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## Using Seawater to Remove SO<sub>2</sub> in a FGD System

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### 1. Introduction

#### 1.1 Introduction

Sea water contains significant amounts of HCO<sub>3</sub><sup>-</sup> and other alkaline compounds that help sulfur dioxide in flue gas dissolve in water. Flue gas desulphurization (FGD) achieves the goals of this system, for sea-water FGD systems. This study conducts a series of simulations or experiments using sea-water at a flue gas combustion plant to identify the advantages and disadvantages of, and related parameters for designing and operating FGD in the future.

#### 1.2 Research objectives

1. Flue gas from a combustion plant is used in a series of experiments. The pre-water method has both advantages and disadvantages associated with relevant parameters.
2. To estimate the amount of tail water and solve the problem of disposing of large amounts of tail-water. To further tail water recycling research and development, one must simultaneously achieve the dual objectives of FGD and the creation of water resources.

### 2. Literature review

#### 2.1 Flue gas desulfurization processes

Flue Gas Desulphurization is divided into wet, dry, and semi-dry methods (2). The wet method is the most efficient and most commonly used method. The wet method uses absorbent desulfurization processes that differ from other processes, which typically use lime, limestone, magnesium hydroxide, sodium carbonate, water, and double-base.

##### 2.1.1 The seawater method uses sea-water that contains some Trona and SO<sub>2</sub> flue gas

The alkalinity of seawater is primarily influenced by calcium, magnesium, carbonate, and other related compounds. The pH of sea-water was 7.5 and 8.5. It can be neutralized with SO<sub>2</sub> during a reaction.

During seawater desulfurization, water is the primary absorber. Adding a small amount of NaOH or Mg (OH)<sub>2</sub> increases the effect, or alters the process than the final pH of sulfur water. The activity of pure water is as follows.

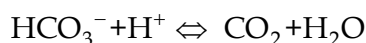
a. Absorption reaction

Flue gas of  $\text{SO}_2$  and water vapor from liquid dissolves into sulfite and hydrogen ions, resulting in fluid absorption at a pH of roughly 3.



b. Neutralization reaction

Bicarbonate ions in seawater and hydrogen ions in the carbon dioxide and water reaction, increase the pH of.

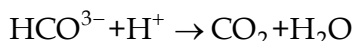
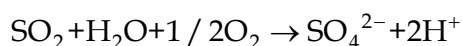


c. Oxidation



Although the oxidation reaction at low pH values (roughly  $\leq 4.5$ ) of the low efficiency of water requirement, yet the pH can increase to roughly 5.6. Additionally, aeration functions can eliminate  $\text{CO}_2$  from the water, thereby increasing pH during the neutralization reaction.

d. Total reaction



The seawater treatment process resembles the conventional wet process in that water and smoke are in contact in the reverse direction. The kinds of the process are filled with different types, such as the spray-type and layer different types of absorber plate. As water absorbs  $\text{SO}_2$  after the acidic ( $\text{pH} \approx 3$ ), adding large amounts of water before increasing the pH facilitates the following aeration reaction:  $\text{SO}_3^{2-}$  is oxidized to  $\text{SO}_4^{2-}$ , and discharge the dissolution of  $\text{CO}_2$ .

### 3. Seawater desulphurization process assessment

#### 3.1 Business transfer performance

In the 1970s, the University of California at Berkeley first used seawater to remove  $\text{SO}_2$  from flue gas. In 1978, Fujikasui, a Japanese researcher, used seawater to in an FGD system at a chemical plant. In 1988, ABB, a company, used seawater in an FGD system at an oil refinery in Norway(4).

#### 3.2 System evaluation

Packing and orifice-plate systems in a field simulation test verified that pure seawater can remove up to 90% of  $\text{SO}_2$  flue gas from combustion-fired units. The two sulfur tower designs have different advantages and disadvantages. For example, a packing system requires an absorber tower with a large volume.

Although the packing system clogs easily happen, the amount of seawater needed is reduced, resulting in energy savings; conversely, the orifice uses an absorber tower with a smaller volume and does not clog easily, however, this requires more seawater (4).

## 4. Experimental method: The seawater FGD process

### 4.1 The selection of a seawater FGD system simulation

According to the assessment of in Section 3.2, the processes that use different water desulfurization have both advantages and disadvantages. In this study, the selection of a seawater FGD orifice plate depends on the following factors.

Although the FGD system electrostatic precipitators (ESP), a small amount of fly ash flows into the desulfurization tower, such that the desulfurization tower can clog after long-term operation.

### 4.2 The orifice-plate type seawater FGD simulation system

The primary component of the system is a desulfurization tower tank, which is divided into a demisting zone, an SO<sub>2</sub> absorption zone (spray zone), and water oxidation zone. Water from a pump in the water tank tower into the desulfurization tower at the top of the absorption zone, and flue gas driven by a fan enters the bottom of the desulfurization tower tank. Gas from the bottom up, seawater from the top down, Seawater and gas in the orifice of the perforated plate then contact and SO<sub>2</sub> is absorbed by the seawater, such that the treated flue gas is emitted from the top side of the demister zone.

### 4.3 Desulfurization tests results

The concentration of flue gas SO<sub>2</sub> is controlled at 50-250ppm, The tested seawater is seawater from the first condenser. Figure 1 shows the simulation device. Figure 2 shows the absorption area in the orifice-plate. During the test, the flue gas flow rate is 1-3 m<sup>3</sup> / min; the water flow rate is 10-40 ft<sup>3</sup> / min; and the gas-to-liquid G/L ratio is controlled at 5 and 20.

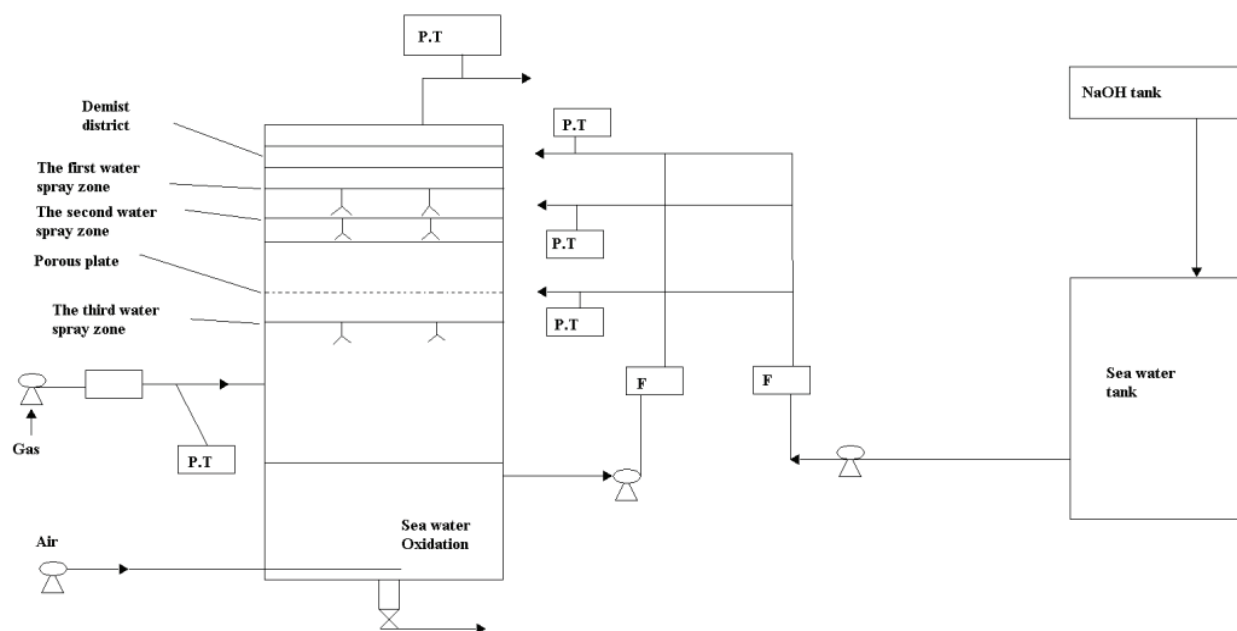


Fig. 1. The orifice-plate style seawater flue gas desulfurization simulation system

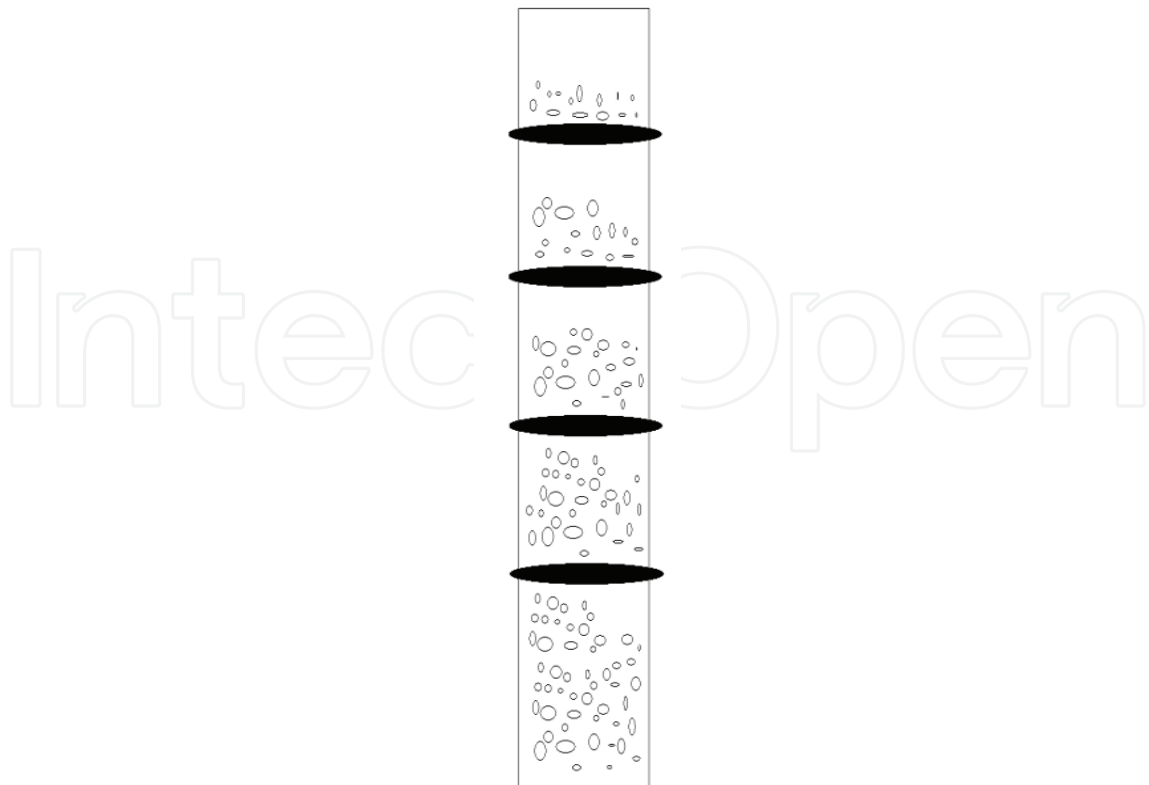


Fig. 2. The situation of gas-liquid mixture in the simulation test of desulfurization tower

#### 4.3.1 Batch seawater desulphurization results

To reduce the amount of seawater used (and reduce pumping energy and the amount of waste-water), some seawater can be reused. The design cycle typically depends on the change in seawater pH and desulphurization efficiency. Via the seawater desulfurization circulation test (a batch test was adopted, and no seawater was discharged), one can identify the relationship between changes in seawater pH and desulphurization efficiency. Figure 4 and 5 list experimental results from two desulfurization tests ( $G/L$  ratio = 10-20). Experimental results show that desulfurization efficiency and the pH of exiting seawater decreased as reaction time increased. Experimental results also show that the amount of alkaline compounds in seawater decreased as reaction time increased. The alkalinity of the exiting sea-water convert to Fig. 3. Desulfurization efficiency and water pH are positively correlated. This experimental result indicates that a high residual water pH and large amounts of alkaline compounds lead to higher desulfurization efficiency. The exiting seawater can keep desulfurization efficiency at  $\geq 90\%$  under a seawater  $pH \geq 6.0$  (Fig. 3).

#### 4.3.2 Test results of continuous seawater desulphurization

When the system is operated continuously, the reflux ratio (reflux ratio  $R = (\text{water flow recovery} / \text{raw water flow})$ ) can explain returning water usage. Figure 6 and 7 show the control loop volume from test results. Experimental results show that as the reflux ratio increased, the pH of exiting seawater decreased, and the amount of alkaline compounds in seawater decreased during the reaction. Adding a relatively smaller amount of fresh seawater reduced desulfurization efficiency; thus, the reflux ratio should not be  $>$  during operation. When the reflux ratio was controlled at  $\leq 1$  (inclusive) (Figure 6 and 7), the pH of

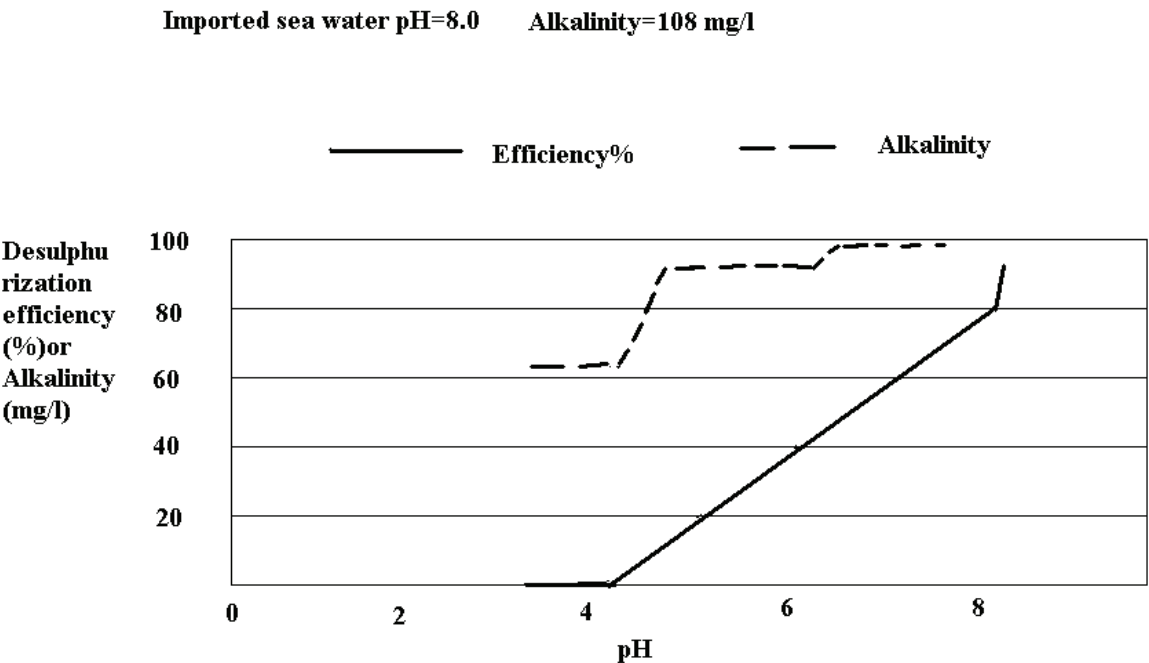


Fig. 3. The pH and alkalinity of exit seawater and desulphurization efficiency diagram

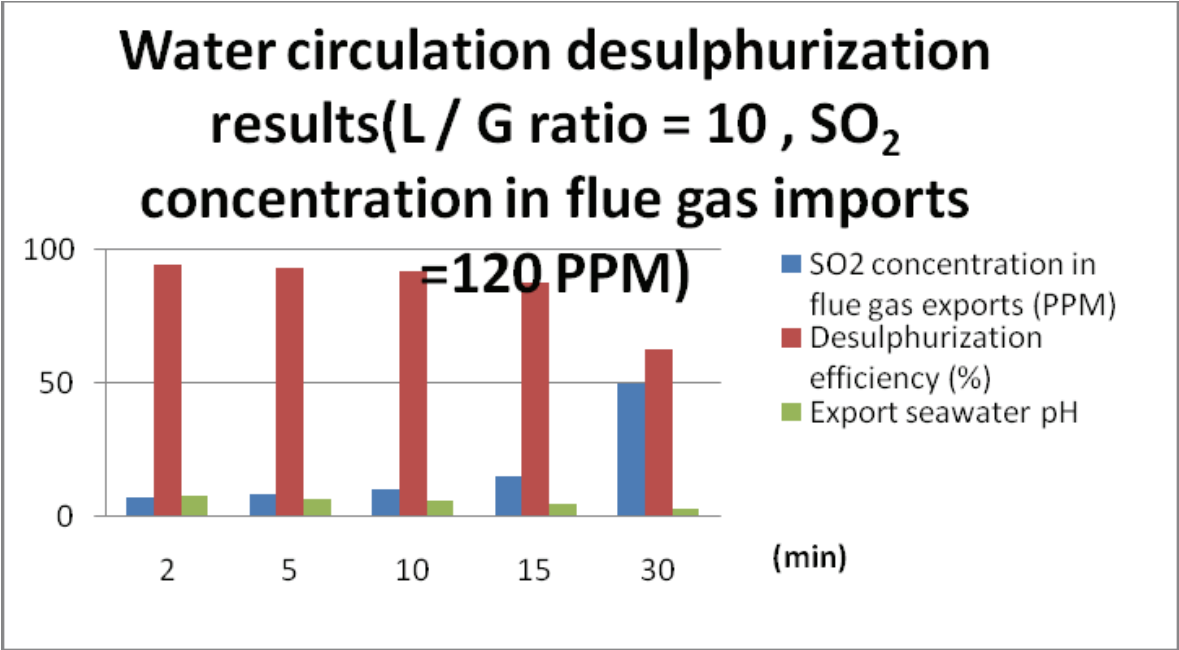


Fig. 4. The seawater circulation desulphurization test results

exiting seawater was kept at > 6.0, resulting in a desulphurization efficiency of ≥ 90%. However, the reflux ratio should be < to reduce seawater usage (which can reduce pump energy and the amount of wastewater used). In summary, the orifice-plate seawater FGD system is an effective system.

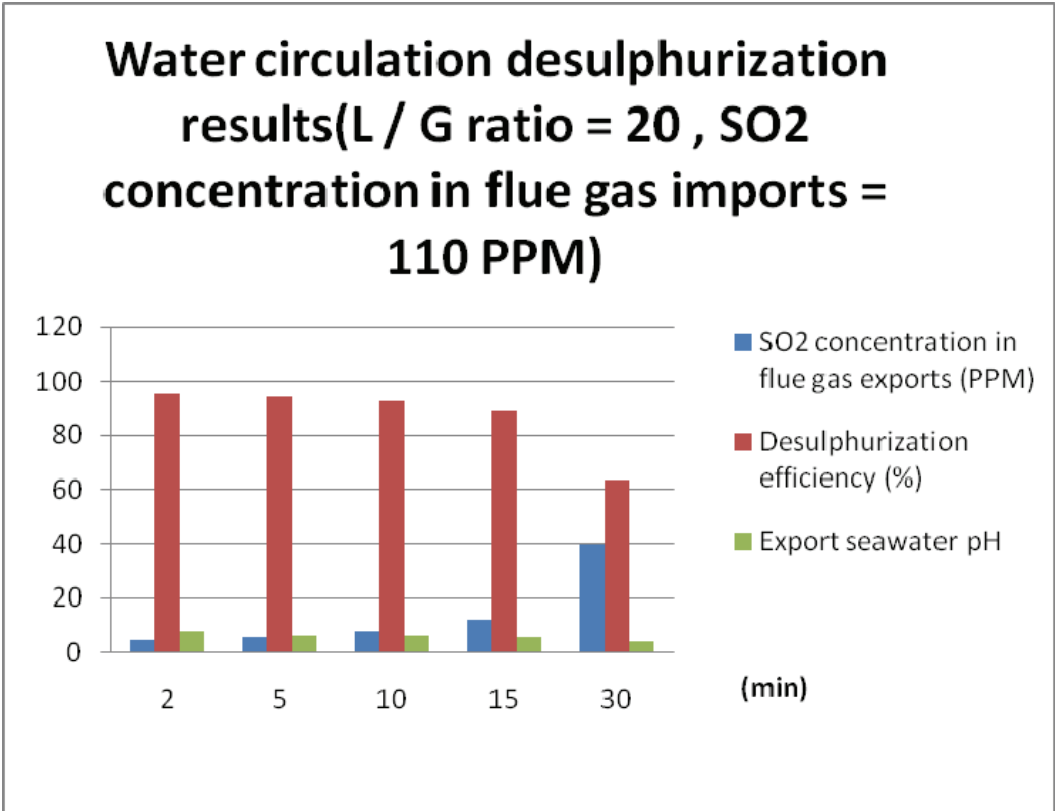


Fig. 5. The seawater circulation desulphurization test results

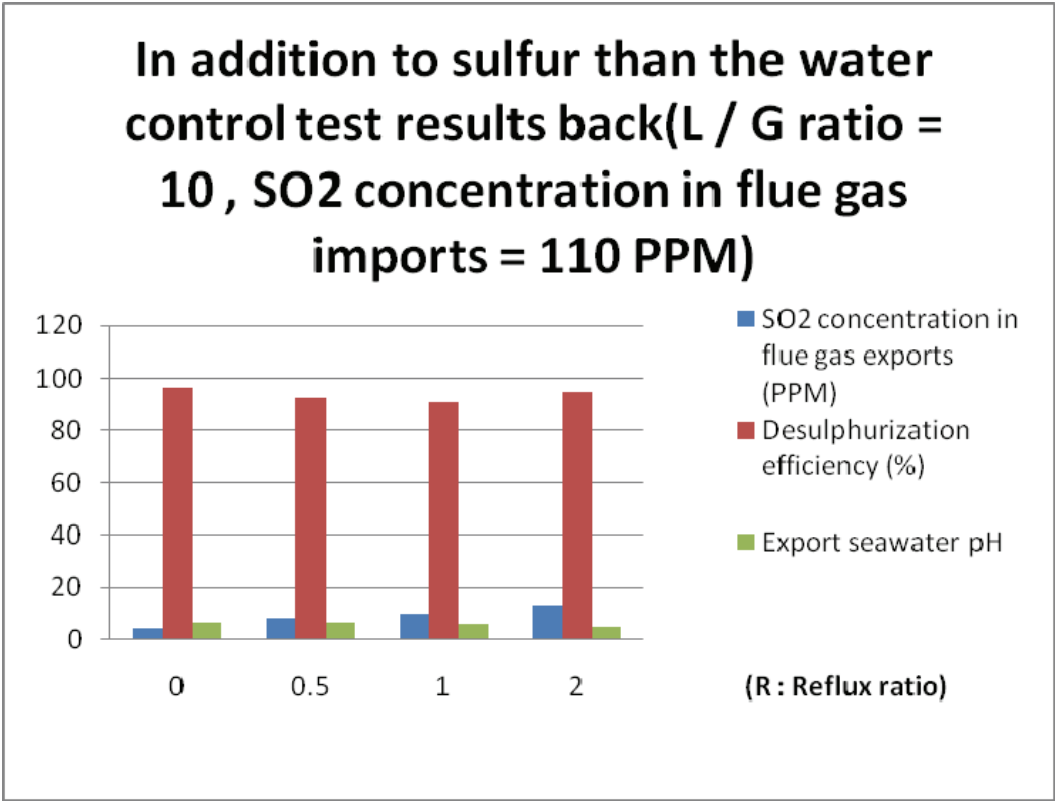


Fig. 6. The results of controlling seawater reflux ratio desulfurization test

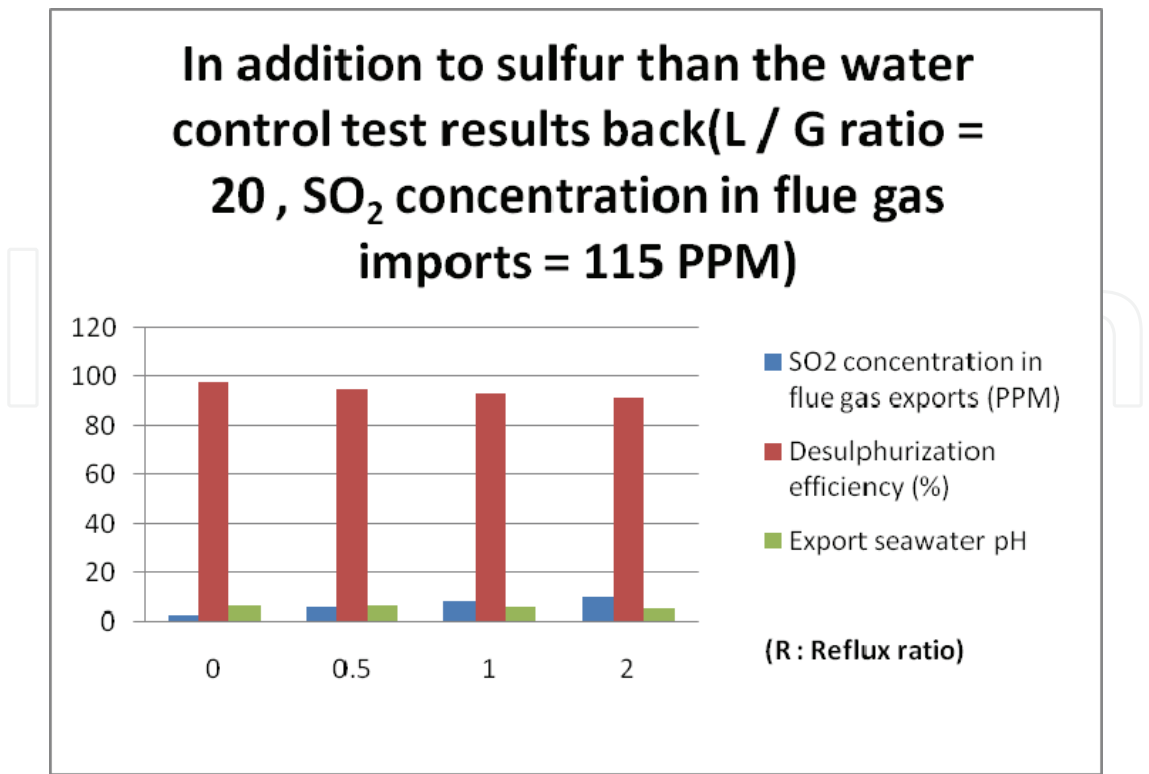


Fig. 7. The results of controlling seawater reflux ratio desulfurization test

4.3.3 Tubular seawater desulphurization results

In the tubular (one-through) seawater desulphurization process, original seawater passes directly through the desulfurization tower instead of being recycled. As the tubular process is used for fresh seawater desulphurization, all alkaline compounds in seawater are in the highest state; thus, a good desulfurization result is expected. Table 1 shows simulation test results. Experimental results confirm that the tubular (one-through) seawater desulphurization process yields excellent desulphurization results. With a G/L ratio > 13, the desulphurization rate exceeded 99%. General designs of often recycle seawater, have G/L ratios of 20 and desulphurization efficiency > 90%.

The entrance flue gas SO2 PPM concentration	L / G ratio	The exit flue gas SO2 PPM concentration	Desulphurization efficiency %	The pH of exit seawater
150	10	5	96.6	6.5
150	13	1	99	6.4
150	17	< 1	> 99	6.5
150	20	< 1	> 99	6.4

Table 1. The seawater desulphurization tubular (one-through) test results listed as follows

4.3.4 Evaluation and selection of a seawater desulphurization system

The best seawater desulphurization process is orifice-plate type. According to test results, desulfurization rate of the orifice-plate-type easily reached as high as 99%. However, the



tubular (one-through) system has a higher desulfurization efficiency, is easier to design, and has a lower installation cost than other designs. The G/L ratio depends on desulphurization efficiency. When the G/L ratio was 10, was 95%; conversely, when the G/L ratio was 15, desulphurization efficiency exceeded 99%.

## 5. Conclusions

1. The orifice-plate type simulated seawater desulphurization equipment, toward a coal-fired (EP) unit exit flue gas, proceeding the field simulation tests for seawater desulphurization. The G/L ratio, desulfurization seawater reflux ratio, number of porous plate boards, area of the perforated plate, the porous plate before and after changes in gas pressure, and the influence of changes in the height of the gas-liquid mixing layer are discussed. After appropriate adjustments, the design achieved a desulphurization efficiency of 99%. This experimental result can be used as the basis for designing and seawater desulphurization systems in power plants.
2. According to test results, the orifice-plate desulphurization system clogs less, has a better desulfurization efficiency, and requires a smaller desulfurization tower than the filling. Based on its economic advantages and limited plant area, the orifice-type is the best seawater desulphurization process for combustion power plants.

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## 7. References

- [1] Intellectual Resources, "FGD Water Recycling Feasibility Study", Taiwan Power Company report, Republic of China on December 92.
- [2] Hermine N Sound, Mitsuru Takeshita "FGD Handbook", IEA Coal Research, 1994 .2.  
Hermine N Sound, Mitsuru Takeshita "FGD Handbook", IEA Coal Research, 1994
- [3] Xu gold, "Power Plant Flue Gas Desulfurization Project Description", Engineering, 2000.
- [4] Katsuo Olikawa, Chaturong yongsiri, Kazuo Takeda Tayoshi Harimoto, "Seawater Flue Gas Desulfurization: It's Technical Implications and Performance Results", Environmental Progress, Vol. 22, No. 1, April 2003.



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