Alternative Method of Uncertainty Treatment in Safety Valve Test Tolerance

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1. Introduction

Pressurizer Safety Valve(PSV) is designed to prevent reactor overpressure during design basis accidents. For Korean plants, the PSVs have been assumed to open within ±1% tolerance of set pressure and the tolerance is verified with an in-service testing in accordance with technical specification.

In the licensing safety analyses for overpressure protection capability of the Korean plants, test equipment (auxiliary lift device) uncertainty of +1% has been simply added to the set pressure as a bias (penalty) for PSV opening. However, PSV set pressure test results so far shows a probability distribution and thus the tolerance should be determined on the basis of the test results not by a bias since statistically all kinds of physical phenomena have a non-zero probability to go beyond certain fixed limits by faults.

A new statistical approach of determining PSV test tolerances by elimination of the test equipment uncertainty and the effects on the licensing safety analyses and plant designs are discussed.

2. Methods and Results

The uncertainty of safety valve set pressure is discussed to provide an alternative approach in determining test tolerance. Based on the discussion, several options to improve the overpressure safety margin are described.

2.1 Uncertainty of PSV set pressure

None of physical phenomena (both natural and artistic) have fixed values but have uncertainties (non-zero probability) to go beyond fixed range. In the light of the engineering point of view, the designer should assume a fixed range of a design parameter.

The uncertainty of the safety valve set pressure goes in the same way. In-service test results of PSV set pressure is shown in Fig.1 (this is for a Korean two-loop plant) and the set pressure has a probability distribution. To obtain set pressure uncertainty, it is conservatively assumed that test results (blue bars) in Fig.1 follows a normal distribution of 95% confidence level. It is conservative since the higher the confidence level, the broader the distribution and the larger the uncertainty. With this 95% confidence level, 95% probability of occurrence of the PSV set pressure spans from -2.59% to +2.67%.

Furthermore, the test equipment uncertainty is also a stochastic phenomenon and thus will follow normal distribution. Previously, however, test equipment uncertainty is simply superimposed to set pressure uncertainty to get tolerance as following:

Set Pressure Tolerance (Total Uncertainty)
= Set Pressure Uncertainty (generally 3%)
+ Test Equipment Uncertainty (generally 1%) (1)

Naturally, however, measured set pressure inherently includes test equipment uncertainty since only one value, the safety valve opening (set pressure) is measured through in-service test. Eq.(1) is therefore an unrealistic duplication of single measured parameter and thus it is suggested that the test equipment uncertainty be eliminated. Furthermore, if we don't utilize auxiliary lift device (test equipment mentioned above) then we can provide more justice for the elimination of the equipment uncertainty.

Generally, 95% probability of occurrence with 95% confidence level is used in calculating plant safety parameters such as fuel rod DNB (departure of nucleate boiling), moderator temperature coefficient of reactivity in ATWS (Anticipated Transients without Scram) analysis, etc.

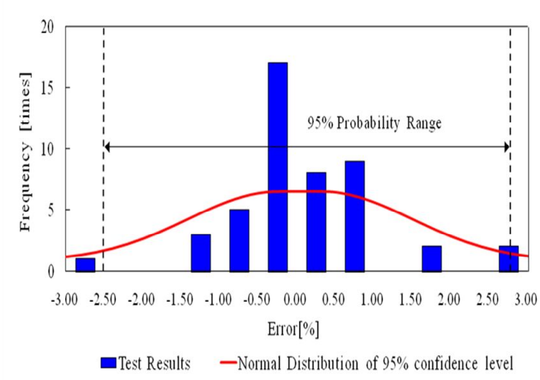

Fig.1 Test results and Uncertainty

2.2 Design feature of PSV

The PSV of Kori 1 is a flat disk type self-actuation valve [3] as shown in Fig.2 and the valve is installed on the flange of the loop seal connected to the pressurizer. During power operation, the loop seal is filled with condensed water to prevent leakage. During an overpressure transient, pressure relief through the PSV may be delayed until the water in the loop seal water is discharged and the set pressure shift of 1% is considered in the safety analyses.

For this reason, some licensees changed the design to continuously drain the condensed water in loop seals to get pop-open the valve by steam only and thus to eliminate the set pressure shift. However, the design change may cause undesirable results in plant operation and maintenance since in-service test specification and operating procedure become complicated. Therefore many licensees is United States still operate without the elimination of loop seals and the PSV test tolerances are expanded by using best-estimate safety analysis codes such as CENTS and RETRAN. The sample US plants are summarized in Table I.

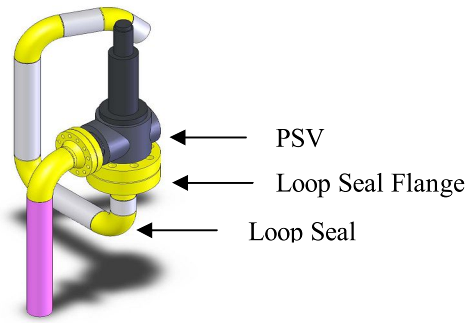

Fig.2 PSV facility for Kori 1 unit

Table I : The US plants operating with loop seals on the PSV and the test tolerances

Units	Test tolerances of PSV set pressure [%]	Number of reactor coolant loops
D.C. Cook 1, 2	± 3	4
R.E. Ginna	+2.4, -3	2
Millstone 3	± 3	4
Prairie Island 1, 2	± 3	2
Salem 2	± 3	4
Seabrook 1	± 3	4
Surry 1, 2	± 3	3

2.3 Computer code for assessment of pressure margin

LOFTRAN[1] computer code was used to assess the overpressure safety margin of Kori unit 1. LOFTRAN is a digital computer code which was developed to simulate transients in a Westinghouse type plant such as Kori 1. The LOFTRAN code was approved to the USNRC for regulatory review in 1972 via WCAP-7907. Since the USNRC's acceptance, The LOFTRAN code has been used for many years by Westinghouse for Non-LOCA evaluations for Safety Analysis Reports.

2.4 Improvement of overpressure safety margin

According to Safety Analysis Report [2], Loss of Load/Turbine Trip (LOL/TT) was the most limiting over pressure transient. For this transient it should be verified the reactor overpressure is limited within the 110% of design pressure with the extended tolerance. To improve the safety margin, sensitivity analyses are performed to find parameters that take major effects on the reactor overpressure in the safety analyses.

1) PSV nominal set pressure
2) PSV set pressure shift due to loop seal water
3) Test equipment uncertainty
4) Loop seal water purge time
5) Reactor trip set point
6) Reactor trip delay time

First, fifth and sixth parameters among the six parameters are not design parameters but Limiting Conditions for Operation (LCOs) and thus can be adjusted without design change. Second and forth parameters are design values related with loop seals and these parameters couldn't be changed without elimination of the loop seal. The test equipment uncertainty has been added to the total tolerance as a bias in Korean plants. However, this can be eliminated when we test the PSV accurately according to the ASME PTC and OM code.

Results of the Sensitivity study are found in Table II. As shown in Table II, reactor system peak pressures for every option is below 110% of reactor pressure (2748.5 psia). Option 3 needs major design change such as continuous loop seal drain and is not cost-effective. The test tolerance in Option 2 is based on the current convention and is too tight to cover the uncertainty of set pressure tests as discussed in section 2.1. Option 1 covers the 95% uncertainty without test equipment uncertainty and is suggested as an alternative to the conventional safety valve test tolerances.

Table II : The sensitivity analysis of PSV set pressure tolerances

Key parameter	Option 1	Option 2	Option 3
PSV nominal set pressure [psia]	2475	2475	2500
PSV set pressure shift due to loop seal water [%]	1%	1%	0%
Test equipment uncertainty [%]	0%	1%	1%
Loop seal water purge time [second]	1.409	1.409	0
Hi Pressurizer Pressure reactor trip set point [psia]	2440	2440	2460
Hi Pressurizer Pressure reactor trip delay time [second]	1.2	1.2	2.0
Test tolerance of PSV set pressure [%]	2.7	1.7	3
Peak reactor pressure from analysis of LOL/TT [psia]	2747.6	2747.6	2665.63

3. Conclusions

Alternative method of pressurizer safety valve test tolerance considered in the safety analyses is discussed. Conventional approach of uncertainty treatment does not provide sufficient and cost-effective safety margin and thus alternative approach based on statistical approach is provided and suggested for plants with loop seal water upstream of the pressurizer safety valve. The result satisfies the acceptance criteria of the safety analyses.

REFERENCES

[1] WCAP-7878, LOFTRAN Code Description and Users' Manual, Westinghouse, February, 2003
[2] Final Safety Analysis Report for Kori 1 unit, Korea Hydrau & Nuclear Power Co, May, 13, 1997,
[3] Installation, Operation and Maintenance Instruction for Crosby Style HB and HB-BP Self-actuated nozzle type safety relief valves, Crosby Valve & Gage Co. September, 11, 1980