ICS 27.010
CCS F 04

National Standard of the People's Republic of China

GB/T 43676-2024

General technical requirements for water-cooled premixed low NOx burner

水冷预混低氮燃烧器通用技术要求

(English Translation)

Issue date:2024-03-15 Implementation date:2024-07-01

Issued by State Administration for Market Regulation

Standardization Administration of the People's Republic of China

Contents

Foreword

SAC/TC441 is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This document is drafted in accordance with the rules given in GB/T 1.1-2020, Guidelines for Standardization Work Part 1: Structure and Drafting Rules of Standardization Documents.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The issuing agency shall not be held responsible for identifying any such patent rights.

This document was proposed and prepared by the SAC/TC 441 (Technical Committee on Combustion Energy Saving and Purification Standardization Administration of China).

General technical requirements for water-cooled premixed low NOx burner

1 Scope

This document specifies the terms and definitions, classification and model, requirements, inspection and test, inspection and test rules, technical documents and identification, packaging, transportation and storage of water-cooled premixed low NOx burners.

This document applies to the design, manufacture and acceptance of water-cooled premixed low NOx burners (hereinafter referred to as ‘burner’) with output power less than 140 MW (A single burner power less than 7 MW).

This document does not apply to naturally ventilated non-electric driven and controlled burners.

2 Normative references

The content of the following documents constitutes indispensable clauses of this document through normative references in the text. For dated reference, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 151-2014 *Heat exchangers*

GB/T 1236-2017 *Industrial fan - Performance testing using standardized airways*

GB/T 2423.1 *Environmental testing for electric and electronic products - Part 2: Test methods - Tests A: Cold*

GB/T 2423.2 *Environmental testing for electric and electronic products - Part 2: Test methods - Tests B: Dry heat*

GB/T 2423.3 *Environmental testing - Part 2: Testing method-Test Cab: Damp heat, steady state*

GB/T 4208-2017 *Degrees of protection provided by enclosure (IP code)*

GB/T 10233-2016 *Basic testing method for low-voltage switchgear and control gear*

assemblies

GB/T 21434-2022 *Phase change boilers*

GB/T 36699-2018 *Specification for liquid fuels and gaseous fuels burners of boilers*

GB/T 37499 Safety and control devices for gas burners and gas-burning appliances - Particular requirements - Automatic and semi-automatic valves

GB/T 37650 *Combustion types - Terms and definitions*

GB/T 38919 *General technical requirements for porous media burners*

HJ/T 398 *Stational source emission - Determination of blackness of smoke plumes - Ringelmann smoke chart*

TSG 11-2020 *Regulation on safety technology for boiler*

3 Terms and definitions

For the purposes of this document, the terms and definitions give in GB/T 37650 and GB/T 38919 and the following apply.

3.1

water-cooled premixed low NO_X burner

the device in which gas and auxiliary gas are premixed and then burned to convert heat energy through a wall heat exchange tube bundle with water as the medium with low nitrogen oxides (NO_X) emissions

3.2

premixed degree

the mixing degree of gas and auxiliary gas

NOTE It is expressed as the ratio of the difference between the maximum and minimum gas concentration at different outlet sections of the premix chamber and the average gas concentration in the premix chamber at same temperature and pressure conditions

[source: GB/T 38919-20, 3.5, with modifications]

3.3
water-cooled tube bundle

a combustion component with an inter-wall water-cooled system
NOTE It is composed of a tube bundle or a tube screen

3.4
premix fan

the fan set in front of the inlet of the gas and auxiliary gas mixing section

3.5
isobaric chamber

the space where gas pressure achieves an equilibrium

3.6
uniform gas distributor

the device for evenly distributing gas or auxiliary gas or gas mixture

3.7
water cooled in tube

the cooling method of the cooling water flowing inside the tube of water-cooled bundle

3.8
water cooled at shell side

the cooling method of the cooling water flowing outside the tube of water-cooled bundle

3.9
outlet characteristic dimension of the water-cooled tube bundle

the minimum size of the nozzle or the width of the slit of the premixed air outlet section of the water-cooled tube bundle

3.10
characteristic length of the water-cooled tube bundle

the travel length of the cooling water flow in the water-cooled bundle

3.11
main flame

the flame burning on the main water-cooled tube bundle

3.12
ignition flame

the flame lit first to ignite the main flame

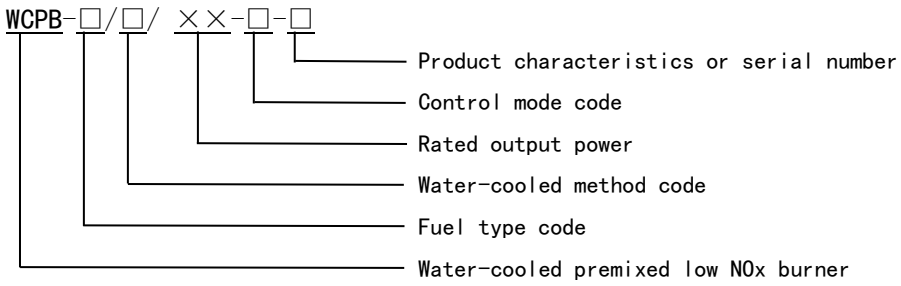
4 Classification and model

4.1 Classification

According to the water-cooled method, the burner is divided into two categories: in-tube cooled burner and shell cooled burner.

4.2 Model compilation method

4.2.1 The model of the burner is shown as follows.



4.2.2 The fuel type code is listed in Table 1.

Table 1 Fuel type code

No.	Fuel type	Fuel code
1	natural gas	T
2	liquefied petroleum gas	Y
3	coke oven gas	J
4	mixed city gas	H
5	low calorific value gas[a]	D
6	methane	Z

a: The heat value of low calorific gas is generally less than 6.28 MJ/m^3, including blast furnace gas, converter gas, generating furnace gas and biomass pyrolysis/gasification gas, etc.

4.2.3 The water-cooled method code is listed in Table 2.

Table 2 water-cooled method code

No.	Water-cooled method	Code
1	water cooled inside the tube	GC
2	water cooled at shell side	QC

4.2.4 The rated output power shall be selected according to Table 3. It can also be expressed by the type of fuel flow, as shown in equation (1):

$$P_0=2.78\times10^{-4}Qq \quad (1)$$

where:

P_0-rated output power, megawatt (MW);

Q-gas flow, cubic meters per hour (m^3/h);

q-low heating value of gas, megajoules per cubic meter (MJ/m^3).

Table 3 Rated output power recommending value

Unit:MW

No.	Rated output power
1	0.03
2	0.05
3	0.10
4	0.20
5	0.35
6	0.70
7	1.05
8	1.40
9	2.10
10	2.80
11	4.20
12	5.60
13	7.00
14	10.50
15	14.00
16	21.00
17	29.00
18	35.00
19	46.00
20	58.00

21	70.00
22	91.00
23	116.00
24	140.00

4.2.5 The control mode code is listed in Table 4.

Table 4 Control mode code

No.	Control mode	Code
1	automatic control	ZD
2	manual control	SD
3	mechanical continuous regulation	JL
4	electronic continuous regulation	DL

4.2.6 The product characteristics or serial number is prepared by the manufacturer.

Example: The fuel is natural gas, automatic control is adopted, the water is cooled inside tube, the rated output power is 0.35 MW, the type of the premixed low NOx burner is: WCPB-T/GC/0.35-ZD-(product characteristics or serial number prepared by the manufacturer).

5 Requirements

5.1 Appearance and composition

5.1.1 Appearance

5.1.1.1 The surface of the burner shell shall be coated with a protective decorative coating suitable for the working conditions. The coating shall be complete, uniform and clean without scratching, foaming or shedding.

5.1.1.2 The clearance between the water-cooled bundle is clear without foreign matter.

5.1.2 Composition

The burner consists of burner body, air supply system, gas system, gases premix system, ignition system, safety protection system and load regulating system (shown in Appendix A), each system is composed of the following components:

a)The burner body is composed of the water-cooled tube bundle and the shell.

b)The air supply system is composed of fan, air duct, air valve set, air filter device and airflow regulating device.

c)The gas system is composed of manual gas quick cut-off valve, gas filter device, gas pressure monitoring device, gas pressure regulating valve, automatic safety cut-off valve, gas flow regulating valve and gas connecting tube.

d)The gases premix system is composed of premix chamber (isobaric chamber) and the flow equalizing device.

e)The ignition system is composed of the ignition transformer, the ignition electrode, ignition flame monitoring device and main flame monitoring device.

f)The safety protection system is composed of automatic gas leakage detection device, gas high and low-pressure detection and protection device, air pressure monitoring device, air and gas linkage adjustment device, ignition gas valve safety cut-off device, flame monitoring device and purge system.

g)The load regulating system is composed of the controller, air and gas regulating actuator, air and gas linkage regulating device.

The main components of each system [b)- g)] of the burner need to meet the requirements of ‘8.3’ in GB/T 36699-2018.

5.2 Aerodynamic performance

When the burner outlet pressure reaches 1.1 times of the mating furnace pressure, the burner outlet air volume shall meet the requirements of normal combustion of maximum flow fuel within the range of burner load regulation

5.3 Operational control

The burner shall be operated normally under automatic or manual mode.

The ignition sequence shall be: power on → startup condition validation → open damper to purge position → open water-cooled system → start fan → pre-purge →regulate fan to ignition speed, damper and ignition gas to the ignition position → open the air, gas main valve V1 → high-pressure ignition → flame ignition→ turn off the ignition transformer → monitor ignition flame → ignition flame is monitored with fire → open gas main valve V2 → monitor main flame → turn off the ignition flame→ main flame is monitored with fire→ normal combustion

(adjust the combustion load automatically or manually) → Purge after gas supply is cut off→ shut down.

The burner restart shall be performed in accordance to '7.1.8' in GB/T 36699-2018.

The load adjustment operation can be performed after the ignition procedure. The flame fault should be interlocked and shut down during operation.

Note 1: When the water-cooled system is operating, if the water pressure of the water-cooled system is insufficient, perform a purge first and then shut down the burner. Restart the system after checking that the water-cooled system is normal.

Note 2: If flame detection indicates no flame after ignition, perform a purge afterwards and then restart. If the restart fails twice, raise an alarm.

Note 3: During normal combustion condition, if the main flame monitoring signal is lost, the air pressure is lower than the set pressure and the water-cooled system experiences water interruption, close the gas valve set.

5.4 Safety protection

5.4.1 Gas, air cleanliness

The gas and air filter devices shall be installed and the pores of the filter device shall not be larger than the minimum clearance of the water-cooled bundle. Reliable anti-corrosion measures shall be taken for the contact surfaces of gas, air and mixture passing through pipelines, mixing devices and water-cooled bundles to ensure smooth and sustainable flow.

5.4.2 Sealing of the gas pipeline

For the gas pipeline from the inlet of the gas valve set to the inlet of the premix chamber, when the gas pressure reaches 1.5 times higher than the design pressure and is not less than 4 kPa, the pressure drop in the pipeline within 15 minutes shall meet the following requirements:

a) Pressure drops of the burners with rated output power less than 2 MW are less than 50 Pa;

b) Pressure drops of the burners with rated output power more than 2 MW are less than 25 Pa.

5.4.3 Sealing of the burner

For each component that gas and combustible mixture flowed from the inlet of the burner premix chamber to the outlet of the burner, when the gas pressure reaches 1.5 times higher than the design pressure and is not less than 4 kPa, the pressure drop in the pipeline within 15 minutes shall meet the following requirements:

a) Pressure drops of the burners with rated power less than 2 MW are less than 50 Pa;

b) Pressure drops of the burners with rated power more than 2 MW are less than 25 Pa.

5.4.4 Main gas control valve system

5.4.4.1 Equipped with two series of automatic safety cut-off valves or combination valves.

5.4.4.2 The configuration of the automatic safety cut-off valve shall meet the requirements of two Class A valves and valve leak detection devices in 5.2.3 of GB/T 36699-2018. The Class A valve need to meet the requirements in GB/T 37499.

5.4.4.3 The main gas control valve shall be equipped with leaking detection device.

5.4.4.4 At least one pressure control device is provided upstream of the first automatic safety cut-off valve.

5.4.4.5 Only after the flame is ignited and verified by the monitoring device, the main gas control valve can be opened to ignite the main flame.

5.4.5 Ignition gas control valve system

5.4.5.1 The ignition gas leads between the two main gas control valves, the ignition automatic safety cut-off valve is set before entering the burner. The downstream main gas automatic safety cut-off valve should not be energized until the ignition flame has been ignited and verified by the flame monitoring device.

5.4.5.2 The configuration of the gas ignition automatic safety cut-off valve shall meet the requirements of two Class A valves of 5.2.3 in GB/T 36699-2018.

5.4.5.3 When the ignition power is larger than 1.2 MW, the valve leak detection device shall be set.

5.4.5.4 Except for the valve leakage detection, the ignition automatic safety cut-off valve shall not be energized before the ignition device is energized.

5.4.6 Flame monitoring device

The flame monitoring device shall meet the requirements of 5.2.4 and 8.3.8 in GB/T 36699-2018.

5.4.7 Premixed fan

5.4.7.1 When the rated output power of the burner is larger than 2 MW, the premix chamber shall be located on the subsequent pipe at the fan outlet.

5.4.7.2 When the premix chamber is located at the fan inlet, explosion-proof and leak-proof measures shall be taken for the fan.

5.4.8 Flameout protection

The burner should be set up with a reliable flameout protection device. When the flame extinction is detected, the gas supply shall be cut off in time and the safety time of the flame extinction is less than 1 second.

5.4.9 Water-cooled system and water-cooled bundle

5.4.9.1 When the rated working pressure of the water-cooled system and water-cooled tube bundle is less than 0.1MPa, the safe operating water pressure shall be 1.4 times higher than the rated working pressure.

5.4.9.2 When the water-cooled system and water-cooled tube bundle are part of the atmospheric pressure boiler, forced circulation shall be adopted.

5.4.9.3 When the water-cooled system and water-cooled tube bundle are part of the boiler and the rated working pressure is less than 0.1 MPa, the requirements of TSG 11-2020 shall be met.

5.4.9.4 When the rated working pressure of the water-cooled system and water-cooled tube bundle is less than 0.1MPa and it is part of the phase change boiler, the requirements of GB/T 21434-2022 shall be met.

5.4.9.5 The water-cooled system and water-cooled tube bundle shall meet the

requirements of Chapter 6 and Chapter 7 in GB/T 151-2014.

5.4.10 Dielectric strength and insulation resistance

5.4.10.1 The insulation between the conductive parts of different polarities of the control box and between all the conductive parts and the shell shall be able to resist the dielectric strength voltage listed in Table 5, breakdown current shall not be larger than 10 mA, and there is no breakdown or flashover within 1 min.

5.4.10.2 The insulation resistance of the control box shall not be less than 10 MΩ before resisting the dielectric strength voltage and the insulation resistance shall not be less than 1 MΩ after resisting it.

Table 5 Dielectric strength voltage

Unit: V

Rated output voltage	Dielectric strength voltage
≤60	500
＞60	2000

5.4.11 Purging

Under automatic or manual operation conditions, the burner shall be able to purge regularly before ignition and after flameout. The pre-purging/post-purging time is more than 20 s, and the air supply is 4 times more than the furnace and flue volume. The air valve is in the maximum adjustment position during purging.

5.4.12 Ignition

5.4.12.1 Set up an independent ignition burner (pilot flame). Before the ignition procedure, ensure that the opening of the air and gas regulating device is at the lowest point of its adjustment range and the water-cooled system is working normally, otherwise the ignition procedure shall not be started.

5.4.12.2 The starting power of the main flame shall not be larger than 2 MW and the power of the independent flame for each ignition shall be lower than 2 MW. When the ignition power is larger than 2 MW, the main flame shall be ignited gradually by multiple surfaces or zone ignition.

5.4.12.3 The setting values of ignition and flameout safety time and flameout time shall be less than the limits listed in Table 6.

Table 6 Ignition safety time limit

Rated output power of the main burner (P_0)/MW	Ignition flame establishing safety time/s	Main flame establishing safety time/s	Flameout safe time/s
$P_0 \leqslant 0.07$	≤5	≤5	≤1
$0.07 < P_0 \leqslant 0.12$	≤5	≤3	≤1
$P_0 > 0.12$	≤3	≤3	≤1

5.4.13 Security interlock and alarm

5.4.13.1 The burner shall have the following safety interlocking and alarm functions under working conditions:

a) If ignition fails or flame fails after normal combustion, enter the interlocking protection state and alarm.

b) If the shutdown procedure is not completed after accidental power failure during work, it shall enter the verification of startup procedure when power is on again.

c) When the flame monitoring device fails, it shall alarm.

d) Alarm when the gas control valve is detected as leakage.

e) If the gas pressure or air pressure does not meet the starting conditions or is higher and lower than the protection signal, stop and alarm.

f) If the gas flow or air flow has fault signal, stop and alarm.

g) If the cooling medium in the water-cooled system is interrupted, or the pressure and temperature exceed the limit, the gas supply should be cut off and it shall enter the interlocking protection state and alarm.

h) The main gas control valve of burner shall be set as normally closed, control valve, ignition and flame detection shall be interlocked.

5.4.13.2 After the burner enters the locked state, it shall not be restarted without manual reset.

5.4.14 Prevent the tempering

5.4.14.1 Set the anti-tempering device after the premix chamber. Under the lowest power condition of the burner, the minimum flow velocity through the nozzle of the anti-tempering device is 2 times larger than the flame propagation velocity of the gas mixture.

5.4.14.2 The outlet characteristic dimension of the water-cooled bundle shall not be larger than 1.2mm and the characteristic length of the water-cooled bundle is not smaller than 18 mm.

5.4.14.3 The size change of the water-cooled tube spacing in the water-cooled bundle is less than 0.1 mm.

5.4.14.4 The pressure drop (ΔP_{st}) of the water-cooled bundle is not less than the pressure drop from the water-cooled bundle outlet to the whole burner device outlet (ΔP_1)+50Pa, namely $\Delta P_{st} \geqslant \Delta P_1$+50Pa.

5.4.14.5 The stray flame is not generated in the adjustable range of the burner flame.

5.5 Starting condition validation

After the burner is powered on, the program control device shall be self-tested. The gas valve group control relay is tested safely. Gas high/low-pressure signals are detected. Leaking of gas valve group is detected. Gas regulator valve and throttle are set to zero. Flame monitoring system is tested safely. Air pressure switch signal is tested safely. Automatic inspection has been verified. It specifically includes:

a) If the starting switch is on, alarm and lock shall work.

b) If the pressure of the cooling water system is insufficient, alarm and lock shall work.

c) If the flame monitoring is abnormal, alarm shall work.

d) The startup condition verification procedure shall include the automatic leak detection procedure for the gas control valve.

e) The startup condition verification procedure shall include automatic inspection procedures for the water-cooled system.

5.6 Fuel flow rate stability

Within the given load adjustment range, the fuel flow rate involved in the burning under any working condition shall meet the requirements and the fluctuation range of the flow rate is within ± 5%.

5.7 Air flow rate stability

5.7.1 The burner shall be equipped with air monitoring devices, which shall monitor the airflow through pressure monitoring, flow monitoring and other measurement methods that can reflect the state of the supply air. Within the given load adjustment range, the airflow rate involved in burning under any working condition shall meet the requirements, and the fluctuation range of the flow is within ± 5%.

5.7.2 Burners with rated output power higher than 2 MW shall control the air-fuel ratio in a closed loop by monitoring the air and gas flow.

5.8 Premix chamber and premixed degree

5.8.1 The specific volume power of a single premix chamber shall not be larger than 0.3 m^3/MW and the maximum volume is less than 1.5 m^3.

5.8.2 The premix chamber shall ensure gas tightness that the gas and air are evenly mixed out of the chamber.

5.8.3 The pressure of the premix chamber outlet section is uniform and the difference between maximum and minimum pressure is less than 100Pa under rated power.

5.8.4 The flame length of the premix chamber outlet is uniform without obvious yellow or red flame.

5.8.5 The premixed degree of premixed gas at the outlet of premix chamber under rated power shall not exceed 10%.

5.8.6 If there is a protective shell outside the premix chamber, a gas leakage alarm device shall be installed outside the protective shell.

5.9 Combustion performance

5.9.1 Combustion stability

When the fuel is normally burning in the burner within its load adjustment range, the change of CO_2 content (volume fraction) in the flue gas shall not exceed ± 1.5% of the average value.

5.9.2 Combustion adequacy

In stable operation under normal working conditions, the O_2 content (volume fraction) in the flue gas should not be more than 6%. The CO content converted according to the 3.5% O_2 in the flue gas shall not be higher than 95 mg/m^3. The blackness of the flue gas should not be higher than Ringelmann level 1.

5.9.3 Nitrogen oxide (NOx) production amount

In stable operation under normal working conditions, when the fuel is natural gas and liquefied petroleum gas, the O_2 content (volume fraction) in the flue gas should not be more than 6%.

a) For the water-cooled furnace with water-cooled heat exchange surface around, the nitrogen oxide (NOx) content converted according to the 3.5% O_2 in the flue gas shall not be higher than 30 mg/m^3.

b) For the adiabatic furnace surrounded by a refractory layer that absorbs less heat from the combustion gas, the nitrogen oxide (NOx) content converted according to the 3.5% O_2 in the flue gas shall not be higher than 50 mg/m^3.

For other gas fuels except for natural gas and liquefied petroleum gas, the original emission concentration of NOx is not required.

5.9.4 Load adjustment

When the burning load is changed within the load adjustment range, the flame transformation shall be stable, without tempering, blow-off, flameout and black flue gas.

5.9.5 Coking and carbon deposition

During the continuous operation within the load adjustment range, the coking and carbon deposition of the burner flame outlet shall not affect the normal burning.

5.9.6 Burner noise

For burner with rated output power lower than 0.4 MW, the operating noise shall be lower than 80dB (A-weighting). For burner with rated output power higher than 0.4 MW, the operating noise shall be lower than 85dB (A-weighting).

5.9.7 Surface temperature of the burner components

5.9.7.1 The actual working temperature of the regulating device, control device

and safety device of the burner shall within the permissible limits, and shall work reliably;

5.9.7.2 The surface temperature increment of the manipulated buttons and pull rods on the burner shall not be higher than 35 ℃ for metal materials, 45 ℃ for ceramic or similar materials and 60 ℃ for plastic or similar materials.

5.10 Auto-oscillation

When the burner operates under the maximum load, its vibration speed shall not be higher than 6.3 mm/s.

5.11 Operational reliability

After the burner is continuously operated according to 'start running - stop burning' for more than 10 cycles (more than 5 min per cycle) and more than 48 hours, each system shall not have abnormal phenomenon.

5.12 Protection level of electrical shell

The shell protection level of control box, motor and other devices shall not be lower than the IP22 requirements specified in GB/T 4208-2017, and the shell protection level of junction box and switch devices shall not be lower than the IP44 requirements specified in GB/T 4208-2017.

5.13 Environmental suitability

5.13.1 Low temperature

According to the provisions of GB/T 2423.1, the harsh level of low-temperature test is -5 ℃, 16h for electronic control equipment and -20℃, 16h for other equipment.

5.13.2 High temperature

According to the provisions of GB/T 2423.2, the harsh level of high-temperature test is 45 ℃, 16 h.

5.13.3 Humidity

According to the provisions of GB/T 2423.3, the harsh level of test is 2d,

temperature is (30±2) ℃ and relative humidity is (85±3)%.

5.13.4 Altitude

When the altitude does not exceed 2000 m, the burner shall work normally. When it exceeds 2000m, the maximum output power decrease of the burner for each 1000 m increase shall not exceed 12%.

5.13.5 Power

The power supply voltage change is within -10% - +6% of the rated value and the power supply frequency change is within ± 5% of the rated value.

6 Inspection and test method

6.1 Test conditions

The test shall be conducted under the following conditions unless otherwise specified:

a)Environmental conditions: The temperature is 5 ℃-40 ℃ and its fluctuation is less than 5℃ during the test. The relative humidity is 20%-80% and its fluctuation is less than 5%. The atmospheric pressure is 86 kPa-106 kPa and its fluctuation is less than 0.1 kPa.

b)The change of power supply voltage shall not exceed -10% - +6% of the rated value. The change of power supply frequency shall not exceed ± 5% of the rated value.

c)The inspection site is well-ventilated.

6.2 Appearance and composition

Visually check according to the requirements of 5.1 and the Table I.1 of ‘Gas Burner’ in GB/T 36699-2018.

6.3 Aerodynamic performance

The test device is type B given in 18.2 in GB/T 1236-2017. The test operation is conducted according to the requirements of Chapter 20 in GB/T 1236-2017. The

static pressure, flow and temperature are measured according to the requirements of chapters 7,13 and 8 in GB/T 1236-2017, respectively. During the test, the regulating valves in the burner air duct should be fully open. During the type inspection, change the opening of the flow control device on the air duct of the test device, measure the static pressure and flow of at least 10 points in the full close and full opening range and make the aerodynamic performance curve. In the factory test, the flow rate can be measured only at the working point requiring static pressure.

The static pressure and flow rate measured under the test conditions shall be converted to 0℃, 1.103×10^5 Pa state as the measured value.

6.4 Operational control

The simulation test of this item is generally carried out under cold condition. To operate the burner in the automatic control state, input the corresponding analog signal to the control system and check whether the burner has entered the normal burning state by observing the light on and off of the relevant program on the panel of the control box. After the burner operates at a normal burning state, input the load adjustment analog signal to observe whether the air and fuel regulating devices adjust accordingly with the change of the adjustment signal. Input the stop-burning simulation signal and check whether the burner stops according to the setting procedure by observing the light on and off of the relevant program on the panel of the control box.

Control the burner in the manual state, operate the switch appliance and load regulator, observe whether the burner enters the corresponding operating state according to the operation requirements.

6.5 Safety protection

6.5.1 Gas, air cleanliness

Check visually and confirm that the gas and air filter devices are installed in place. Confirm that the pores of the filter device are not larger than the minimum clearance of the water-cooled bundle. Check whether there are anti-corrosion measures, and whether the flow channel is smooth and gas is clean.

6.5.2 Sealing of the gas pipeline

Using compressed air as the test medium, except leaving only one air inlet, seal all the openings of the gas pipeline and open all the switching valves in the

pipeline, then inject compressed air. The pressure is raised to 1.5 times higher than the design pressure (not exceeding the rated pressure of the valve group) and not less than 4 kPa. Close the intake valve, maintain the pressure for 15 min and check the pressure drop in the pipeline.

If it is difficult to test all components at the same time, the test can be conducted in stages.

6.5.3 Sealing of the burner

Using compressed air as the test medium, except for only one air inlet, seal the gas from the inlet of the burner premix chamber to the outlet of the burner through all the openings of the parts and open all switching valves in the pipeline, then inject compressed air. The pressure is raised to 1.5 times higher than the design pressure (not exceeding the rated pressure of the valve group) and not less than 4 kPa. Close the intake valve, maintain the pressure for 15 min and check the pressure drop in the pipeline.

If it is difficult to test all components at the same time, the test can be conducted in stages.

6.5.4 Main gas control valve system

The main gas control valve system test is conducted in the following steps:

a) Check visually two series automatic safety cut-off valves or combination valves.

b) Check visually the automatic safety cut-off valve configuration, record the time of the control valve after closing the gas control valve, test three times under the same conditions and calculate the arithmetic average value as the measured value of each closing time.

c) Check visually against the rated output power of the burner.

d) Check visually the upstream pressure control device.

e) Check visually the independent ignition burner, confirm that the ignition flame is ignited and verified by the flame monitoring device before the main gas control valve can be opened, and ignite the main flame.

6.5.5 Ignition gas control valve system

The ignition gas control valve system test is conducted in the following steps:

a)Check visually two series automatic safety cut-off valves or combination valves.

b)Record the time of the control valve after closing the gas control valve, test three times under the same conditions, and calculate the arithmetic average value as the measured value of each closing time.

c)Check visually against the rated output power of the burner.

d)Check visually the upstream pressure control device.

e)Check visually the independent ignition burner, confirm that the ignition flame is ignited and verified by the flame monitoring device before the main gas control valve can be opened and ignite the main flame.

6.5.6 Flame monitoring device

The inspection test of flame monitoring device follows the steps:

a)Confirm visually that the sensor of the flame monitoring device is not disturbed by irrelevant signals.

b)Check visually the ignition flame monitoring system and main flame monitoring system of the burner.

c)Test the main flame monitoring device cannot monitor the ignition flame.

d)Record the establishment time of the self-inspection of the flame monitoring device during the startup process of the burner, test three times under the same conditions and calculate the arithmetic average value as the measured value of each establishment time.

e)Record the flame fault response time of the flame monitoring device, test three times under the same conditions and calculate the arithmetic average value as the measured value of each response time.

6.5.7 Premix fan

The inspection of premix fan follows the steps:

a)When the rated output power of the burner is higher than 2 MW, check visually whether the premix chamber is set at the outlet of the fan.

b)Check explosion-proof measures shall be taken for the fan when the premix chamber is at the inlet of the fan.

6.5.8 Flameout protection

The safe time of flame extinguishing is measured by the flame analog input signal method. Test three times under the same conditions and calculate the arithmetic average value as the measured value each time.

6.5.9 Water-cooled system and water-cooled bundle

Water-cooled system and water-cooled bundle tests are conducted in the following steps:

a)The atmospheric pressure system shall follow the provisions of 8.13 in GB/T 151-2014.

b)Within the scope of boiler safety technical regulations, follow the provisions of 4.5.6 hydrostatic test in TSG 11-2020.

c)For the part of the phase change boiler, follow the pressure resistance test, vacuum leak detection and air sealing test regulations of 7.2 in GB /T 21434-2022.

6.5.10 Dielectric strength and insulation resistance

Conduct the dielectric strength and insulation resistance test on the control box according to provisions of 4.5 and 4.6 in GB/T 10233-2016. In the test, the leakage current is detected at same time. The test is performed as follows (dielectric strength and insulation resistance can be selected one to measure):

a)Before the test, practical safety protection measures shall be taken to disconnect the inverter in the control box from the main circuit. Disconnect the current-consuming devices like program controller, fire inspection module, intermediate relay coil, contactor coil, indicator lamp, alarm, switching power supply, touch screen from the control power supply.

b)For electrical insulation test, the rated insulation voltage of the box is below 500V. First, 500V MΩ device is used to measure the insulation resistance between the conductive parts of the different poles of the active circuit, and between the inlet and outlet lines of the same pole, when all the conductive parts, the control box shell and the main switch are disconnected. The test should be carried out in the circuit without power, the test time is 1 min and the insulation resistance value measured shall be at least the nominal voltage of 1kΩ/V. In principle, the test is passed but it is recommended not to be lower than 2 MΩ. If the fan motor is equipped with frequency converter, the connection

line between the frequency converter and the motor should be removed. The motor and power line should be measured separately.

c)For dielectric strength test (also known as voltage resistance test), the test voltage shall be applied between the main circuit conductive parts and the ground, the main circuit phase (pole), the main circuit and the auxiliary circuit which is not directly connected with it. The test voltage values are shown in Table 5. When the rated insulation voltage of the box is between 380V-660V, the test voltage is AC 1890V (valid value) and the waveform is approximate sine wave with a frequency of 45-65 Hz. At the beginning, the test voltage shall not exceed 50% of the full test voltage value. Then, the test voltage smoothly increases to the full test voltage value, maintaining 5% increase (not less than 10 s) and full-value test lasts for 1 min. The main contact shall be closed or short-connected by 2.5 mm^2 wire in the test. There are no breakdowns and discharges during the test. If there is any abnormal phenomenon, the power supply shall be immediately cut off and the conductive part shall be discharged to the ground, checked and repaired before the test until passing. The conductive part shall also be discharged to the ground after the test.

d)After the dielectric strength test, the insulation resistance shall be tested immediately according to the requirements of b).

6.5.11 Purging

During the test of 6.4, when the burner enters the pre-purging procedure, observe the air valve opening at the maximum position of the regulating range, check visually the working state of the fan and record the time interval of the pre-purging. When the burning stops, measure the time interval between flame extinguishing and fan power off, which is the measurement value of post-purging time.

Test three times under the same conditions and calculate the arithmetic average value as the measured value of each purging time.

6.5.12 Ignition

Start the burner, check visually whether the ignition procedure starts and record the ignition time. The flame simulation input signal method is used to measure the safety time of the ignition flame establishment, the main flame establishment and the flame extinguishing. Test three times under the same conditions and calculate the arithmetic average value as the measured value each time.

6.5.13 Security interlock and alarm

The security interlock and alarm tests are conducted in the following steps:

a) In the automatic control state, start the burner and run to the corresponding procedure, input the analog signal of the fault state listed in 5.4.13.1 according to the burner category, and check whether the burner enters the locked state and emits sound and optical alarm signals. After locking and alarm occurs in a fault state, reset and remove the fault state analog signal, and then restart the burner and test for another fault state. The result shall meet the requirements of 5.4.13.1.

b) After the burner enters the locked state, start the burner without reset and check whether the burner starts. The result shall meet the requirements of 5.4.13.2.

6.5.14 Prevent the tempering

The anti-tempering test follows the steps:

a) Under the lowest power condition of the burner, measure the airflow velocity through the flow gap of the water-cooled bundle and take the minimum value.
b) Use a feeler gauge to measure the outlet characteristic dimension and the size change of tube spacing of the water-cooled bundle. Use a staff gauge to measure the characteristic length of the water-cooled bundle.

c) Measure the pressure drop of the two sides of water-cooled bundle (ΔP_{st}) and the pressure drop from the water-cooled bundle outlet to the whole device outlet (ΔP_1) by differential pressure method within the adjustment range of the burner.

d) Check visually the flame-burning situation of the burner within the adjustment range.

e) After the main flame starts successfully, gradually reduce the load until extinguishing and repeat 5 times without tempering.

f) After the main flame starts successfully, gradually reduce the airflow rate until extinguishing and repeat 5 times without tempering.

6.6 Starting condition validation

The test can be carried out in cold conditions. Open the burner switch under power failure conditions, start power supply and check whether the burner locks and alarms. After the burner is energized, input the analog signal of abnormal flame monitoring and air leakage to check whether the burner is locked and

alarmed.

6.7 Fuel flow rate stability

The fuel flow stability test is performed as follows:

a) The test can be conducted in cold state, the fuel temperature change shall not exceed ±5℃ and the fluctuation of fuel pressure in a certain condition shall not exceed ±10% during the test.

b) During the gas flow test, the water-cooled burner bundle can be loaded into the fan aerodynamic test device, the gas can be replaced by compressed air, the test can be conducted according to the method of 6.3. The result shall be converted to flow value per hour under the 0℃, 1.013×10^5 Pa condition.

c) If possible, a flow meter can also be installed at the appropriate position of fuel supply tube in the water-cooled burner bundle for measurement.

d) For the continuously adjusted burner, at least 1/3 and 2/3 rated flow conditions shall be tested. For the counterpoint-adjusted burner, the flow rate of each section shall be tested. Test three times under the same conditions and the difference of each two measured values is calculated. The maximum difference is taken as the measured value of fuel flow rate change.

The gas flow test shall be measured according to the requirements of b) or c) and the result shall meet the requirements of 5.6.

6.8 Air flow rate stability

The airflow stability test is performed as follows:

a) The test can be conducted in cold state, the air temperature change shall not exceed ±5℃ during the test.

b) The air flow test can be conducted according to the method of 6.3. The result shall be converted to flow value per hour under the 0℃, 1.013×10^5 Pa condition.

c) If possible, a flow meter can also be installed at the appropriate position of air supply tube for measurement.

d) For the continuously adjusted burner, at least 1/3 and 2/3 rated flow conditions shall be tested. For the counterpoint-adjusted burner, the flow rate

of each section shall be tested. Test three times under the same conditions and the difference of each two measured values is calculated. The maximum difference is taken as the measured value of air flow rate change.

The airflow test shall be measured according to the requirements of b) or c) and the result shall meet the requirements of 5.7.

6.9 Premix chamber and premixed degree

6.9.1 Premix chamber

The premix chamber test is performed as follows:

a) The volume of a single premix chamber is determined by geometric measurement.

b) Test the sealing of premix chamber according to 6.5.3. For the premix chamber equipped with protective shell, test the gas leakage alarm device setting outside the protective shell.

c) The pressure probe is used at the premix chamber outlet to measure the pressure at different positions including the center and the side wall, and the maximum and minimum values are taken.

c) Check visually the flame of premix chamber outlet.

6.9.2 Premixed degree

At different positions in the cross-section of the premixed chamber, the gas composition and content of the mixed gas is tested by the gas composition analyzer. The arithmetic average of more than three measurements is taken for calculation. The premixed degree is calculated according to formula (2).

$$\varepsilon = \frac{\left(c_{i,max} - c_{i,min}\right)}{c_{avg}} \quad \cdots\cdots (2)$$

where,

ε–premixed degree, %.

$c_{i,max}$–the maximum value of the gas concentration in the premix chamber, milligram per cubic meter(mg/m^3).

$c_{i,min}$–the minimum value of the gas concentration in the premix chamber, milligram per cubic meter(mg/m^3).

c_{avg}–the average value of the gas concentration measured at each point of the premix chamber, milligram per cubic meter(mg/m^3).

6.10 Combustion performance

6.10.1 Basic requirements

The test shall be conducted on the test furnace or on the user's combustion furnace. The fuel gas shall be the minimum low calorific value of the fuel gas suitable for the burner. The test shall be conducted under all conditions that the operating parameters shall meet the requirements.

6.10.2 Combustion stability

The burner is operated under the minimum fuel flow condition in the load adjustment range. Adjust the combustion air flow until the flame is normal. Measure the CO_2 content every 5-10 min by the flue gas analyzer when the flue gas temperature variation does not exceed ±5℃. Test three times under the same condition. Calculate the difference between each two measured values and take the maximum difference as the measured value of CO_2 content. The result shall meet the requirements of 5.9.1.

The flue gas sampling and analysis shall be conducted in accordance with I.18 in GB/T 36699-2018.

The flue gas blackness shall be regulated by HJ/T 398.

6.10.3 Combustion adequacy

Adjust the combustion air until the flame of the burner is normal. Measure the flue gas composition with the flue gas analyzer every 5-10 min when the load reaches 80%~100% of the rated load and the flue gas temperature change does not exceed ±5℃. Test three times under the same condition, the arithmetic average value is calculated as the measured value of each test. The result shall meet the requirements of 5.9.2.

The flue gas sampling and analysis shall be conducted in accordance with I.18 in GB/T36699-2018. The CO emission concentration is converted to the 3.5% oxygen content condition according to formula (3).

$$c(\mathrm{CO}) = c(\mathrm{CO}') \times 1.25 \times \frac{21 - w(\mathrm{O_2})}{21 - w(\mathrm{O_2}')} \quad \cdots\cdots (3)$$

where,

c(CO) - The CO emission concentration under the reference oxygen content, milligram per cubic meter (mg/m^3).

c(CO') - The measured CO emission concentration, milliliter per cubic meter

(mL/m^3, ppm).

1.25 - CO density, kg per cubic meter (kg/m^3) (0℃, 1.013×10^5Pa).

$w(O_2)$ - The reference oxygen content, %.

$w(O_2')$ - The measured oxygen content, %.

6.10.4 Nitrogen oxide (NOx) production amount

In the 6.10.3 test, the flue gas analyzer is used to measure the NOx and oxygen content in the flue gas. Take the arithmetic average of no less than three measured data as the measured value.

The flue gas sampling and analysis shall be conducted in accordance with I.18 in GB/T36699-2018. The NOx emission concentration is converted to the 3.5% oxygen content condition according to formula (4).

$$c(\mathrm{NO}x) = c(\mathrm{NO}x') \times 2.05 \times \frac{21 - w(\mathrm{O}_2)}{21 - w(\mathrm{O}_2')} \quad \cdots\cdots (4)$$

where,

c(NOx) - The NOx emission concentration based on reference oxygen content in the form of NO_2, milligram per cubic meter (mg/m^3).

$c(NOx')$ - The measured NOx emission concentration, milliliter per cubic meter (mL/m^3, ppm).

2.05 - NO_2 density, kg per cubic meter (kg/m^3) (0℃, 1.013×10^5Pa).

$w(O_2)$ - The reference oxygen content, %.

$w(O_2')$ - The measured oxygen content, %.

6.10.5 Load adjustment

According to the load adjustment order of '50%→100%→50%', the burner is continuously operated for more than two cycles (each cycle time more than 15 min). Check the flame state and test under the minimum/maximum fuel flow condition in the load adjustment range according to 6.7. Take the arithmetic average of no less than three measured data as the measured value of each flow. The load adjustment ratio is calculated by the measured value. The result shall meet the requirements of 5.9.4.

6.10.6 Coking and carbon deposition

Ignite the burner under manual control mode and adjust the operation parameters to run the burner under normal flame conditions in load adjustment range. Adjust the combustion load according to the order of '50%→100%→50%' and complete a cycle every 10-15 min. Let the burner operated continuously for more than 10 cycles before the combustion stops. Then check coke and carbon deposition on all related parts. The result shall meet the requirements of 5.9.5.

6.10.7 Burner noise

The test shall meet the requirements of I.19 in GB /T 36699-2018.

6.10.8 Surface temperature of the burner components

Let the burner operates continuously in the maximum fuel flow condition for 4 hours, and then measure the temperature of the accessible parts of the burner shell by a thermometer.

6.11 Auto-oscillation

The test is conducted at the maximum combustion load of the burner. The vibration speed is tested by the vibration speed tester. For the burner with fan, the vibration speeds of the shell in the vertical, horizontal and axial directions of the fan motor stator are tested. For the burner without fan, the vibration speeds at the inlet and outlet of the combustion air on the shell are tested. Take the maximum value as the measured value of each vibration velocity. The result shall meet the requirements of 5.10.

6.12 Operational reliability

Under manual control mode, operate the burner continuously for more than 10 cycles and each cycle lasts more than 5 min according to the operation order of ‘Start → ignition →50% load →100% load →50% load → Stop’. Check whether any abnormal phenomenon occurs in each system during operation. If there is no abnormal phenomenon, operate the burner continuously for more than 48 h, in which the state of small flame and big flame shall change alternately. The cumulative operation time under the big flame state shall not be less than 4 hours. Monitor whether the operation state is normal during the test and check each system after the test. The result shall meet the requirements of 5.11.

6.13 Protection level of electrical shell

The test shall meet the requirements of GB/T 4208 - 2017.

6.14 Environmental suitability

6.14.1 Low temperature

The test shall meet the requirements in GB/T 2423.1. During and at the end of the test, the test prototype shall be powered on and operated for not less than 15 min. The burner shall be operated normally according to 5.3 and be tested according to 6.4.

6.14.2 High temperature

The test shall meet the requirements in GB/T 2423.2. During and at the end of the test, the test prototype shall be powered on and operated for not less than 15min. The burner shall be operated normally according to 5.3 and be tested according to 6.4.

6.14.3 Humidity

The test shall meet the requirements in GB/T 2423.3. During and at the end of the test, the test prototype shall be powered on and operated for not less than 15min. The burner shall be operated normally according to 5.3 and be tested according to 6.4.

6.14.4 Altitude

The tests can be performed in a compliant simulation environment. In the corresponding simulation environment of 0 m, 2000 m and 4000 m, the test prototype shall be powered on and operated for not less than 15 min during and at the end of the test. The burner shall be operated normally according to 5.3 and be tested according to 6.4.

6.14.5 Power

Adjust the three-phase voltage regulator and the frequency conversion unit to change the power supply parameters of the burner according to Table 7. Each condition lasts for 15 min. The test is conducted according to 6.4.

Table 7 Combinations of AC power supply parameters

Serial number	Change of voltage （%U_n）	Change of frequency （%f_n）
1	+6	+5
2	+6	-5
3	-10	-5
Note: U_n and f_n are rated voltage and rated frequency of the burner power, respectively.		

7 Inspection and test rules

7.1 Inspection and test classification

It is divided into factory inspection and type test.

7.2 Factory inspection

7.2.1 Factory inspection items shall be conducted according to Table 8.

7.2.2 Each product shall be inspected before it leaving the factory.

7.2.3 In the specified inspection items, the re-inspection of non-conformance after improvements is allowed if it is not meet the requirements. The product is not qualified if the item does not meet the requirements after the reinspection.

Table 8 Factory inspection items

No.	Inspecting item	Number of the requirements	Number of the inspection and test methods
1	appearance and composition	5.1	6.2
2	operational control	5.3	6.4
3	gas tube sealing	5.4.2	6.5.2
4	burner sealing	5.4.3	6.5.3
5	water-cooled system and water-cooled bundle	5.4.9	6.5.9
6	dielectric strength and insulation resistance	5.4.10	6.5.10
7	security interlock and alarm	5.4.13	6.5.13
8	prevent the tempering	5.4.14.2 5.4.14.3	**7.2.14)**

7.3 Type test

7.3.1 Type test shall be conducted in the following cases:

a) The prototype identification of a newly designed burner.

b) The type of fuel used by the burner or the burner’s structure and program control mode have been changed.

c) The initial products manufactured by a transferred factory.

d) The burner type test has passed more than 4 years.

7.3.2 Type test items are conducted according to Table 9.

7.3.3 The number of test proto is one.

7.3.4 In the specified tests, a re-test of non-conformance after improvements is allowed if there are items not meeting the requirements. If the items still do not meet the requirements during the test, double test of prototypes should be sampled and conducted. If the double sampling tests still fail to meet the requirements, it is determined that the type test of the prototype is not qualified.

Table 9 Type test items

No.	Test item	Number of the requirements	Number of inspection methods
1	appearance and composition	5.1	6.2
2	aerodynamic performance	5.2	6.3
3	operational control	5.3	6.4
4	Safety protection	5.4	6.5
5	starting condition validation	5.5	6.6
6	fuel flow rate stability	5.6	6.7
7	air flow rate stability	5.7	6.8
8	premix chamber and premixed degree	5.8	6.9
9	combustion performance	5.9	6.10
10	auto-oscillation	5.10	6.11
11	operational reliability	5.11	6.12
12	protection level of electrical shell	5.12	6.13
13	environmental suitability	5.13	6.14

8 Technical documents and identification

It is conducted according to the Chapter 11 in GB/T 36699-2018.

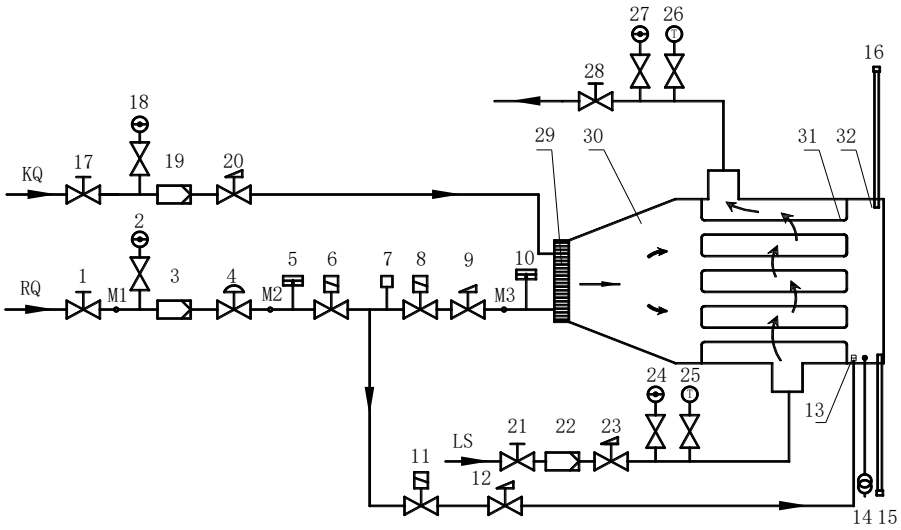
9 Packaging, transportation and storage

It is conducted according to the Chapter 12 in GB/T 36699-2018.

Annex A
(informative)

The basic configuration of the water-cooled premixed low NOx burner

A.1 The basic configuration of the water-cooled in tube premixed low NOx burner is shown in Figure A.1.



Description of indexing number:

1-Gas manual quick cut-off valve

2-Gas pressure monitoring device

3-Gas filtration device

4-Gas pressure regulating device

5-Gas low-pressure protection device

6-First automatic safety cut-off valve

7-Automatic leak detection device

8-Second automatic safety cut-off valve

9-Gas flow rate regulating device

10-Gas high-pressure protection device (when no.4 is not installed)

11-Ignition safety cut-off valve

12-Ignition gas flow regulating device

13-Ignition burner nozzle

14-Ignitor device

15-Ignition flame monitoring device

16-Main flame monitoring device

17-Air valves

18-Air pressure monitoring device

19-Air filtration device

20-Air flow control valve

21-Cooling water inlet switch valve

22-Cooling water filtration device

23-Cooling water regulating valve

24-Cooling water inlet pressure monitoring device

26-Cooling water outlet temperature monitoring device

27-Cooling water outlet pressure monitoring device

28-Cooling water outlet switch valve

29-Flow rectifier

30-Premix chamber (isotonic chamber)

31-Water-cooled bundle

32-Combustion chamber

M1-The first pressure measuring point

M2-The second pressure measuring point

M3-The third pressure measuring point

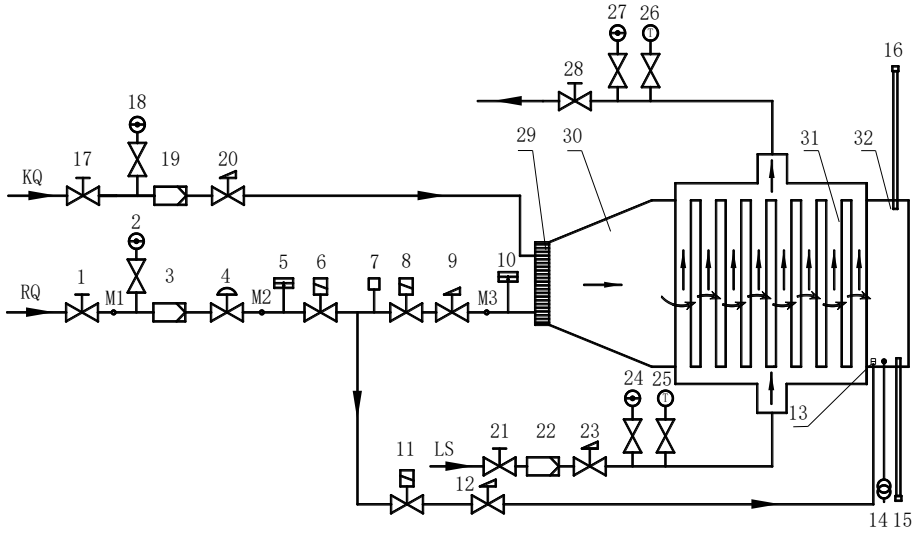
KQ-Air

RQ-Fuel gas

25-Cooling water inlet temperature LS-Cooling water monitoring device

Figure A.1 Basic configuration diagram of the water-cooled in tube premixed low-nitrogen burner

A.2 The basic configuration of the water-cooled at shell side premixed low NOx burner is shown in Figure A.2.



Description of indexing number:

1-Gas manual quick cut-off valve	13-Ignition burner nozzle	26-Cooling water outlet temperature monitoring device
2-Gas pressure monitoring device	14-Ignitor device	27-Cooling water outlet pressure monitoring device
3-Gas filtration device	15-Ignition flame monitoring device	28-Cooling water outlet switch valve
4-Gas pressure regulating device	16-Main flame monitoring device	29-Flow rectifier
5-Gas low-pressure protection device	17-Air valves	30-Premix chamber (isotonic chamber)
6-First automatic safety cut-off valve	18-Air pressure monitoring device	31-Water-cooled bundle
7-Automatic leak detection device	19-Air filtration device	32-Combustion chamber
8-Second automatic safety cut-off valve	20-Air flow control valve	M1-The first pressure measuring point
9-Gas flow rate regulating device	21-Cooling water inlet switch valve	M2-The second pressure measuring point
10-Gas high-pressure protection device (when no.4 is not installed)	22-Cooling water filtration device	M3-The third pressure measuring point
11-Ignition safety cut-off valve	23-Cooling water regulating valve	KQ-Air
12-Ignition gas flow regulating device	24-Cooling water inlet pressure monitoring device	RQ-Fuel gas
	25-Cooling water inlet temperature monitoring device	LS-Cooling water

Figure A.2 Basic configuration diagram of the water-cooled at shell side premixed low-nitrogen burner