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Fossil Fuel Power Plant Steam Temperature Control System – Once-Through Type

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Fossil Fuel Power Plant Steam Temperature Control System —
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1 Purpose

The purpose of this standard is to establish the minimum requirements for the functional design specification of steam temperature control systems for once-through type fossil fuel power plant boilers.

2 Scope

The scope of this standard addresses the major steam temperature control subsystems in once-through boilers with steaming capacities of 200,000 lb/hr (25 kg/s) or greater. These subsystems include, but are not limited to, superheat temperature control and reheat temperature control. Specifically excluded from consideration are turbine bypass control, motor control logic, combustion control, sootblower control, and controls associated with fluidized bed- and stoker-fired furnace combustion units.

3 Definitions

The following definitions are provided to clarify their use in this standard and may not be relevant to the user of the words in other texts. For other definitions, please refer to ANSI/ISA-S51.1-1979 (R1993) Process Instrumentation Terminology.

3.1 attemperator:

mechanical device used for maintaining and controlling the temperature of superheated steam.

3.2 attemperator (direct contact type):

mechanical device in which the steam and the cooling medium (water) are mixed.

3.3 boiler:

the entire vessel in which steam or other vapor is generated for use external to the vessel. This includes the furnace, consisting of waterwall tubes; the firebox area, including burners and dampers; the convection area, consisting of any superheater, reheater, economizer sections or any combination thereof, as well as drums and headers.

3.4 cascade control system:

a control system in which the output of one controller (the outer loop) is the setpoint for another controller (the inner loop). The outer loop is normally a slow responding process as compared to the inner loop.

3.5 control:

maintaining a desired setpoint of steam temperature during operation.

3.6 control loop:

a combination of field devices and control functions arranged so that a control variable is compared to a setpoint and returns to the process in the form of a manipulated variable.

3.7 controller:

a manual or automatic device or system of devices used to regulate the boiler steam temperatures within defined parameters as set forth by a turbine/boiler manufacturer.

3.8 desuperheater:

see 3.2 attemperator (direct contact type).

3.9 deviation:

the difference between the loop setpoint and the process variable.

3.10 error:

see 3.9 deviation.

3.11 feedback:

a signal produced by a measuring device that is proportional to the magnitude of a controlled variable or position of a control element.

3.12 final control element:

component of a control system (such as a control valve) that directly regulates the flow of energy or material to or from the process.

3.13 fuel trip:

the automatic shutoff of a specific fuel as the result of an interlock or operator action.

3.14 gas pass:

an arrangement in which the convection banks of a boiler are separated by gas-tight baffles into two or more parallel gas paths isolating portions of the superheater and reheater surfaces. The proportion of total gas flow through each gas pass may be varied by regulating dampers.

3.15 gas recirculation:

a method by which gas from the boiler, economizer, or air heater outlet is reintroduced to the furnace by means of a fan(s), duct(s), or both.

3.16 integral control action:

an action in which the controller's output is proportional to the time integral of the error input. When used in combination with proportional action, it previously was called reset action.

3.17 integral windup:

the saturation of the integral controller output in the presence of a continuous error, which may cause unacceptable response in returning the process to its setpoint within acceptable limits of time and overshoot.

3.18 interlock:

a device or group of devices (hardware or software) arranged to sense a limit or off-limit condition, or improper sequence of events, and to shut down the offending or related piece of equipment, or to prevent proceeding in an improper sequence in order to avoid an undesirable condition.

3.19 linearity:

the nearness with which the plot of a signal or other variable plotted against a prescribed linear scale approximates a straight line.

3.20 master fuel trip:

(see 3.13 fuel trip.) An event resulting in the rapid shutoff of all fuel.

3.21 primary air:

combustion air that enters the fuel-burning zone and directly supports initial combustion. On pulverized coal-fired units, the primary air is used to transport the coal from the pulverizers to the burners.

3.22 primary (initial, platen) superheater:

a heating surface receiving steam from the furnace. (See figure C.1a, C.1b, C.1c, or C.1d.)

3.23 reheater:

a heating surface receiving steam returning to the boiler from the high-pressure turbine exit.

3.24 secondary air:

combustion air introduced on the edge of the burning zone to supplement the primary air for support of the combustion process.

3.25 secondary (radiant or final) superheater:

a heating surface receiving steam from primary superheater. (See figure C.1a, C.1b, C.1c or C.1d.)

3.26 setpoint:

the desired operating value of the process variable.

3.27 superheater:

a bank of heating surface tubes contained within a boiler, and to which heat is applied to elevate the steam temperature to a desired value above saturation.

3.28 trip:

the automatic removal from operation of specific equipment or the automatic discontinuance of a process action or condition as the result of an interlock or operator action.

3.29 transient correction:

a control action specifically applied to minimize any process error resulting from a temporary process change; e.g., temperature control action applied to counter the effects of over- or under-firing during load changes.

4 Minimum design requirements for a superheat steam temperature control system

The control system shall meet all operational requirements and properly interface with the process. To accomplish these objectives, the following minimum system design requirements are defined below:

- a) Process measurement requirements
- b) Control and logic requirements
- c) Final control element requirements
- d) System reliability and availability
- e) Alarm requirements
- f) Operator interface

4.1 Process measurement requirements

4.1.1 Instrument installations for superheat steam temperature control

4.1.1.1 Instrument installation

Instruments should be installed as close as is practical to the source of the measurement, with consideration being given to excessive vibration, ambient temperature, and accessibility for periodic maintenance. Temperature measurement should be located at least 20 pipe diameters downstream of any attemperator.

Recommendations for the location of instrument and control equipment connections can be found in the joint publication by the Scientific Apparatus Makers Association (SAMA) and the American Boiler Manufacturers Association (ABMA), "Recommendations for Location of Instrument and Control Connections for the Operation and Control of Watertube Boilers."

4.1.1.2 Design of thermocouples and temperature sensors

Design of thermocouples and temperature sensors shall meet the requirements of ASME Power Test Code PTC19.3 "Temperature Measurements".

Design of the attachment of the thermowell to the pipe shall meet the requirements of Boiler ASME BPVC Section I "Power Boilers" for Boilers or per ASME B31.1 "Power Piping" for Boilers as appropriate.

Thermowell installations shall consider location, mounting, and velocity criteria in making a proper interface with the process.

4.1.1.3 Isolation valves and impulse lines

Separate isolation valves and impulse lines shall be provided for head-type instrumentation.

4.1.2 Process measurements for superheat steam temperature control

Process measurements for superheat temperature control are listed below. For location of these measurements see figures C.1a, C.1b, C.1c, and C.1d.

4.1.2.1 Secondary (final) superheater outlet steam temperature measurement

A temperature measurement, taken at the outlet of the secondary (final) superheater, is required for superheat steam temperature control strategies.

4.1.2.2 Secondary superheater inlet temperature measurement

A temperature measurement, taken at the attemperator outlet(s) for single-stage or multiple-stage attemperation and followed by a superheater section, is required as the secondary variable in a three-element control strategy.

4.1.2.3 Primary (initial, platen) inlet temperature measurement

A temperature measurement, taken at the primary superheater inlet (or outlet of the first stage attemperator of multiple-stage attemperation), is required as the secondary variable in a three-element control strategy.

4.1.2.4 Primary (initial, platen) outlet temperature measurement

A temperature measurement, taken at the outlet of the primary superheater section before the stage attemperator, is required in a single or multiple-stage attemperator control strategy.

4.1.2.5 Primary (initial, platen) inlet pressure measurement

A pressure measurement is required in a multiple-stage attemperator control strategy to prevent saturation following first-stage spray attemperation. Typically, this pressure is measured at the inlet of the primary superheater.

4.1.2.6 Attemperator spray water-flow measurement

An attemperator spray water mass flow signal provides an alternative to the use of the attemperator outlet steam temperature as the secondary variable in a three-element control strategy.

4.1.2.7 Waterwall (convention pass) outlet temperature measurement

A temperature measurement, taken at the outlet of the furnace walls (convention pass) section and followed by a superheater section, is required in a multiple-stage attemperator control strategy.

4.2 Control and logic requirements

For once-through type fossil fuel power plant boilers, the transition between water and steam occurs without boiling. Water becomes steam as it flows through the waterwall tubing. With continuous heating, fluid temperatures increase throughout the process. For subcritical boiler, the phase change point between water and steam can move further down the piping within the waterwalls as load (intermediate steam pressure) increases. For supercritical boilers (critical point pressure [3206.2 psia]) there is no change in phase between water and steam.

The ratio of firing rate to feedwater flow determines the final value for the superheat steam leaving the boiler. To improve the transient temperature response, boiler design may include single or multiple stages of spray attemperation.

Since all feedwater entering the waterwalls becomes steam (once-through), the throttle pressure is directly related to feedwater flow. Low pressure requires an increase in feedwater flow; high pressure requires a reduction in feedwater flow. Since all the feedwater entering the boiler must be heated into superheated steam, the firing rate controls (fuel and air) are modulated to provide the required heating. The ratio of feedwater to firing rate determines the final value for the main superheat steam leaving the boiler.

Since superheater spray flow is extracted from feedwater flow, a change of superheat spray flow will not result in a permanent change in final steam temperature leaving the boiler since it does not change the ratio of firing rate to feedwater flow. Eventually, final steam temperature will return to its previous value, as the intermediate steam temperature will rise due to less feedwater flow.

This standard addresses the following means or mechanisms for the control of final steam temperature:

- a) Firing rate–feedwater flow ratio control
- b) Single stage attemperation control
- c) Multiple-stage attemperation control

4.2.1 Firing rate–feedwater flow ratio control

All once-through boilers include a firing rate–feedwater ratio control strategy as a means to control steam temperatures. For boilers without spray attemperation, the firing rate–feedwater flow ratio regulates the final superheater outlet temperature. For boilers with single or multiple spray attemperation, the firing rate–feedwater flow ratio regulates the specified superheater outlet temperature or attemperator differential temperature in accordance with the boiler manufacturer's recommendation.

Referring to figure C.2, two-element firing rate–feedwater flow control is the minimum control strategy to regulate the steam temperature. Final steam temperature is measured and compared to a setpoint with the results used to regulate the firing rate–feedwater flow ratio. As a minimum, the temperature setpoint is derived from a load index and modified by an operator bias. In accordance with the boiler manufacturer's recommendation, the feedback controller is constrained by a waterwall outlet or primary superheater outlet temperature controller to protect against high temperature in the water walls or primary superheater outlet tubes respectively.

A feed-forward signal(s) and transient correction signal(s) is added to the final steam temperature controller. As a minimum, the feed-forward signal is derived from a load index(es). This feed-forward signal should recognize all major influences on steam temperature, including adjustments to heat distribution within the boiler. As a minimum transient correction, waterwall outlet temperature should be an anticipating signal. This signal compensates for upsets due to sudden changes in slag formation, feedwater temperature, mill starts, etc.

For once-through boilers with single or multiple-stage attemperators, the firing rate-feedwater flow ratio control strategy shall return final steam temperature to setpoint and spray attemperation to its nominal value. As a minimum, the average temperature difference across the attemperator is compared to a setpoint. Any deviation from a differential temperature setpoint is included in the control strategy to return the spray attemperator to its nominal value.

The firing rate-feedwater flow ratio control loop provides a signal both to the feedwater control sub-loop and to the fuel control sub-loop. To raise steam temperature, the firing rate-feedwater flow ratio must either increase firing rate or decrease feedwater flow or both (see B2.2 Steam temperature control by ratio adjustment). To lower steam temperature, the firing rate-feedwater flow ratio must either decrease firing rate or increase feedwater flow or both.

The firing rate-feedwater flow ratio control shall be interlocked to manual until the subloops being modified (i.e., feedwater flow and/or firing rate) are in automatic mode.

4.2.2 Single-stage attemperation

Single-stage attemperation refers to the boiler design that provides a single location for the introduction of spray water for the regulation of steam temperature. This application is typical of boilers with only a single superheat section or multiple superheater sections in series commonly called the primary and secondary superheaters. It is normal to have the spray attemperation take place in the headers between two superheater sections or occasionally at the superheater outlet. Note that a single attemperation location does not necessarily refer to a single set of spray equipment.

For once-through boilers, spray attemperator(s) are not used for steady state correction but serve to stabilize steam temperature during transient disturbance. To allow the transient temperature control to operate in both directions (increase/decrease of main steam temperature), the superheat spray valves should be maintained at a normal regulating range.

4.2.2.1 Two-element steam temperature control

Two-element steam temperature control is the minimum control strategy required to regulate the steam temperature leaving the boiler and should be used only in applications with slow to moderate load changes or with steady spray water pressure supply and fixed steam pressure applications.

Referring to figure C.3 final steam temperature is measured and compared to a setpoint with the results used to regulate the spray valve(s). A feed-forward signal and a transient correction signal is added to the final steam temperature controller. As a minimum, the feed-forward signal is derived from a load index(es). This feed-forward signal should recognize all major influences on steam temperature, including adjustments to heat distribution within the boiler.

4.2.2.2 Cascade with feedforward steam temperature control

Cascade with feedforward steam temperature control strategy should be used in applications with rapidly changing loads, with variable steam pressures or with variable spray water pressure supplies.