An Experimental Study of the Swing Check Valve Disc Stability

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1. Introduction

Swing check valves are the most common type of check valve in nuclear power plant and need to be operated properly to perform their functions and to keep the valve internals stable. However, for a swing check valve disc to remain stable, the opening characteristics should be identified and the upstream flow velocity should be enough to hold the disc fully open and without motion. All check valves have limits of minimum velocity in which operation below this velocity may cause wear and damage due to the disc fluctuation. The minimum flow velocity necessary to just open the disc at a full open position is referred to as V_{OPEN}, but V_{MIN} is defined as the minimum velocity to fully open the disc and hold it without motion. These minimum velocities highly depend on the upstream flow conditions of the valve.

In the present study, an experimental loop was designed and installed to investigate the effects of the upstream flow conditions on the disc stability of the swing check valves. The tests were performed at various conditions of disturbance type and distance from the check valves. The experimental results are presented herein.

2. Experimental Setup

2.1 Test Loop

As shown in Figure 1, the main components of the test loop are two water storage tanks, centrifugal pump with rated capacity of 5.4 m^3/min at 71.35m, two flow meters, two horizontal 3-inch and 6-inch test sections, and flow control valves, including the several pipe segments. The test section is of modular construction, allowing piping configuration changes for upstream flow disturbance testing. For the tests, the type of the disturbance sources, such as elbow and globe valve, and the position of the 3-inch or 6-inch swing check valves in the test section can be adjusted. The main pipes have an inner diameter of 143mm (6 inch) but the pipes of 77mm (3 inch) diameter were connected to the main loop for 3-inch valve tests.

Flow measurements were made mainly with the turbine flow meter with the range and accuracy of 80 ~ 800m^3/hr and 1.0% full scale, respectively. On the other hand, the low flow rate, especially for 3-inch valve tests, was covered using the electromagnetic flow meter provided more accurate flow measurements with the range and accuracy of 5 ~ 180m^3/hr and 0.5% full scale, respectively. The potentiometer-type radial displacement transducer was used to determine the disc angular position. Pressure transmitter and pressure taps are located at the equivalent distance upstream and downstream of the test valves. The range of the pressure transmitter is 0 ~ 25bar with 0.15% full scale.

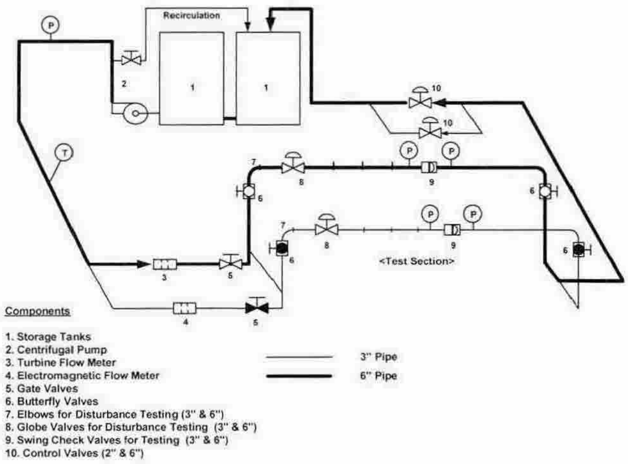

Figure 1. Schematic Diagram of the Test Loop.

2.2 Test Description

Flow loop tests on instrumented check valves were performed to investigate the effects of the upstream disturbance type and distance from the check valves on the disc stability. The elbow and control valve (globe valve) were chosen as the disturbance source and the location of the disturbances are 2, 4, 6, 8, 10 diameters upstream of the check valve. During the test, the measured data include flow rate through the valve, valve disc position, differential pressure of the check valve, upstream and downstream pressures, and water temperature. From these data, the disc position and fluctuation with flow velocity, V_{OPEN} and V_{MIN} were determined for 3-inch and 6-inch swing check valves.

3. Results and Discussion

3.1 Disc Opening Characteristics

Figure 2 shows the measured disc positions and disc fluctuations according to the average flow velocities for each of the 3-inch and 6-inch valves. Each plot is associated with three flow conditions such as uniform, elbow at 2 diameter upstream of the check valve, and globe valve at 2 diameter upstream of the check valve. The disc full open angles of these two valves are 61.3 and 62.7 degrees, respectively. As the valve opens with an increase in flow, the valve disc experiences motion and the valve noise normally occurs just before the valve is fully open by the disc striking the backstop of the valve. Maximum motion or rotational flutter of the disc normally occurs just before the disc is fully open but the disc tapping will continuously occur until the flow velocity reaches V_{MIN} velocity.

3.2 Minimum Velocities

In this study, the V_{MIN} velocity was determined as the minimum flow velocity at which the fluctuation level of disc was reduced below one degree. As one would expect, V_{MIN} velocity (4.43 ~ 5.28m/s) was measured to be higher than V_{OPEN} (2.80 ~ 3.89m/s) but it seemed that the effects of elbow and globe valve on both velocities became very small at distances of 4 diameters and beyond from the check valve inlet.

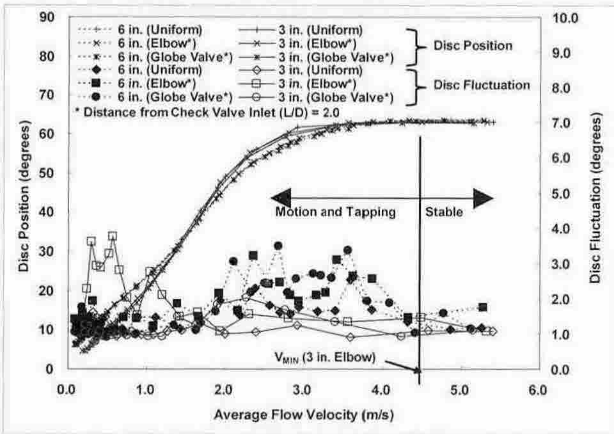

Figure 2. Disc Position and Disc Fluctuation with Average Flow Velocity for 3- & 6-inch Swing Check Valves.

3.3 Effect of the Upstream Flow Condition

In order to minimize the effect of upstream flow disturbance, some pipe length between the upstream disturbance and the check valve is needed to allow recovery from the disturbance [1~3]. EPRI recommended the distance between the disturbance and the check valve should be 2 ~ 10 hydraulic diameters upstream and downstream, depending on the type of disturbance, to limit the disc fluctuations to a reasonable value [3]. However, Figure 2 shows that there is negligible effect of upstream flow conditions on the opening characteristics of the valve, because there is no difference among the three curves (disc positions vs. average flow velocity) for each of the 3-inch and 6-inch valves. On the other hand, there are two noticeable points from the plots of the disc fluctuations. One is that disc fluctuations generated by elbow are greater than glove valve. The second is that the 3-inch valve disc experienced high fluttering in low flow region but the dominant fluctuations of the 6-inch valve occurred in nearly open positions. After the flow velocity reached V_{MIN} velocity, however, the valve disc motion remained fairly stable for both valves.

Figure 3 shows the maximum disc fluctuations with the elbow and globe valve at 2, 4, 6, 8, 10 diameters upstream of the 3-inch and 6-inch check valves. It can be seen that more violent disc motions (fluctuations) for 6-inch valve occurred than that for 3-inch valve.

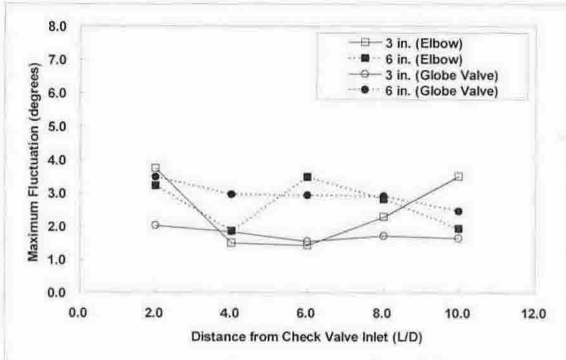

Figure 3. Maximum Fluctuation of the Disc with Distance from Check Valve Inlet.

4. Summary

To investigate the effects of the upstream flow conditions on the opening performance of the swing check valve, the tests were performed at various conditions of the disturbance type and distance from the tested check valves. The results show that the upstream flow disturbances due to elbow and globe valve at 2~10 diameters upstream of the check valve produced minor effects on the check valve performance compared to the uniform flow condition. However, more detail analysis and additional testing with the other disturbance source, such as orifice with a large number of holes, are needed to refine and confirm the present results.

REFERENCES

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