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Analysis of the Water-Hammer Equipped with Many Devices or Accompanied by Water-Column Separations

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Recent pumping plants have been enlarged with rapid progress of industrial developments. Consequently water-hammer seems to have been becoming of great importance when the power supply to the pump is suddenly cut off or put in. The hydraulic engineer is so familiar with the pressure fluctuation theory, and so many works have been published on this subject in recent years. During the last ten years, digital computer methods of water-hammer analysis have been developed. In this paper are described two theoretical methods of calculation and some problems of the swing check valve and high viscous liquid; one is water-hammer analysis in a complex pumping system equipped with one-way surge tanks, needle valve, hoster pumps, and so on; the other is complex hydraulic transients with water-column separations.

In the first chapter is shown digital computer method of analysis which simulates the transient phenomena occuring in a large pump installation equipped with

(1) hydraulic losses concentrated in many discrete points of the system,
(2) some one-way surge tanks,
(3) check valves at each point of surge tanks,
(4) needle valve at the pump,
(5) some booster pumps in the middle of conduit,
(6) weir in the end of conduit.

The method proposed in this chapter can be applied to a system over a wide range of complex installations. And this method makes rapid estimations of surge pressures and yields valuable information in preliminary design stage of a project.

In the second chapter is shown theoretical result calculated on some assumptions and experimental results. And this chapter includes a summary of the major features of two pumping plants at Asaka and Kamiigusa as well as comparisons between the observed and computed water-hammer effects.

The third chapter describes water column separation. These phenomena are common, but rarely discussed, surge phenomena which may result in serious damage to water-pumming plants. In this chapter is described the method of water-hammer analysis with water-column separation taking the effect of viscosity as the friction loss heads into consideration, but it is assumed that, on reaching the vapour pressure (generally speaking, almost absolute vacuum), the water column splits into two parts, in which the pressure fluctuation phenomena play themselves out independently of each other until the two parts surge together once again with a more or less marked hammer. Two calculated examples for actual installations of isogo and Chita Pumping Plants are shown.

In the fourth chapter, the testing installation associated with the pumping plant of cooling-water supply for a thermal power station is made in order to give a validity of the analysis of the previous chapter. In this experiment, water column separations are caused by the negative pressure surge at two positions, just after the valve and at the center of conduit. As experimental results, are shown the effect of gate-closure time, normal head of the pump and normal velocity on the first or the second pressure rise due to the recombination, and the relationship between time of the maximum pressure rise and normal velocity. The theoretical results have a good agreement with experimental results, on the assumption that the boundary between the vapour void and water column is free surface.

In the fifth chapter, some problems are solved:

(1) Analysis of Hydraulic Transient in Pump Discharge Line Equipped with an Air-Chamber: there are two representative devices, one-way surge tank and air chamber, keeping the pressure from rising in a pipe. The latter is not studied more than the former because of little merit, but of late attracting a renewed interest. As an example, the water-hammer pressures are computed and compared for two apparatuses equipped with or without an air-chamber.

(2) Transient Flow Analysis of High Viscous Liquid: Most researchers have dealt with the frequency response of fluid transmission lines. The principal object of this section is to illustrate a characteristic method for quasi-linear hyperbolic systems of first order and to constitute a digital computer method for solving some problems of two-dimensional, a little compressible viscous flow, taking the elasticity of conduit into consideration. As a result, the pressure changes occuring in a pipeline when Poiseville flow is stopped by the sudden closure of a valve are compared with those caused by the flow when frictional hydraulic losses are proportional to the two power of velocity.

(3) Equivalence Problems in Complex Discharge Lines and Water-Hammer Charts with Hydraulic Losses: In this section, formula similar to series and parallel connections in electrical resistances are obtained with respect to conduit constant for transforming complex pumping plants into an equivalent uniflow model. And useful water-hammer charts taking account of hydraulic losses are made by theoretical calculations of a uniflow model with pump characteristic curves ($n_s=1800$).

(4) Reverse Elow and Time Lag of Swing Check Valve: For a pump discharge line with a swing check valve on the discharge side of a pump, the normal discharge of the pump keeps the check valve open. However, when the flow through the pump reverses subsequent to power failure, the swing check valve closes rapidly.

When the check valve closure is delayed, there is one large head rise at the check valve. Then, how long is the time lag between a departure of reverse flow and an end of the valve motion? And how much is the reverse flow in this moment? In this section are given the analytical formular for these questions.
In the last chapter are given conclusions of this thesis.