Vibration	Prediction of Pressure Variations due to Water-hammer of Large Equipment	Plant
Others		

Object Machine

Piping equipment (total length: 20.7km, height difference: 70m, piping diameter: 200A)

Observed Phenomena

During a water conveyance test, pressure variations occurred in the piping at the time of operation switching, almost reaching the maximum design inner pressure.

Cause Estimation

This equipment has a long total length and also a large height difference, so that high pressure difference was anticipated. Moreover, as the operation set time of valves for operation changeover was short, it was estimated that suddenly change and high pressure generated in the piping by water-hammer.

Analysis and Data Processing

Fig.1 shows the piping equipment (total length: 20.7km, height difference: 70m, piping diameter: 200A). Flowrate is 0.015m^3/s (flow speed: 0.48m/s). The receiving equipment of Fig.1 equips a valve that is closed in 3 minutes. The measurement result obtained at Point D in Fig.1 at this time is given in Fig.2. The pressure at the bottom point C might possibly exceed the maximum design inner pressure of 10kgf/cm^2. Thus, water-hammer analysis inside the piping was conducted to estimate the pressure variations inside the piping and the result is shown in Fig.3. After turning the valve to closing side, the pressure rose, and from the moment of complete closing of the valve (t=180 seconds) for about 10 seconds, the maximum pressure (about 9.8kgf/cm^2) remained. Thereafter, the stress waves propagated to the upstream side, while the pressure converged to a value corresponding to the height difference of 7.0kgf/cm^2. The above agrees fairly well with the measurement result in Fig.2, thus it is considered that the analysis model simulates actual phenomena. The analysis result of pressure at the bottom point C was 10.5kgf/cm^2, which is found to have exceeded the design inner pressure. In this case, water compressibility was not taken into consideration. The intermediate facility is constructed so as to release pressure.

Countermeasures and Results

As countermeasures, advanced examinations were made by means of numerical analysis of the following two proposals:

(1) To install a second intermediate facility in the piping equipment in Fig.1, so as to reduce the height difference.

(2) To elongate a valve closing time.

Scope of analysis 1 (Fig.4): from the primary intermediate facility to the second one; total length: 3.2km, height difference: 30m

Scope of analysis 2 (Fig.5): from the second intermediate facility to the receiving facility; total length 17.5km, height difference 40m

Flowrate: 0.02m^3/s (flow speed: 0.64m/s), valve closing time: 3, 6, 9 minutes, respectively

Fig.6 shows one example of analysis results (scope of analysis 1, valve closing time 3 minutes), while Table 1 gives the pressure at Point D (operating pressure P1, maximum pressure P2, Standstill pressure P3). When the valve closing time was 3 minutes in the scope of analysis 2, the maximum pressure P2 was close to the design pressure, so the closing time of 3 minutes was found short. Thus, after closing the valve in 6 minutes, the pressure went down to fall within the design inner pressure.

Lesson

Equipment with a large height difference has a possibility for pressure increase due to water hammer. It is thus important to predict the piping inside pressure in the design stage, so as to modify the equipment layout and to determine the valve closing time.

References

"Water hammering action and pressure pulsations", AKIMOTO Tokuzou, published by the Nippon Kogyo Shinbun

Keywords

Water hammer, pressure variation, numerical analysis

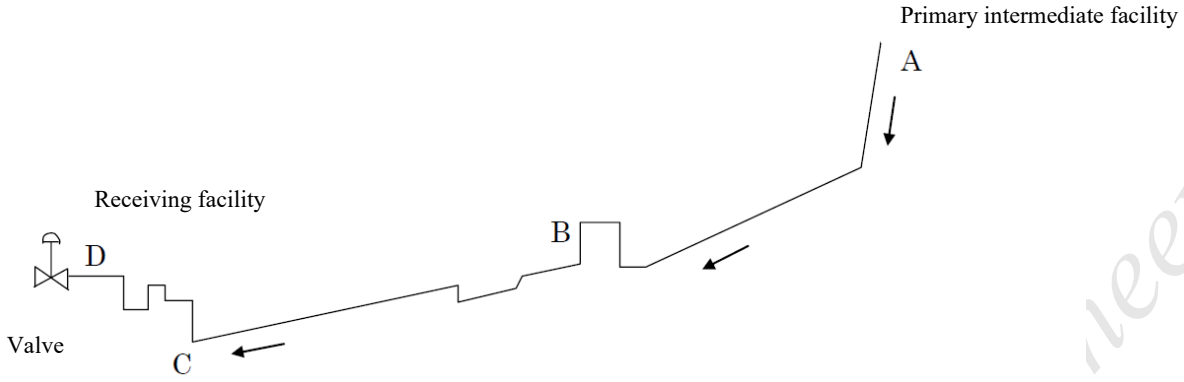

Fig.1 Piping equipment

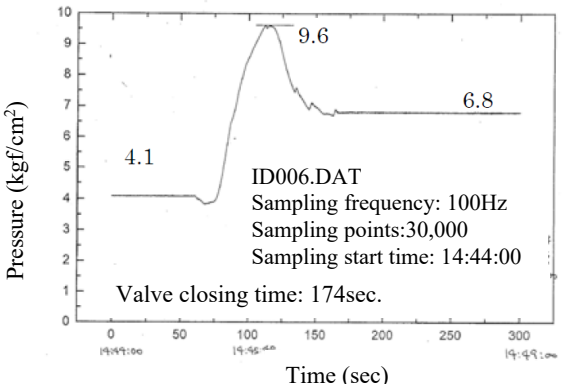

Fig.2 Pressure measurement result (at Point D)

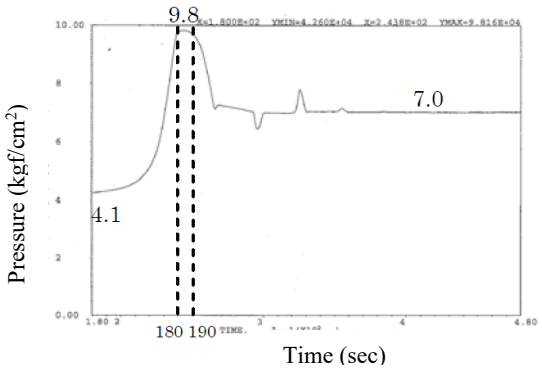

Fig. 3 Pressure analysis result (at Point D)

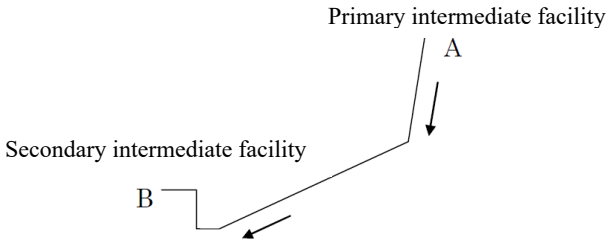

Fig.4 Scope of analysis 1

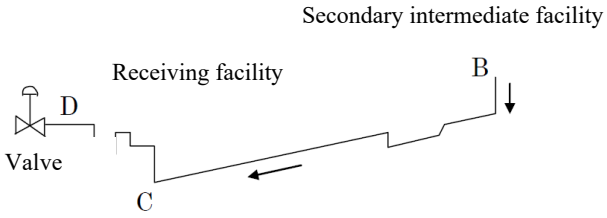

Fig.5 Scope of analysis 2

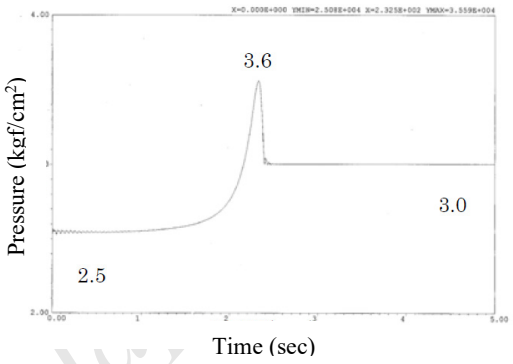

Fig.6 Pressure analysis result
(scope of analysis 1, valve closing time 3 minutes)

Table 1 Summary of analysis result

Scope of analysis	Valve closing time (min.)	P1 Operating pressure (kgf/cm²)	P2 Maximum pressure (kgf/cm²)	P3 Standstill pressure (kgf/cm²)
1	3	2.5	3.6	3.0
1	6	2.5	3.2	3.0
1	9	2.5	3.1	3.0
2	3	1.0	9.7	4.0
2	6	1.0	7.9	4.0
2	9	1.0	6.5	4.0