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Research Paper

One-dimensional simulation for attemperator based on commissioning data of coal-fired steam power plant

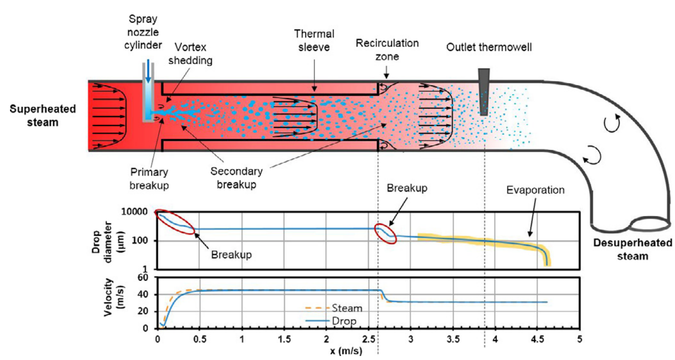
Baekhyun Cho [a,1], Geunwon Choi [a,1], Yumi Uruno [a], Hyunseo Kim [a], Jaewon Chung [a,*], Hyojun Kim [b], Kihyun Lee [b]

[a] Department of Mechanical Engineering, Korea University, Seoul 136-713, South Korea
[b] Corporate R&D Institute, Doosan Heavy Industries and Construction Co. Ltd., Changwon, South Korea

HIGHLIGHTS

- An attemperator is a device to spray water into the superheated steam.
- The evaporation was analyzed using the enthalpy balance from the commissioning data.
- The spray atomization and its concurrent evaporation in an attemperator were physically modeled.
- A simple one-dimensional simulation was conducted to verify the commissioning results.

GRAPHICAL ABSTRACT



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ABSTRACT

An attemperator is a device that is used to spray water into the superheated steam between the primary, platen, and final superheaters and the reheat lines. The goal of the attemperator is to control the temperature of the superheated steam in accordance with desired turbine-inlet temperature during both steady-state and transient operation. Because the thermowell installed at the attemperator outlet is tied back to the feedback control of the spray water, the spray water should evaporate ahead of the thermowell for accurate control of the steam temperature. In this work, the completion of the evaporation ahead of the thermowell was analyzed using the enthalpy balance from the start-up commissioning data of an 800-MW coal-fired steam power plant. In addition, the phenomena of the spray atomization and its concurrent evaporation in an attemperator were physically modeled, and a simple one-dimensional simulation was conducted to verify the analysis of the commissioning data.

1. Introduction

The boiler system in a coal-fired power plant includes various devices to produce superheated steam. Briefly, the steam separated from a drum is superheated through primary, plate-shaped (platen), and final superheaters in series and flows into a high-pressure turbine (Fig. 1). It is well known that the steam temperature should be increased to improve the thermal efficiency of power plants, but this temperature is limited to approximately the creep point of the superheater tubing material. On the contrary, if the temperature of superheated steam is below a setpoint, the thermal efficiency of the power plant decreases, and the mechanical and thermal damages due to the decrease in the steam quality can shorten the lifespan of the turbine blades. In addition, the

* Corresponding author.
E-mail address: jwon@korea.ac.kr (J. Chung).
[1] These authors contributed equally to this work.

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Nomenclature

A	area, m^2
B_H	heat transfer number
BF	blowing factor
c_P	specific heat capacity, kJ kg^{-1} K^{-1}
C_d	drag coefficient
d	droplet diameter, m
D	diameter, m
h	heat transfer coefficient, W m^{-2} K^{-1}
h_{eff}	effective heat transfer coefficient, W m^{-2} K^{-1}
h	enthalpy, kJ kg^{-1}
h_{fg}	latent heat of vaporization, kJ kg^{-1}
I	turbulent intensity
k	thermal conductivity, W m^{-1} K^{-1}
L	length, m
m	mass, kg
$\dot{m}$	mass flow rate, kg s^{-1}
m''_{evap}	evaporative mass flux, kg m^{-2} s^{-1}
n	number of droplets
Nu	Nusselt number
Pr	Prandtl number
P_G	generator load, W
Re	Reynolds number
Re'	turbulent Reynolds number
t	time, s
T	temperature, °C
$T_{s,desuper}$	temperature of completely desuperheated steam, °C
U	relative velocity, m s^{-1}
v'	root-mean square of the turbulent velocity fluctuation, m s^{-1}
V	average velocity, m s^{-1}
We	Weber number
x	distance from the nozzle exit, m

Greek symbols

β	evaporation coefficient
μ	viscosity, kg m^{-1} s^{-1}
ρ	density, kg m^{-3}
σ	surface tension, N m^{-1}

Subscript

0	initial
br	breakup
d	droplet
D	pipe diameter
in	inlet
l	liquid
L	left
N	nozzle
out	outlet
p	pipe
R	right
s	steam
sat	saturation
TS	thermal sleeve
TW	thermowell
v	vapor
w	water

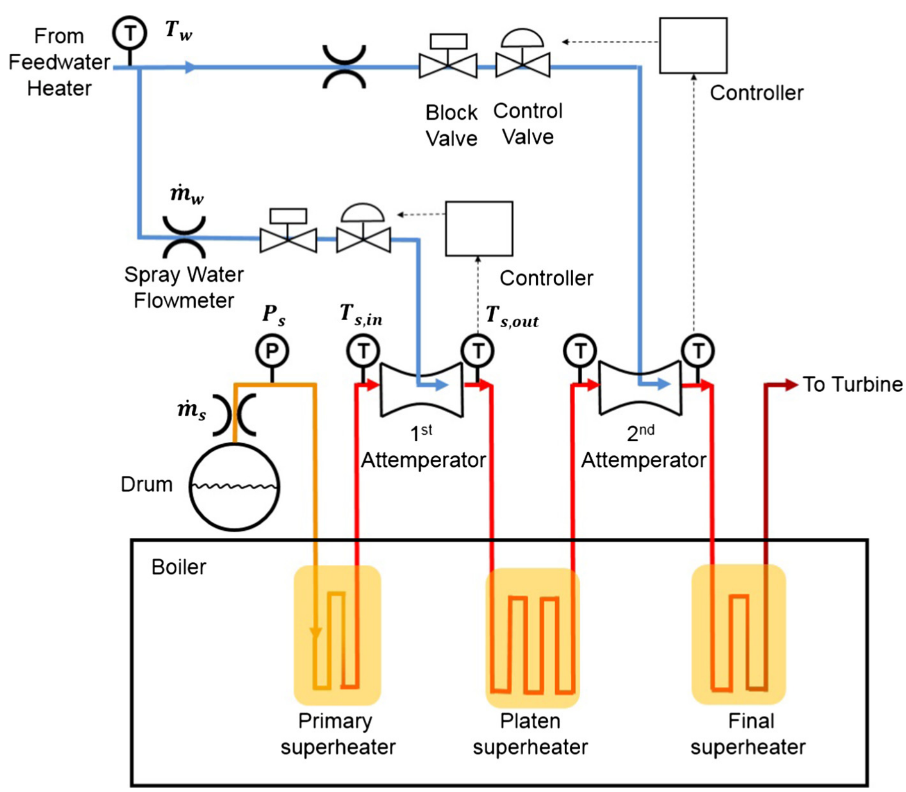

Fig. 1. Typical arrangement of superheaters and attemperators.