Noise	Heating Phenomenon due to Thermo-acoustic Effect of Piping with One Closed End	Plant
Others		

Object Machine

Drain tube (outer diameter 48mm, thickness 10mm, distance to stop valve about 6m, made of alloy steel, provided with heat insulating material, Fig.1) installed on the downstream of a flow control valve (CV) in main steam line of thermal power station.

Observed Phenomena

Drain tubes are heated to temperatures exceeding the steam temperature of the main steam line, resulting in the breakage of drain tubes in extreme cases.

Cause Estimation

Analysis of the broken drain tube materials revealed that the drain tube experienced a high temperature in excess of the main steam temperature. As the drain tubes have no external heat source such as a heater, it was assumed that they might possibly have been heated by a thermo-acoustic effect due to variations in the drain tube inside pressure. As a cause of pressure oscillation in the tube, a possibility was estimated that jet flows coming out of a flow control valve with a supersonic/subsonic speed excited pressure oscillation when passing through the outlet of the drain tube.

Analysis and Data Processing

In a heating test using a drain tube having a heat insulating material of the same specification as the actual equipment and an electric heater, a calculation was made of a calorific value per unit length necessary for an estimated temperature rise of the actual equipment, with the result being about 1.5kW/m (Figs.2, 3). On the other hand, it is reported as Hartmann-Sprenger Tube (HS Tube) phenomenon that the close end side has a higher temperature when a jet flow hits the open end of a tube with one closed end[1]. In case of a thermo-acoustic phenomenon, a fluid in a narrow tube repeats compression and expansion by exchanging heat with the tube wall, which is characterized by large pressure oscillation and heat transfer between the tube wall and fluid (Fig.4).

According to a study[2] that examined the relationship between a calorific value and pressure oscillation in case of in-tube air column resonance by using the perturbation method, the following equation is presented as a summary:

$$Q = K\left(\frac{\tilde{P}}{\gamma}\right)^2\left(\frac{\mu a^2}{\delta/5}\right)\pi R$$

where Q: calorific value per unit length (W/m), $\tilde{P}$=dimensionless amplitude of in-tube pressure oscillation, K=proportional constant, γ=heat capacity ratio, μ=viscosity coefficient (Pa· s), a= sound speed (m/s), δ=thickness of boundary layer (m), R=tube inner diameter(m). For the purpose of identifying the proportional constant K in the above equation, an air spout test was conducted (Fig.5). Thus, K was estimated to be about 4.5. Based on this result, the estimated calorific value per unit length of 1.5kW/m obtained from the steam condition of the actual equipment is evaluated as quite reasonable.

Countermeasures and Results

Fig. 6 shows the tube wall temperature variations when blowing a jet flow to the open end, while the other end: open end -> close end -> open end. In this test, an air spout testing apparatus shown in Fig.5 (where no electric heater was installed) was used. It is clear from this figure that a temperature rise on the tube wall occurs only when the other end (End side in Fig.5) is closed, and that, when opened, the temperature suddenly went down. Thus, the simplest countermeasure is to open the drain stop valve.

Lesson

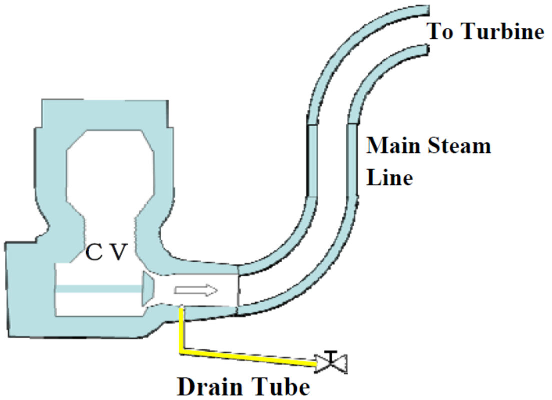
If pressure oscillations in a tube are excited from the open end in case of small diameter tube with one closed end, the tube wall may be heated, leading to unexpected temperature rise.

References

(1) Sprenger, H., “On thermal effects in resonance tubes”, NTRS(1964)
(2) Arakawa, Kawahashi, “Non-linear phenomenon associated with air column vibrations with a finite amplitude (report No.3), Transaction of the Japan Society of Mechanical Engineers B, Vol.62, No.598, p2238-2245 (1996)
(3) SUGIMOTO Nobumasa, “Production and Technology”, Vol.63, No.2 (2011)

Keywords

Thermo-acoustic effect, drain tube, valve, air column resonance



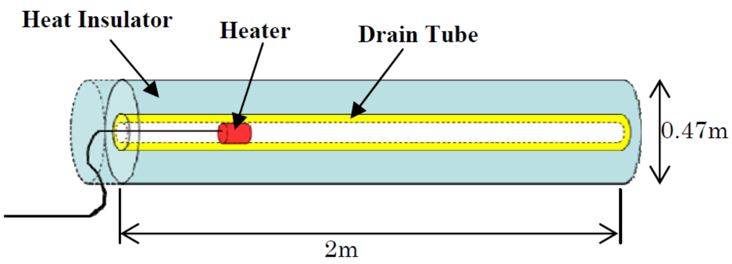


Fig.1 Main steam line, CV and drain tube on the CV downstream

Fig.2 Heat testing apparatus of drain tube

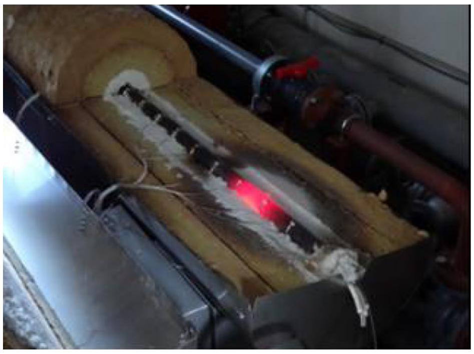


Fig.3 Condition of heat testing (red heat part is the heater)

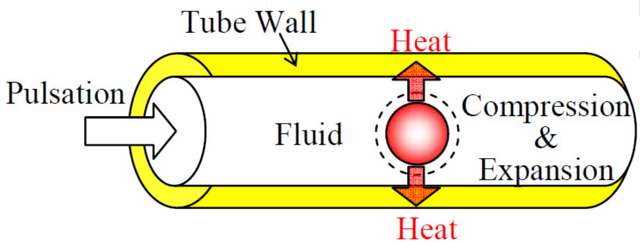


Fig.4 Thermo-acoustic phenomenon

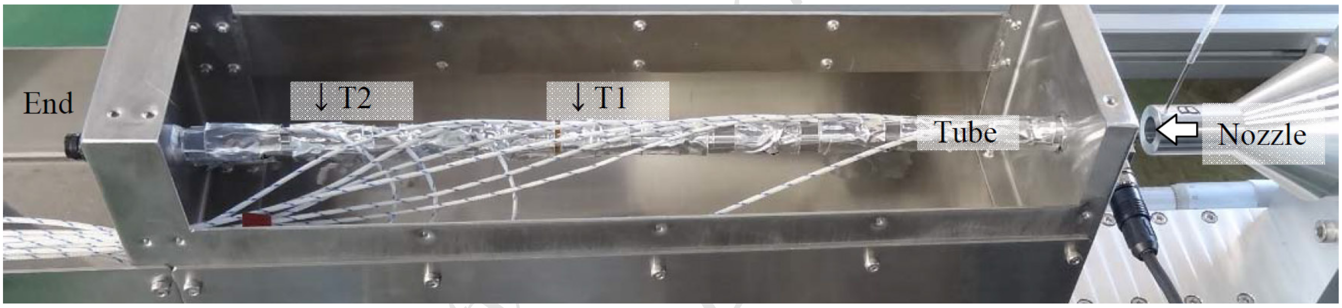


Fig.5 Air spout testing apparatus

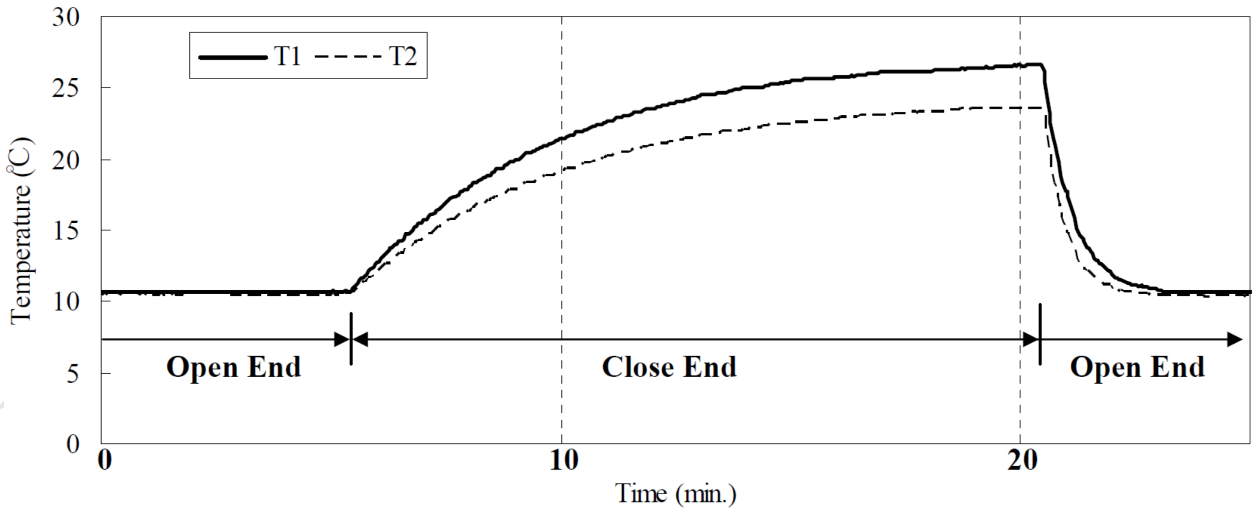


Fig.6 Air spout test result (in case one end: open ⇒ close⇒ open)