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寒冷地区空气源吸收式热泵性能提高途径及对比分析 [刊, 中]

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**摘 要** 空气源吸收式热泵对于北方供暖的意义重大。为了提高空气源吸收式热泵在低温环境下的可靠性和能效,提出了双级吸收式热泵、双级耦合吸收式热泵和增压吸收式热泵。通过建模和模拟分析,对这三种途径在不同环境温度下的性能进行了对比分析。若采用风机盘管末端,当采暖期内气温低于 $-25^{\circ}\text{C}$ 的时间很少时,双级耦合热泵的性能最好;否则可以考虑采用双级空气源吸收式热泵。室外设计温度为 $-15^{\circ}\text{C}$ 和 $-30^{\circ}\text{C}$ 时,空气源吸收式热泵的一次能源效率分别比燃煤锅炉高 28%和 19%。若采用地板辐射末端,则增压吸收式热泵的能效最高,室外设计温度为 $-15^{\circ}\text{C}$ 和 $-30^{\circ}\text{C}$ 时,一次能源效率可达 0.953 和 0.874,分别比燃煤锅炉高 36%和 25%。考虑整个采暖期内气温较高时热泵的性能较好,则增压空气源吸收式热泵用于地板辐射采暖的节能潜力更为可观。

**关键词** 吸收式热泵; 对比; 空气源; 寒冷地区

## Characteristic Analysis of Adiabatic Spray Absorption Process in Aqueous Ammonia Solution

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**Abstract** An absorber is a key device of absorption refrigeration system, and it directly affects the performance of refrigeration system. As an important absorption type, adiabatic spray absorption process disperses the absorption fluid into fine droplets by nozzles and forms immense surface exposed to the coolant vapor. Therefore, it can improve the absorption performance. In the paper, an improved analytical Newman model is presented which can consider the absorption heat effect on adiabatic spray absorption process. Using the model, the absorption characteristics of the adiabatic spray in aqueous ammonia is studied. The results show that increasing absorption time can increase absorption mass, MA. However, when  $t/t_{\text{Max}}$  approaches to 0.6, MA has reached to 90% of the maximum absorption mass. In other words, increasing absorption time can hardly improve MA after  $t/t_{\text{Max}}$  exceeds 0.6. The maximum absorption time,  $t_{\text{Max}}$ , is proportional to the square of the droplet radius. Decreasing droplet radius can improve the absorption rate, but this increases the energy consumption of the refrigeration system. The current investigation can result in a better understanding of absorption mechanisms of the adiabatic spray absorption.

**Keywords** absorption refrigeration; aqueous ammonia; model; adiabatic spray absorption

### 进口结构对水箱性能影响的模拟及实验研究 [刊, 中]

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**摘 要** 建立了高为 80cm, 截面为 40cm×40cm 的长方体水箱, 并对水箱的热力性能进行了模拟及实验研究。实验分别设计了开槽型进口和直接进口结构的水箱 CFD 三维模型, 并利用水箱 Ri 数和用能效率对不同进口结构的性能进行分析比较。同时, 搭建不同进口结构水箱实验台, 验证分析不同进口结构对水箱用能效率的影响。实验结果表明其中的开槽型结构水箱与直接进口结构相比能有效改善用能过程的热分层效果, 明显提高用能效率。在 5L/min 流量条件下, 开槽型进口结构的用能效率比直接进口的高出 7%, 而当流量为 15L/min 时, 两者之间的差距增大至 25%。

**关键词** 用能效率; CFD 模拟; 热分层

### Simulation and Experimental Investigation of the Influence on the Performance of Tanks with Different Inlets

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**Abstract** This paper designed a solar water tank with dimension of 80cm(height)×40cm(width) ×40cm(length) and the slotting inlet and direct inlet to study discharging performance of tank by presenting some experiments and simulations. The Ri number and the discharging efficiency were introduced to investigate the performance of the different inlet-tanks. The discharging efficiency was introduced to evaluate the thermal performance of the tank with different inlets. The result indicated that slotting inlet improved the efficiency of thermal stratification effectively and promoted discharging performance obviously. The discharging efficiency of slotting inlet was 7% higher than the direct inlet with the flow rate of 5L/min and the gap increased to 25% when the flow rate is 15L/min.

**Keywords** discharging efficiency; CFD simulation; thermal stratification performance

#### 一种四级自动复叠制冷系统混合工质组分选取及配比研究 [刊, 中]

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**摘 要** 对于多级自动复叠制冷系统, 混合制冷工质的选取和组分配比具有重要的影响作用。针对四级自动复叠制冷系统, 运用 REFPROP8.0 软件建立了混合工质种类选择及其配比研究的理论模拟方法, 通过分析比较混合工质的饱和压力、蒸发温度, 模拟出混合工质组分和配比: R600a/R23/R14/R740=45/21/19/16, 充入该混合工质配比进行实验研究, 获得了-150℃的设计柜温。研究表明, 该混合工质理论模拟方法, 能够有效指导实验研究, 取得理想的制冷温度。

**关键词** 自动复叠制冷; 混合工质; 模拟计算; 配比

#### Study on Mixed Refrigerants Selecting and Matching of a Four Stage Auto-cascade Refrigeration

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**Abstract** The selection and mixture ratio of the mixed refrigerants are important to a multistage auto-cascade refrigeration system. A simulation method was found for the mixed refrigerants selection and ratio calculation by using

the commercial software REFPROP8.0. The saturation pressure and evaporation temperature of the auto-cascade refrigeration system were compared to get the optimal mixture ratio of the mixed refrigerants, that is R600a/R23/R14/R740=45/21/19/16. The temperature of freezer was  $-150^{\circ}\text{C}$  at this mixed refrigerants and the mixture ratio. The results show that the research of multistage auto-cascade refrigeration system can be guided by this simulation method and the expected temperature was got.

**Keywords** auto-cascade refrigeration; mixed refrigerants; simulation; mixture ratio

### 自然制冷剂 R290 与冷冻机油的相溶性研究 [刊, 中]

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**摘 要** 为了探讨制冷剂 R290 与冷冻机油的相溶性, 建立了一套油与制冷剂相溶性测试实验台, 考察了制冷剂 R290 与矿物油、POE 油、PAG 油、AB 油五种类型冷冻机油的相溶性。结果表明, 制冷剂 R290 在五种冷冻机油中的溶解质量百分含量顺序为: AB 油 > 环烷基矿物油 > 烷基矿物油 > POE 油 > PAG 油; R290 在烷基矿物油、POE 油、PAG 油中的溶解质量百分含量均随温度的增大而降低, 随压力的增大而升高; 在环烷基矿物油、POE 油、PAG 油中的溶解质量百分含量均随运动粘度增大而降低; 与运动粘度相比, 温度和压力对 R290 在冷冻机油中的溶解质量百分含量影响较大。

**关键词** 制冷剂; R290; 冷冻机油; 相溶性

### Investigation on the Miscibility of Lubricants with Natural Refrigerant R290

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**Abstract** In order to explore the miscibility of lubricants with the natural refrigerant R290, an experimental device was established. The miscibility of naphthenic oil, paraffinic oil, polyol ester, polyalkylene glycol and alkylbenzene with the natural refrigerant R290 was investigated. The results showed that the dissolution of the highest mass percentages of the refrigerant R290 was in the AB oil, followed by naphthenic oil and paraffinic oil, and finally polyol ester and polyalkylene glycol. The dissolution of the mass percentage of R290 in paraffinic oil, polyol ester and polyalkylene glycol decreased with increasing temperature, and increased with increasing pressure. Moreover, the dissolution of the mass percentage of R290 in a naphthenic oil, polyol ester and polyalkylene glycol decreased with increasing viscosity.

Compared with viscosity, temperature and pressure presented greater influence on the dissolution percentage of R290 in lubricants.

**Key words** refrigerant; R290; refrigerant oil; miscibility

### 替代工质水平管内流动凝结换热研究综述 [刊, 中]

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**摘 要**流动凝结传热特性对于制冷系统的性能具有重要意义,是制冷剂筛选中的一个重要参考指标。针对近年来有关新型替代工质的凝结传热进行了调研分析,从实验测量和关联模型两个方面综述了国内外替代制冷剂管内流动凝结换热的研究。对凝结换热关联式的适用性和准确性进行了讨论,对凝结换热系数和压降随各影响因素的变化特性进行了概括。

**关键词** 替代工质; 凝结换热; 综述

### Review on Flow Condensation Heat Transfer of Alternative Refrigerants inside Horizontal Tubes

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**Abstract** Flow condensation heat transfer is of great significance for the performance of refrigeration system and is an important index of the refrigerant alternatives. In this paper, condensation heat transfer of the new alternative refrigerants is investigated. Recent developments of experiments measurement and relation models of condensation heat transfer of alternative refrigerants inside tubes are reviewed. The applicability and accuracy of correlations of condensation heat transfer for alternative refrigerants are discussed. The change of condensation heat transfer coefficients and pressure drops with influencing factors are summarized.

**Keywords** alternative refrigerant; condensation heat transfer; review

### 太阳能空调相变蓄冷理论及实验研究 [刊, 中]

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**摘 要** 针对一种自制的能够与太阳能空调系统匹配的相变蓄冷材料,建立了蓄冷球蓄\释冷过程数学模型,得到稳态及非稳态工况下蓄冷球内温度分布、蓄\释冷量、蓄\释冷速率的变化规律及影响因素。同时,在相应工况下对单个蓄冷球进行蓄\释冷循环实验,验证理论结果。研究表明,自制蓄冷球能够在 170min 完成相变。缩小球径、降低冷冻水温度、增大球壁热导率及减小球壁厚度均可缩短蓄冷时间。稳态运行工况下,蓄冷球的蓄\释冷量分别为 17.30kJ 和 16.46kJ; 太阳能空调非稳态运行工况下,蓄冷球在 165min 完成相变,蓄冷量为 16.34kJ。

**关键词** 相变蓄冷; 太阳能空调; 影响因素; 非稳态工况

### **Theoretical and Experimental Study on Solar Air Conditioning System with Phase Change Cold Storage**

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**Abstract** A phase change material (PCM) is prepared for cold storage application of solar air-conditioning systems. On the basis of the self-developed PCM, the mathematical model of a spherical capsule storage ball is built to analyze the variation and influencing factors of the temperature distribution, cold storage capacity and cold storage rate during the charging and discharging process. Experiments on the charging and discharging characteristics of the storage ball are conducted in certain working conditions. The results show that the phase transition of the storage ball completes in 170min. The charging duration can be reduced by decreasing the chilled water temperature, sphere diameter and thickness of the sphere wall, and increasing the thermal conductivity of the sphere wall. In a steady state condition, the charging and discharging capacity are 17.30kJ and 16.46kJ, respectively. In a non-steady state condition, the phase transition completes in 165min with a charging capacity of 16.34kJ.

**Keywords** phase change cold storage; solar air conditioning; influencing factors; non-steady state conditions

### **太阳能、空气源热泵热水系统性能优化实验研究 [刊, 中]**

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**摘 要** 将已实用化的非直膨式太阳能、空气源热泵热水器作为被测对象,测试其基础性能,以对其全年实际性

能进行分析。然后设计拟定出 3 种性能优化方案,对提出方案进行可行性分析并在冬季条件下进行多组实验,以观测所能达到的优化程度。最后提出一种优化方案的综合运行策略,并通过模拟全年不同温度、气候环境计算出该优化方案的综合运行效果,复合系统全年累计电能消耗减少达 45.8%。

**关键词** 太阳能热水器;空气源热泵热水器;复合系统;性能优化;气候因素

### **Experimental Research on Performance Optimization of Solar-air Source Heat Pump Water Heater**

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**Abstract** A practical indirect expansion solar-air source heat pump water heater (IESASHPWH) is tested for its fundamental performances and analyzed for its annual practical performances. Then three performance optimization schemes are designed, analyzed for their feasibilities and tested for the effects several times under the winter condition. Eventually an operation strategy integrated with all the three optimization schemes is proposed and simulated under annual climate conditions. The result shows that the compound system can reduce annual power consumption by 45.8%.

**Keywords** solar water heater; heat pump water heater; compound system; performance optimization analysis; climatic factors

### **低温环境下空气源热泵的研究现状及展望 [刊, 中]**

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**摘 要**空气源热泵作为一种高效、节能环保装置,具有广泛的应用前景和市场价值。但其在低温环境下性能不稳定,制热效率过低,抑制了空气源热泵产品的推广和应用。通过总结国内外学者对改善系统在低温环境下适应性所做的研究,分析了空气源热泵在低温环境下存在的弊端,并根据最新研究进展,分别从新型工质替代问题,相变材料与空气源热泵的结合,新型热泵循环系统的开发方面对今后的研究方向作出展望。

**关键词** 空气源热泵;热水器;低温适应性

## Research Progress and Prospect of Air Source Heat Pump in Low Temperature Environment

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**Abstract** Air source heat pump, a high efficiency, energy conservation and environmental protection device, is in prospect of wide application and market value. But the unstable performance and lower coefficient of performance (COP) in low ambient temperature restrain the promotion and application of air source heat pump products. This paper analyzed the disadvantages of air source heat pump in low temperature environment through the review of both domestic and international investigations on system improvement in low temperature environment. Besides, the development and trend of air source heat pump is also proposed based on the latest research progresses in the aspects of new alternative refrigerant, the combined air source heat pump with phase change materials as well as the development of new heat pump system, respectively.

**Keywords** air source heat pump; water heater; cold adaptation

## 带闪蒸型经济器的风冷螺杆热泵机组性能的实验研究 [刊, 中]

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**摘要** 研究了带闪蒸型经济器风冷螺杆热泵机组对制热性能的影响, 理论分析了补气压力的变化对机组制热性能的影响。研究表明, 带闪蒸型经济器热泵螺杆机组制热量随经济器的补气压力的减小而增大, 压缩机功率也随经济器的补气压力的减小而增大, 压缩机的 COP 随着经济器的补气压力的升高先升高再降低, 存在最佳效率的补气压力点。实验测试了比最佳补气压力点偏高的经济器补气压力对机组性能的影响, 理论计算结果和实测数据吻合良好。

**关键词** 闪蒸型经济器;风冷螺杆热泵机组;经济器补气压力

## Experimental Study on Performance of Air-cooled Screw Heat Pump with Flash Tank Economizer

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**Abstract** The effects of flash tank economizer on performance of air source screw heat pump are studied. The effect of economizer vapor injection pressure on unit performance is theoretically analyzed. The study shows that the lower economizer vapor injection pressure is, the higher heating capacity and compressor power of screw heat pump with flash type economizer are. The COP of heat pump first increased and reduced again with the increase of the economizer vapor injection pressure. There is an optimized point. The experiment was carried out to investigate the effects of flash tank economizer on performance of heat pump at near optimum economizer vapor injection pressure. The simulation results are in good agreement with those of the experiment.

**Keywords** flash tank economizer; air-cooled screw heat pump; economizer vapor injection pressure

### 半导体制冷与固体除湿结合装置的性能探究 [刊, 中]

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**摘 要** 半导体制冷 (又称热电制冷) 因为降温迅速、易于控制等优点, 广泛应用于工业生产、日常生活等方面。而热端散热效果成为制约半导体制冷效率的主要因素。半导体制冷在空气除湿领域的应用研究日趋深入, 但传统的冷却除湿要求半导体冷端温度较低, 使半导体制冷效率降低。建立半导体制冷 (热管排热系统)、固体吸附剂结合的除湿模型, 通过 6 级半导体制冷与热管散热系统的实验装置对干工况进行模拟验证, 再模拟固体除湿工况在不同输入电流下的性能。模拟结果表明: 当除湿量与文献中半导体冷却除湿装置相同时, 该半导体与固体除湿结合的模型的系统 COP 为 1.78, 明显高于文献中装置 COP。说明结合固体吸附剂后可以加强传质动力提高冷端温度, 从而提高系统性能。

**关键词** 空调制冷; 半导体; 固体除湿; 热管排热; 除湿性能

### Performance Research of a Semiconductor Cooling Device with Solid Desiccant

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**Abstract** Semiconductor refrigeration, known as thermoelectric refrigeration, is applied widely in fields such as industrial production and daily life, due to the advantages of rapid cooling and easy control. The heat dissipation on the hot side is the principle element restricting the coefficient of semiconductor refrigeration. In conventional device, dehumidification is realized by condensing dehumidification method, which lowers the temperature of the cold side of semiconductor and hence restricts the system COP. The semiconductor refrigeration model with heat pipe and solid desiccant is built in this paper, and verified by the experimental results of a 6-stage semiconductor refrigeration equipment with heat pipes. Then the model is used to predict the cooling and dehumidification

performances with solid desiccant. The COP of the proposed semiconductor refrigeration system is 1.78, which is much higher than that shown in literature with condensing dehumidification under the same dehumidification amount.

**Keywords** air-conditioning; semiconductor; solid desiccant; heat pipe; dehumidification capacity

### 矿用救生舱降温除湿系统无霜改进及可行性分析研究 [刊, 中]

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**摘 要** 无电自驱式矿用救生舱在矿难发生后为井下被困的人员提供了必要的生存条件。针对现有救生舱的 CO<sub>2</sub> 降温除湿系统的蒸发器容易出现结霜的问题, 提出了一种降温除湿系统的无霜改进设想, 介绍了改进后系统的设备构成和 workflow, 并详细分析了无霜改进的原理及其可行性; 同时还针对系统的可行性进一步阐述了一种运用温度分级控制阀组的控制方法, 分析了系统在变负荷工况下的多种控制调节方式。为矿用救生舱的深入研究提供了参考。

**关键词** 矿难; 救生舱; CO<sub>2</sub> 降温除湿系统; 无霜; 分级控制

### The Frostless Improvement and Feasibility Analysis of Cooling and Dehumidifying System in Mine Rescue Chamber

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**Abstract** Powerless self-driven mine rescue chamber supplies essential survival conditions for the people who are trapped during mine accidents. As the evaporator in the CO<sub>2</sub> cooling and dehumidifying system of current rescue chamber has frosting problem, an idea of frostless improvement of the cooling and dehumidifying system is proposed and the equipment structure and working process of the developed system are introduced in this paper. Then, the principle and feasibility of the frostless improvement are analyzed in detail. Furthermore, a control method which uses temperature hierarchical control group valves is stated, and several regulative methods of the system under variable load conditions are analyzed. The results provide reference for further study of mine rescue chamber.

**Keywords** mine accident; rescue chamber; CO<sub>2</sub> cooling and dehumidifying system; frostless; hierarchical control

### 锯齿斜翅管表面碳酸钙析晶污垢初始阶段结垢特性 [刊, 中]

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**摘 要** 进行光管和锯齿斜翅管在不同碳酸钙浓度和流速下的动态结垢实验, 得到碳酸钙浓度、流速和锯齿斜翅管对碳酸钙析晶污垢结垢过程的影响。结果表明: 浓度增大使溶液中均相成核速率和所形成晶核的生长速率增大, 使溶液换热表面界面的污垢晶粒浓度和成垢离子浓度均增大, 前者使更多的污垢附着换热面而后者使表面异相成核速率和生长速率增大。流速增大使光管表面形成的晶核、污垢晶体和污垢热阻均减少而诱导期延长; 使锯齿斜翅管初始成核增多, 但诱导期延长、而结垢量

和污垢热阻减小。锯齿斜翅管在清洁状态和结垢状态下均具有比光管更大的总换热系数、更小的污垢热阻，尽管结垢量略多。

**关键词** 斜翅管；碳酸钙；析晶污垢

### Characteristics of the Initial Stage of CaCO<sub>3</sub> Crystallization Fouling on Saw-tooth Oblique Fin Tube

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**Abstract** To investigate the effect of CaCO<sub>3</sub> concentration and velocity on CaCO<sub>3</sub> scaling fouling process on plain and saw-tooth oblique fin tubes, experiments have been done at different CaCO<sub>3</sub> concentration and velocity on the two kinds of tubes. The results show that the homogeneous nucleation rate and the growing rate are both increased when CaCO<sub>3</sub> concentration increases. This makes the scaling particle concentration and foulantions concentration increase. The former increase gets more scaling on tubes and the later enlarges the heterogeneous nucleation rate and growing rate. Higher velocity decreases the nucleation of scaling, scaling crystal and fouling resistance, but it can prolong the induction period. Higher velocity increases nucleation rate on saw-tooth oblique fin tube first, but the induction period extends and the mass of scaling and fouling resistance decrease. Saw-tooth oblique fin tube has a bigger heat transfer coefficient than plain tube at both clean and fouling conditions and it has smaller fouling resistance and a little more scaling.

**Keywords** oblique fin tube; calcium carbonate; crystallization fouling

### 振荡流热管汽车散热器传热性能的实验研究 [刊, 中]

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**摘 要** 对振荡流热管汽车散热器和管带式铜质汽车散热器进行了实验研究，得到了两种散热器的传热和阻力特性，对比发现振荡流热管汽车散热器具有较好的传热性能，且风阻和水阻均小于管带式铜质汽车散热器，并进行了热平衡误差分析，实验结果对开发新型汽车散热器有一定的指导意义。

**关键词** 汽车散热器；振荡流热管；传热性能；阻力特性

### Experiment Study on Heat Transfer Performance of Oscillating Heat Pipe Radiator for Automobile

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**Abstract** The heat transfer and pressure drop characteristics of oscillating heat pipe radiator and corrugated copper radiator for automobile were obtained by experiment. And the results were compared and analyzed. The results showed that the heat transfer and pressure drop performance of oscillating heat pipe radiator for automobile were better than the corrugated copper one. And the heat balance error was analyzed. The experimental results have some guidance to the development of new type automobile radiator.

**Keywords** automobile radiator; oscillating heat pipe; heat transfer performance; pressure drop performance

### 蓄冷用 CO<sub>2</sub> 水合物浆的强化制备研究进展 [刊, 中]

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**摘 要**介绍了近几年国内外 CO<sub>2</sub> 水合物浆强化制备的研究进展, 详细介绍了机械扰动和添加剂强化制备 CO<sub>2</sub> 水合物浆的方法。重点介绍了一种新型蓄冷用 CO<sub>2</sub> 水合物浆强化制备装置及其工作原理。最后, 为 CO<sub>2</sub> 水合物浆蓄冷技术尽早实用化, 提出了在 CO<sub>2</sub> 水合物相平衡、强化制备装置、多种促进技术和蓄冷放冷及流动特性四个关键方向进行重点研究。

**关键词** 蓄冷; 综述; CO<sub>2</sub> 水合物浆; 强化制备

### Research Progress of CO<sub>2</sub> Hydrate Slurry Formation Enhancement in Cool Storage Application

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**Abstract** The recent development of CO<sub>2</sub> hydrate slurry formation enhancement in cool storage application was introduced, and the formation enhancement methods of mechanical mixing in combination with additives were presented. A novel CO<sub>2</sub> hydrate slurry formation apparatus in cool storage application was recommended. Finally, CO<sub>2</sub> hydrate phase equilibrium, CO<sub>2</sub> hydrate formation equipment, a variety of CO<sub>2</sub> hydrate formation promoting technology, CO<sub>2</sub> hydrate cool storage and flow characteristics were suggested to be investigated preferentially to improve the application of CO<sub>2</sub> hydrate slurry in cool storage practice.

**Keywords** cool storage; reviews; CO<sub>2</sub> hydrate slurry; formation enhancement

### 牵引整流器热管式空气冷却器散热性能实验研究 [刊, 中]

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**摘要** 为了科学合理的掌握机车 IGBT 功率模块冷却器在正常运行过程中的传热特性,搭建标准风洞实验系统,研究风速 5~7m/s,散热器进风温度 30~45℃,基板温度分别为 70℃和 80℃条件下,热管式空气冷却器的散热量,基板的工作温度范围以及进风速度和温度对换热的影响。实验结果表明:在实验进风速度和进风温度下,冷却器正常工作时,基板温度越高,冷却器散热量就越大,当基板温度为 80℃时,冷却器的散热量在 5400~7400W 之间。通过冷却器的散热量可以得到:在机车正常工作时,冷却器基板的最佳工作温度在 70~90℃之间。进风速度小于进风温度对换热量的影响,考虑到降低能耗和减少噪音污染,流经冷却器的风速应不超过 7m/s。以上实验结果为高速动车组牵引整流器热管式空气冷却器的选型和设计提供科学参考。

**关键词** IGBT; 牵引整流器; 热管; 温度

### Experimental Study on Heat Pipe Cooler of Electric Locomotive Traction Converters

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**Abstract** To master heat transfer characteristics of locomotive IGBT power module cooler, experimental system on the heat dissipation, substrate temperature range and the effects of air velocity and inlet air temperature on the heat transfer of the heat pipe cooler is built. The experiments are conducted under air velocity at 5-7m/s, inlet air temperature at 30-45℃ and substrate temperature at 70-80℃. Experimental results show that the higher the substrate temperature is, the more heat is dissipated; when the substrate temperature is at 80℃, the heat dissipating capacity is 5400-7400W. The results also show that the optimal working temperature of substrate is at 70-90℃ for the cooler. Inlet air temperature has more effects on the heat transfer than air velocity. Considering energy consumption and noise level of, the air velocity flowing through the cooler should not be more than 7m/s. Experimental results provide a scientific basis for the selection and design of the cooler.

**Keywords** IGBT; Traction rectifiers; Heat pipe; Temperature

### 冷冻载体 Cryotop 降温速率的测量及系统优化 [刊, 中]

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**摘要** Cryotop 法是玻璃化保存卵母细胞较有效的方法之一。当 Cryotop 载体插入液氮时, 降温速度极高, 几乎瞬间完成, 常规的方法无法测量。实验使用数字示波器、线径 25  $\mu\text{m}$  的 T 型热电偶建立起高速测温系统, 测量了 Cryotop 法用于卵母细胞低温保存时的降温速率。通过改变载体材料、厚度、冷源温度等条件, 提高 Cryotop 的降温速率。结果发现当使用 60  $\mu\text{m}$  的铜质载板, 使用浆状液氮作为冷源时, 降温速度最高, 可达到  $37130 \pm 1336 \text{ K/min}$ , 较商品化的 Cryotop 的降温速度 ( $11982 \pm 1936 \text{ K/min}$ ) 提高了 2 倍。

**关键词** Cryotop; 降温速率; 高速测温

### Cooling Rate Measurement and System Optimization for Cryotop Device

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**Abstract** Cryotop is one of the best effective methods for oocytes cryopreservation. When Cryotop is inserted into liquid nitrogen, the cooling speed is extremely high, which is difficult to measure by conventional method. In this study, digital oscilloscopes and type T thermocouple of 25  $\mu\text{m}$  diameter were employed to establish a high speed temperature measurement system. The cooling rates of Cryotop device at different carrier material, thickness and cold source temperature were measured. The results showed that when 60  $\mu\text{m}$  copper was used as carrier and slush nitrogen was used as cold source, the cooling rate was increased. It could reach  $37130 \pm 1336 \text{ K/min}$ , which was twice higher than that of commercially available Cryotop ( $11982 \pm 1936 \text{ K/min}$ ).

**Key words** Cryotop; cooling rate; ultra-fast temperature measurement

### 干燥褐煤的热泵技术实验研究 [刊, 中]

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**摘要** 结合目前国内电厂循环水余热利用及褐煤干燥现状,提出了利用热泵技术回收电厂循环水余热干燥褐煤的实验方案,并搭建了实验系统。分别在 60℃、70℃、80℃条件下对褐煤进行了干燥实验,测定了褐煤质量随时间变化曲线。实验结果表明:干燥温度越高,干燥速率越快,有效干燥时间越长,干燥效果越好。在 60℃的条件下脱水量为 22.5%,耗时 25min;70℃时为 31%,耗时 30min;80℃最高可达到 42.6%,耗时 35min。为热泵技术在循环水余热利用以及褐煤干燥中的实际应用提供参考。

**关键词** 热泵;褐煤;干燥;余热利用;循环水

### Experimental Study on Drying Lignite by Heat Pump

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**Abstract** An experimental scheme is proposed to recover the waste heat of power plant circulating water to dry lignite with heat pump, and the experiment system was developed. Experiments of drying lignite in the temperature of 60℃, 70℃ and 80℃ were conducted, and the change of lignite quality with time was measured. The result shows that: the higher the temperature, the faster drying rate; the longer the effective drying time, the better the result. Drying 22.5% water at the temperature of 60℃ takes time 25 min; 30.5%-31.5% at 70℃ takes 30 min; 42.6% at 80℃ takes 35 min. This paper provides a reference for the practical application of heat pump in the utilization of waste heat of circulating water for drying lignite.

**Keywords** heat pump; lignite; dry; utilization of waste heat; circulating water

### 氨水绝热喷雾吸收过程的特性分析 [刊, 中]

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**摘要** 吸收器是吸收制冷系统中的关键部件之一,吸收性能的好坏直接关系着整个制冷系统的性能。作为一种重要的吸收方式,绝热喷雾吸收将吸收工质通过喷嘴在冷剂蒸汽中形成微米级的液滴,进而形成巨大的气液接触面积,可以极大地提高吸收速率。在 Newman 模型的基础上,考虑吸收热对吸收过程中的影响,一个改进的绝热喷雾吸收模型被建立。借助此模型,对氨水绝热喷雾吸收过程进行性能分析。结果显示,吸收时间的延长可以提高吸收量 MA,但是当  $t/t_{Max}$  达到 0.6,吸收量 MA 达到了最大吸收量的 90%,即过分延长吸收时间不是一个经济的强化方法。最大吸收时间与液滴半径的平方成正比,即半径的减少可以提高喷雾吸收效率,但半径的减少会增加系统的能耗。研究结果将为高效绝热喷雾吸收器的设计提供理论参考。

**关键词** 吸收制冷; 氨水; 模型; 绝热喷雾吸收

### **Characteristic Analysis of Adiabatic Spray Absorption Process in Aqueous Ammonia Solution**

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**Abstract** An absorber is a key device of absorption refrigeration system, and it directly affects the performance of refrigeration system. As an important absorption type, adiabatic spray absorption process disperses the absorption fluid into fine droplets by nozzles and forms immense surface exposed to the coolant vapor. Therefore, it can improve the absorption performance. In the paper, an improved analytical Newman model is presented which can consider the absorption heat effect on adiabatic spray absorption process. Using the model, the absorption characteristics of the adiabatic spray in aqueous ammonia is studied. The results show that increasing absorption time can increase absorption mass, MA. However, when  $t/t_{\text{Max}}$  approaches to 0.6, MA has reached to 90% of the maximum absorption mass. In other words, increasing absorption time can hardly improve MA after  $t/t_{\text{Max}}$  exceeds 0.6. The maximum absorption time,  $t_{\text{Max}}$ , is proportional to the square of the droplet radius. Decreasing droplet radius can improve the absorption rate, but this increases the energy consumption of the refrigeration system. The current investigation can result in a better understanding of absorption mechanisms of the adiabatic spray absorption.

**Keywords** absorption refrigeration; aqueous ammonia; model; adiabatic spray absorption