

Development of Desalination Processes in China

(中国脱盐技术的发展)

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1 Introduction (绪言)

- Water is the source of life, is essential for social and economic development.
- With the development of national economy, the increase of population and the raise of peoples living standard, Water shortage has recently become a serious problem worldwide.

水是生命源泉，是社会和经济发展的命脉，是人类宝贵的不可替代的自然资源。当前缺水已成为世界性问题。

- **China is one of the countries short of water, especially in the north and northwest region, coastal cities and islands in the north.** 中国是世界上21个贫水国家之一。尤其是北方沿海地区和众多岛屿普遍缺水，海水淡化对解决沿海地区和岛屿缺水问题是一重要手段。
- **To cater for increasing demand for fresh water by year, desalination is one of the means to solve this problem**

Thermal and membrane methods are mostly used for this purpose. electrodialysis, reverse osmosis and distillation.

目前主要海水淡化方法有反渗透（SWRO）、多级闪蒸（MSF）、多效蒸发（MED）和压汽蒸馏（VC）

2 Desalination Processes **(脱盐过程)**

2.1 Ion Exchange Membranes and electrodialysis (ED)

(离子交换膜和电渗析)

2.2 Reverse Osmosis(RO) and Nanofiltration (NF)

(反渗透 和纳滤)

2.3 MSF and LT-ME

(多级闪蒸-低温多效)

2.1 Ion Exchange Membranes and electrodialysis (ED) (离子 交换膜和电渗析)

- 2.1.1 Ion Exchange Membranes(膜)**
- 2.1.2 applied theories of ED(理论)**
- 2.1.3 ED/EDR units (装置)**
- 2.1.4 Application of ED
processes (应用)**
- 2.1.5 Other development(其他)**

2.1.1 Ion Exchange Membranes (离子交换膜)

- The research on ion exchange membranes and ED began in 1958 with the first membrane based on PVA. (始于1958)
- the most widely used are heterogeneous membranes of polystyrene-divinylbenzene. The annual production of the membranes has reached nearly 400,000 square meters (异相膜, 40万平方米)

- **New homogeneous ion exchange membrane from cross-linked PPO has been developed in recent years.**

(均相膜, 交联的聚苯撑氧)

Ion Exchange Membranes made in China

Type		Thick ness (mm)	Water content (%)	IEC meq./g	Resis tance ($\Omega\text{-cm}^2$)	Permsel ectivity	Blast strength (Mpa)
Heteroge neous*	3361 (cation-exchange)	0.4- 0.5	35-50	\geq 2.0	\leq 12	\geq 92	$>$ 0.3
	3362 (anion-exchange)	0.4- 0.5	35-45	\geq 1.8	\leq 13	\geq 90	$>$ 0.1
Homoge neous**	DD-120-A (anion-exchange)	0.25	49	1.96	2.0	98	$>$ 0.8
	DF-120-C (cation-exchange)	0.22	44	1.57	1.4	92	$>$ 0.7
	DF120-A (anion-exchange)	0.25	49	1.96	2.0	98	$>$ 0.8

2.1.2 Applied theories of ED (ED应用理论)

- The applied theories studied on ED including
concentration polarization, (浓差极化)
water splitting, (水裂解)
Electrode behavior (电极行为)
hydrodynamics in compartments(隔室水力学)
were mainly conducted in the early 1970s.

2.1.3 ED/EDR units (ED/EDR装置)

- There are many configurations of with the largest size of the membrane/spacer area of **1600mm×800mm (最大尺寸)**
- More than **1000 ED units** have been produced each year from **nearly 40 factories (40多个工厂,每年1000多台设备)**

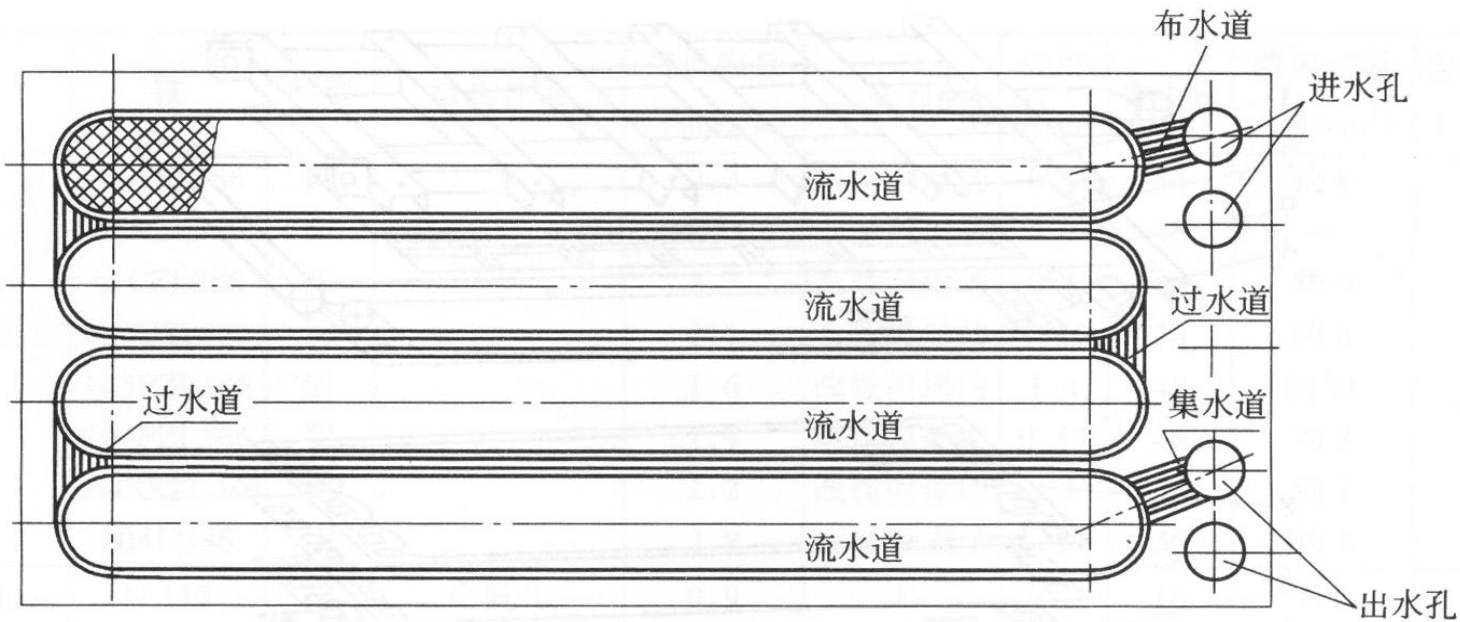
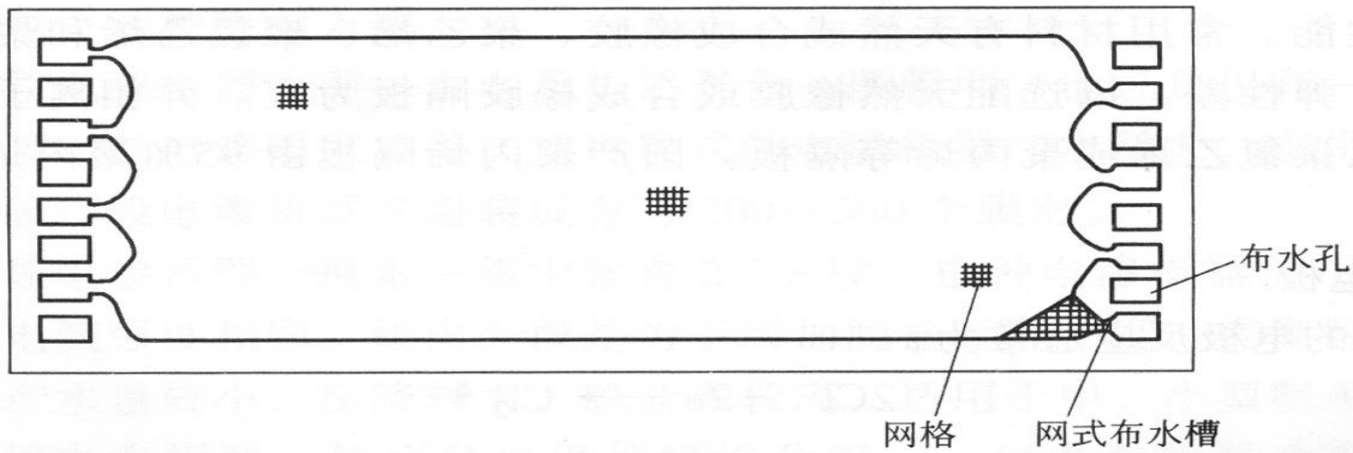
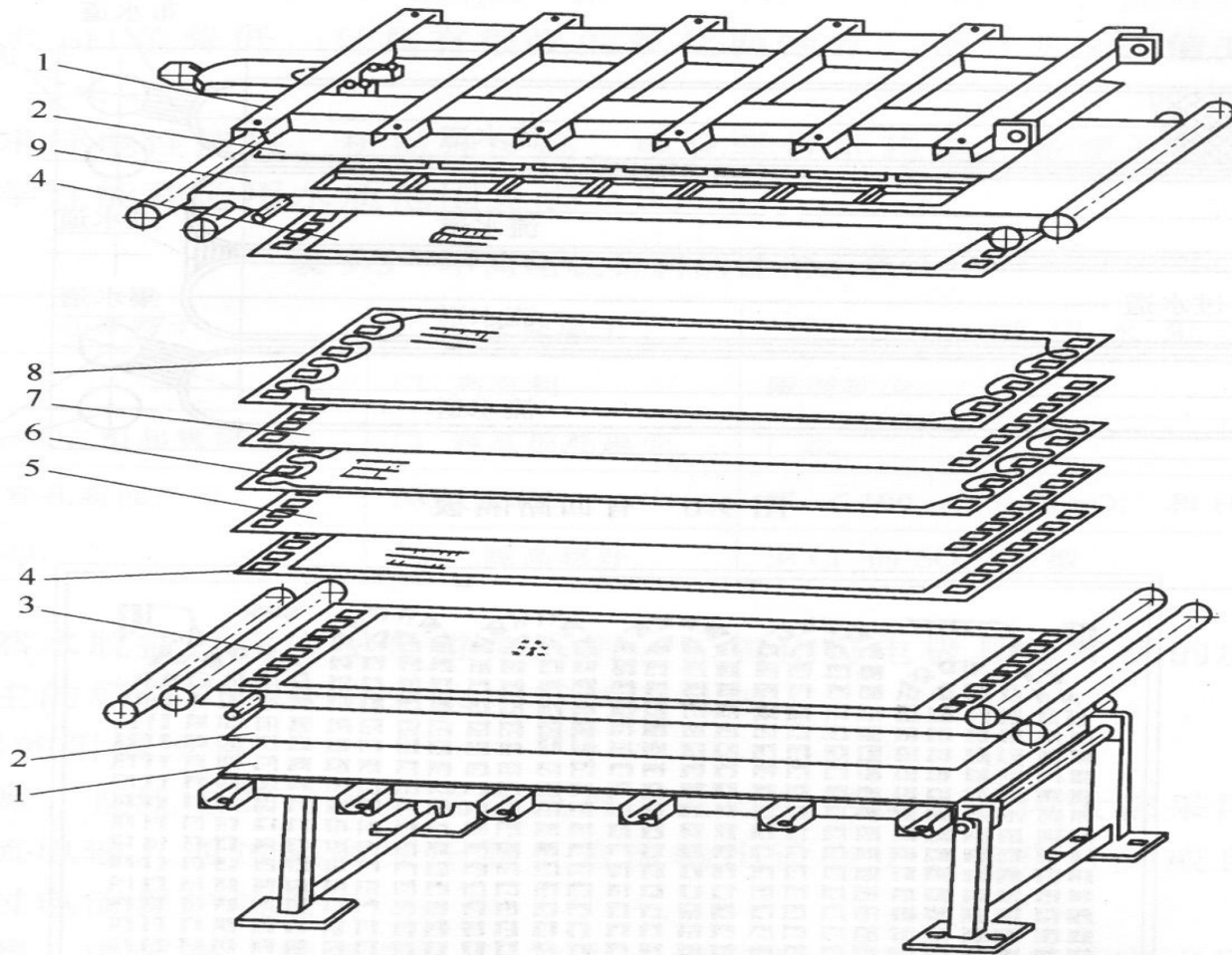


Fig.2-1 Structure of ED spacers



1—加紧板；2—绝缘橡皮板；3—电极（甲）；4—加网橡皮圈；5—阳离子交换膜；
6—浓（淡）水隔板；7—阴离子交换膜；8—淡（浓）水隔板；9—电极（乙）

Fig.2-2 Structure of ED unit

2.1.4 Application of ED processes (ED过程的应用)

- There has been only one **seawater desalination** plant of 200 m³/d at Xisha Islands.(西沙海水淡化站)
- **Brackish water desalination** is the major user for ED, such as Datong Coal Mine Water Desalting Stations were set up between 1975—1986 with the capacity of thousands tons per day.(主要用于苦咸水脱盐)

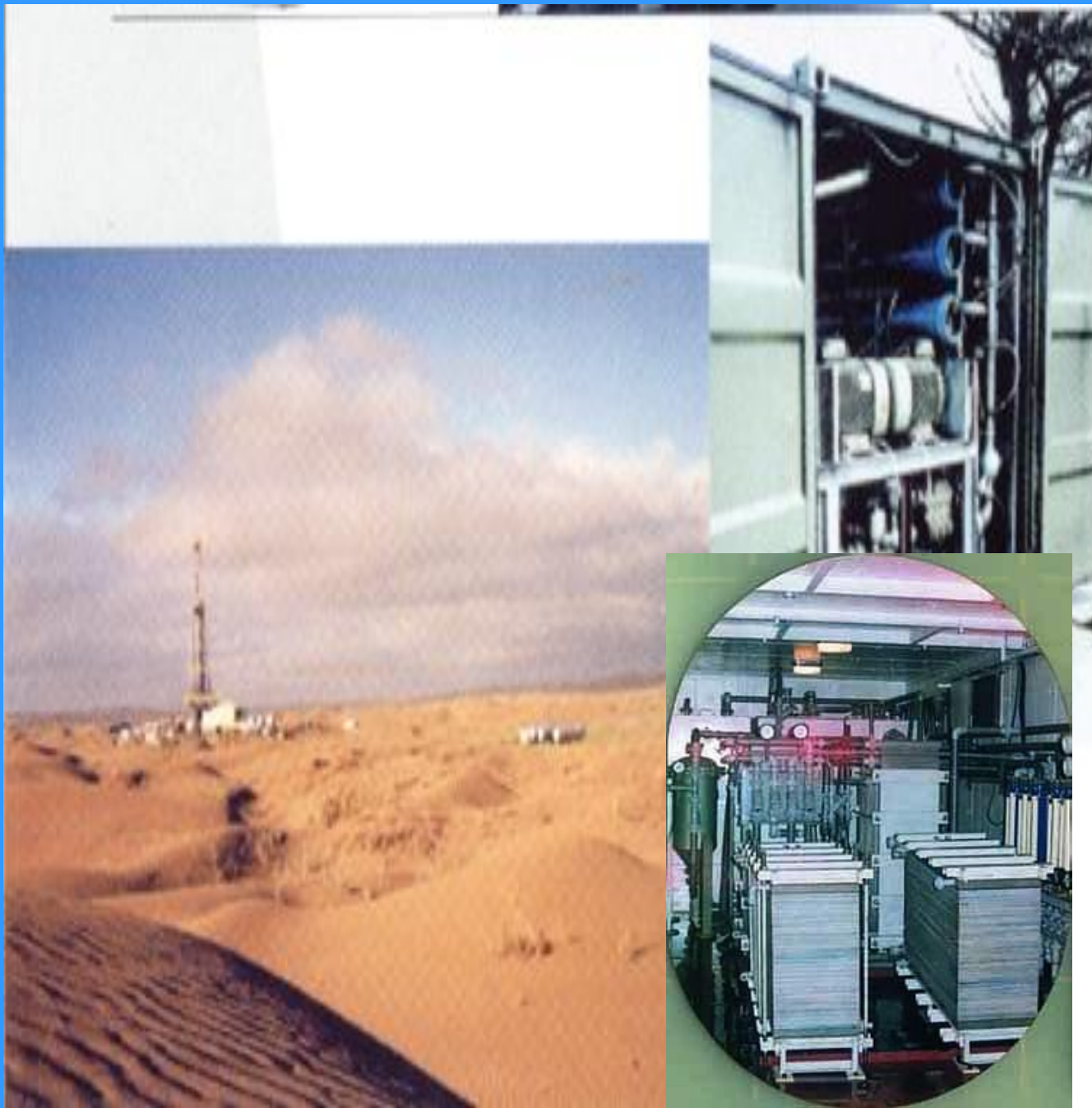


Fig.2-3
Desert
desalina
tion
vehicle
for oil-
drilling

ED沙漠
油田淡化
车

Fig.2-4 200m³/d ED seawater desalting plant in Xisha Islands (1981)



西沙日产200吨电渗析淡化装置

- The other main use is **pure and ultrapure water production** for boilers and other industries. The ED units at Jinshan No.2 Petro-Chemical Plant have produced pure water from tap water with the capacity of $12000\text{m}^3/\text{d}$.

(其他应用于纯水的生产)

2.1.5 Other developments (其他开发)

- Bipolar membranes (双极膜)
- EDI (CDI) processes ,EDI prototypes and equipments with unit capacity of 1-3m³/h were operated for pure water production.
- (电除离子过程)

2.2 Reverse Osmosis(RO) and Nanofiltration (NF)

(反渗透和纳滤)

- **2.2.1** Exploring research (研究开发)
- **2.2.2** Aromatic polyamide membrane (芳香聚酰胺膜)
- **2.2.3** application stage in 1980's(示范)
- **2.2.4** popularization and application in large scale in 1990's. (大规模应用)

2.2.1 Exploring research

(研究开发)

- Exploring research on reverse osmosis (RO) membranes in China was set about **in 1965** (始于1965)
- A national joint research program on sea water desalination began **in 1967**
(1967年海水淡化会战)

2.2.2 aromatic polyamide membrane

- Studies on aromatic polyamide membrane materials, including PSA, and related hollow fiber RO membranes, and CTA hollow fiber RO membranes were started at the **beginning of 1970's.**

(1970's, 研究芳香族聚酰胺PSA膜, CTA中空纤维膜)

- **Studies on RO composite membranes formed by interfacial polycondensation and in-site polymerization, and dynamically formed membranes as well as SPS membrane began in the middle of 1970's.**

(1970's中期, 研究界面缩聚RO复合膜和SPS等膜)

Performance of composite RO membranes and modules, (复合膜、组件性能)

Membrane s& modules	Performance		Test condition
	Flux/output	Rejection(%)	
membrane	>40 (l/m ² .h))	>99	1.6MPa <2000mg/l NaCl
Modules Φ100mm	>6.8m ³ /d	>98	1.6MPa <2000mg/l NaCl

Typical performance of NF membranes (纳滤膜性能)

Membranes & modules	Performance		Test condition
	Flux/output	Rejection(%)	
membrane	~50 (l/m ² .h))	>95	0.7MPa <2000mg/l MgSO ₄
Modules Φ100mm	~10.0m ³ /d	>95	0.7MPa <2000mg/l MgSO ₄



Fig.2-5 RO membrane production line with a capacity of $1.2 \times 10^6 \text{m}^2/\text{a}$

反渗透膜生产线，年产120万平方米的膜元件

2.2.3 Application stage in 1980's

(1980年代的应用)

- It stepped into application stage in 1980s, **Brackish water desalination, pure and ultrapure water production, separation, purification and concentration** of various liquids by RO technology were put into application. A number of demonstrate RO plants using the modules above were built in this period(**苦咸水淡化和超纯水示范**)



(Fig.2-6 Pure water production)
纯水生产

2.2.4 Popularization and application in larger scale in 1990's

A few sea water reverse osmosis desalination plants with the capacities of **500-1000m³/d** have been operated in different region.

1990年代应用

application in recent years

- The largest sea water desalination plant with the capacities of **34000m³/d**, and the largest brackish water desalination plant with the capacity of **18000 m³/d** have been in operation in recent years.
- The sea water desalination plant with the capacity of **100000 m³/d** will be built in coming one or two years.

最近几年的应用

Fig. 2-7 500m³/d RO seawater desalting plant in Chengshan Islands (1997)



嵛山日产500吨反渗透海水淡化装置

Fig.2-8 5000m³/d RO seawater desalting plant in Rongcheng (2003)



荣成5000吨/日海水淡化系统

Fig.2-9 34000m³/d SWRO desalting plant in Yuhuan Power plant (2006)

玉环电厂34000吨/日反渗透淡化装置



2.3 MSF and LT-ME

多级闪蒸和低温多效

- 2.3.1 MSF in 1960's—1970's
- 2.3.2 2×3000 tons/d MSF plant
- 2.3.3 VC/THE process
- 2.3.4 LT-ME desalting system

2.3.1 MSF in 1960's—1970's

- The research and application of MSF in China can be traced back to the 1960's
- In the 1970's, **an experimental MSF system** with a capacity of hundreds of tons per day was employed in Tianjin.

上世纪60—70年代的MSF

- In 1975, a **four-stage experimental MSF unit** was used successfully for recovering the mercerization waters in the fabric dyeing industry in Zhenjiang, Jiangsu Province. Then a **MEMS**(multi-effect and multi-stage)unit, consisting of two effects and fifteen stages was also used successfully for recovering the mercerization waters.

1975年MSF/MEMS回收染织废水

2.3.2 2×3000 tons/d MSF plant

- two MSF units were imported from the **USA in 1988(1990)**.
- The two units with the capacity of **2×3000 tons/d** were constructed and put into operation in the Dagang Power Plant of Tianjin.
- Until now It is the **first and the only one** of the land-based MSF plant for seawater desalination in China.

大港电厂引进**2×3000 tons/d**多级闪蒸

2.3.3 VC/THE process

- A low temperature VC/THE pilot unit with a capacity of **30 m³/d** was built at Da Changshan Island in 1990 and run for one year. The power consumption was about 28 kWh/m³ fresh water.
- Other VC pilot unit with a capacity of **60 m³/d** for seawater desalination was built at Huangdao power plant of Qingdao city in 2000

30 m³/d 和 60 m³/d 的 VC 装置

2.3.4 LT-ME desalting system

- From a thermodynamic and heat transfer point of view the LT-ME desalting system is more efficient than MSF desalting system,
- In 1990s, a plan was made to import LT-ME desalting system from IDE or SIDEM, and finally failed owing to some reasons.
- A LT-ME plant with a capacity of **3000 m³/d** is now in construction in Huangdao power plant of Qingdao city.

LT-ME的优点和引进考虑及自己制造

Fig.2-10 3000 m³/d LT-MED plant in Huangdao power plant of Qingdao



黄岛电厂3000m³/d低温多效蒸馏海水淡化装置
(2004)

黄驸电厂引进的 $2 \times 10000 \text{m}^3/\text{d}$ MED海水淡化装置



Fig.2-11 $2 \times 10000 \text{ m}^3/\text{d}$ MED Equipments imported by Huanghua power plant in 2002

**Fig.2-12 $1.25 \times 10^4 \text{ m}^3/\text{d}$ MED Equipments build
by Huanghua power plant in 2008**



**黄驸电厂自制的 $1.25 \times 10^4 \text{ m}^3/\text{d}$ MED
海水淡化装置**

3 Energy consumption and cost of seawater desalination (能耗和成本)

- 45 seawater desalination plants are under normal operation. The plants are mainly used for supplement of fresh water in industrial enterprises, and a few of them supply the resident in some area for drinking water.
- 现有45个正常运行的工厂,所产脱盐水主要用于所在厂的淡水供给;少部分工厂所产脱盐水用于居民饮用。

Table 3-1 Investment and operation costs of part of seawater desalination projects in China (投资和成本)

Categories	Huangdao Power plant in Shandong	Huaneng Power plant in Weihai	Caofeidian Capital Steel Corporation	Yuhuan Power plant in Zhejiang	municipal use in Shengsi
Scale(m ³ /d)	3000	2500	25000	34560	4000
Technology	LT-MED	SWRO	LT-MED	SWRO	SWRO
Completion time	2004	2001	August, 2008	Match, 2006	2005
Application	boiler water (salt content<20ppm)	boiler water (single stage RO, drinking water standard)	boiler water and recycle system supplement	boiler water (double stage RO)	municipal feed water
Total investment of projects (10 ⁴ RMB)	2400	1980	25000	20000	2880
Operation cost (RMB/m ³)	4.73	5.17	6.7	6.18	3.79
Investment of per ton of water (RMB/m ³ ·d)	8000	7920	10000	5787	7200
Corporation	Qingdao Huaou	Shanghai Semi-island Water Treatment	French SIDEM, Simons (China)	Simons (China)	Development Center of Water Treatment Technology

The investment of water per ton for SWRO is approximately 6000-8000 RMB/t,

The investment cost of per ton water for LT-MED is 8000-10000 RMB/t under certain conditions.

At present, the produced water cost by seawater desalination reaches about 5 RBM/t.

•SWRO吨水投资约6000-8000 RMB/t,

LT-MED吨水投资约8000-10000 RMB/t,

目前，吨水成本约5 RBM/t。

4 Prospect for the desalination processes

- A development program outline on China marine economy issued by the State Council, in which the seawater desalination was listed as one of **a key and new developing industries**. The related plan was also drawn up.
- **RO and LT-ME (MSF for large plants)** were selected as main methods for seawater desalination. The home-made RO membranes and key equipments could be used as more as possible.

(振兴海洋经济，海水淡化受到政府高度重视)

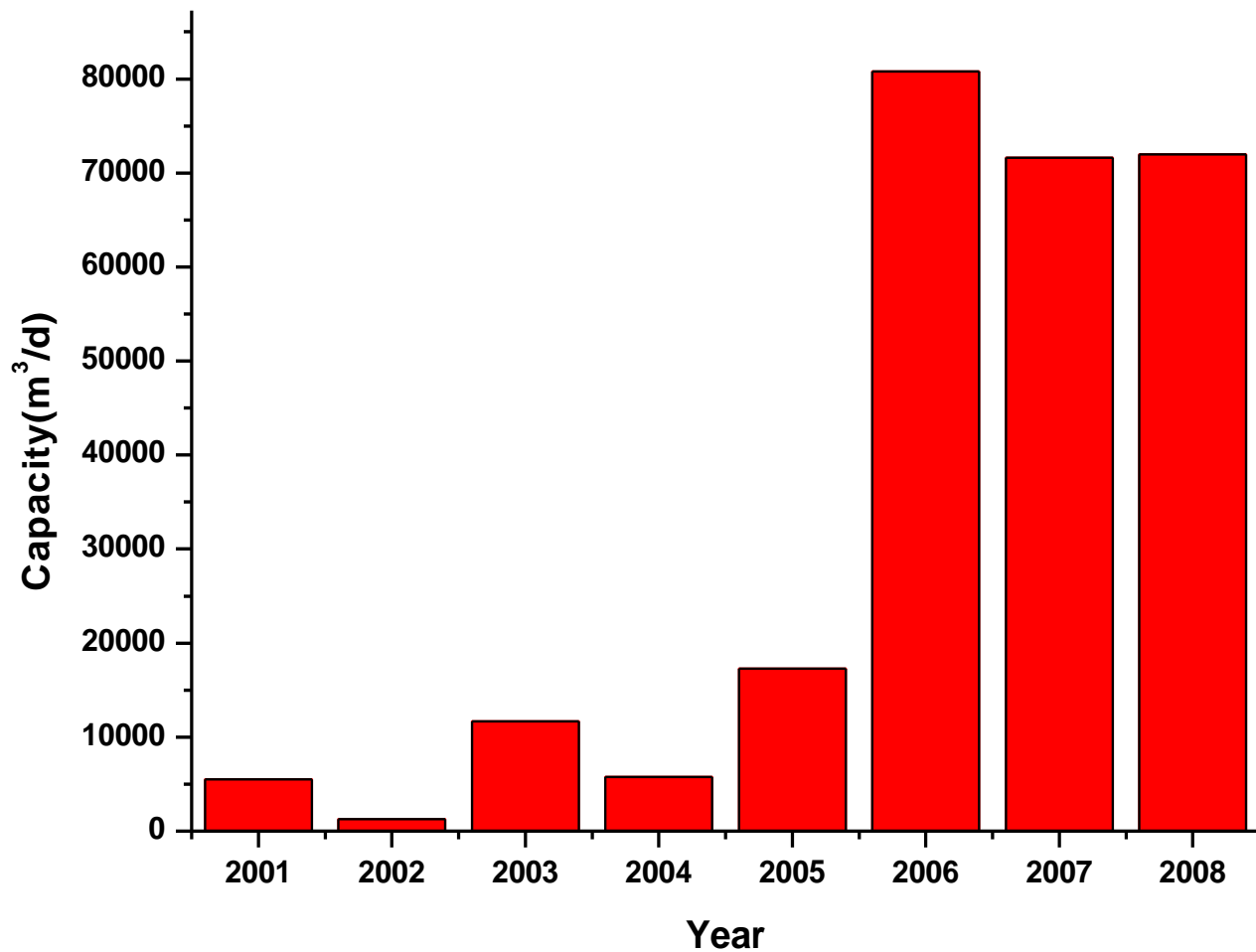


图4-1
2001-
2008年
脱盐厂
年建规模

Fig.4-1 The growth of desalination capacity from 2001-2008.

Plans in 2010 and 2020

2010,2020年预测

- It predicts that fresh water production by desalination will reach $7.0-10 \times 10^5 \text{m}^3/\text{d}$, and have $1.0 \times 10^4 \text{m}^3/\text{d}$ demonstration plants of RO and LT-ME processes **in 2010.**

2010年达70—100万 m^3/d

- The fresh water production by desalination will reach $2.5-3.0 \times 10^6 \text{m}^3/\text{d}$, and have $1.0 \times 10^5 \text{m}^3/\text{d}$ desalination plants **in 2020.**

2020年达250—300万 m^3/d

- **Engineering towards large scale, having 3-4 industrial bases, 3-5 demonstration cities or regions**
- **2-4 engineering research centers & research testing sites**

- **工程规模大型化**
- **形成3—4个产业化基地**
- **建成3—5个示范城市和示范区**
- **建成2—4个工程研究中心和研究试验现场**

Integrated processes

集成过程

- The integrated processes combined **electricity, RO, MSF and LT-ME** will be carried out in some power plants.
- The integrated processes combined **desalination and salt production** may be realized near some cities in the north of China.
- The desalination with **nuclear power** may also be considered in near future.

RO, MFS, LT-ME, 核能 / 水、电、热、盐

Fig.4-2

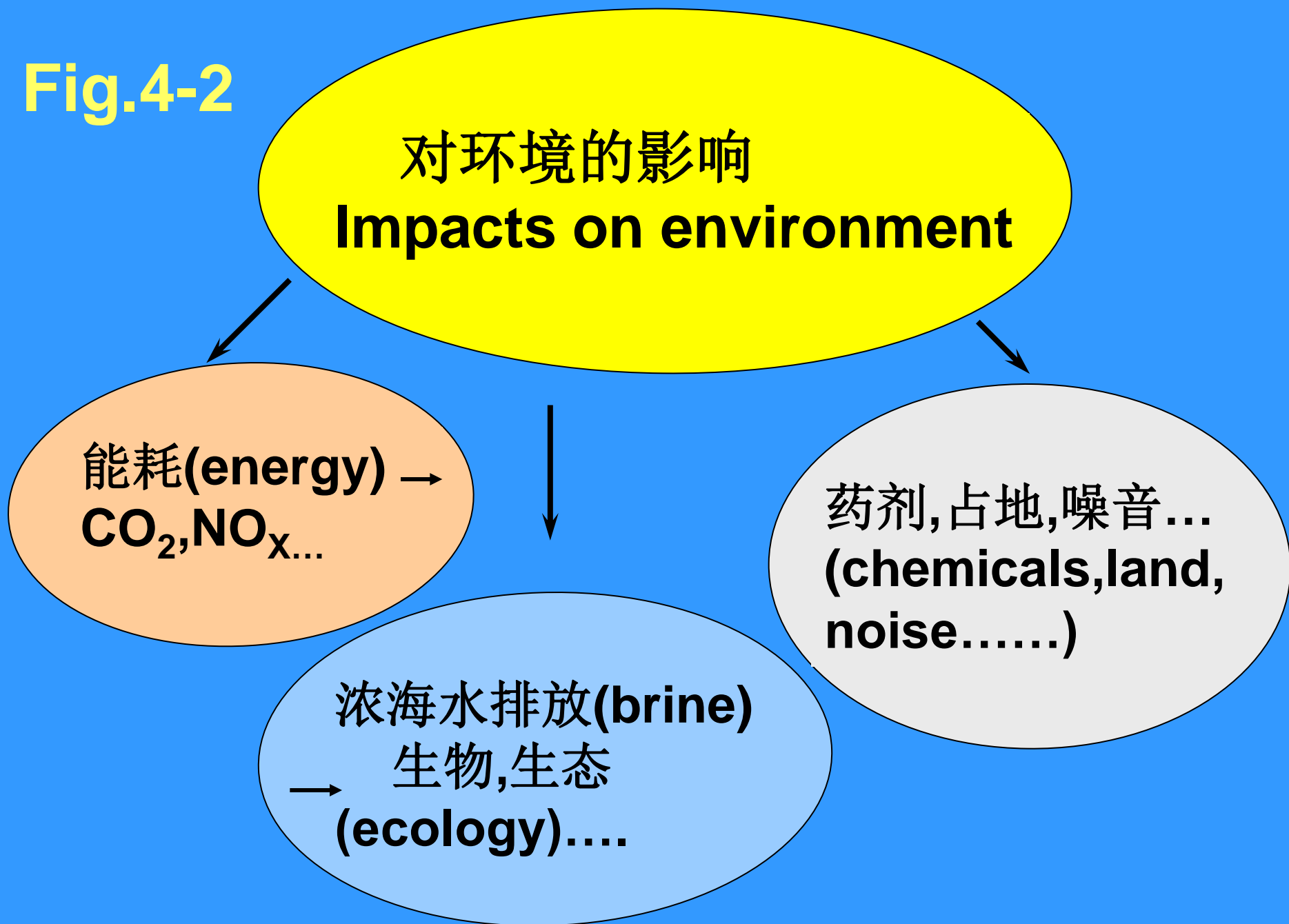
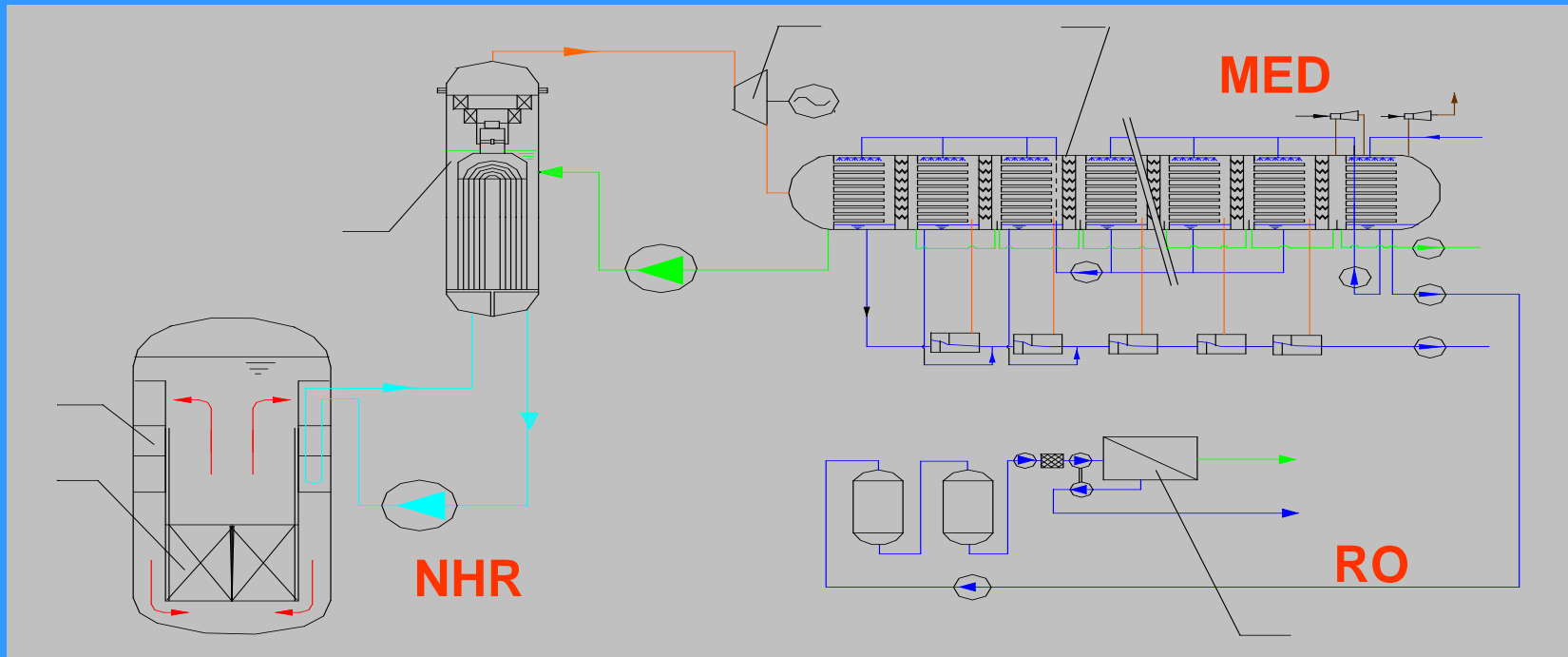


Fig. 4-3 Wind, solar and nuclear energy (风、太阳和核能利用)



Planning and policy Support

- Strengthen the strategic position of seawater utilization
- Make planning, Strengthen supervision, coordination and application
- Establish supporting system of seawater utilization technology

规划和政策支持

- 加强战略统筹，确立海水利用的战略地位
- 搞好规划，强化指导、协调与实施
- 依靠科技进步，构筑海水利用技术装备支撑体系

- **Establish law , regulation and standard system**
- **Support and promote industrialization of seawater desalination**
- **Optimize the structure of water supply in coast region**
- **推进依法管理，加快建立海水淡化法律法规和标准体系**
- **实行激励政策，大力扶持和促进海水淡化产业化发展，包括财政支持、投资体系、能源和水的价格等**
- **加快结构调整，优化沿海地区用水结构**

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With the progress of seawater desalination technology, the desalination have been become an important strategic option in solving the water shortage problem in coastal areas of China.

随着海水淡化技术的进步，海水淡化是解决沿海地区和岛屿缺水问题的一重要战略手段。

A tropical beach scene with several palm trees in the foreground and a blue ocean in the background. The sky is blue with some light clouds. In the bottom left corner, there is a small table with a red and white striped umbrella.

Thank you

谢谢大家