Vibration	Abnormal Vibration Occurring around High Pressure Bypass Valve	Plant
Self -Excitation		

Object Machine

High pressure bypass valve

Observed Phenomena

During plant commissioning, abnormal vibrations in the low frequency region occurred on the piping system between the high pressure bypass valve and the temperature reduction chamber. Then, a countermeasure was taken by installing a perforated plate (orifice) at the immediate downstream of the high pressure bypass valve (refer to Fig.1). Consequently, the abnormal vibrations decreased for the valve opening of 40% or more, but when the valve opening was narrowed to less than 40%, very large abnormal vibrations with a sharp peak around 700Hz appeared which had not been observed before (excessively large near the valve).

Cause Estimation

If a bypass valve is the cause of abnormal vibration, its frequency will generally be in the order of several kHz. Judging from the generated frequency (about 700Hz), an estimation was made that some sort of resonance or self excited phenomenon occurred between the valve and the perforated plate.

Analysis and Data Processing

As the perforated plate could not be taken out, behavior of the valve/piping vibration was checked by changing the valve opening (refer to Table 1). As a result, the main cause was assumed not to be resonance of the piping system, but to be "impinging flow tone" (refer to Fig.2) that occurs at the time of collision between the annular jet flow at the outlet side of the bypass valve and the perforated plate. Two exciting frequencies of the annular jet flow under consideration here are (a) $f_a=S_d \cdot U/d$ and (b) $f_b=S_L \cdot U/L$, where U is the annular jet flow velocity (≈600m/s) at the valve outlet side, d is the diameter of the valve seat (≈0.14m), L is the distance between the bypass valve outlet side and the perforated plate (≈0.40m). S_d and S_L are the Strouhal numbers, respectively. These numbers obtained here are S_d=0.15, and S_L=0.43, which agree well with the values introduced in the literatures [(1), (2)].
Normally, f_a is present in jet flows, and it is well known that circular nozzles emit periodic vortex rings. On the contrary, f_b depends on a mechanism similar to that of cavity tone and edge tone. If pressure disturbances that occur when a jet flow collides with a body such as an edge go upstream, this self excited phenomenon appears to excite jet flow at the valve outlet side. In this case, a feedback loop is established between the valve outlet side and the body (refer to Fig.3). In this case, it is considered that the above (a) and (b) are coupled, to generate an abnormal vibration with a sharp peak at about 700Hz.

Countermeasures and Results

The proposed countermeasures are illustrated in Fig.4, together with three improvements: (a) installation of a perforated plate with a non-acute angle at the immediate backside of the valve outlet (so as to miniaturize jet flows hitting the perforated plate installed beforehand, and to disconnect the feedback loop), (b) modification of valve ~~system~~ stem and (c) modification of the shape of the inlet cage (for confirmation). The above countermeasures eliminated abnormal vibrations. Before installation of the modified perforated plate, the valve outlet had an abrupt enlargement, so that jet flows coming out of the valve outlet did not attach to the piping wall, and flowed downward without damping of turbulent flow. It is assumed that between the high pressure bypass valve and the temperature reduction chamber, resonance occurred in the low frequency range.

Lesson

Although depending on the valve construction and the connected piping system, it is not advisable to install a perforated plate at the immediate backside of the valve outlet (place where jet flows from the valve outlet directly attack) (generally, a feedback loop will be disconnected for L>15 to 20 d). In other words, abnormal vibrations of the valve/piping system depend in many instances on the "system problem". Identification of the mechanism of abnormal vibrations requires site investigations by changing the valve opening.

References

(1) S.Ziada, D.Rockwell, JFM, 1982, Vol.124, p.307-334. (2) S.Ziada et al, JFS, 1989, Vol.3, p.529-549.

Keywords

Valve, jet, impinging flow tone, perforated plate, valve opening

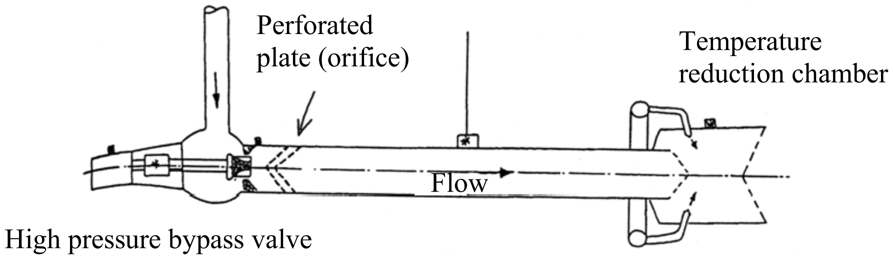

Fig.1 Overview of high pressure bypass valve and piping system

Table 1 Opening of high pressure bypass valve and vibration peak frequency

Valve opening (%)	Peak frequency (Hz)	Temperature (°C)	Pressure (bar)
43.0	560	457	28
43.9	576	471	30
39.0	608	470	31
26.6	640	461	36
24.0	656	453	39
21.5	672	453	41
18.0	704	447	45

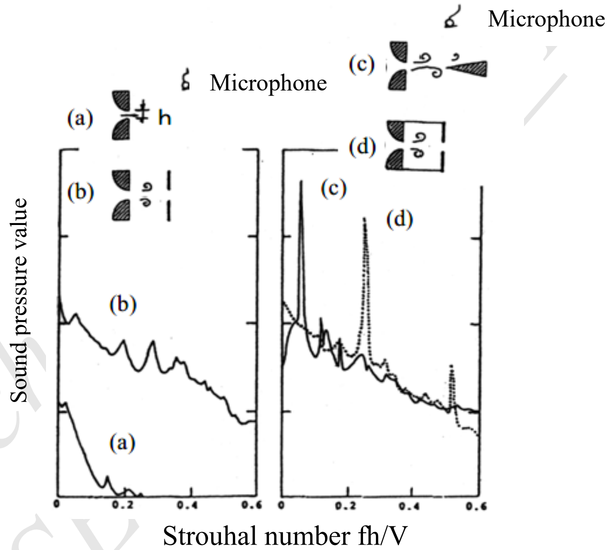

Fig.2 Example of impinging flow tone

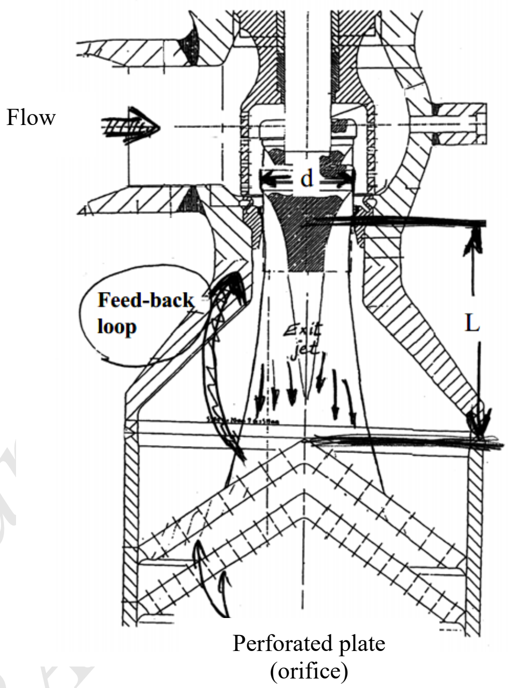

Fig.3 Mechanism of self excitation due to jet flow

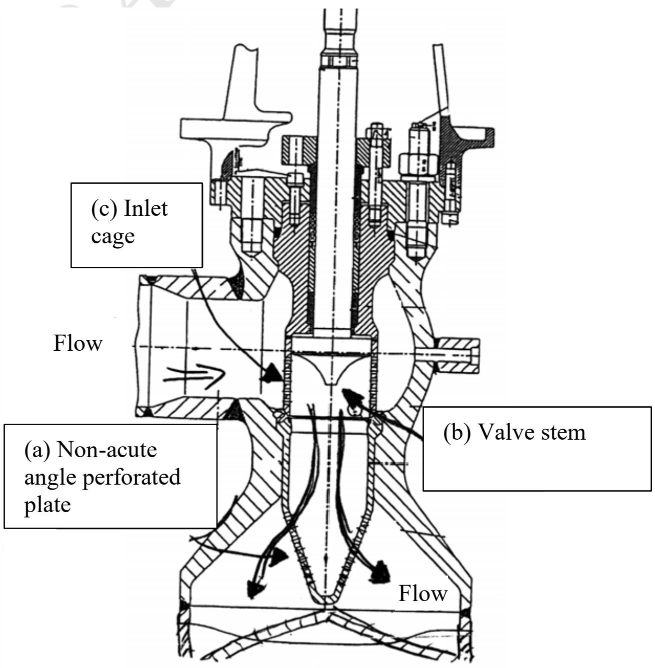

Fig.4 Places where countermeasures were taken