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Development of Operation Strategy for Hybrid-SIT in SBO

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1. Introduction

The Fukushima accident was not managed properly due to a lack of effective mitigation systems against Station Black Out (SBO) accident [1]. For this reason, development of passive system is suggested as an alternative way for active system because passive system doesn't need external energy source and passive system can also increase the diversity of mitigation technique of Nuclear Power Plant (NPP).

H-SIT is a passive injection system that is newly planned to adjust into the Advanced Power Reactor plus (APR+) [2]. This system is specialized for mitigation of SBO scenarios because it is passive system and it can inject coolant even in high pressure condition. Main function of H-SIT is injection of coolant to the Reactor Coolant System (RCS) in a passive way. The H-SIT system can inject water using the pressure from nitrogen gas as a normal SIT in low-pressure accidents such as large and medium break loss-of-coolant accidents. Additionally, the H-SIT system can inject water using the gravitational force in over-pressure accidents, which means that the pressure is higher than the safety injection pump (SIP) injection pressure. If over-pressure accidents is occurred, pressure of H-SIT is equalized with RCS pressure through equalizing pipe. In APR+, four H-SITs are planned to install. Figure 1 presents the outline of the H-SIT system.

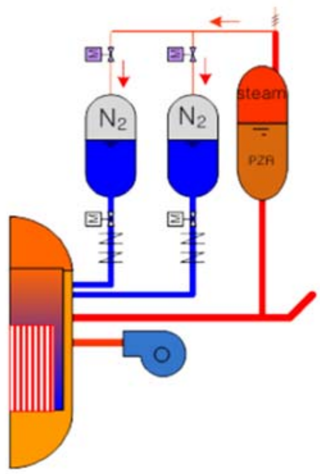

Fig. 1 Outline of H-SIT system [2]

A conventional NPP is mainly composed of active systems; thus, a conventional operating procedure or strategy of SBO are developed to focus on the restoration of electricity. Thus, in order to use the H-SIT system effectively, a new operation procedure is needed. Hence, this study focuses on developing an operation strategy for H-SIT in SBO situation.

2. Methodology

The SBO accident is the one initiated by a total loss of both offside and onsite AC power. Following this accident, the reactor is tripped, main feed water system is terminated, and charging pump is stopped. On the contrary, when water level of Steam Generator (SG) is lower than post trip SG level, Passive Auxiliary Feedwater System (PAFS) is start to work even in SBO accident situation because it is passive system. PAFS has an enough cooling capacity of reactor core by itself in accident situation thus if PAFS works well, operation of H-SIT is not needed. Therefore, use of H-SIT is needed when PAFS is failed. In APR+, standstill seal is applied for preventing seal LOCA thus seal LOCA is no longer considered as a phenomenon in SBO [3].

2.1 Identifying critical factors of H-SIT's operation

Use of H-SIT has a main purpose to remove heat of reactor core thus operation strategy of H-SIT is focused on effective heat removal of core. When PAFS is failed, temperature and pressure of Reactor Coolant System (RCS) are start to increase. If pressure of RCS reaches POSRV open pressure, POSRV is opened and coolant of RCS is released through POSRV in a vapor state because coolant is evaporated in vessel due to pressure down. In that situation, if cold water of H-SIT is injected, RCS can be cooled down because cold water of H-SIT absorb the heat from core and heated coolant. To express this phenomena systematically, heat removal process with H-SIT is expressed by equation.

Firstly, when H-SIT is operated, amount of decay heat generation in unit time is expressed as function of decay heat, w(t). And equation of heat removal is divided into two parts because decay heat is removed by using two mediums in the accident situation. Those are cold water of H-SIT and existing coolant in RCS.

The equation for heat removal from cold water of H-SIT can be expressed as a below. If water of H-SIT injects excessively, all amount of water which is injected is not used for evaporation thus in this equation, α and $β(H_D)$ have to be separated.

$$h_1(t) = α×C×(T_v\text{-}T_0) + β(H_D)×\mu_{fg} \quad (1)$$

h_1= Removed heat from cold water of H-SIT in unit time
α = Mass of injected water of H-SIT in unit time
$β(H_D)$ = Mass of evaporated water of H-SIT in unit time
C = Specific heat
T_v = Evaporating temperature
T_0 = Initial temperature of H-SIT when H-SITs start to injected
H_D = Decay heat in a specific time
μ_{fg} = Vaporization energy

The equation for heat removal from existing coolant in RCS can be expressed as a below. In this study, it is assumed that temperature of existing coolant of RCS when H-SIT operated is same with evaporating temperature thus in thus equation existing coolant is evaporated only.

$$h_2(t) = Δm×\mu_{fg} \quad (2)$$

h_2 = Removed heat from existing coolant in RCS when H-SIT is dried out in unit time.
Δm = changed mass of existing coolant in RCS in unit time
μ_{fg} = Vaporization energy

To prevent core failure, total heat which is generated by core is below than total heat which is removed by water. Therefore, equation is expressed as below.

$$\int_{t_0}^{t_2} w(t) \le \int_{t_0}^{t_1} h_1(t) + \int_{t_1}^{t_2} h_2(t) \quad (3)$$

t_0 = Time when H-SIT starts to operate
t_1 = Time when H-SIT is dried out
t_2 = Time when core is failed

Based on equation (1), (2), (3), four critical factors which are important for developing operation strategy are identified. Those are amount of decay heat and initial temperature of H-SIT, injection mass from H-SIT in unit time and evaporation mass of H-SIT's water.

Amount of decay heat generation when H-SIT is operated is closely related with number of PAFS which are operated. If two PAFSs are all failed, decay heat is high at the time of H-SIT's operation, whereas if two PAFSs work well, decay heat when H-SIT is operated is relatively low. Decay heat generation is also related with operation timing of H-SIT because decay heat is decreased with time thus generally, the latest time is the best for the H-SIT's operation timing.

Initial temperature of H-SIT is one of the important factors because in equation 1, if T_0 increases, T_v-T_0 decrease thus α have to increase in order to satisfy equation (3). If α is increased, total injection time of H-SIT (t_1) decreases because total mass of H-SIT is fixed. That means efficiency of H-SIT decreases due to decreased total cooling time using H-SIT.

Injection mass α and evaporation mass $β(H_D)$ is also important factors because if water of H-SIT is injected excessively (if value of {α - $β(H_D)$} is very high), some amount of water is not used for removing heat of core. It is stuck in other place such as hot leg thus H-SIT cannot removed heat effectively. Therefore, appropriate flow rate of H-SIT have to be found in order to develop operation strategy effectively.

As a result, based on the equations, critical factors of H-SIT's operation are defined as number of PAFSs which are used, operation timing of H-SIT, initial temperature of H-SIT, injection flow rate of H-SIT and evaporation mass of coolant.

2.2 Identification of the best way to inject water in consideration of flow rate of H-SIT

Critical factors are defined in previous section. Among these factors, initial temperature of H-SIT is assumed as a constant and evaporation mass is a decay heat related function thus those are clear to consider for making operation strategy. Control of injection flow rate, however, is difficult to consider because injection flow rate is easily influenced with many variables so it is complex and difficult to apply injection flow rate into operation strategy. Nevertheless, proper injection flow rate have to be found because dry-out time of H-SIT is closely related with amount of injection flow rate. If {α - $β(H_D)$} is close to the zero, injection flow α can be recognized as a proper flow rate as explained above.

2.2.1 Injection flow rate measure analysis

Proper injection flow rate have to be identified for making operation strategy of H-SIT. Identification of proper injection flow, however, has a many difficulties as explained before. For that reason, in this study, consideration points which affect to control of injection flow rate (α) are firstly identified in consideration of the characteristic of H-SIT. Those are size of equalizing pipe, number of H-SITs which are used in a same timing, operation timing of the H-SITs which are operated in a next round, pressure difference between H-SIT and RCS. Generally, identification of injection flow rate is difficult to calculate by hand because all points which are explained before are closely related each other thus in this study, thermo-hydraulic code is used for calculation of injection flow rate.

Identification of injection flow rate also has another difficulty due to many number of consideration points. All those points can be easily changeable by operator thus number of cases which have to be analyzed to identify proper injection flow rate are too many. There are four points for identifying proper injection flow rate. Thus, for example, if five representative variables are existed in each points, number of cases which are needed for analyzing to identify proper injection flow rate can be five to the fourth power. Therefore, it takes many time to calculate the result of all cases by using thermo-hydraulic code. For this reason, some assumptions and flow rate measure concept which is for effective analysis of flow rate setting are suggested in this study.

Firstly, size of equalizing pipe is the constructing variable thus it is not considered when operation strategy of H-SIT. Therefore, inner diameter of pipe is assumed as 1.7in because the pipe which has inner diameter about 1.7in is generally used in nuclear power plant for vapor transport.

Secondly, to limit the analysis cases effectively, flow rate measure concept is suggested in this study.

Flow rate measure concept is the concept to allocate amount of measure to each cases. If we know measure of each case, we can easily predict flow rate approximately by checking measure only without detailed flow rate calculation using code in each case. Flow rate measure is only calculated in consideration of number of H-SITs which are used in same time and operation timing of H-SITs which operate in a next round thus pressure difference is considered separately. Condition of core is not considered thus flow measure can be only used to reduce the number of analysis not for final result. For the final result, code calculation have to be performed. When one H-SIT is used in same time, flow rate measure is calculated as a below.

- H-SIT is operated when level of H-SIT which is operated before is 0% = 1
- H-SIT is operated when level of H-SIT which is operated before is 5% = 1.04
- H-SIT is operated when level of H-SIT which is operated before is 25% = 1.23
- H-SIT is operated when level of H-SIT which is operated before is 50% = 1.6
- H-SIT is operated when level of H-SIT which is operated before is 75% = 2.3

Thirdly, another assumption is that number of H-SITs (b) which is operated in a next round have to smaller than the number of H-SITs which are used in previous round (a) because decay heat decreases continuously thus the number of H-SITs which are operated in the earliest timing has to be the highest. In this way, all measures are calculated as below.

Table 1 Flow rate measure which are calculated by considering number and operation timing of H-SITs

Number of H-SIT (a)	Number of H-SIT (b)	Operation timing	Measure
1	1	0%	1
		5%	1.04
		25%	1.23
		50%	1.6
		75%	2.3
2	2	0%	2
		5%	2.05
		25%	2.28
		50%	2.67
		75%	3.2
	1	0%	1.33
		5%	1.38
		25%	1.6
		50%	2
		75%	2.67
3	1	0%	2
		5%	2.05
		25%	2.29
		50%	2.67
		75%	3.2
4	0	-	4

2.2.2 Identification of the way to inject water

When amount of $\alpha - \beta(t)$ is close to zero, the injection flow rate(α) is called the most optimum flow rate because if $\alpha - \beta(t) = 0$, there is no loss of the coolant. Therefore, the smallest α have to be found if amount of $\alpha - \beta(t)$ is bigger than zero. $\alpha - \beta(t) \leq 0$ means that core is failed. Thus, if $\alpha - \beta(t) \leq 0$, we have to increase the flow rate (α) step by step by changing the way to use H-SIT in this study, based on table of measure, amount of measure is the smallest when one H-SIT is used at same time and the next H-SIT is operated when level of H-SIT which is operated before is 0%. Thus, we have to do analysis using this strategy first then if it is not satisfy with criteria for core failure, the way to inject have to be changed based on the measure of flow rate.

Pressure difference between H-SITs and RCS is also one of main parameters of flow rate as explained before and operation order of H-SIT can mainly affect to pressure difference because length of equalizing pipe is different in each H-SIT. Four H-SITs are installed in APR+ and each H-SIT has equalizing pipe with different length. If H-SIT has short equalizing pipe, amount of pressure drop from POSRV to H-SIT is low. That means pressure difference between H-SIT and core is low. For this reason, injection flow rate will be increased. H-SIT(4) is assumed that it has the shortest equalizing pipe and H-SIT(3), H-SIT(2), H-SIT(1) are in order of length.

Generally, decay heat of core is the highest in the earliest time operation order thus the best operation order is that H-SIT which has the shortest equalizing pipe has first priority. In this study, H-SIT(4) is used first, then H-SIT(3), H-SIT(2), H-SIT(1) is suggested as the best operation order.

2.2.3 Suggestion of the best operation strategy based on the method

Based on the method, the best operation strategy is defined as follow.

In case of decay heat, the lower decay heat is the better thus PAFS operation with two loops is the best situation and operation timing is the best when it is operated as latest as possible.

In case of injection flow rate (α), the less amount of flow is better if $\alpha - \beta(t) \geq 0$ satisfied. The smallest injection rate is existed when one H-SIT is used at same time and the next H-SIT is operated when level of H-SIT which is operated before is 0% theoretically. In this study, however, 5% of water level is the smallest amount which can detected by measuring instrument due to measuring error. Proper flow rate can be calculated by using code in next section.

In case of pressure difference between RCS and H-SITs, the order of H-SIT (4) - H-SIT (3) - H-SIT (2) - H-SIT (1) is suggested as the best operation order.

2.3 Development of operation strategy of H-SIT using code calculation

In this section, the best operation strategy is confirmed by checking results of code. In this study, PAFS is assumed that it has cooling capacity only for 8hours after it starts to operate because 8hours is the time guarantee of PAFS without Passive Condensation Cooling Tank refills [4] and code calculation is stopped when temperature of cladding exceed cladding failure temperature, 1203°C [5]. Analysis cases are divided by considering number of PAFS which are operated in same time for more effective analysis.

2.3.1 The situation in which one PAFS is operated.

In this section, optimal operation strategy is confirmed by using code when one loop of PAFS can be available.

Firstly, analysis by code is performed to find that how many number of H-SITs which is used are the best. This analysis is performed to get core failure time according to the operation number of H-SITs. Operation timing of H-SIT and the timing of H-SIT which is operated in a next round are assumed at the time when POSRV open and at the time when water level of H-SIT which is operated in previous round is 5%. Core failure time is presented in table 2.

Table 2 Core failure time according to operation number of H-SITs

Operation number of H-SITs	Core failure time
Four H-SITs are used at same time	46629s
Three H-SITs are used first then other one H-SIT is used	50711s
Two H-SITs are used first then other two H-SITs are used	51228s
Two H-SITs are used first then other two H-SITs are used individually	53826s
All H-SITs are used individually	55995s

Based on the results of analysis, the operation strategy which is that all H-SITs are used individually (= 1+1+1+1 strategy) makes the core safe for the longest core time. That means 1+1+1+1 strategy is the best for operation number in this conditions. This result is same with result of the method.

Secondly, analysis by code is performed to find that what timing of H-SIT which is operated in a next round is the best. This analysis is performed to get core failure time according to the operation timing of H-SITs. Core failure time is presented in table 3.

Table 3 Core failure time according to operation timing of H-SITs in next round

Operation timing of H-SIT in a next round	Core failure time
When water level of H-SIT which is operated in previous round is 5%	55995s
When water level of H-SIT which is operated in previous round is 25%	54105s
When water level of H-SIT which is operated in previous round is 50%	51833s
When water level of H-SIT which is operated in previous round is 75%	49400s

Based on the results of analysis, the operation strategy which is that H-SIT is operated when water level of H-SIT which is operated in previous round is 5% makes the longest core failure time. That means the time when water level of H-SIT which is operated in previous round is 5% is the best timing in this conditions. This result is same with result of the method.

Thirdly, analysis by code is performed to find that what timing of H-SIT which is operated at first is the best. This analysis is performed to get core failure time according to the operation timing of H-SITs. Core failure time is presented in table 4.

Table 4 Core failure time according to operation timing of H-SITs at first

Operation timing	Core failure time
When PAFS stop	42105s
When SG level is WR25%	42300s
When POSRV open	55995s
Upper plenum level is 50%	56055s
Upper plenum level is 5%	56428s

Based on the results of analysis, the operation strategy which is that H-SIT is operated when upper plenum level of core is 5% makes the longest core failure time. That means the time when upper plenum level of core is 5% is the best timing in this conditions. This result is same with result of the method.

In the case of operation timing, one critical problem exists when H-SIT is operated before POSRV open. That problem is related with T_0 which is explained in section 2.1. T_0 is initial temperature of H-SIT when H-SIT start to operate. When H-SIT is operated before POSRV open, pressure of POSRV decreases dramatically thus water level of POSRV increase a lot. That is reason of full level of POSRV for a long time. For that reason, lots amount of hot water of POSRV transport to H-SIT thus water level of H-SIT is maintained or increased, even though H-SIT keep injecting water to RCS. It is called POSRV over flow. Water level of H-SIT is presented in figure 2.

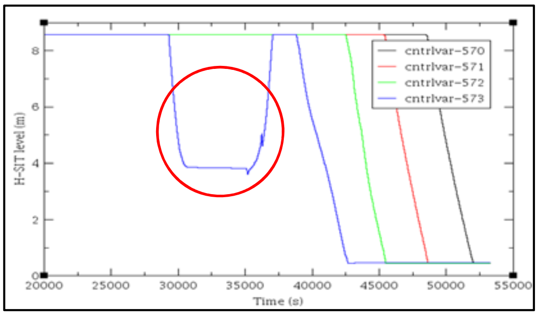

Figure 2 Change of H-SIT level when H-SIT is operated before POSRV open

H-SIT keep injecting water, even though over flow is occurred in POSRV. Problem, however, is that T_0 increase a lot due to hot water from POSRV thus water flow which is injected by one H-SIT cannot satisfy to cool down core in accident situation. Thus situation shows figure 3 which is presented below. Therefore, 1+1+1+1 operation strategy must not be used when H-SIT is operated before POSRV open.

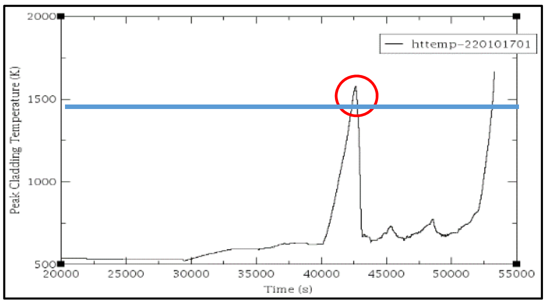

Figure 3 Change of cladding temperature when H-SIT is operated before POSRV open

If 1+1+1+1 operation strategy cannot be used, efficiency of H-SIT decreases a lot. Therefore, operation timing before POSRV open is not recommended in this study.

Fourthly, analysis by code is performed to find that what operation order of H-SIT is the best. This analysis is performed to get core failure time according to the operation order of H-SITs. Core failure time is presented in table 4. In this table, number of H-SIT represents according to the length of equalizing pipe. The H-SIT which has the longest equalizing pipe is named as H-SIT(1).

Table 5 Core failure time according to operation order

Operation order	Core failure time
The H-SITs are operated in the order of length of equalizing pipe (short) (4-3-2-1)	56428s
The H-SITs are operated in the order of length of equalizing pipe (long) (1-2-3-4)	56119s
The H-SITs are operated in the diagonal order (4-1-3-2)	56205s
The H-SITs are operated in the order of distance from failed PAFS (4-2-3-1)	56260s

Based on the results of analysis, the operation strategy which is that operation order is 4-3-2-1 makes the longest core failure time. That means the time when H-SIT is operated in a 4-3-2-1 order is the best operation order in this conditions. This result is same with result of the method.

Additionally, analysis by code is performed to find that how long time can core be endured against failure without injection of H-SIT during the time between dry-out time of previous H-SIT and injection time of next H-SIT. This analysis is performed to get core failure time according to the waiting time of H-SITs. Core failure time is presented in table 4.

Table 6 Core failure time when waiting time is added

Waiting time	Core failure time
+ 5min	56747s
+ 10min	44084s

Based on the results of analysis, only 5 min is allowed for waiting time between dry-out time of previous H-SIT and injection time of next H-SIT. If this strategy is used, core failure time is extended a few more however temperature of core is almost reach to the reference temperature of core failure thus use of this strategy increases probability of the core failure. Therefore, this strategy is unsuitable to apply for operation strategy.

Based on the results by code, we confirm what strategy is the best in SBO accident situation. As a result, when one loop of PAFS is alive, H-SIT is recommended to use operation strategy which is explained as follow. In case of operation number, 1+1+1+1 strategy is the best and first operation timing, the time when upper plenum level is 5% is the best and next operation timing, the time when water level of H-SIT which is operated in previous round is 5% and operation order, 4-3-2-1 is the best.

In case of this situation in which one loop of PAFS alive, minimum injection flow rate is acceptable for the best flow rate because decay heat is not very high. That means this operation strategy is also the best in the condition in which two loop of PAFS are used because decay heat in this condition is much lower than the condition in which on loop of PAFS can be used. Therefore, the condition in which two loop of PAFS are used is not considered as the condition for analysis using code.

2.3.2 The situation in which all PAFSs are failed.

In this section, optimal operation strategy is confirmed by using code when all PAFSs are failed. As the same way of previous section, analysis is performed step by step.

Firstly, analysis by code is performed to find that how many number of H-SITs which is used in same time are the best. This analysis is performed to get core failure time according to the operation number of H-SITs.

Unlike previous analysis, the operation strategy which is that all H-SITs are used individually (= 1+1+1+1 strategy) makes the core failure even though all H-SITs are not dried out because injection flow is very small to remove the decay heat in this condition thus other strategy have to be found based on the injection flow measure which is presented in table 1. If all H-SITs are used individually with operation timing when level of H-SIT is 5%, injection measure is 1.04 thus we start to analyze using the way which has the measure slightly higher than 1.04. For the analysis, few ways are selected; the way that all H-SITs are used individually with operation timing when level of H-SIT is 25%, the way that two H-SITs are used first then other two H-SITs are used individually with operation timing when level of H-SIT is 5%, the way that all H-SITs are used individually with operation timing when level of H-SIT is 50%, the way that two H-SITs are used first then other two H-SITs are used individually with operation timing when level of H-SIT is 25%, the way that two H-SITs are used first then other two H-SITs are used with operation timing when level of H-SIT is 5%. Based on those selection, core failure time is calculated and presented in table 7.

Table 7 Core failure time according to operation strategy which has different flow measure

Operation number and timing of H-SITs (amount of measure)	Core failure time
All H-SITs are used individually with operation timing when level of H-SIT is 5% (1.04)	10346s*
All H-SITs are used individually with operation timing when level of H-SIT is 25% (1.23)	15582s*
Two H-SITs are used first then other two H-SITs are used individually with operation timing when level of H-SIT is 5% (1.38)	8536s
All H-SITs are used individually with operation timing when level of H-SIT is 50% (1.6)	13566s
Two H-SITs are used first then other two H-SITs are used individually with operation timing when level of H-SIT is 25% (1.6)	9222s
Two H-SITs are used first then other two H-SITs are used with operation timing when level of H-SIT is 5% (2.05)	13530s*

Based on the results of analysis, if the measure of the way is lower than 1.5, core is failed failure even though all H-SITs are not dried out because of the low injection flow. Otherwise, if the measure of the way is higher than 1.5, the operation way makes core failure time long and all H-SITs are dried out clearly. As a result, the way that all H-SITs are used individually with operation timing when level of H-SIT is 50% is considered as the best way among many ways

Secondly, analysis by code is performed to find that what timing of H-SIT which is operated at first is the best. This analysis is performed to get core failure time according to the operation timing of H-SITs. Core failure time is presented in table 4. In this analysis, the way that all H-SITs are used individually with operation timing when level of each H-SIT is 25% has the longest core failure time however, in this situation, temperature of core is very unstable. It reaches almost 1100°C even though cladding is not failed because of the small injection flow rate thus it cannot be used as an operation strategy of H-SIT for conservative purpose. The ways which are placed asterisk in the table have a same problem. Therefore, the way that all H-SITs are used individually with operation timing when level of each H-SIT is 50% is selected for operation number and timing.

Table 8 Core failure time according to operation timing of H-SITs at first when all PAFS are failed

Operation timing	Core failure time
When SG level is WR25%	13033s
When POSRV open	13432s
Upper plenum level is 5%	13566s

Based on the results of analysis, the operation strategy which is that H-SIT is operated when upper plenum level of core is 5% makes the longest core failure time. That means the time when upper plenum level of core is 5% is the best timing in this conditions. This result is same with result of the method. If H-SIT is operated before POSRV open, lots amount of hot water of POSRV transport to H-SIT. This phenomenon is same with the condition in which one PAFS is operated. Therefore, H-SIT have to start to use when upper plenum level of core is 5% in this condition also.

Thirdly, analysis by code is performed to find that what operation order of H-SIT is the best. This analysis is performed to get core failure time according to the operation order of H-SITs. Core failure time is presented in table 4. In this table, number of H-SIT represents according to the length of equalizing pipe. The H-SIT which has the longest equalizing pipe is named as H-SIT(1).

Table 9 Core failure time according to operation order when all PAFS are failed

Operation order	Core failure time
The H-SITs are operated in the order of length of equalizing pipe (In the order short) (4-3-2-1)	13566s
The H-SITs are operated in the order of length of equalizing pipe (In the order long) (1-2-3-4)	13485s
The H-SITs are operated in the diagonal order (4-1-3-2)	12840s
The H-SITs are operated in the order of distance from failed PAFS (4-2-3-1)	13458s

Based on the results of analysis, the operation strategy which is that operation order is 4-3-2-1 makes the longest core failure time. That means the time when H-SIT is operated in a 4-3-2-1 order is the best operation order in this conditions. This result is same with result of the method.

Based on the results by code, we confirm what strategy is the best in SBO accident situation. As a result, when all PAFSs are failed, H-SIT is recommended to use operation strategy which is explained as follow. In case of operation number, 1+1+1+1 strategy with operation timing when level of H-SIT is 50% is the best and first operation timing, the time when upper plenum level is 5% is the best and next operation timing, the time when water level of H-SIT which is operated in previous round is 5% and operation order, 4-3-2-1 is the best.

3. Conclusion

In this study, operation strategy of H-SIT in SBO is developed. This operation strategy is divided according to numbers of PAFS which can be used. When one H-SIT is used, H-SIT is recommended to use operation strategy which is explained as follow. In case of operation number, 1+1+1+1 strategy is the best and first operation timing, the time when upper plenum level is 5% is the best and next operation timing, the time when water level of H-SIT which is operated in previous round is 5% and operation order, 4-3-2-1 is the best. Even if one PAFS can be used, the minimum flow of H-SIT can maintain core in normal condition before H-SIT dried out thus if two PAFS can be used, the strategy which is used in the condition one PAFS can be operated is also used as a best operation strategy. When all PAFS are failed, H-SIT is recommended to use operation strategy which is explained as follow. In case of operation number, 1+1+1+1 strategy is the best and first operation timing, the time when upper plenum level is 5% is the best and next operation timing, the time when water level of H-SIT which is operated in previous round is 50% and operation order, 4-3-2-1 is the best.

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