Sterilizer Reliability Analysis Using Reliability Blockdiagram Based on Failure Identification Through Fault Tree Analysis

by Syamsul Bahri

Sterilizer Reliability Analysis Using Reliability Blockdiagram Based on Failure Identification Through Fault Tree Analysis

Syamsul Bahri [1,a]*, Fatimah [1,b], Saifuddin Muhammad Jalil [2,c], Amri[1,d], Muhammad Ilham[1,e]

[1]*Industrial Engineering Department, Universitas Malikussaleh, Aceh, Indonesia*
[2]*Electrical Engineering, Universitas Malikussaleh, Aceh, Indonesia*

[a] *irsyamsul.bahri@unimal.ac.id*;* [b] *Fatimah.ft@unimal.ac.id;* [c] *saifuddin@unimal.ac.id;*[d] *iramri@unimal.ac.id;*
[e]*13muhammadilham05@gmail.com*
*Corresponding author E-mail: irsyamsul.bahri@unimal.ac.id

Abstract

A sterilizer is a pressurized steam vessel used to boil palm oil. The condition of the sterilizer at PT .X often emits steam at the door and body of the stew. Throughout 2020, there were 12 critical components that were frequently damaged, such as ball valve, actuator, exhaust valve, packing door, elbow, condensate nozzle, liner, pipe, condensate valve, strainer valve, pipe flange, and packing flange. Fault Tree Analysis is an analysis tool that graphically translates the combinations of errors that cause system failures. Reliability Block Diagram is a diagramming method for showing reliability components contribute to the success or failure of a complex system. Based on the results of the failure calculation using fault tree analysis, the probability of failure of the horizontal sterilizer component is the ball valve 12.2%, exhaust valve 10.9% actuator 6%, door packing 0.24%, elbow 0.24%, condensate nozzle 4.8%, liner 8.61%, 0.25% pipe, 0.21% condensate valve, 4.4% filter valve, 0.22% pipe flange and 0.27% packing flange. The reliability value of the horizontal sterilizer from the calculation using the reliability block diagram is 85.69% if it operates for 8 hours, 62.93% if it operates for 27 hours, 39.6% if it operates for 54 hours, 13.34% if it operates for 117 hours. o'clock. o'clock. o'clock. hours and 1.81% when operating for 234 hours. To maintain reliability above 60%, the preventive maintenance schedule is: Every 80 hours of operation a door packing inspection is carried out. Every 234 hours of operation, elbow tubing and flanges are checked. Every 300 hours of operation, a pipe inspection is carried out. Every 450 operational hours an inspection is carried out on the ball valve, condensate nozzle, liner, actuator, and exhaust valve. Every 30 hours of operation, valve condensate, filter valves and packing flanges are checked.

Keywords: Sterilizer; Reliability Block Diagram; Fault Tree Analysis; damage

1. Introduction

PT. X is a company engaged in the processing of fresh fruit bunches (FB) into Crude Palm Oil and Palm Kernel. Palm oil processing is carried out by carrying out a series of continuous processes so that crude palm oil (Crude Palm Oil) and palm kernel (Palm Kernel) can be separated from palm bunches. Errors in certain processes cannot be corrected in subsequent processes. The performance of Palm Oil Companies must follow the standards and principles of palm oil mills, namely to collect as much oil and palm kernel as possible to achieve the desired results. PT. X has a production capacity of 45 tons/hour. It should be noted that the yield at PT.X limited liability company is 18% for oil and 5% for kernels.

A sterilizer is a pressurized steam vessel used to boil palm oil. In the palm oil production process, the sterilizer is the first mechanical processing device for oil palm fruit. This sterilizer uses wet steam as a heating medium which comes from the rest of the steam turbine exhaust which is fed to the supply tank or return vessel[1].

The good or bad quality and quantity of processed palm oil is largely determined by the success of the decoction using a sterilizer. Therefore, boiling the fruit must follow the existing provisions and is an absolute thing to do.

The object of this research is a sterilizer used to boil fresh fruit bunches. This is due to the condition of the sterilizer at PT. X, a palm oil company, where steam leaks often occur at the stew door and body sterilizer. Throughout 2020, there were 12 critical components that were frequently damaged, such as ball valve, actuator, exhaust valve, door packing, elbow, condensate nozzle, liner, condensate pipe, condensate valve, strainer valve, pipe flange, and packing flange. This causes the engine performance to be less effective and efficient so that the boiling time becomes longer and the company can experience time losses in the production process, therefore engine damage is something that needs to be considered more wisely.

Based on this description, this study tries to discuss the problem of failure and analysis of the reliability of sterilizers with the title "Analysis of the reliability of Sterilization Equipment Using Reliability Block Diagrams Based on Failure Identification Through Fault Tree Analysis". The purpose of this study was to determine the level of reliability and probability of failure of the sterilizer.

2. Literature Review

2.1. Sterilizier

The sterilizer is a pressurized steam vessel used to boil fresh fruit bunches with steam (steam). The steam used is saturated steam. The use of saturated steam allows the process of hydrolysis / evaporation of water on the fruit, if using dry steam will cause the skin of the fruit to become charred so that it inhibits the evaporation of water in the fruit flesh and can make pressing difficult. process. Therefore, quality control of the steam used as a source of boiling heat is very important to get perfect boiling results. Sterilizers are divided into 2 types, namely horizontal sterilizers and vertical sterilizers.

2.2. Basic Concepts of Maintenance

Maintenance is defined as a form of activity carried out to achieve a result that can return an item or maintain it in a condition that can always function. Maintenance is also a supporting activity that ensures the continuity of machines and equipment so that when they are needed they can be used as expected.

2.3. Failure Analysis

Failure Analysis is an activity that aims to determine the cause of specific damage to the main equipment, supporting equipment, and equipment installed in the factory. Types of Failure Analysis of the material can be in the form of fracture, crack, or corrosion.

When a failure occurs, an analytical technique is needed to find out the causes that occur and the steps that must be taken to overcome them. The main steps modeled for the troubleshooting process are as follows:

a. Identification
b. Determine the root cause
c. Determine corrective action
d. Validation and verification of corrective actions
e. Standardization

2.4. Failure Analysis Method

The failure analysis process relies on collecting the failed components for subsequent examination of the cause or causes of failure using various methods. There are several methods for identifying system failures, namely:

a. Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is one of the reliable techniques, where unwanted failures are managed by summing up and presented with pictures. This fault tree analysis method is effective in finding the heart of the problem because it ensures that an undesired event or loss does not originate from a single point of failure.

b. Failure Mode and Effect Analysis (FMEA)

FMEA is a systematic method for identifying and preventing defects in a process before they occur, improving safety and increasing customer satisfaction. Ideally FMEA is carried out at the product development stage[2] [8].

c. Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a troubleshooting process to investigate issues, concerns or discrepancies found. RCA requires investigators to find solutions to pressing problems and understand the underlying or underlying cause of a situation and deal with the problem appropriately, thereby preventing the recurrence of the same problem. It may therefore involve identifying and managing processes, procedures, activities, activities, behaviors, or conditions.

2.5. Reliability Theory

Reliability or reliability shows the existence or condition of a facility. This condition can be said to be positive or negative. The concept of reliability involves statistical methods. Through this measurement, the company has an overview of the condition of the equipment it owns, so it can predict the maintenance of the equipment. Reliability can also be measured by using the average number of failures in a certain period of time (failure rate). It can also be expressed as the average time between failures [9]–[15].

a. Analysis failure

The failure rate ($\lambda(t)$) is known as the risk value or a function of the error value. This value provides alternative solutions to explain the distribution of damage.

b. Distribution in Failure Analysis

The distribution used in the failure analysis is as follows:

1. Exponential distribution
2. Weibull distribution

2.6. Reliability Block Diagram

A reliability block diagram (RBD) is a diagramming method for showing how components of reliability contribute to the success or failure of a complex system. An RBD can be converted into a success tree by replacing the series path with AND gates and parallel paths with OR gates[16]–[22].

3. Methods

3.1 Research Object

The object of this research is a sterilizer used to boil fresh fruit bunches. This is due to the condition of the sterilizer at PT.X is palm oil company where steam leaks often occur at the stew door and body sterilizer. throughout 2020, 12 critical components fail frequently

3.2 Data Collection Method

The types of data collected in conducting this research are as follows:

A. Main data

Primary data is data obtained directly from the source, observed, and recorded for the first time. In the process of observation, it was obtained about the production process or the working principle of the sterilizer from the initial stage of boiling to the release of FFB. The primary data used is the assessment data of the cause of damage to the sterilizer component based on fault tree analysis.

B. Secondary Data

Secondary data is data obtained indirectly from the source, such as quotes from books, literature, scientific readings, and company archives that have relevance to the theme of writing.

3.3 Analysis Method

Based on results of observations and data collection, data processing was carried out. The analytical method used is through a fault tree analysis approach and reliability block diagrams. The steps to solve the problem in this research are as follows:

A. Recapitulation of Data Collection Results

Recapitulation of questionnaire data and historical engine performance data.

B. Fault Tree Analysis Calculation

• Creating a Sterilization Failure Tree

• Creating a Component Failure Tree

• Calculate the probability of component failure

C. Reliability of Block Diagram Processing (RBD)

• Calculate the Mean Time Between Failure (MTBF) of each component using the formula:

$$MTBF = \frac{Operating\ time}{Failure}$$

• Calculate the failure rate using the formula:

$$\lambda = \frac{1}{MTBF}$$

• Calculate the reliability of each component using the formula:

$$R = e^{-(\lambda \times t)}$$

4. Results and Discussion

4.1 Data Sterilizer

The data collected is the horizontal history of the PT. X palm oil company sterilizer for the period July 2020 – June 2021. This data consists of planned downtime data, sterilizer operating hours data, and sterilizer damage data.

A. Sterilization Operation Time Data

The following is data on the operating time of the horizontal sterilizer at PT. X palm oil company for one year, which can be seen in Table 1. below:

Table 1. PT.X palm oil company Operation Time Data

Period	Operating Time (hours)
July 2020	179,8
August 2020	152,73
September 2020	181,25
October 2020	192,93
November 2020	149,2
Desember 2020	168,67
January 2021	180,85

February 2021	233,17
Maret 2021	120,82
April 2021	114,1
Mey 2021	207,57
June 2021	159,33

B. Data Planned DowntimeSterilizer Horizontal

The following is the downtime data for the horizontal sterilizer plan at PT. X palm oil company for one year, which can be seen in Table 2 below:

Table 2. Data Planned Downtime palm oil company PT.X

Period	*Planned Downtime* (Jam)
July 2020	20
August 2020	15
September 2020	20
October 2020	15
November 2020	20
Desember 2020	15
January 2021	20
February 2021	15
Maret 2021	15
April 2021	20
Mey 2021	15
June 2021	20

C. Horizontal Sterilizer Component Failure Data

The following is a summary of the components that fail in the number 1 sterilizer. This failure data is data on the failure of the sterilization component for one year. Data on components that fail in the number 1 sterilizer can be seen in Table 3. below:

Table 3. Sterilizer Component Failure Data

No	Component	Number of Failures
1	Packing door	11
2	Elbow	4
3	Flange Pipe	4
4	Pipe	3
5	Ball Valve	2
6	Nozzle Condensat	2
7	Liner	2
8	Actuator	2
9	Valve Exhaust	2
10	Valve Condensat	1
11	Streiner Valve	1
12	Packing Flange	1

4.2 Calculating Sterilization Failures Using Fault Tree Analysis

A. A failure that causes the machine to stop operating

There are 3 components that cause the engine to stop operating if it fails, namely the ball valve (P1), exhaust valve (P2), and the actuator (P3). The failure tree that causes the machine to stop operating can be seen in Figure 1 below:
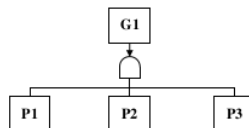

Figure 1. Fault Tree Failure That Causes the Machine to Stop Operating

As for finding the failure value on the components that cause the machine to stop operating, it can be seen as follows:
P1 = 0.122, P2 = 0.109, P3 = 0.06

G1 = P1 x P2 x P3
    = 0.122 x 0.109 x 0.06
    = 0.0008 = 0.8%

B. Failures That Cause Decreased Engine Performance

Nine components that cause engine performance to decrease if it fails are Packing Door (P4), Elbow (P5) and Nozzle Condensate (P6), liner (P7), Condensate Pipe (P8), Condensate Valve (P9), Streiner Valve (P10), flanges pipe (P11) and packing flange (P12). The failure tree that causes engine performance to decline can be seen in Figure 2 below:
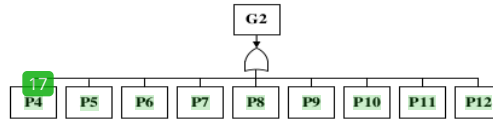

Figure 2. Fault Tree Failures That Cause Decreased Machine Performance

As for finding the failure value on the components that cause the machine to stop operating, it can be seen as follows:

P4 = 0.0024, P5 = 0.0024, P6 = 0.048, P7 = 0.0861, P8 = 0.0025, P9 = 0.0021, P10 = 0.044, P11 = 0.0022, P12 = 0.0027

G2 = (P4 + P5 + P6 +...+P12)

    = (0.0024 + 0.0024 + 0.048 + ...+ 0.0027)

    = 0.1798 = 17.98%

C. Sterilization Failure

There are 2 types of major failures that occur, namely failures that cause the engine to stop operating (G1) and failures that cause engine performance to decrease (G2). The horizontal sterilization failure tree can be seen in Table 4 below:
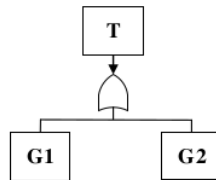

Figure 3. Sterilization Failure Error Tree

Horizontal

As for finding the failure value on the horizontal sterilizer, it can be seen as follows:

G1 = 0.0008, G2 = 0.1798

Top Event = (G1 + G2) – (G1 x G2)

        = (0.0008 + 0.1798) - (0.0008 x 0.1798)

        = 0.1806 – 0.0001

        = 0.1805

        = 18.85%

Based on the above calculation, the probability of failure of the horizontal sterilizer is 18.85%.

Calculating Sterilization Reliability Using the Reliability Block Diagram

As for getting the value of the reliability of the sterilizer at PT.X palm oil company, it can be calculated using the following formula:

a. Average Time Between Failures

The formula for calculating the temporary between failures is as follows:

$$MTBF= \frac{Operating\ time}{Failure}$$

Note: The operating time of the Sterilizer for one year is 2040 hours

The calculation results of the temporary between failure sterilizer can be seen in Table 5. below:

Table 4. MTBF of Sterilization Components

Component	Number of Failures	MTBF
Packing door	11	185,49
Elbow	4	510,1
Flange Pipe	4	510,1
Pipe	3	680,13
Ball Valve	2	1020,2
Nozzle Condensat	2	1020,2
Liner	2	1020,2
Actuator	2	1020,2
Valve Exhaust	2	1020,2
Valve Condensat	1	2040
Streiner Valve	1	2040
Packing Flange	1	2040

b. Failure rate

The formula for calculating the failure rate is as follows:

$$\lambda = \frac{1}{MTBF}$$

The results of the calculation of the failure rate can be seen in Table 5. below:

Table 5. Sterilizer Component Failure Rate

Component	MTBF	Failure Rate
Packing **door**	185,49	0,005391
Elbow	510,1	0,00196
Flange Pipe	510,1	0,00196
Pipe	680,13	0,00147
Ball Valve	1020,2	0,00098
Nozzle Condensat	1020,2	0,00098
Liner	1020,2	0,00098
Actuator	1020,2	0,00098
Valve Exhaust	1020,2	0,00098
Valve Condensat	2040	0,00049
Streiner Valve	2040	0,00049
Packing Flange	2040	0,00049

C. Calculating the Reliability of Horizontal Sterilizer Components

The formula for calculating component reliability is as follows:

$$R = e-(\lambda\ x\ t)$$

The results of the calculation of component reliability can be seen in Table 6 below:

Table **6**. Reliability of Sterilizer Components

Component	Reliability In Hours (%)				
	9	54	117	234	1404
*Packing **door***	95,26	74,74	53,22	28,32	0,05
Elbow	98,25	89,95	79,5	63,21	6,38
Flange Pipe	98,25	89,95	79,5	63,21	6,38
Pipe	98,69	92,37	84,2	70,89	12,69
Ball Valve	99,12	94,84	89,16	79,5	25,25
Nozzle Condensat	99,12	94,84	89,16	79,5	25,25
Liner	99,12	94,84	89,16	79,5	25,25
Actuator	99,12	94,84	89,16	79,5	25,25
Valve Exhaust	99,12	94,84	89,16	79,5	25,25
Valve Condensat	99,56	97,39	94,43	89,16	50,25
Streiner Valve	99,56	97,39	94,43	89,16	50,25
Packing Flange	99,56	97,39	94,43	89,16	50,25

D. Reliability of Horizontal Sterilizer at PT. X

The reliability of the sterilizer can be calculated and shown in the reliability block diagram as follows:
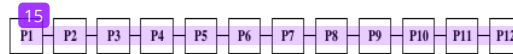
Fig 4. Reliability Block DiagramSterilizer Horizontal

The reliability of the horizontal sterilizer for 9 hours of operation can be seen in the calculation below:

Rsys= R1x R2 x R3xR4 x R5x R6 x R7xR8 x R9x R10 x R11xR12

The results of the calculation of the reliability of the sterilizer using the reliability block diagram can be seen in Table 7 below:

Table **7.** Sterilizer Reliability Calculation Results Using Reliability Block Diagram

Sterilizer Operating Hours	Reliability
9 jam	85,69 %
27 jam	62,93 %
54 jam	39,6 %
117 jam	13,34 %
234 jam	1,81 %

5. Conclusion

Based on the processing that has been done, it can be concluded:

a.   The probability of failure of each component of the horizontal sterilizer is different because the cause of the failure of the component is also different. Based on the failed horizontal sterilizer component, there are 3 components (ball valve, exhaust valve, and actuator) that can cause the sterilizer to stop operating, and 9 components (packing door, elbow, condensate nozzle, liner, condensate pipe, condensate valve, filter valve, flanges). pipe and packing flange) which causes the sterilizer to experience a decrease in performance. Then the results of the calculation of the probability of fault tree analysis based on two major failures, the probability of failure of the horizontal sterilizer at PT.X palm oil company is 18.85%.

b.   The reliability of horizontal sterilization is different for each hour of operation. The longer the operating hours, the lower the reliability of the sterilizer. The following is the reliability value of the Horizontal Sterilizer at PT.X palm oil company:

1.   The reliability of the Horizontal Sterilizer for 9 hours of operation is 85.69%.
2.   Horizontal Sterilizer reliability for 27 hours of operation is 62.93%.
3.   The reliability of the Horizontal Sterilizer for 54 hours of operation is 39.6%.
4.   The reliability of the Horizontal Sterilizer for 117 hours of operation is 13.34%.
5.   Horizontal Sterilizer reliability for 234 hours of operation is 1.81%.

With this reliability value, the company is expected to re-evaluate the horizontal sterilizer maintenance schedule.

References

[1]   M. Jiménez-Rosado, V. Perez-Puyana, A. Guerrero, and A. Romero, "Controlled release of zinc from soy protein-based matrices to

plants," *Agronomy*, vol. 11, no. 3, 2021, doi: 10.3390/agronomy11030580.

[2] M. Mardani Shahri, A. Eshraghniaye Jahromi, and M. Houshmand, "Failure Mode and Effect Analysis using an integrated approach of clustering and MCDM under pythagorean fuzzy environment," *J. Loss Prev. Process Ind.*, vol. 72, p. 104591, 2021, doi: https://doi.org/10.1016/j.jlp.2021.104591.

[3] J. Zhu, B. Shuai, G. Li, K.-S. Chin, and R. Wang, "Failure mode and effect analysis using regret theory and PROMETHEE under linguistic neutrosophic context," *J. Loss Prev. Process Ind.*, vol. 64, p. 104048, 2020, doi: https://doi.org/10.1016/j.jlp.2020.104048.

[4] A.-Y. Yu, H.-C. Liu, L. Zhang, and Y. Chen, "A new data envelopment analysis-based model for failure mode and effect analysis with heterogeneous information," *Comput. Ind. Eng.*, vol. 157, p. 107350, 2021, doi: https://doi.org/10.1016/j.cie.2021.107350.

[5] G. Huang, L. Xiao, and G. Zhang, "Improved failure mode and effect analysis with interval-valued intuitionistic fuzzy rough number theory," *Eng. Appl. Artif. Intell.*, vol. 95, p. 103856, 2020, doi: https://doi.org/10.1016/j.engappai.2020.103856.

[6] M. J. Kalathil, V. R. Renjith, and N. R. Augustine, "Failure mode effect and criticality analysis using dempster shafer theory and its comparison with fuzzy failure mode effect and criticality analysis: A case study applied to LNG storage facility," *Process Saf. Environ. Prot.*, vol. 138, pp. 337–348, 2020, doi: https://doi.org/10.1016/j.psep.2020.03.042.

[7] H. Li, H. Diaz, and C. Guedes Soares, "A developed failure mode and effect analysis for floating offshore wind turbine support structures," *Renew. Energy*, vol. 164, pp. 133–145, 2021, doi: https://doi.org/10.1016/j.renene.2020.09.033.

[8] M. Tang and H. Liao, "Failure mode and effect analysis considering the fairness-oriented consensus of a large group with core-periphery structure," *Reliab. Eng. Syst. Saf.*, vol. 215, p. 107821, 2021, doi: https://doi.org/10.1016/j.ress.2021.107821.

[9] R. Sireesha, C. Srinivasa Rao, and M. Vijay Kumar, "Graph theory based transformation of existing Distribution network into clusters of multiple micro-grids for reliability enhancement," *Mater. Today Proc.*, 2021, doi: https://doi.org/10.1016/j.matpr.2021.07.067.

[10] T. Cui and S. Li, "System movement space and system mapping theory for reliability of IoT," *Futur. Gener. Comput. Syst.*, vol. 107, pp. 70–81, 2020, doi: https://doi.org/10.1016/j.future.2020.01.040.

[11] L. Wang, Y. Liu, D. Liu, and Z. Wu, "A novel dynamic reliability-based topology optimization (DRBTO) framework for continuum structures via interval-process collocation and the first-passage theories," *Comput. Methods Appl. Mech. Eng.*, vol. 386, p. 114107, 2021, doi: https://doi.org/10.1016/j.cma.2021.114107.

[12] J.-M. Hu, H.-Z. Huang, and Y.-F. Li, "Reliability growth planning based on information gap decision theory," *Mech. Syst. Signal Process.*, vol. 133, p. 106274, 2019, doi: https://doi.org/10.1016/j.ymssp.2019.106274.

[13] P. E. Clayson, K. A. Carbine, S. A. Baldwin, J. A. Olsen, and M. J. Larson, "Using generalizability theory and the ERP Reliability Analysis (ERA) Toolbox for assessing test-retest reliability of ERP scores part 1: Algorithms, framework, and implementation," *Int. J. Psychophysiol.*, vol. 166, pp. 174–187, 2021, doi: https://doi.org/10.1016/j.ijpsycho.2021.01.006.

[14] M. L. Koç and D. Imren Koç, "A cloud theory based reliability analysis method and its application to reliability problems of breakwaters," *Ocean Eng.*, vol. 209, p. 107534, 2020, doi: https://doi.org/10.1016/j.oceaneng.2020.107534.

[15] Y. Liu, L. Deng, W. Zhong, J. Xu, and W. Xiong, "A new fatigue reliability analysis method for steel bridges based on peridynamic theory," *Eng. Fract. Mech.*, vol. 236, p. 107214, 2020, doi: https://doi.org/10.1016/j.engfracmech.2020.107214.

[16] J. Wang, Q. Zhang, S. Yoon, and Y. Yu, "Reliability and availability analysis of a hybrid cooling system with water-side economizer in data center," *Build. Environ.*, vol. 148, pp. 405–416, 2019, doi: https://doi.org/10.1016/j.buildenv.2018.11.021.

[17] J. E. Staley and P. S. Sutcliffe, "Reliability block diagram analysis," *Microelectron. Reliab.*, vol. 13, no. 1, pp. 33–47, 1974, doi: https://doi.org/10.1016/0026-2714(74)90209-1.

[18] W. Ahmed, O. Hasan, and S. Tahar, "Formalization of Reliability Block Diagrams in Higher-order Logic," *J. Appl. Log.*, vol. 18, pp. 19–41, 2016, doi: https://doi.org/10.1016/j.jal.2016.05.007.

[19] G. Kaczor, S. Młynarski, and M. Szkoda, "Verification of safety integrity level with the application of Monte Carlo simulation and reliability block diagrams," *J. Loss Prev. Process Ind.*, vol. 41, pp. 31–39, 2016, doi: https://doi.org/10.1016/j.jlp.2016.03.002.

[20] L. Jia, Y. Ren, D. Yang, Q. Feng, B. Sun, and C. Qian, "Reliability analysis of dynamic reliability block diagram based on dynamic uncertain causality graph," *J. Loss Prev. Process Ind.*, vol. 62, p. 103947, 2019, doi: https://doi.org/10.1016/j.jlp.2019.103947.

[21] J.-P. Signoret, Y. Dutuit, P.-J. Cacheux, C. Folleau, S. Collas, and P. Thomas, "Make your Petri nets understandable: Reliability block diagrams driven Petri nets," *Reliab. Eng. Syst. Saf.*, vol. 113, pp. 61–75, 2013, doi: https://doi.org/10.1016/j.ress.2012.12.008.

[22] L. Xie, M. A. Lundteigen, and Y. Liu, "Performance analysis of safety instrumented systems against cascading failures during prolonged demands," *Reliab. Eng. Syst. Saf.*, vol. 216, p. 107975, 2021, doi: https://doi.org/10.1016/j.ress.2021.107975.

Sterilizer Reliability Analysis Using Reliability Blockdiagram Based on Failure Identification Through Fault Tree Analysis

Conference on Electronic Packaging
Technology (ICEPT), 2017
Publication

8   Jantiara Eka Nandiasa, Dega Rizkan. "Analysis
     of Drainage Capacity in Cimanggis Hill Clove II
     Housing Area Depok City", Journal of Applied
     Science, Engineering, Technology, and
     Education, 2019
     Publication

1 %

9   Submitted to University of Technology,
     Sydney
     Student Paper

1 %

10   www.slideshare.net
     Internet Source

1 %

11   Georges Habchi, Christine Barthod. "An
     overall methodology for reliability prediction
     of mechatronic systems design with industrial
     application", Reliability Engineering & System
     Safety, 2016
     Publication

<1 %

12   Submitted to University of Lincoln
     Student Paper

<1 %

13   Dedik Romahadi, Hui Xiong, Hadi Pranoto.
     "Intelligent System for Gearbox Fault
     Detection & Diagnosis Based on Vibration
     Analysis using Bayesian Networks", IOP

<1 %

tool including early failures", Reliability
Engineering & System Safety, 2021
Publication

23 P. Gonçalves, J. Sobral, L.A. Ferreira.   <1%
"Unmanned aerial vehicle safety assessment
modelling through petri Nets", Reliability
Engineering & System Safety, 2017
Publication

24 R. Pawin vivid, N. Selvakumar, M.   <1%
Ruvankumar. "Determination of hazard in
truck manufacturing industry using hazard
identification risk assessment technique",
Materials Today: Proceedings, 2020
Publication

25 docobook.com   <1%
Internet Source

26 tel.archives-ouvertes.fr   <1%
Internet Source

27 seecs.nust.edu.pk   <1%
Internet Source