The First Salt Plant in the Middle East Using Electrodialysis and Ion Exchange Membranes

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ABSTRACT

Tokuyama Soda has been undertaking a vital role in the modernized salt manufacturing industry in Japan, that is, supplying ion-exchange membranes called NEOSEPTA and establishing the seawater concentration technology which was granted to two other membrane producers in Japan. Now Tokuyama Soda, which initiated this process, continues to pioneer throughout the world.

Recently Tokuyama Soda signed a consultant contract with a Kuwaiti government company for installation of a salt manufacturing plant that will supply ion-exchange membranes and electrodialyzer based on the Tokuyama Soda salt manufacturing process following its successful export to that country of superior technology for an ion-exchange membrane process chlor-alkali plant. It has been a long-lasting dream to produce industrial salt from seawater and then electrolyze it to produce chlorine and caustic soda in commercial operation by means of ion-exchange membranes. This dream is going to be realized in Kuwait for the first time anywhere in the world.

In connection with this consistant membrane technology, Tokuyama Soda's ion-exchange membrane process is presented in this paper in the light of its experiences and background.

INTRODUCTION

Tokuyama Soda Co., Ltd. has aimed to produce salt from seawater industrially and to self-supply it for the soda industry. For this purpose, research and development have been carried out since 1950 and during this period ion exchange membranes ("NEOSEPTA") and an electrodialysis process using "NEOSEPTA" have been successfully established. These technologies have advanced to the extent that the two Japanese salt manufacturers—Kinkai Salt Manufacturing Co., Ltd. and Sanuki Salt Manufacturing Co., Ltd.—have been producing 360,000 tons per year of edible salt for over 10 years.

In an attempt to produce salt more economically by this process, Tokuyama Soda further continues its efforts for the development and improvement of the technologies.

With the ample experience of this salt manufacturing process using "NEOSEPTA", Tokuyama Soda made the contract to supply its process engineering and consulting services for construction of a salt manufacturing plant by the membrane process in Kuwait with Petrochemical Industries Co. (June 1982).

Petrochemical Industries Co. is proceeding with the construction project of an integrated complex for salt and chlor-alkali production in Kuwait, where salt is to be produced from seawater by the membrane process, and then further processed into caustic soda and chlorine by the ion-exchange membrane electrolytic process of Tokuyama Soda.

This paper introduces this Kuwait project and reports the present circumstances and future prospect of the ion-exchange membrane and electrodialysis technology of Tokuyama Soda, for commercial operation.

SEAWATER CONCENTRATION BY ION EXCHANGE MEMBRANE PROCESS

Ion-exchange Membranes

Ion exchange membranes NEOSEPTA produced by Tokuyama Soda is basically classified into two categories, cation exchange membranes furnished with sulfonic acid type functional groups, and anion exchange membranes furnished with quarternary amine type functional groups, both of which are based on styrene-divinylbenzene copolymer. Table 1 gives NEOSEPTA membranes presently available for commercial use.

NEOSEPTA membranes are reinforced with backing

TABLE I

Properties of NEOSEPTA

1. Standard Grades

Name	CL-25T	CH-45T	C66-5T	AV-4T	AF-4T	AVS-4T	AFS-4T
Type	Strongly acidic cation permeable	Strongly acidic cation permeable	Strongly acidic cation permeable	Strongly basic anion permeable	Strongly basic anion permeable	Strongly basic anion permeable	Strongly basic anion permeable
		Medium electric resistance	Low electric resistance		Low electric resistance	Perm selective for univalent anion	Perm selective for univalent anion
							Low electric resistance
	Na-form	Na-form	Na-form	Cl-form	Cl-form	Cl-form	Cl-form
Electric Resistance	2.2～3.0	1.8～2.5	1.1～1.7	2.7～3.5	1.8～2.5	3.7～4.7	2.5～3.2
Transport Number							
Total Cation or Anion	0.98<	0.98<	0.98<	0.98<	0.98<	0.98<	0.98<
$Na^{+}+K^{+}$	0.70	0.70	0.70				
$Ca^{++}+Mg^{++}$	0.28	0.28	0.28	} 0.02>	} 0.02>	} 0.02>	} 0.02>
Cl^{-}						0.98<	0.98<
SO_4^{--}	} 0.02>	} 0.02>	} 0.02>	} 0.98<	} 0.98<	0.005>	0.005>
Burst Strength	3～5	3～5	2～4	6～7	6～7	4～6	3～5
Water Content	0.25～0.35	0.25～0.35	0.35～0.45	0.20～0.30	0.25～0.35	0.25～0.30	0.30～0.40
Exchange Capacity	1.5～1.8	1.8～2.3	2.2～2.8	1.5～2.0	1.8～2.5	1.5～2.0	1.8～2.5
Thickness	0.15～0.17	0.15～0.17	0.13～0.18	0.14～0.18	0.15～0.20	0.15～0.17	0.15～0.20
Reinforcing	yes	yes	yes	yes	yes	yes	yes
Standard Size (m)	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50

2. Special Grades

Name	ACH-45T	ACS	AFN	ACLE-5P	CLE-E
Type	Strongly basic anion permeable	Strongly basic anion permeable	Strongly basic anion permeable	Strongly basic anion permeable	Strongly acidic cation permeable
	Cl-form	Cl-form	Cl-form	Cl form	Na-form
Properties	Anion permselective	Mono-Anion permselective	Diffusion-dialysis	Operable in high pH solution	Cation permselective
	Resistant against organic fouling		Resistant against organic fouling	Resistant against organic fouling	Resistant against organic solvent
	Operable in high pH solution				Operable in high temperature solution
Electric Resistance	2.0～2.7	2.0～2.5	1.2～2.0	20～30	15～25
Transport Number					
Total Cation or Anion	0.98<	0.98<	0.98<	0.98<	0.98<
$Na^{+}+K^{+}$					
$Ca^{++}+Mg^{++}$	} 0.02>	} 0.02>	} 0.02>	} 0.02>	} 0.98<
Cl^{-}		0.98<			
SO_4^{--}	} 0.98<	0.005>	} 0.98<	} 0.98<	} 0.02>
Burst Strength	4～6	4～6	5～7	8～10	8～10
Water Content	0.20～0.35	0.20～0.30	0.35～0.45	0.2～0.3	0.3～0.4
Exchange Capacity	1.3～2.0	1.5～2.2	1.8～2.5	1.3～2.0	1.3～1.8
Thickness	0.14～0.20	0.14～0.20	0.15～0.20	0.20～0.30	1.0～1.5
Reinforcing	yes	yes	yes	yes	yes
Standard Size (m)	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50	1.00×1.50

Measurement Basis

Electric Resistance — Equilibrated with 0.5N-NaCl solution at 25°C [Ω·cm²]

Transport Number — Measured by electrophoresis with sea water. Current density 2 [A/dm²] at 25°C

Burst Strength — [kg/cm²]

Water Content — Equilibrated with 0.5N-NaCl solution [g H_2O/g Na-form dry membrane (or Cl form)]

Exchange Capacity — [meq/g Na-form dry membrane (or Cl form)]

Thickness — [m/m]

cloth and are synthesized by a paste method, provided with the following characteristics;

1. High ionic permselectivity
2. Low electric resistance, less salt diffusion and less water osmosis
3. High dimensional stability and mechanical strength
4. Good chemical stability and long durability.

The ion-exchange membranes used for the salt manufacturing process require, in addition to general requisites, special performance such as high permselectivity to monovalent ion, low electric resistance, high NaCl concentration of produced brine, etc.

For improvement of the salt manufacturing process, efforts were focused on the improvement of NEOSEPTA's properties and the electrodialyzer's performance, as will be referred to later, as well as the process design under optimum economic conditions.

Thus, NEOSEPTA membranes applied to the salt manufacturing process have changed in their grades in the past, as shown in Table 2.

CLS-25T, CHS-45T and C66S-5T are models corresponding to CL-25T, CH-45T and C66-5T, respectively, as given in Table 1, and specifically provided with permselectivity to monovalent cations so as to be applicable to the salt manufacturing process. Comparative data of cation permselectivity between C66-5T and C66S-5T are given in Table 3. Anion exchange membranes with a high permselectivity to monovalent anions are also applied to the salt manufacturing process.

By use of membranes with high permselectivity to cations and anions, respectively, the salt manufacturing process is able to produce NaCl brine in high concentration and high purity without causing scaling in a long continued operation.

The electrical resistance of the membranes has been

TABLE 2

Membranes in Salt Manufacturing Process

Period of Service	Cation Exchange Membrane	Anion Exchange Membrane	Type of Electrodialyzer
Beginning of 1970s	CLS-25T	AVS-4T	Unit Cell Type
End of 1970s	CHS-45T	AFS-4T	Unit Cell Type
Beginning of 1980s	C66S-5T	ACS	Filter Press Type
Present	CIM	A10KS	Filter Press Type

TABLE 3

Comparison of Cation Permselectivity

Membrane Grade	C66-5T	C66S-5T
Electric Resistence ($\Omega \cdot cm^2$)	1.1 ~ 1.7	1.1 ~ 1.4
Tranceport Number (-)		
Total cation	0.98 <	0.98 <
$Na^+ + K^+$	0.70	0.93 <
$Ca^{2+} + Mg^{2+}$	0.28	0.05 >

Electric Resistence; Equilibrated with 0.5N-NaCl solution, at 25°C

Transport Number ; Measured by electrophoresis with seawater
Current density; $2A/dm^2$, at 25°C

reduced gradually over the last decade and has served to lower consumption of electricity significantly, as shown in Table 1.

Pretreatment of Seawater

The ion-exchange membrane process uses seawater as feedstock; the presence of suspended solids in seawater such as microorganisms, algae, shells, plankton and mud, etc., is not advisable for operation of the electrodialyzer. The electrodialyzer constitutes a narrow seawater flow path of 0.5 to 0.75 mm clearance in which suspended solids may accumulate in the electrodialyzer and block the flow of seawater. At times a blockage causes a scale deposit of calcium carbonate or magnesium hydroxide. These scale particles may deposit on the surface of membranes and damage them. Therefore, it is required that seawater must be purified by two stages, using a sand filter and then a secondary filter, to be sufficiently clean for safe and continued operation of the electrodialyzer.

However, the internal structures of electrodialyzers tend to be fouled after prolonged operation so that it is necessary to disassemble and clean the equipment and membranes periodically (generally 3- to 4-month intervals) to maintain a reasonable service life. For simple maintenance of an electrodialyzer, Tokuyama Soda is trying to develop a nondisassembly cleaning method, although some difficulties are still involved because of the different properties of seawater due to different locations and seasonal variation.

NEOSEPTA, however, is stable in both chemical and mechanical properties so that it can operate without changing the performance after repeated disassembly and cleaning.

Unit Cell Type Electrodialyzer

A unit cell type of electrodialyzer is composed of plural stacks and a pair of electrode chambers at both ends in a water tight vessel. Each stack is composed of 17 to 25 pairs of Unit Cells (a cation-exchange membrane and an anion-exchange membrane sealed together to form a bag) and spacer (a diagonally crossed plastic net) installed alternately. Seawater flows upward from the bottom of the vessel through the spacers between membrane bags at a constant flow rate and overflows from the top. When direct current is applied to the pair of electrodes at both ends, Na^+ and Cl^- in seawater are selectively electrodialyzed into each Unit Cell and concentrated brine is accumulated. This brine is taken out through a siphon tube under vacuum pressure (Figure 1).

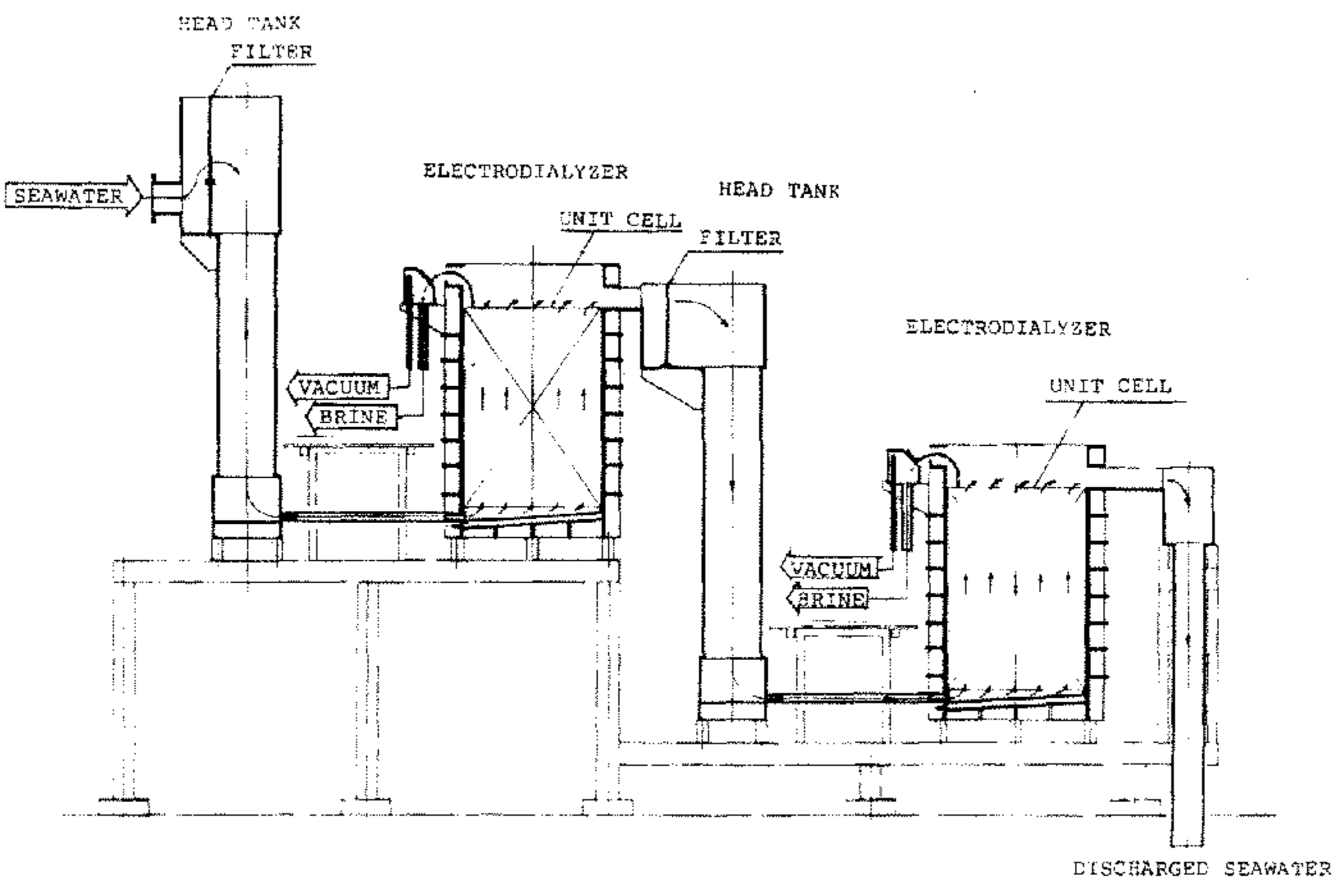

Figure 1. Flow of seawater and brine in unit cell process.

This type of electrodialyzer has been in service for more than 10 years since Kinkai Salt Manufacturing Co., Ltd. and Sanuki Salt Manufacturing Co., Ltd. first employed this process in place of the conventional salt field process of solar evaporation. This type of electrodialyzer is simple in its mechanism and has the following features.

1. Low electricity consumption
2. Almost no current leakage at the concentrated brine side
3. Easy operation and maintenance due to simple mechanism
4. Easy detection of defective membranes and easy replacement, disassembly and cleaning because of open type of design
5. Less susceptibility to fouling by suspended solids during operation because air cleaning is jointly used, and good durability for a long time service operation.

Filter Press Type Electrodialyzer

Tokuyama Soda has applied the filter press type of electrodialyzer to the production of potable water or industrial water from seawater and groundwater, separation and purification of foods, and waste water treatment, etc., as another use of ion-exchange membranes. Tokuyama Soda has also supplied more than 20 units of package-type electrodialysis desalination equipment, called UX type, for the Middle East area which were intended for the production of drinking water at a construction site or for villagers.

To meet the requirement in the 1980s, when energy saving and high productivity are of utmost importance, Tokuyama Soda is shifting the type of electrodialyzer for salt manufacturing from the Unit Cell type to the filter press type.

A flow sheet and the internal structure and external view of an electrodialyzer are shown in Figures 2, 3 and 4, respectively.

Raw seawater is filtered by sand filter and secondary filter in series so as to provide 0.05 ppm or less turbidity before it is fed to the electrodialyzer. An electrodialyzer (type TSW-200) is arranged with plural stacks and a pair of electrode chambers at both ends. Each stack is composed of 150 to 200 pairs of membranes. Each compartment is to hold two sheets of membrane with an effective area of 1 m^2, and gaskets with a partition at the center are to be installed alternately.

Each compartment actually has two independent compartments because of the partition in the center provided by a gasket. Therefore, brine feed is provided to all compartments separately, and thus uniform flow distribution is accomplished and reduction of electric current leakage is well maintained.

One unit of electrodialyzer is of a double type, composed of twelve stacks with anode chamber in the center and cathode chamber at both ends.

When direct electric current is applied, Na^+ and Cl^- in seawater are electrodialyzed into the recirculating brine stream and accumulated as concentrated brine. Then the accumulated brine is successively tranferred to the evaporating crystallization and salt separating section.

MANUFACTURE OF EDIBLE SALT

The manufacture of edible salt in Japan (approx. 1,200,000-ton-a-year production) was entirely converted from the salt field process to the ion-exchange membrane process under the direction of The Japan Tobacco and Salt Public Corporation. At present, Tokuyama Soda supplies the ion-exchange membrane electrodialysis process to two salt manufacturers of Kinkai and Sanuki, which manufacture 360,000 tons of edible salt yearly.

The membrane process calls for energy saving and high production performance. Under such circumstances, Tokuyama Soda has changed the type of electrodialyzer from Unit Cell type to Filter Press type, aimed at meeting the following goals:

1. Structure of electrodialyzer that can be cleaned without disassembly
   Object: Reduction of man-hours required for maintenence
2. Reduction of the consumption unit of electricity
   Object: Energy saving
3. Production of brine with high concentration and purity
   Object: Energy saving
4. Large capacity of an electrodialyzer
   Object: High productivity.

Table 4 gives a list of electrodialyzers for salt manufacturing which are always supplied for users by Tokuyama Soda. As listed, the filter press type of electrodialyzers have been furnished to the aforesaid two manufacturers to meet their goal of modernization of the salt manufacturing process started during the latter part of the 1970s.

A comparative description of the specification and operation performance of each unit electrodialyzer between filter press type and Unit Cell type is provided in Table 5.

An electrodialyzer of type TSW-200 supplied to Sanuki in 1982 is improved on the following points as compared with the conventional type:

1. NEOSEPTA CIM and A10KS of low electric resistance are used
2. One compartment consists of two sheets of membranes for the purpose of easy handling
3. Spacer used in this electrodialyzer has a performance for low stream pressure drop and high limiting current density
4. The structure and seawater feed method are well designed

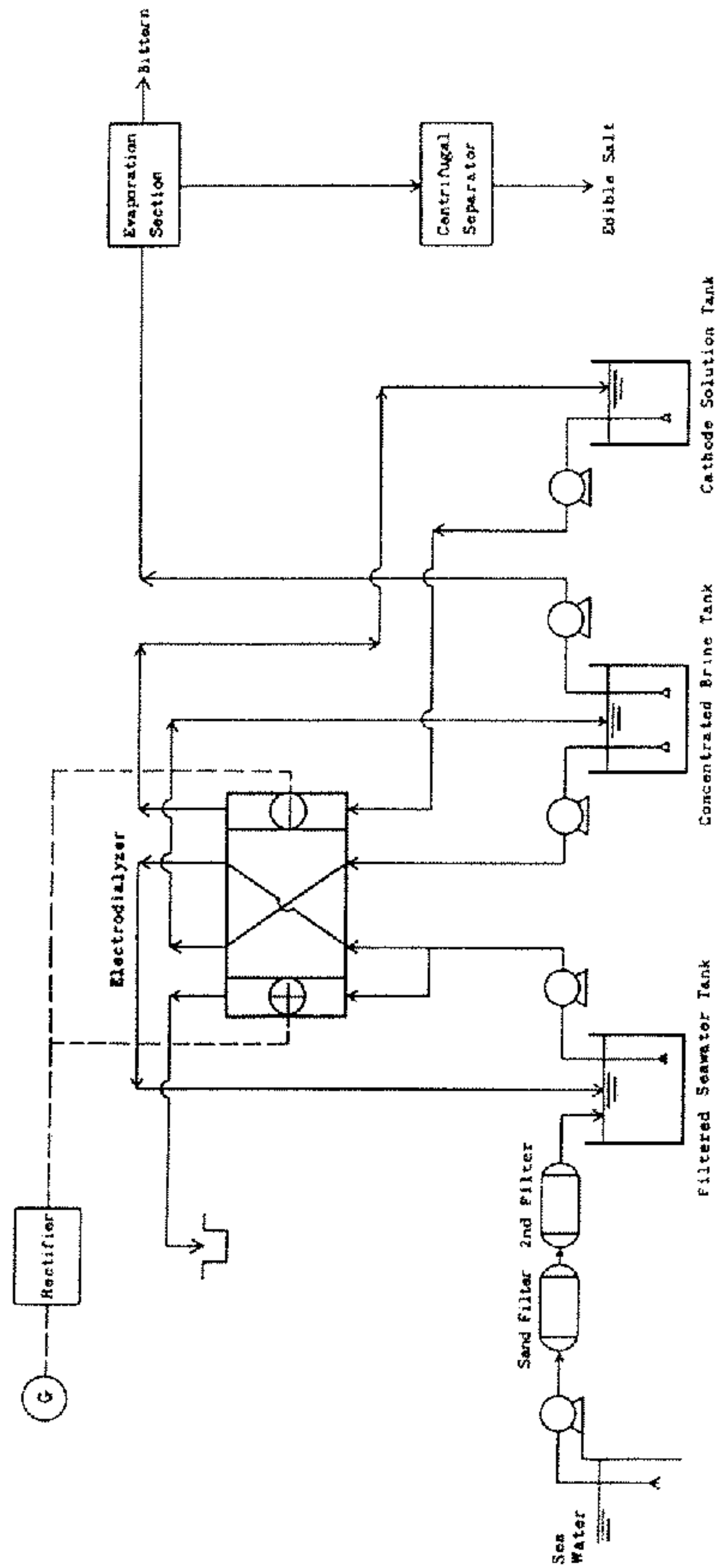

Figure 2. Flow diagram of salt production by electrodialysis.

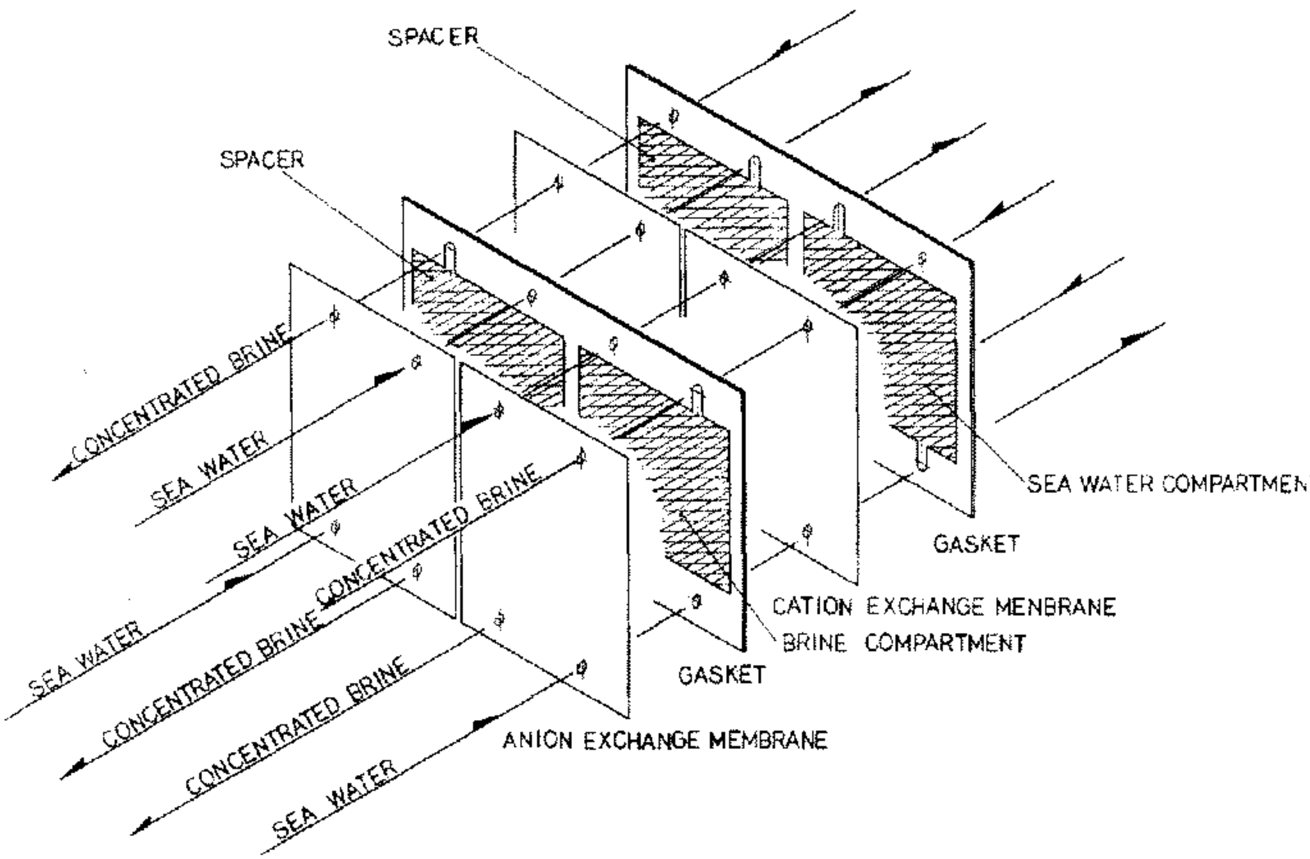

Figure 3. Internal structure of electrodialyzer.

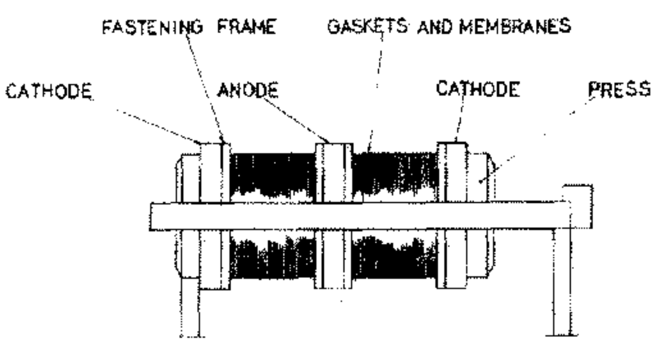

Figure 4. External view of filter press type electrodialyzer.

5. The controls of electric current, voltage and PH are well designed for simple maintenance.

With these improvements, the operation performance of the electrodialyzer (type TSW-200), based on its recent performance records, is demonstrated as follows:

1. The productivity of unit electrodialyzer increased due to higher operation current density and an increased number of membrane pairs installed
2. Handling of ion exchange membrane becomes easier, resulting in less damage through handling
3. Acid consumption for PH adjustment is reduced to one-tenth
4. The electric power consumption is reduced to a considerable extent
5. Concentration of NaCl in produced brine is increased.

MANUFACTURE OF INDUSTRIAL SALT

Industrial Salt

As mentioned above, this membrane process is able to produce edible salt from seawater economically. In the field of industrial salt production that Tokuyama Soda has been aiming at, the technical and economical position of the membrane process is studied in comparison with other production processes.

Quality of Salt

The comparative contents of main components between the field salt imported to Japan from Mexico and Australia and the wet salt produced by this membrane process in Japan are shown in Table 6.

TABLE 4

Salt Plants by Tokuyama Soda's Seawater Concentration Technology

Name of company	Construction date	Capacity (Salt. t/y)	Type of Electrodialyzer
Kinkai Salt Manufacturing Co., Ltd.	1965	3,000	WI - 32
Ajino Salt Manufacturing Co., Ltd.	1967	3,000	SI - 32
Kinkai Salt Manufacturing Co., Ltd.	1967	22,000	SI - 32
"	1969	36,000	WII - 64
"	1971	44,000	WIII - 64
"	1972	53,000	WIII - 76
"	1973	26,000	WIV - 76
Sanuki Salt Manufacturing Co., Ltd.	1973	156,000	WIII - 76
Tokuyama Soda Co., Ltd.	1973	5,500	TS - 160
Sanuki Salt Manufacturing Co., Ltd.	1974	26,000	WIV - 76
Kinkai Salt Manufacturing Co., Ltd.	1977	6,000	TS - 160
"	1979	17,500	TSW - 200
Sanuki Salt Manufacturing C., Ltd.	1980	26,000	TSW - 200
"	1981	26,000	TSW - 200
"	1982	26,000	TSW - 200

TABLE 5

Specification and Performance of an Electrodialyzer

Type of Electrodialyzer	Newest Filter Press TSW-200	Filter Press in 1981 TSW-200	Unit Cell
Specification			
Ion-exchange membrane (Cation/Anion)	CIM/A10KS	C66S-5T/ACS	CHS-45T/AFS-4T
NOs. of membrane (Pairs)	3200	2088	1974
Effective area (m^2)	2	2	1.15
Thickness between membranes (mm)	0.75	0.75	1.2
Operation Condition			
Current density (A/dm^2)	3.5	3.5	2.3
Flow rate of seawater (cm/sec)	6	6	6
pH of seawater (-)	7 to 8	7 to 8	5 to 6
Temperature of seawater (°C)	25	25	25
Performance			
Production capacity (T-NaCl/Year)	26000	17400	6500
Concentration of brine			
Cl (equ./liter)	3.9	3.56	3.2
SO_4 (equ./liter)	0.0026	0.0026	0.0026
NaCl (g/liter)	205	188	170
Current efficiency of Cl^- (%)	86.0	86.0	84.0
Power consumption for electrodialyzer (DC-KWH/T-NaCl)	205	227	300

TABLE 6

Comparison of Main Components in Salt

unit;g/100g-Salt

Contents	Na^+	K^+	Mg^{2+}	Ca^{2+}	SO_4^{2-}	Cl^-	Moisture	Insoluble Matters	NaCl
Membrane Salt (Wet Salt)									
Distribution	38.26 ~38.47	0.096 ~0.203	0.044 ~0.091	0.045 ~0.080	0.029 ~0.118	59.41 ~59.61	1.39 ~1.65		97.26 ~97.80
Average	38.34	0.151	0.068	0.060	0.075	59.51	1.58	0.000	97.47
Field Salt									
Mexican	38.31	0.02	0.02	0.05	0.15	59.19	1.99	0.02	97.38
Australian	38.07	0.02	0.03	0.04	0.13	58.81	2.43	0.02	96.79

The quality of wet salt is compared with that of imported field salt as follows;

1. The content of NaCl is nearly the same
2. The content of K^+ is several times higher
3. The content of SO_4^{2-} is less than a half.

This comparison indicates that the wet salt is usable in place of field salt for industrial use.

Differences of Quality Requirements for Edible Salt and Industrial Salt

In Japan, the Japan Tobacco and Salt Public Corporation regulates the quality of edible salt in three items: 1) contents of NaCl, 2) the kind and quantity of additives and 3) the granule size and distribution. In the meantime, the quality required for industrial salt varies in accordance with the purpose. The salt for soda-alkali industries, which consume a predominant part of industrial salt, is required from their economical viewpoint to be low in impurities, and field salt suppliers in each country are decreasing the contents of impurity to meet such requirement.

Production Cost

Assuming that the salt produced by the ion-exchange membrane process is applied to the soda-alkali industries, we have studied the differences in salt production costs and brine purification costs between the membrane process salt and the imported industrial salt. Because plant cost varies broadly according to the conditions of the plant site and economical circumstances, we have excluded the comparison of installation cost and depreciation and compared the energy consumptions that are the major operation cost under the following assumptions;

1. The kind of salt to be compared is wet salt
2. For evaporating crystallization, a triple effect evaporator using 1.0 kg/cm^{2}G steam is assumed to be used
3. The facilities of the membrane process are composed of brine production and evaporating facilities
4. The working efficiency of boiler and turbine is 90% and 40%, respectively.

The energy consumption cost at the present technical level of the membrane process and the theoretical values for the membrane process are indicated against the unit cost of energy in Figure 5.

At the present status, the energy consumption cost seems to be a little higher than for the field salt, with the exception of some areas where energy cost is significantly lower than elsewhere.

We have made great efforts to decrease the energy consumption for self-supply of industrial salt. The present situation of energy consumption is summarized in Table 7, comparing former, near future and theoretical consumption.

The theoretical energy consumption needed for this membrane process is approximately 40% of the present

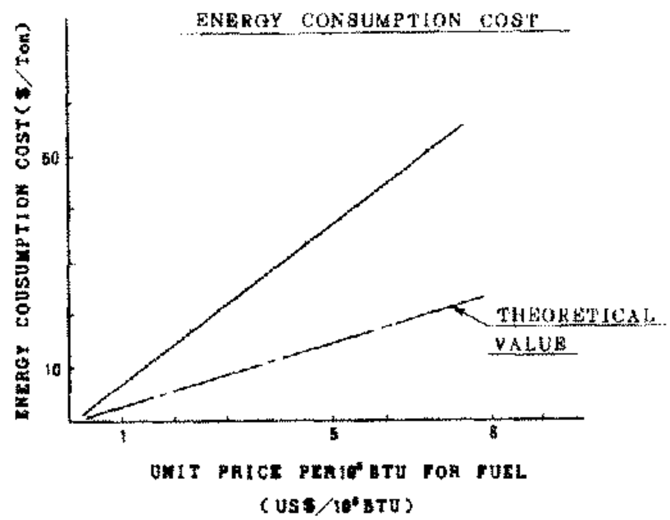

Figure 5. Energy consumption cost.

one, and we are continuing efforts to bring the energy consumption closer to the theoretical value.

The comparative chemical consumption for brine purification between the salt produced by the membrane process and the field salt is shown in Table 8, based on the components indicated in Table 6.

The chemical consumption of the membrane salt is considered to be less than that of field salt. The development of electrodialysis technology aims at the improvement of NaCl purity in salt, so that the chemical consumption will be decreased in the future together with the decrease of salt production cost.

There are two directions for reduction of the cost of salt production: 1) the expansion of plant capacity and 2) the technical improvement of the production process.

For the technical improvement, both the brine production process and evaporating crystallization process should be taken into consideration.

The current density to the electrodialyzer is an important factor, besides the improvement of efficiency of each piece of equipment in the brine production process. The relationship between the current density and salt production cost is shown in Figure 6.

As shown in Figure 6, there is an optimum current density at the point of "D."

In case the operation current density does not reach the optimum point, performance of the electrodialysis system can be improved by increasing the current density to be applied to the electrodialyzer. In case the operation current density is higher than the optimum point, the total economies will be improved by reducing the installation cost and operation cost.

The evaporating crystallization process requires minimum heat loss and brine of higher concentration and purity to reduce total steam consumption.

TABLE 7

Comparison of Energy Consumption

Original	Present	Near Future	Theoretical
1.3	1.0	0.85	0.4

TABLE 8

Comparison of Chemicals Consumption

Chemicals	NaOH	$CaCl_2$	Na_2CO_3
Membrane Salt	2.0+α	0.4	0.9+β
Field Salt	0.7+α	2.7	2.2+β
Differencies	+1.3	-2.3	-1.3

Note; The unit is Kg/T-NaCl.
The word of "α" and "β" means necessary excess quantity respectively.

Moreover, in case both electric power and steam are supplied from an associated power plant, the optimum production cost can be regulated by using electric power that corresponds to necessary quantity of steam in the evaporating crystallization process.

SALT AND CHLOR-ALKALI COMPLEX OF PETROCHEMICAL INDUSTRIES CO.

Petrochemical Industries Company (PIC) in Kuwait has proposed a project for the construction of a salt and chlor-alkali plant using seawater as raw material in Shuaiba, Kuwait. This project is worth noting in two respects: 1) production of salt, chlorine and caustic soda is to be made in an integrated complex by the ion-exchange membrane process, and 2) the salt manufacturing process originated in Japan for edible salt is now to be utilized for manufacture of industrial salt.

PIC held an international tender for its "Chlorine Plant" in August 1981 and successively in April 1982 for the "Salt Plant." In both cases, Tokuyama Soda made the successful bid for the contracts.

Under the contract, with regard to the Salt Plant, Tokuyama Soda will supply PIC with license, basic engi-

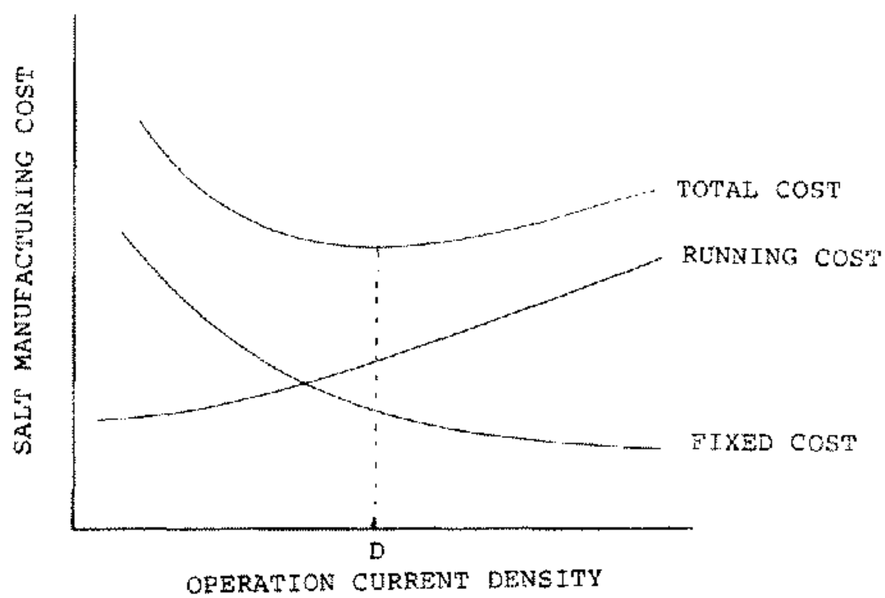

Figure 6. Salt manufacturing cost vs operation current density.

neering, detailed engineering, proprietary equipment and material for salt production and tender specifications for the plant construction as well as relevant consulting services.

As of October 1982, PIC called for an international bid for the contract of construction of the said plants in accordance with bid specifications prepared by Tokuyama Soda.

Table 9 gives an outlined construction schedule for this project.

Block diagrams for the Salt Plant and Chlorine Plant, respectively, are shown in Figures 7 & 8. The Salt Plant produces from seawater wet salt, dry salt and water as a by-product. Wet salt is directly supplied to the Chlorine Plant to be used for ion-exchange membrane salt electrolysis. Dry salt is packaged in a 750 g plastic bottle, 1 Kg bag and

TABLE 9

Construction Schedule

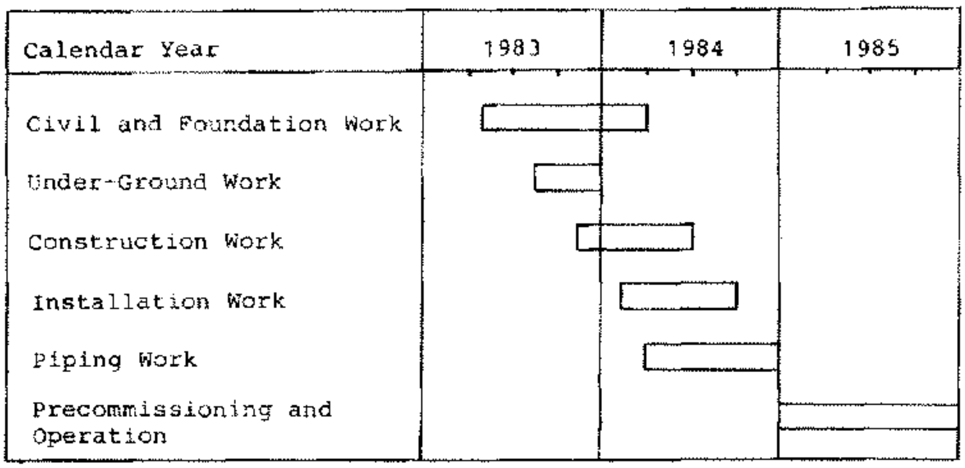

TABLE 10

Planned Specification of Salt Plant

Production Capacity	
1 Salt	150 MTPD as Dry Basis
2 Packing of Eadible Salt	
1) 25 Kg Bag Packing	25 MTPD in Day Time
2) 1Kg Bag Packing	50 MTPD in Day Time
3) 750g Plastic Bottle Filling	10 MTPD in Day Time
Specification Of Main Equipment	
1 Pretreatment Facilities	Gravity sand filter with automatic back-washing system Two stages of continuous treatment system
2 Electrodialyzer	TSW-200 Type
3 Evaporating Crystallization Facilities	Triple effects with four evaporators Counter flow type
4 Dryer	Fluidized-bed type with steam heating
5 Packers	
6 Boilers	Water-tube boiler

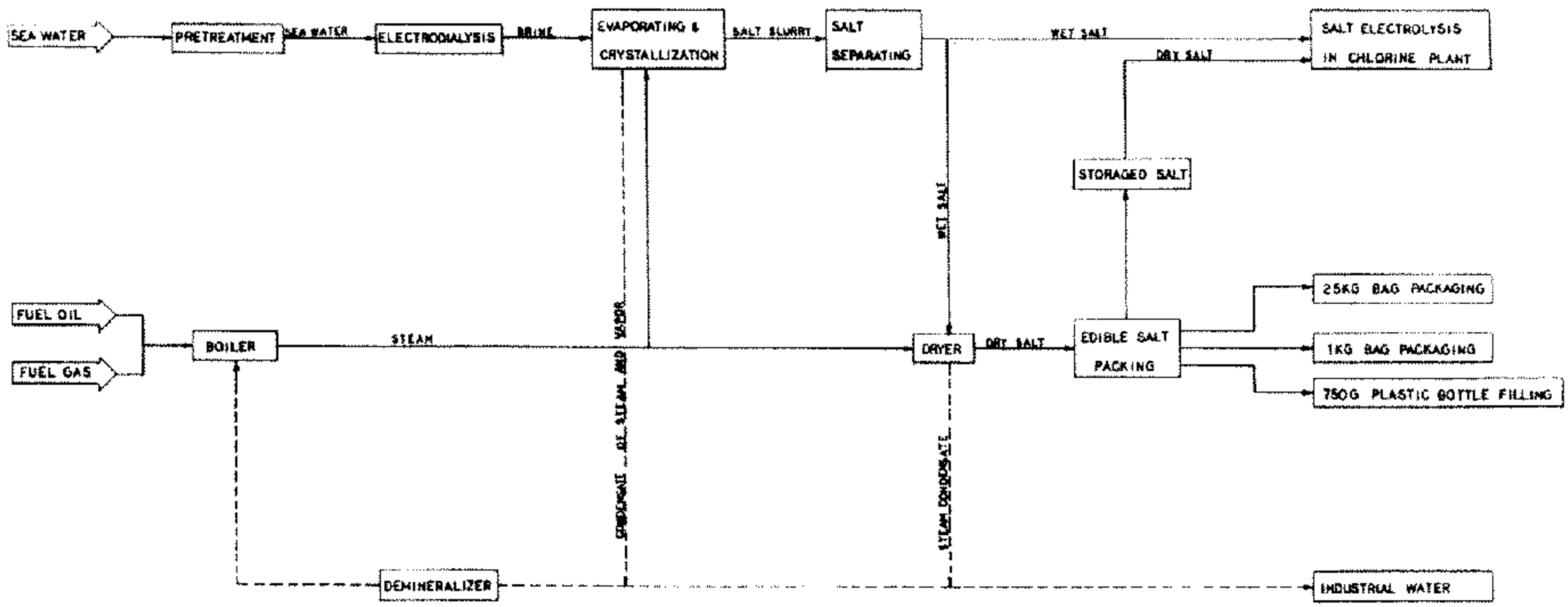

Figure 7. Block diagram of salt plant.

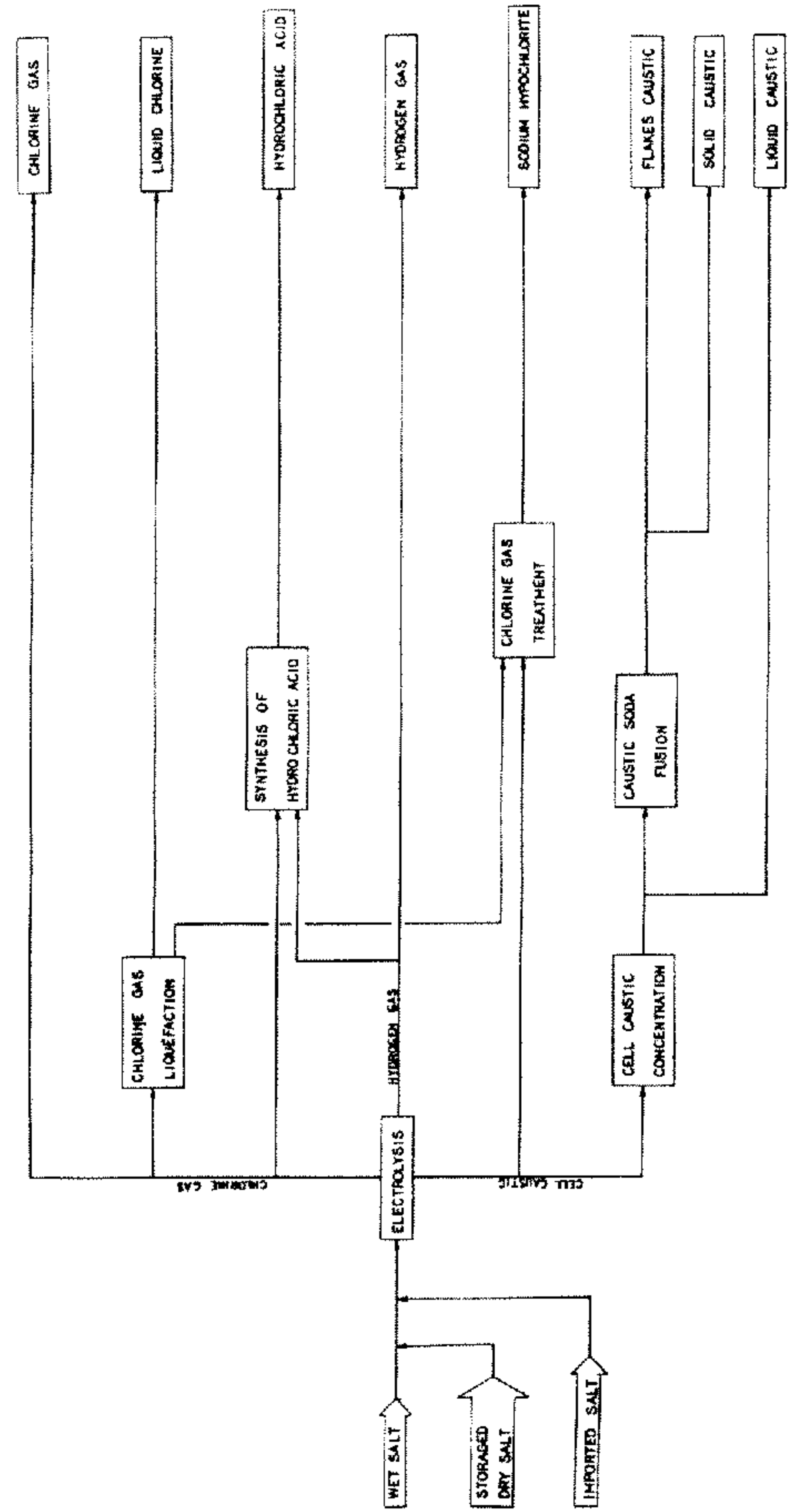

Figure 8. Block diagram of chlorine plant.

25 Kg bag as edible salt for sale on the market. A surplus of dry salt is stored in the salt warehouse and kept for emergency use in the Chlorine Plant.

Condensate generated in the evaporating crystallization facilities is utilized in the Salt Plant and Chlorine Plant as industrial water and further surplus is appropriated for other plants. Also, a part of the industrial water is desalinated to be used as make-up water for the boiler. For Kuwait, where availability of fresh water for industrial use is limited, the water condensate obtained in the Salt Plant would be a significant advantage. The Chlorine Plant makes chlorine and caustic soda by the ion-exchange membrane electrolytic process using wet salt or dry salt made in the Salt Plant, or imported salt as the case may be.

In this salt-electrolysis process, chlorine gas, hydrogen gas and caustic liquor are produced, and sodium hypochlorite and hydrochloric acid are synthesized as by-products. Caustic liquor is processed into three kinds of products–solution, solid and flake caustic soda.

Chlorine gas and sodium hypochlorite are used for sterilization of seawater in Shuaiba and other districts, and hydrochloric acid and caustic products are partly directed for internal use.

The plan specification of the Salt Plant is provided in Table 10. Specifications for the Chlorine Plant are not provided, since it is not the object of this report.

CONCLUSION

The ion-exchange membrane process developed by Tokuyama Soda has been applied in Japan for the manufacture of 360,000 tons of edible salt per year. Tokuyama Soda further aims to apply this membrane process to the production of industrial salt for soda-alkali industries. Economics does not yet justify industrial salt production in relation to the cost of imported salt in Japan. However, the project of PIC for a salt and chlorine complex in Kuwait indicates that the salt production for industrial use should be viable and justified under certain circumstances. Therefore, similar projects may be justifiable in other Middle East areas, for example.

Therefore, Tokuyama Soda recommends that countries and users needing industrial salt study the membrane salt manufacturing process under the consideration of their circumstances and economy.

ACKNOWLEDGMENT

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