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° C 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 Arrhenius Query

Add to Material File Run Another Query

							Matt
2	KAPTON TEFLON	POLYIMIDE WITH FLUORINATED ETHYLENE PROPYLENE (FEP)	0.9145	CABLE/WIRE INSULATION	NOT STATED	DUPONT	603
4	KAPTON TEFLON NOMEX	POLYIMIDE FLUORINATED-ETHYLENE PROPYLENE (FEP)-POLYIMIDE AROMATIC	1.2982	CABLE/WIRE INSULATION	NOT STATED	DUPONT	604
7	TEFLON TYPE E	POLYTETRAFLUOROETHYLENE (PTFE)	1.7712	CABLEWIRE	DIELECTRIC	NOT STATED	1285
	TEFLON TYPE EE	FLUORINATED ETHYLENE PROPYLENE (FEP)	1.7712	CABLE/WIRE INSULATION	DIELECTRIC	NOT STATED	1267
7	TEFLON TYPE K	FLUORINATED ETHYLENE PROPYLENE (FEP)	1.9287	CABLE/WIRE INSULATION	DIELECTRIC	NOT STATED	1268
V	TEFLON TYPE KK	FLUORINATED ETHYLENE PROPYLENE (FEP)	1.9287	CABLE/WIRE INSULATION	DIELECTRIC	NOT STATED	1269
N	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	2 3018	PLASTIC	DATA CONVERSION	NOT	1270
7	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	3.4744	PLASTIC	DATA CONVERSION	NOT STATED	1271
7	TEFLON	TAPE, POLYTETRAFLUOROETHYLENE (PTFE)	2.2163	TAPE	FLEXURAL STRENGTH	NOT STATED	1694

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.

Expected/Design Life Calculation

se Ci	urrent Arrhenius File		Servic	e Temperature	Profile test		
			Service Temperature Profile				
	Descrip	tion:					
		Cofety For	ton 2				
		Salety Fac					
		Service Temperature Pro	file:	Servi	ce Temperatur	arature Profile:	
				% (Servi	ce Life) Tempe	rature Units	
				100 00	50.00	C	
		Expect	ted/Design Life				
Mat. (# Description	Comm. Name	Slope	Intercept	Design Life:		
603	No Description Provided	KAPTON TEFLON	10,613.69150452	-12.58824230	24,219.6665	Years	
604	No Description Provided	KAPTON TEFLON NOMEX	15,065.74830512	-20 12968000	1.2446E+007	Years	
1266	No Description Provided	TEFLON TYPE E	20,555.07523199	-28.89147320	4.6838E+010	Years	
1287	No Description Provided	TEFLON TYPE EE	20,655.07523199	-28.89147320	4.6838E+010	Years	
1288	No Description Provided	TEFLON TYPE K	22,382.77401060	-37.42872390	2.6328E+009	Years	
1269	No Description Provided	TEFLON TYPE KK	22,382.77401060	-37.42872390	2.0326E+009	Years	
1270	No Description Provided	TEFLON	26,711.85742238	N/A	N/A	Years	
4774	No Description Provided	TEFLON	40,319.78478851	N/A	N/A	Years	
1211	No Description Provided	TEFLON	25,720.51150000	-41.19084580	1.8811E+012	Years	
1694			Voore				
1694		Select Time Un	it for Grid. Teals				

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

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

				3	Options						
Use Arrhenius Material File							Tir	me-Temp Profi	e: Wolson	g#1 DBA	1.
Desci	iption	Calcula	te	Clear		Print		/iew Plot			
			Reference	Temperatu	ure: 50			Celsius	¥		
				Accie	ient Profil	le					
			Point #:	Time:	Unit:	Temp.	: Unit:				
			1	0.00	Seconds	45.00	Celsius	8			
			2	10.00	Seconds	140.00	Celsius	5			
			10	300.00	Seconds	140.00	Celsius	8			
			300	3,000.00	Seconds	130.00	Celsius	5			
			3000	10,000.00	Seconds	70.00	Celsius	8			
			10000 6	04,800.00	Seconds	60.00	Celsius				
				Material	File w/ R	esults					
	Aat #	Descr	iption	Co	mm. Nam	ie.	Ea	Equiv. Time	Unit		
	603	No Descript	ion Provided	KAP	TON TEFL	ON	0.9145	0.2208	Years		
	604	No Descript	ion Provided	KAPTON	TEFLON	NOMEX	1.2982	2.3623	Years		
	1266	No Descript	ion Provided	TEF	LON TYPE	ΕE	1.7712	74.6219	Years		
	1267	No Descript	ion Provided	TEFL	ON TYPE	EE	1.7712	74.6219	Years		
	1268	No Descript	ion Provided	TEF	LON TYPE	K	1.9287	242.8723	Years		
	1269	No Descript	ion Provided	TEFL	ON TYPE	KK	1.9287	242.8723	Years		
	1270	No Descript	ion Provided		TEFLON		2.3018	4,054.4665	Years		
	1271	No Descript	ion Provided		TEFLON		3.4744	3.0779E+007	Years		
	1694	No Descript	ion Provided		TEFLON		2.2163	2,123.2543	Years		

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 8,073 years. Table 1 shows the thermal qualified life calculation.

			*				
Mat. #	Descripti on	Comm. Name	Expected Life	Expected ADE Equiv. Life Time		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.

Radiation Query

		Add to Material File	Add to Material File Run Another Query				
		Resu	Its Count: 79				
							Matt
23	TEFLON THE	POLYTETRAFLUOROETHYLENE (PTFE)	THRESHOLD at 1.7E4 Rads	PLASTIC	OVERALL PROPERTIES	DUPONT	10
63	TEFLON THE	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 3.4E4 Rads	PLASTIC	OVERALL PROPERTIES	DUPONT	11
E)	TEFLON/ML	POLYTETRAFLUOROETHYLENE (PTFE) POLYIMIDE	THRESHOLD at 1.0E3 Rads	CABLE/WIRE INSULATION	MECHANICAL	DUPONT	45
13	TEFLONML	POLYIMIDE WITH FLUORINATED ETHYLENE PROPYLENE (PEP)	TESTED at 1.0E3 Rads	CABLE/WIRE INSULATION	MECHANICAL	DUPONT	46
83	TEFLON TYPE E/ML	POLYTETRAFLUOROETHYLENE (PTFE) POLYIMIDE	TESTED at 1,0E3 Rads	CABLE/MIRE INSULATION	MECHANICAL	DUPONT	47
1	TEFLONML	POLYTETRAFLUOROETHYLENE (PTFE) POLYIMIDE	TESTED at 0.0E4 Rada	CABLE/WIRE INSULATION	MECHANICAL	DUPONT	48
2	TEFLON FEP/ML	POLYTETRAFLUOROETHYLENE (PTFE) POLYIMIDE	TESTED at 6.0E4 Rads	CABLE/WIRE INSULATION	MECHANICAL	NOT STATED	49
13	TEFLON TYPE E/ML	POLYTETRAFLUOROETHYLENE (PTFE) POLYIMIDE	TESTED at 0.0E4 Reds	CABLE/WIRE INSULATION	MECHANICAL	NOT STATED	60
83	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	77% DAMAGE at 4.8E6 Rada	PLASTIC	ELONGATION	DUPONT	246
23	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	TESTED at 1.0E6 Rads	CABLE/WIRE INSULATION	MECHANICAL	DUPONT	827
E)	KAPTON TYPE HF TEFLON	POLYIMIDE WITH FLUORINATED ETHYLENE PROPYLENE (FEP)	TESTED at 1.0E9 Rads	CABLE/WIRE INSULATION	ELECTRICAL	DUPONT	728
13	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 3.7E4 Rada	PLASTIC	MECHANICAL	DUPONT	2347
83	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 1.2E5 Rads	PLASTIC	TENSILE STRENGTH	DUPONT	2348
63	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 3.4E4 Rads	PLASTIC	ELONGATION	DUPONT	2349
E)	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 4.0E5 Rads	PLASTIC	SHEAR STRENGTH	DUPONT	2350
13	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	25% DAMAGE at 3 665 Rads	PLASTIC	IMPACT STRENGTH	DUPONT	2361
23	TEFLON	POLYTETRAFLUOROETHYLENE (PTFE)	TESTED at 1.0E5 Rada	ELASTOMER	OVERALL PROPERTIES	DUPONT	3677

Figure 4. the 25% degradation level Teflon seal

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

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

= 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 N2tank, 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

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

[2] CSA standard N290.13-05 "Environmental qualification of equipment for CANDU nuclear power plants"

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

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