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压水堆核电机组二回路热力系统矩阵分析法

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摘　要: 基于各级加热器的热平衡方程, 通过严密的数学推导, 提出了基于矩阵的压水堆核电机组二回路热力系统的定功率方程式。对该矩阵的填写规则进行了详细阐述, 指出了各矩阵的物理意义, 该方程式全面考虑了二回路热力系统的结构特点以及辅助汽水系统, 在定功率条件下, 可以一次性求出汽耗量和各级抽汽量, 通用性强, 在应用时、具有简洁、准确和快速的特点。通过对某 900 MW 机组进行算例分析, 验证了该方程的准确性。

关　键　词: 核电机组; 热力系统; 二回路; 矩阵法; 定功率

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引　言

核电因不消耗化石能源、无污染的特点正蓬勃发展。目前, 我国已建和在建的核电站总装机容量为 8 700 MW, 预计到 2010 年中国核电装机容量约为 20 000 MW, 2020 年约为 40 000 MW。由于现代核电机组均采用具有蒸汽中间再热的回热循环, 因此其系统就比火电站热力系统更为复杂, 给分析带来了一定的困难。通常, 热力系统的分析方法有等效热降法、循环函数法、矩阵法等[1~6]。由于等效热降法在对热力系统进行局部定量分析时简洁方便, 因此, 已被广泛应用于核电机组热力系统的分析研究[7~14]。但是, 在设计、大修或改造后往往要求机组输出功率达到一定值, 或是在一定功率下进行热经济性比较, 目前, 对于这方面的研究还较少。因此, 本文提出了一种在定功率条件下能够从整体上分析核电机组二回路热力系统的方法。

1　压水堆核电机组二回路热力系统矩阵方程

1.1　系统简介

压水堆核电机组二回路热力系统除高压加热器、低压加热器、除氧器以及给水泵外, 为了保障低压缸的安全运行, 二回路一般都设置中间汽水分离器和蒸汽中间再热器[15]。如图 1 所示, 高压缸排汽进入汽水分离器, 分离出的饱和蒸汽经再热器进行再热后进入低压缸; 而分离出的饱和水流入除氧器, 部分第一级抽汽和新蒸汽分别通过两级再热器, 对由分离器来的饱和蒸汽进行再热, 其疏水流入高压加热器。

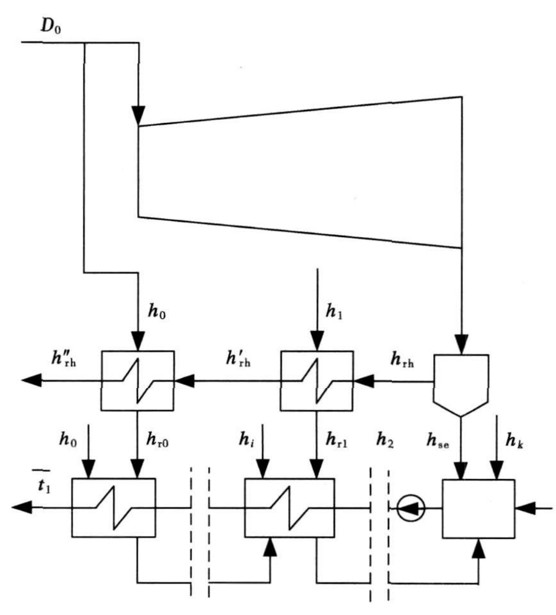

图 1　二回路高压加热器及再热系统

1.2　热平衡方程式和质量方程式

对汽水分离器列热平衡方程:

$$(D_{rh}+D_{se})h_m=D_{rh}h_{rh}+D_{se}h_{se} \tag{1}$$

对两级再热器分别列热平衡方程:

$$D_{r0}(h_0-h_{r0})=D_{rh}(h''_{rh}-h'_{rh}) \tag{2}$$

$$D_{r1}(h_1-h_{r1})=D_{rh}(h'_{rh}-h_{rh}) \tag{3}$$

再热系统质量平衡方程:

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$$D_{rh}=D_0-D_{r0}-D_{r1}-D_{se}-\sum_{i=1}^{m}D_i-D_{hf} \tag{4}$$

式中：D_{rh}—再热蒸汽流量；h_m—高压缸排汽比焓；D_{se}—汽水分离器分离出的疏水流量；h_{se}—疏水的比焓；h_{rh}—分离出的饱和蒸汽的比焓；D_{r1}、D_{r0}—第1级和第2级再热器的用汽量；h'_{rh}、h''_{rh}—第1级和第2级再热器出口的蒸汽的比焓；D_i—进入第 i 级加热器的抽汽量；D_{hf}—高压缸漏汽量。

由第二级再热器来的流量为 D_{r0}、比焓为 h_{r0}的疏水进入1号高加，则其热平衡方程为：

$$D_{r0}q'_{r0}+D_1q_1=D_0\tau_1 \tag{5}$$

由第一级再热器来的流量为 D_{r1}、比焓为 h_{r1} 的疏水进入第 i 级高加，则其热平衡方程为：

$$D_{r1}q'_{r1}+D_{s(i-1)}\gamma_i+D_iq_i=D_0\tau_i \tag{6}$$

对于第 i 级低压加热器，离其最近的汇集式加热器序号为 k，有：

$$\sum_{j=k+1}^{i-1}(D_j+D_{fj})\gamma_i+D_iq_i=D'_c\tau_i \tag{7}$$

$$D'_c=D_0-D_{r0}-D_{r1}-D_{se}-\sum_{j=1}^{k}(D_j+D_{fj}) \tag{8}$$

式中：q_i—第 i 级抽汽在该级的放热比焓降；τ_i—第 i 级加热器的给水焓升；γ_i—1kg 上一级（第 $i-1$ 级）的疏水在本级（第 i 级）的放热量。

1.3 矩阵方程

在对热力系统进行分析时，由于矩阵法形式简洁，容易把复杂问题转化成简单的数学问题，近年来得到了较广泛的应用[16~18]。根据压水堆二回路热力系统各级加热器的热平衡方程和质量方程，得出其矩阵热平衡方程式为：

$$AD+A_fD_f+A_\tau D_w+\Delta Q=D_0\tau \tag{9}$$

对于由汽水分离器和再热器汇入高压加热器的疏水，归到 A_fD_f 项中。

$$A=\begin{bmatrix} q_1 \\ \gamma_2 & q_2 \\ \vdots & \vdots & \ddots \\ \gamma_k & \gamma_k & \cdots & q_k \\ \tau_{k+1} & \tau_{k+1} & \cdots & \tau_{k+1} & q_{k+1} \\ \tau_{k+2} & \tau_{k+2} & \cdots & \tau_{k+2} & \gamma_{k+2} & q_{k+2} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots \\ \tau_z & \tau_z & \cdots & \tau_z & \gamma_z & \gamma_z & \cdots & q_z \end{bmatrix}$$

矩阵 $\boldsymbol{A}$ 是一个下三角矩阵，其阶数为回热级数 z，反映回热系统（加热器类型和疏水方式）的结构。主对角线是 1 kg 回热抽汽在本级加热器中的放热比焓降，即 $A_{i,i}=q_i$，在 $i>j$ 时，如果第 i 级加热器有j 级加热器来的疏水，则 $A_{i,j}=\gamma_i$；如果第 j 级加热器的疏水汇入汇集式加热器则 $A_{i,j}=\tau_i$，如果第 j 级加热器的疏水直接汇入凝汽器，则 $A_{i,j}=0$。

$\boldsymbol{D}$ 为由进入各级加热器的蒸汽流量组成的矩阵，即 $\boldsymbol{D}=[D_1\ D_2\cdots D_z]^T$。

矩阵 $\boldsymbol{A}_f$ 也是一个下三角矩阵，其阶数为 z，主对角线是 1 kg 各级辅助汽水在该级加热器中的放热比焓降，因为各辅助汽水流向与其相应级的主抽汽一致（如疏水流向等），则其它元素与 $\boldsymbol{A}$ 矩阵相应元素完全一致。

$\boldsymbol{D}_f$ 为进入各级加热器的辅助蒸汽流量或由汽水分离器和再热器汇入的疏水流量组成的列矩阵，即 $\boldsymbol{D}_f=[D_{f1}\ D_{f2}\cdots D_{fz}]^T$。

$\boldsymbol{A}_\tau$ 是反映各级辅助水流系统的结构矩阵，它同样也是一个下三角矩阵，其阶数为回热级数。主对角线上的元素是辅助水流在各加热器中的焓升即 $A_{\tau(i,i)}=\Delta\tau_i$；$i>j$ 时，$A_{\tau(i,j)}=\tau_i$；$i<j$ 时，$A_{\tau(i,j)}=0$。

$\boldsymbol{D}_w=[D_{w1}\ D_{w2}\cdots D_{wz}]^T$。

$\Delta\boldsymbol{Q}$：反映各级加热器的外热量，凡是不能包含在辅助汽水流量中的外界因素均可包含在该项里，如给水泵焓升的热量、轴封冷却器的散热量等等。

1.4 定功率方程式

机组在设计时、大修或改造后往往要求输出功率达到一定值，或是在一个不变的功率下进行热经济性比较，而热平衡法处理的思路是先假设主蒸汽流量 D_0，反复计算逐次接近定功率条件，这无疑加大了计算量。为了减少计算量，在式(9)的基础上探讨能够适应定功率条件下求解的矩阵。这里将一部分未经汽轮机做功直接进入再热器的新蒸汽视为汽轮机的漏汽，在方程中以辅助蒸汽的形式出现，所以压水堆机组的功率表达式为：

$$D_0\hbar_0-\sum_{i=1}^{z}D_i\hbar_i-\sum_{i=1}^{z}D_{fi}\hbar_{fi}=3\,600P_e/(\eta_m\eta_g) \tag{10}$$

式中：$\hbar_0=h_0-h_c+\sigma$；$\hbar_i=h_i-h_c+\sigma$，$i\leqslant m$；$\hbar_i=h_i-h_c$，$i>m$；$\hbar_{f0}=0$；$\hbar_{fi}=h_{fi}-h_c+\sigma$，该级的辅助蒸汽为再热前漏汽；$\hbar_{fi}=h_{fi}-h_c$，该级的辅助蒸汽为再热后的漏汽。式(10)同热平衡方程式(9)联立可得：

$$\boldsymbol{BD}'=\boldsymbol{B}_f\boldsymbol{D}'_f+\boldsymbol{B}_\tau\boldsymbol{D}'_w+\Delta\boldsymbol{Q}'+\boldsymbol{N} \tag{11}$$

式中：

$$\boldsymbol{B}=\begin{bmatrix} \hbar_0 & \hbar_1 & \hbar_2 & \cdots & \hbar_z \\ \tau_1 \\ \tau_2 & & \boldsymbol{A} \\ \vdots \\ \tau_z \end{bmatrix};\quad \boldsymbol{D}'=\begin{bmatrix} D_0 \\ -D_1 \\ -D_2 \\ \vdots \\ -D_z \end{bmatrix};$$

$$\boldsymbol{B}_{\mathrm{f}}=\begin{bmatrix} \bar{h}_{\mathrm{f}0} & \bar{h}_{\mathrm{f}1} & \bar{h}_{\mathrm{f}2} & \cdots & \bar{h}_{\mathrm{f}z} \\ \tau_1 & & & & \\ \tau_2 & & \boldsymbol{A}_{\mathrm{f}} & & \\ \vdots & & & & \\ \tau_z & & & & \end{bmatrix};\ \boldsymbol{D}'_{\mathrm{f}}=\begin{bmatrix} 0 \\ D_{\mathrm{f}1} \\ D_{\mathrm{f}2} \\ \vdots \\ -D_{\mathrm{f}z} \end{bmatrix};$$

$$\boldsymbol{B}_{\tau}=\begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ \tau_1 & & & & \\ \tau_2 & & \boldsymbol{A}_{\tau} & & \\ \vdots & & & & \\ \tau_z & & & & \end{bmatrix};\ \boldsymbol{D}'_{\mathrm{w}}=\begin{bmatrix} 0 \\ D_{\mathrm{w}1} \\ D_{\mathrm{w}2} \\ \vdots \\ D_{\mathrm{w}z} \end{bmatrix};$$

$\Delta\boldsymbol{Q}'=[\Delta Q_0\ \Delta Q_1\ \Delta Q_2 \cdots \Delta Q_z]^T$,$\Delta Q_0$ 为有做功但并不回收于加热器的轴封漏汽的做功不足;$\boldsymbol{N}=[3\,600P_{\mathrm{e}}/\eta_{\mathrm{m}}\eta_{\mathrm{g}}\ 0\ 0\ \cdots 0]^T$,$P_{\mathrm{e}}$ 为汽轮机的功率,η_{m} 和 η_{g} 分别为机械效率和发电机效率。

根据式(1)~式(4),得出 D_{se}、D_{r1}和 D_{r0}同 D_0 以及 D_i 的关系,即可通过式(11)一次性计算得出各待求量。

2　算例分析

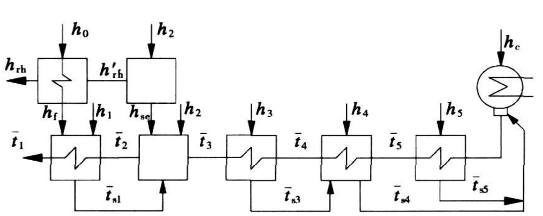

图 2　某 900 MW 核电机组二回路热力系统

以图 2 所示的某压水堆核电机组二回路热力系统为例,应用本文方法计算该机组在额定功率 962.55 MW 下汽水流量和热经济指标。该机组的热力系统参数如表 1 所示。

表 1　某压水堆 900 MW 机组热力系统参数 (kJ/kg)

	H1	H2	H3	H4	H5	SEP	RH
抽汽比焓	2 675.6	2 561.3	2 719.1	2 520.9	2 365.5	2 561.3	2 781.6
疏水比焓	837.6	—	409.8	275.4	264.9	801.8	1 158.3
出口水焓	954.3	795.6	569.0	390.6	256.8	2 763.5	2 939.2

对式(11)中的矩阵 $\boldsymbol{B}$ 和 $\boldsymbol{B}_{\mathrm{f}}$ 给出具体表达式:

$$\boldsymbol{B}=\begin{bmatrix} \bar{h}_0 & \bar{h}_1 & \bar{h}_2 & \bar{h}_3 & \bar{h}_4 & \bar{h}_5 \\ \tau_1 & q_1 & & & & \\ \tau_2 & \gamma_2 & q_2 & & & \\ \tau_3 & \tau_3 & \tau_3 & q_3 & & \\ \tau_4 & \tau_4 & \tau_4 & \gamma_4 & q_4 & \\ \tau_5 & \tau_5 & \tau_5 & 0 & 0 & q_5 \end{bmatrix};$$

$$\boldsymbol{B}_{\mathrm{f}}=\begin{bmatrix} \bar{h}_{\mathrm{f}0} & \bar{h}_{\mathrm{f}1} & \bar{h}_{\mathrm{f}2} & \bar{h}_{\mathrm{f}3} & \bar{h}_{\mathrm{f}4} & \bar{h}_{\mathrm{f}5} \\ \tau_1 & q_{\mathrm{orh}} & & & & \\ \tau_2 & \gamma_2 & q_{\mathrm{se}} & & & \\ \tau_3 & \tau_3 & \tau_3 & 0 & & \\ \tau_4 & \tau_4 & \tau_4 & \gamma_4 & 0 & \\ \tau_5 & \tau_5 & \tau_5 & 0 & 0 & q_{\mathrm{f}5} \end{bmatrix};$$

$\boldsymbol{D}'_{\mathrm{f}}=[0\ D_{\mathrm{orh}}\ D_{\mathrm{se}}\ 0\ 0\ D_{\mathrm{f}5}]^{\mathrm{T}}$,$\bar{h}_{\mathrm{f}0}=0$,$\bar{h}_{\mathrm{f}1}=h_0-h_{\mathrm{c}}+\sigma$,$\bar{h}_{\mathrm{f}2}=h_2-h_{\mathrm{c}}+\sigma$,$\bar{h}_{\mathrm{f}3}=\bar{h}_{\mathrm{f}4}=0$,$\bar{h}_{\mathrm{f}5}=\bar{h}_{\mathrm{f}5}-h_{\mathrm{c}}$。

计算结果如表 2 所示,表 2 中的数据同文献[15]中的结果基本一致,由此验证了本方程的准确性。

表 2　计算结果

	D_0 /kg·s^{-1}	D_1 /kg·s^{-1}	D_2 /kg·s^{-1}	D_3 /kg·s^{-1}	D_4 /kg·s^{-1}	D_5 /kg·s^{-1}	D_{orh} /kg·s^{-1}	D_{se} /kg·s^{-1}	q_0 /kJ·(kWh)$^{-1}$	η_{t} /%	d_0 /kg·(kWh)$^{-1}$
热平衡法	1 589.68	109.65	135.83	85.36	60.64	44.43	119.35	126.09	10 864.10	34.05	5.945
本文方法	1 589.86	109.66	135.82	85.32	60.70	44.43	119.37	126.11	10 868.86	33.98	5.946

3　结　论

(1) 通过推导,提出了压水堆核电机组二回路热力系统矩阵热平衡方程,该方程考虑了辅助汽水系统和热力系统的结构特点。方程中的矩阵为下三角阵或列向量,这为研究二回路热力系统局部扰动对机组的影响提供了理论基础。

(2) 提出了定功率矩阵方程,该方程可以一次性求出主蒸汽流量和各级抽汽量,简化了计算过程,不再需要先假设主蒸汽流量,并反复计算逐次逼近,该方程具有较强的通用性。

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(编辑 伟)

新技术、新工艺

DOE 为下一代燃气轮机研究选择大学合作者

据《Gas Turbine World》2008 年 7—8 月号报道, 美国 DOE(能源部)已启动了选择大学合作者参加的 4 个研究项目。这些项目将评定并精选用于新一代先进涡轮的技术, 这些新一代涡轮专门被设计成燃烧由煤得到的合成气和氢燃料。

DOE 研究倡议的目标是开发低成本的涡轮, 这些涡轮能提供高效率和近零排放的性能。先进涡轮能以从煤的合成气得到的高含氢量燃料运行, 这对于开发能捕获 CO_2 的 IGCC(整体煤气化联合循环)发电装置是至关重要的。

UTSR(大学涡轮系统研究)于 1992 年设立, 在国家能源技术实验室的指导下, 计划产生了第一个能以大于 1 427 ℃(2 600 ℉)温度运行的涡轮, 以及第一次得到超过 60% 的效率, 并且首先采用了一些现在已经常使用的减少 NO_x 的燃烧技术。

所选择的研究项目涉及许多与实际应用 HHC(高含氢量)燃料有关的设计、材料和燃烧问题:

·加利福尼亚—Irvine 大学—燃料混合: 这个项目将评定用于描述燃料分布和混合程度的方法, 并应用这些方法来提供燃料浓度分布数据。分布图型可用于制定并证实 CFD(计算流体力学)模拟方法, 以便确定由典型预混策略产生的燃料分布。

·宾夕法尼亚州大学—燃料的动态稳定性: 与佐治亚理工学院的研究组合作, 制定精确和健全的火焰响应模型, 它可以被结合进设计工具, 以便估算以 HHC 燃料运行的预混多喷嘴燃烧室内纵向的和横向的不稳定性。

·俄亥俄州大学—热燃气通路设计: 俄亥俄州大学将与 Brigham Young 的研究者一道工作, 发掘创新的端壁设计, 该设计能增加涡轮的寿命并减轻端壁上沉积物的不利影响。

·俄亥俄州大学—TBC(热障涂层): TBC 用于保护并隔离在 IGCC 燃气轮机中的热燃气通路金属部件。但是, 证据表明合成气燃料可能以在使用常规燃料时没有被观察到的方式降低 TBC 的性能。这方面的研究将力图达到对沉积物及其对 TBC 不利影响的全面的理解, 并找到减轻它的方法。

(吉桂明 供稿)

(Zhongye Huatian Engineering Technology Co. Ltd., Nanjing, China, Post Code: 210018)// Journal of Engineering for Thermal Energy & Power. — 2009, 24(3). —378~381

Through a study of air and pulverized coal two-phase flow theory, analyzed were the basic characteristics of an air and pulverized coal mixing process in a pulverized-coal boiler, featuring the transport of pulverized coal by exhaust gas. From the standpoint of engineering applications, several basic assumptions were proposed. A method based on kinetic-energy for measuring pulverized coal concentration was put forward, which has been commonly used in a bin and feeder system. Through a statistical analysis of numerous acquired data and by using a method combining relevant mechanism with regression, a calculation model was obtained and used on a real-time basis in an on-line air and pulverized coal monitoring system, thus simplifying the related problem description, and guaranteeing the simplification of the mathematical model established for air and pulverized coal mixing processes. The forgoing has laid a solid theoretical basis for subsequent research on the measurement of pulverized coal concentration. It has been found that the ratio of the kinetic pressure between two cases, namely, the kinetic pressure after the mixing of the air and pulverized coal and that of the primary air (exhaust gas) prior to the above mixing, can represent the magnitude of pulverized coal concentration in the pipeline. The method under discussion is applicable for measuring pulverized coal concentration in bin and feeder systems. **Key words**: pulverized coal concentration, kinetic energy method, air and pulverized coal mixing, pulverized coal feed by exhaust gas

SO_2气体在微孔 CaO 脱硫剂颗粒内的 Knudsen 扩散＝**Knudsen Diffusion of SO_2 Gas in Microporous CaO Desulfurizer Particles** [刊, 汉] / SHANG Jian-yu, WANG Song-ling, WANG Chun-bo (College of Energy Source and Power Engineering, North China University of Electric Power, Baoding, China, Post Code: 071003)// Journal of Engineering for Thermal Energy & Power. — 2009, 24(3). —382~385

Proceeding from the rarified gas effect and by describing the aerodynamic diffusion mechanism of SO_2 gas molecules in micro-scale pores of CaO desulfurizer particles, the authors have revised the effective diffusion coefficient and established Knudsen diffusion mathematical model, which is based on an aggregate concept. The model was solved mathematically and simplified by using an error function with a functional relationship being established. A simulation analysis shows that when SO_2 gas molecules through the Knudsen diffusion have penetrated into first-stage and second-stage pores, both the fractal porosity and relatively large pore porosity can increase the gas resistance to diffuse inwards, thus enhancing the radial gradient of SO_2 concentration distribution. The research results show that it is feasible to consider only the Knudsen diffusion and ignore gas-solid chemical reaction and other factors during the analysis of gas diffusion in the CaO particles. **Key words**: desulfuration agent, CaO, aggregate, Knudsen diffusion, SO_2, diffusion model

气相温度脉动对煤粉颗粒热解氮化合物释放的影响＝**Influence of Gas-phase Temperature Fluctuations on the Release of Nitrogen Compound in the Pyrolysis of Pulverized Coal Particles**[刊, 汉] / ZHANG Hong-tao, ZHANG Jian (Engineering Mechanics Department, Tsinghua University, Beijing, China, Post Code: 100084)// Journal of Engineering for Thermal Energy & Power. — 2009, 24(3). —386~390

In the presence of gas-phase temperature fluctuations, the transient release process of nitrogenous compound resulting from the pyrolysis of pulverized coal particles was calculated. A functional group (FG-DVC) model was adopted for calculating the transient release rate of nitrogen compound. It has been found that at various time-averaged gas-phase temperatures, the release of pulverized-coal particle nitrogen compound (HCN) in a variety of particle diameters is all influenced by the gas-phase temperature fluctuations. Compared with the case when gas-phase temperature fluctuations have not been taken into account, the release of pulverized coal particle HCN is quickened by such fluctuations. With an increase of the gas-phase temperature fluctuation intensity, the quickening action will be further enhanced. **Key words**: pulverized coal particle, nitrogen compound release, gas-phase temperature fluctuation

压水堆核电机组二回路热力系统矩阵分析法＝**A Matrix Analytic Method for the Second Loop Thermodynamic System of a Pressurized Water Reactor-based Nuclear Power Plant**[刊, 汉] / LIU Qiang, XIN Hong-xiang, CHEN Ling-hai (School of Energy and Power Engineering, Nanjing Engineering College, Nanjing, China, Post Code: 211167),

YANG Ling (Beijing Energy-Net Distribution Energy Technology Co. Ltd., Beijing, China, Post Code: 100035)//Journal of Engineering for Thermal Energy & Power. — 2009, 24(3). —391 ~394

On the basis of the thermal balance equations for heaters at various stages, through a strict mathematical deduction, presented was a constant power equation for the second loop thermodynamic system of a pressurized water reactor-based nuclear power plant based on matrixes. The rules for filling out the matrixes were expounded in detail and the physical meanings of various matrixes, pinpointed. The equation in question considers in a comprehensive way the structural features of the second loop thermodynamic system and auxiliary steam and water systems. Under the condition of a constant power output, the equation can be used to obtain at the first attempt the steam consumption rate and the amounts of steam bled at various stages, demonstrating its strong versatility. Its applications feature a simple, accurate and quick process. The authors have verified the accuracy of the equation through the analysis of a 900 MW power plant calculation case. **Key words**: thermal power engineering, thermodynamic system, second loop, matrix method, constant power

新型 CPC 热管式集热器的设计与模拟分析= **Design and Simulation Analysis of a Novel CPC Heat-pipe Heat Collector** [刊, 汉] / ZHANG Wei-wei, ZHU Yue-zhao, JIAN Jin-zhu, QIAN Qiang (College of Mechanical and Power Engineering, Nanjing University of Technology, Nanjing, China, Post Code: 210009)//Journal of Engineering for Thermal Energy & Power. — 2009, 24(3). —395 ~399

On the basis of the present development status of CPC type heat collectors, a novel one of the same type was designed. In addition, the light accumulating surface of the collector and the calculation process for the structural design of the receiver were described along with a heat collection analysis of the heat collector. Matlab modeling-simulation technology was adopted for the modeling and dynamic simulation of the collector to predict its operating conditions and a chart showing the change of the effective output energy, outlet temperature and transient heat collection efficiency of the collector was obtained. Through an experimental study, it is verified that the collector can be used for producing steam and refrigeration, especially ammonia absorption type refrigeration, which requires a relatively high standard of heat sources. In the meanwhile, it can also be used for steam-turbine power generation units and solar energy-based sea water demineralization plants etc. **Key words**: CPC heat collector, heat pipe, oil for heat conduction, structural design, heat transfer analysis, simulation

炉排式垃圾焚烧炉的结渣特性研究= **A Study of the Slagging Characteristics of a Grate Type Solid Waste Incinerator** [刊, 汉] / YU Hai-miao, WANG Gui-ying, CHEN De-zhen, GENG Cui-jie (Thermal Energy and Environmental Engineering Research Institute, Tongji University, Shanghai, China, Post Code: 200092)// Journal of Engineering for Thermal Energy & Power. - 2009, 24(3). -400 ~404

To gain a better understanding of the slagging characteristics and slag formation mechanism of a grate type solid waste incinerator, the authors have chosen a typical in-furnace slag chunk for research purposes. Through a X-ray diffraction (XRD) phase analysis, as well as a scanning electronic microscope and energy spectrum analysis, the in-furnace slagging characteristics were studied. In addition, thermochemical equilibrium reaction calculation results were compared with test ones. It has been found that the presence of eutectic phase with a low melting point formed by calcium compounds resulting from reactions among CaO, Al_2O_3/MgO/ZnO and SiO_2 etc. constitutes the main cause of ash and slag formation. Si and Ca distribution tendencies inside the slag chunk are almost completely identical and Fe is locally enriched while Na and K play a dominant role in the formation of an initial layer. **Key words**: solid waste incineration, slagging, X-ray diffraction (XRD) phase analysis, equilibrium calculation, energy spectrum analysis