An approach for implementing Risk-Informed evaluation on Check Valves in Taiwan BWR type Nuclear Power Plant

Graduate School of LungHwa
University of Science and Technology
K.Ting Y.C. Li

Agenda

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- Background
- Objects
- Risk-Informed Analysis
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- Conclusion

Introduction

- Risk-Informed relevant implementations have been utilized throughout Nuclear Industry Since 1994.

- Implementing Risk-informed Inservice Testing, RI-IST ,can be an alternative testing program of current ASME Section BPVC XI and 10 CFR 50.55a.

- Using RI-IST can concentrate testing resources on the High Safety Significance Component (HSSC) 、reduce unnecessary testing burden and achieve cost saving both for the plant’s operation and maintenance under the expectation of nuclear safety.

Background

- BWR and PWR NPPs equip with numbers of Valves and Pumps throughout systems. Current testing program is in accordance with 10CFR50.55a and ASME XI implementing overall test and maintenance.

- Nuclear Industry has gradually incorporated with Performance Based aspect into ASME OM and USNRC R.G.1.174、R.G.1.175 as alternatives for the licensing change basis to the licensee.

- Implementing Risk-Informed relevant implementations can find the vulnerability of plant’s Structure 、System and Component (SSCs). Concentrates testing resource on HSSCs effectively and Achieves the philosophy of defense-In-depth

Objects

- Choosing check valves as objects implement Risk-Informed evaluation for BWR-4 NPP under current IST program.

  - Refers current Regulatory Guide and ASME OM and follows NUREG-1150’s IPE implementing risk assessment.

  - Choosing C.S. unit 1 100 pieces of Check Valves, incorporate current PRA models and traceable maintaining records or data over last decade as evaluation sources.

  - Utilizing WinNupra solves PRA modeled equations for 28 check valves which designed under current PRA and assesses non PRA modeled 72 check valves by using traditional engineering analysis.

- From the evaluating outcome in PRA modeled check valves, classify its safety significance in accordance with NUMARC 93-01 regulation.

- From non PRA modeled 72 CVs, by using traditional engineering analysis, assess its Failure Probability in order to provide failure probability relevant evidence based on the performance based to the licensee.

Risk-Informed Analysis

- Risk-Informed application based upon Quantitative or Qualitative analysis acquiring NPP’S Risk Insight.
- Through the findings of SSCs safety significance, utilizes Deterministic or Probabilistic analysis to conclude final implementation for licensee as licensing change basis.
- This study includes 3 major processes as follow：

Step 1 ：Selecting objects

- Employing current C.S. NPP IST program, defines safety related 100 pieces CVs as evaluation objects.

- Under the definition of current IST program. Check valves can be defined into Type A , B and C three categories.

Step 2：Implementing PRA analysis

- Evaluating Safety Significance and Core Damage Frequence (CDF) from PRA modeled CVs under current IST program - 28 CVs.

- Utilizing WinNUPRA software package solving CVs cutsets.

Step 2： Implementing PRA analysis Cont’

- Risk Achievement Worth (RAW) as measuring indix：

Assuming event i occurred (p=1), the contribution to the total core damage frequency (CDF) defines:

$$RAW_i = Q_i^+ \ / \ Q_{\mathbf{total}} = CDF^+ / CDF_{\mathbf{total}}$$

Q_i^+ defines when the cutsets combination of event i occurred ,the total risk contribution or total CDF contribution. ；Q defines as total cutsets .

- Based on the regulation of NUMARC 93-01 year 2000 version 3, Classifies the safety significance as shown on Table 1. 。

Step 2： Implementing PRA analysis Cont’

- The result of RAW from 28 PRA molded CVs refer as Table 2
- Level 1 Internal Event Total CDF and △CDF contribution result refer as Table 3.
- From the Table 2 result:
  - 10 quarterly test and 4 outage test CVs can be classified into Low Safety Significant Components (LSSCs) due to RAW<2 threshold.
  - 14 quarterly test CVs due to RAW >2; therefore, can be classified into High Safety Significant Components (HSSCs).

Step 3 ： Implementing Traditional Engineering Analysis

- Based on the R.G. 1.175 regulatory requirements, 72 pieces of non PRA molded CVs should be evaluated by traditional analysis in order to proceed qualitative or quantitative assessment.

- Reviewing the performance of 72 non PRA modeled Check Valves from last both 7 outage relevant reports and MMCS.

- Treating these 72 Check Valves as one evaluating group then implementing failure probability analysis by using Statistics.

Step 3 ：Implementing Traditional Engineering Analysis Cont’

- Based on the performance data from last 7 outages: Due to no failure evidence found, confidence limit should be established before implementing failure probability distribution analysis shown as below：

$$P^{+} = 1 – r^{1/n}$$

P^{+} defines the confident upper limit of P; therefore, it has 1-r confident that assures P value smaller then P^{+} 。

Step 3 ：Implementing Traditional Engineering Analysis Cont’

- Each quarterly test and outage test Check Valve under current IST program will be tested 48 times and 8 times over next 10 years.
- Under 99% of confidence level, P+ for quarterly and outage test Check Valves are 9.148E-2 and 4.377E-1.
- Apply P+ values into Binomial distribution of point estimation shown as below for assessing failure probability distribution

$$P(r) = \binom{n}{r} p^{r} (1-p)^{n-r}$$

$r=0,1,\ldots n$

Step 3 ：Implementing Traditional Engineering Analysis Cont’

- With obtained failure probability from Binomial distribution for the quarterly test CVs, the maximum failed probability occurs at 4 times and failed probability value contributes to 2.000E-1 in the next 10 years

- Outage test based Check Valves maximum failed probability occurs at 3 times and failed probability value contributes to 2.634E-1.

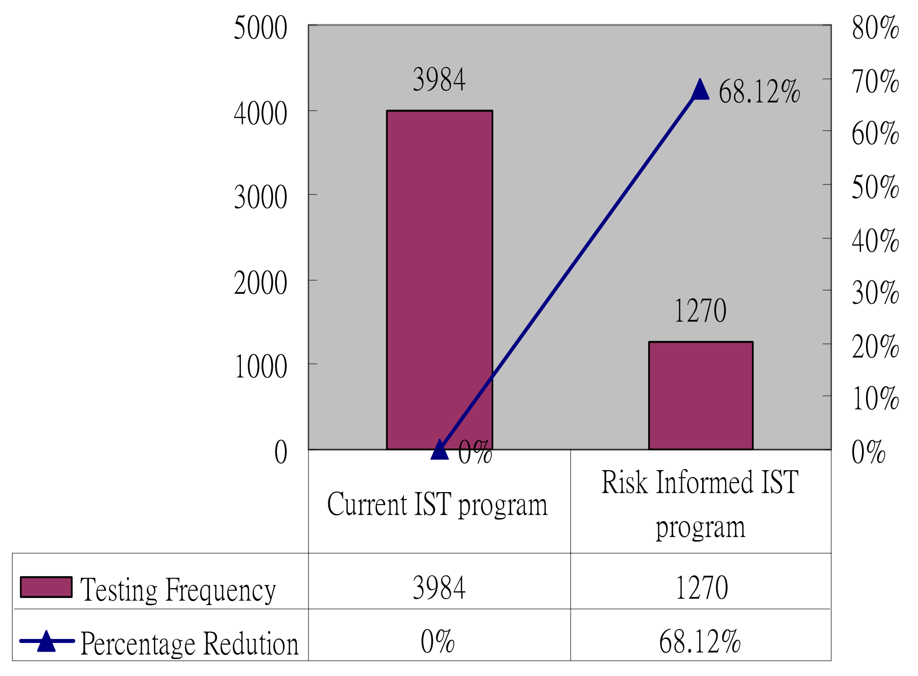
Results

- Safety significance results obtained from the previously analysis, 14 Check Valves can be classified into HSSC and 86 Check Valves can be classified as LSSC:

HSSC	LSSC
14 Pieces **14 quarterly test under current IST program**	**86 Pieces** **66 quarterly test, 18 outage test and 2 pieces without test regulation under current IST program**

- Integrating both PRA modeled and non PRA modeled Check Valves under current IST program, total testing frequency relief recommendation can be reduced from 3984 times down to 1270 times over next decade and reduction percentage up to 68.12% , shown as below:

100CVs	**Testing frequencies**	**Percentage reduction**
Current IST program	**3984**	**0%**
Risk-informed recommendation	**1207**	**68.12%**



	Current IST program	Risk Informed IST program
🟥 Testing Frequency	3984	1270
▲ Percentage Redution	0%	68.12%

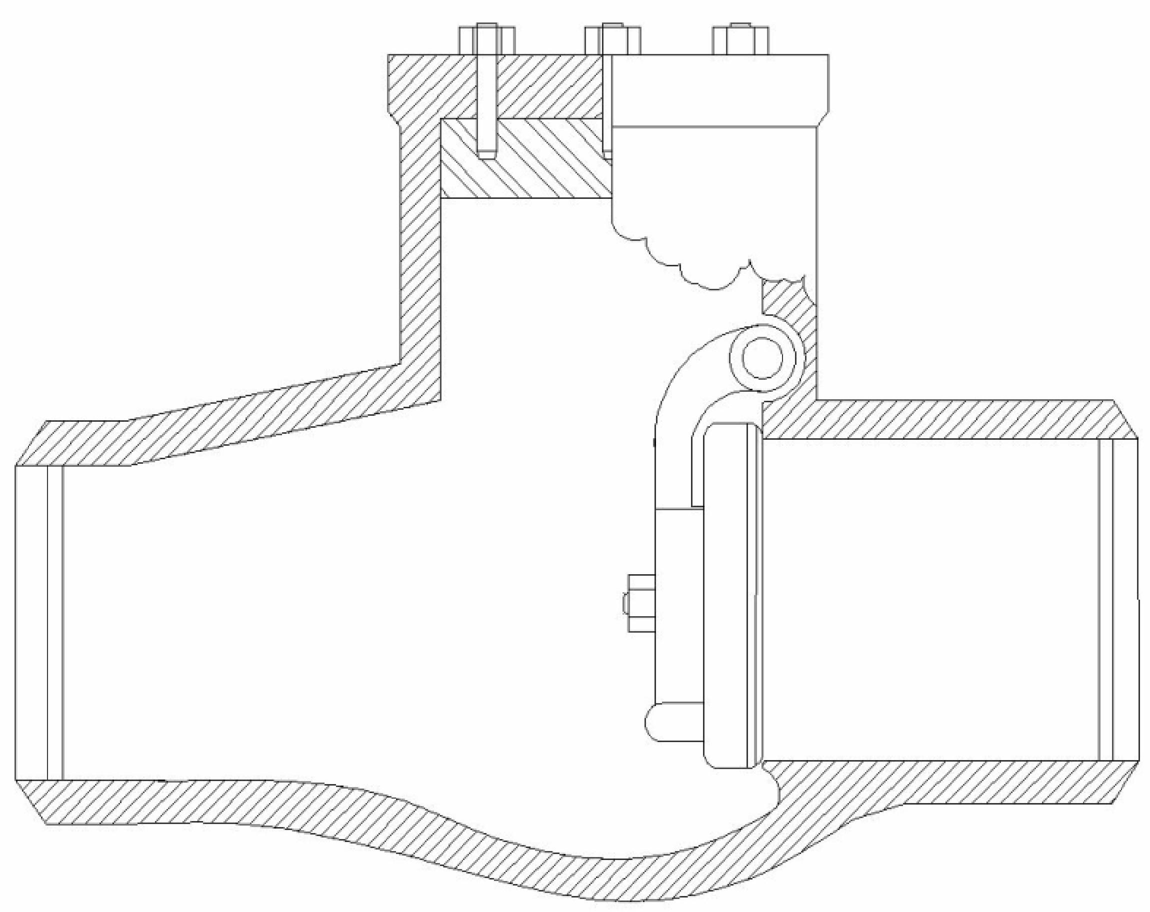
Conclusion

- Based on the traditional analysis result, it can provide licensee to team up Expert Panel implementing further more qualitative assessment for 72 non PRA modeled CVs in order to classy these CVs into HSSC or LSSC category.

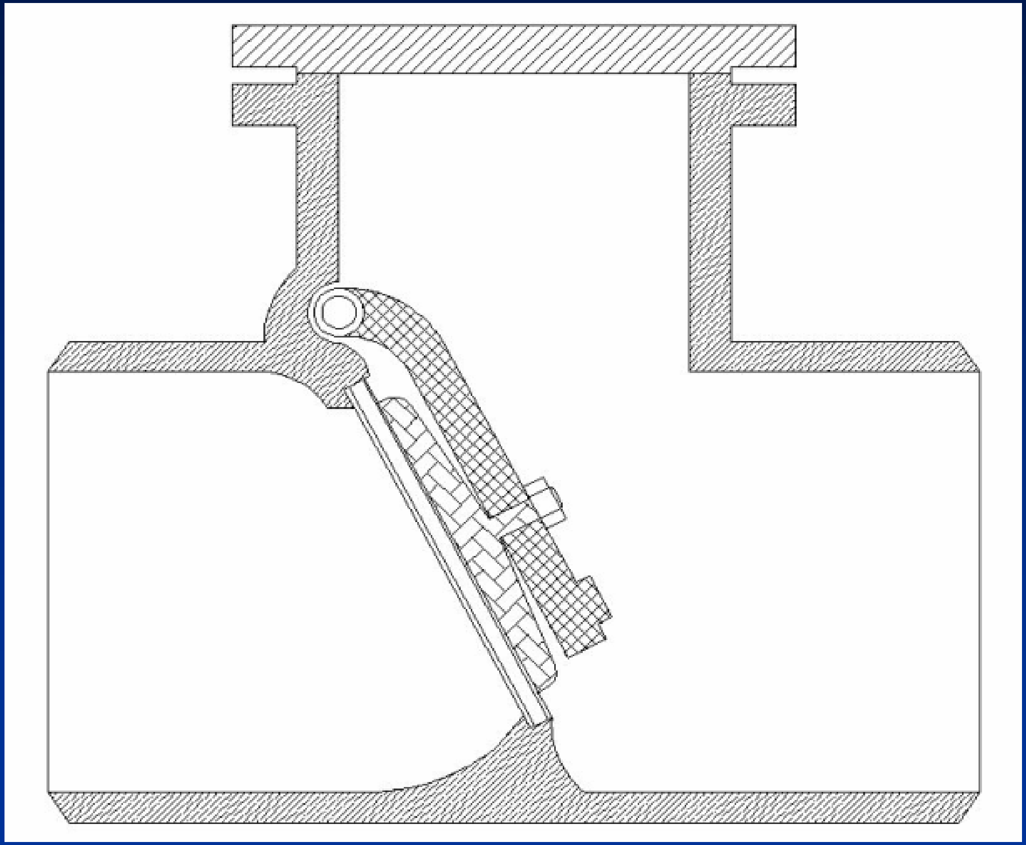
- Verification and Validation process can be determined by Peer Review process in order to meet the requirements from relevant regulatory criteria.

- According to the analysis findings of this study, it can incorporates with 10CFR 50.69 (RISC 1~4) , NUREG-1801 (Aging Lesson learned) and AP-913(Equipment Reliability Process Description) into Risk-Informed evaluation in order to achieve the goal and expectation for RI-IST in the future.

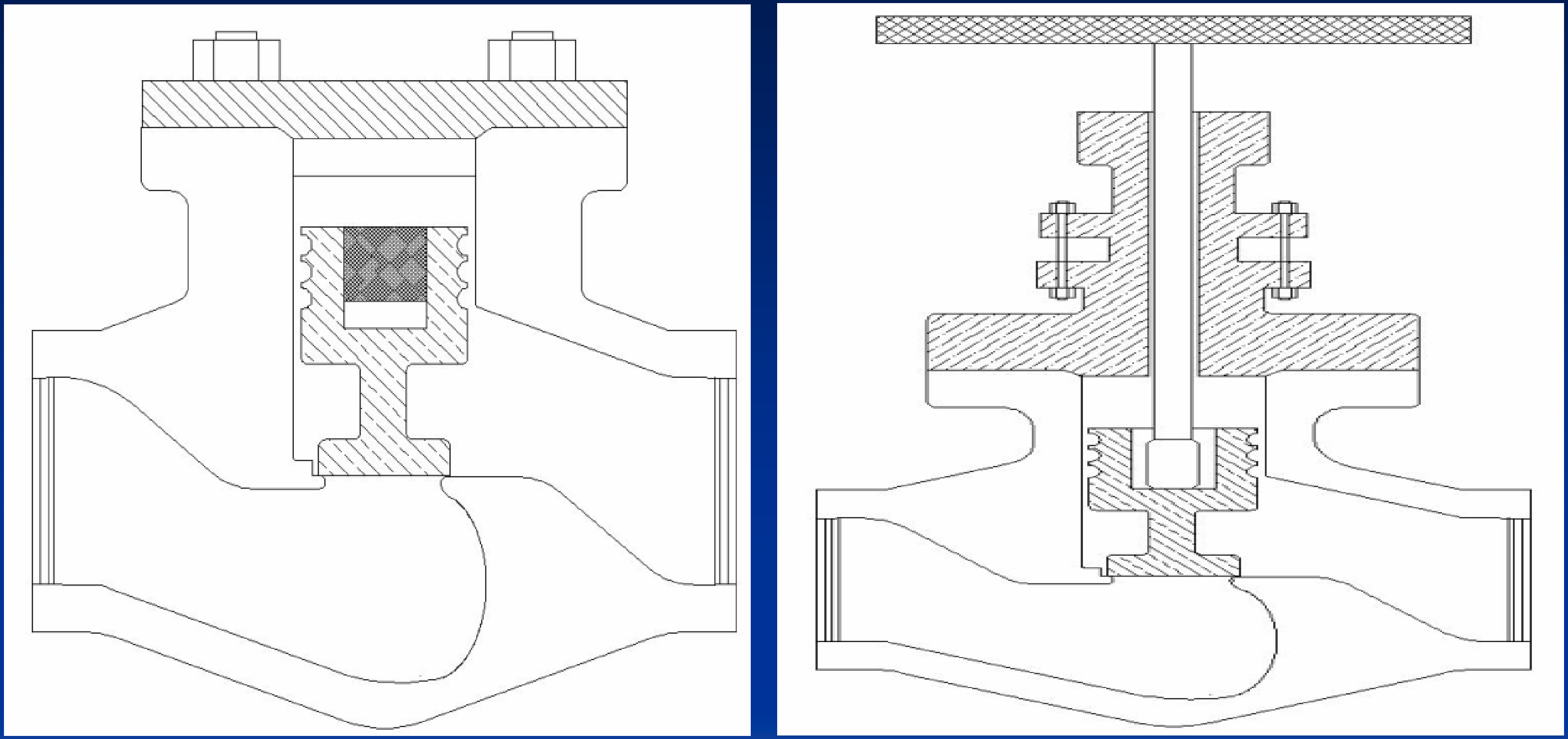
Thank you for your patience and participation



Type A：Swing Check Valve suitable applying on high temperature and pressure pipes.



Type B：Swing Check Valve suitable applying on high temperature and pressure pipes.



Type C ：Global check or Global Stop Check Valves
Same function as Type B CV accompany with stop function

Table 1 NUMARC 93-01 Year 2000 version 3

Risk Significance measuring indices	Classifying standard
Risk Reduction Worth (RRW)	
System Level	>1.05
Component Level	>1.005
Fussel-Vesely importance	
System Level	>0.05
Component Level	>0.005
Risk Achievement Worth (RAW)	
System/Component Level	**>2**

Table2 28 CVs RAW sorting result

CV ID	RAW
CVDNE41-F049	**7.07**
CVDNE41-F077	**7.07**
CVDNE41-F076	**7.07**
CVDNE41-F005	**7.07**
CVDNE41-F019	**7.02**
CVDB104-V-368B	**5.01**
CVDNE51-F011	**4.99**
CVDNE51-F063	**4.99**
CVDNE51-F014	**4.99**
CVDNE51-F064	**4.99**
CVDNE51-F040	**4.99**
CVDA104-V-368A	**4.71**
CVDB104-V283B	**3.69**
CVDA104-V283A	**3.44**
CVDAE11-F005A	**1.64**
CVDBE11-F005B	**1.62**
CVDNE51-F030	**1.62**
CVDNC41-F006	**1.58**
CVDNC41-F007	**1.58**
CVDNE41-F045	**1.47**
CVDAC41-F033A	**1.06**
CVDCE11-F031C	**1.01**
CVDAE11-F031A	**1.01**
CVDBC41-F033B	**1.01**
CVDBE11-F031B	**1.01**
CVDDE11-F031D	**1.01**
CVDAE21-F003A	**1.00**
CVDBE21-F003B	**1.00**

RAW >2 3.44~7.07 14 pieces

RAW <2 1.00~1.64 14 pieces

Table 3 Total CDF and △CDF contribution of 28 CVs

CV ID	Baseline CDF	Total CDF	△CDF
CVDNE41-F049	**3.930 E-06**	**2.780E-05**	**2.387E-05**
CVDNE41-F077	**3.930 E-06**	**2.780E-05**	**2.387E-05**
CVDNE41-F076	**3.930 E-06**	**2.780E-05**	**2.387E-05**
CVDNE41-F005	**3.930 E-06**	**2.780E-05**	**2.387E-05**
CVDNE41-F019	**3.930 E-06**	**2.760E-05**	**2.367E-05**
CVDB104-V-368B	**3.930 E-06**	**1.970E-05**	**1.577E-05**
CVDNE51-F011	**3.930 E-06**	**1.960E-05**	**1.567E-05**
CVDNE51-F063	**3.930 E-06**	**1.960E-05**	**1.567E-05**
CVDNE51-F014	**3.930 E-06**	**1.960E-05**	**1.567E-05**
CVDNE51-F064	**3.930 E-06**	**1.960E-05**	**1.567E-05**
CVDNE51-F040	**3.930 E-06**	**1.960E-05**	**1.567E-05**
CVDA104-V-368A	**3.930 E-06**	**1.850E-05**	**1.457E-05**
CVDB104-V283B	**3.930 E-06**	**1.450E-05**	**1.057E-05**
CVDA104-V283A	**3.930 E-06**	**1.350E-05**	**9.570E-06**

Table 3 Total CDF and △CDF contribution of 28 CVs Cont’

CV ID	Baseline CDF	Total CDF	△CDF
CVDAE11-F005A	3.930 E-06	6.440E-06	2.510E-06
CVDBE11-F005B	3.930 E-06	6.380E-06	2.450E-06
CVDNE51-F030	3.930 E-06	6.350E-06	2.420E-06
CVDNC41-F006	3.930 E-06	6.200E-06	2.270E-06
CVDNC41-F007	3.930 E-06	6.200E-06	2.270E-06
CVDNE41-F045	3.930 E-06	5.790E-06	1.860E-06
CVDAC41-F033A	3.930 E-06	4.170E-06	2.400E-07
CVDCE11-F031C	3.930 E-06	3.960E-06	3.000E-08
CVDAE11-F031A	3.930 E-06	3.960E-06	3.000E-08
CVDBC41-F033B	3.930 E-06	3.950E-06	2.000E-08
CVDBE11-F031B	3.930 E-06	3.950E-06	2.000E-08
CVDDE11-F031D	3.930 E-06	3.950E-06	2.000E-08
CVDAE21-F003A	3.930 E-06	3.930E-06	0.000E+00
CVDBE21-F003B	3.930 E-06	3.930E-06	0.000E+00

Failure probability of quarterly test CV over next decade

C.L. Failure time	99%	95%	90%	85%
1	4.833E-02	1.546E-01	2.359E-01	2.903E-01
2	1.144E-01	2.339E-01	2.724E-01	2.750E-01
3	1.766E-01	2.310E-01	2.052E-01	1.700E-01
4	2.000E-01	1.673E-01	1.135E-01	7.710E-02
5	1.773E-01	9.483E-02	4.906E-02	2.735E-02
6	1.279E-01	4.377E-02	1.728E-02	7.902E-03
7	7.728E-02	1.691E-02	5.094E-03	1.911E-03
8	3.988E-02	5.582E-03	1.283E-03	3.949E-04
9	1.785E-02	1.598E-03	2.802E-04	7.076E-05
10	7.009E-03	4.013E-04	5.370E-05	1.113E-05
:	:	:	:	:
45	2.361E-43	2.171E-51	2.251E-56	4.568E-60
46	1.550E-45	9.117E-54	7.214E-59	1.201E-62
47	6.643E-48	2.498E-56	1.508E-61	2.060E-65
48	1.394E-50	3.352E-59	1.544E-64	1.730E-68

Failure probability of outage test CV over next decade

C.L. Failure time	99%	95%	90%	85%
1	6.223E-02	1.817E-01	2.668E-01	3.211E-01
2	1.696E-01	2.888E-01	3.115E-01	3.008E-01
3	2.634E-01	2.624E-01	2.078E-01	1.610E-01
4	2.568E-01	1.490E-01	8.662E-02	5.386E-02
5	1.599E-01	5.413E-02	2.310E-02	1.153E-02
6	6.223E-02	1.230E-02	3.854E-03	1.543E-03
7	1.384E-02	1.595E-03	3.672E-04	1.180E-04
8	1.346E-03	9.059E-05	1.531E-05	3.947E-07