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Component Analysis of Purification System of RSG-GAS

Mike Susmikanti*[1], Entin Hartini[1], Aep Saepudin[2], Jos Budi Sulistyo[3]
[1]Center for Nuclear Reactor Technology and Safety, [2]Center for Multipurpose Reactor, [3]Center for Nuclear Facilities Engineering, BATAN, Kawasan Puspiptek, Serpong, Tangerang Selatan, Indonesia, 15310

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ABSTRACT

COMPONENT ANALYSIS OF PURIFICATION SYSTEM OF RSG-GAS. Component reliability analysis is required in the aging management of RSG-GAS that has reached an age of 30 years. One of the required analyses is the assessment of the distribution of repair data and the estimation of related parameters. The Primary Purification System (KBE01) and the Purification and Warm Water Layer System (KBE02) are important components of RSG-GAS. By knowing the repair data distribution, the parameters of the most frequently occurring component repair and the average of the repair period can be estimated, so that the required provision of spare parts for the smooth operation of the reactor can be predicted. The purpose of this study is to analyze the components of the KBE01 and KBE02 systems through the data distribution approach using the matching test method. With the matching test, the form of data distribution can be determined, so the parameter of the average component repair period that can be used as a comparison of the maintenance period of the components can be estimated. The repair times of KBE01 and KBE02 in RSG-GAS on Core 52 through Core 88 (2006-2015) were analyzed using goodness-of-fit test. The repair times of AA068 and AP001 KBE01 follow the exponential distribution with average repair times of 631.6 and 451.2 days, respectively. The repair times of WWL and AA002 KBE02 followed an exponential distribution with average repair times of 239.5 days and 888.0 days.

ABSTRAK

ANALISA KOMPONEN SISTEM PEMURNIAN DARI RSG-GAS. Analisis keandalan komponen diperlukan dalam manajemen penuaan RSG-GAS yang mencapai 30 tahun. Salah satunya adalah mengkaji sebaran data perbaikan dan pendugaan parameter terkait. Sistim Purifikasi Primer (KBE01) serta Sistim Purifikasi dan Lapisan air hangat (KBE02) merupakan komponen penting di RSG-GAS. Dengan mengetahui sebaran data perbaikan maka dapat diestimasi parameter perbaikan komponen yang paling sering muncul dan rata rata masa perbaikan sehingga dapat diprediksi penyediaan suku cadang untuk kelancaran operasi reaktor. Tujuan penelitian ini melakukan analisis komponen sistem KBE01 serta KBE02 melalui pendekatan sebaran data menggunakan metoda uji kecocokan. Dengan uji kecocokan dapat diketahui bentuk sebaran data, sehingga dapat diestimasi parameter rata-rata masa perbaikan komponen yang dapat digunakan sebagai perbandingan terhadap masa perawatan. Waktu perbaikan KBE01 dan KBE02 RSG-GAS pada Core 52 hingga Core 88 (2006-2015) dianalisis menggunakan uji goodness-of-fit. Waktu perbaikan AA068 dan AP001 KBE01 mengikuti distribusi eksponensial dengan rata-rata waktu perbaikan masing-masing adalah 631,6 dan 451,2 hari. Waktu perbaikan WWL dan AA002 KBE02 mengikuti distribusi eksponensial dengan rata-rata waktu perbaikan masing-masing adalah 239,5 hari dan 888,0 hari.
Kata kunci: Analisis Keandalan, Manajemen Penuaan, Struktur Sistem Komponen Sistem Purifikasi Primer Sistem, Lapisan Air Hangat, Reaktor RSG-GAS

1. INTRODUCTION

The RSG-GAS research reactor has reached an age of 30 years. The RSG-GAS has many systems with many components. Reliability analysis of each component is needed in aging management of RSG-GAS. The aging management of RSG-GAS includes repair and maintenance activities over a period of time.

Revisions and updates are performed every five years for the document "Safety Analysis Report (SAR) RSG-GAS"[1]. An evaluation of system availability based on RSG-GAS component reliability has been conducted by data envelopment analysis (DEA)[2]. A report of RSG-GAS reactor operation has been written for Core 53 up to Core 88[3]. In addition, the results of the evaluation of the operation of nuclear power plants has been reviewed by the IAEA[4]. A modeling of degradation level of digital system and component intrumentation and control system based on Multi-State Physics

*Correspondence author.
E-mail: mike@batan.go.id

modeling approach has been performed[5]. Safety Classification of Systems, Structures, and Components for Pool-Type Research Reactors Nuclear Engineering has been evaluated[6]. Currently, the RSG-GAS component database system that has been created has not been used optimally to assess the reliability of each component. The prototype of the RSG-GAS reactor operation database system for systems and components has been made for system and component repair[7]. We have analyzed the reliability of the network component distribution based on the failure database[8]. The maximum entropy principle has applied to the annual wind speed probability distribution[9]. The speed and source of extreme wind energy are analyzed by the estimation method[10]. Furthermore, wind velocity modeling has been done with the application of four distribution probabilities[11]. Another work explored the distributionally robust method to estimate exceedance probabiliities[12].

One of the reliability analyses performed is the examination of how model data distribution and parameter estimation are related. Two of the most important systems of RSG-GAS are the Primary Purification System (KBE01) and the Warm Water Layer Purification System (KBE02) For each component in this system, there is a possibility of damage that necessitates repair. To anticipate the requirements of provision of component parts to ensure the smooth operation of the reactor, it is necessary to analyze the distribution of repair data so that some parameters of the requirements of components for repairs can be estimated.

The purpose of this research is to analyze the reliability of components in the Primary Purification System of KBE01 and the Purification and the Warm Water Layer System KBE02 at RSG-GAS through data distribution approach using reliability and survival method. With this method the data distribution of each component can be known, so that the average of repair period component can be estimated.

A component reliability analysis of the database system based on RSG-GAS operation activities has been conducted for data for 10 years starting from Core 52 (2006) to Core 88 (2015). The data used include core data, system code, component code, repair date, repair type, completed repair and description. Reliability studies were performed for the KBE01 and KBE02 system components. Reliability analysis was performed by probability distribution fitting for the most commonly-repaired components.

2. THEORY

In relation to the RSG-GAS management activities, it is essential that the operation of the data collection system is well-documented. RSG-GAS has the structure, system and components (SSC). The operation parameters for each SSC can be accessed by authorized parties online. The use of web-based database system is expected to facilitate the acquisition and tracking of data and information quickly and easily.

The primary cooling water purification system KBE01 is intended to extract activation products and mechanical impurities from the reactor pool water and maintain the quality of the primary coolant at a specified level. This is important for limiting radiation levels in operating halls and installation rooms as well as providing clean water in reactor ponds[1].

The refrigeration system and the warm water layer of the pool KBE02 provide a purified warm water layer on the surface of the reactor pool at temperatures slightly higher than the pool temperature to prevent the rise of activated impurities into the pond surface. This system provides water filling and flushing on neutron beam tubes. The purification system and the warm water layer consists of pumps, mechanical filters, and ion exchangers The system is equipped with a heater with a maximum thermal capability of 180 kW which allows the quality and activity of the warm water layer to be determined[1].

Time To Failure (TTF) is the predicted time between failures of a component as expressed in equation (1).

$$TTF = T_i - T_{i-1} \tag{1}$$

where: T_i is the time a particular failure occurs/a particular repair becomes needed;

and T_{i-1} is the time the previous failure occurred/the previous repair became necessary.

Continuous distributions of data include exponential, Weibull, normal, and lognormal distributions, among others. The exponential probability distribution has a probability density function (pdf) as expressed in equation (2),

$$f(x) = \lambda \exp(-\lambda x) \text{, x>0} \quad (2)$$

The cumulative distribution function (cdf) is expressed in equation (3),

$$F(x) = 1 - e^{-\lambda t} \quad (3)$$

The average value, or expected value, E(x) for the exponential distribution is expressed in equation (4),

$$E(x) = \frac{1}{\lambda} \quad (4)$$

The pdf of Weibull distribution is expressed in equation (5),

$$f(x) = \frac{\beta}{\eta}(\frac{x}{\eta})^{\beta-1} \exp[-(\frac{x}{\eta})^{\beta}] \text{ x>0}, \eta, \beta \geq 0 \quad (5)$$

The Weilbull cdf is expressed in equation (6),

$$F(x) = 1 - \exp[-(\frac{x}{\eta})^{-\beta}] \quad (6)$$

The average value E(x) for the Weilbull distribution is expressed in equation (7),

$$E(x) = \eta x \, \Gamma(\frac{1}{\beta} + 1] \quad (7)$$

The pdf of the normal distribution is expressed in equation (8),

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp(-\frac{1}{2})(\frac{t-\mu}{\sigma})^2) \text{ ,x>0}, \eta, \beta \geq 0 \quad (8)$$

The cdf of the normal distribution is expressed in equation (9),

$$F(x) = \Phi(z) = \Phi(\frac{x-\eta}{\sigma}) \quad (9)$$

Equation (10) represents the average of the normal distribution,

$$E(x) = \eta \quad (10)$$

The pdf of lognormal distribution is expressed in equation (11),

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp(-\frac{1}{2})(\frac{\ln t - \mu_x}{\sigma_x})^2) \quad (11)$$

The cdf of lognormal is expressed in equation (12),

$$F(x) = \Phi(z) = \Phi(\frac{\ln a - \eta_x}{\sigma_x}) \quad (12)$$

Its average value is expressed in equation (13).

$$E(x) = \eta \quad (13)$$

3. METHODOLOGY

This research includes recording of component type and RSG-GAS system based on Kern Kraft Cheighmungen System (KKS). The classification of system types including KBE01 and KBE02 systems is shown in Table 1.

Table 1. The Classification of KKS KBE System Components

Classification	Classification Name
A	Unit including drive
AA	valves/slide valves
AC	Heat exchanger
AH	Heating and Cooling Units
AP	Pumping Units
C	Direct Measuring Circuit
CF	Flow Rate
CP	Presure
CR	Radiation values
CT	Temperature

The components code of KBE01 and KBE02 systems are shown in Tables 2 and 3.

Repair data for Cores 52 through 88 was collected and an SQL program to search KBE01 and KBE02 system component data was creaated.

Calculation of repair frequency and analysis of data distribution and goodness-of-fit or probability distribution fitting were performed for four distributions, i.e., exponential, Weilbull, lognormal, and normal. The subsequent parameter estimation of each distribution covers the mean value, standard deviation, parameter range and P-value distribution match value.

Table 2. KBE01 Component Codes

Component Codes	Component Name
AP01	Heater
AA 068	Pompa/Pump
CR 001	Pompa/Pump
AA 013	Shut of valve
AP 002	Shut of valve
AA 003	Radiation values
AA 010	Radiation values
AA 019	Shut of valve
AA 018	Flow Rate
AA 067	Shut of valve
CR 002	Shut of valve

Table 3. KBE02 Component Codes

Component Codes	Component Name
WWL	Warm Layer System
AH 001	Heater
AP 002	Pompa/Pump
AP 001	Pompa/Pump
AA 002	Shut of valve
AA 011	Shut of valve
CR 002	Radiation values
CR 001	Radiation values
AA 008	Shut of valve
CF 003	Flow Rate
AA 023	Shut of valve
AA 024	Shut of valve
AA 062	Shut of valve
CT 001	Temperature
CT 002	Temperature
CP 003	Presure

P-value is a calculated statistic using Anderson Darling method. The P-value indicates goodness-of-fit test for the distribution of data which are expected. This value indicates whether it is receiving or rejection area of the initial hypothesis. The initial hypothesis is assumed that the distribution is as expected. The P-value should be in the range of greater than α and maximum is $(1-\alpha)$. α is a level of significance. The value $(1-\alpha)$ is dependent on the level of confidence which are given. The two sided area of all probability value is 0.5. For optimality of the goodness of fit, the P-value should greater than 0.5.

4. RESULT AND DISCUSSION

Repair data obtained from Core 52 to 88 are shown in Table 4 according to KBE01 component code and repair frequency.

Table 4. Frequency of KBE01 Component Repair

No	Component Codes	Frequency
1	AP 001	10
2	AA 068	6
3	CR 001	4
4	AA 013	4
5	AP 002	2
6	AA 003	2
7	AA 010	1
8	AA 019	1
9	AA 018	1
10	AA 067	1
11	CR 002	1

The repair frequencies of KBE01 Core 52 to 88 in Table 4 are shown in the bar diagram in Figure 1.

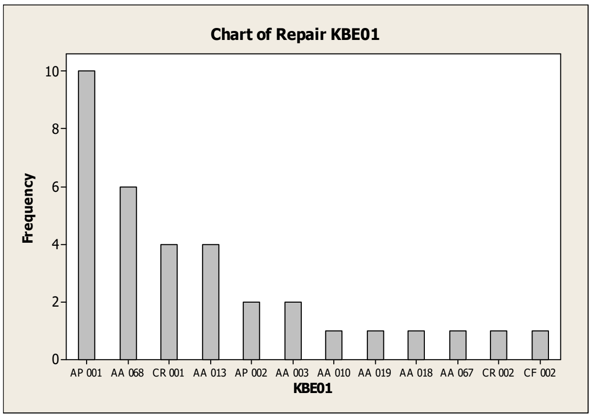

Figure 1. Frequency Diagram of KBE01.

The most common repair data are those for AP001, AA068, CR001, and AA013. Other components are not analyzed because they do not meet the requirements of the sample.

AP001 repair data and TTF value from Eq. 1 are shown in Table 5.

Table 5. TTF Value of Improvement for AP001

Core	Repair Done	TTF (days)
52	12/02/2004	0
59	23/01/2007	1076
65	6/07/2008	530
71	01/04/2010	634
80	21/09/2012	904
85	16/01/2014	482
85	06/02/2014	21
85	25/04/2014	78
86	21/07/2014	87
87	03/02/2015	197

AA068 repair data and TTF values from Eq. 1 are shown in Table 6.

Table 6. TTF Value of Improvement for AA068

Core	Repair Done	TTF (days)
54	18/08/2005	0
66	11/02/2009	1273
71	08/06/2010	482
74	28/01/2011	234
85	24/02/2014	1123
85	01/04/2014	36

CR001 repair data and TTF values from Eq. 1 are shown in Table 7.

Table 7. TTF Value of Improvement for CR001

Core	Repair Done	TTF (days)
56	20/03/2006	0
58	09/08/2006	142
59	16/12/2006	129
60	16/02/2007	62

AA013 repair data and TTF values use Eq. 1 are shown in Table 8.

Table 8. TTF Value of Improvement for AA013

Core	Repair Done	TTF (days)
67	18/05/2009	0
85	24/04/2014	1802
85	13/05/2014	19
86	4/07/2014	52

Through the distribution approach using reliability and survival probability distribution in Minitab by Anderson's test method, obtained were the P-values of AP001, AA068, CR001 and AA013 components, respectively, for exponential, weibull, lognormal, and normal distributions.

Exponential distribution probabilities are shown in Figure 2.

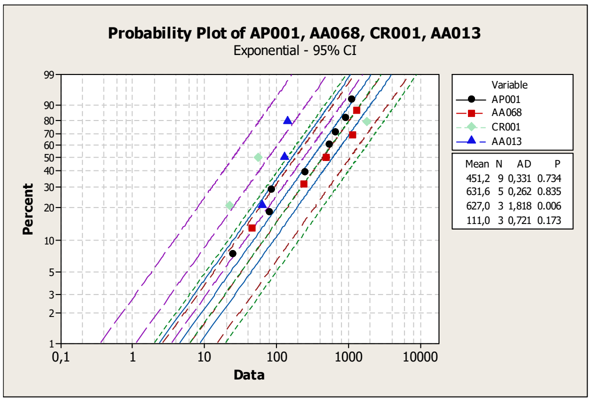

Figure 2. Plots of Exponential Spreads AP001, AA068, CR001 and AA013.

The P-values of the components of AP001, AA068, CR001, AA013 of the lognormal distribution are shown in Figure 3.

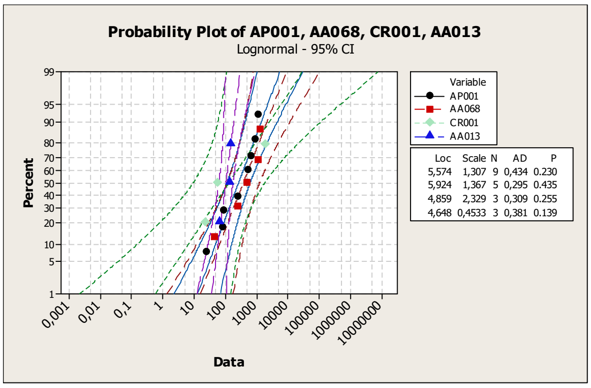

Figure 3. Plots of Lognormal Spreads AP01, AA068, CR001 and AA013.

The P-values of the components of AP001, AA068, CR001, AA013 of the normal and Weibull distributions are shown in Figure 4 and 5.

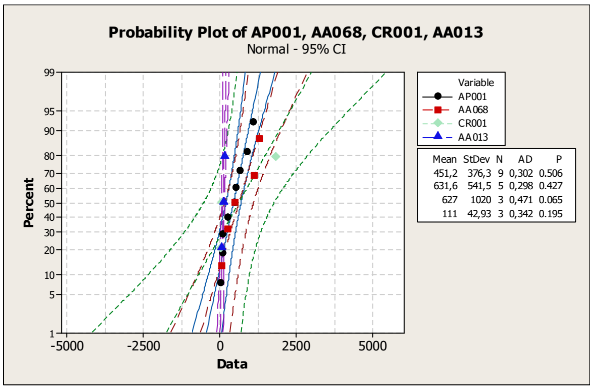

Figure 4. Plots of Normal Spreads AP001, AA068, CR001 and AA013

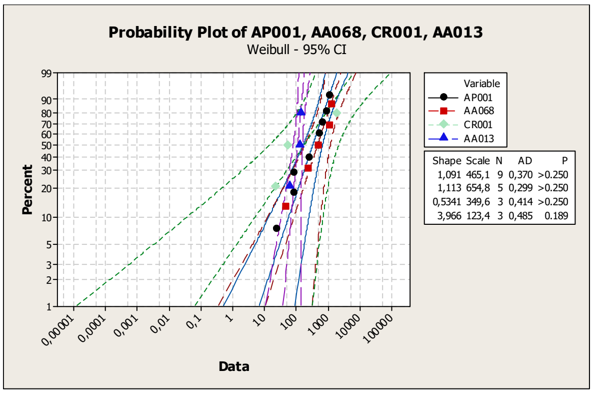

Figure 5. Plots of Weibull Spreads AP001, AA068, CR001 and AA013.

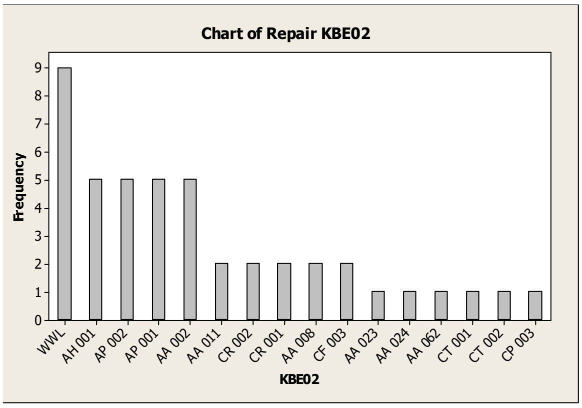

Figure 6. Frequency Diagram of KBE02.

For the goodness-of-fit test by Anderson's method the minimum sample size is five. The sample size of AA013 and CR001 components' repair data is just three, so the data is inadequate and the Anderson's test cannot be used. The confidence interval used is 95%. The value of the match test standard is expressed in the largest P-value. The P-value is a statistic calculate value For lognormal distribution, all components of AP001, AA068, CR001, and AA013 are not suitable because the P-value is less than 0.5. Similarly, for normal distribution, only the component of AP001 is 0.506. That is more than 0.5 but statistically is not significant. Thus, the Weibull's distribution is inappropriate.

The largest value of P-value was obtained for exponential distribution with P-value 0.734 for AP001 and 0.835 for AA068. The sample sizes were nine and five, respectively. It can be calculated that the average repair times were 631.6 days for AA068 and 451.2 days for AP001, respectively. It means that need for repairs for AP001 components were likely to be faster than AA068 repairs. These results are used as comparison between the component maintenance intervals.

Based on KBE02 repair data, the repair frequency values are shown in Table 9. The repair frequencies of KBE02 Core 52 to 88 in Table 9 are shown in the bar chart in Figure 6.

The WWL component is the largest frequency component followed by AP001, AP002, AH001, and AA002. Other components are not analyzed because they do not satisfy the sample size requirement.

Table 10 shows the WWL components that experienced repairs from Core 52 to 88 with their TTF values (Eq. 1).

Table 9. Frequency of KBE02 Component Repair

No	Component Codes	frequency
1	WWL	9
2	AH 001	5
3	AP 002	5
4	AP 001	5
5	AA 002	5
6	AA 011	2
7	CR 002	2
8	CR 001	2
9	AA 008	2
10	CF 003	2
11	AA 023	1
12	AA 024	1
13	AA 062	1
14	CT 001	1
15	CT 002	1
16	CP 003	1

Table 10. TTF Values of WWL Component

Core	Repair Done	TTF (days)
64	25/04/2008	0
66	28/11/2008	217
66	17/02/2009	81
85	10/03/2014	1847
85	23/04/2014	44

Table 11. TTF Values of AA002 Component

Core	Repair Done	TTF (days)
55	13/09/2005	0
56	08/03/2006	176
64	21/04/2008	775
85	24/04/2014	2194
88	05/06/2015	407

Table 12. TTF Values of AH001 Component

Core	Repair Done	TTF (days)
52	12/02/2004	0
59	23/01/2007	1076
65	6/07/2008	530
71	01/04/2010	634
80	21/09/2012	904
85	16/01/2014	482
85	06/02/2014	21
85	25/04/2014	78
86	21/07/2014	87
87	03/02/2015	197

Table 13. TTF Values of AP001 Component

Core	Repair Done	TTF (days)
61	11/06/2007	0
68	10/07/2009	760
70	28/12/2009	171
83	20/08/2013	61
85	24/02/2014	188

Table 14. TTF Values of AP002 Component

Core	Repair Done	TTF (days)
55	28/10/2005	0
58	04/10/2006	341
60	02/05/2007	210
68	01/07/2009	791
76	14/09/2011	805

The TTF values for components AA002, AH001, AP001, and AP002 are shown in Tables 11, 12, 13, and 14, respectivel.

The goodness-of-fit test using Anderson's method obtained by each P-value of WWL, AP001, AP002, AH001, and AA002 components for lognormal, normal, weibull and exponential distributions are shown in Figure 7 to Figure 10.

From the distribution goodness-of-fit tests, the components that give the largest P-value values with lognormal distribution are WWL and AA002 with 0.736 and 0.838. For AP001, AP002, and AH001, the P-values show a less good fit with the lognormal distribution (Figure 7).

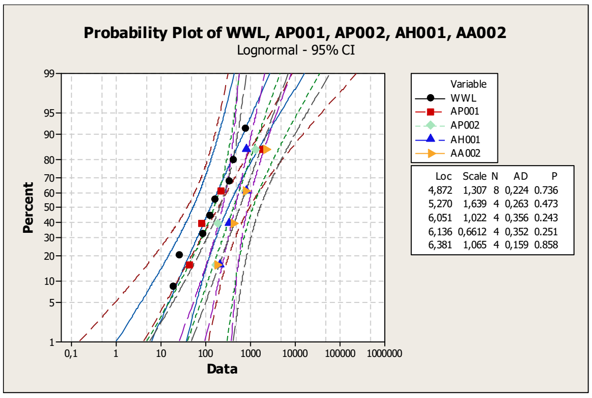

Figure 7. Plot of Lognormal Distribution for WWL, AP001, AP002, AH00 and AA002.

For normal distribution, the P-value for KBE02 component is <0.25 except for AP002, P-value is 0.28, so in this case the normal distribution is not suitable for WWL, AP001, AH001 and AA002 components and is less suitable for AP002 (Figure 8).

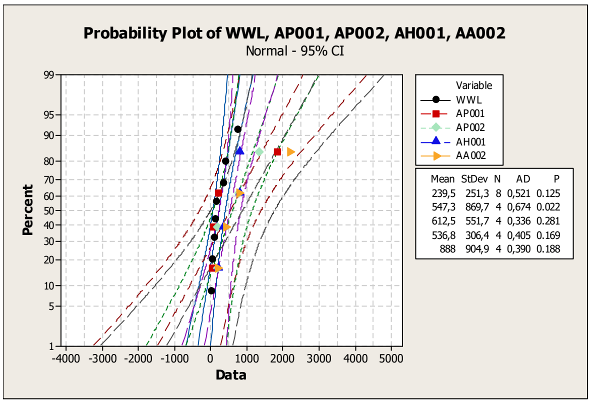

Figure 8. Plot of Normal Distribution for WWL, AP01, AP002, AH00 and AA002.

For Weibull distribution, the above components' P-values >0.25 except for AH001, P-value value <0.25. However, the Weibull distribution is less significant for the five components of KBE02 (Figure 9).

For the exponential distribution, the components with highest P-values are WWL and AA002 with P-values of 0.905 and 0.918, respectively; Also the P-value of AP002 is 0.671>0.5 (Figure 10).

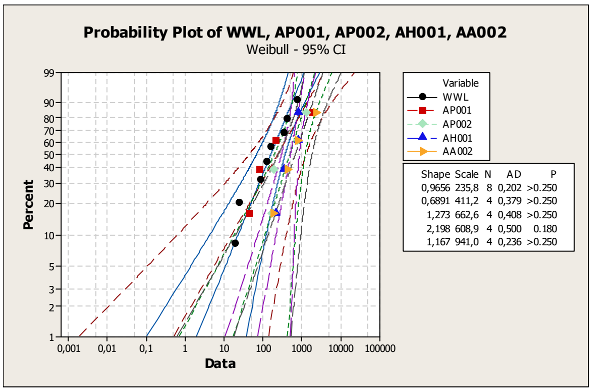

Figure 9. Plot of Weibull Distribution for WWL, AP001, AP002, AH00 and AA002.

Thus, the WWL and AA002 components better fit the exponential distribution compared to the lognormal distribution whereas AP002 fits the exponential distribution. From the exponential distribution, it can be calculated that the average parameter of repair time is 239.5 days for WWL, 888.0 days for AA002, and 612.5 days for AP002, which means that the WWL component repair time is likely to come earlier than components AA002 and AP002. This result can be used in comparison to the reference interval of the maintenance period of a component.

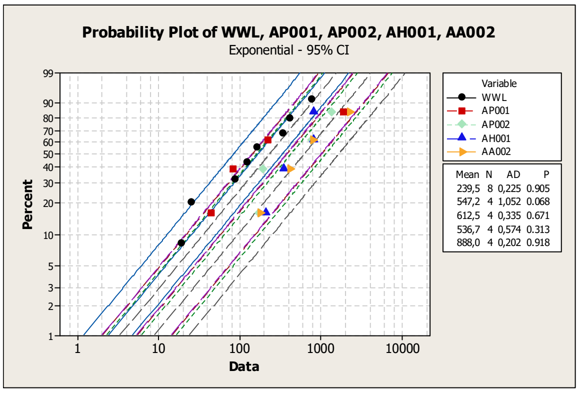

Figure 10. Plot of Exponential Distribution for WWL, AP01, AP002, AH00 and AA002.

5. SUMMARY

The reliability analysis using component repair data was performed for the KBE01 and KBE02 RSG-GAS purification systems on Core 52 (2006) through Core 88 (2015) using a probability distribution fitting/goodness-of-fit test. The distribution of AA068 and AP001 component repair data on KBE01 follows the exponential distribution with an average repair time of 631.6 days for AA068 and 451.2 days for AP001. The distribution of data for WWL and AA002 repair times in KBE02 follow an exponential range with an average repair time of 239.5 days for WWL and 888.0 days for AA002.

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