Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 24-25, 2024

Study on the Impact of SAMG According to the Set-point for Containment Pressure Capacity

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***Keywords :** Severe Accident Management Guideline (SAMG), Factored Load Category (FLC), Ultimate Pressure Capacity (UPC)

1. Introduction

The containment pressure capacity is one of the critical reference parameters as a set-point to which the SAMG (Severe Accident Management Guidelines) strategy is supposed to refer.

The containment pressure capacity has been understood to have a higher value than the containment design pressure. A methodology based on ‘fragility’ which is the cumulative containment failure probability presented by NUREG/CR-6906 [1] has been taken as a referential guidance for identification of the containment pressure capacity. In domestic current SAMGs, the set-point value of Containment Pressure of Severe Challenge, which is defined as one that can bring about the containment failure imminently, has been generally set as the 5-percentile pressure value of the containment fragility curve. Also, in the PWROG SAMG (2016) that is the current newest technical standard for PWR type SAMG, 5-percentile pressure value of the containment fragility curve is still used as a set-point value for Containment Pressure of Severe Challenge [2].

Meanwhile, through a comprehensive assessment of the severe-accident mitigating capability of the domestic operating NPPs, named of AMP (Accident Management Program) assessment, an alternative way of determining the set-point of Containment Pressure of Severe Challenge is being raised. The main idea is that the value of the identified FLC (Factored Load Category) load would be taken for the set-point.

In this paper, it is tried to figure out what kind of the effects would be brought and how significant they would be when changing the set-point of Containment Pressure of Severe Challenge.

2. Options for set-point of Containment Pressure of Severe Challenge

The existing practice for defining the set-point of Containment Pressure of Severe Challenge has been based on a containment fragility curve. The recently presented alternative way is to utilize the FLC load for the set-point of Containment Pressure of Severe Challenge.

2.1 Pressure Capacity based on fragility

The existing practice for defining the set-point of Containment Pressure of Severe Challenge has been to take use of the 5-percentile pressure value from the containment fragility curve. In NUREG/CR-6906 [1], the possible range of the containment failure pressure has been presented to between 5-percentile and 95 percentile of the fragility curve and the 5-percentile had been taken as a conservative ‘lower bound’. This value is still valid and used in the PWROG SAMG(2016) as below [2] ;

“The lowest reasonable pressure (5% probability) pressure at which the containment could fail may range from 5 psi to as much as 30 psi less than the median pressure. It is recommended that this setpoint be specified at 10 psi less than 5% failure value to allow adequate time for evaluation and implementation of the recommended containment pressure control strategy.”

2.2 FLC load

According to USNRC R.G. 1.136 [3], the integrity of the containment structure should be demonstrated for the combustible gas loading conditions for the factored load category :

(1) FLC = D + Pg1 + [Pg2 or Pg3]

Where,

D : dead load

Pg1 : pressure resulting from an accident that releases hydrogen generated from 100-percent fuel cladding-coolant reaction

Pg2 : pressure resulting from uncontrolled hydrogen burning (for an accident that is accompanied by hydrogen burning)

Pg3 : pressure resulting from post-accident inerting, assuming carbon dioxide is the inerting agent (for an accident that is accompanied by post-accident inerting)

For Pg2, the AICC (Adiabatic Isochoric Complete Combustion) pressure of hydrogen has been usually applied instead of Pg3.

In other words, the FLC is the possible maximum pressure peak value in order to confirm whether the stress-strain allowable limit of liner deformation is maintained by the severe accident phenomena such as the uncontrolled burn of combustible gas, not the value representing the containment damage.

3. Review of SAMG Impact

3.1 Application of Containment Pressure Capacity in SAMG

In PWROG SAMG(2016), the containment pressure capacity is applied as a set-point, defined as the Containment Overpressure of Severe Challenge based on the pressure corresponding to a 5-percentile of the containment fragility curve. It is also used as a criterion indicating the RED region in Diagnostic Process Guideline (DPG) Worksheet as presented in Fig. 1.

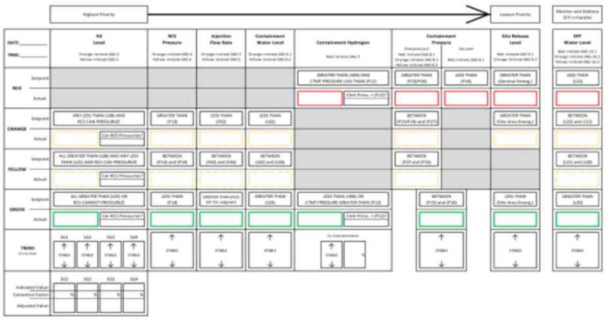

Fig. 1. DPG Worksheet

This set-point is utilized in various Severe Accident Guidelines (SAGs) within the PWROG SAMG, with the primary applications being as follows:

a. To initiate containment venting in the strategy of Control Containment Pressure
b. To distinguish between 'Hydrogen Burn' region and 'Hydrogen Severe challenge' region in fig. 2 [3] where active strategies to remove hydrogen such as hydrogen igniters cannot be used in 'Hydrogen Severe challenge' region. The diagram such as Fig. 2 is used as the calculational aids in the SAMG

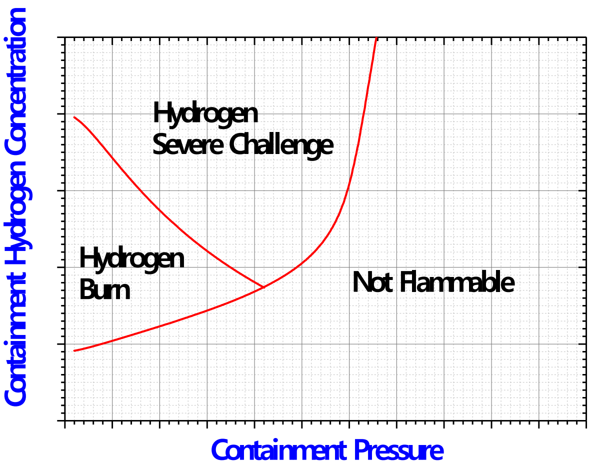

Fig. 2. Hydrogen Flammability in Containment

c. To limit reduction of containment pressure to prevent entry into 'Hydrogen Severe Challenge' region from 'Not Flammable' region

3.2 Impact of SAMG According to the application of FLC value

The containment pressure capacity based on the 5-percentile of containment fragility curve is reasonably expected higher than the FLC load because that the former is identified with rather structural capacity perspective and the latter is kind of a conservative load to be considered. Thus, applying the FLC to Containment Pressure of Severe Challenge might result in lowering the allowable containment pressure upper limit in SAMG.

Establishing the containment pressure upper limit lower than the current level may result in the following impacts:

a. The criteria for containment venting will be lowered, leading to the intended release being performed earlier. In some cases, the venting and intended release of fission product should be carried out, despite that the actual containment integrity is maintained. Naturally, the adverse impact on the radiological environment will increase and occur more quickly. Fig. 3 shows the results of example analyses for Large Break Loss of Coolant Accident (LBLOCA) and Loss of Off-site Power (LOOP) scenarios in the OPR1000 plant. According to the example analysis results, containment venting is performed more than 20 hours earlier in each scenario compared to the current practice. Although there may be differences in timing depending on the assumptions of the example analysis, it is highly probable that the timing of containment venting would be brought forward.

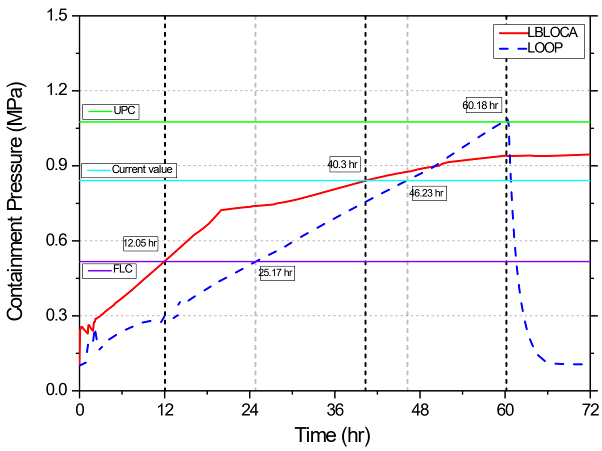

Fig. 3. Containment venting timing based on containmnet limiting pressure

b. The area of 'Hydrogen Severe Challenge' region in Fig. 2 increases, which limits the strategy of containment depressurization using containment spray and containment hydrogen removal using active means such as hydrogen igniters. Fig. 4 shows the changes in the 'Hydrogen Severe Challenge' region based on the change of set-point value for containment pressure capacities. When applying the FLC load, 'Hydrogen Severe Challenge' region, as shown in Fig. 4, will increase significantly. This could lead to the situation that the Ultimate Decision Maker (UDM) fails to perform mitigation actions at the appropriate time due to concerns about potential negative impact for unintended combustion or detonation of combustible gas. Additionally, if the implement of containment depressurization strategies continues to be restricted, even though the appropriate means are available, the SAMG termination may be delayed.

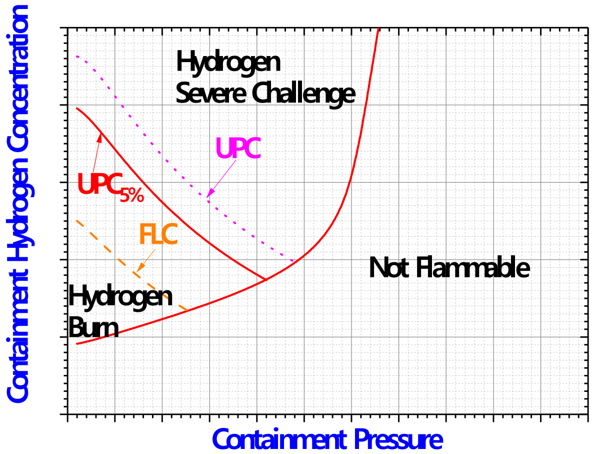

Fig. 4. Hydrogen Severe Challenge region based on containment limiting pressure

4. Conclusion

The impact of applying the set-point based on the FLC for the containment pressure capacity on SAMG was reviewed. Specifically, it was confirmed that the set-point based on the FLC, which decrease the containment pressure capacity compared to the current level, may raise some significant negative impacts. So, in the integrated view point for SAMG, it is judged that the containment pressure capacity should be considered based on practical structural strength rather than FLC value. Recently, RG 1.216 [4] has been applied to domestic nuclear power plants to derive a more reliable containment UPC (ultimate pressure capacity). This new UPC is expected to enhance the effectiveness of SAMG since the maximized utilization of the containment structural capacity would be significantly beneficial for minimizing the environmental effects and enabling the pressure control in implementation of SAMG more flexible in a safe direction. And it should be the right way consistent with the philosophy of SAMG.

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