Article title: Pressure transient prediction in district cooling network: Surge analysis study for condenser water piping

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Pressure Transient Prediction in District Cooling Network

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ABSTRACT

Cooling tower piping is an open network in the district cooling plant. Pipe supports are designed from the load values of pipe stress analysis. In addition to that, surge study is very much required to find out the shock load that occurring due to the various scenarios such as pump start up, sudden trip of pump and immediate closure of valves.

NOMENCLATURE

a_{acoustic}	- Acoustical velocity through the fluid
K	- Bulk modulus of elasticity of the fluid
ρ	- Density of the fluid
E	- Modulus of elasticity of pipe
D	- Inner diameter of pipe
e	- Wall thickness of pipe
Δ	- The time takes for a wave to travel from one end of a pipe to the other
L	- The distance travelled by the wave from one end of a pipe to the other
ΔP	- Change in Pressure

ΔV - Change in the flow velocity

INTRODUCTION

The surge analysis is carried out for the condenser water supply and return pipes as a single system.

The surge analysis is carried out to check the integrity and operability of the condenser water piping under most severe scenarios. The system comprises of 6 Condenser water Pumps (CWP), 6 Chillers and 6 Cooling Towers in the Central Utility Building. This document provides the detailed description of fluid parameter variations for the Condenser Water Piping. The analysis and calculations are performed using exclusively for incompressible flow.

An important consideration in fluid transient studies is how long it takes a wave to propagate through the system. When a transient event occurs at one end of a pipe, the wave travels at the wave speed to the other end of the pipe. It requires double the above

time for the wave to travel to the end of the pipe and return back.

Excessively high surge pressures can burst pipes and damage equipment. Low pressure surge can result in pipe collapse if the difference between internal and in velocity. Therefore, a reduction in pressure response requires a reduction in density, wave speed or velocity change.

EQUATIONS USED

$$a_{acoustic} = \sqrt{\frac{K/\rho}{1 + \frac{K D}{E e}}}$$

$$= \sqrt{\frac{2.10 \text{ E}+09 / 1000}{1 + \left[\frac{2.10 \text{ E}+09 \times 0.3032}{2.04 \text{ E}+11 \times 0.0101} \right]}}$$

$$= 1269.6 \text{ m/s}$$

$$\Delta \text{end-to-end} = L / a$$

$$\text{Communication Time} = 2L/a$$

Joukowsky Equation, $\Delta P = -\rho a \Delta V$

SCENARIOS CONSIDERED

Scenario- 1- CWP Pump Trip

atmospheric pressure is high. If we consider the simplified case of the instantaneous water hammer equation, pressure change is directly proportional to the fluid's density, wave speed, and change

The 6 no. of Condenser water Pumps are initially working in this case. The Pump Trip Event is defined for all pumps in the software as trip will occur when analysis time reaches t=0 sec and simulation is set for 15 sec duration. The Check Valve Type is Swing check valve and it is modeled in the software with Deceleration Curve as shown in the figure

Pump speed with time is shown in below graph.

The pump trip starts at t=0 sec and pump speed decreases in the graph

Location	Pipe	Max. Static Pressure (barG)	Max. Static Pressure Time (seconds)	Min. Static Pressure (barG)	Min. Static Pressure Time (seconds)
CWP-1 Inlet	104	5.9878	1.179	-0.942832	1.167
CWP-1 Outlet	108	7.5983	1.184	-0.942952	1.144
Chiller-01 Inlet	237	4.773	0.03143	1.698921	1.215
Chiller-01- Outlet	239	4.0648	0.04243	1.469297	1.205
Cooling Tower 01 Inlet	90	0.4087	1.249	0.006777	1.352
Max pressure location	108	7.5983	1.184	-0.942952	1.144
Minimum pressure location	108	7.5983	1.184	-0.942952	1.144

Table results Show that the maximum Pressure wave developed during the surge event is 7.598 bar at pipe No.-108.

Joukowsky Equation, $\Delta P = -\rho a \Delta V$

Max. Surge pressure = $7.598 \times 10^{-5} \text{ N/m}^2$

$\rho = 1000 \text{ Kg/m}^3$

$a = 1400 \text{ m/sec}$

Reverse velocity, $\Delta V = (7.598 \times 10^{-5}) / (1269.6 \times 10^3)$

$= 0.598 \text{ m/sec}$

Deceleration of valve (from the graph) in above

reverse velocity $= 4 \text{ m/sec}^2$

Valve closure time $= 0.598/4$

$= 0.15 \text{ Sec}$

From the velocity-deceleration graph, above value is falls under severe slam area and recommended to change the check valve to nozzle type.

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