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新型的烟气分析设备及其应用

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摘　要: 介绍一种具有数据采集分析功能的便携式烟气分析设备的组成、工作原理、功能和应用情况。这种烟气分析设备可有效地进行燃烧试验研究和设备调试。

关　键　词: 数据采集; 烟气分析

中图分类号: TK31　　文献标识码: A

1　前言

如何评价现有燃烧设备的工作状况？如何改进燃烧设备, 合理组织燃烧, 最大限度地减少排放, 减少环境污染？解决上述问题, 烟气分析无疑是必不可少的手段。具有数据采集分析功能的烟气分析设备将能够更加精确地分析燃烧产物, 为我们更加科学地设计和改进燃烧器, 进行燃烧试验提供可靠的依据。本文介绍一种 Testo 公司生产的具有数据采集分析功能的便携式烟气分析设备。

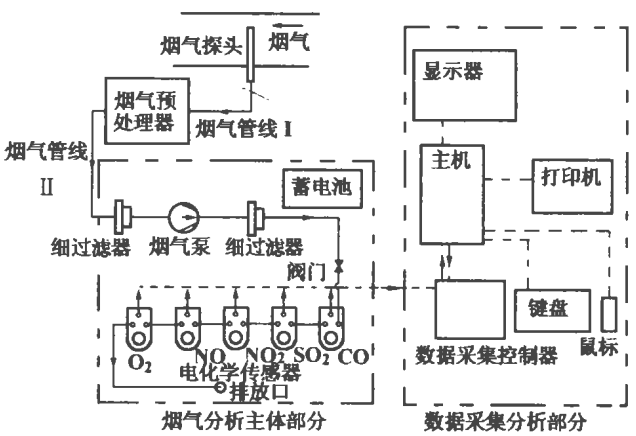

图 1　烟气分析设备示意图

2　烟气分析设备的组成、工作原理及功能

2.1　设备组成

该烟气分析设备主要由烟气探头、烟气管线 I、烟气预处理器、烟气管线 II、烟气分析主体部分和数据采集分析部分构成。烟气分析设备示意图见图 1。

2.2　设备的工作原理

该烟气分析设备的基本工作原理是: 通过烟气分析主体部分的烟气泵将待测的烟气打入到各个电化学传感器中, 经过电化学反应, 产生电信号, 并由数据采集控制器接受, 最后经专用软件处理编辑得到直观的数据和表格; 温度信号是由烟气探头中热电偶传给数据采集控制器而获得的; 一部分烟气参数是根据预先设定值和测量值计算获得的。

该烟气分析设备的工作过程如下:

(1) 首先将烟气探头置于外界新鲜空气中, 启动数据采集分析部分, 按下数据采集控制器上的启动按钮, 烟气分析设备进行自检, 自检大约需要 60 秒钟。数据采集分析部分将记录一些外界气体参数值, 作为后面自动计算时参考。

(2) 自检完成后, 通过数据采集分析部分选择燃料。

(3) 将烟气探头置于烟气主流中, 通过数据采集分析部分启动烟气泵, 烟气将由烟气探头经过烟气管线和烟气预处理器, 到达烟气分析主体部分。烟气在烟气预处理器中过滤掉灰尘和凝结水。在烟气分析主体部分, 烟气依次通过细过滤器、烟气泵、细过滤器, 流经 CO 电化学传感器、SO_2 电化学传感器、NO_2 电化学传感器、NO 电化学传感器、O_2 电化学传感器, 剩余气体从烟气排放口排出。烟气在各个电化学传感器中发生电化学反应, 同时产生电信号, 经数据传输线传送到数据采集分析部分。数据采集分析部分随时记录, 并以直观的图表形式表达烟气参数。

(4) 测量完成后, 为了延长烟气分析设备的寿

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命,应将烟气探头再置于外界新鲜空气中,使新鲜空气能够冲刷电化学传感器一段时间。然后关闭燃气泵,完成数据采集处理工作。

2.3 设备功能

2.3.1 可测量的燃料种类

该设备可测量天然气、轻油、重油、液化石油气、丙烷等燃料。该设备为每种燃料设定了相应的燃料系数,供计算时调用,因此在测量时必须选择正确的燃料种类。

2.3.2 通过测量得到的参数(表 1)

表 1 烟气分析设备测量得到的参数

序号	项 目	单位	响应时间	测量范围
1	环境温度(AT)	℃	/	0~1 200 ℃
2	烟气温度(FT)	℃	/	0~1 200 ℃
3	O_2 浓度	V%(体积百分比)	20 S	0%~21%
4	CO 浓度	ml/m^3	40 S	0~20 000 ml/m^3
5	NO 浓度	ml/m^3	20 S	0~3 000 ml/m^3
6	NO_2 浓度	ml/m^3	40 S	0~500 ml/m^3
7	SO_2 浓度	ml/m^3	40 S	0~5 000 ml/m^3
8	环境氧气浓度 O_{2set} 浓度	V%(体积百分比)	20 S	0~21%

2.3.3 经计算得到的参数及计算公式

(a) CO_2 浓度 $= CO_{2max} \times (O_{2set} - O_2)/O_{2set}$ (V%)

(b) 过量空气系数 $\lambda = O_{2set}/(O_{2set} - O_2)$ (V%)

(c) $NOx = (NO + NO_2)$ (ml/m^3)

(d) 未稀释的 CO 浓度 $puCO = CO \times O_{2set}/(O_{2set} - O_2)$ (单位: ml/m^3)

注: CO_{2max} 为燃料系数

2.4 数据采集分析部分

2.4.1 硬件配置

(1) 数据采集控制器

数据采集控制器主要由操作按钮、显示屏和红外打印机三部分组成,通过控制操作按钮可以在显示屏上得到一系列的烟气参数,红外打印机可以打印出某一时刻的烟气参数。

(2) 计算机

可以使用工控机或电脑笔记本,486 型号以上主机,内存 8 M 以上。

(3) 打印机

2.4.2 数据采集分析控制软件

TESTO 公司为该烟气分析设备设计了专用分析控制软件,该软件以 WINDOW3.1 以上版本的操作系统为操作平台,可以实时快捷地处理从数据采集控制器得到的信息,以直观的数据图表显示出来,并可将测量到的所有数据全部记录下来,供试验后分析。

该软件共有 Diagram、Scale、Analog、Table、Parameter、Histogram 六种工作界面可供选择。这些直观的工作界面,大大地方便了观察分析烟气参数。

该软件可以在笛卡儿坐标系和对数坐标系下对采集到的参数点进行曲线拟合,还可以针对指定的时间段求最大值、最小值、平均值等。

3 应用情况

利用该设备在哈尔滨船舶锅炉涡轮机研究所某台正在调试的燃油直流锅炉上做了燃烧对比试验,通过普通柴油与添加 SAYVOL—EC2 燃油增效剂的柴油燃烧对比试验,检验 SAYVOL—EC2 燃油增效剂对减少排放、增加热效率的作用。

3.1 试验设备介绍

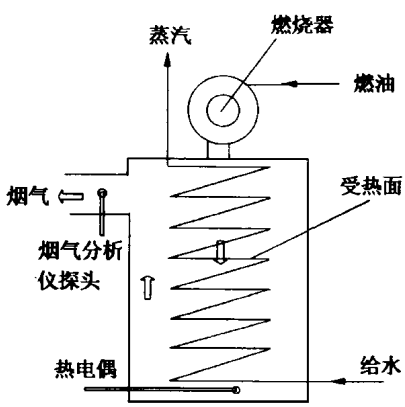

图 2 直流锅炉示意图

燃油直流锅炉的示意图见图 2。该锅炉为全自动控制,蒸汽试验压力 0.60 MPa,蒸汽试验温度 160 ℃。烟气分析设备的烟气探头位于锅炉烟囱入口处,随时监测记录锅炉排烟参数。在锅炉底部有一个热电偶监测炉膛出口温度。

3.2 主要试验步骤

(1) 对烟气分析设备和燃油直流锅炉进行调试准备,使两台设备达到试验要求。

(2) 进行普通柴油燃烧试验,记录有关数据。

(3) 用量筒量取少许 SAYVOL—EC2 燃油增效剂,倒入柴油罐中,搅动片刻,柴油与增效剂的混合比例为 1050:1

(4) 进行添加燃油增效剂的柴油燃烧试验,记录有关数据。

(5) 试验结束,整理现场。

3.3 测试结果

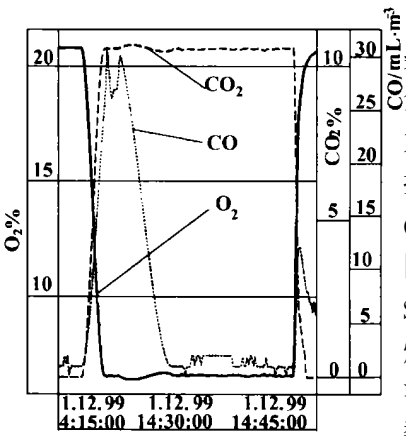

图 3　烟气参数随时间变化曲线（不加添加剂）

图 3 为普通柴油燃烧试验部分数据曲线，图 4 为普通柴油燃烧排烟温度 FT 与 CO 的关系曲线，图 5 为添加了 SAYVOL — EC2 燃油增效剂的柴油燃烧试验部分数据曲线，图 6 为添加了 SAYVOL — EC2 燃油增效剂的柴油燃烧排烟温度 FT 与 CO 的关系曲线。除去锅炉启动和停机时不稳定数据，将燃烧平稳时的数据整理，得到了燃烧对比试验各数据的平均值（表 2）。

表 2　燃烧对比试验数据

序号	项　目	单位	有增效剂	无增效剂
1	烟气中 CO	ml/m^3	0.292 8	4.754 1
2	烟气中 O_2	V%	6.766 1	6.684 49
3	燃气温度 FT	℃	313.279 4	320.482 5
4	环境温度 AT	℃	9.10	9.10
5	烟气中 CO_2	V%	10.505 2	10.566 1
6	未稀释的 CO 浓度	ml/m^3	0.4 366	6.969 8
7	烟气中 NOx	ml/m^3	62.704 2	61.278 7
8	环境 O_{2set}	ml/m^3	21.0	21.0
9	炉膛出口温度	℃	813.5	812.0
10	空气过量系数 λ	/	1.475 35	1.466 94

3.4　试验结果分析

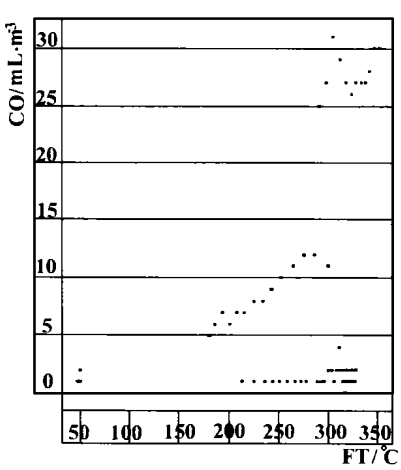

图 4　烟气温度与 CO 关系曲线（不加添加剂）

从表 2、图 3 ~ 图 6 中，可以看出 SAYVOL — EC2 燃油增效剂对于减少 CO 浓度有很好的效果。不论排烟温度高低，添加 SAYVOL — EC2 燃油增效剂的柴油燃烧所放出的 CO 浓度比普通柴油燃烧所放出的 CO 浓度要小得多。从这点上可以看出，添加 SAYVOL-EC2 燃油增效剂的柴油燃烧得更充分。该锅炉排烟温度过高，空气过量系数过大，说明燃烧器调试的不合理，需要调试。

3.5　测量误差分析

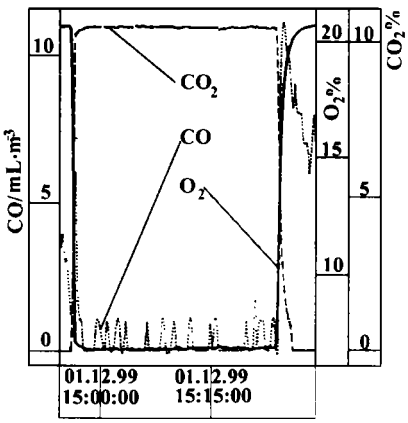

图 5　烟气参数随时间变化曲线（加添加剂）

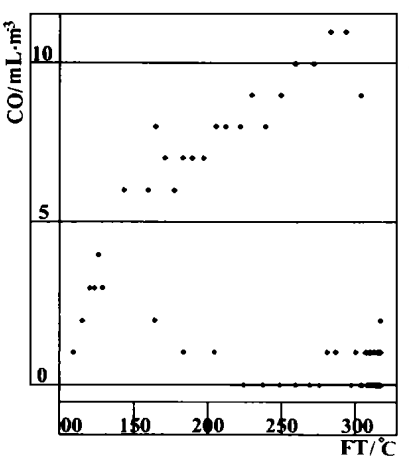

图 6　烟气温度与 CO 关系曲线（加添加剂）

该设备的电化学传感器有 20 ~ 40 秒的响应时间，因此测量结果稍稍滞后。试验时将烟气分析设备设定为每 20 秒记录一组数据，会产生随机误差。另外试验中只测量烟气通道中心处的烟气成分。

4　结论

该烟气分析设备功能齐全、安装快捷、携带方便，数据处理能力强，大大地减少了试验时间，减少了燃料消耗，降低了试验费用。本文所述的试验从试验准备到试验结束全部时间为 2 小时，对比燃烧试验时间仅为 72 分钟。该烟气分析设备具有精确地显示全部烟气参数变化的功能和较强的试验数据后处理能力，大大地方便了对燃烧试验的研究。

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（何静芳　编辑）

so played a beneficial role in devising a method for the modeling of combustors with a complicated shape. **Key words**: single-tube return-flow combustor, numerical simulation, turbulent flow

舰船锅炉炉膛热力计算方法的修正＝**Revision of the Thermodynamic Calculation Method for a Naval Boiler Furnace** [刊, 汉] / Li Zhi-tao, Zhang Yu-hui, Chen Bing, *et al* (Harbin No. 703 Research Institute, Harbin, China, Post Code: 150036) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —83 ~ 85

With regard to the specific features of a naval boiler furnace the authors have analyzed and compared the calculation results obtained when using various methods set forth in "the United Standards of 1973" etc. In the present paper recommended is a revision method adapted for the thermodynamic calculation of boiler furnace off-design conditions. **Key words**: naval boiler, thermodynamic calculation, furnace heat transfer

国产 200 MW 汽轮机转子在线热应力监测与寿命管理＝**On-line Monitoring of Rotor Thermal Stresses and Service Life Management for a Chinese-made 200 MW Steam Turbine** [刊, 汉] / Li Ai-jun, Xie Dan-mei, Yang Jun, Wang Jian-mei, Liu Xian-fei (Power Engineering Department, Wuhan University of Water Resources and Electrical Power, Wuhan, China, Post Code: 430072), Huang Shu-hong, Shen Tao (Power Engineering Department, Central China National University of Science & Technology, Wuhan, China, Post Code: 430074) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —86 ~ 88

Through the use of an object-oriented language the authors have developed a software designed for the on-line monitoring of rotor stresses and service life management for a Chinese-made 200 MW steam turbine. In addition to thermal stress monitoring the software is also capable of abnormal data inquiry, offering guidance for start-up and shutdown operations as well as their recollection, etc. **Key words**: steam turbine, rotor, thermal stress, service life

能源消费与国民经济发展的灰色关联分析＝**Grey Correlation Analysis of Energy Consumption and National Economy Development** [刊, 汉] / Huang Fei (Wuxi Division under the Harbin Institute of Technology, Wuxi, China, Post Code: 214151) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —89 ~ 90

Grey correlation analysis is a kind of systemic analytical method. Through the use of this analysis it is possible to identify the major factors which influence the evolution and variation of key variables. Analyzed in this paper is the grey correlation of energy consumption and national economy development. The results obtained therein may serve as reference data for relevant administrative departments and sectors. **Key words**: grey correlation analysis, energy consumption, national economy development

亚临界炉锅水 pH 降低原因分析及预防对策＝**An Analysis of the Causes of Boiler Water pH Value Reduction in a Subcritical Pressure Boiler and Some Measures Taken for Its Prevention** [刊, 汉] / Yang Zhong-hao (North China Institute of Water Resources and Hydroelectric Power Engineering, Zhengzhou, China, Post Code: 450045) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —91 ~ 92, 100

In connection with a series of boiler water quality failures occurring at a certain power plant an analysis was conducted of the cause of the decrease in boiler water pH value. As a result, it is ascertained that the above-cited decrease has been caused by the leakage of mixed bed resin into the main system. The use of a water distribution device equipped with stainless steel trapezoid-shaped wound wires and a negative-pressure reverse-rinsing resin catcher has led to the prevention of the above-mentioned failure. **Key words**: thermal power plant, operation, accident analysis, feedwater, boiler water pH value

新型的烟气分析设备及其应用＝**A New Type of Flue-gas Analyzing Device and Its Applications** [刊, 汉] / Wang Tie-cheng, Liu Min, Xun Bai-qiu, *et al* (Harbin No. 703 Research Institute, Harbin, China, Post Code:

150036) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —93 ~ 95
This paper describes a portable flue-gas analyzing device, detailing its composition, operation principle, functions and usage conditions. The recommended device can be employed to conduct experimental research of the combustion process and the commissioning test of power generation plants. **Key words**: data acquisition, flue gas analysis

125 MW 汽机快冷系统的设计和使用＝**Design and Operation of a 125 MW Steam Turbine Rapid-cooling System** [刊, 汉] / Diao Xiang-dong (Anhui Provincial Electric Power Design Institute, Hefei, Anhui Province, China, Post Code: 230022) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —96 ~ 98
A relatively detailed description is given of the design and installation of a steam turbine rapid cooling system now in operation at Suidong Power Plant, including an analysis of the temperature dropping process of a turbine cylinder. On the basis of relevant data the cost-effectiveness and operation safety of the rapid cooling system have been validated. **Key words**: steam turbine, rapid cooling system, turbine cylinder temperature drop, turbine cylinder differential expansion

国产 50 MW 汽轮机轴端汽封的改造＝**Modification of the Shaft End Gland Seal of a Chinese-made 50 MW Steam turbine** [刊, 汉] / Cai Guo-liang (Guangzhou Yuancun Thermal Power Generation Co. Ltd., Guangzhou, China, Post Code: 510655) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —99 ~ 100
Two Chinese-made 50 MW steam turbines suffered from a high leakage of shaft end gland seal steam and an excessively low vacuum in the condenser. On the basis of a formula for calculating gland seal leakage an analysis was conducted of the various influencing factors of the gland seal leakage. This has been done in the light of the operating condition of the gland seal system as well as its structural parameters (tooth type and quantity) and mounting clearance. As a result, the basic cause of the problem has been determined. This was followed by a modification of the original gland seal construction as well as its fabrication material and mounting clearance. The operation results after the above modification show that the gland seal leakage problem has been solved with significant energy-savings being attained. **Key words**: 50 MW steam turbine, shaft end gland seal, modification of gland seal

远场涡流无损检测技术在电厂的应用研究＝**The Applied Research of Remote-field Eddy Current-based Nondestructive Inspection Technology at a Power Plant** [刊, 汉] / Jin Wan-li (Huainan Pingwei Power Plant, Huainan, Anhui Province, China, Post Code: 232089) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —101 ~ 103
Remote-field eddy current-based non-destructive inspection technology has been widely used in advanced nations with significant effectiveness. However, in China the application of this technology still remains at an investigation and research stage. The authors have made an analytical study of the theory of the above-mentioned technology and reported its effective use for the first time in the quality inspection of steel tubes of a high-pressure heater for a 600 MW power plant. **Key words**: remote-field eddy current, measurement, theoretic analysis, high-pressure heater, steel tube, check and inspection

SHW46—1.6/150/90—AⅡ(65 吨)型热水锅炉研制＝**The Development of a Model SHW46-1.6/150/90-AII Hot-water Boiler** [刊, 汉] / Ding Li-qun, Wang Wen-yu, Dong San (Harbin Institute of Technology, Harbin, China, Post Code: 150001), Qiao Li-ying (Harbin Heavy Machinery Works, Harbin, China, Post Code: 15000), Sun Hong-tao (Industrial Boiler Co. under the Harbin Boiler Works, Harbin, China, Post Code: 150030) // Journal of Engineering for Thermal Energy & Power. —2001, 16(1). —104 ~ 105
This paper covers the development and manufacture of a 65 t/h reciprocating grate boiler along with a narration of the authors' design experience. It can serve as a guide during the design and fabrication of large-sized natural circulation hot-water boilers. **Key words**: natural circulation, reciprocating grate, boiler, design