The comparison of System 1000 analysis and type testing for neoprene gasket environmental qualification

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1. Introduction

The typical environmental qualification is to ensure that equipment will operate on demand to meet system performance requirements during normal and abnormal service conditions. There are four environmental qualification methods, type testing, operating experience, analysis and combined method.

Generally, the American EQ do not contain the mechanical equipments like pumps and valves in their EQ equipments list because their EQ standard 10CFR50.49 limits EQ equipments as electrical equipments. On the other hand, Canadian EQ contain the mechanical equipments like pumps and valves in their EQ components list, Canadians usually call American 'equipments' as 'components', because their EQ standard CSA N290.13-05 do not limits EQ equipments as electrical equipments.

System 1000 program is typical Canadian EQ analysis method using mathematical modeling and comparison with established engineering information and manufacturers' data. Most of Canadian nuclear power utilities like NB Power, Hydro Quebec and OPG use the System 1000 program to evaluate the design life for their EQ components.

To qualify a pump, I had to list all the non-metallic parts in the pump and found there are lots of gaskets made by neoprene material. I tried to qualify these neoprene gaskets by analysis using System 1000 program and by type testing.

In this paper, I'd like to introduce the qualification results of neoprene gasket both type testing and analysis using System 1000 program.

2. Methods and Results

2.1. Qualification factors

The neoprene material is widely used as gaskets in several pumps and valves. Therefore I selected the highest qualification temperature, radiation level and DBE profile.

The normal temperature and radiation level is 56℃ and 87.6rad/year. The accident radiation level is 2.3E+07rad. The target qualified life during the type testing was 40 years. Figure 1 shows DBE profile of both qualification methods.

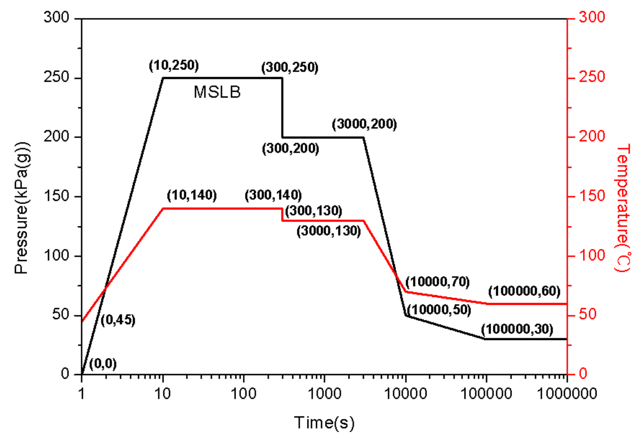

Figure 1. accident temperature and pressure profile

2.2 Design Life calculation result using System 1000 program

System 1000 program is mathematical modeling and comparison program with established engineering information and manufacturers' data. Therefore there are tens of neoprene gasket data made by various manufacturers. In these results, I have to choose the most conservative value. The design life neoprene gasket is calculated as 0.14years as follows; Equations 1 shows the calculation process of the design life.

◎ Design Life Calculation by Temperature Aging

Design Life=(Expected Life-Accident Degradation Equivalency)/3

slope $= \frac{E_a}{K_b}$, (Found on System 1000) =

Int = intercept found on System 1000 =

E_a=Activation Energy (Found on System 1000)

k_B=Stephan Boltzmans Constant=8.617 E−5eV/°K

Properties of NEOPRENE GASKET used in pump			
Elastomer	Slope	Intercept	Activation Energy
NEOPRENE	7527.4	-14.627	0.6486

$$\text{Expected Life} = e^{\left[\left(\frac{\text{Slope}}{\text{Temp(Kelvin)}}\right)+\text{int}\right]}$$

Temperature (°K) = T(℃) + 273

$$\text{ExpectedLife} = e^{\left[\left(\frac{7527.4}{56℃+273}-14.627\right)\right]} = 3837.7259067 \text{ hr} = 0.4380966 \text{ years}$$

⊙ Accident Degradation Equivalency(Temperature Ageing):

To calculate "Accident Degradation Equivalency" (to) we use the accelerated aging form of the Arrhenius equation shown below:

$$T_o = T_s \cdot e^{\left[slope*\left(\frac{1}{T_o}-\frac{1}{T_s}\right)\right]}$$

Where;

T_o = Accident Degradation Equivalency (hours) at reference temperature (normal service temperature) T_o (Kelvin)

T_s = time(hours)at temperature T_s(accident temperature)in Kelvin

Slope = same as above

$$\text{Accident Degradation Equivalency} = T_o = \sum T_{ox}$$

In the following formulas T_o is continuous steady normal service temp:

※ Interval #1(140°C for 300 sec)

$$t_{o1} = \left(\frac{300sec}{3600sec/h}\right) * e^{\left[Slope*\left(\frac{1}{(T(°C)+273)}-\frac{1}{140+273}\right)\right]}$$

t_{o1} = 8.74584 hr = 0.000998 years

※ Interval #2(130°C for 6900 sec)

$$t_{o2} = \left(\frac{6900sec}{3600sec/h}\right) * e^{\left[Slope*\left(\frac{1}{(T(°C)+273)}-\frac{1}{130+273}\right)\right]}$$

t_{o2} = 127.972 hr = 0.0146 years

Total Accident Degradation Equivalency $t_o = t_{o1} + t_{o2}$ = 0.0156 yrs

⊙ Design Life(Temperature Aging):

Design Life = (Expected life-Total Accident Degradation Equivalency)/3

Design Life = (0.4380966 -0.0156)/3 = 0.14083 years

◎ Design Life Calculation by Radiation aging

$$DesignLife(Rad) = \frac{25\%DegradationLevel - AccidentDose}{NormalDose/year} = x \ldots years$$

$$Design\ Life(Radiation) = \frac{1.44 * 10^6 - 1.48 * 10^5}{87.6} = 14710.9773\ years$$

◎ Component Design Life

Design Life(Component)=Min(Design Life (Thermal)) = 0.14083 years,
Design Life (Radiation) = = 14710.9773 years

◎ Device Design Life

Design Life(Device) = 0.14083 years

Equations 1. calculation process of the design life

2.3 Qualification by type testing results.

To qualify the neoprene gasket by type testing, I got two test specimen from nuclear power plant spare parts warehouse, one is to calculate the activation energy and one is to do the testing. Figure 2 shows the test specimen.

The principle function of gasket in valves or pumps is sealing, that is to prevent the fluid in valves or pumps from overflow or leakage through the gasket. Therefore I prepared a zig that 1 can verify if there exist leakage or not. Figure 3 shows the zig components and Figure 4 shows the assembled zig.

Figure 2. Test Specimen

Figure 3. zig components

To verify the gasket is preserving its function, sealing, I prepared leak test equipments composed of air-tank, tubes and pressure gauge. Figure 5 shows the leakage test equipments.

Figure 4. the assembled zig

Figure 5. leak test equipments

To show its sealing ability for 40 years of normal and abnormal conditions, executed all the test steps according to the IEEE std 323, that is normal 40 years thermal & radiation aging, accident radiation aging and abnormal condition(DBE) testing.

During all the test steps, test pressure is determined as 23.75 bar, 1.25 times of its usage pressure 19 bar to give conservatism. Before the type testing, I decided to make it 'pass' if there is no leakage for more than 10 minutes.

For all the pre or post function test of all type testing steps, there was no leakage for more than 10 minutes. As the result of this type testing, the neoprene gasket is qualified for 40 years in the conditions mentioned in 2.1.

3. Conclusions

By the analysis qualification method, using System 1000 program, the design life of the neoprene gasket is calculated as 0.14 year.

The neoprene gasket is type tested according to IEEE Std 323 type testing steps, the function test pressure is determined as 1.25 times of its usage pressure to make it conservative. There was no leakage during all the function tests.

Both analysis and type testing, the results showed very big difference, as the System 1000 program a kind of database, it selects the lowest value of the results derived from various manufacturers' data. To make matters worse, the program divides the calculated design life with safe factor '3' to give more conservatism.

In general, non-metallic parts in mechanical components like o-rings and gaskets, the activation energy is obtained by elongation test even though the gaskets shall never be elongated in the components.

In this test, the gasket is tested in compressed condition through all test steps. It is qualified to be functional for normal 40 years and abnormal conditions if it is not disjointed in compressed condition.

REFERENCES

[1] IEEE Standard 323-2003 "Qualifying Class 1E Equipment for Nuclear Power Generating Stations"

[2] RCM Technology "System 1000 revision 17 user's manual"