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The environmental qualification of non-metallic part of pneumatic valve by System 1000 analysis and type testing

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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.

Canadian EQ(Environmental Qualification) standard is CSA N290.13-05 mentioned about qualification by analysis is possible only there exists mathematical modelling and comparison with established engineering information and manufacturers' data. So in Canada, EQ qualification by analysis alone are used very often whereas American's. American EQ qualification by analysis is usually used with another qualification method like type testing or operation experience.

The typical Canadian environmental qualification method by analysis is using System 1000 program. Most of Canadian nuclear power utilities like NB Power(owns PointLepreau NPP), Hydro Quebec(owns Gentilly-2 NPP) and OPG(owns Pickering & Darlington NPPs) use the System 1000 program to evaluate the design life for their EQ components. This is the difference with American EQ. Type testing method is preferred than qualification by analysis in America.

To qualify a pneumatic valve, I had to list all the non-metallic parts in the valve and found there are lots of seals made by Teflon material. These non-metallic parts also can be qualified by type testing, operating experience, analysis and combined method

In this paper, I'd like to introduce the qualification results of non-metallic parts, especially Teflon seals by analysis using System 1000 program for the design life calculation and by type testing.

2. Methods and Results

2.1. Qualification factors

The Teflon material is widely used as seals in pumps and valves. To qualify conservatively, I selected the highest qualification temperature, radiation level and DBE profile in the design basis accident conditions of a Canadian NPP.

The normal temperature and radiation level is 50℃ and the accident radiation level is 7E+06rads.

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 several Teflon seals data made by various manufacturers. The activation energy of Teflon seal was found in the System1000 program and the most conservative activation energy value is found as 0.9145eV. Figure 1 shows the activation energy of Teflon seal

Figure 1. The activation energy of Teflon seal

The thermal expected life Teflon seal is calculated as follows. Figure 2 shows the thermal design life Teflon seal.

Figure 2. The thermal expected life Teflon seal

The ADE is an abbreviation of Accident Degradation Equivalency, means the degradation equivalent time by

the design basis accident, is calculated as follows. Figure 3 shows the calculated ADE value.

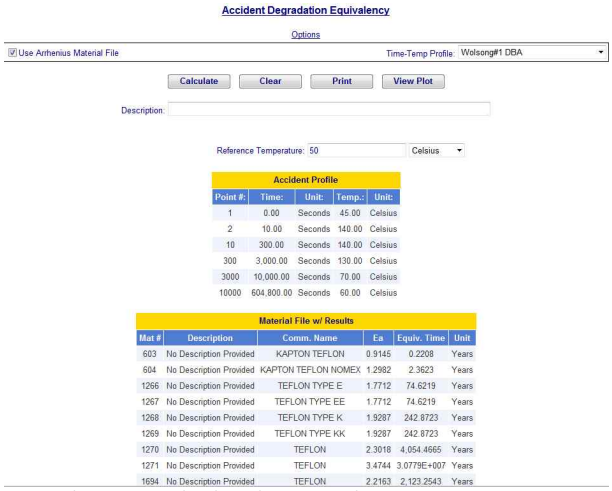

Figure 3. calculated ADE value

The thermal qualified life calculation equation is [(Expected Life – ADE Equiv. Time)/3]. By this equation the thermal qualified life calculation as 8,073years. Table 1 shows the thermal qualified life calculation.

Mat. #	Description	Comm. Name	Expected Life	ADE Equiv. Time	Safety Factor	Qualified Life	Unit
603	-	KAPTON TEFLON	24219.67	0.2208	3	8073.15	Years
604	-	KAPTON TEFLON NOMEX	1.24E+07	2.3623	3	4148199	Years
1266	-	TEFLON TYPE E	4.68E+10	74.6219	3	1.6E+10	Years
1267	-	TEFLON TYPE EE	4.68E+10	74.6219	3	1.6E+10	Years
1268	-	TEFLON TYPE K	2.63E+09	242.8723	3	8.8E+08	Years
1269	-	TEFLON TYPE KK	2.63E+09	242.8723	3	8.8E+08	Years
1694	-	TEFLON	1.88E+12	2123.254	3	6.3E+11	Years

Table 1. the thermal qualified life calculation.

Radiation threshold or 25% degradation level was found in the System1000 program, will be used to calculate the radiation qualified life, the most conservative 25% degradation level is 34000rads. Figure 4 shows the 25% degradation level Teflon seal.

Figure 4. the 25% degradation level Teflon seal

Radiation qualified life is calculated following equation. Equation 1 shows radiation qualified life calculation equation.

$$\text{DesignLife(Radiation)} = \frac{25\%\text{DegradationLevel} - \text{AccidentDose}}{\text{NormalDose/year}}$$

$$= \text{x ... years}$$

Equation 1. radiation qualified life calculation equation

By the Equation 1, radiation qualified life is minus because 25% degradation level is smaller the accident dose, means this material is not strong in radiation condition. So I tried to verify the functional ability of Teflon seals in the same radiation conditions.

2.3 Qualification by type testing results.

To qualify the Teflon seals by type testing, I got two test specimen from commercial shop, one is to calculate the activation energy and one is to do the testing. Figure 5 shows the test specimen.

The principle function of seals in valves or pumps is sealing, that is to prevent the fluid in valves or pumps from overflow or leakage through the seals. Therefore I prepared a zig that 1 can verify if there exist leakage or not. Figure 6 shows the zig components.

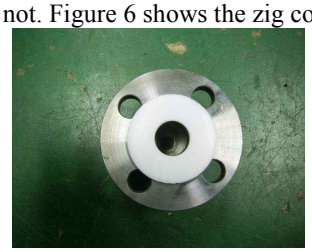

Figure 5. Test Specimen

Figure 6. zig components

To verify the seal is preserving its function, sealing, I prepared a set of leak test equipment composed of N2-tank, tubes and pressure gauge. Figure 7 shows the

assembled zig and Figure 8 shows the set of leakage test equipment.

Figure 7. the assembled zig

Figure 8. leak test equip. set

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 Teflon seal is qualified for 40 years in the conditions mentioned in 2.1.

3. Conclusions

For the mechanical EQ components like pumps and air-operated valves, not for the electrical EQ components, the System 1000 program can be used as qualification method as a kind of "qualification by analysis".

By the analysis qualification method, using System 1000 program, the thermal design life of the Teflon seals was enough but the radiation design life is calculated as minus, means will be weaken in radiation condition.

To compare the environmental sealing ability, Teflon seals 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.

The type test result is 'pass' because there was no leakage during all the function tests.

Both analysis and type testing results showed very big difference, as the System 1000 program is a kind of database, it selects the lowest value of the results derived from various manufacturers' data.

It is more profitable to qualify by type testing than the System1000 analysis if it is not disjointed in compressed condition because the seal is tested in compressed condition through all type testing steps.

REFERENCES

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[4] Hydro-Quebec G2-P-03 "Development of environmental qualification assessment(EQA)"