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Corrosion control engineering life cycle in fossil fuel power plants — General requirements

Ingénierie du contrôle de la corrosion au cours du cycle de vie dans les centrales électriques à combustibles fossiles — Exigences générales

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Foreword

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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*, Subcommittee SC 1, *Corrosion control engineering life cycle*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Corrosion control engineering life cycle in fossil fuel power plants — General requirements

1 Scope

This document specifies general requirements for each element in the life cycle of corrosion control engineering in fossil fuel power plants.

This document is applicable to corrosion control engineering of all types of fossil fuel power plants.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

ISO 23123, *Corrosion control engineering life cycle — General requirements*

ISO 23222, *Corrosion control engineering life cycle — Risk assessment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044, ISO 23123, ISO 23222 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
corrosion control engineering in fossil fuel power plants
process of controlling the metal corrosion rate of fossil fuel power plant equipment, facilities and systems within the required range by applying various corrosion control technologies

3.2
water and steam quality regulation and control
process of controlling metal corrosion by adding chemical agents into the water and steam system to regulate the water and steam quality

3.3
combustion adjustment
process of adjusting the combustion conditions of a boiler to avoid corrosion of heat exchange tubes

3.4
flow accelerated corrosion
corrosion in which the wall thickness of metal pipe is reduced due to dissolution of oxidation film on the inner wall of the pipe accelerated by medium flow under a particular operating condition

3.5
high-temperature steam corrosion
corrosion on the metal component surface under high-temperature steam conditions

3.6
high temperature corrosion on the fire side
corrosion at high temperature on the external wall of metal tubes for the water-cooled wall, superheater and reheater on the fire side of the boiler heating surface

3.7
low temperature corrosion
corrosion due to condensation of sulfuric acid gas in the flue gas on a metal surface at a temperature below the sulfuric acid dew point

3.8
lay-up corrosion
corrosion during lay-up of fossil fuel power plant equipment

4 General principles

4.1 This document specifies all elements related to the fossil fuel power plants corrosion control engineering life cycle, including objectives, corrosion sources, materials, technology, design, research and development, manufacturing, storage and transportation, construction and installation, commissioning, acceptance, operation, maintenance, overhaul, scrapping and disposal, documents and records, resource management and comprehensive assessment. The requirements of all the elements are specified in accordance with holistic, systematic, coordinated and optimized principles.

4.2 The main systems associated with corrosion control engineering in fossil fuel power plants include boiler and its auxiliary system, turbine and its auxiliary system, electrical equipment, water and wastewater treatment system and civil facilities. An example of a fossil fuel power plant is depicted in Annex A. The crucial points of corrosion control in fossil fuel power plants include, but are not limited to:

— high temperature corrosion on the fire side, stress corrosion, flow accelerated corrosion, high-temperature steam corrosion of boiler and its auxiliary system;

— high-temperature steam corrosion and flow accelerated corrosion of turbine and its auxiliary system;

— generator hollow conductor corrosion, acid and alkali corrosion of water and wastewater treatment system;

— atmospheric corrosion and soil corrosion of civil facilities.

4.3 A system to oversee corrosion control shall be established to achieve overall control and continuous improvement of all aspects of corrosion of each system in fossil fuel power plants. An example of a continuous improvement cycle for corrosion control engineering in a fossil fuel power plant is illustrated in Annex B.

4.4 The organization of corrosion control shall include establishing the owner, technical management team, operation team and maintenance team, and the responsibilities and authorities of personnel shall be clearly defined.

5 Objectives

5.1 Implementation of this document is intended to help control effectively the corrosion of each system in fossil fuel power plants, eliminate or slow down the corrosion hazards, and optimize the benefits of safe, economical and long-cycle operation and environmental protection in fossil fuel power plants.

5.2 The objective of corrosion control of fossil fuel power plants shall be implemented as appropriate into all elements in the life cycle of all equipment and systems of fossil fuel power plants, communicated, implemented and maintained in all links of the life cycle, and its continuous suitability shall be reviewed and improved.

6 Corrosion sources

6.1 The technical management team shall establish procedures for identifying corrosion sources of each system in the life cycle of fossil fuel power plants. The operation team and maintenance team shall investigate and analyse corrosion sources, and identify corresponding corrosion sources comprehensively, accurately and concretely in accordance with the procedures.

6.2 The internal corrosion sources of each system in fossil fuel power plants are as follows:

a) the corrosion sources of boiler and its auxiliary system, including, but not limited to, atmosphere, flue gas, water, steam, molten salt, acid, ash;

b) the corrosion sources of steam turbine and its auxiliary system, including, but not limited to, atmosphere, water, steam, impurities in oil;

c) the corrosion sources of electrical equipment, including, but not limited to, atmosphere, soil, water, hydrogen, impurities in oil and impurities in insulating gas, current;

d) the corrosion sources of water and wastewater treatment system, including, but not limited to, atmosphere, soil, water, acid, alkali and oxidant;

e) the corrosion sources of civil structure, including, but not limited to, atmosphere, soil and water.

6.3 The impact of external environment of each system on corrosion shall be considered, including, but not limited to, temperature, pressure, flow rate, stress state and other external environment.

6.4 Reasonable and effective management requirements and technical measures for corrosion control engineering in fossil fuel power plants shall be formulated for corrosion sources of each system.

7 Materials

7.1 Service environment of materials for the fossil fuel power plant equipment and systems shall be investigated and the optimal materials resistant to corrosion sources shall be selected according to corresponding standards.

7.2 Materials for the fossil fuel power plant equipment and systems shall be selected on the basis of ensuring the service life and due consideration shall be given to the materials' corrosion resistance, processability and welding performance, economy and environmental protection.

7.3 Materials shall be selected using the following procedures.

a) The corrosion sources and corrosion magnitude of materials for each system shall be determined.

b) Corresponding standards and manuals shall be referred to so that materials that meet corrosion resistance requirements shall be selected.

c) Corrosion resistance of materials shall be assessed.

7.4 The selected materials shall have corresponding specific achievements and supporting implementation cases as references. In the absence of same performance or similar application, laboratory simulation or field test is required for material selection.

7.5 The selected materials shall be reviewed and assessed by established procedures.

7.6 Boiler and its auxiliary system shall use the optimal materials resistant to corrosion sources such as flue gas, high temperature and high-pressure steam and stress. The requirements include, but are not limited to, the following.

a) High-temperature steam pipes, high-temperature headers and high-temperature pipe fittings should be resistant to oxidation and high temperature corrosion. ASTM A335 may be referred to for information on the selection of materials.

b) Boiler heating surface tubes should be resistant to flue gas corrosion, coal ash corrosion, steam-water corrosion and stress corrosion.

c) Boiler drums and steam-water separators should be resistant to steam-water corrosion.

d) Boiler heating surface fixtures should have appropriate thermal strength and shall be resistant to oxidation and corrosion.

e) Soot blowers shall possess excellent oxidation resistance and good corrosion resistance performance.

f) The denitration device shall be made of materials resistant to corrosion of denitration reductants, such as liquid ammonia, ammonia water or urea.

g) The desulfurization device should be made of materials resistant to corrosion of desulfurized slurry or flue gas. Anti-corrosion materials in direct contact with desulfurized wet flue gas shall be acid-resistant, impermeable, aging-resistant and durable with firm adhesion. When there is desulfurization bypass, the anti-corrosion material shall be able to stand the rapid and alternative changes of flue gas temperature and humidity.

7.7 The steam turbine and its auxiliary system shall use the optimal materials resistant to corrosion sources such as high temperature and high-pressure steam, vibration and stress. The requirements include, but are not limited to, the following.

a) High and medium pressure rotors shall be resistant to high-temperature steam corrosion. For the selection of materials, reference should be made to ASTM A470.

b) Steam turbine blades shall be corrosion-resistant and possess excellent anti-fatigue performance, especially the performance to resist corrosion fatigue. Low pressure blades served in wet steam area should be made of materials with good corrosion resistance performance. Materials for low-pressure last stage moving blades may be selected with reference to ASTM A564 and ASTM A473.

c) Fasteners shall be resistant to oxidation.

d) Titanic materials or stainless steel shall be preferred for wet condenser tubes. Non-aluminium materials should be selected for heat exchange tubes of indirect air-cooling systems and air heat exchangers. Materials with good resistance to flow accelerated corrosion shall be selected for heat exchange tubes of direct air-cooling systems.

e) Materials with good resistance to flow accelerated corrosion shall be selected for heat exchange tubes of high-pressure heaters. Stainless steel may be used for heat exchange tubes of low-pressure heaters. Alloy sensitive to ammonia corrosion shall not be selected.

7.8 The influence of corrosion sources such as current, moisture in hydrogen, SF_6 and impurities in oil, soil and water shall be considered for material selection of electrical equipment.

7.9 The optimal materials resistant to corrosion sources such as acid and alkali, as well as to heavy salt water, shall be selected for the water and wastewater treatment system. The inner surface of the equipment, pipes, valves and drainage ditches contacting corrosive media or affecting effluent quality, and the outer surface of the equipment, pipes and valves affected by corrosive environment, shall be coated with appropriate corrosion-resistant paintings and made of corrosion-resistant materials.

7.10 The optimal materials resistant to corrosion sources such as atmosphere, water and soil shall be selected for civil structures. The requirements include, but are not limited to, the following.

a) Isolation and anti-corrosion measures, such as lining rubber to prevent inner wall corrosion, or cladding with polyurethane and other anti-corrosion materials for external wall corrosion, should be taken for buried pipes.

b) Corrosion control protective layer shall be designed for buried components, and corrosion-resistant steel bars should be selected.

c) Materials resistant to wet flue gas corrosion shall be selected for chimneys.

d) Materials resistant to atmospheric corrosion shall be selected for steel structures.

8 Technology

8.1 When selecting corrosion control technologies for each system of fossil fuel power plants, comprehensive evaluation shall be carried out according to corresponding technical standards or specifications, and the following principles shall be followed.

a) The safety of corrosion control technologies, including their safety relative to equipment, systems, personnel and environment, shall be assessed.

b) The advancement and economy of corrosion control technologies shall be assessed.

c) The selected corrosion control technology shall meet the operation requirements of the system and equipment under various conditions, ensuring that equipment and parts can operate in accordance with the objectives of long-life cycle operation and environment protection.

d) One or more technologies suitable for corrosion sources corresponding to various systems in fossil fuel power plants can be selected to impose corrosion control.

8.2 Corrosion control technologies for systems of fossil fuel power plants include, but are not limited to, the following.

a) Water and steam quality regulation and control: The material properties, corrosion medium, operating conditions and other aspects of water and steam circulation system in fossil fuel power plants shall be fully understood, to ensure the selection of appropriate water and steam quality regulation agents and control strategy to mitigate the corrosion of system materials, and the cost shall be evaluated if this technology is adopted. This technology generally applies to the corrosion control of boiler and its auxiliary system, steam turbine and its auxiliary system, and water and wastewater treatment system. The technologies include, but are not limited to:

- all-volatile treatment (reduction) of boiler feedwater;
- all-volatile treatment (oxidization) of feedwater;
- oxygenated treatment of feedwater;
- phosphate treatment of boiler water;
- sodium hydroxide treatment of boiler water;
- all-volatile treatment of boiler water;
- corrosion and scale inhibition treatment of circulating water;

— acid treatment of circulating water;

— by-pass weak acid treatment of circulating water;

— electrochemical treatment of circulating water;

— condensate polishing treatment;

— drying, nitrogen filling, pH adjustment and corrosion inhibitor filling technologies avoiding lay-up corrosion;

— online water quality purification and water quality regulation technologies such as nitrogen filling and alkalescency adjustment of generator cooling water.

b) Coating protection: It is advisable to select the coating suitable for the operating conditions and the feasible construction technology and adopt a coating protection scheme with optimal environmental protection and technical economy. This technology generally applies to the corrosion control for each system in fossil fuel power plants, including boiler and its auxiliary system, steam turbine and its auxiliary system, electrical equipment, water and wastewater treatment system, and civil structures. ISO 2063-1 provides information on thermal spraying. The technologies include, but are not limited to:

— spraying metal, alloy, ceramic or other wear-resistant, corrosion-resistant and high-temperature-resistant materials on outer surface of water-cooled wall of boiler;

— spraying zinc or other anti-corrosion coatings on steel structures;

— cladding buried pipes with organic materials;

— painting anti-corrosion paint on surface of system equipment.

c) Combustion adjustment: The purpose is to achieve complete combustion and uniform heat release of fuel in the boiler, control component temperature within a reasonable range, prevent slagging on the heating surface, improve reducing atmosphere in the water-cooled wall surface area, etc. This technology is mainly used for corrosion protection on the fire side of boiler. The technologies include, but are not limited to:

— adjusting ratio of fuel feeding and water quantity;

— adjusting air distribution parameters;

— adjusting spraying water quantity.

d) Cleaning: In the case of chemical cleaning, the deposit composition and amount shall be analysed, and the optimal cleaning process and time shall be selected to control under-deposit corrosion. This technology generally applies to the corrosion control for each system in fossil fuel power plants, including boiler and its auxiliary system, steam turbine and its auxiliary system, electrical equipment, water and wastewater treatment system, and civil structures. The technologies include, but are not limited to:

— acid cleaning;

— high-pressure water flushing.

e) Cathodic protection: This technology can be used for the corrosion prevention of steam turbine and its auxiliary system, electrical equipment, water and wastewater treatment system, and civil structures. For the corrosion prevention of underground pipe network and grounding grid, impressed current or sacrificial anode can be adopted. ISO 12473, ISO 12696 and ISO 13174 may be referred to for information on cathodic protection. The technologies include, but are not limited to:

— impressed current;

— sacrificial anode;

— the combination of both.

f) Compound technology. Various anti-corrosion technologies are used in combination to optimize the corrosion control effect. This technology generally applies to the corrosion control for each system in fossil fuel power plants, including boiler and its auxiliary system, steam turbine and its auxiliary system, electrical equipment, water and wastewater treatment system, and civil structures. The technologies include, but are not limited to:

— selecting high-temperature-resistant materials for boiler superheater and reheater tubes, adopting combustion adjustment to control steam temperature within a reasonable range, and adopting water and steam quality regulation to control high-temperature steam corrosion;

— selecting high-temperature-resistant materials for water-cooled wall of boiler and adopting combustion adjustment and water and steam quality regulation and control to control inner wall corrosion;

— selecting glass flake lined steel for desulfurizing tower and controlling the chloride ion concentration of desulfurized slurry to prevent tower wall corrosion;

— adopting surface galvanization and cathodic protection (impressed current or sacrificial anode) for corrosion control of grounding grid materials.

8.3 The selected technologies shall be proved by corresponding specific achievements and supporting cases as reference; otherwise, they shall be verified by experiments before application.

8.4 The selected corrosion control technologies shall be reviewed and evaluated by established procedures.

8.5 The typical corrosion control technologies in fossil fuel power plants are listed in Annex C.

9 Design

9.1 In the design of systems of a new fossil fuel power plant, the elements and corresponding risks associated with corrosion control engineering life cycle shall be taken into full account, according to ISO 23222. The corrosion control design for the systems (including corrosion source identification, material selection, corrosion detection, and corrosion control technology design and optimization) shall be implemented according to applicable codes or standards, and corrosion control requirements for subsequent stages such as manufacturing, storage, transportation, installation, commissioning, operation, maintenance and scrapping shall be set out.

9.2 In the design of corrosion control of systems of fossil fuel power plants, materials shall be selected according to 7.6 and appropriate anti-corrosion technology shall be selected according to 8.2. Targeted anti-corrosion measures shall be designed considering the specific characteristics of corrosion sources of systems and equipment.

9.3 In the anti-corrosion design of boiler and its auxiliary system, measures shall include, but are not limited to, the following.

a) Measures for the prevention of high temperature corrosion on the fire side of water-cooled wall shall be designed. Such measures include, but are not limited to:

— adopting suitable fuel or coal blending technology to control the sulfur content of coal fed into the boiler;

— selecting appropriate boiler combustion mode and burner arrangement;

— selecting suitable furnace characteristics and furnace structural parameters to control furnace outlet temperature;

— optimizing burner design to prevent flame from impacting the wall;

— designing a closing-to-wall air system;

— spraying wear-resistant anti-corrosion coatings on the heating surface tubes;

— optimizing the nitrogen oxide emission indexes of the furnace outlet and the boiler-tail denitration post-treatment unit outlet to prevent high-temperature corrosion caused by dry low NOx combustion.

b) Measures for the prevention of high temperature corrosion of convection heating surface shall be designed. Such measures include, but are not limited to:

— adopting suitable fuel or coal blending technology to control the sulfur content of coal fed into the boiler;

— appropriately arranging the heating surface with high working medium temperature in the area with relatively low flue temperature;

— reducing temperature difference between tubes to control heating surface wall temperature;

— for boilers that are Π-shaped, taking measures to reduce the residual rotation strength of flue gas in the upper furnace to reduce unevenly distribution of flue gas flow energy at the furnace outlet, so as to prevent local overtemperature of superheater and reheater;

— designing sufficient boiler heating surface wall temperature monitoring devices; designing complete soot blowers to prevent tube wall corrosion caused by contamination or coking of convection heating surface.

c) Measures for the prevention of low temperature corrosion on low temperature heating surfaces such as air pre-heater and low temperature economizer shall be designed. Such measures include, but are not limited to:

— adopting enamelled elements for the heating surface at the cold end of the air pre-heater and selecting corrosion-resistant materials for the low temperature economizer;

— designing higher integrated temperature for the air pre-heater to ensure sufficient safety margin;

— adopting hot air recirculation, air heaters or other methods of increasing the water temperature at the low temperature economizer inlet to ensure the operating temperature of the low temperature economizer is higher than the safe temperature;

— designing effective cleaning and soot blowing devices to prevent clogging of air pre-heater and low temperature economizer.

d) Measures for prevention of corrosion of water and steam system shall be designed. Such measures include, but are not limited to:

— selecting high temperature Fe-Cr-Ni alloy with good resistance to high-temperature steam corrosion for the convection heating surface of ultra (super) critical boiler;

— selecting low-chrome steel and other materials resistant to flow accelerated corrosion for feedwater pipes and connecting pipes;

— designing boiler feedwater dosing and oxygenation device, boiler water dosing device, lay-up protection inhibitor dosing device, nitrogen filling protection device or air-drying device;

— setting water and steam sampling and water and steam quality monitoring devices for the water and steam circulating system.

e) Measures for prevention of corrosion of desulfurization device shall be designed. Such measures include, but are not limited to:

— selecting corrosion-resistant materials such as glass flake lined, or rubber lined carbon steel substrate for the tower body structure;

— selecting corrosion-resistant materials such as glass flake lined, rubber lined, titanium lined or other corrosion-resistant alloy lined carbon steel substrate for flues contacting wet flue gas;

— selecting corrosion-resistant materials such as ceramic, stainless steel and engineering plastics for demisters and other components; designing reasonable chloride ion control indexes for desulfurized slurry.

f) Measures for prevention of corrosion of denitration device shall be designed. Such measures include, but are not limited to, selecting stainless or anti-corrosion materials lined stainless steel for the parts contacting urea solution.

9.4 In the anti-corrosion design of steam turbine and its auxiliary system, measures shall include, but are not limited to, the following.

a) Measures for prevention of solid particle erosion and water erosion of steam turbine shall be designed. Such measures include, but are not limited to:

— optimizing the design of blade shape;

— selecting wear-resistant and corrosion-resistant coatings such as cobalt-chromium alloys and wear-resistant metal ceramic.

b) Measures for prevention of water and steam corrosion shall be designed. Such measures include, but are not limited to:

— designing condensate polishing treatment device; designing condenser leakage detection device; designing closed cooling water dosing device.

— designing nitrogen filling device for heater lay-up maintenance.

c) Measures for prevention of corrosion of circulating water pump shall be designed. Such measures include, but are not limited to, designing corrosion-resistant passage components for the circulating water pump.

d) Measures for prevention of condenser corrosion shall be designed. Such measures include, but are not limited to:

— preferentially selecting stainless steel or titanium for wet condenser tubes;

— considering the worst water quality conditions when selecting materials for condenser and auxiliary equipment cooler heat exchange tubes in coastal power plants or the power plants subjected to seasonal seawater intrusion;

— designing rubber lined protective layer, anti-corrosion coating and electrochemical protection for the condenser water chamber shell made of carbon steel plates;

— selecting titanium tube plates, composite titanium tube plates and stainless-steel tube plates under seawater conditions;

— designing rubber ball cleaning device;

— considering prevention of flow accelerated corrosion in the design of air-cooling condenser heat exchange tubes;

— selecting non-aluminium materials for heat exchange tubes of indirect air-cooling systems and direct air-cooling systems.

e) Measures for prevention of corrosion of the circulating cooling water system shall be designed. Such measures include, but are not limited to:

— selecting organic anti-corrosion coating lined carbon steel or stainless-steel pipes;

— designing circulating water acid and scale & corrosion inhibitor adding devices;

— designing circulating water quality monitoring device; designing cathodic protection device.

f) Measures for prevention of corrosion of the heat supply network heater system shall be designed. Such measures include, but are not limited to:

— designing heat supply network circulating water dosing and monitoring device;

— selecting stainless steel for heat supply network heater tubes;

— selecting stainless steel tube materials for heat supply network expansion joints;

— selecting anti-corrosion insulating layer cladded carbon steel for heat supply network circulating water pipes.

9.5 In the anti-corrosion design of electrical equipment, measures shall include, but are not limited to, the following.

a) Measures shall be designed to prevent corrosion of generator cooling medium, including, but not limited to, the following:

— the hollow conductor of generator shall be made of stainless steel;

— the water quality of cooling water in generator shall be adjusted by alkaline ion exchange device and alkali addition;

— monitoring instrument of internal cooling water quality shall be designed;

— hydrogen dryer and hydrogen purity and humidity monitoring instrument shall be designed.

b) Measures shall be designed to prevent shaft current corrosion, including, but not limited to, the following:

— monitoring devices for shaft voltage and shaft current shall be designed;

— grounding device for rotating shaft shall be designed.

c) Measures shall be designed to prevent corrosion of transmission towers and conductors, including, but not limited to, the following:

— galvanized steel, steel-cored aluminium alloy stranded wire, copper, and other materials resistant to atmospheric corrosion shall be used.

d) Measures shall be designed to prevent corrosion of grounding devices, including, but not limited to, the following:

— galvanized steel, copper, flexible graphite and stainless-steel composite materials shall be selected;

— during design, dissimilar metal connection shall be avoided, or anti-corrosion coating shall be applied to the connection parts to prevent galvanic corrosion;

— cathodic protection devices should be designed.

9.6 In the anti-corrosion design of water and wastewater treatment system, measures shall include, but are not limited to, the following.

a) Carbon steel lined with organic anti-corrosive coating or stainless-steel pipe or container shall be used. The trench or pool body shall be lined with organic anti-corrosive coatings such as glass fibre reinforced plastic. Instruments for monitoring water corrosivity shall be designed.

b) Anti-corrosion measures shall be taken for the floor, wainscot, wall ceiling, channel, ventilation facilities, steel platform escalator, external surface of equipment and pipeline in acid storage and metering room.

c) The floor, wainscot and channel of alkali storage and metering room shall be protected against corrosion.

9.7 In the anti-corrosion design of civil engineering facilities, measures shall include, but are not limited to, the following.

a) Measures shall be designed to prevent chimney corrosion, including, but not limited to, the following:

   — the chimney cylinder shall be designed with titanium steel composite board, glass fibre reinforced plastic and other materials resistant to acid smoke corrosion;

   — the inner surface of chimney shall be lined with corrosion-resistant coatings such as glass flake, glass brick, titanium, or composite organic coating.

b) Measures shall be designed to prevent corrosion of steel structures, including, but not limited to, the following:

   — galvanized steel and other materials resistant to atmospheric corrosion shall be used;

   — the surface shall be sprayed with zinc or painted with organic paint and corrosion-resistant coating.

c) Measures shall be designed to prevent corrosion of underground facilities, including, but not limited to, the following:

   — galvanized steel and other materials resistant to soil corrosion shall be used, or the surface of carbon steel shall be painted with corrosion-resistant coatings such as zinc, organic coating and organic isolation layer;

   — cathodic protection devices shall be used.

9.8 In the renovation design of corrosion control engineering in fossil fuel power plants in service, the targeted improvement and renovation design of corrosion control shall be carried out according to the hidden dangers of corrosion during operation and with reference to 9.2.

9.9 Environmental plans for scrapping and disposal of anti-corrosion engineering in fossil fuel power plants shall be put forward.

9.10 The applicability of the design shall be evaluated in accordance with the optimum benefits of safe, economical and long-cycle operation and environmental protection. The design shall be improved constantly.

9.11 Design documents and changes shall be reviewed and evaluated by established procedures.

10 Research and development

10.1 During the implementation of the whole life cycle, all elements affecting the corrosion control engineering in fossil fuel power plants shall be continuously studied, improved and developed to optimize safety, cost-effectiveness, long-term operation and environmental protection.

10.2 Research and development include, but are not limited to, the following.

a) Research and development of technologies to slow down the corrosivity of corrosion sources: The burner and combustion adjustment technology shall be researched and developed to control the wall temperature of heating surface. The technology of blending coal and burning shall be researched and developed to reduce fuel corrosivity. Water quality adjustment and optimization technology by adding chemicals to water and steam shall be researched and developed to reduce corrosivity.

b) Research and development of technologies to improve the corrosion resistance of materials: New corrosion-resistant materials shall be researched and developed. Grain refinement technology of superalloy shall be researched and developed. Surface sand blasting/shot blasting technology shall be researched and developed. Surface corrosion resistant coating technology shall be researched and developed.

c) Research and development of corrosion process inhibition technology: High-temperature-resistant and wear-resistant cermet protective coating shall be researched and developed. Cathodic protection technology of buried pipeline in coastal power plant shall be researched and developed. The control technology of wall atmosphere improvement by wall wind shall be researched and developed.

10.3 The whole research and development process of corrosion control shall be carried out according to certain procedures and the principles of scientificity, technology and economy shall be maintained.

11 Manufacturing

11.1 The optimal manufacturing process of corrosion control engineering in fossil fuel power plants shall be selected to achieve the goals of safe, economical and long-life cycle operation and environmental protection.

11.2 The optimal manufacturing process shall be based on the corresponding standards.

11.3 Manufacturers shall have corresponding achievements and supporting cases of similar fossil fuel power plants as references.

11.4 The manufacturer shall formulate the corresponding quality, safety and environmental protection management guarantee system and implement them effectively.

11.5 Elements related to product manufacturing process and affecting anti-corrosion performance shall be controlled, including personnel, machinery, materials, process and environment.

12 Storage and transportation

12.1 Storage and transportation measures for equipment or materials related to corrosion control engineering in fossil fuel power plants shall be formulated according to corresponding standards and specifications to avoid corrosion damage, especially when shipped by sea. The stainless steel, copper alloy equipment and pipes or tubes shall be protected as a priority from contact with seawater.

12.2 Anti-corrosion measures shall be taken during storage and transportation of equipment or materials that are prone to corrosion.

12.3 The storage and transportation procedures of equipment or materials related to corrosion control engineering in fossil fuel power plants shall be identified.

13 Construction and installation

13.1 Safety measures shall be formulated for the construction and installation of corrosion control engineering in fossil fuel power plants to ensure the safety of personnel, equipment and environment.

13.2 The construction and installation of the corrosion control engineering in fossil fuel power plants shall follow the installation procedures based on the design documents and relevant standards.

13.3 For equipment and pipe fittings with anti-corrosion coating, the safety and convenience of anti-corrosion construction shall be considered, and attention shall be paid to completing all welding work before anti-corrosion.

13.4 Special installation equipment and specific protection facilities shall be specified for corrosion control engineering materials, equipment and components of fossil fuel power plants with special needs.

13.5 The construction and installation contractors shall be selected based on corresponding achievements and supporting cases.

13.6 The construction and installation site shall be supervised.

14 Commissioning

14.1 Projects and devices related to corrosion control in fossil fuel power plants that need commissioning shall be debugged according to corresponding standards, design documents or operation specifications. Such projects and devices include:

— boiler water pressure test;

— chemical cleaning works;

— steam purging works;

— cathodic protection works;

— condensate polishing device;

— steam-water quality monitoring and dosing device;

— condenser leakage detection device.

14.2 The commissioning entities shall be selected with reference to corresponding achievements and supporting cases.

14.3 Preparation before commissioning shall include:

a) making commissioning plans or measures and other documents;

b) training commissioning personnel;

c) checking the necessary commissioning tools and instruments, which shall be within the qualified calibration period;

d) evaluating possible risks according to ISO 23222 and formulating corresponding control and emergency measures.

14.4 Control requirements of commissioning process shall include the following.

a) The commissioning process shall be strictly implemented in accordance with the commissioning measures, relevant standards and specifications, design documents and equipment specifications.

b) Commissioning measures shall include quality, occupational health and safety and environmental management, and shall be strictly implemented during commissioning.

c) Safety risks such as electric shock and mechanical injury shall be avoided during commissioning.

d) During commissioning, the parameters of the trial operation shall be recorded and kept.

e) Acceptance documents of commissioning results shall be made.

14.5 Commissioning steps shall include the following.

a) Before commissioning, the corrosion control engineering or devices shall be inspected in detail and recorded.

b) During commissioning, the operating parameters of the equipment shall be gradually adjusted according to the requirements of design or standard specifications.

c) After commissioning, parameter measurement or data recording shall be carried out according to the acceptance conditions after the equipment runs stably, and the acceptance documents shall be completed according to the requirements of design or standard specifications.

14.6 If the commissioning results do not meet the design requirements, the works shall be reformed and debugged again to make it meet the design requirements.

14.7 During commissioning, documents such as commissioning measures, commissioning records, acceptance and commissioning reports shall be made.

15 Acceptance

15.1 Before being put into operation, corrosion control engineering in fossil fuel power plants shall be subjected to acceptance in accordance with the requirements of relevant standards and design documents. The engineering that fails to pass the acceptance shall not be delivered for use.

15.2 The following materials shall be submitted for the completion acceptance of the corrosion control engineering in fossil fuel power plants:

a) documents concerning corrosion sources and materials selection;

b) documents concerning corrosion control technologies, design documents and changes thereof, and documents for related research and development projects;

c) corrosion control documents during manufacturing;

d) corrosion control documents during storage and transport;

e) corrosion control documents during construction and installation of fossil fuel power plants;

f) supervision control documents for corrosion control construction;

g) control documents for the commissioning process of corrosion control engineering system;

h) treatment record of non-conforming corrosion control items;

i) completion acceptance documents for corrosion control engineering and others.

16 Operation

16.1 Systematic corrosion control shall be implemented at the operation stage of fossil fuel power plants to ensure safe, economical, green and long-cycle operation.

16.2 The following aspects shall be considered for corrosion control of operating fossil fuel power plants.

a) Targeted corrosion control shall be implemented according to the conditions of the corrosion sources of various systems.

b) Operation and maintenance personnel of fossil fuel power plants shall master basic knowledge of corrosion control of systems and participate in regular training and assessment.

c) A management manual for operation and corrosion control of fossil fuel power plant equipment shall be prepared.

d) A management database for operation and corrosion control engineering systems of fossil fuel power plant equipment shall be established.

16.3 Corrosion control of boiler and its auxiliary system shall include the following.

a) The concentration of corrosive medium on the fire side of high-sulfur coal shall be monitored, blended coal combustion shall be carried out to reduce the sulfur content in fuel, and combustion adjustment shall be coordinated to avoid the formation of adherent reducing atmosphere.

b) The tube wall temperature of heating surface shall be monitored, and combustion adjustment shall be made to prevent overheating of heating surface from aggravating high temperature corrosion and oxidation.

c) The water wall of boiler furnace and high temperature convection heating surface shall be adjusted for soot blowing, so as to avoid slagging and molten salt corrosion. If necessary, coal with high melting point and low alkali metal shall be mixed to reduce pollution and slagging of heating surface.

d) The denitration and ammonia injection shall be conducted to reduce ammonia slip, and the air preheater shall be soot-blown and cleaned in time to avoid low temperature corrosion caused by ammonium bisulfate sticking ash at the low temperature end of the air preheater.

e) The quality of boiler feed water, boiler water and steam shall be detected, the dosing shall be adjusted, the operation mode of condensate polishing treatment shall be optimized, and the water and steam index shall be controlled within the standard requirements, including pH value, conductivity, hydrogen conductivity and dissolved oxygen. If water quality deteriorates, tertiary treatment measures shall be implemented.

f) The indexes such as slurry of desulfurization system and desulfurization wastewater shall be reasonably adjusted and controlled within the standard requirements, including pH value and chloride ion concentration.

16.4 Corrosion control of steam turbine and its auxiliary system shall include the following.

a) Water quality indexes shall be monitored, such as condenser outlet water, polishing treatment outlet water, deaerator inlet water and high-pressure heater drain water, and polishing treatment operation mode shall be optimized to reduce corrosion of impurity ions in water to water and steam system.

b) The deterioration of water quality caused by leakage of condenser and heating network shall be monitored. If the condensate water quality is abnormal, tertiary treatment measures shall be implemented.

c) Indicators such as concentration ratio, chloride ion concentration and pH value of circulating water shall be monitored, and acid addition, concentration of bactericide or scale and corrosion inhibitor shall be adjusted to slow down corrosion to circulating water system.

d) The conductivity and pH value of water in heating network shall be monitored, and the dosage of corrosion inhibitor shall be adjusted to slow down the corrosion to heating network system.

e) The steam temperature and pressure shall be monitored and controlled within a reasonable range as required by the regulations, so as to prevent water erosion of the last stage blades of the low-pressure cylinder caused by carryover.

f) During the start-up and shut-down stages of the unit, the erosion of solid particles of blades by scale particles in the thermal system shall be reduced by means of bypass steam purging.

16.5 Corrosion control of electrical equipment shall include the following.

a) The hydrogen purity and humidity of the generator shall be monitored and controlled.

b) The conductivity, pH value and copper ion concentration of generator cooling water shall be monitored and controlled.

c) For grounding devices designed with impressed current cathodic protection, the protection potential and current shall be monitored and adjusted.

d) The generator shaft voltage and shaft current should be monitored. The cause shall be found in time when it exceeds the alarm value and elimination shall be conducted.

16.6 During the operation of water and wastewater treatment system, the concentration of acid or alkali, pH value of acid-base wastewater and desulfurization wastewater shall be monitored and controlled.

16.7 During the operation of civil engineering facilities, such indexes as cathodic protection potential and current of facilities like underground pipelines or containers designed with cathodic protection shall be monitored and controlled on-line or regularly.

17 Maintenance

17.1 Daily, regular and comprehensive maintenance cycles and plans shall be formulated according to the conditions of systems and corrosion sources of fossil fuel power plants. Corresponding maintenance procedures shall be prepared by referring to the equipment manufacturer's maintenance manual. In addition, attention shall be paid to the following aspects.

a) Routine maintenance includes patrol, inspection and cleaning.

b) Regular maintenance includes performance status inspection and planned repair of the corrosion control engineering in fossil fuel power plants.

c) Maintenance procedure documents shall be consistent with material or equipment maintenance manuals, technical specifications, etc.

d) Maintenance personnel shall have relevant skills and experience in corrosion control.

e) Before maintenance, the possible risks shall be fully evaluated, corresponding emergency measures shall be formulated, and relevant inspection and maintenance records shall be made.

17.2 The technical team shall work out the lay-up maintenance procedures for thermal equipment in fossil fuel power plants, and the maintenance team shall carry out maintenance as following according to the requirements of the procedures.

a) The thermal equipment of the units shall be protected against rust based on the parameters and types of units, feedwater and boiler water treatment method, shutdown duration and its nature, site conditions, operability and economy.

b) The rust protection methods used shall not affect the unit start-up, water and steam quality during normal operation of the units, and protective film formed in the thermal system during normal operation of the units.

c) The maintenance methods of fossil fuel power plants shall be compatible with the feedwater treatment process used in the operation of fossil fuel power plants and shall not affect the normal operation of condensate polishing equipment.

d) The maintenance and protection methods adopted shall not affect the overhaul work and the safety of operations and maintenance personnel of the thermal equipment.

17.3 Specific maintenance plans without causing new risks of corrosion or damage to the main works shall be formulated according to the inspection results.

17.4 The corrosion problems found during maintenance shall be tracked and dealt with in time to ensure the effectiveness of the corrosion control engineering in fossil fuel power plants.

18 Overhaul

18.1 Before overhaul of fossil fuel power plants, the technical management team shall investigate and evaluate the corrosion of systems of fossil fuel power plants, evaluate the risk of unacceptable corrosion defects according to the investigation and evaluation results, and optimize the overhaul plan and overhaul scheme with risk control measures according to relevant standards, and put forward relevant overhaul items and requirements. The maintenance team shall carry out maintenance according to the maintenance plan and scheme.

18.2 Overhaul of corrosion control engineering that have an impact on important equipment such as boiler, steam turbine, generator and transformer shall be undertaken by entities with corresponding qualifications.

18.3 During overhaul of fossil fuel power plants, the heating surface of boiler such as economizer, water wall, superheater and reheater shall be inspected for pipe cutting according to the needs of overhaul work. If it is found that the scaling amount or the thickness of oxide layer reaches the limit specified by the standard, chemical cleaning shall be carried out. If oxide scale of superheater and reheater falls off, pipe cutting and cleaning shall be conducted. For important equipment such as steam drum, steam turbine, condenser, deaerator, high- and low-pressure heater and buried pipe network, inspection shall be conducted. Their corrosion damage degree shall be obtained and repair shall be made. Maintenance work related to corrosion control for important equipment shall be conducted, including, but not limited to, spraying and maintenance of boiler heating surface, maintenance of steam turbine blade, replacement of thinned pipe due to flow accelerated corrosion, anti-corrosion repair of desulfurization and denitration equipment, overhaul of anti-corrosion coating of steel structure, replacement of cathodic protection sacrificial anode, maintenance of anti-corrosion coating of underground pipe network.

18.4 The overhaul of corrosion control engineering in fossil fuel power plants shall not affect the safety function of system equipment in fossil fuel power plants and shall comply with relevant codes, standards and design regulations.

18.5 The overhaul quality of the corrosion control engineering in fossil fuel power plants shall not be lower than the standard required during original construction and shall be coordinated and optimized with other elements. In addition, it shall achieve the optimum benefits of safe, economical and long-cycle operation and environmental protection.

18.6 Emergency support shall be provided during the overhaul of corrosion control engineering in fossil fuel power plants. Emergency plans for the overhaul shall be prepared in accordance with relevant standards. Documents shall be formed. Emergency measures shall be formulated and emergency resources shall be prepared.

18.7 After overhaul of fossil fuel power plants, a comprehensive analysis of corrosion, scaling and salt deposit of thermal equipment shall be conducted and rectification measures and improvement suggestions in view of existing problems shall be provided.

19 Scrapping and disposal

19.1 Scrapping shall be carried out according to the green plan formulated in the design stage and a detailed scrapping and disposal plan shall be formulated and implemented.

19.2 For discarded equipment that can be recycled, the corresponding entities shall be selected appropriately to carry out recycling treatment.

19.3 The owner shall bear social responsibility for the equipment to be scrapped and disposed of and shall prevent the scrapped equipment from polluting the environment.

20 Documents and records

20.1 Supporting documents and traceable records shall be provided for all elements, equipment and systems involved in the whole life cycle of corrosion control engineering in fossil fuel power plants. Reference can be made to ISO 9001 regarding requirements for the management of documents and records.

20.2 The documents and records for corrosion control engineering of the fossil fuel power plants shall be reviewed on a regular basis to obtain the latest corrosion control information.

21 Resource management

21.1 Resource management plans for manpower, equipment, materials and technologies, methods, environment, communication and changes required by the corrosion control engineering in fossil fuel power plants, shall be formulated and adapted to the conditions of each element in the life cycle of the corrosion control engineering in fossil fuel power plants.

21.2 All elements, links and nodes of the corrosion control engineering in fossil fuel power plants shall meet the relevant requirements for personnel, process tools, testing equipment, workplaces and supervision. Necessary instruments, such as ion chromatography, Inductively Coupled Plasma (ICP), shall be provided in the corrosion monitoring.

21.3 The responsibilities and authorities of corrosion control related personnel shall be clearly defined and communicated in fossil fuel power plants, to improve the understanding of corrosion control and ensure the effectiveness of work assignment. The minimum training and ability requirements and qualifications of all roles shall be determined. For example, fuel, water and steam quality and corrosion product analysts, corrosion control engineers, chemical cleaning engineers in fossil fuel power plants shall receive professional training, examinations and obtain corresponding qualifications.

22 Comprehensive assessment

22.1 All elements in the whole life cycle of corrosion control engineering in fossil fuel power plants shall be comprehensively evaluated regularly according to relevant standards.

22.2 The comprehensive assessment results shall be used as the basis for the management, maintenance or scrapping of corrosion control engineering in fossil fuel power plants.

Annex A
(informative)

Example of a fossil fuel power plant

A diagram of a fossil fuel power plant is shown in Figure A.1.

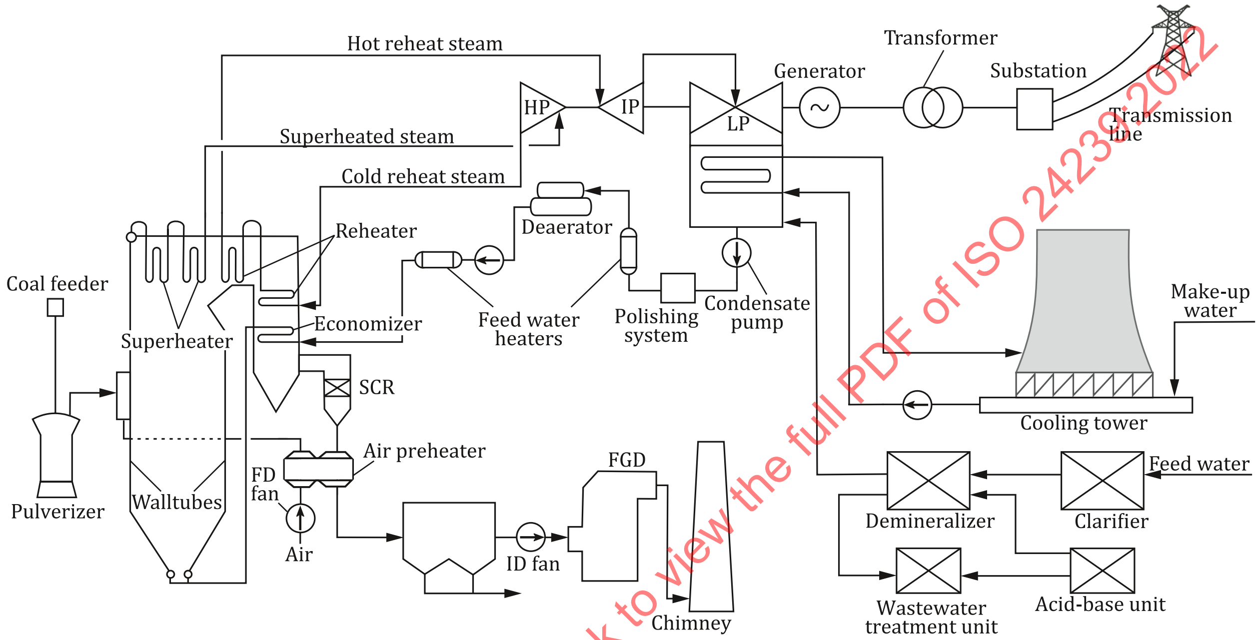

Figure A.1 — Example of a fossil fuel power plant

Annex B
(informative)

Example of a continuous improvement cycle for corrosion control engineering in a fossil fuel power plant

An example of a continuous improvement cycle for corrosion control engineering in a fossil fuel power plant is illustrated in Figure B.1.

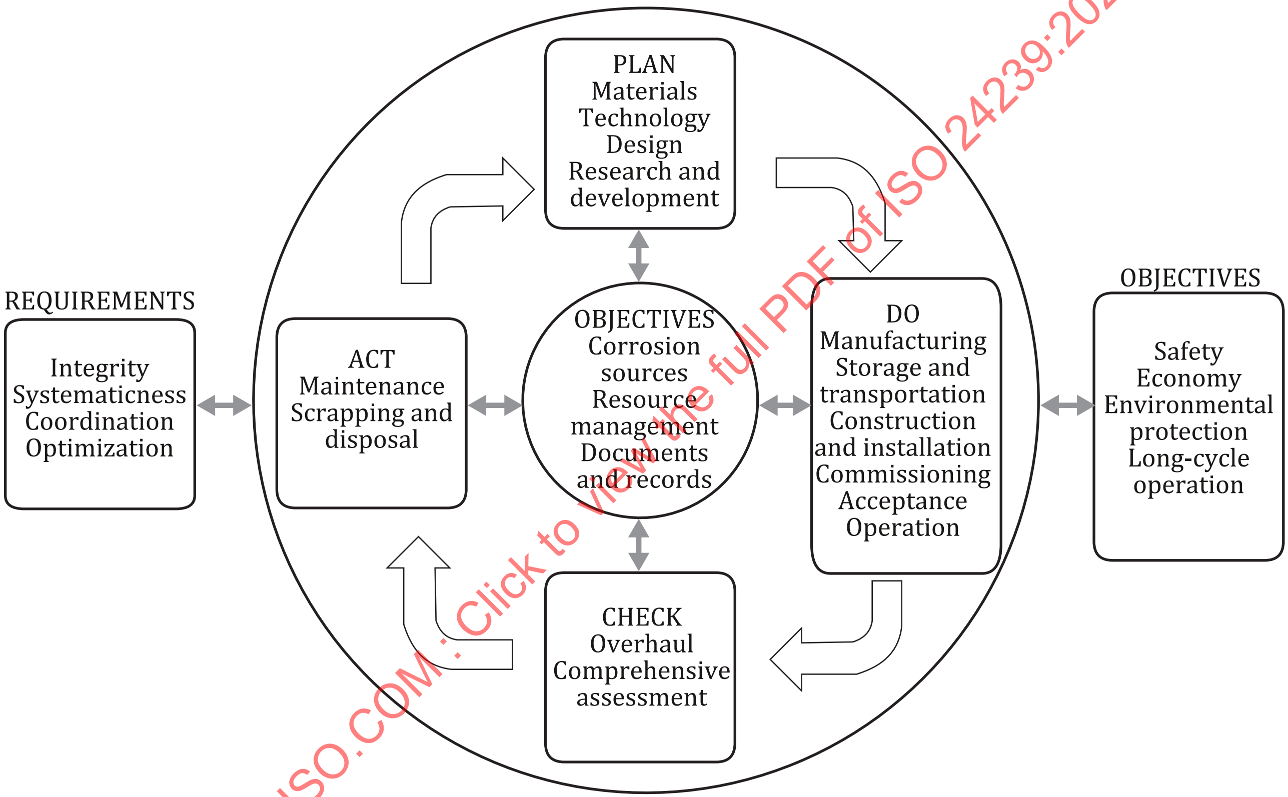

Figure B.1 — Example of a continuous improvement cycle for corrosion control engineering in a fossil fuel power plant

Annex C
(informative)

Typical corrosion control technologies in a fossil fuel power plant

Typical corrosion control technologies used in a fossil fuel power plant are described in Table C.1.

Table C.1 — Typical corrosion control technologies in a fossil fuel power plant

System	Component	Corrosion form	Typical corrosion control technologies and key indicators
Boiler and its aux-iliary system	Water wall	High tempera-ture corrosion on the fire side	1. The sulfur content of the coal as fired may be controlled by blending of different coals, whose total sulfur content on a dry basis should be less than or equal to a mass fraction of 1,5 % generally. 2. The design and layout of boiler burners should be considered to prevent slagging of water wall and erosion, by using small tangential circle diameter and some secondary off-centre air for the tangential circle boiler or using closing-to-wall air for the opposed boiler. 3. Combustion optimization adjustment should be carried out to reduce the corrosion of flue gas attached to water wall, and the content of H_2S in the flue gas near the wall should be controlled to be less than 200 ppm. 4. It is advisable to adopt thermal spraying to prepare corrosion-resistant metal coating during construction and installation, such as arc spraying 45CT wire. Control the coat thickness to be 250 µm to 350 µm, the porosity to be less than a mass fraction of 3 % and the coating bonding strength to be not less than 40 MPa. After spraying, high temperature hole sealing agent should be used to close the pores in coating. 5. Comprehensively monitor the thickness of the coating and tubes during overhaul.
		Oxygen cor-rosion on the water and steam side, and under deposit corro-sion	1. Strictly control water quality indicators, including the pH value, dissolved oxygen, chloride ion content, electrical conductivity and hydrogen conductivity. Treat boiler water with solid alkali agent or through all-volatile treatment according to the boiler type and pressure. 2. Avoid overtemperature of boiler tubes during unit operation. 3. Deposit on the inside of water wall tubes should be cleaned when exceeding 200 g/m^2 in the once-through boiler or 250 g/m^2 in drum boiler. Chemical cleaning method may be adopted. The cleaning agent is mainly determined according to the composition of the water wall scale. For once-through boilers and drum boilers with Fe_3O_4 and Fe_2O_3 in the scale crust of water wall, organic acids, such as glycolic acid-formic acid, citric acid and ethylenediaminetetraacetic acid (EDTA), should be selected. For drum boilers with complex water wall scale crust composition and no hydrogen damage, hydrochloric acid should be preferred. During the chemical cleaning process, an appropriate amount of corrosion inhibitor (the concentration of the corrosion inhibitor is usually determined by tests) and reductant (Fe^{3+} is controlled to be lower than 300 mg/l) should be added to control the corrosion of the tubes. When the chemical cleaning process is finished, the total corrosion amount of the corrosion test piece (made of the same material as the pipeline) hung in the monitor tubes should be controlled to be lower than 80 g/m^2 and the corrosion rate should be lower than 2 g/(m^2·h).

Table C.1 *(continued)*

System	Component	Corrosion form	Typical corrosion control technologies and key indicators
	High temperature convection heating surface	High temperature corrosion on the fire side	1. Low furnace outlet smoke temperature should be selected and the uniform heat load should be adjusted and realized through design and operation. The deviation of furnace outlet smoke temperature should be no more than 50 °C. 2. Properly reduce the flame centre or blend high ash fusion temperature coal to avoid slagging and corrosion of the high temperature convection heating surface. 3. Arrange a soot blower in the high temperature convection heating surface area to remove ash in time. 4. Corrosion-resistant alloy coating should be sprayed during the construction and installation process to prevent high-temperature flue gas corrosion, such as arc spraying 45CT wire, with the coating thickness to be 250 µm to 350 µm, the porosity to be less than a mass fraction of 3 % and the coating bonding strength to be not less than 40 MPa. Another measure is spraying NiCr-Cr3C2 powder with High-Velocity Oxygen Fuel (HVOF) spraying at severely corroded parts, with the coating thickness to be 250 µm to 350 µm, the porosity to be less than a mass fraction of 2 % and the coating bonding strength to be not less than 60 MPa. After spraying, high temperature sealing agent should be used to seal the pores in coating. 5. For overtemperature conditions, plasma sprayed ceramic coatings with low thermal conductivity can be employed to reduce overtemperature of tubes, and the suggested coating thickness is 250 µm to 350 µm. 6. The protective tiles should be provided for protection when needed.