

# CO<sub>2</sub>工质在大中型冷冻冷藏领域的 工程应用拓展

The Application Development of CO<sub>2</sub> in the Field of  
Large and Medium-sized Refrigeration Engineering

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# CO<sub>2</sub>制冷系统得到业内广泛认同

CO<sub>2</sub> refrigeration system is widely recognized by the refrigeration industry

CO<sub>2</sub>制冷系统自2008年第一个工程至今，其安全、环保、节能效果得到了行业的认可，并得到了大力的推广应用；目前已经运转的系统已经达到30余套，涵盖了冷冻冷藏的各种需求，系统运行良好，节能效果显著。

We launched the first set of CO<sub>2</sub> refrigeration system in 2008, and its safety, environmental protection, energy saving effect has been recognized and be widely applied. Up to now, the number of operation equipment has reached more than 30 sets which can meet the various needs of freezing refrigeration.



# 星星之火，可以燎原

A single spark can start a prairie fire



**截至2014年底，陆续承  
建了33个CO<sub>2</sub>项目**

By the end of 2014, we have  
signed 33 CO<sub>2</sub> Projects.



**CO<sub>2</sub>项目合同金额：约  
3.7亿元**

**销售CO<sub>2</sub>主机台套数：  
68套**

Total contract amount:370  
million CNY

Equipment number : 68 sets



**有13个CO<sub>2</sub>项目已经在  
国内成功运行（含调试  
成功）**

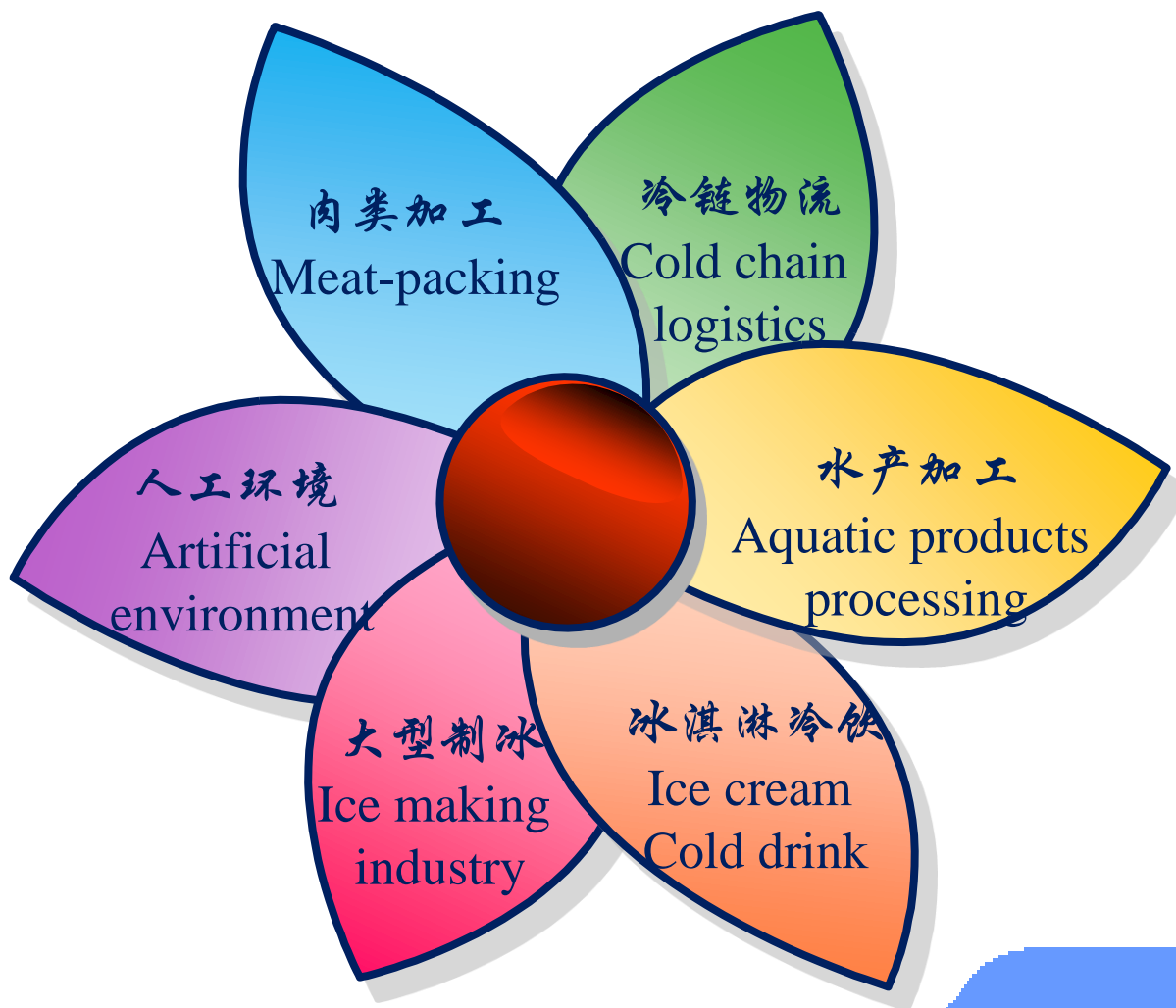
**有7个CO<sub>2</sub>项目正在施工**

Successful runing:13

Under construction:7

# 已广泛应用的行业

Industry that CO<sub>2</sub> projects were widely used

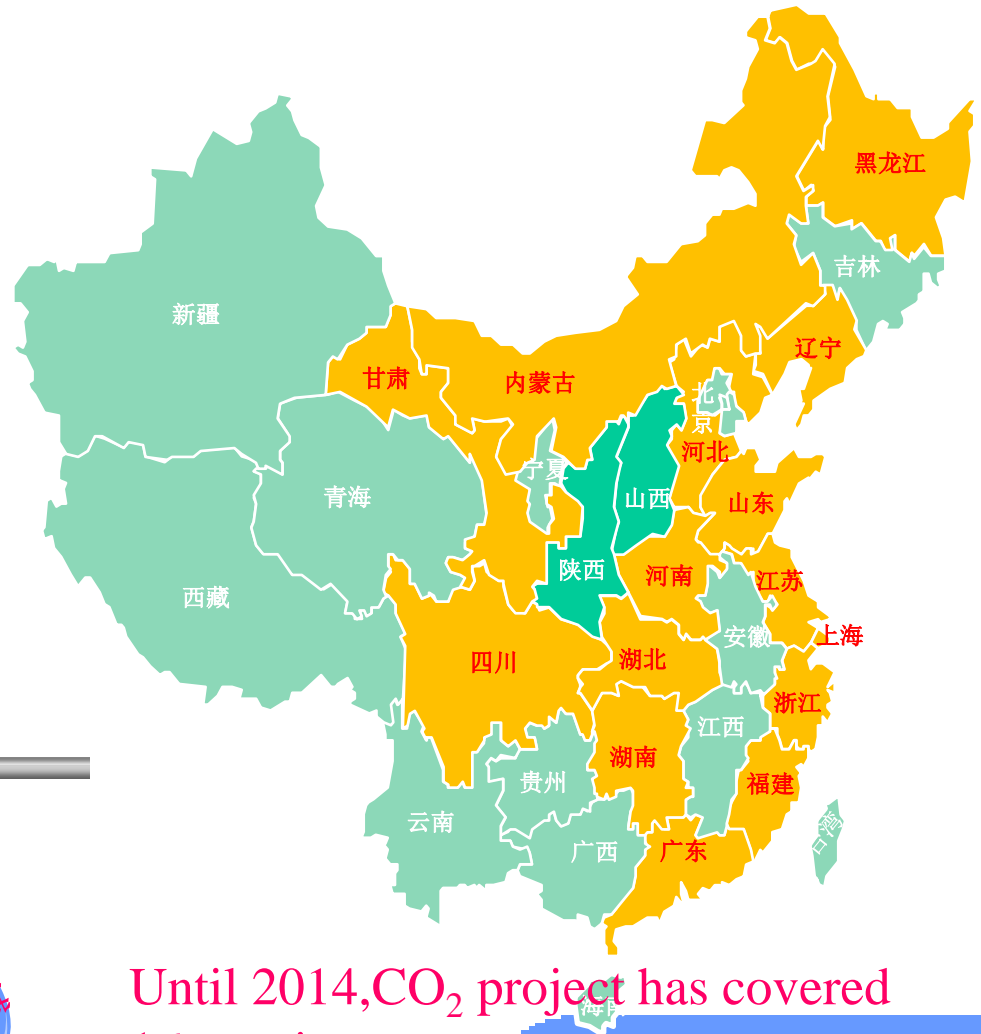


# 已应用区域

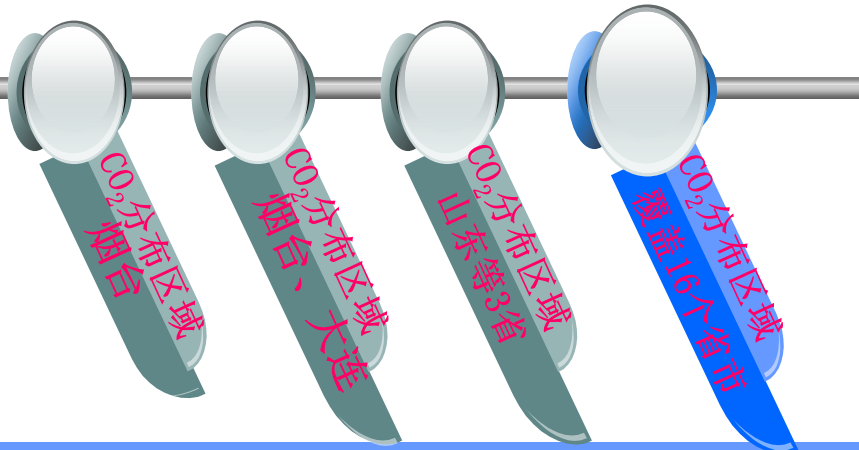
Regions that have CO<sub>2</sub> project

成功布局东北、华北、华东、  
华中、华南、西北、西南

CO<sub>2</sub> project covers seven major  
regions.



2008 2012 2013 2014



Until 2014, CO<sub>2</sub> project has covered  
16 provinces.

# CO<sub>2</sub>的实际工程应用研究

## Research on practical application

商业冷冻冷藏的实际工程应用存在很多个性化需求，在2008年开始研究,我们根据CO<sub>2</sub>工质的特点和实际工程运转数据，仍然不断地进行大量的工程应用验证：

Faced with the individual needs of refrigeration project, according to the characteristics of CO<sub>2</sub> and practical engineering data, we conducted a large number of application research since 2008.

### ➤ 复叠系统和载冷剂系统的应用范围论证

Application argument of cascade system and secondary refrigerant system.

### ➤ 不同末端型式：排管、冷风机、搁架排管、平板、螺旋、隧道、网（板）带、制冰

Different ends such as: calandria , air cooler, shelf, plate freezer, IQF spiral, tunnel, Ice making etc.

# CO<sub>2</sub>的实际工程应用研究

## Research on practical application

- 不同供液方式：泵供液（最佳循环倍率）、重力供液、直膨供液，

Liquid supply mode: pump ,gravity, direct expansion.

- 不同换热器型式：壳管、板换、满液

Heat exchanger: shell and tube , plate, flooded heat exchanger.

- 不同融霜方式：工质热气、水、电各种融霜方式以及融霜阀门的设置  
融霜压力、循环量、控制程序、融霜时间、融霜工质回收容积的确定

Defrost: research on defrost methods such as hot gas defrosting, water defrosting and electric defrosting, research on valve settings and determining the defrost pressure, the circulation quantity, the defrost time and the control program.

- 撬装CO<sub>2</sub>制冷系统的开发

Development of skid mounted CO<sub>2</sub> refrigeration system.



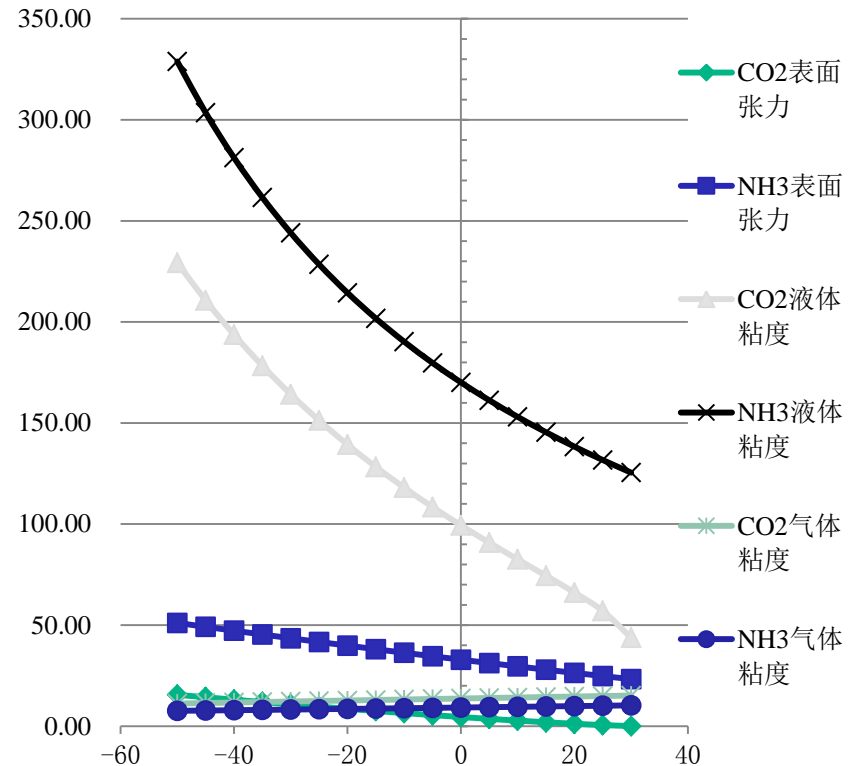
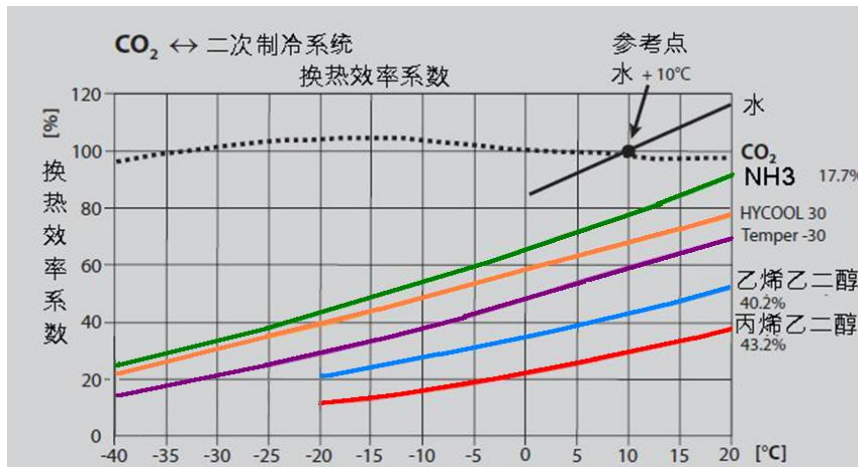
# CO<sub>2</sub>的换热特性研究

## Research on heat transfer characteristics of CO<sub>2</sub>

CO<sub>2</sub>具有良好的输送与传热特性:

CO<sub>2</sub> has excellent heat and mass transfer characteristics.

- 单位容积制冷量大 Large cooling capacity per unit volume
- 运动粘度小 Smaller kinematic viscosity
- 较小的表面张力 Smaller surface tension
- 相同压力差的温度损失小 Smaller temperature drop caused by pressure drop
- 气液密度比小 smaller gas-liquid density ratio





# 冷凝蒸发器的研究

## Research on evaporative condenser

➤ 结构型式：壳管(虹吸、满液)、板换

Structure: shell, tube and plate

➤ 板换论证了各个品牌的换热性能: Analysis of heat transfer performance of different manufacturers

➤ 壳管进行了以下研究: Studies of the shell and tube heat exchanger

● 管型：内外部高效结构、材质

Pipes: efficient structure and material

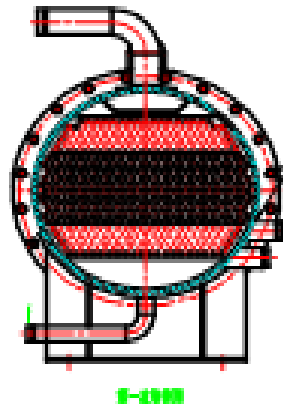
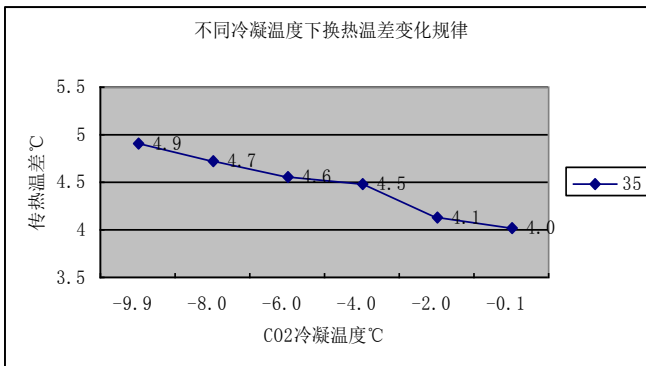
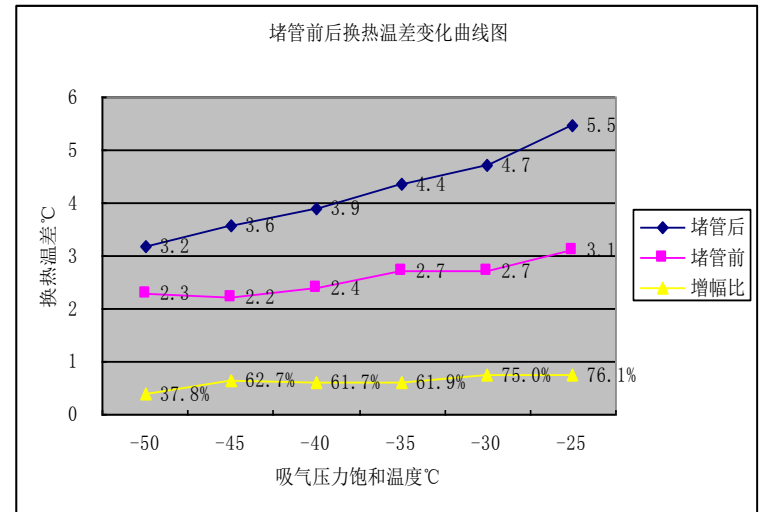
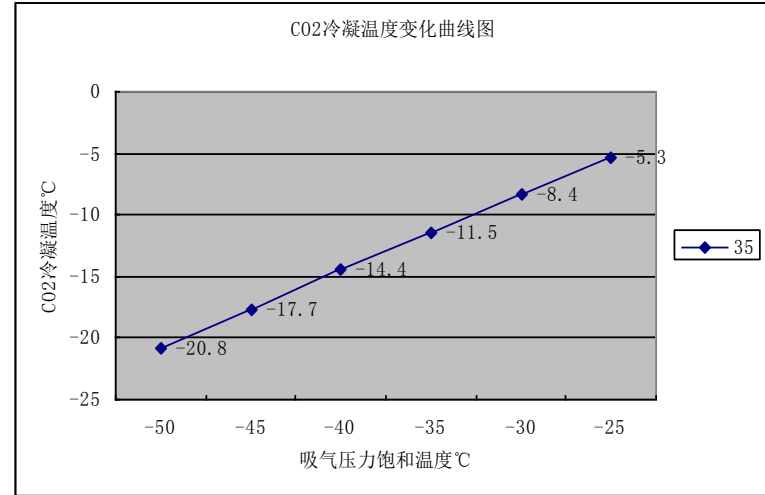
● 工质管壳程分布 Shell distribution

● 工质各自的流速 Flow velocity

● 长径比合理 Suitable ratio of length to diameter

● 均匀分液结构 Uniform dispensing structure

● 气液分布 Gas and liquid distribution



# 壳管式冷凝蒸发器的工程案例

## Project cases about shell and tube evaporative condenser

- 烟台丰润食品有限公司速冻
- 乳山华信食品有限公司速冻冷藏
- 大连獐子岛集团贝类速冻冷藏
- 连云港天缘物流冷库项目
- 福建蓝丰物流冷库项目
- 上海长兴岛中心渔港速冻冷藏

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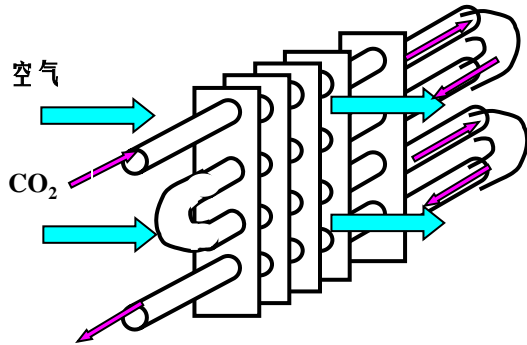
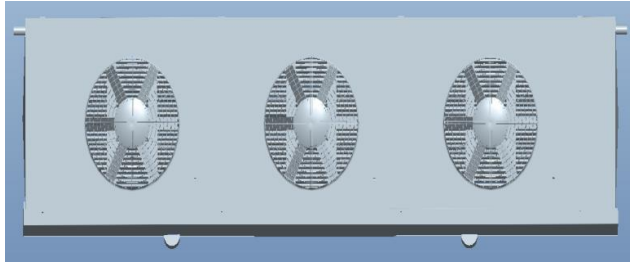
目前烟台冰轮承接的CO<sub>2</sub>制冷系统90%采用虹吸壳管式冷凝蒸发器，运行效率高

90% of the CO<sub>2</sub> projects that we undertaken used the siphon shell and tube evaporative condenser for its higher operating efficiency.



# 冷风机的换热研究

## Research on heat transfer of air cooler



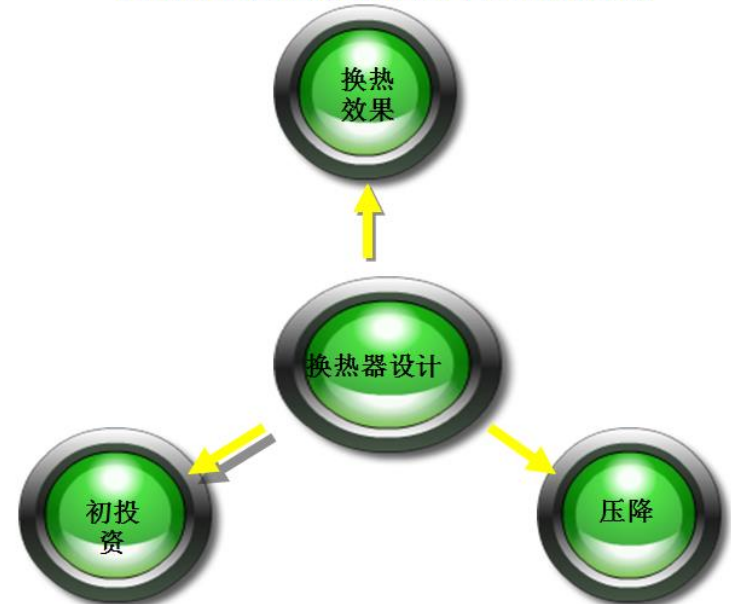
- 型式、材质：管与翅片 Structure and material : tube and fin
- 单管长度 Length of tube
- 循环倍率 circulation rate
- 供液方式 liquid supply mode
- 强化空气侧换热 strengthen heat transfer of the air side

➤ 对于CO<sub>2</sub>空气换热器来说，主要热阻还在空气侧，主要研究空气侧强化传热结构

➤ We enhance heat transfer on the air side for the bigger heat resistance.

The performance of the heat exchanger directly affects the performance of the whole system, due to the influence of the initial investment, the system pressure drop and heat transfer effects.

换热器优劣直接影响整个系统的性能



# 高效风机工程案例

## Project cases about efficient air cooler

- 连云港天缘物流库
- 大连獐子岛集团贝类速冻冷藏
- 乳山华信食品有限公司速冻冷藏
- 长江桂柳禽类速冻冷藏
- 鹤壁赛德速冻冷藏
- .....





# 顶排管的换热研究

## Research on overhead coil

➤ 分组原则：换热性能、安装方便、合理融霜

Grouping : consider the heat transfer performance, installation and defrost

➤ 管径选择：换热、材料的承压

Diameter of tubes : consider the heat transfer performance and strength of materials

➤ 单管长度：换热、安装 Length of tube

➤ 均匀分液：换热 Uniform dispensing

➤ 循环倍率 Circulation rate

➤ 排管蓄冷功能 Storage capacity

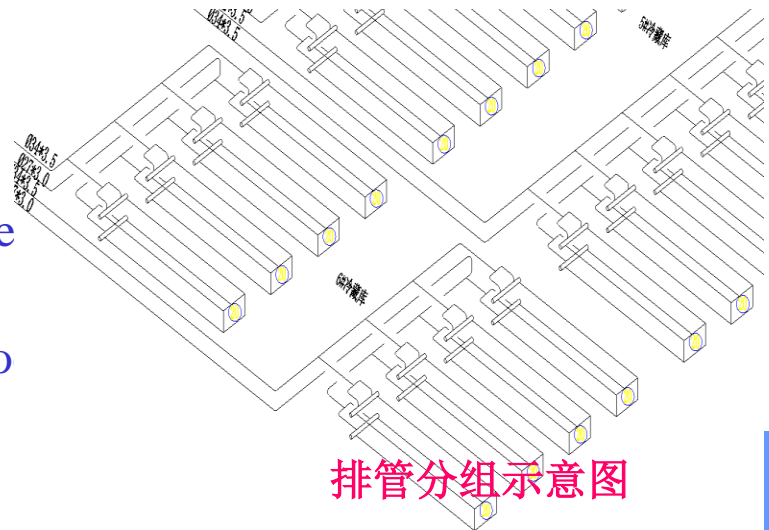
➤ 换热温差 Temperature difference

➤ 结霜实验 Frost experiment

➤ 融霜抽空的时间 Defrost evacuation time

➤ 霜层厚度 Thickness of frost

➤ 不同融霜方式的研究 Defrosting metho



排管分组示意图

# 顶排管工程案例

## Project cases about overhead coil



➤福建蓝丰

➤广州品纳

➤长江桂柳禽类速冻冷藏

➤赤峰新新杰物流冷库

➤甘肃新联友物流冷库

➤.....



# 搁架排管的换热研究

## Research on heat transfer of shelf pipes

➤ 搁架排管分类：立式、平板

Classification of Shelf pipes

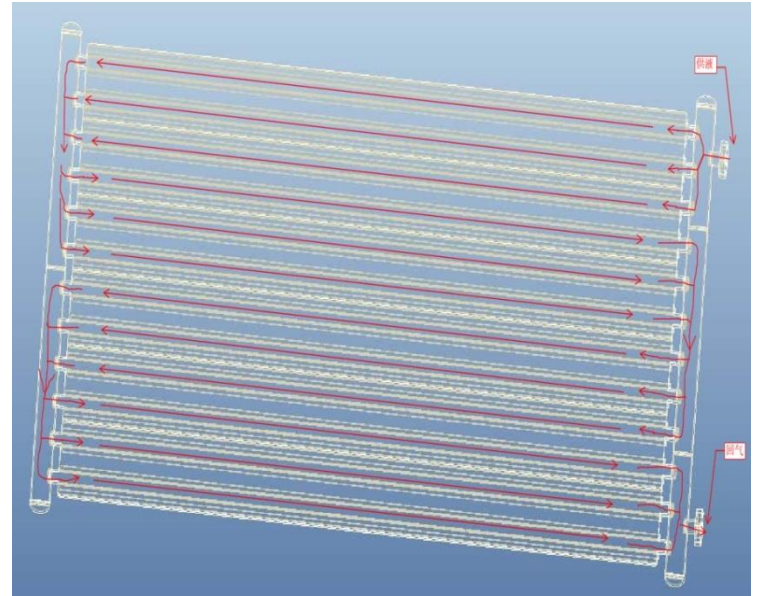
➤ 最大单组容积确定

Maximum capacity of single group

➤ 供液型式 liquid supply mode

➤ 均匀分液结构

Uniform dispensing structure

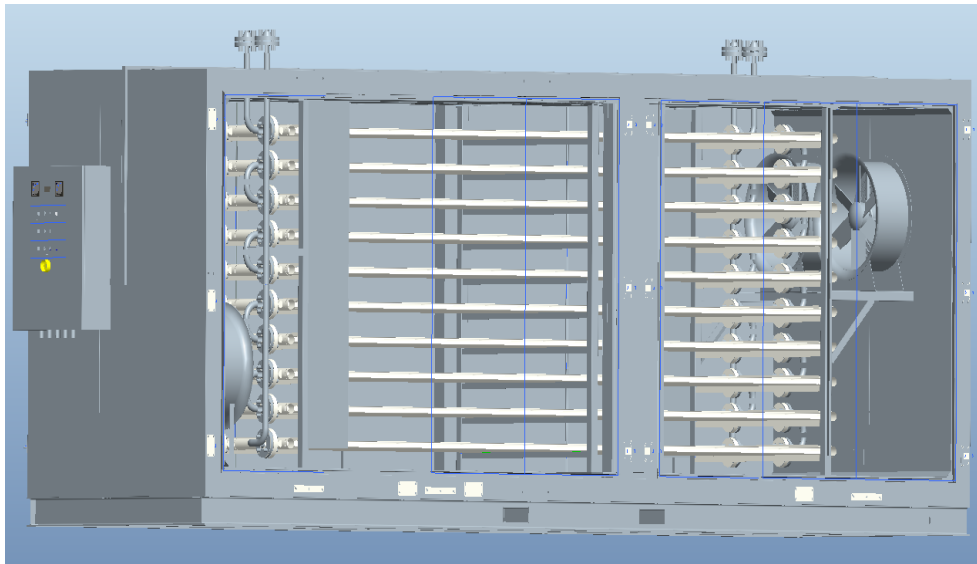


➤ 供液分组

Liquid supply packet

➤ 单程蛇排管总长度

Length of single row tube





# 搁架排管与平板工程案例

Project cases about shelf pipes and plate

## 长江桂柳禽类速冻冷藏

➤ 复叠系统: -39/35

Cascade system: -39/35°C

➤ 冻结间: 冷风机、搁架

Freezing room: air cooler/shelf pipes

➤ 低温冷藏: 顶排管

Cold storage: overhead coil

➤ 热工质融霜 Hot gas defrosting



## 烟台伟成水产速冻

➤ 食品置于冷冻板上传导换热

Heat conduction between the foods and the freezing plate

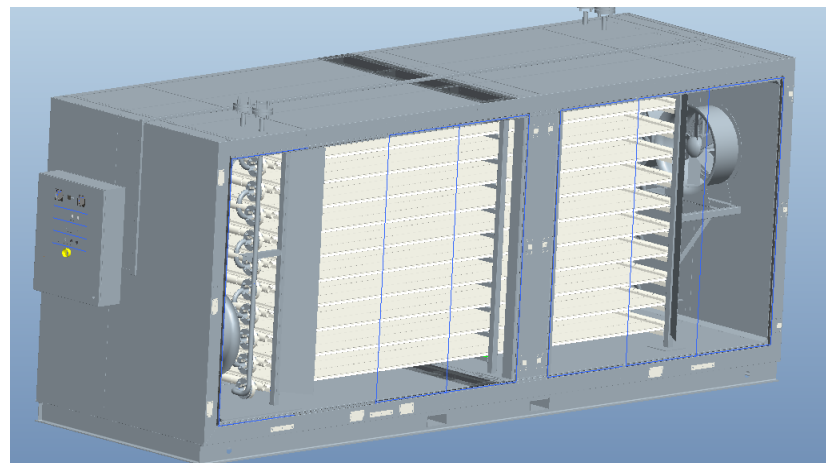
➤ 食品表面通过风机冷风对流换热

Convective heat transfer between foods and cold wind

➤ 可作小冷库使用、也可独立速冻

Applied to small cold storage or single frozen

➤ 高效风机 Efficient air cooler



# 制冰系统研究

## Research on ice making system

### ➤ CO<sub>2</sub>制冰螺旋盘管蒸发器结构研究

Research on structure of spiral tube evaporator

### ➤ 螺旋盘管蒸发器的换热研究

Research on heat transfer of spiral tube evaporator

### ➤ CO<sub>2</sub>的蓄冷作用研究

Research on cold storage of CO<sub>2</sub>



# CO<sub>2</sub>速冻装置

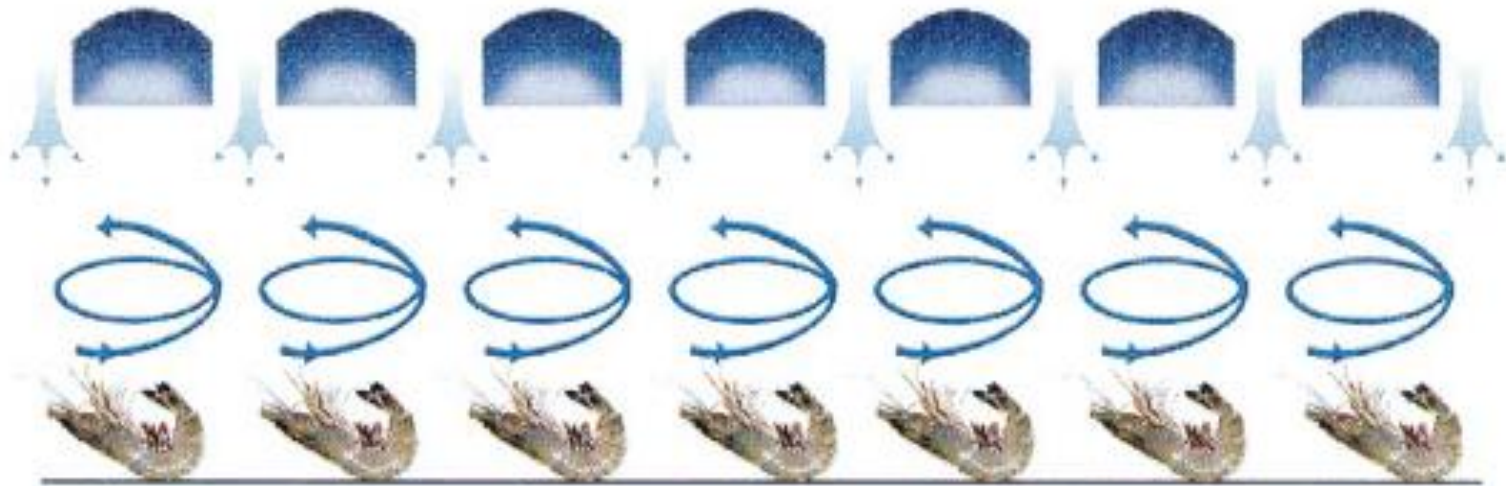
## CO<sub>2</sub> quick-freezing equipment

➤采用CO<sub>2</sub>专用高强度蒸发器，低温高压，整机设计压力5.2MPa，试验压力15MPa

➤Using special high strength evaporator , design pressure 5.2MPa, strength test pressure 15MPa, suitable for the case of low-temperature high-pressure.

➤独特的配风方式，形成独立的冷冻区域，冻结速度更快、干耗更小

The unique wind distribution forms an independent frozen area, making faster freeze, lower energy consumption and smaller loss.



# 速冻设备工程案例

## Project cases about quick-freezing equipment

- 烟台丰润食品有限公司速冻
- 乳山华信食品有限公司速冻
- 大连獐子岛集团贝类速冻冷藏
- 上海长兴岛中心渔港速冻冷藏
- 烟台伟成水产速冻
- 鹤壁赛德速冻冷藏
- .....





# 制冰工程案例

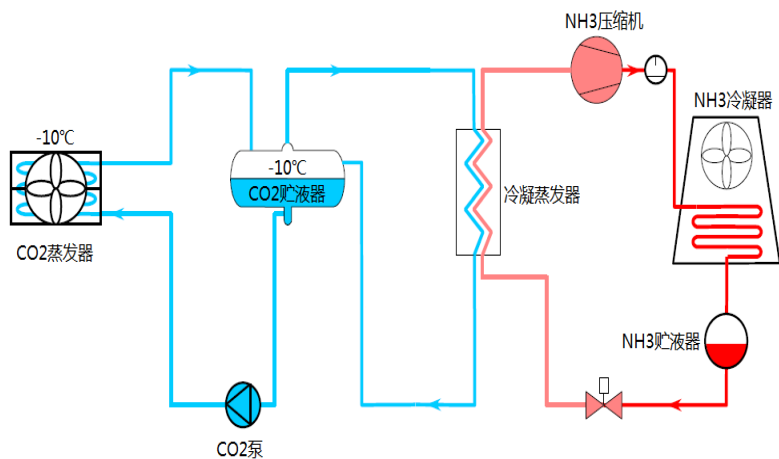
## Project cases about ice making



### 广州品纳制冰 CO<sub>2</sub>载冷剂系统

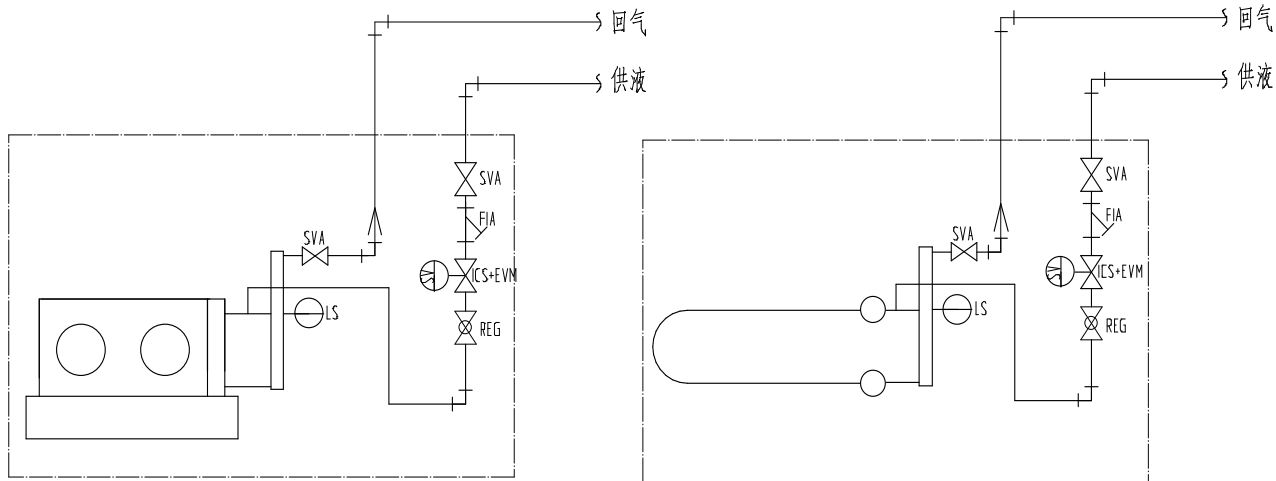
CO<sub>2</sub> secondary refrigerant system

- 制冰量为600吨/15小时
- Capacity: 600 tons per 15h
- 另有一间储量1000吨的冰库
- the capacity of ice storage is 1000 tons
- 制冰：冰池末端设备为螺旋管蒸发器
- Ice-making: spiral tube evaporator
- 600吨制冰分为16座制冰池
- Using 16 ice-making pools
- 每座冰池配套2组螺旋管蒸发器
- 2 spiral tube evaporators for every ice-making pool

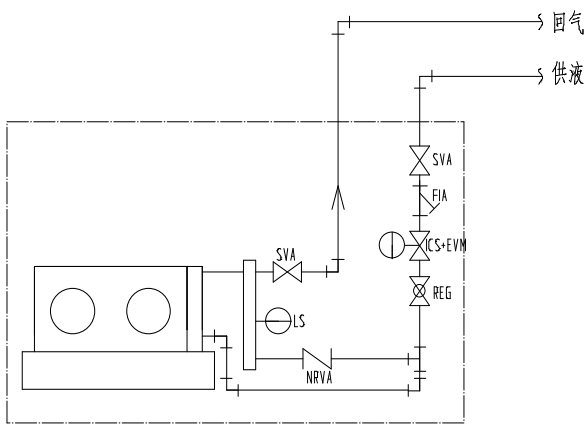


# 供液方式的研究

## Research on gravity for Supply



### 高位控制/Upper control



### 低位控制/Lower control

- 可应用于复叠系统重力供液
- Applied in cascade system
- 主要应用于机房位于高处的多层库，优势在于减小静液柱对不同层库间蒸发温度的影响。
- Applied in high cold storage ,its advantage is minimizing liquid impact on evaporating temperature of different cold storages.

# 泵供液工程案例

## Project cases about pump for liquid supply



- 烟台丰润食品有限公司速冻
- 乳山华信食品有限公司速冻
- 大连獐子岛集团贝类速冻冷藏
- 上海长兴岛中心渔港速冻冷藏
- 烟台伟成水产速冻
- 鹤壁赛德速冻冷藏
- .....



- 循环倍率与系统性能的验证  
Test of circulation rate to system performance
- CO<sub>2</sub>液体压力降的测试  
Test of pressure drop of CO<sub>2</sub> liquid
- CO<sub>2</sub>气体或气液两相流的阻力损失，对系统性能的影响  
Research on the influence of CO<sub>2</sub> gas or gas-liquid mixture pressure drop to system performance



# 重力供液工程案例

## Project cases about gravity for Liquid Supply



### 大连獐子岛物流库

- CO<sub>2</sub>载冷剂
- Secondary refrigerant system
- 重力供液
- Gravity for liquid supply
- 低温冷藏
- Low temperature cold storage



# 融霜方式的研究

## Research on defrosting

➤ 各种融霜方式的研究，重点工质热气融霜的研究

Research on defrosting, especially hot gas defrosting

➤ 融霜压力控制：保证恒定的融霜压力，确保融霜压缩机的稳定运行

Pressure control of defrosting: hold defrosting pressure to ensure stable operation of compressor

➤ 融霜过程控制：避免热气进入引起的压力冲击，缩短融霜整体时间。根据末端设备类型的不同，确定不同的抽空时间。避免吸气压力冲击及“液锤”风险

Process control of defrosting: to avoid the pressure impact, shorten defrosting time, avoid pressure impact for suction line and liquid hammer.

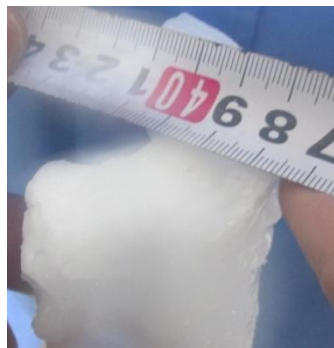
➤ 对于复叠制冷系统，可采用CO<sub>2</sub>制冷压缩机兼做融霜压缩机，对于CO<sub>2</sub>载冷剂制冷系统，需设置融霜压缩机

For cascade system CO<sub>2</sub> compressor can be used as defrosting compressor, but in secondary refrigerant system, special compressor is needed.

排管表面结霜情况

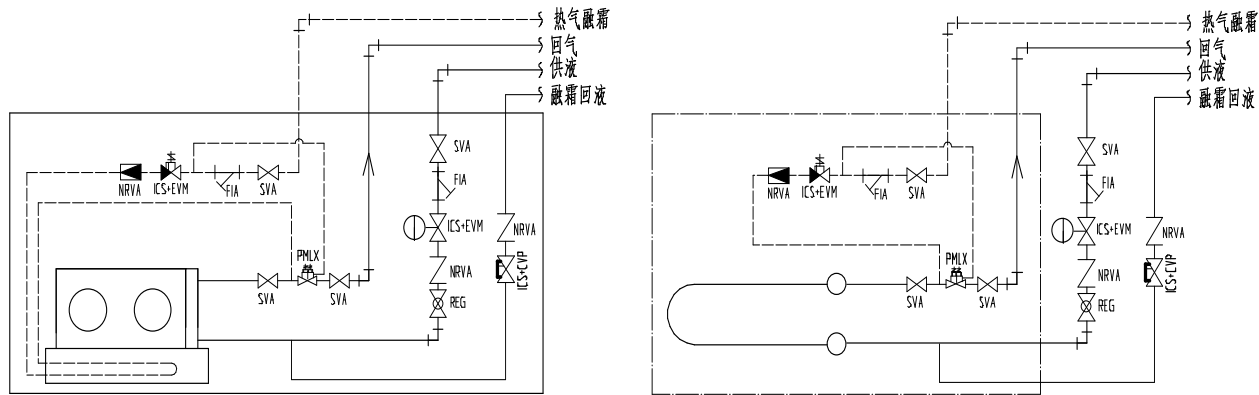


融霜排管冰层脱落情况

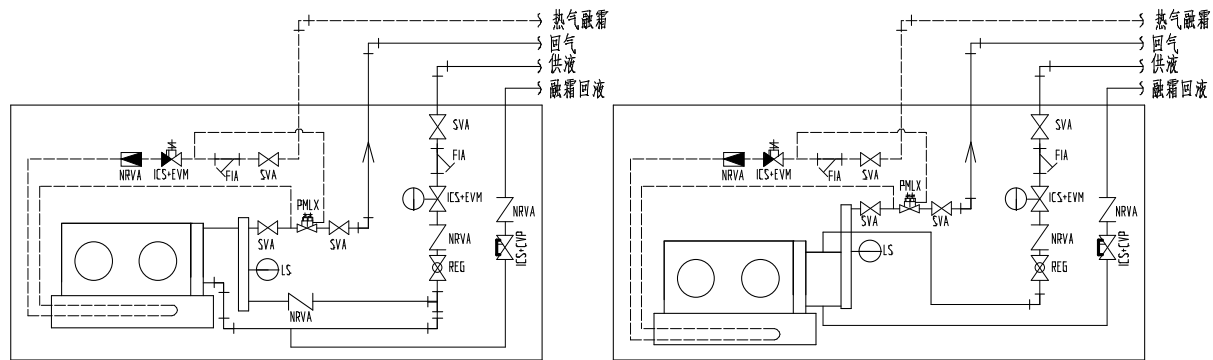


# 不同供液方式的融霜的研究

## Research on defrosting using refrigerant



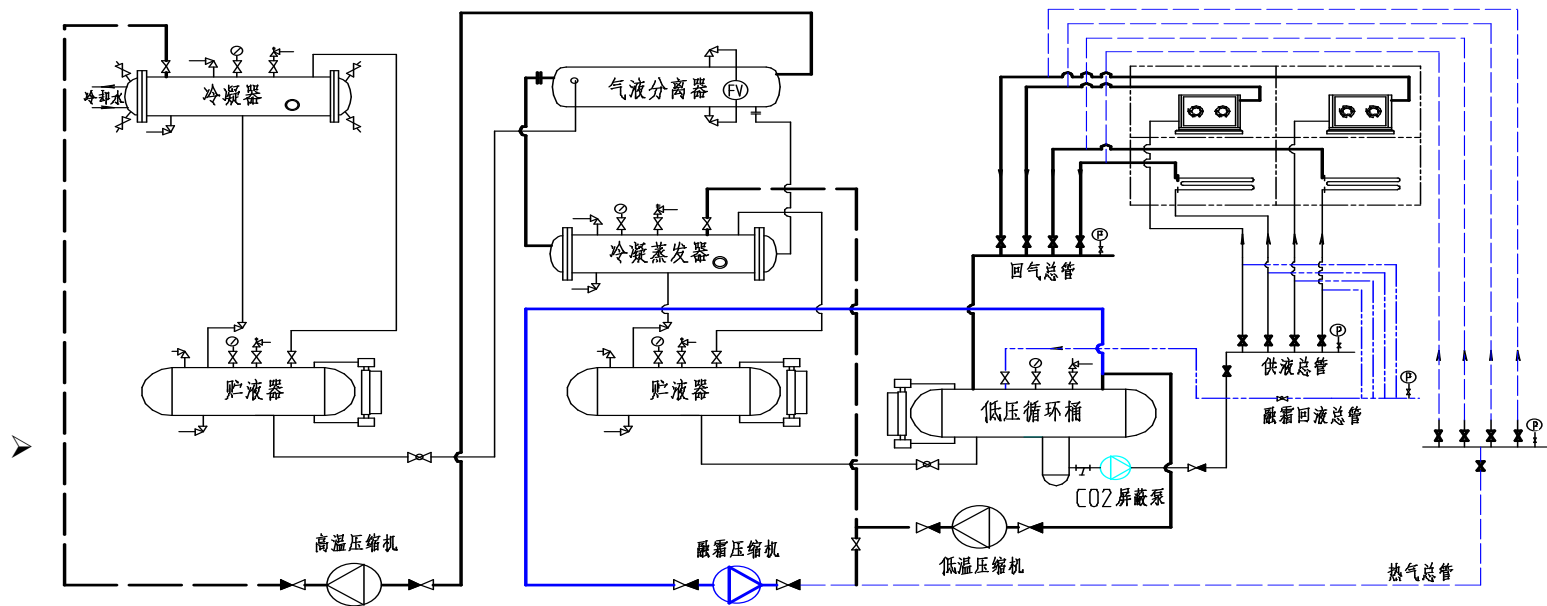
泵供液热工质融霜  
Hot gas defrosting using pump



重力供液热工质融霜  
Hot gas defrosting using gravity liquid supply

# 热工质融霜工程案例

## Project cases about hot gas defrosting



**福建蓝丰物流冷库：**复叠系统：顶排管热工质融霜

Cascade system: hot gas defrosting , overhead coil

**广州品纳物流库：**载冷系统；顶排管热工质融霜

Secondary refrigerant system :

**长江桂柳禽类速冻冷藏：**复叠系统：冷风机、搁架、顶排管，热工质融霜

Cascade system: air cooler, shelves, overhead coil, hot gas defrosting

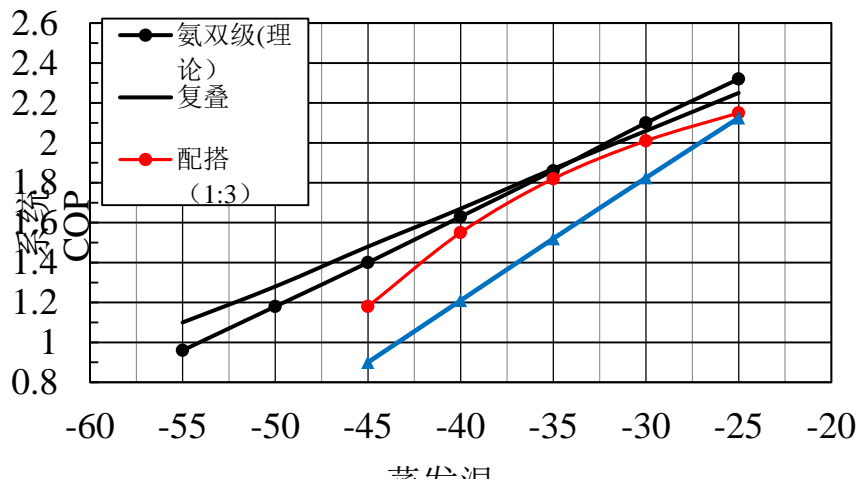
# 复叠系统与载冷剂系统的应用分区研究

Research on application of cascade system and secondary refrigerant system

在CO<sub>2</sub>蒸发温度低于-25℃时，从系统的经济性方面应优先选用复叠系统

Cascade system is suitable when CO<sub>2</sub>'s evaporating temperature is lower than -25℃.

- 复叠系统与载冷剂系统氨侧的压缩机组效率比较：二次进气、单机双级、双机配搭
- Comparison of efficiency for R717 compression unit in cascade system and secondary refrigerant system: second intake, two-stage compressor, two compressors unit
- 载冷剂系统的冷凝蒸发器的换热温差对系统效率的影响
- Temperature difference of evaporative condenser affects system efficiency



# 市场预测

## Market forecast

### R717的安全压力 Safe limit of R717

氨安全的压力巨大（10吨重大危险源分级基准，40吨氨的单系统上限等等）。

huge security pressure of R717, and filling quantity is restricted

### R22的环保压力 Environment pressure of R22

R22临近淘汰，国内大多数地区环评很难通过R22。

R22 is to be vanishing, and it's difficult to pass the environmental assessments

### R404\R507

R404\R507效率低下，泄露后存在温度滑移，且价格很高，维护费用高

Low Efficiency  
Temperature slip after leakage ,  
Higher price and maintenance cost

**安全 节能 环保**

Safe, Environmentally Friendly, Energy-saving

**发展环保制冷技术 共享绿色低碳生活**

Developing friendly refrigeration technology,  
and sharing a low-carbon life

**谢谢大家**

**Thank you**