A Study on the Main Steam Safety Valve Opening Mechanism by Flashing on NPPs

Kim BaeJoo
Nuclear Power Education Institute, Instruction Group, Maintenance & Engineering Training Team,
991, Sinam-Ri Seosaeng-Myon, Ulju-Gun, Ulsan-Si, South Korea, 689-882
**Corresponding author: oojeab@khnp.co.kr*

1. Introduction

A safety injection event happened by opening of the Main Steam Safety Valve at Kori unit 1 on April 16, 2005. The safety valves were opened at the lower system pressure than the valve opening set point due to rapid system pressure drop by opening of the Power Operated Relief Valve installed at the upstream of the Main Steam System. But the opening mechanism of safety valve at the lower set point pressure was not explained exactly. So, it needs to be understood about the safety valve opening mechanism to prevent a recurrence of this kind of event at a similar system of Nuclear Power Plant. This study is aimed to suggest the hydrodynamic mechanism for the safety valve opening at the lower set point pressure and the possibility of the recurrence at similar system conditions through document reviewing for the related previous studies and Kori unit 1 event.

2. Main Steam System and Equipment

The Main Steam System has the function to transfer the heat energy from Steam Generator to the Main Turbine. The Main Steam Pipe containing high energy can be broken by the over pressure. So the Main Steam Safety Valves are installed on the pipe by the requirement of ASME Code. This spring loaded safety valve is actuated on the pressure set point under steam condition. It cannot be actuated on saturated water condition normally.

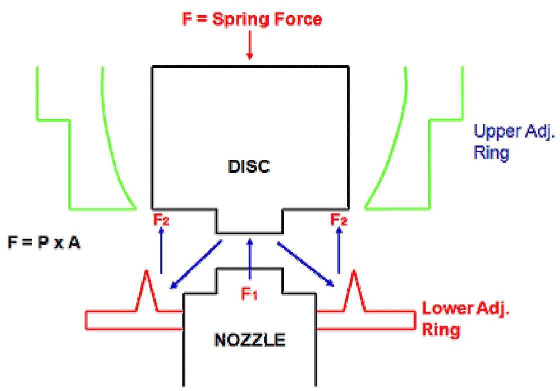

Figure 1. ASME section Ⅰ power boiler safety valve operation

When the system pressure reached to the set point like Figure 1 the safety valve would be opened quickly like Figure 2. And this valve would be reclosed at the lower pressure than opening set point.

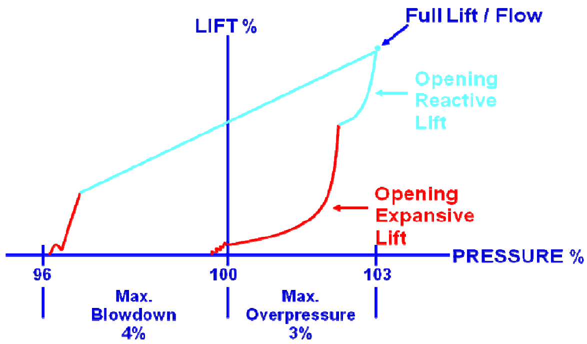

Figure 2. ASME section Ⅰ power boiler safety valve operation

3. Thermodynamic Phenomenon

Two kinds of thermodynamic phenomenon are associated with the Main Steam Safety Valve opening event at the lower pressure than opening set point.

3.1 Flashing Phenomenon

Flashing is the instant evaporation phenomenon of saturated water, which can happen when rapid pressure drop occurs in closed system.

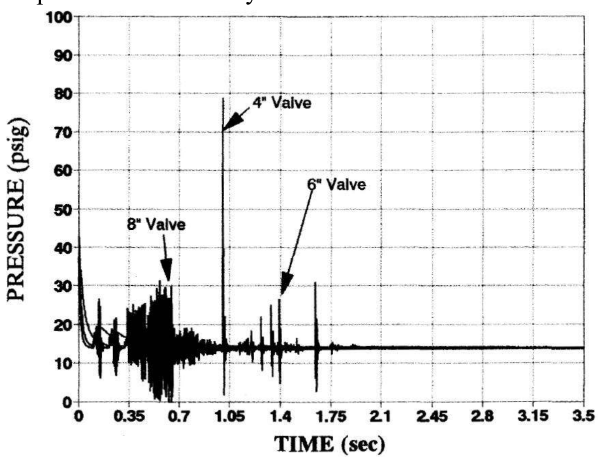

Figure 3. Peak pressure trace of 4″, 6″, 8″ valve with flashing for quick open type

Rapid pressure drop of the system containing saturated vapor and saturated water makes pressure peak phenomenon like Figure 3. This pressure peak happens by shock wave followed vapor collapse after flashing. This pressure peak was 3~5 times of normal pressure at A.R Wolf experiment [1]. Also, the peak pressure was 2~7 times of normal pressure at computer code analysis of Han, Y.G, it lasted for 0.1~1.0 milli sec [2].

3.2 Water Hammering Phenomenon

Water hammer occurrences may occur due to pump starts or stops, control or isolation valve operation, check valve closure, safety or relief valve operations, turbine trips and the filling of normally empty systems [3].

Usually, designs and procedures minimize the effects of these events and no damage occurs from them.

There are other abnormal and unanticipated types of water hammer events like Figure.4 which are severe, and which may cause damage or profoundly affect plant operation. These events can be very complex and difficult to analyze, and often occur in the presence of two-phase flow.

The pressure transient amplitudes in two-phase flow are not necessarily easy to analyze in complex systems where secondary or reflected waves may actually exceed the first transient in amplitude, depending on the configuration of the pipe.

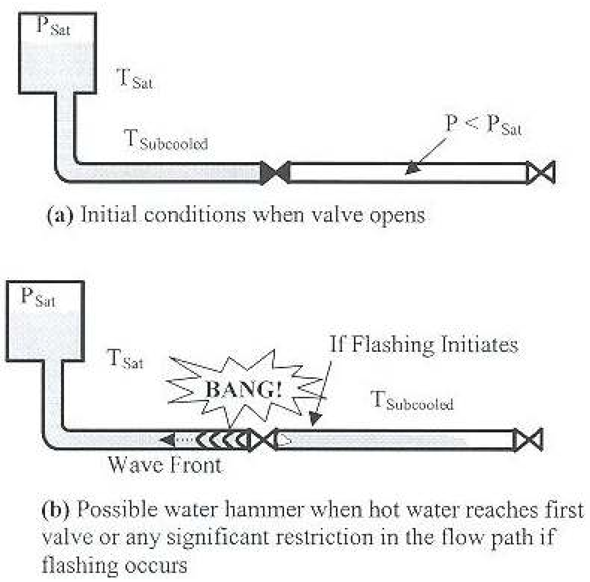

Figure 4. Low pressure discharge hammer

4. Consideration of the Main Steam Safety Valve Opening Mechanism at the lower pressure than set point

At Figure 5, the velocity of the saturated water accumulated in the Main Steam Pipe can be ignored if there is no change of discharged steam flow through PORV. Although there is discharge steam flow transient the saturated water velocity could not exceed 5m/sec that is the general design velocity of system water. This velocity energy can change to 20.6kg/㎠ with water hammer shock wave by calculation. The Kori unit 1 safety valve cannot be opened by this additional pressure.

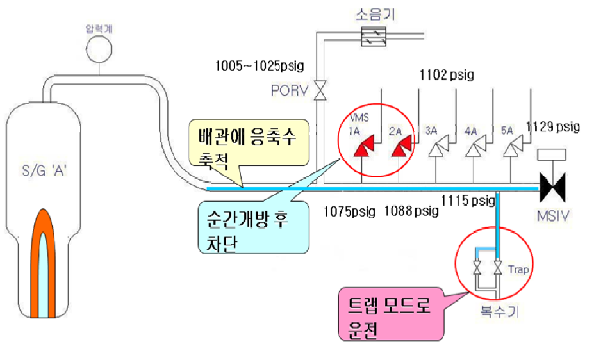

Figure 5. Main Steam System conceptional drawing of Kori unit 1

If there is flashing phenomenon by rapid opening of the PORV the system pressure exceeds the safety valve opening set point with shock wave by steam bubble collapse.

5. Conclusions

Some results were obtained through this study as following. (1) The Main Steam System Pressure cannot reach to the safety valve opening point by only the water hammer induced by the condensed water flowing inside the Main Steam Pipe due to large steam flow change in condition of the Main Steam Isolation Valve closed. (2) The Main Steam System Pressure cannot reach to the safety valve opening point by flashing of condensed water alone with rapid system pressure drop. (3) Shock pressure lasting for 0.1~1.0 milli seconds followed by flashing and condensing can open five safety valves for 1~2 second. (4) At the condition of filled with condensed water to the safety valve nozzle, the safety valves cannot be opened because of 0.2~0.3 second delay time for flashing. (5) It needs to be careful in operation not to make the shock pressure by condensing of bubble in pressurizer in period of making and breaking bubble during plant start up & shut down.

REFERENCES

[1] A.R. Wolf et al., "Passive Water Hammer in Pipes due to Flashing" J. of Fluid Eng. ASME, 1992, Vol. 231, pp.127-133

[2] Young-kil, Han "A Study on the Simulation for Transient Phenomena due to Flashing in High Temperature Pipe" November, 1994.

[3] "Water Hammer" EPRI TR-109623, January 28, 1999.