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Technical Code for Design and Calculation of Combustion System of Fossil-fired Power Plant

火力发电厂燃烧系统设计计算技术规程

（英文版）

Issue Date: May 24, 2010 Implementation Date: October 1, 2010

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Foreword

This code is prepared as arranged by the *Notice on Issuance of Plan for Development of Electric Power Industry Standards in 2008* issued by the General Office of National Development and Reform Commission (FGBGY〔2008〕1242).

This code is proposed and managed by the China Electricity Council.

This code is drafted by Northwest Electric Power Design Institute of China Power Engineering Consulting Group Corporation.

Chief drafting staff of this code: Zhang Jianzhong and An Yongyao.

Any opinions and suggestions proposed during the implementation of this code are to be referred to the Standardization Center of China Electricity Council at the following address: No. 1 Ertiao Lane, Baiguanglu Rd., Xuanwu Distric, Beijing, China, 100761.

This code is translated by SUNTHER Consulting Co. Ltd. under the authority of China Electric Power Planning & Engineering Association.

Introduction

The combustion system and coal pulverizing system are the two main components for the design of boiler equipment and system in fossil-fired power plants. To improve the design quality, accelerate the design progress, and for ease of the cooperation between design units and manufacturers, the drafting of the *Calculation Handbook for Combustion and Pulverizing Systems* was jointly initiated in 1973 by Inner Mongolia Power Design Institute, Northwest Power Design Institute and Eastern China Power Design Institute according to the arrangement made by the former Ministry of Water Resources and Electric Power in a standardization conference convened in Xi'an city. In 1975, the first edition of this handbook was completed and published for internal use. This handbook has ever greatly contributed to the design of fossil-fired power plants. After all, more than 30 years have passed since its publication, the contents are no longer applicable to the design requirements of rapidly developing power industry. Since the late 1980s, the former Department of Energy and China Electricity Council has organized the relevant units to draft the "Design and Calculation Methods (Standard) of Pulverized Coal Preparation System of Fossil-fired Power Plants", which updates some contents of the *Calculation Handbook for Combustion and Pulverizing Systems* for the first time. In 1997, this document was brought under management by the former Electrical Planning and Design Institute and named as the *Technical Code for Design and Calculation of Pulverized Coal Preparation System of Fossil-fired Power Plants*, which was published as an electric power industry standard on April 27, 2002. In addition, the *Technical Code for Design of Thermal Power Plant Air & Flue Gas Ducts/Raw Coal & Pulverized Coal Piping* and the *Technical Code for Designing Fossil Fuel Power Plants* have been revised by the relevant units under the organization of the former Electrical Planning and Design Institute. Moreover, the former Electrical Planning and Design Institute has delegated the Northwest Electric Power Design Institute to draft DL/T 5240—2010 *Technical Code for Design and Calculation of Combustion System of Fossil-fired Power Plant*, which serves the purpose of linking with the above newly established specifications and codes and combining with the *Technical Code for Design and Calculation of Pulverized Coal Preparation System of Fossil-fired Power Plant* to constitute a complete technical code system.

This code matches with DL/T 5145—2002 *Technical Code for Design and Calculation of Pulverized Coal Preparation System of Fossil-fired Power Plant* and DL/T 5121—2000 *Technical Code for Design of Thermal Power Plant Air & Flue Gas Ducts/Raw Coal & Pulverized Coal Piping*, and links with and serves as the check basis of the industrial standards or codes involved in boiler thermodynamic calculation. This code is established not only aiming at regulating the design calculation of the combustion system of fossil-fired power plant, but for ease of the interface and coordination between power plant design and boiler design parties, thereby promoting the technical advance in design of fossil-fired power plants.

Contents

1 Scope

This code specifies the calculation methods for design of the boiler combustion system of fossil-fired power plants.

This code is applicable to the design calculation of combustion system of pulverized coal-fired boiler rated 65 t/h—3000 t/h.

The design of circulating fluidized bed combustion (CFBC) boiler, oil-fired boiler, and gas-fired boiler may be performed by referring to the relevant parts of this code.

2 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this code. For dated references, subsequent amendments (excluding the contents of errata) to, or revision of, any of these publications do not apply. However, parties to agreements based on this code are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative documents apply.

GB/T 211 *Determination of Total Moisture in Coal*

GB/T 212 *Proximate Analysis of Coal*

GB/T 213 *Determination of Calorific Value of Coal*

GB/T 214 *Determination of Total Suffer in Coal*

GB/T 219 *Determination of Fusibility of Coal Ash*

GB/T 476 *Determination of Carbon and Hydrogen in Coal*

GB/T 1574 *Test Method for Analysis of Coal Ash*

GB/T 1920 *Standard Atmosphere (below 30 kilometers)*

GB/T 2565 *Determination of Grindability Index of Coal (Hardgrove method)*

GB/T 2900.48 *Electrotechnical Terminology of Boilers*

GB/T 3715 *Terms Relating to Properties and Analysis of Coal*

GB/T 5751—2009 *Chinese Classification of Coals*

GB/T 7562—1998 *Technical Condition of Coal Used for Pulverized Coal-fired Boiler for Power Generation*

GB/T 10184—1988 *Performance Test Code for Utility Boiler*

GB 13223 *Emission Standard of Air Pollutants for Thermal Power Plants*

GB 13271 *Emission Standard of Air Pollutants for Coal- burning, Oil-burning and Gas-fired Boiler*

GB/T 15224.1—2004 *Classification for Quality of Coal-Part 1: Ash*

GB/T 15224.2—2004 *Classification for Coal Quality-Part 2: Sulfur Content*

GB/T 15224.3—2004 *Classification for Coal Quality-Part 3: Calorific Value*

GB/T 15458 *Determination of Abrasion Index of Coal*

GB 50041—2008 *Code for Design of Boiler Plant*

DL/T 387—2010 *Guideline for Flue Gas Bag Filter Selection for Thermal Power Plants*

DL/T 435 *Code for the Prevention of Pulverized Coal Firing Furnace Explosions/Implosions in Power Plant Boilers*

DL/T 461—2004 *Guide for Operation and Maintenance of Electrostatic Precipitation for Coal-fired Power Plants*

DL/T 465 *Determination of the Impingement Abrasion Index of Coal*

DL/T 466—2004 *Guide for Type Selection for Pulverizers and Pulverizing Systems of Power Stations*

DL/T 468—2004 *Guidelines on Type Selection and Application of Power Boiler Fans*

DL/T 514—2004 *Electrostatic Precipitator*

DL/T 660—2007 *Test Procedure for the Viscosity of Coal Ash under High Temperature*

DL/T 831—2002 *Guide on Selection of Furnace Characteristic Parameters for Large Pulverized Coal Fired Power Boilers*

DL/T 1121—2009 *Engineering Criteria of Bag Filter System for Coal-fired Power Plants*

DL 5000 *Technical Code for Designing Fossil Fuel Power Plants*

DL/T 5121—2000 *Technical Code for Design of Fossil-fueled Power Plant Air & Flue Gas Ducts/Raw Coal & Pulverized Coal Piping*

DL/T 5145—2002 *Technical Code for Design and Calculation of Pulverized Coal Preparation System of Fossil Fuel Power Plants*

DL/T 5153—2001 *Technical Rule for Designing Auxiliary Power System of Fossil-fueled Power Plants*

DL/T 5203—2005 *Technical Code for Explosion Prevention Design of Coal and Pulverized Coal Preparation System of Fossil- fueled Power Plants*

DL/T 5196—2004 *Technical Code for Designing Flue Gas Desulfurization Plant for Fossil Fired Power Plants*

MT/T 597—1996 *Classification for Chlorinity in Coal*

MT/T 849—2000 *Classification for Volatile Matter of Coal*

MT/T 850—2000 *Classification for Total Moisture in Coal*

MT/T 852—2000 *Classification for Hardgrove Grindability Index of Coal*

MT/T 853.1—2000 *Classification for Coal Ash Fusibility*

MT/T 853.2—2000 *Classification for Flow Temperature of Coal Ash*

MT/T 963—2005 *Classification for Mercury in Coal*

MT/T 966—2005 *Classification for Fluorine in Coal*

NFPA 85—2007 *Boiler and Combustion Systems Hazards Code*

TRD 413—1996 *Kohlenstaubfeuerungen an Dampfkesseln*

ASME PTC. 4.1 *Power Test Code for Steam Generating Units*

ASME PTC.4.3 *Power Test Code for Air Heaters*

ASTM D 388—2005 *Standard Classification of Coals by Rank*

EPRI *Wet Stacks Design Guidelines*

3 Terms, Definitions, and Symbols

3.1 Terms and Definitions

The terms and definitions specified herein shall comply with the provisions of GB/T 2900.48 and GB/T 3715 in addition to this code.

3.1.1

Combustion system

A combination of equipment and the associated fuel (e.g., coal, pulverized coal, oil, and gas) ducts, air ducts and flue gas ducts, which organizes the combustion of fuels and air in boiler furnace, and purifies and exhausts the combustion products, generally consisting of burner, coal and pulverized coal preparation system, and air & flue gas system.

The combustion system mentioned herein mainly refers to the air & flue gas system described in the above coal combustion process and the parts matching with boiler unit and pulverized coal preparation system.

3.1.2

Standard coal; equivalent reference coal

The coal with a net calorific value (on an as-received basis) $Q_{net,ar}$=29 271 kJ/kg (namely, 7000 kcal/kg)[1)].

The consumption of fuels with different calorific values can be converted to the consumption of standard coal using Formula (3.1.2):

$$B_{STD}=\frac{BQ_{net,ar}}{29\,271} \quad (3.1.2)$$

Where:

B_{STD}—consumption of standard coal;

B—actual coal consumption;

$Q_{net,ar}$—actual net calorific value (on an as-received basis) of fuel, kJ/kg.

3.1.3

Specific fuel composition

For each unit of calorific value fed into the furnace, the ash, moisture and sulfur contents contained in fuel fed into the furnace are respectively referred to as specific ash, specific moisture, and specific sulfur. As the unit calorific value is defined to be 4182 kJ/kg (1000 kcal/kg) herein, then:

$$A_{sp}=4182\frac{A_{ar}}{Q_{net,ar}} \quad (3.1.3\text{-}1)$$

$$M_{sp}=4182\frac{M_{ar}}{Q_{net,ar}} \quad (3.1.3\text{-}2)$$

$$S_{sp}=4182\frac{S_{ar}}{Q_{net,ar}} \quad (3.1.3\text{-}3)$$

1) The heat conversion from Calorie to Joule is based on Calorie 20 degrees Celsius, using $|cal|_{20}$=4.181 6 J rather than international table calorie $|cal|_{IT}$ = 4.186 8 J. Therefore, the calorific value of standard coal (7000 kcal/kg) shall be expressed to be 29 271 kJ/kg rather than 29 307 kJ/kg. When converting the heat from Calorie to other units, use the relationship of $|cal|_{IT}$=4.186 8 J.

Where:

A_{sp}, M_{sp}, and S_{sp}—specific ash, specific moisture, and specific sulfur;

A_{ar}, M_{ar}, and S_{ar}—ash, moisture, and sulfur in coal on an as-received basis, %.

3.1.4

Boiler rated load (BRL)

Given the rated steam parameters and rated feedwater temperature, the specified evaporation capacity of boilers operating on design fuel is called boiler rated load, also referred to as boiler rated capacity. The rated load of utility boiler is usually matched with turbine rated load (TRL). The main steam flow under TRL condition is the same as that under turbine maximum continuous rating (TMCR) condition. BRL condition shall occur within the load range where the boiler has the maximum thermal efficiency, generally being the guaranteed thermal efficiency condition when the boiler operates on design coal.

3.1.5

Boiler maximum continuous rating (BMCR)

BMCR refers to the maximum continuous evaporation capacity produced by the boiler operating on design coal and check coal with the rated steam parameters and rated feedwater temperature. The BMCR of utility boilers usually refers to the maximum continuous output thermal power (MW) matching with the design flow rate of turbine units, which is often expressed with the main steam flow (t/h) under this condition. BMCR is the guaranteed value of design rating when the boiler operates on design coal and check coal. The thermal efficiency of boiler under BMCR condition is allowed to be lower than that under BRL condition, but the design pressure and water circulation reliability shall meet the requirements BMCR condition. Under BMCR condition, the furnace shall be free of severe or high slagging tendency and the auxiliary equipment parameters shall meet the relevant requirements.

3.1.6

Boiler minimum stable load without auxiliary fuel support (BMLR)

BMLR is defined as the minimum load at which the boiler can operate continuously and stably for a long time without auxiliary fuel support. For coal-fired boilers, it is often called boiler minimum stable load without oil support. Generally, it is expressed by the ratio between the minimum stable load without auxiliary fuel support and BMCR, namely

BMLR = (boiler minimum stable load without auxiliary fuel support/BMCR)×100%

Both numerator and denominator are expressed with the output thermal power of boilers. In case of condensing turbine units for which no strict accuracy requirements in this respect are set forth, the numerator and denominator can be expressed with main steam flow.

3.1.7

Boiler gross efficiency

Boiler gross efficiency refers to a ratio of heat output (Q_{out}) to heat input (Q_{inp}) expressed in percentage, namely

$$\eta_{SG} = \frac{Q_{out}}{Q_{inp}} \times 100\% \tag{3.1.7-1}$$

For large capacity boilers, as large error occurs when measuring fuel flow rate, heat input and heat output, indirect balance method is often used to measure the boiler efficiency. In this case:

$$\eta_{SG} = 100 - (q_2 + q_3 + q_4 + q_5 + q_6) \tag{3.1.7-2}$$

Where:

q_2—heat loss due to exhaust of flue gas, %;

q_3—heat loss due to unburned gases, %;

q_4—heat loss due to unburned carbon in refuse, %;

q_5—heat dissipation loss, %; ·

q_6—heat loss due to sensible heat in slag, %.

Depending upon the application situations, the boiler efficiency may be expressed in different ways below:

1 Test efficiency η_{SG}^{T}: An actually measured efficiency, which is calculated based on the actually measured air temperature at the inlet of air pre-heater and the actually measured exhaust flue gas temperature and is used for boiler performance test.

2 Calculation efficiency η_{SG}^{CG} : It is calculated based on the determined air temperature at the inlet of air pre-heater and exhaust flue gas temperature obtained through thermodynamic calculation, which is used for boiler thermodynamic calculation.

3 Correction efficiency η_{SG}^{CR} : The corrected test efficiency or calculation efficiency based on the determined datum temperature and the corresponding exhaust gas temperature, which is used for design of fossil-fired power plant.

4 Guaranteed efficiency η_{SG}^{CR} : An efficiency provided by the boiler manufacturer in bidding process or equipment supply contracts, which incorporates a margin L_{mm} (usually in range of 0.5%—0.8%) and an instrument measuring error *IT* [usually in range of ±(0.3%—0.5%)] employed in performance acceptance test.

The boiler efficiency (η_{SG}) mentioned herein generally refers to the correction efficiency or guaranteed efficiency.

3.1.8

Abbreviated boiler efficiency

The abbreviated boiler efficiency is one that is calculated only taking into account the main heat loss and taking the net calorific value of fuels on an as-received basis as the heat input.

3.1.9

Datum temperature, T_D

T_D is the initial point selected for energy calculation, which is used to calculate various heat inputs and heat losses in heat balance systems.

In boiler performance test, the ambient temperature or inlet air temperature of heat balance system is often taken as the datum temperature; in boiler thermodynamic calculation, the inlet air temperature of air preheater is usually taken as the "design datum temperature". In combustion system calculation, the datum temperature used to determine the efficiency value is the annual average ambient temperature specified by the boiler manufacturer or the ambient temperature specified in contracts.

3.1.10

Reference temperature, T_{RT}

T_{RT} is a datum temperature specified in boiler bidding documents or supply contracts for easy comparison between different boiler efficiencies or for unifying the calculation conditions of guaranteed efficiency for boiler design. T_{RT} may be set at the inlet of heat balance system, which is called "ambient T_{RT}" and usually taken as 25℃.

If T_D is different from T_{RT}, the flue gas exhaust temperature and boiler efficiency shall be subjected to correction.

3.1.11

Fuel consumption rate

1 Design fuel consumption rate, *B*

The design fuel consumption rate refers to the fuel consumption rate of boiler per unit time. In design calculation of combustion system, the fuel consumption rate under BMCR condition and average ambient temperature is usually taken as the reference value, namely

$$B=\frac{Q_{out}}{Q_{inp}\eta_{SG}}\times 100 \quad (3.1.11\text{-}1)$$

Where:

Q_{out}—heat output of boiler, kJ/h;

Q_{inp}—heat input, kJ/h;

η_{SG} —boiler gross efficiency, %.

2 Fuel consumption rate for calculation, B_{cal}

The fuel consumption rate for calculation refers to the design fuel consumption rate minus the heat loss due to incomplete combustion of solids in fuels, namely

$$B_{cal}=B\left(1-\frac{q_4}{100}\right) \quad (3.1.11\text{-}2)$$

3.1.12

Theoretical air

Theoretical air refers to the air quantity required for complete combustion of each kilogram of solid, liquid fuels or each cubic meter of gas fuels at stoichiometric ratio.

3.1.13

Excess air ratio (coefficient)

The excess air ratio (coefficient) refers to the ratio of the actual air supplied for combustion V_{act}^{0} to theoretical air V^0, or the ratio of the sum of theoretical air V^0 and air leakage rate ($V_{dg}-V_{dg}^{0}$) to theoretical air V^0, expressed as "α", namely

In air

$$\alpha=\frac{V_{act}^{0}}{V^{0}} \quad (3.1.13\text{-}1)$$

In flue gas

$$\alpha=\frac{V^{0}+(V_{dg}-V_{dg}^{0})}{V^{0}} \quad (3.1.13\text{-}2)$$

Where:

V^0 and V_{act}^{0}—theoretical dry air and actual dry air needed for combustion of 1 kg coal under standard conditions, m^3/kg;

V_{dg}^{0} and V_{dg}—theoretical dry flue gas and actual dry flue gas needed for combustion of 1 kg coal under standard conditions, m^3/kg.

Generally, the excess air ratio used for design of combustion system is respectively determined at the points below:

—excess air ratio at furnace outlet (α_F), which is determined based on the standard of boiler thermodynamic calculation;

—excess air ratio in burner (α_B), which is determined during the boiler performance design;

—excess air ratio at any calculation point in flue gas process of boiler units (α_i), namely, the sum of α_F and $\Delta\alpha$ (air leakage factor of the gas ducts between that point and the furnace).

3.1.14

Air leakage factor

The air leakage factor refers to the ratio of air leakage into boiler gas ducts to theoretical air required by fuel combustion, i.e., the difference between the excess air ratio at the outlet and inlet of the gas duct, which is expressed as "$\Delta\alpha$" (Note: The denominator does not include excess air ratio α), namely

$$\Delta\alpha = \alpha'' - \alpha' = \frac{\text{outlet fuel gas mass} - \text{inlet fuel gas mass}}{B_{\text{cal}} \times \text{theoretical air}} \tag{3.1.14-1}$$

In case of air preheaters, Formula (3.1.14-1) can be modified to be:

$$\Delta\alpha_{\text{L}} = \frac{\text{inlet air mass} - \text{outlet air mass}}{B_{\text{cal}} \times \text{theoretical air}} \tag{3.1.14-2}$$

Where:

α''—excess air ratio at gas side outlet of gas ducts or air preheaters;

α'—excess air ratio at gas side inlet of gas ducts or air preheaters.

3.1.15

Air leakage rate

The air leakage rate refers to the ratio of mass of air leakage into the gas side of gas duct or air preheater to the mass of flue gas entering the gas duct (Note: The denominator includes the excess air ratio α).

—The air leakage rate of air preheater is expressed as "A_{L}", namely

$$A_{\text{L}} = \frac{\text{outlet flue gas mass} - \text{inlet flue gas mass}}{\text{inlet flue gas mass}} \times 100\% \tag{3.1.15-1}$$

or

$$A_{\text{L}} = \frac{\text{inlet air mass} - \text{outlet air mass}}{\text{inlet flue gas mass}} \times 100\% \tag{3.1.15-2}$$

—Conversion relationship between air leakage rate (A_{L}) and air leakage factor ($\Delta\alpha$) is

$$A_{\text{L}} = \Delta\alpha \frac{B_{\text{cal}} \times \text{theoretical air}}{\text{inlet flue gas mass}} \times 100\% \tag{3.1.15-3}$$

or

$$A_{\text{L}} = \frac{\alpha'' - \alpha'}{\alpha'} R_{\text{g}} = \frac{\Delta\alpha}{\alpha'} R_{\text{g}} \tag{3.1.15-4}$$

$$R_{\text{g}} = \frac{1}{1 + \dfrac{1 - 0.01 A_{\text{ar}}}{1.306\alpha' V^0}} \times 100\% \tag{3.1.15-5}$$

Where:

R_{g}—reduction coefficient.

According to GB 10184, R_{g}=90% is permissble for boiler performance test and general engineering calculation, namely

$$A_{\text{L}} = \frac{\alpha'' - \alpha'}{\alpha'} \times 90\% = \frac{RO_2' - RO_2''}{RO_2''} \times 90\% \approx \frac{O_2'' - O_2'}{21 - O_2''} \times 90\% \tag{3.1.15-6}$$

Where:

RO_2', RO_2''—RO_2 contained in inlet/outlet dry flue gas expressed in percentage;

O_2', O_2'' —O_2 contained in inlet/outlet dry flue gas expressed in percentage.

3.1.16

Primary air leakage rate