(Continued)

°C	°F	°C	°F
95	203 0	123	253 4
96	204 8	124	255 2
97	206 6	125	257 0
98	208 4	126	258 8
99	210 2	127	260 6
100	212 0	128	262 4
101	213 8	129	264 2
102	215 6	130	266 0
103	217 4	131	267 8
104	219 2	132	269 6
105	221 0	133	271 4
106	222 8	134	273 2
107	224 6	135	275 0
108	226 4	136	276 8
109	228 2	137	278 6
110	230 0	138	280 4
111	231 8	139	282 2
112	233 6	140	284 0
113	235 4	141	285 8
114	237 2	142	287 6
115	230 0	143	280 4
116	240 8	144	291 2
117	242 6	145	203 0
118	244 4	146	294 8
119	246 2	147	200 6
120	248 0	148	298 4
121	249 8	149	300 2
122	251 6	150	302 0

SALT

TABLE III—(Continued)

B	Sp Gr	Tw	Salimeter
		41 0	94 23
		42 0	96 15
		43 0	98 08
		44 0	100
24 5	1 205	45 1	
25	1 210	46 2	
25 5	1 215	47 2	
26	1 220	48 2	
26 5	1 225	49 3	
27	1 230	50 4	
27 5	1 236	51 5	
28	1 241	52 6	
28 5	1 246	53 7	
29	1 251	54 8	
29 5	1 257	55 9	
30	1 262	57 0	
30 5	1 268	58 2	
31	1 274	59 4	
31 5	1 280	60 5	
32	1 285	61 0	
32 5	1 291	62 8	
33	1 296	64 0	
33 5	1 302	65 2	
34	1 308	66 4	
34 5	1 314	67 7	
35	1 320	69 0	
35 5	1 326	70 2	
36	1 332	71 4	
36 5	1 339	72 7	
37	1 345	74 0	
37 5	1 351	75 3	
38	1 357	76 6	
38 5	1 364	78 0	
39	1 370	79 4	
39 5	1 377	80 6	
40	1 384	82 0	
40 5	1 391		
41	1 397		
41 5	1 404		
42	1 411		

Table V

SPECIFIC GRAVITIES OF SOLUTIONS OF SODIUM CHLORIDE.

Per cent. NaCl	Spec grav at 15°/15° (Gerlach)	Spec grav at 20° (Schiff)	Per cent NaCl	Spec grav at 15°/15° (Gerlach)	Spec grav at 20° (Schiff)
			15	1 11146	1 1090
			16	1 11938	1 1168
1	1 00725	1 0066	17	1 12730	1 1247
2	1 01450	1 0133	18	1 13523	1 1327
3	1 02174	1 0201	19	1 14315	1 1408
4	1 02899	1 0270	20	1 15107	1 1490
5	1 03624	1 0340	21	1 15931	1 1572
6	1 04366	1 0411	22	1 16755	1 1655
7	1 05108	1 0483	23	1 17580	1 1738
8	1 05851	1 0556	24	1 18404	1 1822
9	1 06593	1 0630	25	1 19228	1 1906
10	1 07335	1 0705	26	1 20098	1 1900
11	1 08097	1 0781	26 4	1 20433	
12	1 08859	1 0857	27		1 2075
13	1 09622	1 0934			
14	1 10384	1 1012			

Table VI

BOILING POINTS OF SOLUTIONS OF SODIUM CHLORIDE

NaCl per cent.	Boiling point Degrees	NaCl per cent.	Boiling point. Degrees	NaCl per cent.	Boiling point Degrees
				21	105 81
				22	106 16
1	100 21	11	102 86	23	106 52
2	100 42	12	102 94	24	106 89
3	100 64	13	103 23	25	107 27
4	100 87	14	103 53	26	107 65
5	101 10	15	103 83	27	108 04
6	101 34	16	104 14	28	108 43
7	101 59	17	104 46	29	108 83
8	101 85	18	104 70	29 4	108 99
9	102 11	19	105 12		
10	102 38	20	105 46		

SALT

Table IX

SOLUBILITY OF CALCIUM CARBONATE IN WATER AT DIFFERENT TEMPERATURES

C	Grms CaCO₃ per litre
	0 081
0	0 070
10	0 065
20	0 056
25	0 052
30	0 044
40	0 038
50	

Table X

SOLUBILITY OF CALCIUM SULPHATE IN WATER

°	Grms CaSO₄ per 100 grms	
	Solution	Water
		0 1762
	0 1759	0 1932
	0 1928	0 2020
0	0 2016	0 2084
10	0 2080	0 2094
18	0 2090	0 2100
25	0 2096	0 2101
30	0 2097	0 2013
35	0 2009	0 1936
40	0 1932	0 1850
55	0 1847	0 1622
65 3	0 1619	
75		
100		

Table XII

SOLUBILITY OF POTASSIUM CHLORIDE AT VARIOUS TEMPERATURES

°C.	Potassium Chloride KCl	
	Weight in 100 parts of water	Weight of water to dissolve 1 part of salt
0	28 5	3 51
5	30 3	3 30
10	32 0	3 13
15	33 4	2 99
20	34 7	2 88
25	36 1	2 77
30	37 4	2 67
35	38 8	2 58
40	40 1	2 49
45	41 5	2 41
50	42 8	2 33
55	44 2	2 26
60	45 5	2 20
65	46 9	2 13
70	48 3	2 07
75	49 7	2 01
80	51 0	1 96
85	52 4	1 91
90	53 8	1 86
95	55 2	1 81
100	56 6	1 77

Table XIV

SOLUBILITY OF SODIUM SULPHATE IN WATER
AT DIFFERENT TEMPERATURES

| °C | Grms Na_2SO_4 per 100 Grms | |
	Solution	Water
0	4 76	5 0
5	6 0	6 4
10	8 3	9 0
20	16 3	19 4
25	21 9	28 0
30	29 0	40 8
40	32 8	48 8
50	31 8	46 7
60	31 2	45 3
80	30 4	43 7
100	29 8	42 5
120	29 5	41 95
140	29 6	42 0

SOLUBILITY OF SODIUM SULPHATE AT VARIOUS TEMPERATURES

| °C | Sodium Sulphate Na_2SO_4, $10 H_2O$ | |
	Weight in 100 parts of water	Weight of water to dissolve 1 part salt
0	12 16	8 224
10	23 04	4 340
15	(18°)	
20	48 41	2 065
25	98 48	1 015
30	184 1	0 543

Table XVI

SOLUBILITY OF MAGNESIUM CHLORIDE IN WATER AT DIFFERENT TEMPERATURES

°C	Grms MgCl$_2$ in 100 Grms	
	Solution	Water
0	34 5	52 8
10	34 9	53 5
25	36 2	56 7
40	36 5	57 5
60	37 9	61 0
80	39 8	66 0
100	42 2	73 0
116 7	46 2	85 5
152 6	49 1	96 4
186	56 1	128 0

SOLUBILITY OF MAGNESIUM CHLORIDE AT VARIOUS TEMPERATURES

°C	Magnesium Chloride MgCl$_2 \times 6H_2O$	
	Weight in 100 parts of water	Weight of water to dissolve 1 part of salt
25	364 7	0 27
40	416 5	0 24
60	485 6	0 20
80	558 6	0 17 ·

Table XVIII

SOLUBILITY OF MAGNESIUM BROMIDE IN WATER

°C	Grms MgBr$_2$ per 100 Grms	
	Solution	Water
		90 5
		91 9
		94 5
−10	47 2	96 1
0	47 9	96 5
10	48 6	97 6
18	49 0	99 2
20	49 1	101 6
25	49 4	104 1
30	49 8	107 5
40	50 4	113 7
50	51 0	120 2
60	51 8	127 5
80	53 2	138 1
100	54 6	163 1
120	56 0	
140	58 0	
160	62 0	

Table XX

Vapour Pressure of Saturated Salt Solutions.

°C	mm
10	7 34
11	7 93
12	8 38
13	8 95
14	9 55
15	10 18
16	10 86
17	11 52
18	12 30
19	13 10
20	13 93
21	14 80
22	15 73
23	16 70
24	17 74
25	18 84
26	19 99
27	21 21
28	22 48
29	23 83
30	25 25

Imports of Chemicals into India

Bleaching Materials

	Quantity	Value	Rate per cwt.
	Cwts	Rs	Rs
1919–20	97,339	19,88,355	20
1920–21	163,825	36,64,964	22
1921–22	84,256	15,76,308	19
1922–23	52,073	6,80,328	13

BICARBONATE OF SODA

	Quantity	Value	Rate per cwt.
	Cwts	Rs	Rs
1915–16	120,253	6,38,775	5
1916–17	109,433	6,98,850	6
1917–18	90,749	7,22,325	8
1918–19	166,549	17,65,950	11
1919–20	85,617	10,33,065	12
1920–21	86,196	7,50,018	9
1921–22	108,345	11,10,909	10
1922–23	93,651	9,46,982	10

CAUSTIC SODA

	Quantity	Value	Rate per cwt
	Cwts	Rs	Rs
1915–16	87,901	9,72,675	12
1916–17	57,091	11,86,920	21
1917–18	117,105	33,42,915	29
1918–19	71,147	21,99,495	31
1919–20	101,989	24,32,835	24
1920–21	83,951	16,54,778	20
1921–22	67,136	13,36,263	20
1922–23	111,947	20,85,284	19

DISTANCES OF PRINCIPAL PLACES BY RAIL FROM NIMAKNAGAR

	Miles
Dhrangadhra	11
Wadhwan	32
Bhavnagar	136
Wankaner	80
Rajkot	106
Veraval	220
Porbunder	250
Jamnagar	157
Viramgam	72
Ahmedabad	112
Baroda	174
Broach	218
Surat	255
Bombay	422
Mehsana	113
Abu Road	186
Ajmer	375
Sambhar Lake	421
Delhi	610

SALT

PRODUCTION OF SEA SALT IN BOMBAY PRESIDENCY

	1919-20 Mds	1920-21 Mds	1921-22 Mds	1922-23 Mds
Dharasna	300,352	440,492	517,224	472,039
Bhandup	151,240	235,044	255,283	302,761
Naroli	20,208	22,475	18,012	15,443
Bassein	1,515,822	1,402,472	1,467,718	1,790,848
Rai	1,216,840	1,132,400	1,135,707	1,476,725
Trombay	949,430	887,025	814,409	1,031,508
Dadar	910,854	778,821	687,649	823,360
Belapur	730,034	809,383	726,525	806,771
Shewa	15,43,532	1,552,209	1,175,890	1,871,365
Uran	770,042	1,057,013	565,828	1,043,297
Karanja	409,882	339,216	272,345	533,788
Pen	225,050	103,135	167,270	407,816
Shiroda	73,337	72,025	58,196	96,123
Sanikatta	193,415	236,511	57,925	244,797
Total Sea Salt	9,109,129	9,072,487	7,019,090	11,006,631
Kharaghoda Brine Salt	3,395,925	4,944,702	4,125,756	4,527,110
GRAND TOTAL	12,505,054	14,017,243	12,045,746	15,533,741

WORLD'S PRODUCTION OF SALT
(Million Tons)

	1913	Per cent	1920	Per cent
U S A	4 300	25 0	6 107	32 7
U K.	2 248	13 1	2 158	11 5
Germany	1 888	10 0	2 887	15 4
India	1 299	7 6	1 704	9 4
France	1 262	7 3	1 230	6 6
Russia	1 910	11 2	0 539	2 0
Spain	0 590	3 4	0 974	5 2
Japan	0 610	3 5	0 580	3 1
Other Countries	3 093	18 0	2 461	13 2
Total	17 200	100 0	18 700	100 0