ANALYSIS OF THE CURRENT STATUS OF THE OPERATION BEYOND THE DESIGN PRODUCTION CAPACITY

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Abstract: In 1994, the vacuum salt production line with capacity of 300,000 tons was put into operation in CNSIC Haolong Pingdingshan Branch Co., Ltd. Its production capacity, and process design took the lead at that time among the domestic enterprises. After several years of production, in order to achieve breakthroughs in design and capacity, the company has taken a great deal of technical innovation and achieved good results. In this article, the technical measures taken by the Haolong to achieve the breakthrough in the production capacity are summarized and discussed. Our views on the production balance are discussed to provide reference for the salt industry colleagues.

Key words: productivity; balance of production; technical innovation

1. INTRODUCTION

The production line of CNSIC Haolong Co., Ltd. (the original Pingdingshan salt) with an annual output of 300,000 tons started its construction in 1992. Its engineering and design were carried out by Zigong Design Institute. This production line is the first one that uses anti-evaporation cycle process. It had a designed annual production capacity of 300,000 tons of refined salt. The characteristics of the process included advection for feed flow, co-current flow for salt vent, combined vapor and power production, vacuum salt production with four effects and concentration effect. Since commissioning, production capacity has increased year by year, and has now exceeded the design capacity. 2000, with an annual output of nearly 360,000 tons of salt. In 2001, output reached 370,000 tons and in 2002 reached 388,000 tons. In 2005, the output reached the highest value of 47.5 million tons that is 58.33 percent higher than the design capability. In order to summarize experience together, we introduced the situation of the production as follows.

2. EFFORTS TO CONTROL THE KEY FACTORS OF PRODUCTION IS THE MAIN WAY TO INCREASE THE PRODUCTION CAPACITY

We all know that the main impacts of the vacuum salt production can be summed up in three aspects: 1, the effective production time; 2, the concentration of brine; 3, evaporation intensity of the evaporator. They are a combination of factors, but in the production process the situation often tends to undermine the stability of these areas. Analysis indicates that the reasons are not only a result of technology, but also on the lack of production management.

2.1 Capacity of production is directly proportional to the effective time

In the design, the production time is based on the effective performance of equipment, production conditions and characteristics of the technology requirements. However, in practice, there are also the failures of production of equipment, power, the supply of brine and the unscheduled factors that cause shut down. From our company's

production over the past few years, as long as the adoption of technology innovation, improvement some of the key equipment, and at the same time reasonably practical arrangements for the production plan, the normal stopping time can be shortened, so that any unexpected disruptions that causes loss of time can be reduced to a minimum. The production time in our company is 7200 hours for a whole year. Through several years operation, the effective production time of our company has increased year by year. Since 1994, the actual production of crude salt and production time are shown in the table below:

Table 1 1995 -2005 annual output and the effective production time

Year	Annual production (tons)	Annual effective production time (hours)	Average hourly production (tons)
1995	220518.74	6243	35.3
1996	183399.00	5273	34.8
1997	200307.42	5460	36.7
1998	300333.75	7249	41.4
1999	313371.05	7414	42.3
2000	359576.25	8013	44.9
2001	370695.55	7998	46.4
2002	388201.65	7960	48.8
2003	405681.47	8092	50.1
2004	437720.91	8365	52.3
2005	475279.82	8532	55.71

From the table, the actual production time reached and exceeded the designed effective production time, and the productivity also began to reach and exceed the design value. At the same time, it can be seen that the average hourly productivity increases as the actual production time increases.

Certainly, the effective production time is not only related to the actual production time but also related to the continuity of production. The discontinuous production causes waste of a great amount of materials. In the first three years of the operation of the process, there were frequent accidents and shut down, resulting that the effective production time is far lower than the designed production time. The problems include: firstly, the key equipment of circulating pump for salt production. If the circulating pump does not run normally, the mechanical seal will be damaged which will cause leakage. When the process is in normal operation, the process will have to be shut down because of the leakage of a effect. The circulating pumps of the main steam emptying cans have to be replaced and this will cause 6-8 hours. Sometimes, two or three circulating pumps have to be replaced in one month. In view of this, we replace the circulating pump during the washing of the cans in every month. The compulsory replacement of the circulating pumps avoids the sudden accidents. Secondly, the boiler can not run normally. In our company, we originally have only two 35 tons chain furnace. According to the actual requirement, the steam supply should be around 60 tons per hour. Because the chain furnace runs for long time and cannot stop to be maintained, accidents happen frequently. Often only one furnace works normally. In order to meet the steam requirement, the furnace is often overloaded, causing coke of the furnace coke, grate deformation, and .frequent accident of the fans. The problem of inefficient heat supply can not be solved for a long time. In view of this situation, our company installed a new 35 tons of boiling fluid bed furnace which was put into use in the same year. In this way, one of the other two furnaces can be shut down to

be maintained thoroughly and the steam requirement is met. Thirdly, the plan of maintenance and washing of the cans was made to prevent the sudden accidents. According to the actual situation, our company makes it a rule to wash the can once a month. During the time of shut down, the key valves (such as feed valve and switch valve) and the pipes were examined and replaced. The bearings of the key equipment should also be replaced during the shut down time, especially for the single equipment. The preventative maintenance avoids the sudden accidents, provide conditions for continuous production, and gains effective production time.

2.2 The effect of the brine concentration on the productivity of evaporation equipment

The designed salt content of the brine is 280 g/l. Over the past few years, the salt content of the brine has increased to 310g/l through technological innovation. See Table 2:

Table 2 1995-2005 the salinity of brine

year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
The average salinity (g/l)	280	288.8	291.7	302.7	305.8	313.2	315	310-320	310-320	310-320	310-320

As can be seen from the table, the change of the brine concentration is an important reason why the productivity of our company is higher than the designed value. In our company, the brine is the convection in a single well. After efforts of the technical staff, the single well fracturing technical has been changed to convection of dual well. Three fracturing wells have been successfully completed which increased the salt content remarkably from 290 g/l to around 310 g/l. This is the significant change brought by the technological innovations.

2.3 The vacuum salt production capacity and production intensity are the indicator of the economic performance of the evaporation equipment. According to the equation of the productivity:

$$V = \frac{k\Delta t}{r^1}$$

In the equation: V-intensity of production; k-total heat transfer coefficient;
$\triangle$t-heat temperature difference; r^1-heat of vaporization
As can be seen, in order to increase the production intensity of the evaporator, we have to try to increase the total evaporator heat transfer coefficient k and the total heat transfer temperature difference $\triangle$t.
2.3.1 the total heat transfer temperature difference $\triangle$t depends primarily on the steam pressure difference between the heating steam and the condenser. The greater the pressure difference, the higher the productivity of the evaporation system which means higher temperature difference. Table 3 shows the steam pressure and vacuum variation used by our company in these years.

year	1995	1996	1997	1998	1999	2000	2001
Steam pressure (MPa)	0.23-0.27	0.20-0.25	0.18-0.23	0.25-0.28	0.25-0.28	0.27-0.32	0.30-0.33
End Vacuum (KPa)	90-93	86-88	87-90	86-88	83-85	89-91	91-92.5

As can be seen from the table, over the past few years, in order to achieve efficient temperature difference, our company adopted the method of increasing the steam pressure within the range required by the technology. The pressure was increased 0.14 MPa, from 0.20 MPa to 0.33 MPa. With a constant heat transfer coefficient, the increase of the effective temperature difference means the increase of the heat load per vaporization area and the evaporation ability also increases.

Although the effective temperature difference can be increased by increasing the steam pressure, this method should not be adopted, because the steam pressure must be in the range required by the process. Increase of steam pressure will speed up corrosion and coke. Consequently the heat efficiency decreases and other adverse consequences are caused. (Literature indicates that the rate of equipment corrosion increase 0.6-1 times for a temperature increase of 10 ℃) And at the same time, problems may be brought to the safe operation.

Another effective method to increase the effective temperature difference should be increasing the vacuum of the last effect. Our company has improved the cooling tower for three times. The feeding type nozzle was firstly changed to rotating nozzle and then changed to atomizing nozzle with fixed post. In 2003, a circulating water twice cooling system was added to decrease the cold water temperature. Using this method, the last effect vacuum was increased from 0.090 MPa to -0.093 MPa (winter). In 2004, we changed the two water circulating vacuum pump to 3+2 Roots vacuum blower (two vacuum pumps and three Roots blowers). The last effect vacuum was increased to higher than -0.094 MPa (winter) and the effective total temperature difference was increased further.

2.3.2 Maintain relatively high heat transfer efficiency. The efficiency of the heat transfer can be described by the heat transfer coefficient. The overall heat transfer coefficient k depends on the convection heat transfer coefficient, the heat resistance and the fouling resistance. In our company the brine is gypsum-based brine. This impurity has a kind of inverse solubility. The brine is easy to scale on the internal wall of the heating tank. Especially for III effect, the thickness can be as high as 1mm. This will decrease the evaporation intensity and the productivity. One or two months after acid washing, scale appears again. This is almost periodic. In 2001, the thickness of the scale on the internal wall of the III effect heating tank was shortened to two months. We organized relevant technicians to analyze the phenomenon. Finally, the decreasing of the velocity in circulating pump was believed to be the main cause. In 2002, the circulating pump was improved and novel circulating pump with high efficiency was used. After operation of 6 months, the scaling phenomenon did not happen again. Moreover, there was an increase of 50-60 tons in the productivity and the maximum value reached 1390 tons per day.

3. TECHNOLOGICAL INNOVATION IS AN IMPORTANT METHOD TO INCREASE THE PRODUCTION CAPACITY

The innovation to improve the equipment, process and materials. Our company originally used carbon steel as the material of the main equipment and pipes. Though the cathodic protection was used at that time, but the equipment still could not withstand the pH changes in the feeding brine and the corrosion effect of the salt material. Hence, the circulating pipe and switch pipe are eroded seriously. The leakage is heavy and frequent maintaining is required. In order to solve the corrosion problem, we changed the material of the circulating pipe to 316L stainless steel and changed the material of valve from the carbon steel to stainless steel. We also changed the bearing of the key equipment to imported SKF bearing. Through the improvement above, the operation period of the equipment and the effective time were increased and the productivity increased.

3.1 Reform the process

3.1.1 Restoring the first, the second, and the third level pre-heaters

Pre-heater makes full use of the waste heat. The use of the pre-heater directly affects the efficiency of the heat transfer. At the same time, the pre-heating temperature also affects the evaporation capacity. In order to increase the feed brine temperature, we changed the preheating of V effect, III, IV effect cooling

water, III effect exhausted steam pre-heater to the two-stage II effect twice steam device. Therefore, the temperature of the feeding brine increased to higher than 70℃. This definitely increases the vaporization intensity and capacity. However, the scaling of the pre-heater is more serious than that of the vaporization tank. We adopted high pressure washer to clean the scale periodically. The use of the two-stage II effect twice vaporizer was our another method to enhance the heat transfer efficiency and productivity.

3.1.2 Improvement of mother liquor recovery system. The recycle flow of the salt slurry cyclone was originally designed to be sent back to IV effect and had been changed to II effect vaporization crystallization. Hence, the continuity of the salt venting of II effect was improved.

3.1.3 In order to control the gypsum content in III, IV effect, the dead end pipe was installed for gypsum venting. By venting the gypsum through the dead end pipe, the stability of the gypsum content of the tank was improved and the problem that the gypsum was hard to control was solved.

3.2 Match the equipment well and improve the equipment.

The circulating pump of evaporation system was updated, and changed to novel circulating pump. The dewatering centrifuge system which was originally the cone type was changed to the domestically advanced type of P60 centrifuge. In 2004, we successfully introduced a P80 centrifuge made in Switzerland. Consequently, the bottleneck problem that the capacity of the dewatering process was inefficient was solved. In order to meet the requirement of the drying system with capacity of 60 tons per hour, we changed the originally designed vibrating fluidized bed to novel internally heating bed. The drying capacity was as high as 70 tons/hour. A series of improvement of the equipment provided a solid foundation for the gaining high process stability and productivity of our company.

4. CONCLUDING REMARKS

Over the past few years of production practice, we have achieved productivity higher than the designed level. However, comparing with other companies in our country, our production technology and capacity are still low. The purpose of this introduction of the situation of our company is actually to learn from other companies and provide some ideas and methods to increase the productivity.

Reference

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