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Optimization Strategy of the APR+ BOP Technical Specifications

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1. Introduction

The BOP is one of the key factors for successful project implementation of NPP. In constructing the APR1400 NPP, the BOP procurement has been one of the biggest concerns. Due to the design changes and increased capacity of equipment in NPP, lots of BOPs should be 'first supplied equipment' [hereinafter, '**FSE**']. The manufacture-ability, and the performances of FSEs have not been fully proved and tested, manufacturers and suppliers are requested to submit Reports for Equipment Qualification Evaluation in accordance with 10 CFR 50.49, IEEE 323. They need at least 1~2 years' tests for Environment Qualification (EQ) and Seismic Qualification (SQ). This study is focused how to prepare the BOP purchase specifications in order to control the FSEs, especially in safety class equipment. With the optimization plan for BOP packages of this study, the FSEs' occurrence can be reasonably controlled as low as possible.

2. APR+ BOP design characteristics

In APR+ design, the passive auxiliary feedwater system (PAFS) and 4-trains safety system concepts, along with the increased capacities in primary & secondary systems, were incorporated. And two emergency diesel generators (EDG) were supplemented. Moreover because safety-related HAVC systems also become 4-trains, the capacities of essential chillers and pumps were also increased 120% and 100% respectively. The increased capacity of APR+ equipment seems to cause lots of FSEs issues in manufacturing and supplying the BOPs in APR+ projects in the future.

Table.1 Examples of expected FSEs in APR+ BOP Design

Sys	BOP	Equipment	APR+ Design Changes
454	New	Hx, Vv	PAFS is newly designed
461	N202/204	Pp/Hx	13.5% ↑ (Hx: 6→8ea)
462	N201	Pp/Flt	23.5% ↑ (Flt: 6→8ea)
473	New	SRS Solidifier	Polymer → Vitrification Sys.
592	M264	AAC	7,200 kW(DG) → 6,500 kW(GT)
611	M251	RCFC	10% ↑
633	M227	Ess. Chiller/Pump	120% ↑ / 100%↑
811	E201	Main TR	7% ↑

3. BOP T/S Optimization Strategy

3.1 BOP Tech. Spec Optimization

In order to optimize BOP packages, the Section 4.0, 'T/S' of BOP package, should have clear criteria with reflecting the change requests & the solutions for the experiences occurred in the APR1400 projects. For this, the following three types of equipment can be considered.

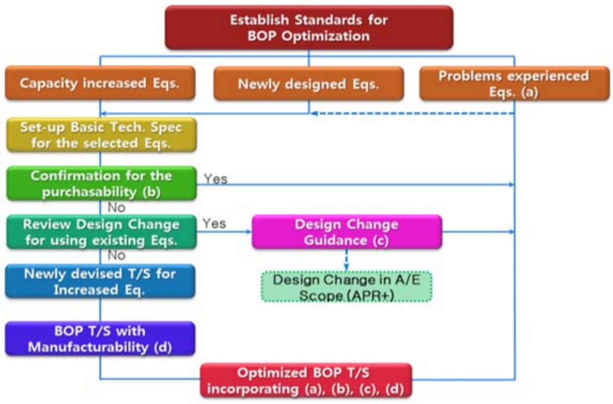

Fig.1 BOP T/S Optimization strategy

First, the equipment of increased capacity. Second, the equipment in the newly designed system. Third, the equipment needs the reflection of the experiences of APR1400 projects. As for the BOPs selected by these criteria, the T/S should be renewed especially in 4.3 (Quality Standard), 4.5 (Design Conditions), 4.6 (Material and Fabrication). For the solutions of the experiences in previous projects should be identified and applied to the BOP T/S [(a) in Fig.1]. In case of the capacity increase of BOP equipment, it should be previewed whether the equipment with increased capacity could be purchased or supplied through BOP suppliers [(b) in Fig.1]. If the equipment is considered difficult in supply, the design should be modified including capacity reduction, multiple installation and so on. The guidelines for detailed design & component design should be derived out [(c) in Fig.1], and provided to A/E. However, unless the design modification is possible, the FSEs design with increased capacity should be considered. The new design shall be reviewed and confirmed the possibility in manufacturing and purchasing through suppliers. And the review result should be applied to the BOP T/S [(d) in Fig.1]. Through these 4-steps, (a) ~ (d), the optimized BOP T/S can be derived out.

3.2 BOP Equipment Qualification Optimization

Equipment Qualification is major concern which makes it difficult for BOP to be supplied in time.

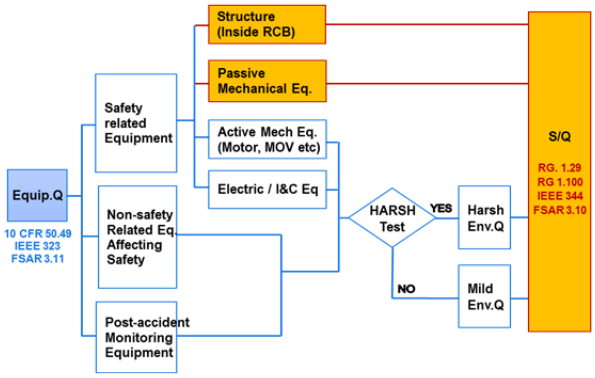

Fig.2 Equipment Qualification Flow chart

The Equip. Qualification is implemented according to the above Fig.2, Environment Qualification (EQ) in accordance with 10 CFR 50.49, IEEE 323, FSAR 3.11 and Seismic Qualification (SQ) with RG. 1.29, RG 1.100, FSAR 3.10, IEEE 344.

Environment Qualification is consisted of Aging Test, DBE Test(LOCA, MSLB, HELB), EMI Test and Final Function Test. However the Thermal/Radiation Aging Test should be taken to cover the qualified life (Plant Life). The test time can be calculated by Arrhenius equation : [$k = A\exp(\frac{-E}{RT})$].

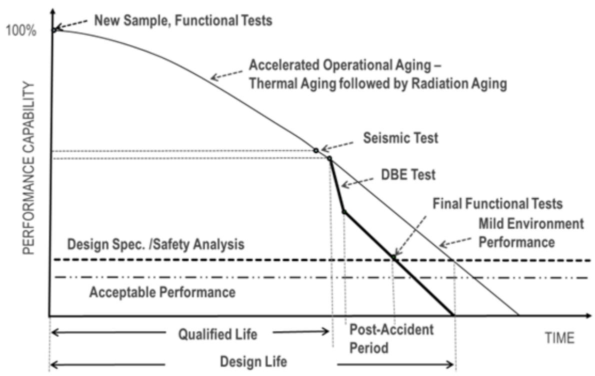

Fig.3 Equipment Qualification for Equipment life cycle.

The total reaction rate (K) during equipment Life (t_L) is : $K = k\,t_L = A\exp[\frac{-E}{RT}]\,t_L = At_L\exp[\frac{-E}{RT}]$

The total accelerated reaction rate (Ka) during the test time(t_a) is equal to the total reaction rate (Ks) during the service time(t_s) : Ks = Ka

$$\frac{t_s}{t_a} = \frac{\exp\left[\frac{-E}{RT_a}\right]}{\exp\left[\frac{-E}{RT_s}\right]} = \exp(\frac{E}{R})(\frac{1}{T_s} - \frac{1}{T_a})$$

k = Chemical Reaction Rate (i.e., Aging Rate)
E = activation energy (eV)
R = Boltzmann Constant (8.62×10^{-5} eV/°K)
T = Temperature (°K) = (273℃ + t℃)

If a silicon element(k= 0.94eV) is tested for EQ, where the plant life is 60 years and normal operation temperature is 40℃, and the temperature of accelerated aging test is 75℃ , then the Thermal Aging Test period can be calculated as the followings:

$$\frac{60}{x} = \exp[\left(\frac{0.94}{8.62\times10^{-5}}\right)\left(\frac{1}{(273+40)} - \frac{1}{(273+75)}\right)]$$

$$\therefore x = \frac{60}{33.25} = 1.805\ (yr) = 659\ (d)$$

Generally, the EQ test requires 1~2 years' period, which is big concern to both owner and suppliers. Therefore, the optimization process for shortening or minimizing the EQ test scope has two steps: (1) Optimizing the (Thermal, Radiation) Aging Test, (2) Optimizing the DBE Test scope.

First, in order to optimize the Aging Test, the EQERs (EQ Evaluation Reports) of all the equipment belonging to EQ items should be reviewed whether its margin could cover the APR+ requirements. The EQERs submitted in previous APR1400 projects are to be listed and controlled through EQMS (EQ Management System).

Second, in order to minimize the DBE Test Scope, new methodologies in P/T analysis in containment and auxiliary bldg. with using latest codes such as RELAP5-ME, CONTEMPT4/MOD3, GOTHIC are under developing now(~2019.5). The analysis result will be used for determining the optimized EQ curve to minimize the BOP EQ test scope as well.

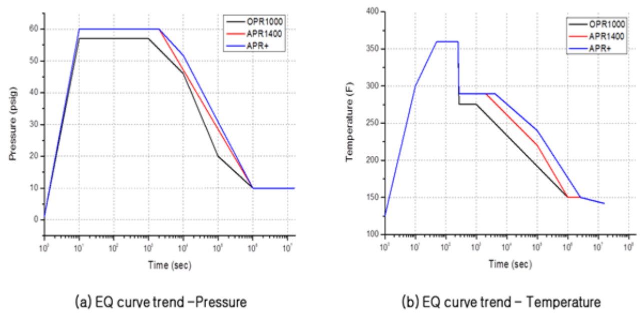

Fig.4 EQ P/T curve trends comparison of OPR1000/ APR1400/APR+

4. Conclusions

For successful NPP project, the concerns in procuring BOPs shall be fully analyzed beforehand. Now Korea is preparing new era of APR+, with closing the time of APR1400. The technical specification of APR+ BOPs can be developed and prepared successfully and very effectively according to this optimization plan. This will be a great contribution not only in constructing APR+ in time, but also in exporting APR+ overseas, all over the world in the future.

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