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ME与MVR制盐工艺比较及兼容结合的设想

Comparison and compatibility of ME and MVR salt making technology

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摘要：本文对ME和MVR制盐工艺进行了简要的分析和运行比较，得出了ME与MVR是各有所长，无法相互取代的两种先进制盐工艺模式的结论。并提出了一种ME+MVR取长补短，兼容并存，创新结合的制盐工艺模式的设想。

关键词：ME、MVR、蒸发工艺、分析、比较

Abstract: In this paper, the ME and MVR salt production process and operation are compared. It’s concluded that both ME and MVR are advanced salt making technology, and have its own advantages, and can’t be fungible by each other.　Thus a new innovative idea of salt making is proposed to combine the advantages of ME and MVR. This idea could show the compatibility for both technology.

Keywords: ME, MVR, evaporation process, discussion and comparison

一、前言

Preface

蒸发是制盐的主要过程。

Evaporation is the main process of salt production.

不论是从海水、盐湖卤水还是井矿盐卤水中制取固体氯化钠，必须

通过蒸发浓缩才能让氯化钠结晶析出。历史上的 “煮海为盐”、“垦畦营种”、“刮土淋卤”、“燃薪熬盐”，以及现代的多效真空蒸发（ME）、蒸汽机械再压缩(MVR)制盐工艺技术，其实质都是通过蒸发浓缩让氯化钠饱和结晶析出。制盐技术的进步发展，其本质就是蒸发工艺的进步发展。

The preparation of solid sodium chloride from sea water, Saline Lake brine or well mineral halogen water must be concentrated by evaporation so that the crystallization of sodium chloride can be precipitated. The history of "boiled seawater for salt", "lake water solarizaiton for salt", "saline soil scraping and elutriation", "wood burning for brine concentration", and modern multi-effect vacuum evaporation (ME), mechanical vapor recompression (MVR) salt production technology, the actual quality is through evaporation and concentration of sodium chloride to precipitate the crystallization of sodium chloride. The development of salt making technology is essentially the progress of evaporation technology.

我国制盐技术，特别是井矿盐区的深井钻凿技术，历史上曾居于世界领先地位。到了近代，伴随着工业革命的步伐，西方的制盐蒸发技术有了突飞猛进的发展。1887 年，LM.邓肯在纽约州第一次利用单效蒸发罐制盐，1899 年美国曼里斯蒂铁工厂（Manis tee lrom work）第一次采用多效真空蒸发制盐，使蒸发技术有了重大的变革。1885 年法国萨勒特(Salet)制盐工厂首次采用了热泵法进行了蒸发制盐的试验，1930 年，瑞士埃舍纳斯公司（Eschcr Wyssco）公司研发制造了离心式涡轮蒸汽压缩机，成功地利用蒸汽压缩机将蒸发产生的二次蒸汽压缩升

温，开了 MVR 蒸发制盐的先河。

China's salt making technology, especially the deep well drilling technology in well salt area, has always been in the leading position in the world. In modern times, with the pace of industrial revolution, the evaporation technology of salt making in the West has developed rapidly. In 1887, LM. Duncan used single effect evaporation tank to make salt in New York firstly. In 1899, the Manis tee lrom work (US lrom work) first used multi-effect vacuum evaporation to make salt, which made the evaporation technology significant changed. In 1885, the French salt factory of Salet used the heat pump method for the first time to carry out the experiment of evaporation and salt making. In 1930, the Swiss Eschcr Wyssco company developed a centrifugal turbine steam compressor, successfully using it to heat up the secondary steam produced by evaporation and it's the first reference of salt making by MVR evaporation system.

此时，我国制盐技术依旧停留在“平锅熬盐”的水平上。虽然 1939 年留学欧美的学者肖家干在自贡试验“灶用真空机”成功，取得专利后于 1942 年投资建厂，但由于技术不过关、资金短缺倒闭。不久西南盐业公司聘请著名科学家侯德榜为总工程师筹建真空蒸发制盐厂，也因资金不足，外汇难以筹措，成为了一个难园的梦。

In the same time, the salt making technology in China still stays at the level of "salt producing in the pan". Although Xiao Jiagan, a scholar who studied in Europe and America in 1939, succeeded in testing the "vacuum machine" in Zigong, and invested the factory in 1942 after obtaining a patent, he failed because of the lack of technology and the shortage of funds. In a later time, the southwest salt company hired a famous scientist, Hou de bang, as the chief engineer to prepare a vacuum evaporation plant. But due to the shortage of funds and difficult foreign exchange raise, this vaccum evaporation plant also became a difficult dream.

1958 年青岛永裕盐厂在留日学者，著名盐业专家吴鹿苹先生主持下设计的以海盐化水净化精制卤为原料的四效强制循环真空真空蒸发制盐装置投产，掀开了我国真空蒸发制盐的序幕。从此，我国的真空蒸发制盐装置从无到有从小到大，发展状大。目前，60 万吨甚至 100 万吨的五效真空制盐生产线不断投入运行。1986 年自贡张家坝 10 吨机械热压缩蒸发（MVR）制盐装置的引进，　2011 年中盐金坛的 100 万吨机械热压缩蒸发（MVR）制盐装置的建成投产，使我国制盐蒸发工艺又有了一种新的选择。不可否认的是，　ME 制盐工艺虽然在自主创新方面有了明显的进步，但很少有实质性的突破；MVR 制盐工艺技术，乃至关键设备如大型压缩机，仍然处于引进阶段。

In 1958, the foureffect forced circulation vacuum evaporation salt plant was put into production by the famous salt expert Mr. Wu Luping, a famous salt expert. It opened the curtain of the vacuum evaporation and salt making in our country. Since then, China's vacuum evaporation salt making equipment has grown from scratch to development. At present, 600 thousand tons or even 1 million tons of five-effect vacuum salt production line has been put into operation continuously. In 1986, the introduction of 10 tons mechanical thermal compression evaporation (MVR) in Zhangjiaba, Zigong, and the completion and production of 1 million tons mechanical thermal compression evaporation (MVR) salt making device of mid salt Jintan in 2011 have given new choice to salt evaporation process selection inour country a new choice. It is undeniable that, although the ME salt making technology has made obvious innovative progress, there are few substantial breakthroughs; MVR salt making technology and even key equipment, such as large compressor, are still in the introduction stage.

如何选择、探索出一条符合我国国情自主创新的发展道路，把我国制盐行业整体提升到国际一流水平，是我们必须深刻思考、认真探索的一个严肃的问题。

It is a serious problem that we must think deeply and earnestly explore how to choose and explore a development path which is in line with the national conditions of our country and to raise the overall salt industry to the international first-class level.

二、ME 与 MVR 制盐工艺

ME and MVR salt making process

2.1、ME 与 MVR 机理

Mechanism principle of ME and MVR

多效蒸发（ME）是将多个蒸发器连为一个操作系统，一般采用大气冷凝器使未效二次蒸汽急骤凝结，形成“真空”。使多个蒸发罐组中的蒸发压力，在正压与 “真空” 不同状态下实现依次压降移动，热量从高温向低温依次转移传递，各效蒸发罐组中液体的沸点随着压降形成递降沸腾蒸发、浓缩结晶的一种正压与真空并存的多效蒸发过程。

Multi-effect evaporation (ME) is to connect multiple evaporators as one operating system. Generally, the air condensers are used to make the secondary steam condenses rapidly and form a "vacuum". The evaporation pressure in the multiple evaporation tank group is moved in turn under the different state of the positive pressure and the "vacuum". The heat transfer from high temperature to low temperature is achieved. The boiling point of the liquid in each effect evaporator decreases with the pressure drop to form a kind of multi-effect evaporation process with the coexistence of positive pressure and vacuum coexistence of descending boiling evaporation and concentrated crystallization.

MVR 是蒸汽机械再压缩技术（mechanical vapor recompression ）的简称。是通过机械压缩，把低品位的二次蒸汽温位提高利用的一种蒸汽热量提升装置。其实质是根据波义尔定律原理，外加压缩机作功，压缩功瞬时转化为蒸汽的内能，使二次蒸汽的体积减小，压力、热焓、温度升高，作为热源代替新鲜蒸汽，反复循环使用，使液体沸腾蒸发、浓缩结晶的一种蒸发过程。

MVR is the abbreviation of the recompression technology of steam machinery. It is a steam heat lifting device that improves the utilization of low-grade secondary steam temperature by mechanical compression. Its essence is based on the principle of Boer's law, and the compression work is instantaneously converted into internal energy of steam, which makes the volume of the two steam reduced, the pressure, the enthalpy and the temperature rise, as a heat source instead of fresh steam, and the evaporation process of boiling evaporation and condensation crystallization of the liquid.

2.2、ME与MVR制盐工艺分析

Discussion of salt making process of ME and MVR

多效真空蒸发（ME）制盐，一般是以煤为燃料生产蒸汽发电，发电后的背压蒸汽再去蒸发制盐的一种热电联产的生产方式。热电联产相对于单纯发电的循环来说，降低了热效率，但由于蒸汽发电后，排出的低压、低温蒸汽又进行了蒸发制盐，蒸汽得到了多次利用。不仅为蒸发制盐提供了电力而且提供了热能，总的能量利用率显著提高。是一种电能、热能共用的热能多梯级综合利用的节能工艺模式。在煤炭资源相对丰富价格低的地区，优势是明显的。是目前我国乃至世界各国制盐业发展最快、普遍采用的工艺技术。

Multi-effect vacuum evaporation (ME) is usually produced by coal as a fuel to produce steam power generation, and then the back pressure steam is then evaporated to make salt. Compared with the cycle of pure power generation, cogeneration can reduce the thermal efficiency, but because of steam power generation, the low pressure and low temperature steam are evaporated, and the steam has been used many times. It not only provides electricity for evaporation of salt, but also provides heat energy, and the total energy utilization rate is significantly improved. It is a kind of energy saving technology mode of multi-level and comprehensive utilization of electric energy and heat energy. In areas where coal resources are relatively abundant and prices are low, the advantages are obvious. It is the most rapid and widely used technology in salt making industry in China and even in the world.

不可否认的是，随着效数的增加，设备投资、动力、运行费用都将增加，设备、管道的热损失也相应增加。而且，首效蒸发器至末效混合冷凝器的总温差是一定的，每增加一个效就使有效温度差损失8—10℃，超过一定的效数后，生产能力反而越低，节能效果也依次降低。同时，蒸发系统的总有效温差主要是通过使用大量的循环冷却水与末效二次蒸汽直接接触，使蒸汽迅速冷凝，蒸喷水喷机组或真空机组排除不凝汽，提高末效真空度来实现的。以中盐榆林为例，当地海拔高度约1000米，对应的蒸汽饱和温度为47℃，因此含有600余千卡/公斤热量的末效二次蒸汽不仅不能再利用，还需要大量的循环冷却水去降温冷凝。

It is undeniable that with the increase of efficiency, equipment investment, power and operation cost will increase, and the heat loss of equipment and pipeline will also increase correspondingly. Moreover, the total temperature difference between the first effect evaporator and the end effect mixed condenser is certain.Temperature difference is reduced by 8 to 10 C for each effect, and actually the production capacity is lower and the energy saving effect is reduced if exceeding several effects . At the same time, the total effective temperature difference of the evaporation system is mainly achieved by using large amount of cooling water to directly contact with secondary steam from end effect, thus the steam condenses quickly, together with NCG removal from steam/water spray devices and vacuum machine units, resulting the improvement the final effect vacuum degree.

Taking the China salt Yulin as an example, the local altitude is about 1000 meters, and the corresponding steam saturation temperature is 47. Therefore, the final secondary steam containing 600 kilos / kg of heat can not be used again, and a large amount of cooling water is needed to cool and condensate.

采取Ⅳ效还是Ⅴ效蒸发，采取正循环还是反循环工艺，采取顺流还是逆流、平流、错流流程，业界多有研究，同行多有实践，对此，不再赘述。

Whether or not using IV or V evaporation, positive or reverse circulation process, forward flow or reverse flowor advection flow or cross flow, many people in this industry have made researches and practices, hence these will not be discussed here.

蒸汽机械再压缩（MVR）制盐，一般采用电机或蒸汽透平机驱动压缩机，对二次蒸汽压缩，提升压力及热焓，去重新利用。

The steam mechanical recompression (MVR) salt production is generally used by the motor or steam turbine to drive the compressor. The secondary steam is compressed, thus its pressure and enthalpy are lifted and could be reused.

初始生蒸汽在加热室管外传热、放热冷凝，卤水在管程中吸热传热，蒸发沸腾产生的二次蒸汽，通过除沫后进入洗汽塔中，采用冷凝水进行逆流洗涤、消除蒸汽内夹带的盐份及其他微量杂质后，由压缩机吸入增压，汽温提高，作为加热热源进入加热室传热。启动运行后，只要二次蒸汽达到正常蒸发所需要的数量后，生蒸汽停止供给。压缩机将二

次蒸汽吸入，经增压后变为加热蒸汽，源源不断地将热量提供给卤水，进行反复循环蒸发。蒸汽换热后的冷凝水一部分作为二次蒸汽的洗涤水，一部分与卤水在板式换热器中进行热交换，去提高卤水初始进罐温度。

The heat of initial steam is transferred outsideof heating chamber tube and initial steam will condense after heat release. The brine absorbs heat in the tube process and secondary steam will be produced by evaporation . This steam will enter vapor washer after defoaming. Condensate is used for countercurrent washing in vapor washer, and salt and other trace impurities entrapped in the steam are eliminated. Then this secondary steam will be supplied to compressor and pressurized to increase the temperature. As a heating source, heat of secondary steam will transfer into the heating chamber. After start-up and operation, the steam will be stopped as long as secondary steam reaches the required quantity of normal evaporation. The compressor will take in secondary steam and make it heated by pressurization. It will continuously supply heat to brine for reduplicative evaporation. Part of the condensate is used as washing water for secondary steam, andpart of the water is fed to preheater to raise the initial temperature of feed brine.

MVR 是以补充一定的压缩功（耗电或耗汽）代替了消耗大量的加热蒸汽（耗煤）。与多效真空制盐相比，二次蒸汽得到了充分的循环利用，而且取消了大气冷凝循环冷却水系统，节约了水和电。同时，由于工艺路线较短，生产过程的设备、管道热损失相对少得多。节汽、节能

的效果是显而易见的。MVR 流程相对较简洁，自动化程度高、蒸汽利用率高、热损失少、节能环保。以电驱动压缩机的 MVR，真正可以做到节能、净洁、环保生产，在水电、核电充裕的地区具有无可比拟的发展优势。

MVR is to replace a large amount of heating steam (coal consumption) by supplying a certain amount of compression work (electricity consumption or steam consumption). Compared with multi-effect vacuum salt making, the secondary steam has been fully reused, and condensation circulating cooling water system has been abolished, and water and electricity have been saved. At the same time, due to the shorter process route and lessheat loss of equipment and pipeline in production process, effect of steam saving and energy saving is obvious. MVR process is relatively simple, high degree of automation, high utilization rate of steam, less heat loss, energy saving and environmental protection. The MVR driven by electric drive can truly save energy, and it's clean and environmental friendly, and has unique development advantage in rich hydropower and nuclear power areas.

不可讳言的是，二次蒸汽的温升是以耗电或耗汽压缩作功，将机械能转换为蒸汽热能的。根据热力学第二定理可知，一切实际过程都具有不可逆性，从能量转换的角度来看，不可逆性意味着能量的贬值，可用能与功的损失。对于压缩机而言，吸入温度和要求的压升、温升，内效率，绝热效率，多变效率、与多方指数 κ 和吸入气体的摩尔质量 M，决定着压缩机的功率消耗。而各项效率只能达到 85－90% 左右。同时，原动机（电动机、透平机等）的实际耦合功率、机械损耗，也必须

考虑。如何尽量减少不可逆损失，提高效率，是需要仔细研究的问题。

It can not be denied that the temperature rise of secondary steam is by converting mechanical energy to steam energy under driven of electricity or steam compression. According to the second law of thermodynamics, all actual processes have irreversibility. From the point of view of energy conversion, irreversibility means the devaluation of energy and the loss of available energy. For the compressor, the suction temperature and the required pressure rise, temperature rise, internal efficiency, adiabatic efficiency, variable efficiency, multi-square exponential kappa and the molar mass of the inhaled gas M, determine the power consumption of the compressor. And the efficiency can only reach about 85 to 90%. At the same time, the actual coupling power and mechanical loss of prime movers (motors, turbines, etc.) must also be considered. How to reduce irreversible losses and improve efficiency is a topic that needs careful study.

2.3、ME 与 MVR 装置运行效果比较

Comparison of operation effect between ME and MVR device

以中盐榆林 100 万吨真空制盐生产线和中盐金坛 100 万吨机械再压缩制盐生产线为例，试对两种装置运行效果作一简单的分析比较。

Taking the 1 million ton vacuum salt production line of China Salt Yulin and the 1 million ton mechanical recompression salt production line of Jintan salt as an example, a simple analysis and comparison of the operating effects of the two kinds of devices are made.

中盐榆林 100 万吨真空制盐生产采用了自主研发的石膏型卤水“正

循环、轴向进料、平流补料、分效排盐、盐脚淘洗热量回收、石膏晶种防垢、顺流集中排石膏”的五效蒸发工艺。采用卤井下处理的方式，除去 $CaSO_4$+ $CaCl_2$ 卤水中的 $CaCl_2$ 后进罐制盐。母液分离石膏后，经简单处理回制盐再次利用。2011 年 11 月底投入运行，基本实现了汽电平衡生产。

The production of 1 million tons vacuum salt production in China Salt Yulin adopts the five-effect evaporation process of "positive circulation, axial feeding, advection feed, separation of salt, salt foot cleaning heat recovery, gypsum crystal seed anti scaling, and flow centralization of gypsum". Using pretreatment to remove $CaCl_2$ from $CaSO_4$+ $CaCl_2$, feed brine is then sent to crystallizer for salt production. After the mother liquor was separated from gypsum, the salt was reused again after simple treatment. At the end of November 2011, the steam power balance production was basically realized.

装置全部选择了国产设备、材料。炉、机、电选择标准型配置。循环流化床锅炉（型 号 CFB-130/3.82 额定蒸发量 130t/h；出口蒸汽压力 3.82mpa 出口汽温 450℃），配 12MW 背压式汽轮发电机组（汽机型号 B12-3.43/0.49，发电机型号 QF-12/15-2）蒸发罐加热室总加热面积 10250㎡ (单效加热面积 2050㎡)。

All the equipment and materials were selected from domestic brands. Standard configurations are selected for furnace, machine and electricity. Circulating fluidized bed boiler (model CFB-130/3.82 rating evaporation capacity 130t/h; outlet steam pressure 3.82MPa outlet steam temperature 450), with 12MW back pressure turbine generator unit (turbine model B12-

3.43/0.49, generator model QF-12/15-2). Total heating area of heating room of evaporator is 10250m2 (heating area 2050m2 for single effect).

2014 年有效生产时间为 338 天，实际产量达 124 万吨。

In 2014, the effective production time was 338 days, and the actual output reached 1 million 240 thousand tons.

中盐金坛 2009 年引进国外的 100 万吨 MVR 盐硝联产制盐技术，2011 年投入运行。卤水经净化后经多级预热依次进入热压罐、节能装置和制盐蒸发罐。热压罐产生的二次蒸汽经除沫、减温洗汽、进入洗汽塔二次洗汽净化后进入压缩机压缩增温再进入热压罐循环多次利用。制盐含硝母液经预热器预热后进制硝蒸发罐结晶，母液再次返回制盐蒸发罐制盐。

In 2009, Jintan salt imported 1 million tons of MVR NaCl and Na2SO4 coproduction technology, and put into operation in 2011. After being purified, through multistage preheating, the brine enters the hot pressing tank, the energy saving device and the salt evaporation tank. The secondary steam produced by the hot pressing tank, after defoaming, temperature decreasing and washing, enter into vapor washer for second time purification, and then enters the compressor for pressurization, in order to be reused many times in hot pressing tank... The mother liquor including Na2SO4 is preheated by preheater and then goes into Na2SO4 crystallizer for crystallization. Its mother liquor is returned back to NaCl crystallizer.

主要装置如压缩机、循环泵、离心机等从国外引进；蒸发罐、加热室等容器类设备采用国外技术国内制造。

The main devices such as compressors, circulating pumps, centrifuges and so on are imported from abroad; evaporator, heating rooms, etc. are made of foreign technology and made in China.

主要能耗指标、制造成本比较表：

The main energy consumption index and manufacturing cost comparison table:

能　耗 Energy consumption	中盐榆林五效 ME 制盐 Five-effect ME salt production China Salt YuLin	中盐金坛 MVR 制盐 MVR salt production China Salt JinTan
蒸发能耗 Kg ce//t 盐 Evaporation energy consumption **Kg ce//tSalt**	65	59
综合能耗 Kg ce//t 盐 Comprehensive energy consumption **Kg ce//tSalt**	75	80
能源动力成本 元/ t 盐 Energy power cost RMB/tSalt	36	80
综合制造成本 元/ t 盐 Comprehensive manufacturing cost RMB/tSalt	116.63	133

注：金坛能耗指标、制造成本数据来自参考文献（3）

Note: Jintan's energy consumption index and manufacturing cost are derived from references.(3)

从上表可以看出，MVR 蒸发能耗低于 ME。但由于中盐榆林卤井深2800m，地热优势明显，通过卤水井下处理，输卤管道、贮罐保温，使供给制盐的原卤温度达 50℃，充分利用了卤水的地热能。同时在卤水、母液处理输送等环节中，利用位差自流进罐，节能效果明显，故综

合能耗低；榆林当地煤炭价格低，与用电驱动的热泵相比，能源动力成本、综合制造成本也较低。通过分析、对比，笔者认为 ME 与 MVR 各有所长，是无法相互取代的两种先进的制盐工艺模式。那种假定二次蒸汽为废弃物，进而研究得出的论断是不够科学严谨的；以引进国外最前沿的 MVR 制盐工艺与运行多年的 ME 制盐工艺做比较也有失偏彼。

As shown in above table, the energy consumption of MVR evaporation is less than ME. However, because of the deep 2800m of the halogen well in Yulin, the geothermal advantage is obvious. Through brine pretreatment down in the well, warm insulation for pipelines and storage tanks, this could make brine temperature reach 50℃, and the geothermal energy of the brine is fully utilized. At the same time, for brine and mother liquid treatment, gavity flow between tanks is designed, thus the energy saving effect is obvious, hence comprehensive energy consumption is low.Also local coal price in Yulin is low, its energy power cost and comprehensive manufacturing cost is also low, compared with the electricity driven heat pump. Through discussion and comparison, the author thinks that ME and MVR have their own strengths and are two kinds of advanced salt making technology models which can not replace each other. The hypothesis that the secondary steam is a waste is not scientific and rigorous. The comparison between state-of-art MVR salt making technology introduced abroad and ME salt making process which has been operated for years is also biased.

三、ME+MVR 工艺的设想

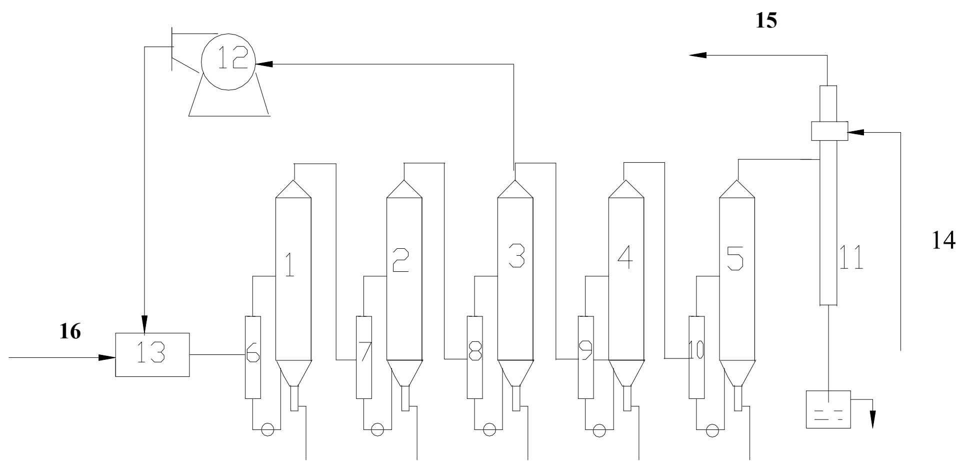
The idea of ME+MVR process

2015 年 1 月 1　日开始实施的新《环保法》对雾霾、碳排量等大气污染治理，作出了更加严格的要求与规定。提高排放标准无疑会增加生产成本，会导致一部分原本利润空间极为有限的企业举步维艰。以节能、环保的 MVR 制盐工艺技术，淘汰、置换落后产能，必将会成为我国制盐工艺发展的主流。但煤炭资源以及电煤比价依然是决定 MVR 工艺是否经济的关键因素。因此，　笔者认为 ME　与 MVR 取长补短，兼容并存，创新结合的制盐工艺模式，不失为一种有发展前景的设想。

The new environmental protection act, which began in January 1, 2015, has made more stringent requirements and regulations on air pollution control such as haze and carbon emissions. Raising emission standards will undoubtedly increase production costs, which will lead to a difficult part of enterprises with limited profit margins. With energy saving and environmentally friendly MVR salt making technology, eliminating and replacing backward production capacity will surely become the mainstream of the development of salt making technology in China. But coal resources and electricity coal price are still the key factors to decide whether the MVR technology is economic. Therefore, the author thinks that ME and MVR combination could be a promising idea, which could take advantages for both technology, showing innovation and compatibility.

对于运行多年，由发电厂供应蒸汽的 ME 制盐生产线而言，除了传统的Ⅳ效改Ⅴ效，推广分效预热等技术而外，可以从Ⅲ效引一定量的二次蒸汽，添设一套国产小型多级热压缩机，采用　MVR 工艺技术对 ME 进行技术改造。见工艺原理示意图（1）：

For ME salt production line, which has been operated for years, steam supplied by power plant, besides traditional revamp ways, e.g. change four-effect to five-effect and promotion of preheating for different effects, it is able to introduce part of secondary steam from three-effect to a small multistage heat compressor (domestic type)and to modify ME with MVR technology. See the schematic diagram of the process principle (1):



1.2.3.4.5 Crystallizer6.7.8.9.10Heating room11.Atmospheric condenser12.Heat compressor
13.Saturating device14.Circulating cooling water15.Non condensate gas16.backpressure steam

工艺原理示意图（1）

Schematic diagram of process principle

改造的优点是：

The advantages of the modificaiton are:

1、二次蒸汽阶梯利用的同时蒸汽前移加压升温循环再利用，减少了背压蒸汽（生蒸汽）的用量，充分发挥了 ME 与 MVR 两者的优势。

When secondary steam is under step useage,in the same time steam is moved forward for pressurization and temperature increase for further recycle reutilization. This could reduce the back pressure steam (raw steam) consumptions, and fully play the advantages of both ME and MVR.

2、部分二次蒸汽前移后，Ⅳ效、Ⅴ效二次蒸汽量相对减少，比容减小，有利于形成较高的真空度，增加蒸发传热的推动力。末效二次蒸汽减少，热损失相应减少，同时减少了循环水的用量，减少了蒸喷的用汽量，节约了电力。

After partial secondary steam moves forward, volumes of secondary steam from four-effect and five-effectdecrease relatively, and the specific volume also decreases, which is beneficial to the formation of higher vacuum degree and increase the driving force of evaporation heat transfer. The decrease of secondary steam in final effect will help to decrease the heat loss, together with the consumption amount of cooling water, thus steam consumption in steam jet unit is decreased,and electricity is saved.

但Ⅲ效的二次蒸汽是负压，二次蒸汽从负压增压到 0.35MPa 左右，热压缩机能否满足此压缩比，改造后热电是否平衡是改造的关键。

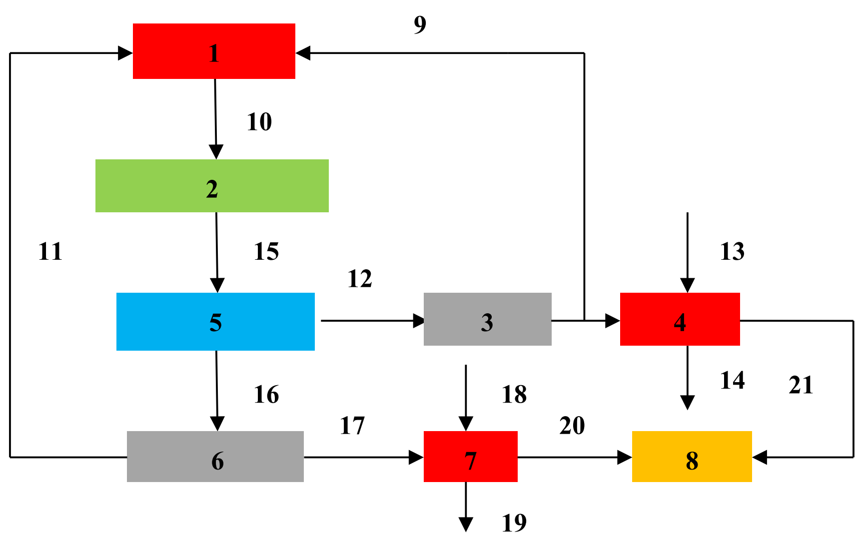
However, the secondary steam from three-effect is negative pressure, and it needs to be increased to around 0.35 MPa, hence whether the heat compressor can satisfy this compression ratio and heat & electricity could be balanced after modification are the key points..

新上项目要充分考虑区域优势、资源优势，避免不计市场容量的重复建设。煤炭资源相对丰富价格低廉的地区，可以选择 ME+MVR 热电联产的制盐工艺模式。

The new project should give full consideration to regional advantages and resource advantages so as to avoid redundant construction without considering market capacity. In the areas where coal resources are relatively abundant and low in price, the process of salt production with ME+MVR cogeneration can be selected.

ME+MVR 热电联产的制盐工艺模式Ⅰ蒸汽三级利用方框图（2）

Salt making process mode of ME+MVR cogeneration (I) block diagram of three-stage steam utilization(2)



1.boiler2.Turbogenerator3.MVR salt production4.7.Plate heat exchanger5.Steam turbine compressor6.ME salt production8.Halogen mining9.Condensate back boiler10.First stage steam11.First stage condensing water back boiler12.drive13.14.18.19.brine15.Two stage back pressure steam16.third stage back pressure steam17.Two to five effect condensate20.21Condensate water

高温高压锅炉生产的高温高压蒸汽驱动背压式汽轮电机组发电后，排出的定压中温背压蒸汽驱动背压式蒸汽透平机拖动 MVR 压缩机，吸入蒸发罐蒸发产生的经过除沫洗汽后的二次蒸汽，源源不断地增压，提高汽温，进入加热室，将热量提供给卤水，进行反复循环蒸发；背压式蒸汽透平机排出的压降温降的背压蒸汽，再进入 ME 多效蒸发系统制盐。

After power generation from back pressure turbine electricity units driven by high temperature and high pressure steam(from high temperature and high pressure boiler), the back pressure turbine driven by discharged constant mesotherm steam could drive MVR compressor, which will take in secondary steam (after defoaming and vapor washing),to increase steam temperature and enter the heating room. The heat is supplied to the brine for reproducible circulation evaporation, and the back pressure steam from the pressure drop of the back pressure steam turbine is fed to the ME multi effect evaporation system.

用蒸汽驱动透平机带动压缩机与电机带动压缩机相比，减少了一个蒸汽热能机电转换过程的损失，在充分满足 MVR 与 ME 制盐工艺用热要求前提下，实现了热能的三级使用，蒸汽热能达到最大限度的利用，充分热电联产的优势。但 MVR+ME 耦合制盐工艺梯级能效利用热力学分析，透平机排出的背压蒸汽量、压力、温度能否稳定；ME+MVR 的匹配协调运行以及汽电平衡，是关系到设想能否实现的关键，必须深度研究。

Compare the steam driven turbine driving the compressor with driving the compressor by motor, the loss of the mechanical and electrical conversion process of steam heat energy is reduced. Under the premise of fully meeting the heat requirement of MVR and ME salt making technology, the three level of heat energy is realized, the steam heat energy is utilized to the maximum limit, and the advantages of fully cogeneration of heat and power are achieved. However, the thermodynamic analysis of the step energy efficiency utilization of the MVR+ME coupled salt production process, the stability of the back pressure steam, pressure and temperature discharged from the turbine, the matching and coordinated operation of ME+MVR and the balance of steam and electricity, is the key to the realization of the assumption, and it must be studied in depth.

不论选择那种制盐蒸发工艺，都必须有先进的装置设备以及先进的卤水处理供应、母液处理回收，可靠的离心脱水、干燥，现代化的包装物流等相关环节支撑；不论选择那种制盐蒸发工艺，描准国际前沿先进技术，突破制约产业升级的关键共性技术，实现装置大型化、国产化，实现自备电站与制盐装置一体化、标准化，提高自动化程度，提高产品质量，实现效益最大化，提升产业国际竞争力，应当是我国制盐工艺未来发展的方向。

No matter how to choose the salt evaporation process, we must have advanced equipment, advanced brine supply and treatment, recovery of mother liquid, reliable centrifugal dehydration, drying, modern packaging logistics and other related aspects. The key common technology of upgrading, realizing the large-scale and domestic production of the equipment, realizing the integration and standardization of the self-contained power plant and the salt making device, improving the degree of automation, improving the quality of the products, maximizing the benefit and improving the international competitiveness of the industry, should be the direction of the development of the salt making process in our country.

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