Study on the Material Balance and Energy Balance on the Okinawa Chlorine Industry Co. Ltd.

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ABSTRUCT

The factory of the Okinawa Chlorine Industry Co. Ltd. is only one project to produce hydrochloric acid and its compounds. This investigation was done during the period of September, October, November and January. Because of mechanic trouble, at the factory, data could not obtained in December.

Following datas was taken up under investigation from the project;

Table 1 Materials and Energy

Month	Salt (Kg)	Electric Power (KWH)
September	56,300	29,500
October	95,080	49,176
November	60,200	59,792
January	127,900	71,526
Total	339,480	209,994

Efficiency of materials and energy were examined by calculation and analytical methods, results are shown as follows;

(A) Per centage of salt to be used for production is 17.96 %.

(B) Efficiency of electric power for products is 38.04 %.

(C) Operating efficiency of the electrolytic cell is 23.8 %.

Cause of trouble at the project is depended on poor condition of electrolytic cells and misuse of waste solution.

1. INTRODUCTION.

The factory of the Okinawa Chlorine Industry Co. Ltd., is located in Makiminato, Ginowan City. Because of poor productivity and lower operating efficiency, investigation was taken to find neck points to be improved.

For this purpose, material balance was calculated and energy balance was investigated. Then, electrolytic cells and thes Synthetic tower was examined.

2. ELECTROLYTIC CELL.

This cell is of the vertical type with unsubmerged cathodes and contains, according to its capacity, one or several cathodic elements placed in cathode boxes.

The cathodes are formed by perforated sheet boxes in the shape of a U or a W. Figure 1 illustrates a W-type cathode. Brine feeds to the cell, is through a hydraulic level regulator[2]. The feature of the cell is the ease of replacement of the diaphragms. These have an average service life about 9 months.

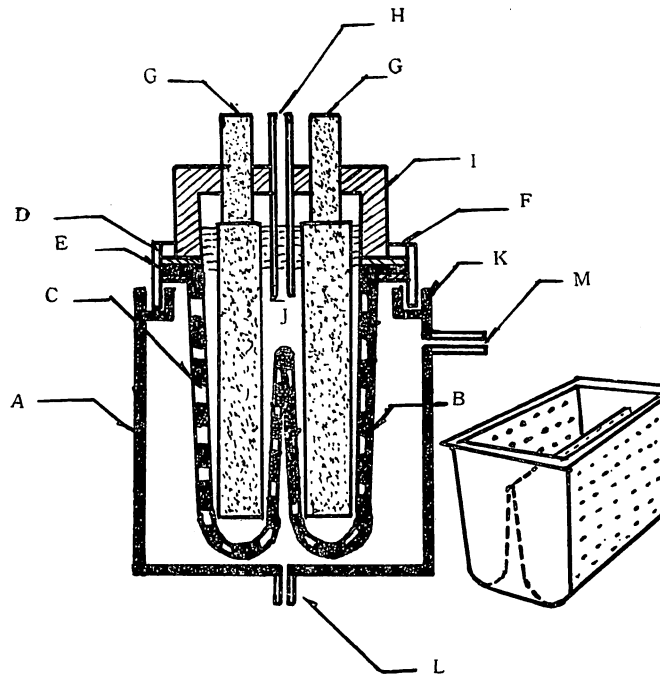

Fig. 1 Diagrammatic sketch of the electrolytic cell.[3)]
A, cathode tank; B, Perforated cathode; C, diaphragm of asbestospaper and tissue; D, T-iron frame to which the perforated cathode is welded; E, special joint which, together with joint; F, insures tightness inside the cell; G, artificial graphite anodes; H, brine feed; I, anode box or chlorine trough, made of refractory material not affected by chlorine gas or by electrolyte J; K, hydraulic joint between cathode tank A and cathode B-D; L, caustic exit; M, hydrogen outlet.

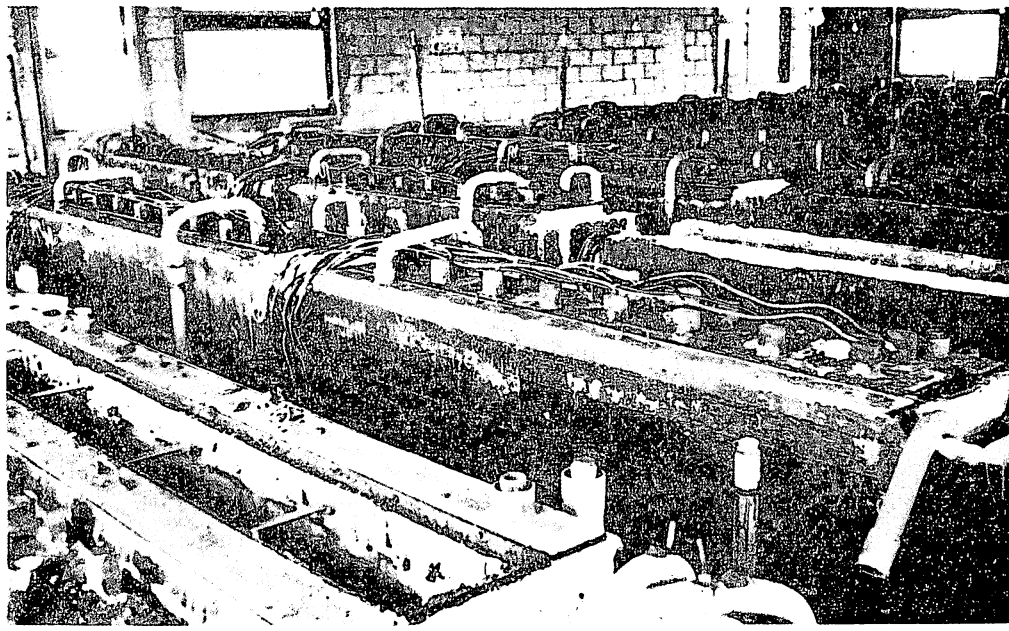

Fig. 2-A Cell room

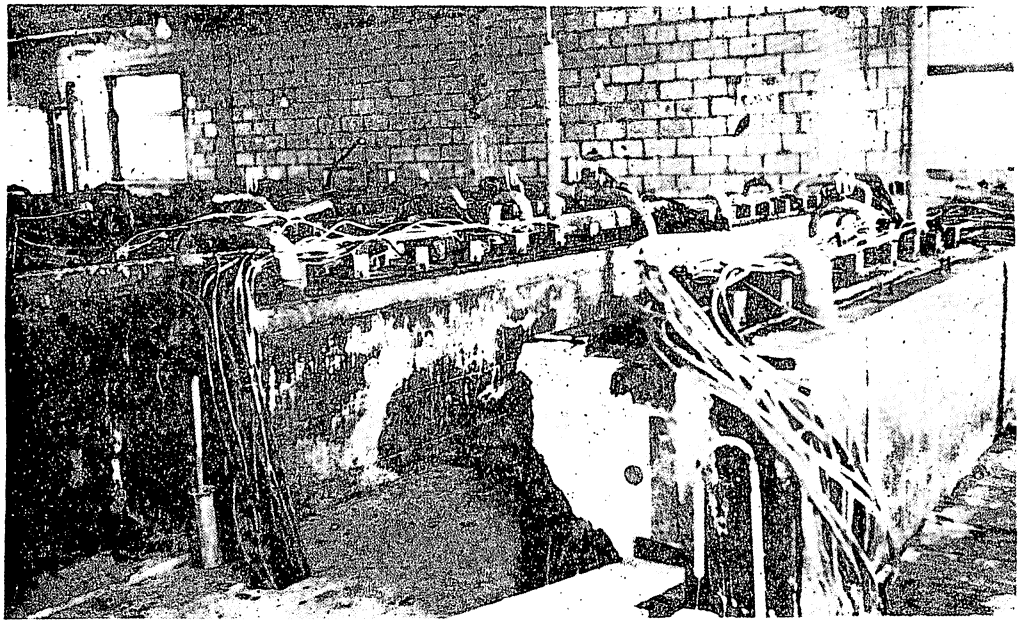

Fig. 2-B Cell room

The cathode, fixed to the T-iron frame, is readily lifted up. The anodes, the anode box, and the cathodes are all taken out of the tank in one operation. The cell room of the project is shown in Figure 2.-A and B.

3. OPERATING DETAILS.

(a) Feeding brine:

For the purpose of separation Mg^{2+} and Ca^{2+} from the feeding solution before electrolytic dissociation, caustic soda or soda ash to be added.

Component of the feeding brine is prepared; concentration of sodium chloride is between 300 g/l to 310 g/l, concentration of $[SO_4^{2-}]$ is 5 g/l and pH should be 6.5 as the standerd feeding solution[5].

(b) Theoretical products:

On this method, theoretical products are shown as the following table.

Table 2 Theoretical products[6]

Electric Power (KWH)	Products		
	NaOH (Kg)	Cl_2 (Kg)	H_2 (Kg)
1 KWH	1.493	1.323	0.418
1,000 KWH	649	575	182

(c) Theoretical voltage for electrolytic dissociation;

In general, electric power efficiency is in the midst of 90 % to 96 % and voltage efficiency is between 57 % to 70 %. On this method, the theoretical voltage is 2.26 volts as the following calculations:[1]

$$NaCl = Na + 1/2Cl_2 - 96,400 \text{ Cal} \quad (1)$$

$$Na + aq = NaOH\ aq + 1/2H_2 + 43,400 \text{ Cal} \quad (2)$$

$$NaCl = NaOH + 1/2Cl_2 + 1/2H_2 - 53,000 \text{ Cal} \quad (3)$$

$$\text{Theoretical voltage} = 53,000/23,110 = 2.26 \text{ volts.} \quad (4)$$

(d) Operating voltage:

The table 3 is one of the data which is operating at the very top condition for the same type of project in Japan.

Table 3 Operating voltage

Parts of Cell	Maximum vol.	Minimum vol.
Cathode	1.260	1.160
Anode	1.685	1.610
Voltage drop for the solution	0.403	0.403
Voltage drop for diaphragm	0.145	0.145
Voltage drop at the Anode	0.100	0.100
Voltage drop at the contact point	0.100	0.100
Total	3.693	3.518
Average	3.606	

4. MATERIAL BALANCE.

Investigation was done during the period of September, October, November and January for Hydrochloric acid, Bleaching powder and Bleaching solution, as products of Sodium chloride. Then, the following data was obtained:

Table 4 Sodium chloride and its product

Month	Sodium Chloride NaCl (Kg)	Hydrochloric Acid (Kg)	Bleaching Powder (Kg)	Bleaching Solution
September	56,300	16,400	1,775	6.2 (Koku)
October	95,080	24,100	—	6.7 (Koku)
November	60,200	26,500	950	10.95 (Koku)
January	127,900	34,927	800	52.28 (Kg)*
Total	339,480	101,927	3,525	

Note (*) Calculated as Cl_2.
(1) Purity of the Hydrochloric acid is 35%.
(2) Purity of the Bleaching powder is 32% as Cl_2.
(3) For the Bleaching solution, in September, October and November, "Koku" was used as unit of production. Concentration of the Bleaching solution was Bé 8° to Bé 15°.

(a) Chlorine content in the Hydrochloric acid which was producted from Sodium chloride among the period of the above.[4]

$$101,927 \times \frac{35}{100} \times \frac{35.5}{36.5} = 3.47 \times 10^4 \text{ Kg} \quad (5)$$

(b) Chlorine content in the Bleaching powder,

$$3,525\times\frac{32}{100}=1,129 \quad \text{Kg} \qquad (6)$$

(c) Chlorine content in the Bleaching solution,

$6.2+6.7+10.95=23.85$ Koku

$23.85\times180.39=4,3023$ Liter

Because of deferences of 8 °Bé and 15 °Bé, specific gravity is calculated by the logarithmic mean;

Specific gravity at 8 °Bé is 1.058 and 1.115 for 15 °Bé, then, the logarithmic mean shown as the following equation:

$$\text{Specific gravity}=\frac{1.115-1.058}{\log_e\frac{1.115}{1.058}}=1.084 \qquad (7)$$

With compare the products, Hydrochloric acid and Bleaching powder, amont of Bleaching solution is very small. Therefore, Chlorine content in the Bleaching solution is calculated by applied 8% as Chlorine per-centage.

$$4,3023\times1.084\times(8/100)=373.087 \quad \text{Kg} \qquad (8)$$

hence, Chlorine content for the period from September to January is shown as 425.37 Kg.

$$373.087+52.28=425.37 \quad \text{Kg} \qquad (9)$$

Now the total Chlorin content for all of products are

$$34,700+1,129+425.37=36,254 \quad \text{Kg} \qquad (10)$$

Total Chlorine content in salt which used as the feeding material is calculated by the following equation, 98% is purity of Sodium chloride.

$$339,480\times\frac{35.5}{58.5}\times\frac{98}{100}=201,889 \quad \text{Kg} \qquad (11)$$

(d) Per centage of salt which is used for production is 17.96%.

$$\frac{36,254}{201,889}\times100=17.96\,\% \qquad (12)$$

5. ENERGY BALANCE.

Inspection of electric power, during the period of investigation, are shown as the following table 5:

(a) Total amount of Sodium chloride for this electrolytic dissociation by 26.02×10^5 Faraday:

$$26.02\times10^5\times58.5\times\frac{100}{98}=155,323 \quad \text{Kg} \qquad (13)$$

(b) Quantity of Sodium chloride which is actully used for production:

$$\frac{35,855}{35.5}\times58.5=59,077 \quad \text{Kg} \qquad (14)$$

(c) Efficiency of electric power for products is 38.04%,

$$\frac{59.077}{155,323}\times100=38.04\,\% \qquad (15)$$

Table 5 Electric power which was used at the project

Month	Electric Power (KWH)	Ampere	Voltage	Faraday
September	29,500	2,500 to 3,000	2.6	4.2×10^5
October	49,176	2,900 to 3,000	2.6	7.05×10^5
November	59,792	3,300 to 3,400	3.3	6.77×10^5
January	71,526	3,200 to 3,800	3.3 to 3.4	7.97×10^5
Total	209,994			26.02×10^5

6. MATERIAL BALANCE FOR ELECTROLYTIC CELL.

For the reason of the poor result of operation, special consideration was paid for the electrolytic cell. Concentration of Chlorine ion; $[Cl^-]$ was determined by Mohr's method.[4]

(a) The first experiment for the solution of electrolytic cell and waste solution:

i) Chlorine ion concentration of the solution of electrolytic cell is 4.674 N, and the specific gravity of the solution of it, 1.201, therefore the per centage of Sodium chloride in the solution is calculated as

$$\frac{4.674 \times 58.5}{1.201} \times 10^{-3} \times 10^2 = 22.5\ \% \qquad (16)$$

ii) Chlorine ion concentration for the waste solution is 3.608 N, then, the percentage of Sodium chloride in it:[6]

$$\frac{3.608 \times 58.5}{1.211} \times 10^{-\infty} \times 10^2 = 17.4\ \% \qquad (17)$$

Specific gravity of waste solution=1.211

iii) Per centage of Sodium chloride which actually used,

$$\frac{4.674 - 3.608}{4.674} \times 100 = 22.8\ \% \qquad (18)$$

(b) The second treatment for the solution of electrolytic cell and waste solution was done and the following result were obtained;

i) Concentration of Chlorine ion for the solution of the electrolytic cell is 4.745 N, then concentration of Sodium chloride is shown as the following;[1]

$$\frac{4.745 \times 58.5}{1.201} \times 10^{-3} \times 10^2 = 22.9\ \% \qquad (19)$$

Specific gravity of the solution=1.201

ii) Chlorine ion concentration of the waste solution is 3.577 N, and the percentage of Sodium chloride is 17.4 %.[6]

$$\frac{3.577 \times 58.5}{1.211} \times 10^{-3} \times 10^2 = 17.4\ \% \qquad (20)$$

Specific gravity of the solution=1.211

iii) Per-centage of Sodium chloride which is actually used,

$$\frac{4.745-3.57}{74.745}\times 10^2=24.7\ \% \tag{21}$$

(c) Results:

Table 6 Percentage of Sodium chloride

Subject	I	II	Average
Solution of cell	22.5 %	22.9 %	22.7 %
Waste solution	17.4	17.4	17.4
Actually used	22.8	24.7	23.8

7. CONCLUSION.

On the result of this investigation, the per centage for Sodium chloride which is dissociated by electrysis, is 23.8 %, and the per centage of salt which is used for production is 17.96 %. Therefore, 5.8 % of salt will be wasted from either the synthetic tower or elsewhere.

$$23.8-17.96=5.8\ \% \tag{22}$$

In general, the per centage of Sodium chloride which actually used, should be in between 57 % to 70 %. On this project, the per centage of electrolysis is only 23.8 % which is more less than as usual condition.

Efficiency of electric power conceren, even though 90 % to 96 % of theoretical condition, at this factory, only 38.04 % is obtained.

As the result, cause of trouble in this process at the factory is in the electrolytic cell. On the other hand, concentration of Hydroxyl group [OH^-] in the waste solution was determined as 1.368 N.[5]

Hence, the concentration of Sodium hydroxide is 4.54 %;

$$\frac{1.368\times 40}{1.211}\times 10^{-3}\times 10^2=4.54\ \% \tag{23}$$

Specific gravity of the waste solution is 1.211.

As compared with usual condition, 10 % to 12 %, the concentration of Sodium hydroxide in the waste solution, 4.54 %, is also more less than half of the usual condition.

To show the result more clearly, the following table 7 was prepared:

Table 7 Comparison with normal condition

Item	Operating condition	Normal condition[5]
i) Percentage of NaCl in electrolysis	23.8 %	57 % to 70 %
ii) Efficiency of Electric power	38.04 %	90 % to 96 %
iii) Production of NaOH inthe waste solution	4.54 %	10 % to 12 %

8. REFERENCES.

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